INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print) 2222-5234 (Online)
http://www.innspub.net
Vol. 25, No. 6, p. 365-375, 2024

RESEARCH PAPER OPEN ACCESS

Contribution of protected areas to the flora conservation in West Africa: Case of Koulbi classified forest, Burkina Faso

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Key words: Degradation, Burkina Faso, Open forests, *Isoberlinia* spp.

http://dx.doi.org/10.12692/ijb/25.6.365-375 Article published on December 09, 2024

Abstract

Forest ecosystems are subject to strong human pressures. This seems to be real even in classified area. The Koulbi Classified Forest appeared to be a good illustration for this situation, showing a sharply deteriorating vegetation cover. This would not be without consequences for the existing flora in this conservation area. To assess the floristic diversity of the plant stands, floristic surveys were carried out using 134 plots. Adjusted Factorial Correspondence Analysis (DCA) and ascending hierarchical classification using PC-ORD 6 were used to group the different floristic surveys. Diversity indices were calculated to evaluate plant diversity. Results showed that the woody flora of the Koulbi Forest had 159 woody species belonging to 114 genera and 45 families. The best represented families were: Rubiaceae (15 species), Combretaceae (14 species), Fabaceae-Caesalpinioideae (13 species), and Fabaceae-Mimosoideae (13 species). Seven types of vegetations were characterised including that of *Isoberlinia* spp. and *Anogeissus leiocarpa* (DC.) Guill. et Perr., showing a distinctive appearance to the Koulbi Forest; mixed wooded savannahs, dense shrub savannahs resulting from fallow land being reconstituted, sparse shrub savannahs on clay soil with strong drying cracks, forest galleries and *Mitragyna inermis*, vegetations adjacent to gallery plants. The plant vegetation composed with *Anogeissus leiocarpa* and *Mintragyna inermis* were not very diverse. However, these plants were under heavy pressure. Protective actions need to be stepped up in order to ensure better conservation of this forest.

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Introduction

Classified forests and reserves are areas of shelter for biological diversity in Burkina Faso (Ouoba, 2006; Ouédraogo, 2009). These forests are increasingly subject to a range of anthropogenic pressures contributing to a reduction of the natural vegetation cover in favor of anthropogenic areas (Tankoano *et al.*, 2015 and 2016; Dimobé *et al.*, 2015; Soulama *et al.*, 2015). The growing demand for agricultural land as a result of population growth and farming activities was thought to be one of the driving forces behind the degradation of protected areas (Ouédroago *et al.*, 2010; Kakedi *et al.*, 2023). Poor farming practices, gold panning, and grazing (pruning of fodder species) were also considered to be contributing to this issue. KCF, like other protected areas, was subject to a variety of human pressures (Tankoano, 2012), which have led government of Burkina Faso to carry out repeated clearance operations of which the most recent one occurred in 2009. The threat happened to be currently real and the loss of some habitats like open forests have been reported by Sanon *et al.* (2015). In addition, the degradation of these protected areas has resulted in the fragmentation of homogeneous blocks of natural ecosystems. This led to significant modifications for ecological processes in the fragments (Haddad *et al.*, 2015; Collins *et al.*, 2017), some of which may be slowed or halted. Sanon *et al.* (2019) revealed that degradation processes of natural vegetation such as open forest and tree savannah occurred in the KCF. Kaboré *et al.* (2014), Kaboré *et al.* (2015), and Kaboré *et al.* (2024) studied ecosystem services.

Studies by Ginn and Nekaris (2014) focused on the conservation status of the Koulbi classified forest. Few studies concerned flora in that forest. Thus, based on this context of anthropogenic pressure and climate change, it has to be worried that this issue would seriously affect the biological diversity of the various vegetation being main supports of this classified forest. Furthermore, rational management of the resources of the Koulbi classified forest would not be possible without good knowledge of the floristic composition and characterisation of the vegetation in that forest. Therefore, this study was designed on the assessment of the woody floristic diversity of the Koulbi classified forest. The aim was to characterise the different type of vegetation that contribute to the establishment of the Koulbi classified forest.

Materials and methods

Study area

The study was carried out in the south-west region of Burkina Faso in the Koulbi classified forest. The Koulbi classified forest extends between 9°29'-9°45' north latitude and 2°58'-2°42' west longitude over an area of 40,000 ha. It is bounded to the north and south by the municipality of Batié and Kpéré, respectively. It borders from the west by Republic of Côte d'Ivoire and the east by Ghana (Fig. 1).

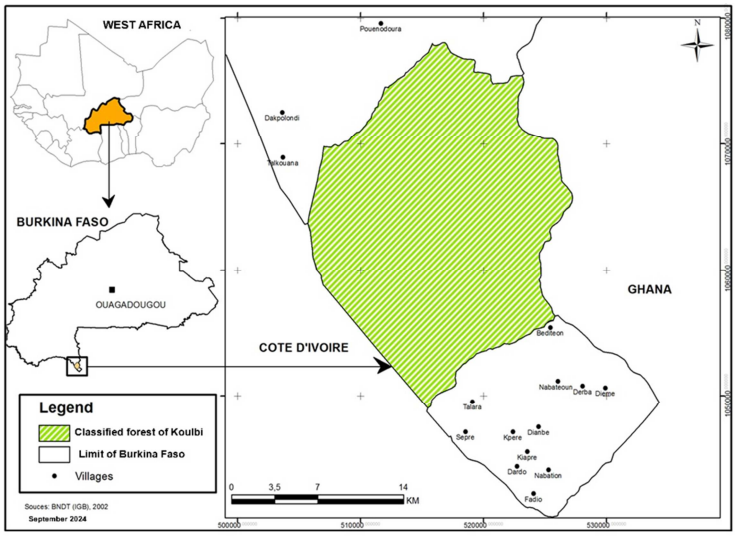


Fig. 1. Geographical location of the study area

The study area belongs to the Sudanian phytogeographical domain (Fontès and Guinko, 1995). The climate is tropical and dry, characterised by a rainy season and a dry season. Average rainfall and temperature over the period 1971-2014 was 1057±149 mm and 27.4±0.4°C, respectively (Direction Générale de la Météo). The vegetation is of the savannah type, with the addition of open forests characterised by the gregarious species such as Isoberlinia doka Craib. and Stapf (Fontès and Guinko, 1995).

Data collection

Systematic sampling as described by Glèlè-Kakaï *et al.* (2016) was adopted as it gives a better chance of covering several forest facies. Plot center coordinates were generated using a 2-km grid covering the entire KCF. Additional plots were established on some facies because of their specific characteristics, in order to balance the surveys. A total of 134 floristic surveys were carried out in 900 m plots in savannah vegetation and woodlands and 500 m plots in gallery forests.

Table 1. Braun Blanquet abundance-dominance scale

Scales	Average recovery (%)	Meaning
5	87,5	Overlap greater than 75%
4	62,5	Recovery between 50 and 75%
3	37,5	Recovery of between 25 and 50%
2b	20	Recovery between 16 and 25%
2a	10	Recovery between 5 and 15%
1	3	Low Overlap
+	0,5	Simply present

Floristic surveys were carried out using the Braun-Blanquet (1932) sigmatiste method. This method has been used by several authors in West Africa (Houinato, 2001; Ouoba, 2006; Ouédraogo, 2009; Toko, 2014). It is based on the principle of floristic homogeneity of the studied area. An abundance-dominance coefficient was assigned to each species encountered in the plot (Table 1). A forest inventory was carried out in addition to the floristic surveys. The circumference at 1.30 cm from the ground of all trees with a diameter greater than or equal to 5 cm was measured.

Data analysis

Characterisation of vegetation stands

The vegetation was characterised on the basis of 134 plots. The floristic data were typed using Excel sheet, in a matrix of "X" rows (species) and "Y" columns (plots), taking into account the species abundance-dominance coefficient obtained from each survey.

Multivariate analysis methods such as ordination and ascending hierarchical classification were used for data summarising and groupings. These two methods, individually or combined, have been widely used in flora analysis in West Africa (Mahamane, 2005; Ouoba, 2006; Nacoulma, 2012; Toko, 2014). Ordination was carried out using Detrended Correspondence Analysis (DCA). Data were projected in a factorial plan and grouped according to floristic similarity and environmental parameters using PC-ORD 6.0 software.

The DCA is robust and summarises the information contained in a multivariate contingency table, but by describing the relationships between the element-rows and element-columns.

However, its application requires knowledge on the gradient length. Thus, when the gradient of the DCA was about 2 standard deviations, then Principal Component Analysis (PCA) is recommended for data analysis. On the other hand, if the standard deviation of the DCA gradient is greater than 4, it is recommended to apply DCA or Factorial Component Analysis (Glèlè-Kakaï *et al.*, 2016). After applying the DCA, the group of non-individualised plots was subject to a cluster analysis (ascending hierarchical classification). Plots were grouped according to their floristic similarities and represented as a classification tree called a 'dendrogram'.

Floristic diversity and diversity indices

For evaluating floristic diversity, the intra-community Shannon (H') and Pielou equitability indices (Eq) were used following equations bellow:

$$H' = -\sum_{i=1}^{S} P_i \, lnP_i$$

Pi: *ni*/*n* where *ni*: number of individual species *i* and *n*: total number of individuals, *S*: species richness.

$$Eq = \frac{H'}{lnS}$$

H'= Shannon's index (*H'*); *lnS*: natural logarithm of species richness

The ecologically important value index (IVI) was also calculated (Table 2). The importance value of a species is the sum of its relative dominance (Domr.), its relative density (Dr.) and its relative frequency (Fr.). IVI = Domr+Dr+Fr. IVI is a quantitative index to identify ecologically important species in a plant community (Adomou *et al.*, 2009; Dossou *et al.*, 2012). It varies from 0 (no dominance) to 300 (mono-dominance). A species is ecologically important when it's IVI > 10% (Reitsma, 1988).

Fr= (Species frequency/Sum of frequencies)×100

Dr= (Number of individuals of the species/ Total number of individuals of all species)×100

Domr= (Basal area of the species/ Basal area of all species)×100

Domr = Relative dominance; Dr = Relative density; Fr = Relative Frequency

Table 2. Number of genera and species of the main families

Families	Number of species	Proportion (%)	Number of genera	Proportion (%)
Rubiaceae	15	9,43	11	9,65
Combretaceae	14	8,81	4	3,51
Fabaceae-Caesalpinioideae	13	8,18	12	10,53
Fabaceae-Mimosoideae	13	8,18	6	5,26
Apocynaceae	10	6,29	9	7,89
Fabaceae-Faboideae	9	5,66	7	6,14
Anacardiaceae	9	5,66	6	5,26
Euphorbiaceae	7	4,40	5	4,39
Moraceae	5	3,14	1	0,88

Results and discussion

Floristic composition

The inventory of woody flora in the KCF permitted to identify 159 woody species in 114 genera and 45 families. Table 2 shows the importance of the families in terms of the number of genera and species. The best represented families were: Rubiaceae (15 species), Combretaceae (14 species), Fabaceae-Caesalpinioideae (13 species), FabaceaeMimosoideae (13 species), Apocynaceae (10 species), Fabaceae-Faboideae (9 species), Anacardiaceae (9 species), Euphorbiaceae (7 species), Moraceae (5 species) and Tiliaceae (4 species).

These results were found to be higher than those observed by Tankoano (2017) in the National Park of Deux Balé (109 species). On the other hand, high values were recorded by Ouoba (2006) in the Niangoloko classified forest (353 species), Ouédraogo (2009) in the Arly National Park (454 species) and Nacoulma (2012) in the W National Park (622 species). The inclusion of herbaceous species in the above-mentioned studies could explain the huge difference between their results and ours. Thus, this study shows that the FCK is a good reservoir of biodiversity. However, because of its geographical position, it was expected to record greater species richness than forests being located in north of the country, which do not benefit from the upwelling of flora from the Guinean zone via the watercourses. Factors related to anthropogenic disturbance may be considered to be blamed. A large part of the forest, particularly in the south, has been heavily used for agricultural activities. It is therefore likely that some of the plant species in this area were cut down during fields' establishment. This contributed to the depletion of the species richness in the forest.

The above mentioned families, except that of Rubiaceae, were very well represented in the

savannahs and steppes of the four agro-climatic zones of Burkina Faso (Traoré, 2013). These families were the most common and represented in the tropics, particularly in the Sudano-Sahelian savannahs (Dimobé *et al.*, 2012; Savadogo *et al.*, 2016; Abdourhamane *et al.*, 2017). These results also confirmed that the Combretaceae family is widespread in Burkina Faso (Thiombiano, 2005).The winged fruits of Combretaceae favored it's easily transportation by the wind facilitating its dispersal.

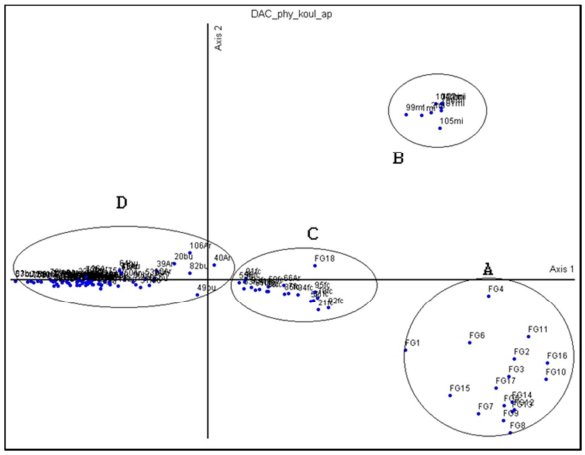
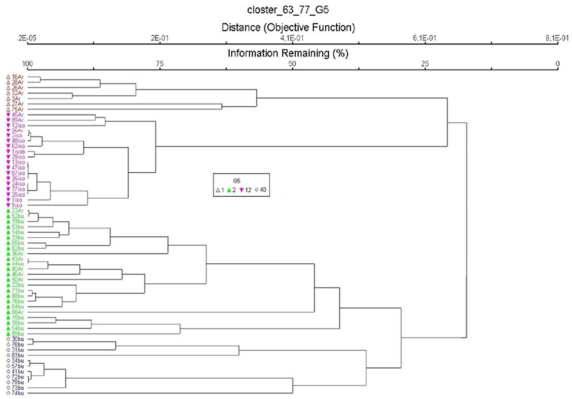


Fig. 2. Detrended correspondence analysis

Identification of stands

The first analysis, using DCA (Detrended Correspondence Analysis), identified 4 groups. The standard deviations for axis 1 and axis 2 were 7.3 and 5.2, respectively. On axis 1, the floristic surveys were discriminated following a moisture gradient. On axis 2, discrimination is based on the floristic weight of each record (Fig. 2). The total variance (inertia) among species was 8.46%. The eigenvalue of the actual data for axes compared with the randomisation eigenvalue showed a significant difference (P= 0.001). The four floristic groups represented in Fig. 2 correspond to those from the surveys carried out in forest galleries (group A), surveys carried out in vegetation with *Mitragyna inermis* (group B), surveys carried out in open forest vegetation with *Anogeissus leiocarpa* (group C) and surveys carried out in savannah (group D).

The second analysis, which focused on Group D, was a discrimination analysis using ascending hierarchical classification (HAC). It allowed identification of 04 subgroups (Fig. 3). Subgroup D1 (mixed wooded savannahs); subgroup D2 (*Isoberlinia spp.* plant); subgroup D3 (shrub savannahs resulting from fallow being reconstituted) and subgroup D4 (sparse shrub savannahs).



grp_D1: Mixed wooded savannahs ; grp_D2: Isoberlinia spp. stand; grp_D3: Dense shrub savannahs, grp_D4: Sparse shrub savannahs

Fig. 3. Ascending hierarchical classification

Characterization of plant groups

Group A: gallery forests

Gallery Forests were found mainly along the Mouhoun and Koulbi rivers. These were found to be dense vegetation. Individuals were entangled in places, with the presence of voluble species helping to increase the rate of cover. The species richness was 57 species and the average number of species per plot was 14±4 species. The Shannon and Piélou indices appeared to be 4.02 and 0.7, respectively (Table 3). Thus, this ecosystem was shown to be diverse, with no dominance in this vegetation. The following species were commonly found with an IVI greater than 10%: *Pterocarpus santalinoides, Mitragyna inermis, Dialium guineense, Cola laurifolia, Diospyros mespiliformis, Celtis integrifolia, Aphania senegalensis* (Table 4).

The gallery forests were mainly established along the Mouhoun River. They were found to be very thin not affected by bush fires. However, it was observed a heavy animal pressure in that area. During the dry season, Mouhoun is the only watering area for

animals. This contributed to the degradation of the riverbanks and, consequently, that of the vegetation. However, in the same phytogeographical zone, Ganamé *et al.* (2019) noted more or less the same dominant species in the gallery forest.

Group B: Mitragina inermis vegetation

Mitragyna inermis were vegetation juxtaposed with the gallery forests and colonise the flood zones corresponding to the major bed of the Mouhoun River. The soil is siltyclayey. In the *Mitragyna inermis* vegetation, 21 species were recorded, with an average species richness of 05±03 species per survey. The Shannon diversity index (H') and equitability index (Eq) were 2.24 and 0.54, respectively, reflecting low floristic diversity with the dominance of one or a small number of species (Table 3).

Table 3. Diversity of the different stands of vegetation

Groups	H'	Eq	Number of species	Number of species/plot
GRP_A	4,02	0,70	57	14±4
GRP_B	2,24	0,54	21	05±3
GRP_C	2,92	0,51	62	12±3
GRP_D1	4,41	0,77	76	12±4
GRP_D2	4,38	0,78	67	13±5
GRP_D3	4,30	0,74	69	14±4
GRP_D4	3,70	0,76	56	11±4

GRP_A: Gallery forest; GRP_B: Stand of *Mitragyna inermis*; GRP_C: Stand of *Anogeissus leiocarpa*; GRP_D1: Mixed wooded savannahs; GRP_D2: Stand of *Isoberlinia* spp.; GRP_D3: Dense shrub savannahs, GRP_D4: Sparse shrub savannahs.

Mitragyna inermis stands have been identified on soils with temporary hydromorphy. During the raining season, it appeared to be in a marshy area. These are vegetation with very little diversity. These results corroborated with those of Ouoba (2006). Temporary flooding of varying duration affected the establishment and development of other woody species, and even of the main species, *Mitragyna inermis*. Few plants of this species were found during data collection. This was also observed by Ouédraogo (2009).

Group C: Woodland with Anogeissus leiocarpa

Woodlands with *Anogeissus leiocarpa* were found in depressed areas on soils with clay and clay-loam surface textures. These were generally small patches scattered throughout the Koulbi classified forest. In group C, 62 plant species were recorded of which an average species richness of 12±3 species/survey was observed. Floristic diversity was calculated as H'= 2.92 with a dominance of one or a few species with Eq = 0.51 (Table 3). The species *Anogeissus leiocarpa, Vitellaria paradoxa, Pterocarpus erinaceus, Adansonia digitata* and *Lannea barteri* were the characteristic species of these vegetation with an IVI greater than 10% (Table 4).

Group D1: Mixed wooded savannas

Mixed tree savannas have been recorded among *Isoberlinia* spp. vegetation, stopping the spread of its stands. It has been recorded on soils with a clay and gravel surface texture. They were fairly rare in the southern and western parts of the classified forest. A total of 76 species were recorded in group D1 during the inventory, with an average richness of 12±4 species per survey. This group was diverse (H'= 4.41), Eq = 0.77, reflecting the even distribution of species in this type of vegetation (Table 3). The most frequent species were: *Vitellaria paradoxa, Pterocarpus erinaceus, Terminalia laxiflora, Lannea acida, Combretum adenogonium, Burkea africana, Detarium microcarpum, Pseudocedrela kotschyi* (Table 4).

Group D2: vegetation with Isoberlinia spp.

Isoberlinia spp. colonise well-drained soils with a clay-gravel, gravel and/or rocky surface texture. They were found on lower slopes, hillsides and hilltops. In the KCF, they extend from the northern part to the

limit of the Koulbi river in the south. Vegetation of *Isoberlinia* spp. have a species richness of 67 species, i.e. an average per plot of 13±5. The Shannon and Piélou indices were 4.38 and 0.78, respectively, showing that this ecosystem was diverse, with a regular species distribution (Table 3). The species commonly associated with *Isoberlinia* spp were: *Vitellaria paradoxa, Pterocarpus erinaceus, Lannea acida and Burkea africana* (Table 4).

Stands of *Anogeissus leiocarpa* have been noted in the classified forest in the form of islands. Several authors have also mentioned this type of vegetation in various forests in Burkina Faso and West Africa (Ouoba, 2006; Nacoulma, 2012; Traoré 2013; Toko, 2014). Open forests are little affected by bush fires. The very high density reduces the development of herbaceous vegetation. In Burkina Faso, these woodlands are found in the four phytogeographic sectors of the country (Ouédraogo *et al.*, 2013). Bationo (1990) placed the species *Anogeissus leiocarpa* between the 600 mm and 1100 mm annual precipitation. These woodlands are mostly dominated by *Anogeissus leiocarpa*. This was the leading cause of low diversity (Toko, 2014). However, there has been an intrusion of some savannah species as a result of climatic deterioration and the often very small size of the patches. This helped to increase the species richness of this vegetation. This could explain the significant presence of other species such as *Vitellaria paradoxa, Pterocarpus erinaceus, Adansonia digitata, Lannea barteri* etc. Stands of *Isoberlinia* spp. exist in the Koulbi classified forest in the form of tree savannah, wooded savannah and woodland. This was observed as a distinctive appearance to landscape in southern of Burkina Faso (Fontès and Guinko, 1995; Traoré, 2013). In the Koulbi classified forest, it covered a large area and tends to be fairly rich and diverse ecosystems.

Table 4. Ecological importance value (IVI)

Species	Fck	Grp_A	Grp_B	Grp_C	Grp_d1	Grp_d2	Grp_d3	Grp_d4
Anogeissus leiocarpa (DC.) Guill. and Perr.	30,49*	3,86	7,40	115,34*	2,24	---	2,37	7,91
Vitellaria paradoxa Gaerten. F.	26,63*	---	---	13,11*	40,52*	25,52*	61,79*	116,16*
Pterocarpus erinaceus Poir	14,28*	3,14	4,53	22,72*	20,82*	12,52*	8,73	6,42
Isoberlinia doka Craib and Stapf	11,95*	---	---	---	21,29*	58,15*	0,66	3,29
Pterocarpus santalinoides L. Hér. Ex DC.	11,17*	51,15*	---	---	---	---	---	---
Terminalia laxiflora Engl.	11,15*	---	---	----	13,00*	3,13	42,01*	18,43*
Lannea acida A. Rich.	10,57*	---	3,80	8,43	17,07*	19,42*	8,39	7,01
Mitragyna inermis (Willd.) Kuntze	10,27*	14,92*	160,28*	---	---	---	---	---
Dialium guineense Willd	10,19*	46,94*	---	---	---	---	---	---
Combretum adenogonium Stend.ex A. Rich.	10,18*	---	15,71*	9,15	17,51*	3,28	13,69*	17,01*
Burkea africana Hook. f.	8,57	---	---	0,78	27,08*	12,84*	1,87	4,98
Cola laurifolia Mast.	8,06	35,54*	---	---	---	---	---	---
Diospyros mespiliformis Hochst. ex A. Rich.	6,92	23,01*	---	4,20	2,02	0,53	---	---
Detarium microcarpum Guill. and Perr.	6,37	---	---	---	13,37*	0,89	17,79*	2,50
Adansonia digitata L.	6,12	---	---	16,00*	14,18*	---	---	---
Piliostigma thonningii (Schumach) Milne-Redh	5,38		12,65*	3,83	4,02	2,19	9,56	20,46*
Pseudocedrela kotschyi (Schweinf.) Night	5,34	---	----	1,61	16,37*	4,82	2,94	---
Combretum collinum Fresen.	5,17		4,94	4,94	5,41	5,38	4,88	11,44*
Crossopteryx febrifuga (Afzel.ex G. Don) Benth	4,22	0,93	21,97*	8,20	8,20	0,67	6,42	6,73
Daniellia oliveri (Rolfe) Hutch. and Dalz	4,21	1,72	21,76*	---	5,35	0,92	6,35	3,37
Acacia dudgeoni Craib ex Hall.	4,17	---	---	---	2,52	4,22	13,68*	7,30
African Entada Guill. and Perr.	3,96	---	---	---	4,01	4,79	10,13*	10,89*
Lannea barteri (Oliv.) Engl.	3,89	1,05	---	13,30*	1,25	0,64	1,34	---
Celtis integrifolia Lam.	3,06	10,38*	---	0,82	---	---	---	---
Aphania senegalensis (Juss. ex Poir.) Radlk.	2,59	10,00*	---	4,70	0,62	---	---	---
Terminalia macroptera Guill. & Perr.	2,50	---	---	---	12,17*	0,40	1,16	---
Isoberlinia tomentosa (Harms) Craib & Stapf	1,89	---	---	---	0,89	12,93*	---	---
Acacia sieberiana DC.	1,49	---	11,92*	2,44	0,90	---	1,49	---
Ziziphus mauritiana Lam.	0,48	---	15,56*	---	---	---	---	---

GRP_A: Gallery forest; GRP_B: Stand of *Mitragyna inermis*; GRP_C: Stand of *Anogeissus leiocarpa*; GRP_D1: Mixed wooded savannahs; GRP_D2: Stand of *Isoberlinia* spp.; GRP_D3: Dense shrub savannahs, GRP_D4: Sparse shrub savannahs. FCK: Classified Forest of Koulbi; *= IVI ≥ 10%

Group D3: Dense shrubby savannahs

The dense shrub savannahs or savannahs resulting from the fallow being reconstituted were more recorded in the southern and western parts of the classified forest. The soils are sandy to sandy-clay. This area was occupied by illegal occupants for yams production. A total of 69 species were recorded in group D3 during the inventory, with an average species richness of 14±4 species/survey. Floristic diversity was high, with a Shannon index of 4.3 and a Piélou equitability index of 0.74 (Table 3). The most common species were: *Vitellaria paradoxa, Entada africana, Terminalia laxiflora, Combretum adenogonium, Detarium microcarpum* and *Acacia dudgeoni* (Table 4).

The dense shrub savannahs were the result of fallow land being reconstituted. Its existence was favored by human activity. In fact, the south and west parts of the classified forest in which these savannahs were developed, were once occupied by people living close to the forest. Because of the various clearances, the vegetation on these sites tends to be recovered, supported by relatively good rainfall and less anthropogenic pressure. These are dense ecosystems of which woody flora is dominated by Combretaceae. Large diameter trees were agroforestry species and these cope with human activities.

Group D4: sparse shrub savannahs

Sparse shrub savannahs develop on soil with a clay surface texture. This soil is marked during the dry season by more or less deep shrinkage cracks. The species richness from vegetation of group D4 was 56 species and the average per survey was 11±4. The Shannon diversity index was 3.70 and the equitability index 0.76 (Table 3). The most frequent species were: *Vitellaria paradoxa, Terminalia laxiflora, Combretum adenogonium, Piliostigma thonningii, Combretum collinum, Entada africana* (Table 4).

The sparse shrub savannahs were identified on heavy clay soil that was subject to shrinkage during the dry season. This substrate appeared to be unfavorable to the development of woody vegetation. Several species have been identified. But these individuals were stunted. Ouédraogo (2009) also described these types of vegetation, which are not very conducive to the development of woody vegetation.

Conclusion

The Koulbi classified forest, like most classified forests in Burkina Faso, is subject to various anthropogenic and climatic pressures that seem to affect biological diversity. Analysis of the woody flora revealed 159 species. These were divided into 114 genera and 45 families, the most represented of which were Rubiaceae, Combretaceae and Fabaceae-Caesalpinioideae.

Factor analysis and classification allowed identifying 7 types of vegetation: gallery forests, stands of *Anogeissus leiocarpa,* stands of *Mitragyna inermis,* stands of *Isoberlinia* spp., mixed tree savannahs, dense shrub savannahs resulting from fallow land being reconstituted and sparse shrub savannahs on clay soil with cracks. Mixed tree savannahs and *Mitragyna inermis* stands had the highest and lowest species richness, respectively. This showed that Koulbi classified forest is a good reservoir for biodiversity development.

Existence of several vegetation facies, such as woodland of *Anogeissus leocarpa* and stands of *Isoberlinia* spp, was responsible for making this zone a conservation area for relict vegetation. To ensure sustainable conservation, rigorous protection actions need to be taken to reduce the human impact on this forest. In addition, a more advanced analysis of the flora needs to be performed, taking into account the herbaceous species.

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