INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 21, No. 6, p. 80-93, 2022
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Structure and dynamics of Classified Forest of Péni's woody flora in western Burkina Faso

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Article published on December 06, 2022

Key words: Biodiversity, Fragmentation, Regeneration, Classified forest, Burkina Faso

Abstract

The Lack of knowledge of forests' state and their conditions in terms of composition, structure and regeneration are constraints to the sustainable management of protected areas. The aims of this study are: (i) to determine vegetation units' composition of the Classified Forest of Péni and (ii) to describe their structure and dynamics. Data were collected according to an inventory stratified in plots of 900m² and 500m² for the adult stratum and sub-plots of 25m² for regeneration according to vegetation units. This study identified 121 species in 88 genera and 33 families. The specific richness and Shannon index vary significantly between vegetation units, with the highest values at the level of wooded savannahs. All vegetation units have stable structures. Nevertheless, at the level of gallery forests, some difficulties exist for individuals of initial diameter class. We also note a near absence of large-diameter individuals in tree and shrub savannahs due to the strong anthropic pressures probably in these ecosystems. The rate of regeneration varies between vegetation units. The strongest is observed in wooded savannah and the weakest in gallery forests. Protection measures based on these results should be considered for vegetation units and particularly gallery forests.

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Introduction

Forest ecosystems play a significant socio-economic and environmental role for people in sub-Saharan countries (Hounkpèvi *et al.*, 2011). Anthropogenic pressures and climate hazards contribute to significantly reducing the capacity of these ecosystems to play this role (Zaouri, 2021).

In Burkina Faso, forest ecosystems are facing accelerated degradation (Ministry of Environment and Sustainable Development, 2011). These degradations are mostly attributable to Man who, in his quest for well-being, weakens, through various actions, natural resources. Among these actions, shifting cultivation, overexploitation of forest resources and overgrazing remain the most important (Diouf *et al.*, 2002; Faye *et al.*, 2003; Borsali *et al.*, 2014).

These actions create disturbances that influence tree dynamics and density at the local and regional levels (Ouédraogo, 2006) and are important in structuring plant communities (Gnoumou, 2013; Tindano, 2016).

However, in-depth knowledge of forest ecosystems' structural characteristics of is essential in this context of growing anthropization. Several studies have been conducted to understand woody stand dynamics (Ouoba 2006; Ganaba, 2008; Nacoulma, 2012; Savadogo, 2013; Traoré, 2013; Gnoumou, 2013; Tindano, 2016). These studies have provided information for the sustainable management of forest ecosystems. Indeed, according to Herrero-Jáuregui *et al.* (2012), structural characteristics of a population are important parameters for characterizing population demography.

In addition, Godoy (1992) and Hitimana *et al.* (2004), argue that the constraints to sustainable forest management in sub-Saharan Africa are, among others, the lack of knowledge of forests' state and their conditions and functions in terms of structure, composition, regeneration. It is in this context that this study is conducted in the Classified Forest of Péni (CFP) with the aim to provide information on its structure. Specifically, these included: (i) determine floristic composition of each vegetation unit's woody trees and (ii) establish adult and Juvenile demographic structures and characteristics of each vegetation unit.

Material and methods

Study site

The study was conducted in the Classified Forest of Péni (CFP) in southwestern Burkina Faso. The CFP is in Péni commune at 32 km from Bobo-Dioulasso city, on Bobo--Dioulasso - Banfora axis (Fig. 1). Geographically, it is located between latitudes 10°55'02.5" and 10°56'33" North and between longitudes 4°27'26.5" and 4°29'37.5" West. CFP belongs to the South Sudanese phytogeographic sector (Guinko, 1984).

The climate is Sudano-Guinean. The average annual rainfall over thirty years (1992-2021) in Péni commune is 1064.78 mm. The rainy season extends from May to September, with some rain throughout the year. The rainiest month is August with 281.51 mm. From 1992 to 2021 the average temperature is equal to 27.55°C with minima of 13.17°C in December and a maximum of 41.54°C in April (Fig. 2).

The thermal range is 28.37 °C. CFP's vegetation consists of a mosaic of savannahs (woods, grasses, shrubs, and trees) and gallery forests (Fontès and Guinko, 1995). The main soil types are ferrallitic soils, poorly developed soils, and sesquioxide soils and rapidly mineralizable organic matter (BNDT, 2012).

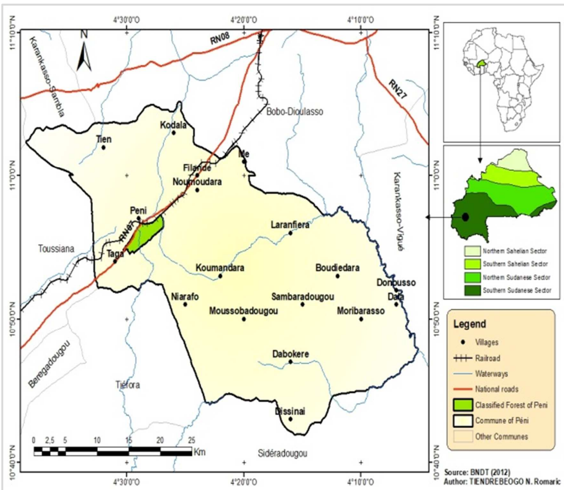

Fig. 1. Location of the Classified Forest of Péni in Burkina Faso, West Africa.

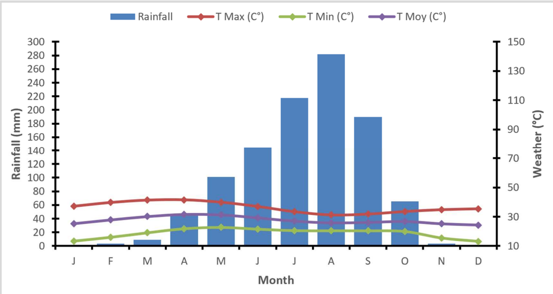

Fig. 2. Umbrothermic diagram of Péni department from 1992 to 2021 (Source: NAZA, POWER Data Access Viewer v2.0.0).

Sampling and data collection

The sampling method was stratified according to the CFP's vegetation units. Plots of 900 m² (30 m x 30 m) and 500 m² (50 m x 10 m) were used in savannahs and gallery forests, respectively (Thiombiano *et al.*, 2016). On each plot, the following data were recorded: the geographical coordinates in the center of the plot, the scientific name, the total height, and the girth at breast height (GBP) of each tree individual present on the plot.

GBP was converted to diameter at breast height by the formula: DHP= GBP/π with reference to previous work (Yaro, 2018; Ganamé, 2020). The diameters of some individuals of shrub species have been measured by collar (Traoré, 2013). Dendrometric measurements were performed only on adult trees (Diameter ≥ 5 cm) in accordance with previous studies (Sambaré *et al.*, 2020).

A total of 95 dendrometric plots were established. In the same 500 m² and 900 m² plots, 25 m² (5 m x 5 m) sub-plots were installed at the four corners and then at the center of these for the juvenile stratum study. Data collection consisted of counting all individuals with a diameter of less than 5 cm. This 5cm threshold is commonly used for woody regeneration of vegetation (Ouédraogo, 2006; Ouédraogo *et al.*, 2009; Traoré *et al.*, 2013).

All juvenile individuals were counted by species and placed in five height classes within each subplot, with intervals 0.5 cm: 0-0.5; 0,51-1; 1,1-1,5; 1,51-2 and > 2 m. This subdivision into height class, according to Steven (1994), allows the development constraints of woody species to be highlighted. A total of 475 sub-surveys were conducted.

Data processing and analysis

Floristic and demographic characterization of the adult population

The relative ecological importance of each woody species and family were expressed using the Importance Value Index (IVI) and the Family Importance Value (FIV), respectively. The IVI of a species is defined as the sums of its relative dominance, relative density and relative frequency which are calculated as follows, used in several studies (Traoré, 2013; Gnoumou *et al.*, 2021):

- Relative Dominance $= \frac{\text{basal area of a species}}{\text{All species basal area}} \times 100$

- Relative Density $= \frac{\text{Number of species' individuals per ha}}{\text{Number of total individuals per ha}} \times 100$

- Frequency $= \frac{\text{Number of plots in which a species is found}}{\text{Total number of plots}} \times 100$

- Relative Frequency $= \frac{\text{frequency of a species}}{\text{Species frequency sum}} \times 100$

- Relative Diversity $= \frac{\text{Number of species in a family}}{\text{Total number of species}} \times 100$

Importance Value Index (IVI) = Relative Dominance + Relative Density + Relative Frequency

Family Importance Value (IVF) = Relative Dominance + Relative Density + Relative Diversity

The basal area (G) m²/ha was calculated by the following formula:

$$G = \sum (\pi d_i^2/4)$$

With di: the tree diameter measured at 1.30 m from the ground or at the collar.

Floristic richness, Shannon index and taxonomic distribution were then evaluated. Then parameters such as Shannon index, density, average diameter, and basal area were calculated.

The density (D) by the formula:

$$D = \frac{n}{s}$$

With n: the number of species' individuals considered; s: plot surface in ha.

The average diameter (DM) by the formula:

$$DM = \frac{\sum_{n=1}^{n} d_i}{N}$$

With di: the diameter of the tree measured at 1.30 m from the ground and N: the total number of individuals of the species.

For a multicaule individual with t rods below the measuring height, the diameter d is equal to the quadratic sum of all diameters dsi of the stems of the measured individual. The formula for diameter d is as follows:

$$d = \sqrt{\sum_{i=1}^{t} ds_i^2}$$

The basal area (G) m²/ha by the following formula:

$$G = \sum (\pi d_i^2/4)$$

With di: the diameter of the tree measured at 1.30 m from the ground or at the collar.

The overall horizontal structure of the CFP and vegetation units has been established. To do this, all inventoried individuals were gathered in diameter class intervals of amplitude 5cm in histograms. Then the observed structures were fitted to the theoretical Weibull distribution with 3 parameters (Johnson and Kotz, 1970). According to Lorimer and Krug (1983) and Baker *et al.* (2005), this distribution, simple and flexible, fits perfectly to positive and negative skewed distributions as well as normal distributions. Its probability density function, *f* follows the formula:

$$f(x) = \frac{a}{b}\left(\frac{x-a}{b}\right)^{c-1} e^{-\left(\frac{x-a}{b}\right)^{c}}$$

where x is the diameter of the trees; a is the minimum measured diameter threshold (5cm); b the scale parameter related to the central value of the diameters of the trees of the stand under consideration and c the shape parameter related to the diameter structure considered.

Parameters b and c were first estimated with Minitab 19 software using diameter data from all individuals. This is possible thanks to an algorithm based on the maximum likelihood method (Zarnock and Dell 1985).

Depending on the value of the parameter of form c, the Weibull distribution can take several forms (Ryniker *et al.*, 2006). Thus, when: c < 1, the distribution is in "inverted J", characterizing multispecific or uneven-aged stands; c = 1, the distribution is exponentially negative, characterizing, stands with high regeneration potential; 1< c < 3.6, the distribution is positive asymmetric, characterizing monospecific stands with predominance of young individuals or small diameters; c = 3.6, the distribution is approximately normal, characterizing stands that present a regeneration problem; c > 3.6, the distribution is negative asymmetric, characterizing monospecific stands predominantly of old or large diameter individuals.

Inspired by the method proposed by Condit *et al.* (1998), the population trend was analyzed globally and per vegetation unit. This approach consists in calculating a logarithmic linear regression with the value of the centers of the diameter classes as the independent variable, and the number of individuals of this class (Ni) as the dependent variable. This method has been used successfully in previous studies (Lykke, 1998; Obiri *et al.*, 2002, Traoré *et al.,* 2012 and Yaro, 2018). The slope and correlation values of the regression equations were considered an indicator of structure (Condit *et al.*, 1998; Lykke, 1998; Obiri *et al.*, 2002; Tabuti, 2007). A negative slope reflects the dominance of small individuals, a zero slope reflects codominance between large and small individuals, and a positive slope reflects the dominance of large individuals. This interpretation of the diameter class structure is inspired by the approaches of Shackleton (1993), Everard *et al.* (1995) and Obiri *et al.* (2002).

Demographic characterization of juvenile population

Regeneration rate (RR), which according to Hakizimana *et al.* (2011) assesses the potential for regeneration, was calculated by relating the total number of juveniles to the total population size (Koulibaly *et al.*, 2010; Tindano, 201-6; Kébé *et al.,* 2020). It has the following formula:

$$RR = \frac{\text{Total number of seedlings}}{\text{Total population size}}$$

For the height structure of juveniles, histograms were also established, and regression slopes of the height classes were calculated by considering the median of the height classes (mi) as an independent variable and the number of individuals in each height class as a dependent variable.

A negative slope was considered an undisturbed stable structure and a positive slope indicates an unstable structure. This interpretation of the height class structure of juveniles is inspired by the same approaches cited for the diameter class structure.

Statistical analyses

Excel 2019 spreadsheet was used for data entry and graph making. After verification of the normality of the data by the Shapiro-Wilk test.

A one-factor analysis of variance was used to determine the variation in demographic characteristics between vegetation units and then between plant groups. The mean values were then compared with each other using the Tukey test at the 5% threshold using the R software version 4.1.3.

Result and discussion

Result

Adult population

Floristic composition and demographic characteristics

A total of 3225 trees and shrubs were measured in the Classified Forest of Péni including 898 in gallery forests, 877 in shrub savannahs, 752 in wooded savannahs and 698 in *Gmelina* plantations.

The individuals measured are divided into 121 woody species for all vegetation units in the forest. Wooded savannahs have the largest number of species, 72 species in 57 genera and 26 families; followed by shrub savannahs with 60 species in 48 genera and 21 families.

Gallery forests and plantations in *Gmelina* have 59 species in 50 genera and 28 families and 35 species in 29 genera and 15 families, respectively (Fig. 3).

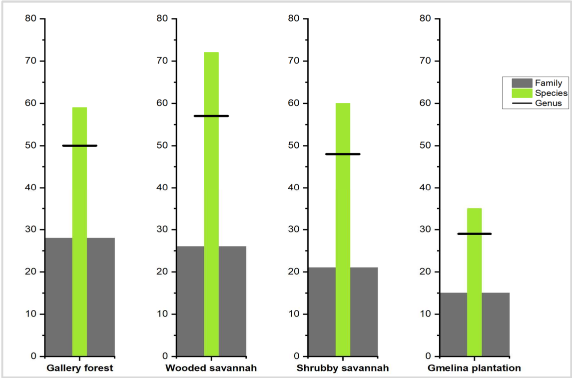

Fig. 3. Taxonomic distribution in genus, families, and species per vegetation unit.

The highest average species richness is observed in wooded savannahs (12±5 species) and lowest in *Gmelina* plantations (7±3 species) (F=4.48; p=0.005). The Shannon index varies from one vegetation unit to another (F = 13.69; p<0.0001) and the highest is observed in wooded savannas with 2.06±0.56 bits (Tab. 1).

Table 1. Number of plots, species richness, number of individuals, mean specific richness and mean Shannon index per vegetation unit in CFP.

Vegetation units	Number of plots (n=95)	Specific richness (n=121)	Number of individuals (n=3225)	Average specific richness	Shannon index
Forest gallery	29	59	898	9±3[a]	1.79±0.47[a]
Wooded savannah	23	72	877	12±5[b]	2.06±0.56[a]
Shrub savannah	32	60	752	10±4[ab]	1.94±0.42[a]
Gmelina plantation	11	35	698	7±3[a]	0.99±0.45[b]

Legend: Superscript letters indicate significant differences according to the Tukey test at the 5% threshold. Averages followed by the same letter in the same column are not statistically different.

In gallery forests, species with importance indices ≥ 20 are: *Syzygium guineense* (IVI=76.34), *Carapa procera* (IVI=32.91), *Berlinia grandiflora* (IVI=32.15) and *Uapaca togoensis* (IVI=26.99). In wooded savannahs, *Vitellaria paradoxa* (IVI=31.44), *Afzelia africana* (IVI=26.83), *Terminalia laxiflora* (IVI=26.34) and *Isoberlinia doka* (IVI = 20.00) are the species with the highest importance value indices. The species with IVI≥ 20 in shrub savannahs are *Combretum nigricans* (IVI=27.29) and *Terminalia laxiflora* (IVI= 25.74). In the *Gmelina* plantations, only *Gmelina arborea* and *Vitellaria paradoxa* have IVI ≥ 20 (Tab. 2).

Table 2. Species Importance Value Indices of vegetation units.

Vegetation units	Species	Relative dominance	Relative density	Relative frequency	IVI
Forest gallery	*Syzygium guineense*	30.18	22.83	23.33	76.34
	Carapa procera	12.83	11.25	8.84	32.91
	Berlinia grandiflora	12.13	12.25	7.77	32.15
	Uapaca togoensis	7.33	9.69	9.98	26.99
	Gmelina arborea	3.85	4.12	8.84	16.81
	Elaeis guineensis	1.14	6.35	7.77	15.26
	Vitex doniana	2.31	2	5.83	10.14
	Manilkara multinervis	2.42	2.78	4.18	9.38
	Synsepalum pobeguinianum	1.23	2.56	4.97	8.76
	Khaya senegalensis	2.82	0.78	1.69	5.29
	Other species	23.77	25.39	16.81	65.97
Wooded savannah	*Vitellaria paradoxa*	10.35	9.57	11.51	31.44
	Afzelia africana	21.3	4.26	1.28	26.83
	Terminalia laxiflora	2.91	8.64	14.79	26.34
	Isoberlinia doka	10.31	7.85	1.84	20
	Daniellia oliveri	4.38	4.26	7.37	16
	Lannea acida	3.73	2.93	8.65	15.3
	Parkia biglobosa	6.37	2.39	6.19	14.96
	Zanthoxylum zanthoxyloides	7.04	5.98	1.28	14.31
	Monotes kerstingii	1.89	6.78	2.51	11.18
	Burkea africana	0.88	2.39	5.12	8.39
	Other species	30.84	44.95	39.46	115.25
Shrub savannah	*Combretum nigricans*	10.97	9.81	6.51	27.29
	Terminalia laxiflora	7.31	9.92	8.51	25.74
	Vitellaria paradoxa	5.43	4.33	9.6	19.37
	Daniellia oliveri	8.26	4.56	5.62	18.43
	Parkia biglobosa	8.71	3.88	4.02	16.6
	Lophira lanceolata	7.1	6.73	1.2	15.03
	Acacia dudgeonii	4.65	5.82	0.83	11.3
	Lannea velutina	3.05	2.05	4.02	9.12
	Gardenia ternifolia	2.08	1.82	4.79	8.69
	Piliostigma thonningii	1.49	3.65	3.32	8.46
	Other species	40.96	47.43	51.58	139.98
Plantation	*Gmelina arborea*	94.82	71.2	34.38	200.4
	Vitellaria paradoxa	1.11	9.89	23.01	34.01
	Parkia biglobosa	0.99	1.29	4.55	6.83
	Terminalia mollis	0.15	1.72	4.55	6.41
	Prosopis africana	0.24	1.58	4.55	6.36
	Parinari curatellifolia	0.12	1.15	4.55	5.82
	Pericopsis laxiflora	0.1	0.86	4.55	5.51
	Terminalia laxiflora	0.07	1.15	2.56	3.77
	Combretum adenogonium	0.07	0.86	2.56	3.48
	Khaya senegalensis	0.91	1.29	1.14	3.33
	Other species	1.42	9.03	13.64	24.08

Family Importance Value Index (FIV) per vegetation unit are presented in Tab. 3. Myrtaceae, Fabaceae-Caesalpinioideae, Meliaceae, Phyllanthaceae and Lamiaceae families have the highest FIV in gallery forests. In the wooded savannahs, Fabaceae-Caesalpinioideae, Combretaceae, Sapotaceae, Fabaceae-Mimosoideae and Anacardiaceae families dominate with FIV ≥ 20. In shrub savannahs, Combretaceae, Fabaceae-Mimosoideae, Fabaceae-Caesalpinioideae families and Rubiaceae dominate with FIV ≥ 20. *Gmelina* plantations are dominated by Lamiaceae, Sapotaceae and Combretaceae families with FIV ≥ 20.

The *Gmelina* plantation is densest with 705±109 stems.ha^{-1} followed by gallery forest with 619±228 stems.ha^{-1} which are not statistically different ($p<0.05$) (Tab. 4). Similarly, the high value of burrowed area is observed in *Gmelina* plantation followed by gallery forest. The average diameter of trees and shrubs varies from 9.51±1.35 cm to 27.93±6.85 cm respectively from shrub savannahs to gallery forests ($F=109.7$; $p<^{2e-16}$) and are significantly different from each other. The low mean height value of trees and shrubs is observed in shrub savannas (2.84±0.52m) and highest in gallery forests (9.39±2.22m).

Table 3. Family Importance Value Indices of vegetation units.

Vegetation unit	Families	Relative dominance	Relative density	Relative frequency	FIV
Forest gallery	Myrtaceae	30.18	22.83	17.68	70.69
	Fabaceae-Caesalpinioideae	17.86	15.03	12.66	45.55
	Meliaceae	15.83	12.14	9.44	37.41
	Phyllanthaceae	7.64	10.8	10.46	28.91
	Lamiaceae	6.16	6.12	12.66	24.94
	Moraceae	5.55	3.23	9.44	18.22
	Sapotaceae	3.65	5.35	8.48	17.47
	Araceae	1.14	6.35	5.89	13.38
	Gentianaceae	1.88	3.12	3.77	8.76
	Clusiaceae	2.43	3.56	1.28	7.27
	Other families	7.7	11.47	8.24	27.41
Wooded savannah	Fabaceae-Caesalpinioideae	38.81	22.07	15.09	75.98
	Combretaceae	6.09	18.48	18.26	42.83
	Sapotaceae	11.95	10.37	12.23	34.55
	Fabaceae-Mimosoideae	8.44	5.72	13.62	27.78
	Anacardiaceae	8.26	6.25	10.91	25.42
	Rutaceae	7.04	5.98	0.94	13.97
	Rubiaceae	2.44	4.12	6.38	12.94
	Fabaceae-Faboideae	2.32	3.06	6.38	11.75
	Dipterocarpaceae	1.89	6.78	1.85	10.52
	Meliaceae	3.14	2.79	3.77	9.71
	Other families	9.61	14.36	10.57	34.54
Shrub savannah	Combretaceae	25.29	35.46	23.49	84.24
	Fabaceae-Mimosoideae	18.42	12.88	15.03	46.33
	Fabaceae-Caesalpinioideae	16.04	13.8	16.31	46.14
	Rubiaceae	5.02	4.45	11.51	20.97
	Sapotaceae	5.43	4.33	7.54	17.3
	Anacardiaceae	6.11	3.42	5.87	15.4
	Ochnaceae	7.1	6.73	0.94	14.77
	Chrysobalanaceae	3.82	5.13	3.76	12.71
	Fabaceae-Faboideae	3.29	3.53	3.76	10.59
	Annonaceae	2.17	2.96	5.11	10.25
	Other families	7.32	7.3	6.68	21.3
Gmelina plantation	Lamiaceae	95.16	71.92	28.72	195.81
	Sapotaceae	1.11	9.89	19.23	30.23
	Combretaceae	0.38	4.87	21.43	26.68
	Fabaceae-Mimosoideae	1.35	3.58	5.93	10.87
	Chrysobalanaceae	0.24	2.44	5.93	8.61
	Fabaceae-Caesalpinioideae	0.23	1.29	5.93	7.45
	Fabaceae-Faboideae	0.11	1	3.8	4.91
	Meliaceae	0.92	1.43	2.14	4.49
	Rubiaceae	0.07	0.43	2.14	2.64
	Anacardiaceae	0.07	0.43	2.14	2.63
	Other families	0.36	2.72	2.61	5.69

Table 4. Demographic characteristics of vegetation units.

Vegetation units	Average height (m)	Average diameter (cm)	Density (stems.ha^{-1})	Basal area (m^2.ha-1)
Forest gallery	9.39±2.22^a	27.93±6.85^a	619±228^a	52.22±24.22^a
Wooded savannah	4.16±0.73^b	12.88±2.57^c	363±142^b	6.41±3.25^b
Shrub savannah	2.84±0.51^c	9.51±1.35^d	304±109^b	2.81±1.68^b
Gmelina plantation	8.22±0.79^a	21.89±3.39^b	705±109^a	40.53±14.97^a

Legend: Superscript letters indicate significant differences according to the Tukey test at the 5% threshold. Averages followed by the same letter in the same column are not statistically different.

Structure and dynamics of adult population

individual's diameter classes distributions (Fig. 4) display an inverted "J" shaped structure for the overall stand with parameters of form c < 1. The regression equation (R^2=93.98; p=0.000) reflects the dominance of short individuals (Tab. 5).

Table 5. Regression equations indicating adult population trend within CFP and vegetation units.

Vegetation units	Regression equations	R^2	p-value
Global	$y = -2.32x + 12.55$	87.13	0.000
Forest gallery	$y = -1.52x + 8.98$	72.13	0.000
Wooded savannah	$y = -2.76x + 12.02$	92.45	0.000
Shrub savannah	$y = -2.73x + 11.50$	89.29	0.000
Gmelina plantation	$y = -2.25x + 10.82$	73.65	0.000

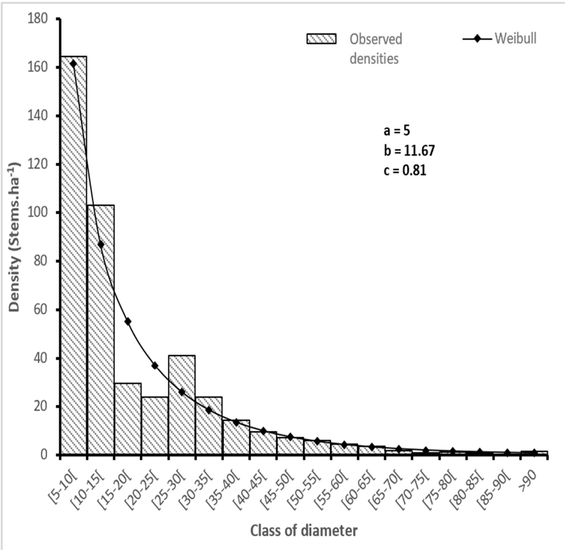

Fig. 4. Overall diameter structure of CFP.

This same distribution is observed within the vegetation units except for gallery forest which presents more individuals in class [15-20 [than class [5-15]. Form parameters c are < 1 in wooded and shrub savannah, and >1 in gallery forest and *Gmelina* plantation (Fig. 5). The regression equations lines show that the populations are stable, with predominantly juvenile populations (Tab. 5).

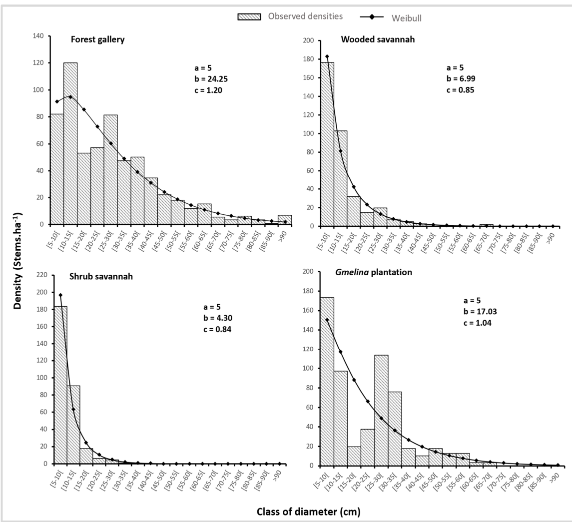

Fig. 5. Diameter structure of CFP vegetation units.

Juvenile population

Recovery rate

The overall recovery rate is 52.18% for the entire CPF. The unit assessment (Fig. 6) shows regeneration difficulties in the gallery forest and *Gmelina* plantation with regeneration rates of 32.48% and 30.69% respectively. Wooded savannah and shrub savannah have high regeneration rates with 66% and 59% respectively.

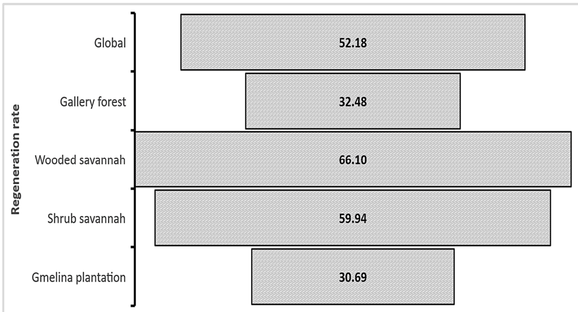

Fig. 6. Overall and vegetation unit recovery rates.

Structure and dynamics

Juvenile population structure is stable in the CFP (Fig. 7) and in all its vegetation units (Fig. 8). The slope and R^2 values of the regression equations confirm this stability for the gallery forest (p=-0.36; R^2=62.25), wooded savannah (p=-0.30; R^2=55.63) and shrub savannah (p=-0.32; R^2=53.08). However, for *Gmelina* plantation, slope and R^2 values reflect instability in the juvenile stand (Tab. 6).

Table 6. Regression equations showing juvenile population trend within CFP and vegetation units.

Vegetation unit	Regression equations s	R^2	p-value
Global	$y = -0.29x + 6.25$	59.28	0.080
Forest gallery	$y = -0.36x + 4.06$	62.25	0.073
Wooded savannah	$y = -0.30x + 5.37$	55.63	0.091
Shrub savannah	$y = -0.32x + 5.22$	53.08	0.100
Gmelina plantation	$y = -0.14x + 4.01$	29.67	0.200

Overall, 10.68% of juveniles fail to cross the first class [0-0.5]. The gallery forest is the vegetation unit with the highest rate (13.66%) of difficulty of emancipation from the first class to the next.

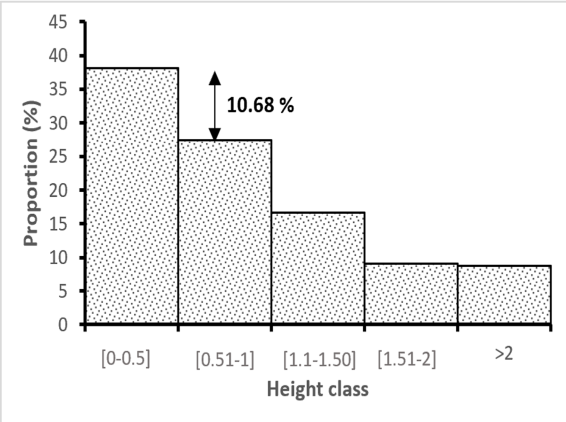

Fig. 7. Overall structure of the youth population in CPF.

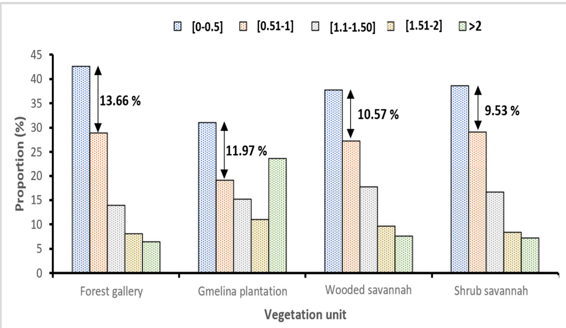

Fig. 8. Juvenile population structure in CFP vegetation units.

Discussion

The overall diameter class structure of CFP, in the shape of an inverted "J", is characterized by a high density of individuals in small diameter classes compared to higher diameter classes. According to Gnoumou *et al.* (2021), this evolutionary trend is characteristic of stable plant formations with good natural regenerative capacity. This trend is also observed in plant formations in Burkina Faso located in the same phytogeographical zone as the CFP (Belem-Ouédraogo, 2008). However, according to Wala (2004), Sambou (2004) and Mbayngone (2008) this trend is due to the phenomenon of compensation that is created between the missing diameter classes in some species by those of others (Bognounou *et al.*, 2009; Traoré *et al.*, 2013; Adekunle *et al.*, 2013; Ganamé, 2020). Specifically, the structure of gallery forests and *Gmelina* plantation are stable with a distribution of individuals in all diameter classes. These vegetation units have the highest average heights, average diameters, densities, and burrowed areas due to the presence of large-diameter individuals. In addition, studies have shown that gallery forests have the highest densities and basal areas (Gnoumou *et al.*, 2020), compared to other vegetation units. This is not the case in our study because the *Gmelina* plantation is the densest vegetation unit with the highest basal area compared to other vegetation units.

This result could be explained by a high density of individuals observed in underbrush and the rapid growth of the species *Gmelina arborea*. Indeed, according to Sanogo (2008), this vegetation unit was created following a forest management project and was intended to supply the national company for industry and trade with wood products for the manufacture of match strands. As the company did not survive, silvicultural maintenance was abandoned in 1978 and the timber was never exploited. Hence the strong recolonization of its underbrush by local vegetation and the large size of trees today.

In tree savanna and shrub savanna, diameter class structures show a high density of species in the [5-10 cm [class and low density of large diameter individuals. As shown by Abdourhamane *et al.* (2013), high densities in the small diameter classes ensure the future of a natural formation. In the shrubby savanna, species hardly exceed the [25-30cm [class.

This could be explained by the shrubby nature of the species that dominate this vegetation unit, such as *Combretum nigricans* and *Terminalia laxiflora*, on the one hand, and the edaphic conditions of the FCP, on the other. Indeed, a large part of the soils in this vegetation unit are comparable to those of the inselbergs. The species develop between the faults of the rocks at shallow depths with extreme aridity. These living conditions slow down the growth of the species found there.

Similar studies have also reported on the impact of severe living conditions on the structure of inselberg vegetations (Tindano *et al.*, 2011; Tindano, 2016).

Juvenile population structures in vegetation units show good regeneration within vegetation units, indicating potential for renewal of the adult woody population (Zegeye *et al.*, 2006; Traoré, 2013). However, according to Ouédraogo (2006), Traoré (2013), the overall structure does not show the actual state of the regeneration of certain formations because there are only a small number of species that contribute mainly to the renewal of stands.

Conclusion

The study of the overall structure and vegetation units reveal stability within the woody flora of the Classified Forest of Péni. All its ecosystems have a good regeneration dynamic. Protection actions are necessary so that these ecosystems do not disappear from the CFP. Our study was limited to the overall structure of the vegetation. Additional studies are needed to determine the status of the dominant species in each vegetation unit. However, since humans remain the most important factor in the accelerated degradation of protected areas, these protection actions must consider the usefulness of this forest for local populations. This will make it possible to design management plans that can inspire the support of all in the process of conservation and sustainable management of this forest. A study on its ecosystem services, at the social level, is necessary for this.

Conflicts of interest

The authors have not declared any conflicts of interest.

Acknowledgement

We are very grateful to the government of Burkina Faso for its financial support through the national scholarship.

References

Abdourhamane H, Morou B, Rabiou H, Mahamane A. 2013. Caractéristiques floristiques, diversité et structure de la végétation ligneuse dans le Centre-Sud du Niger : cas du complexe des forêts classées de Dan kada Dodo-Dan Gado. International Journal of Biological and Chemical Science **7(3),** 1048-1068.

Adekunle VAJ, Olagoke AO, Akindele SO. 2013. Tree species diversity and structure of a Nigerian strict nature reserve. Tropical Ecology **54(3),** 0275-289.

Baker PJ, Bunyavejchewin S, Oliver CD, Ashton PS. 2005. Disturbance history and historical stand dynamics of a seasonal tropical forest in western Thailand. Ecology Monographs **75,** 317-343. https://doi.org/10.1890/04-0488

Base Nationale de Données Topographiques (BNDT). 2012. Institut Géographique du Burkina. Données SIG.

Belem-Ouédraogo M. 2008. Les galeries forestières de la Réserve de la Biosphère de la Mare aux Hippopotames du Burkina Faso : caractéristiques, dynamique et ethnobotanique. Thèse de doctorat d'état, université de Ouagadougou 279p.

Bognounou F, Thiombiano A, Savadogo P, Boussim JI, Odén PC, Guinko S. 2009. Woody vegetation structure and composition at four sites along latitudinal gradient in Western Burkina Faso. Bois et Forêt des Tropiques **300(2),** 29-44. http://dx.doi.org/10.19182/bft2009.300.a20412

Borsali AH, Benabdeli K, Gros R. 2014. Dynamique structurelle de la végétation en zone semi-aride: cas de la forêt de Fénouane (monts de Saida, Algérie occidentale). Afrique SCIENCE **10(2),** 419-433.

Condit R, Sukumar R, Hubbell SP, Foster RB. 1998. Predicting population trends from size distribution: a direct test in a tropical tree community. The American Naturalist **152(4),** 495-509. https://doi.org/10.1086/286186

Diouf M, Akpo LE, Rocheteau A, DO F, Goudiaby V, Diagne AL. 2002. Dynamique du peuplement ligneux d'une végétation sahélienne au Nord-Sénégal (Afrique de l'ouest). Journal des Sciences **2,** 1-9.

Everard DA, Midgley JJ, Van Wyk GF. 1995. Dynamics of some forests in KwaZuluNatal, South Africa, based on ordinations and size class distribution. South African Journal of Botany **61,** 283-292. http://dx.doi.org/10.1016/S0254-

Faye EH, Masse D, Diatta M. 2003. Dynamique de la régénération ligneuse durant la phase de culture dans un système de culture semi-permanente du sud du Sénégal. Actes du colloque 27-31, Garoua, Cameroun.

Fontès J, Guinko S. 1995. Carte de la végétation et de l'occupation du sol du Burkina Faso. Notice explicative plus carte. Toulouse : Ministère de la coopération française, projet Campus 67 p.

Ganaba S. 2008. Caractérisation, utilisation, tests de restauration et gestion de la végétation ligneuse au Sahel, Burkina Faso. Thèse de Doctorat d'Etat ès Sciences Naturelle, Université Cheikh Anta-Diop, Faculté des Sciences et Techniques 287 p.

Ganamé M. 2020. Dynamique spatio-temporelle et potentiel du stock de carbone aérien des écosystèmes forestiers du Burkina Faso. Thèse de doctorat, Université de Ouagadougou 167p.

Gnoumou A. 2013. Diversité et dynamique spatio-temporelle de la végétation de la forêt classée et réserve partielle de faune de la Comoé-Léraba (sud-ouest du Burkina Faso). Thèse unique, Université de Ouagadougou 183 p.

Gnoumou A, Ouattara AH, Sambaré O, Ouédraogo A. 2021. Caractérisation de la diversité et structure de la végétation ligneuse des formations ripicoles de la Forêt Classée de Kari, Burkina Faso. Afrique SCIENCE **18(1),** 69-89.

Gnoumou A, Savadogo S, Thiombiano A. 2020. Les groupements végétaux de la réserve de la Comoé-Léraba : caractérisation et impact des sols sur leur distribution. International journal of Biological and Chemical Sciences **14(9),** 3168-3187. https://doi.org/ 10.4314/ijbcs.v14i9.16

Godoy R. 1992. Some organizing principles in the valuation of tropical forests. Forest Ecology and Management **50,** 171-180.

Guinko S. 1984. La végétation de la Haute-Volta. Thèse de Doctorat ès Sciences, Université de Bordeaux III, Bordeaux, **Vol I & II,** 394 p.

Hakizimana P, Bangirinama F, Havyarimana F, Habonimana B, Bogaert J. 2011. Analyse de l'effet de la structure spatiale des arbres sur la régénération naturelle de la forêt claire de Rumonge au Burundi. Bulletin Scientifique de l'Institut National pour l'Environnement et la Conservaton de la Nature **9,** 46-52.

Herrero-Jáuregui C, García-Fernández C, Sist PL, Casado MA. 2012. Recruitment dynamics of two low-density neotropical multiple-use tree species. Plant Ecology **212(9),** 1501-1512. http://dx.doi.org /10.1007/s11258-011-9924-0

Hitimana J, Kiyiapi JL, Njunge TJ. 2004. Forest structure characteristics in disturbed and undisturbed sites of Mt. Elgon Moist Lower Montane Forest, western Kenya. Forest Ecology and Management **194,** 269-291.

Hounkpevi A, Yévidé ISA, Ganglo CJ, Devineau, JL, Azontonde HA, Adjakidje V, Agbossou KE, Foucault DB. 2011. Structure et écologie de la forêt à *Diospyros mespiliformis* Hochst. ex A.DC. et à *Dialium guineense* Willd. de la réserve de Massi (La Lama), Bénin. Bois et forêts des tropiques **308(2),** 33-46.

Johnson NL, Kotz S. 1970. Distributions in Statistics: Continuous univariate distributions. John Wiley and Sons, New York, USA 333p.

Kébé MI, Sagna MB, Diallo MD, Diallo A, Diatta S, Ngom D, Peiry JL, Goffner D, Guissé A. 2020. Étude des caractéristiques écologiques d'un peuplement ligneux de la grande muraille verte dans le Ferlo nord, Sénégal. Revue de l'Environnement et de la Biodiversité, PASRES **5,** 63-76.

Koulibaly A, Kouamé N, Traoré D, Polembski S. 2010. Structure et régénération de la végétation ligneuse, le long de transects forêts-savanes, dans la région de la réserve de Lamto (Côte d'Ivoire). Annales de Botanique de l'Afrique de l'Ouest **06,** 56- 72.

Lorimer CG, Krug AG. 1983. Diameter distribution in even-aged stands of shade-tolerant and midtolerant tree species. American Midland Naturalist **109,** 331-345.
https://doi.org/10.4000/ vertigo.14352

Lykke AM. 1998. Assessment of species composition change in savanna vegetation by means of woody plants' size class distribution and local information. Biodiversity and Conservation **7,** 1261-1275.
http:// dx.doi.org/10.1023/A:1008877819286

Mbayngone E. 2008. Flore et végétation de la réserve partielle de faune de Pama, sud-est du Burkina Faso. Thèse de Doctorat unique, Université de Ouagadougou 181p.

Ministère de l'Environnement et du Développement Durable. 2011. Programme d'Investissement Forestier (PIF-Burkina Faso) **2,** 70 p.

Nacoulma MIB. 2012. Dynamique et stratégies de conservation de la végétation et de la phytodiversité du complexe écologique du parc national du W du Burkina Faso. Thèse de Doctorat unique, Université de Ouagadougou 202p.

Obiri J, Lawes M, Mukolwe M. 2002. The dynamics and sustainable use of high-value tree species of the coastal Pondoland forest of the Eastern Cape Province South Africa. Forest Ecology and Management **166,** 131-148.
http://dx.doi.org /10.1016/ S0378-1127(01)00665-X

Ouédraogo A. 2006. Diversité et dynamique de la végétation ligneuse de la partie orientale du Burkina Faso. Thèse de Doctorat unique, Université de Ouagadougou 195p.

Ouédraogo O, Thiombiano A, Hahn-Hadjali K, Guinko S. 2009. Diversité et dynamique de la végétation ligneuse juvénile du Parc National d'Arly (Burkina Faso). Candollea **64(2),** 257-278.

Ouoba P. 2006. Flore et végétation de la forêt classée de Niangoloko, Sud-ouest, Burkina Faso. Thèse de Doctorat, Université de Ouagadougou, 144p.

Ryniker KA, Bush JK, Van Auken OW. 2006. Structure of *Quercus gambelii* communities in the Lincoln National Forest, New Mexico, USA. Forest Ecology and Management **233,** 69-77.
https:// doi.org/ 10.1016/j.foreco.2006.06.008

Sambaré O, Savadogo S, Traoré L, Ouédraogo I, Thiombiano A. 2020. Structure et dynamique des espèces ligneuses des forêts-galeries des rivières et ruisseaux du secteur sud-soudanien du Burkina Faso. Bois et Forêts des Tropiques **345,** 25-42.
http://dx.doi.org/10.19182/bft2020.345.a31928

Sambou B. 2004. Evaluation de l'état, de la dynamique et des tendances évolutives de la flore et de la végétation ligneuse dans les domaines soudanien et sub-guinéen au Sénégal. Thèse Doctorat ès Sciences Naturelles. UCAD, Faculté des Sciences et Technique. Institut des Sciences de l'environnement 210p.

Sanogo M. 2008. Evaluation des potentialités et des contraintes de la Forêt Classée de Péni : perspectives de valorisation durable. Mémoire d'Inspecteur des Eaux et Forêts, Ecole Nationales des Eaux et Forêts 117p

Savadogo S. 2013. Les bois sacres du Burkina Faso: diversité, structure, dimension spirituelle et mode de gestion de leurs ressources naturelles. Thèse de Doctorat Unique, Université de Ouagadougou 280 p.

Shackleton CM. 1993. Demography and dynamics of the dominant woody species in a communal and protected area of the eastern Transvaal Lowveld. South African Journal of Botany **59,** 569-574.
https://doi.org/10.1016/S0254-6299(16)30672-X

Tabuti JRS, Lye KA, Dhillion SS. 2003. Traditional herbal drugs of Bulamogi, Uganda: plants, use and administration. Journal of Ethnopharmacology **88,** 19-44. https://doi.org/ 10.1016 /s0378-8741(03)00161-2

Tankoano B. 2017. Contribution de la télédétection et des Systèmes d'Informations Géographiques à l'évaluation de l'impact des activités humaines sur la couverture végétale du Parc National des Deux Balé (PNDB) à l'Ouest du Burkina Faso. Thèse de Doctorat unique. Université Nazi BONI 135p.

Thiombiano A, Glèlè-Kakai R, Bayen P, Boussim JI, Mahamane A. 2016. Méthodes et dispositifs d'inventaires forestiers en Afrique de l'Ouest : état des lieux et propositions pour une harmonisation. Annales des Sciences Agronomiques 20, **spécial Projet Undesert-UE** 15-31.

Tindano E. 2016. Etat et dynamique de la végétation et de la flore des inselbergs du Burkina Faso. Thèse de Doctorat, Université Ouaga I Pr Joseph KI-ZERBO 237p.

Traoré L, Sop TK, Dayamba SD, Traoré S, Hahn K, Thiombiano A. 2013. Do protected areas really work to conserve species? A case study of three vulnerable woody species in the Sudanian zone of Burkina Faso. Environment, Development and Sustainability **15,** 663-686.

Traoré L. 2013. Influence du climat et de la protection sur la végétation ligneuse de la partie occidentale du Burkina Faso. Thèse de Doctorat de l'Université de Ouagadougou, Burkina Faso 228 p

Wala K. 2004. La végétation de la chaîne de l'Atakora au Bénin: diversité floristique, phytosociologie et impact humain. Thèse de Doctorat, Université de Lomé 140p.

Yaro OSV. 2018. Les plantes médicinales vétérinaires et structures démographiques de quatre espèces ligneuses les plus utilisées dans le traitement des bovins au Sud-Ouest du Burkina Faso. Mémoire d'Ingénieur du Développement Rural, Université Nazi BONI 90p.

Zaouri GJM, Yao NO, Soro K, Soro D. 2021. Diversité végétale de la Forêt Classée de Yaya au Sud-Est de la Côte d'Ivoire. International Journal of Biological and Chemical Sciences **15(6),** 2554-2567. https://doi.org/10.4314/ijbcs.v15i6.24

Zarnock SJ, Dell TR. 1985. An evaluation of percentile and maximum likelihood estimators of Weibull parameters. Forest Sciences **31,** 260-268. https://doi.org/10.1093/forestscience/31.1.260

Zegeye HL, Teketay D, Kelbessa E. 2006. Diversity, regeneration status and socio-economic importance of the vegetation in the islands of Lake Ziway, southcentral Ethiopia. Flora **201,** 483-498. https://doi.org/10.1016/j.flora.2005.10.006