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Floristic composition, structure and diversity of the woody vegetation of Deux Balé national park, Burkina Faso

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Abstract

Large areas of protected forests in Burkina Faso are degraded yearly due to human pressures and climatic change. The effects of this process are clearly reflected in the state of the forest canopy. This study aims to clarify the local effects of forest degradation in Deux Balé National Park through an assessment of the richness, diversity and structure of the woody vegetation. The floristic analysis revealed a richness of 109 woody species belonging to 30 families, where the most common included Rubiaceae (13.64%), Combretaceae (12.73%), Mimosaceae (11.82%) and Caesalpiniaceae (10.91%). An analysis of floristic diversity and stem diametric structure enabled a separation of 13 plant communities in the area. The stem structure follows a Weibull distribution and shows a prevalence of small trees in the park. Some of the plant communities have values of the parameter of form c lower than 1 and other groups have values of coefficient of form c ranging between 1 and 3.6, which indicates a good health of these plant communities.

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Introduction

The degradation of forest ecosystems represents one of the most important causes of biodiversity loss globally. The annual rate of deforestation was estimated to more than 13 million hectares between 1990 and 2010 (FAO, 2010), with the highest rate in developing countries.

In Burkina Faso, forest areas occupied 13.3 million hectares in 2000 (Direction des Forêts, 2007). In 2010 the forest areas was estimated to 5 million hectares (FAO, 2010). One of the main causes of deforestation in Burkina Faso is agricultural expansion through slash and burn practices (Diallo *et al.*, 2011; Tankoano *et al.*, 2016a).

In addition to agriculture, the increased demand for wood fuel, grazing areas and, more recently, mining operations also constitute important causes of deforestation (Tankoano *et al.*, 2016a; Ozer *et al.*, 2010; Niggemann *et al.*, 2009; N'Da *et al.*, 2008).

The outcome has been a reduction or disappearance of a significant number of plant species sheltered by these ecosystems. In order to counter the threat of biodiversity loss, Burkina Faso has established protected areas to protect flora and fauna. Unfortunately, these protected areas have often been illegally occupied by riparian populations who farm the land.

This has happened in Deux Balé National Park (PNDB) where agriculture occupied 4,918 ha in 2015 (Tankoano *et al.*, 2016b). This park is among the most important protected areas in Burkina Faso, as well as in West African, due to its high biodiversity.

In addition to the floristic diversity, the PNDB harbors valuable wildlife, including a large population of elephants. Thus, the rapid forest degradation does not only represent a threat to the flora, it also constitutes a threat to the animals that depend on it.

One of the main concerns of governmental agencies in charge of the management of PNDB is to know the exact state of the vegetation in terms of flora and structure. Such information is critical for developing policies for the sustainable management of the park and its biodiversity.

Thus, the aim of this study is to characterize the composition, diversity, and the structure of the woody vegetation of PNDB.

Materials and methods

Study area

PNDB was created in 1988 by Zatu AN VII/FP/PRES/MET, following the merging of two protected forests (Deux Balé and Dibon), and covers an area of 80 600 ha (Kafando, 2003).

The park is located on the “horse back” between the provinces of Balé and Tuy (11°25'-11°36' latitude N; 2°45' and 3°12' longitude W; Fig. 1). PNDB extends on a peneplain with altitudes ranging between 240 m and 320 m (Coziadom, 2009).

At ground level, the park is characterized by vertisols, hydromorphic soils and ferruginous tropical soils (Diawara, 2012).

The climate is classified as Sudanian with two distinct seasons, including a rainy season from May to October and a dry season from November to April (Fontès and Guinko, 1995), and an annual average temperature is around 28°C with a thermal amplitude in the order of 7°C (Coziadom, 2009).

The PNDB is located in south-Sudanian zone (Fontès and Guinko, 1995) where the landscape is characterized by woody savannas, shrub savannas and forest galleries. The river Mouhoun runs through the area and receives water from temporary watercourses (smaller streams and creeks).

Traditional agriculture on subsistence basis is the main livelihood strategy of the riparian populations in and around the park. In recent years cotton-growing (Fig. 2) has been stimulating the clearing of new lands (Sawadogo, 1996).

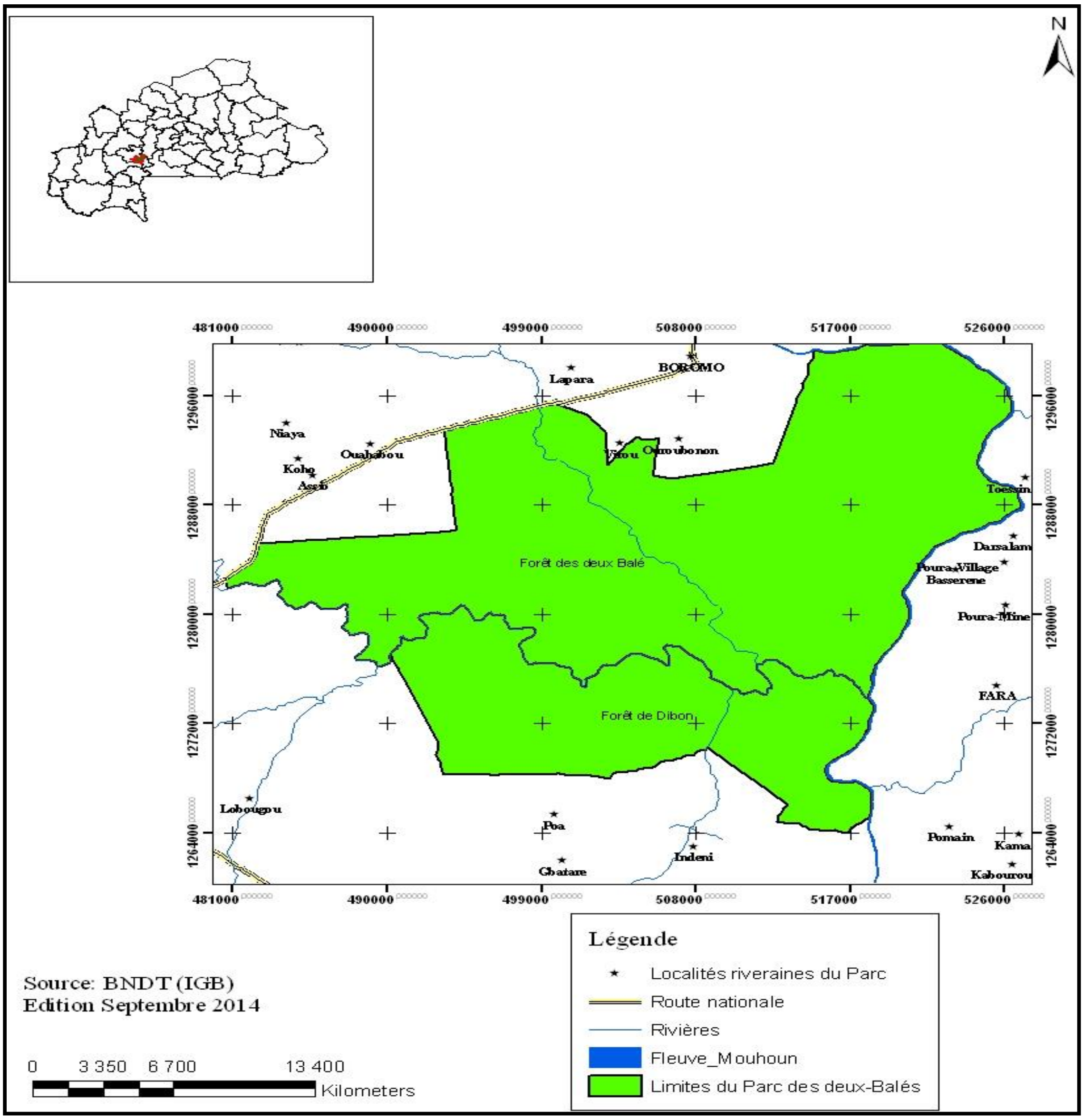

Fig. 1. Location of Deux Balé National Park (PNDB).

Fig. 2. Cotton-growing in Deux Balé National Park.

Materials

The following equipment was used in the study:

Field material, including i) a 50 m ribbon to delineate the plots, ii) a 1.5 m ribbon for the measurement of tree stem circumferences at breast height (CHP), iii) a flora (Arbonnier, 2009) to identify the plant species, iv) a GPS Garmin "62" for the registration of the geographical coordinates of the plots, and v) a photographic camera for documenting the vegetation cover in the plots.

Land use map derived from Landsat 8 imagery (scene 196-52; 21 October 2015). This map has been edited by Tankoano *et al.* (2016b);

PC-Ord 6.0 software and Minitab 17 software were used for the analysis of floristic data and stem diameter distributions.

Collection of floristic data

Survey plots were randomly distributed throughout the park in areas with homogeneous vegetation, which were identified on the basis of the 2015 land use map and field visits. The survey was carried out using circular plots with a radius of 17 m following the method of abundance-dominance of Braun-Blanquet (1932). In areas with gallery forest, plots of 50m x 10m were installed. In addition to collecting phytosociological data, a forest inventory was also conducted. Trees with circumference at breast height higher than or equal to 16 cm were included.

Identification of plant communities and character-ristic species

A dataset consisting of 154 phytosociological samples and 109 woody species was used for the analysis of plant communities. A hierarchical classification of the plots through cluster analysis was conducted with the PC-Ord 6.0 software using the Euclidean distance and according to Ward's method (McCune and Grace, 2002). This method has already been used with success to distinguish plan communities by several authors (Ganglo *et al.,* 2006; Ouoba, 2006; Nacoulma, 2012).

Plant communities obtained from the hierarchical classification were subjected to a second analysis in the PC-Ord 6.0 software in order to characterize the flora of each plant community and to identify the characteristic species. Each woody species found in the park was characterized by 3 phytosociological variables, including the relative abundance, the relative frequency or fidelity, and the indicator value, which is the multiplication between the relative abundance and the relative frequency. This method, developed by Dufrêne and Legendre (1997), is implemented in the PC-Ord 6.0 software under the program indicator species analysis and was used to calculate the indicator value of each species, and for digitally identify the characteristic species of each plant community from Monte Carlo test (P-value 0.05). This method is increasingly used to determine the characteristic species of plant communities (Ouoba, 2006; Ouédraogo, 2009; Nacoulma, 2012; Dossou *et al.*, 2012).

In addition, the characteristic species were used to appoint the plant communities. To do this, the dataset (154 plots) was submitted to the analysis, but this time the abundance-dominance for each species were considered.

The scale of Braun-Blanquet was transformed into quantitative units according to the scale of Van Der Maarel (Ouoba, 2006 and Nacoulma, 2012). This transformation facilitated the analysis in the PC-Ord software that uses only numeric data.

Analysis of plant community diversity

We also wanted to derive a more or less exhaustive list (specific richness) of the flora of PNDB, since it constitutes the most basic indicator of biological diversity. For the analysis of the floristic diversity of the plant communities, the coefficient of similarity of Sorensen was applied using Equation 1:

$$\mathrm{Cs} = \frac{2c}{(a+b)} \times 100 \quad \text{Equation 1}$$

Where a= the total number of species recorded in the first community, b= the total number of species recorded in the second community, and **c**= the number of species common to the two communities.

Parameters of plant community structure

For each plant community, the following parameters were considered:

The tree-density: it is determined by the average number of trees per hectare in each plant community according to the formula:

$$\mathrm{D} = \frac{\mathrm{N}}{\mathrm{S}} \qquad \text{Equation 2}$$

Where N is the overall number of trees inventoried in the plant community and S the total area sampled in the community in hectare;

The basal area (gi) expressed in m²/ha, which is calculated by the formula:

$$g_i = d_i^2 \times \frac{\pi}{4} \quad \text{Equation 3}$$

Where di is the diameter at breast height of the tree i.

The distribution of stems by diameter class

The analysis of the diametric structure of the woody vegetation was carried out through the histograms of relative frequency distribution calculated by diameter class. To do this, 14 classes of amplitude 5 cm were defined. In addition, to better characterize the variability of the forms of the observed structures and to make comparisons between structures possible, an adjustment to the theoretical distribution of Weibull based on the method of maximum likelihood was applied (Husch *et al.,* 2003) using the Minitab 17 software. This method is based on the probability density function of the Weibull distribution F according to the following formula:

$$F(x) = \frac{c}{b} \times \left[\frac{(x-a)}{b}\right]^{c-1} \times exp\left[-\frac{(x-a)}{b}\right]^{c}$$

Where c = the shape parameter (or slope of Weibull) linked to the structure considered, a= the parameter of position and b = the scale parameter is linked to the central value of the probability distribution of the variable x = diameter.

A value of $c < 1$, distribution in "J overthrown" is characteristic of the multi-species or uneven-aged stands, whereas a value of $c > 3.6$ is characteristic of stands to predominance of older individuals. If $1 < c < 3.6$ the value indicates stands with predominance of individuals young or of low-diameter.

Results and discussion

Woody vegetation of PNDB

The forest inventory in PNDB identified 109 woody species distributed in 74 genera and 30 families. Six dominating families were identified, including Rubiaceae (13.64%), Combretaceae (12.73%), Mimosaceae (11.82%), Caesalpiniaceae (10.91%), Anacardiaceae (6.36%) and Fabaceae (5.45%; Fig. 3). The remaining 24 families represented 39,09% of the dataset.

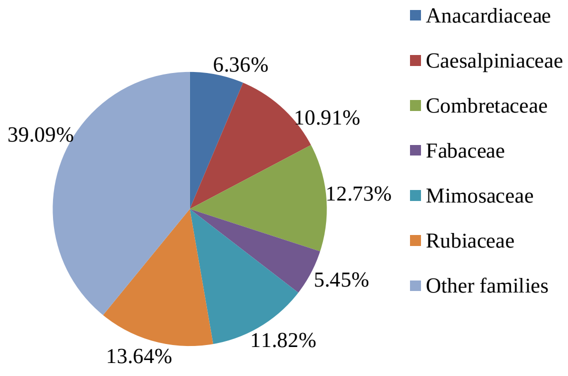

Fig. 3. Family spectrum of the woody vegetation in Deux Balé National Park.

Plant communities and their indicator species

The dendrogram obtained from the hierarchical classification (Fig. 4) allowed to distinguish different plant communities. The plots belonging to a same plant community are closer between them than with any other plot.

This clear individualization is also confirmed by the percentage of chaining that is particularly low (0.92%). Thus, thirteen (13) plant communities were identified with indicator species which are *Combretum molle* R. Br. ex G. Don, *Anogeissus leiocarpus* (DC.) Guill. *et al.* Perr., *Burkea africana* Hook. f., *Pteleopsis suberosa* Engl. and Diels.

Terminalia laxiflora Engl., *Acacia dudgeoni* Craib ex Hall., *Pseudocedrela kotschyi* (Schweinf.) Harms, *Lannea microcarpa* (Hochst.ex A. Rich.) Engl., *Terminalia avicennioides* Guill. and Perr., *Lonchocarpus cyanescens* (Schum. And Thonn.) Benth., *Maranthes polyandra* (Benth.) Prance, *Isoberlinia tomentosa* (Harms) Craib and Stapf and *Mitragyna inermis* (Willd.) Kuntze.

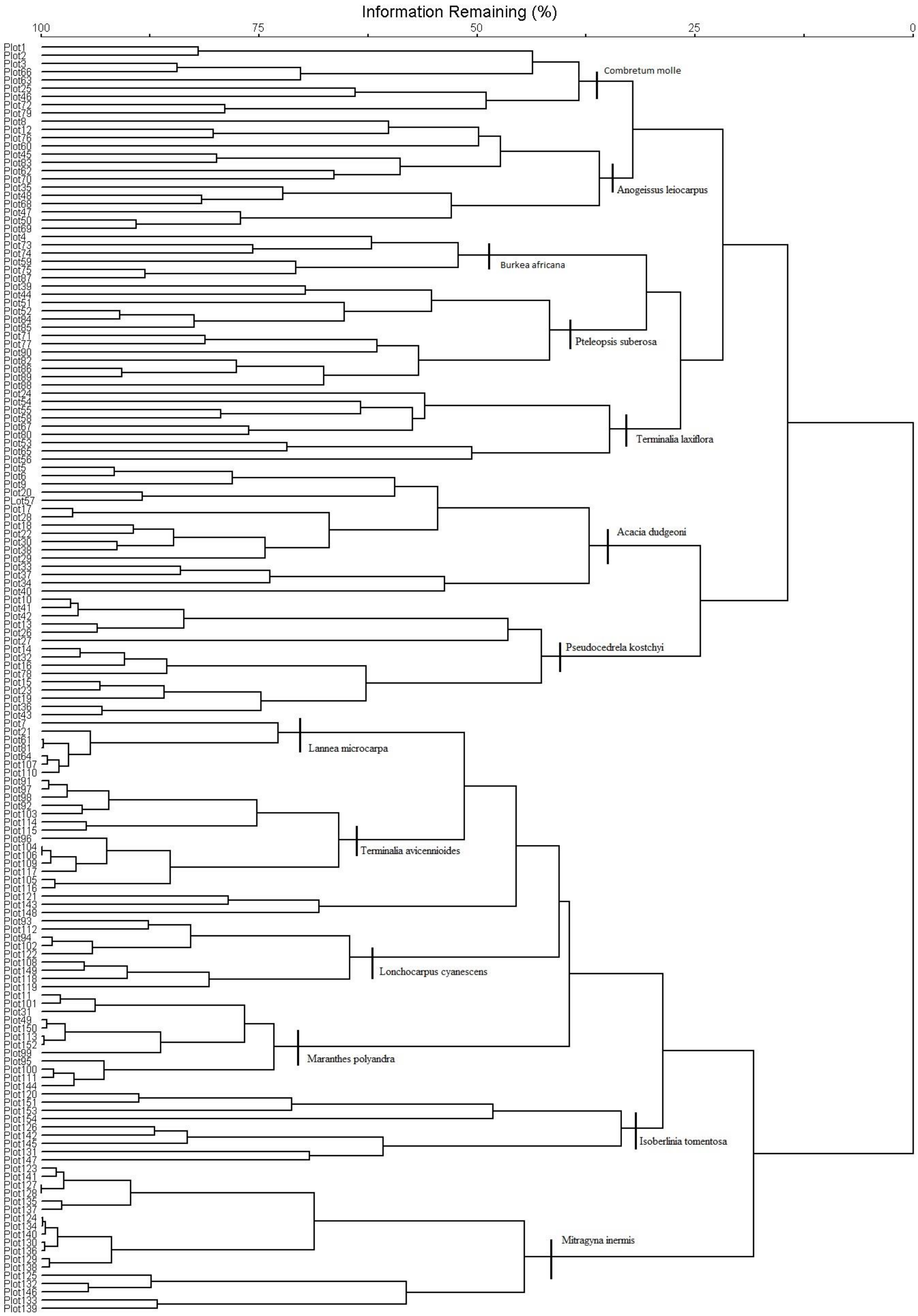

Fig. 4. Dendrogram of classification of 154 plots of woody vegetation of the PNDB.

Table 1 presents the indicator species and indicator value of each of the 13 plant communities of the PNDB identified by the classification.

Thus, only species whose statistical connection is significant (Monte Carlo test on the indicator value with $p < 0.05$) were considered.

Table 1. Indicator species of the 13 plant communities.

Code of communities	Indicator species	Indicator Value	P value (Monte Carlo test with p < 0.05)
g1	*Combretum molle*	32.8	0.002
g2	*Anogeissus leiocarpa*	47.3	0.001
g3	*Burkea africana*	48.6	0.001
g4	*Pteleopsis suberosa*	23.1	0.007
g5	*Terminalia laxiflora*	28.1	0.006
g6	*Acacia dudgeoni*	24.96	0.001
g7	*Pseudocedrela kostchyi*	27.9	0.04
g8	*Lannea microcarpa*	29.6	0.005
g9	*Terminalia avicennioides*	20.7	0.019
g10	*Lonchocarpus cyanescens*	26.8	0.01
g11	*Maranthes polyandra*	21.4	0.04
g12	*Isoberlinia tomentosa*	55.6	0.001
g13	*Mitragyna inermis*	80.1	0.001

Diversity of plant communities

The coefficient of similarity was calculated for the 13 plant communities took two to two (Table 2). The plant communities g1 and g3 are those who resemble the most with a value of coefficient of similarity of 0.72. The other communities which also present a significant similarity (coefficient of Sorensen>0.50) areg1g9, g2g9, g1g7, g7g11, g7g12, g7g9, g4g10, g7g10, g3g7, g3g10, g4g9, g2g4, g6g10, g5g10, g5g7, g4g12, g2g7, g9g12, g5g12, g9g10, g4g7, g3g6, g1g2, g2g10, g10g12, g4g6, g1g6, g3g5, g2g3, g3g12, g5g6, g1g12, g6g12, g1g4, g1g5, g4g5, g2g6, g2g5, g3g4, g6g7, g2g12, g1g3.In general there is a differentiation of all these communities of savanna. The communities g8, g11 and g13 are differentiated more from the others with indices less than 0.50. This is particularly apparent for g8, which is most dissimilar to g13 with a coefficient of similarity of Sorensen of 0.11.

Table 2. Floristic similarity between plant communities (coefficient of similarity).

	g1	g2	g3	g4	g5	g6	g7	g8	g9	g10	g11	g12	g13
g1	**1**												
g2	0.64	**1**											
g3	0.72	0.66	**1**										
g4	0.68	0.56	0.70	**1**									
g5	0.68	0.70	0.65	0.68	**1**								
g6	0.65	0.69	0.64	0.65	0.66	**1**							
g7	0.52	0.60	0.55	0.63	0.59	0.70	**1**						
g8	0.28	0.30	0.24	0.18	0.28	0.24	0.22	**1**					
g9	0.51	0.51	0.45	0.56	0.46	0.46	0.54	0.25	**1**				
g10	0.55	0.64	0.56	0.54	0.59	0.58	0.55	0.32	0.63	**1**			
g11	0.38	0.50	0.46	0.34	0.50	0.41	0.52	0.18	0.30	0.44	**1**		
g12	0.67	0.70	0.66	0.60	0.61	0.67	0.53	0.27	0.60	0.64	0.49	**1**	
g13	0.32	0.36	0.27	0.23	0.26	0.24	0.26	0.11	0.34	0.35	0.23	0.33	**1**

Structural characteristics of plant communities

Our results on the structure of the plant communities (Fig. 5) show that the shape parameter c of the Weibull distribution is less than 1 for *Combretum molle*-community (Fig. 5a), *Burkea Africana* community (Fig. 5c) and *Isoberlinia tomentosa* community (Fig. 5l). As for structure of *Anogeissus leiocarpa*-community (Fig. 5b), *Pteleopsis suberosa* community (Fig. 5d), *Terminalia laxiflora* community (Fig. 5e), *Acacia dudgeon* community (Fig. 5f), *Pseudocedrela kotschyi* community (Fig. 5g), *Lannea microcarpa* community (Fig. 5h), *Terminalia avicennioides* community (Fig. 5i), *Lonchocarpus cyanescens* community (Fig. 5j), *Maranthes polyandra* community (Fig. 5k) and *Mitragyna inermis* community (Fig. 5m), the shape parameter c of the Weibull distribution is between 1 and 3.6.

At horizontal structure level (Fig. 6(a) and Fig. 6(b), *Lannea microcarpa*-community (g8) presents the lowest average density (95 stems/ha) and the lowest basal area (0.95m²/ha).

In contrast, *Mitragyna inermis*-community (g13) presents the highest average density (533 stems/ha) and the highest basal area (29.8m²/ha).

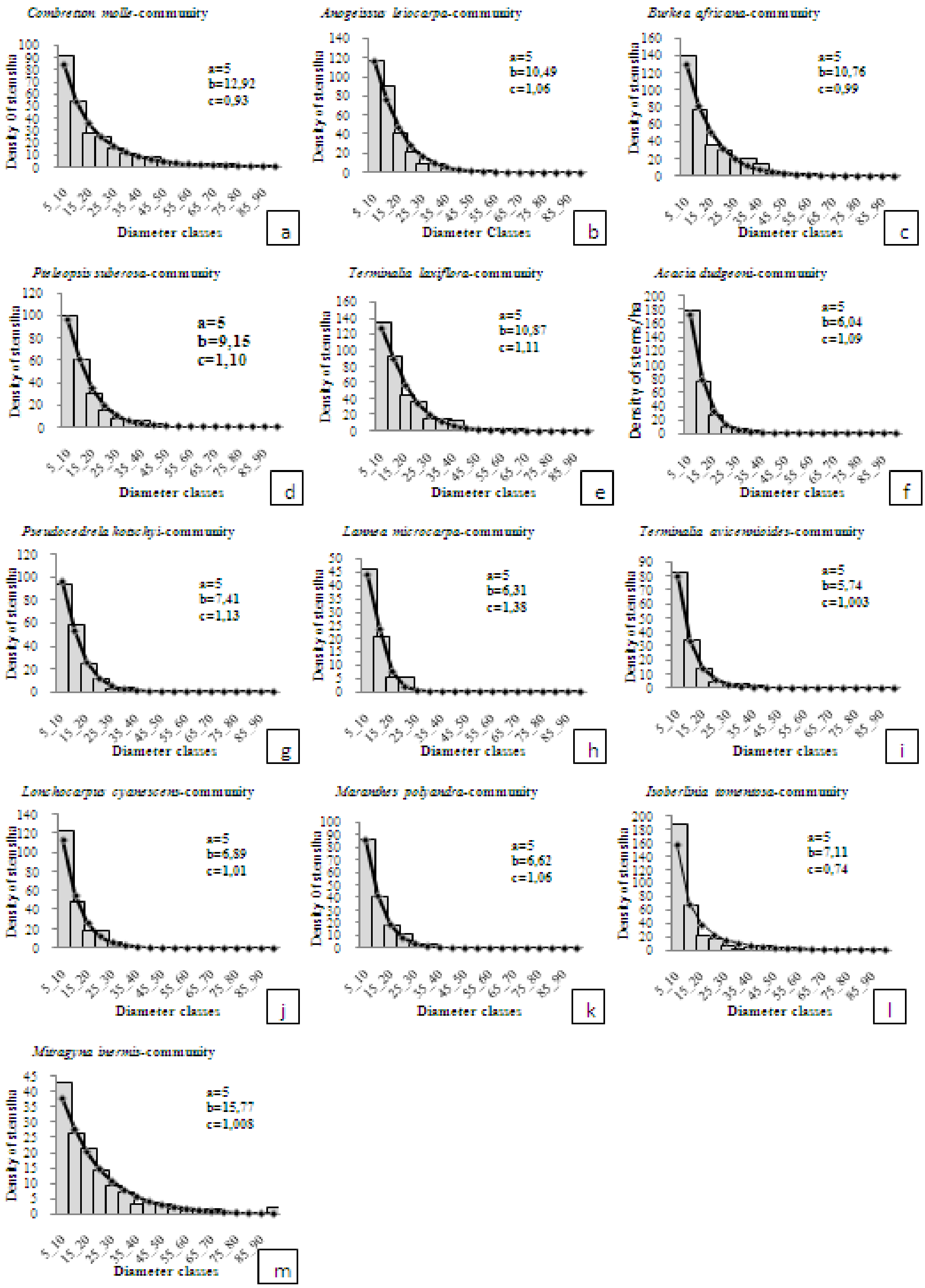

Fig. 5. Diametric structures of the 13 plant communities.

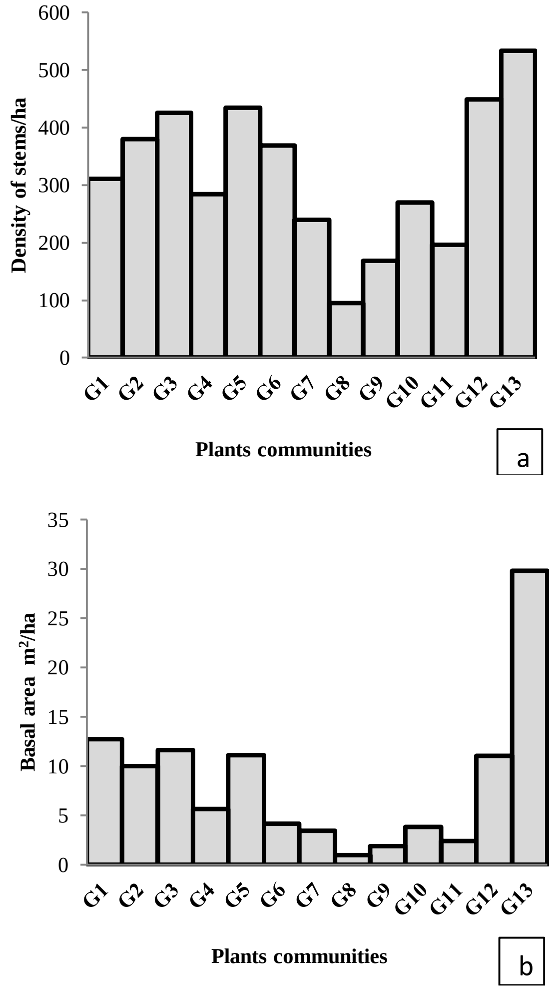

Fig. 6. Tree-density per hectare and basal area (m^2/ha) of each plant community.

Discussion

The focus of this study concerned trees, shrubs and lianas, but not the herbaceous vegetation. In total, 109 woody species distributed in 30 families were identified. Our results show that the floristic richness of PNDB is lower than in other protected areas in Burkina Faso (Ouoba, 2006; Mbayngone *et al.*, 2008; Nacoulma, 2012). This difference may be due to climatic conditions and the effort of protection that benefit the other protected areas. In addition, the relatively low floristic richness in PNDB could be due to non-consideration of herbaceous plants in this study.

Our results also show a predominance of six (6) families (Rubiaceae, Combretaceae, Mimosaceae and Caesalpiniaceae, Anacardiaceae and Fabaceae) in the park, which can be linked to the climate of the area. According Savadogo *et al.* (2016), droughts in the Sahel allowed a natural selection of xeric species, such as those in the Combretaceae family. This family can withstand such droughts, but also high temperatures. Other authors (Froumsia *et al.,* 2012; Bognounou *et al.,* 2009) have found similar results in the Kalfou forest reserve in Cameroon and in different areas in Burkina Faso.

In addition, species in the Combretaceae familly are known to be able to withstand disturbances. This family is the most common and strongly represented in the tropical areas, particularly in the savanna of Africa and more typically in the Sudano-Sahelian region (Savadogo *et al.*, 2016). The dominance of Combretaceae and Mimosaceae species suggests that the areas is generally dry (Mbayngone *et al.*, 2008) and could in part be explained by the mode of dispersal of species belonging to these families (Ouédraogo, 2009; Abdourhamane *et al.*, 2013). This dominance of Mimosaceae and Combretaceae is also noticed by Dimobé *et al.* (2012) in the north of Togo.

Our results from the structural analysis show that the shape parameter c of the Weibull distribution is less than 1 for *Combretum molle*-community, *Burkea africana*-community, *Isoberlinia tomentosa*-community, which indicates a distribution characteristic of multi-species stands with a predominance of young individuals or low-diameter (Husch *et al.*, 2003; Glèlè *et al.*, 2006; Dossou *et al.*, 2012, Abdourhamane *et al.*, 2013).

As for the structure of *Anogeissus leiocarpus*-community, *Pteleopsis suberosa*-community, *Terminalia laxiflora*-community, *Acacia dudgeoni*-community, *Pseudocedrela kotschyi*-community, *Lannea microcarpa*-community, *Terminalia avicennioides*-community, *Lonchocarpus cyanescens*-community, *Maranthes polyandra*-community, *and Mitragyna inermis*-community, the shape parameter c of the Weibull distribution is between 1 and 3.6. This highlights an asymmetrical distribution positive or right asymmetric, characteristic of the stands mono-specific with predominance of young individuals or low-diameter (Husch *et al.*, 2003; Dossou *et al.*, 2012; Abdourhamane *et al.*, 2013).

The high proportion of individuals with low stem diameter in the plant communities can be interpreted as an indicator of good health. According Whitmore (1990), high densities in the small diameter classes ensure the future of the natural re-generation. Such a distribution is typical when a population is stable and natural re-generation is ensured (Mbayngone *et al.*, 2008). According to Dossou *et al.* (2012), this situation should be qualified at different populations of species level in the group because of the particular pressure on some species. For Whitmore (1990), the individuals of trees with a large diameter resulting from natural selection are in fact the seed companies who provide the sustaina-bility of the stand. The strong dominance of individuals with low diameter was also found by Mbow (2009) in the savannas of the classified forests of Ouli and Wélor in Senegal.

The reduced number of individuals of large diameters can be linked to human activities, especially agriculture (Fig. 7), rearing (Fig. 8) and woody exploitation. During the collection of our floristic data, we counted 20 of pits used for charcoal production (Fig. 9) in both the northern and southern parts of the park. However, in certain conditions it is the floristic composition that imposes this structure (Mbow, 2009).

Some of the plant communities were characterized by high density and basal area, which can be linked to the favorable natural conditions (edaphic and water). Humid soils surrounding the different watercourses ensure high water availability and nutrition even during the dry season (N'da *et al.,* 2008). In contrast, other communities are of low densities and basal area. The situation in these groups could have an anthropogenic origin.

In addition, each year the savannas are traversed by bush fires (Fig. 10) which can be more or less harmful (N'da *et al.,* 2008). The exploitation of wood energy in the PNDB contributed to reduce the number of stems per hectare. In view of the strong anthropogenic pressure at periphery level, the PNDB appears to be an isolated ecosystem, which is prejudicial to its conservation in the medium and long terms.

Fig. 7. Agricultural areas around the Deux Balé National Park.

Fig. 8. Stay animals in Deux Balé National Park.

Fig. 9. Carbonization activities in Deux Balé National Park.

Fig. 10. Bush fires in Deux Balé National Park.

Conclusion

The aim of this study was to improve the knowledge about the diversity and the structure of woody vegetation in DBNP. Through the collection of floristic data, we have been able to identify 13 plant communities. This study contributes to a best knowledge of the floristic composition and the structure of these plant communities of DBNP.

The floristic richness of the park is sufficient to justify its protection and sustainable management in view of the conservation of biodiversity in Burkina Faso. We believe that the list of the flora obtained can still be improved by other studies. The park is dominated by individuals of low diameter and has a low proportion of individuals of big diameter. This predominance of individuals on low-diameter signals a good future for these plant communities. The low proportion of individuals of big diameter can be linked to human activities (cotton-growing, carbonization, wood-energy, farming, gold activities) within the park.

Facing the persistent pressures associated with a loss of monitoring of the DBNP in the southern part, we could attend in the medium-term to an exacerbated degradation of woody cover and wildlife, especially in the absence of a real management policy.

In order to contribute to a sustainable management of the park, awareness and an effective involvement of the populations of all bordering villages is required. It is especially important to prevent the colonization and forest clearing in the southern part of the park, which presently is heavily occupied. In addition, there is a need for an intensified surveillance of the park in collaboration with the riparian populations.

This study has opened up two important perspectives. Firstly, there is a need to also study the state of regeneration potential and herbaceous vegetation in DBNP. Secondly, there is a need to monitor the medium and long term evolution of each vegetation type via the establishment of an experimental device coupled with satellite images at high resolution.

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Conflicts of Interest

The authors declare no conflict of interest.

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