



Floristic diversity in a unique ecosystem of Burkina Faso: The case of the Kou classified forest

Yaovi Comlan René^{*1}, Hien Mipro¹, Kaboré Sibiry Albert¹, Kassi N'Dja Justin², Somda Irénée¹

¹Laboratory of Natural Systems, Agro-Systems and Environmental Engineering (Sy.N.A.I.E), Institute of Rural Development (IDR), Nazi Boni University, Bobo-Dioulasso, Burkina Faso

²Botany Laboratory, UFR Biosciences, Félix Houphouët-Boigny University, Abidjan, FHB University (Biosciences), Ivory Coast

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Abstract

The objective of this study is to provide a better knowledge of the flora of a classified forest relic and its capacity to preserve biodiversity. A forest inventory on 28 plots for woody species and 11 plots for herbaceous species was carried out in the Kou Classified Forest (KCF). The results show that the flora of the KCF is rich in 207 species belonging to 62 families and 165 genera. It includes 121 woody species and 85 herbaceous species. The most represented family is the Fabaceae 38 taxa. The diversity indices show that the woody and herbaceous flora is diverse, with respectively 13.61 and 7.85 for Margalef's absolute species richness, 3.36 and 3.80 for Shannon-Weaver's diversity index (H'), 0.93 and 0.97 for Simpson's dominance (D'); 0.74 and 0.92 for Piélou's equitability index (E). A total of 36 special-status species and 87.86% rare species (rarity index >80%) were recorded. Structural parameters such as basal area (15.73 ± 2.86 m²/ha), density (456 ± 51 ft/ha), average herbaceous cover (22% ± 4%) and Weibull's form factor (C=0.7) show good ecological health and stability of the vegetation with a high regeneration potential of 1280 seedlings/ha and a regeneration rate of 236.37%. This ecosystem is of major importance in the conservation of phytodiversity in Burkina Faso.

*Corresponding Author: Yaovi Comlan René ✉ yaoreca@gmail.com

Introduction

In sub-Saharan Africa, vegetation pattern formations in drylands play a major role in biodiversity conservation. They host rare and endemic species that are well adapted to harsh ecological conditions and provide local populations with essential goods and services (FAO, 2010). The strong dependence of rural populations on natural resources means that remnants of original formations and plant species with high socioeconomic value are generally only found in protected areas (Ouédraogo *et al.*, 2010a). This is the case of the Kou Classified Forest (KCF), which is among the best maintained classified forests in Burkina Faso and still abounds in a significant diversity of plant species due to effective conservation actions (Ouédraogo *et al.*, 2010b). According to Guinko (2005), it is one of the last relics of Guinean-type forest in Burkina Faso and its gallery forest constitutes a unique ecological reserve for a Sahelian country.

Despite their importance, these classified forests are threatened by climate change, urbanization and rapid population growth. Thus, each year, 13 million hectares of forests are lost while the continuous degradation of drylands has led to the desertification of 3.6 billion hectares worldwide (UNDP, 2018). According to the Burkina Faso Forestry Department, 60% of the country's classified areas are already occupied by farms, crop hamlets and even villages with socio-economic infrastructure (DIFOR, 2007). The direct result of this degradation of forest ecosystems is the loss of biodiversity, mainly floristic diversity. In such contexts, it is very important to identify the classified forests that still resist this pressure, both anthropic and climatic. For these remaining classified forests, it is important to have a better knowledge of their floristic richness and their capacity to preserve this biodiversity. It is in this context that this study was conducted in the Kou Classified Forest (KCF) with the following research questions: (i) in response to anthropic and climatic pressure and the increasing urbanization of the city of Bobo-Dioulasso, has the flora of the KCF regressed? (ii) What are the species with special status or conservation value that abound in this flora? (iii) Can

KCF vegetation continue to support the protection of biodiversity and the provision of ecosystem services to the local community?

The main objective of the study is to provide a better knowledge of the floristic resources of the surviving classified forests and their capacity to preserve biodiversity. Specifically, the objectives are: (1) To evaluate the woody and herbaceous flora of the KCF; (2) To identify species with special status or conservation value in the KCF; (3) To evaluate the state of the vegetation of the KCF through its structure and dynamics.

Materials and methods

Study site

The Kou Classified Forest is located in the Hauts-Bassins region in southwestern Burkina Faso, about fifteen kilometers west of the city of Bobo-Dioulasso. It mainly lies between 11°11'47" and 11°10'54" North latitude and between 04°26'38" and 04°26'04" West longitude (fig.1). It was classified by the decree n°132/FOR of January 30, 1951, in application of the decree of July 4, 1935 on the constitution of a forestry regime in French West Africa (AOF) and bears the name of the river that crosses it from south to north. It is a small forest that extends over 115 ha and its main purpose is to protect the springs of the "guinguette" which flow permanently all year round. The forest is located in a Sudanian phytogeographic domain and has a South Sudanian climate (Thiombiano *et al.*, 2012) with a mean annual rainfall of 1055.12 mm and a mean annual temperature of 26.9 °C.

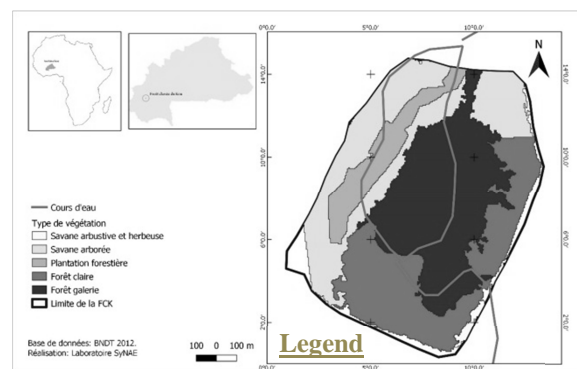


Fig. 1. Location and vegetation types of the Kou Classified Forest

Data sampling

The study was conducted in November 2017 and consisted of a forest inventory of woody species on 28 plots and herbaceous species on 11 plots, with a sampling rate of 1.70%. Stratified random sampling was applied to minimize variability in estimated characteristics. Plots were distributed as follows: 11 in gallery forest, 6 in tree savanna, 3 in shrub savanna, 2 in plantations, 2 in open forest, and 4 in agrosystems that are on the periphery of the KCF. Their area was 1000m² for savannas, open forests, and plantations; 500m² for gallery forests and 2500m² for agrosystems (Thiombiano *et al.*, 2016). In each plot, a comprehensive census of all plant species was conducted. Dendrometric measurements were done for all woody individuals with Diameter at Breast Height (DBH) ≥ 5 cm. Individuals less than 5 cm in diameter are considered in regeneration, which was assessed in 5 subplots of 25 m² installed in the woody plots. Within these subplots, the number of woody individuals was counted by different height classes of: 0 to 0.5m; 0.5 to 1m; 1 to 1.5m; 1.5 to 2m; and 2m and above.

The sampling of the herbaceous flora was done by the quantitative point-quadrat method (Daget and Poissonet, 1990) at the time of maximum phytomass. The 11 sampling plots were installed at the rate of 5 stations in the shrub savanna, 4 stations in the tree savanna and 2 stations in the gallery forest (for herbaceous and aquatic plants). Species identification was done using the floras of Berhaut (1971), Geerling (1987), Hutchinson *et al.* (1972), Okezie Akobundu and Agyakwa (1989), Poilecot (1995), Arbonnier (2002) and Akoègninou *et al.* (2006). The nomenclature used is that of Lebrun and Stork (1991). The biological types were determined from the classification of Raunkier (1934) adapted to the tropical zone (Trochain, 1966). The phytogeographical distribution of species is that proposed by White (1986).

Data processing

Biodiversity analysis

Biodiversity analysis of the KCF was carried out using several indicators such as: species richness (S),

biological and phytogeographical spectra, diversity indices, rarity index and the list of species with special status.

The biological and phytogeographical spectra give an idea of the evolution of the floristic composition under the cumulative effects of different environmental pressures (climatic, edaphic, anthropic factors, etc.).

As diversity index, the absolute specific richness of Margalef (R_{mg}), the diversity index of Shannon-Wiener (H'), the dominance index of Simpson (D') and the equitability index of Pielou (E) were calculated using the PC-ORD 6.0 software.

The list of special-status species provides information on the importance of the ecosystem in the conservation of biodiversity, and more specifically that of sensitive species. It was established from the IUCN Red list of threatened species (www.iucnredlist.org) and the list of threatened species of Burkina Faso (Thiombiano *et al.*, 2010). The Rarity-weighted Richness Index (IR) was calculated to identify species with a restricted distribution within the KCF and to identify sites at risk. It was calculated according to the equation of Géhu and Géhu (1980) :

$$IR = \left(1 - \frac{ni}{N}\right) \times 100$$

where ni = number of surveys in which species i is present and N = total number of surveys. The interpretation thresholds used are those of Traoré *et al.* (2011) on sudanian plant formations: (1) $IR < 60\%$, for species that are very frequent in the plant formations (2) $60 \leq IR < 80\%$ for moderately frequent species and (3) $IR \geq 80\%$ for so-called rare species.

Assessment of vegetation condition

The capacity of the ecosystem to maintain floristic diversity was assessed using some indicators of vegetation structure and dynamics. The observed density of woody plants (D_{obs}), expressed in number of individuals/ha, is obtained by the ratio between the total number of individuals in the sample and the sampled area.

Basal area (g), expressed as m²/ha, is obtained from the following formula:

$$g = \frac{\sum \pi \left(\frac{d_{1.3}}{2}\right)^2}{SE}$$

with d_{1.3}= diameter in meter (m) of the trunk at 1.3 m; SE = sampled area in hectare (ha);

Overall herbaceous cover (RGH) was calculated by the formula:

$$RGH (\%) = \frac{N-ni}{N} \times 100 \text{ where:}$$

N is the total number of herbaceous contacts and ni is the number of points with bare ground.

Woody stand structure was assessed using histograms of diameter class distribution. The histograms of each vegetation type was adjusted to the theoretical 3-parameter Weibull distribution which density function *f* is expressed for a diameter *x* as follows :

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

Where *x* : the stem diameter ; *a* : the position parameter equal to 5 cm in this study; *b* : the size or scale parameter and *c* : the shape parameter.

The different parameters of the function were determined with the Minitab18 software and their interpretation was made according to the criteria proposed by Glèlè Kakai (2016). The stand regeneration rate (TRP) to gauge the regenerative capacity of the stand was calculated as the percentage ratio of the total number of seedlings (DHP<5cm) to the stand population. The interpretation scale used was that of Rothe (1964) :

- (1) TRP<100 % indicates difficulty in regeneration;
- (2) 100 % ≤ TRP ≤ 1000 % good regeneration and
- (3) TRP>1000 % very good regeneration.

Results

Floristic diversity of the Kou Classified Forest

Floristic richness and composition

The floristic inventory of the Kou classified forest identified 207 species belonging to 62 families and 165 genera. Table 1 presents the list of the different species identified in the KCF. The most represented families in terms of number of species are Fabaceae followed by Rubiaceae, Poaceae and Malvaceae with respectively 38 taxa (18.45 %), 16 taxa (7.77 %), 15 taxa (7.28 %) et 14 taxa (6.80 %).

Table 1. List of species identified in the Kou classified Forest

Families	Genera	Species	Guinko (2005)
Acanthaceae	<i>Dyschoriste</i>	<i>Dyschoriste heudelotiana</i> (Nees) Kuntze	-
	<i>Lepidagathis</i>	<i>Lepidagathis anobrya</i> Nees	-
	<i>Phaulopsis</i>	<i>Phaulopsis barteri</i> T.Anderson	+
Adiantaceae	<i>Adiantum</i>	<i>Adiantum trapeziforme</i> L.	- **
Alismataceae	<i>Sagittaria</i>	<i>Sagittaria latifolia</i> Willd. var. <i>latifolia</i>	- **
Aloaceae	<i>Aloe</i>	<i>Aloe buettneri</i> A.Berger	+
Amaranthaceae	<i>Achyranthes</i>	<i>Achyranthes aspera</i> L.	-
	<i>Pandiaka</i>	<i>Pandiaka angustifolia</i> (Vahl) Hepper	-
	<i>Pupalia</i>	<i>Pupalia lappacea</i> (L.)	-
Amaryllidaceae	<i>Crinum</i>	<i>Crinum ornatum</i> (L.f. ex Aiton) Bury	+
	<i>Lansea</i>	<i>Lansea acida</i> A.Rich.	+
Anacardiaceae	<i>Lansea</i>	<i>Lansea velutina</i> A.Rich.	+
	<i>Rhus</i>	<i>Rhus crenulata</i> A.Rich.	-
Annonaceae	<i>Sclerocarya</i>	<i>Sclerocarya birrea</i> Hochst.	+
	<i>Annona</i>	<i>Annona senegalensis</i> Pers.	+
Anthericaceae	<i>Uvaria</i>	<i>Uvaria chamae</i> P. Beauv	+
	<i>Chlorophytum</i>	<i>Chlorophytum orchidastrum</i> Lindl.	-
Apocynaceae	<i>Baissea</i>	<i>Baissea multiflora</i> A.DC.	+
	<i>Holarrhena</i>	<i>Holarrhena floribunda</i> (G. Don) Dur et Schlz	+
	<i>Pachycarpus</i>	<i>Pachycarpus lineolatus</i> (Dense) Bullock	+
	<i>Rauwolfia</i>	<i>Rauwolfia vomitoria</i> Afzel.	+
	<i>Saba</i>	<i>Saba comorensis</i> (Boj. ex DC) Pichon	+
Araceae	<i>Saba</i>	<i>Saba senegalensis</i> (A.DC.) Pichon	+
	<i>Strophanthus</i>	<i>Strophanthus sarmentosus</i> DC.	+
	<i>Voacanga</i>	<i>Voacanga africana</i> Stapf	+
Araceae	<i>Amorphophallus</i>	<i>Amorphophallus aphyllus</i> (Hook.) Hutch.	+
	<i>Anchomanes</i>	<i>Anchomanes difformis</i> (Blume) Engl.	+

Families	Genera	Species	Guinko (2005)
	<i>Stylochaeton</i>	<i>Stylochaeton hypogaeus</i> Lepr.	+
Araliaceae	<i>Cussonia</i>	<i>Cussonia arborea</i> Hochst. ex A. Rjch.	-
	<i>Borassus</i>	<i>Borassus akeassii</i> Bayton, Ouédraogo & Guinko	+
Arecaceae	<i>Calamus</i>	<i>Calamus deerratus</i> G. Mann et H. Wendl.	+
	<i>Elaeis</i>	<i>Elaeis guineensis</i> Jacq.	+
	<i>Ageratum</i>	<i>Ageratum conyzoides</i> L.	+
Asteraceae	<i>Aspilia</i>	<i>Aspilia rudis</i> Oliv. & Hiern	+
	<i>Bidens</i>	<i>Bidens engleri</i> O.E.Schulz	+
Bignoniaceae	<i>Stereospermum</i>	<i>Stereospermum kunthianum</i> Cham	+
Bixaceae	<i>Cochlospermum</i>	<i>Cochlospermum planchonii</i> Hook.f	+
		<i>Cochlospermum tinctorium</i> Perr.ex A.Rich.	+
Boraginaceae	<i>Cordia</i>	<i>Cordia myxa</i> L.	+
Caesalpiniaceae	<i>Senna</i>	<i>Senna alata</i> (L.) Roxb.	-
	<i>Celtis</i>	<i>Celtis toka</i> (Forssk.) Hepper & J.R.I.Wood	+
Cannabaceae	<i>Trema</i>	<i>Trema orientalis</i> (L.) Blume	-
Celastraceae	<i>Gymnosporia</i>	<i>Gymnosporia senegalensis</i> (Lam.) Loe.	+
Chrysobalanaceae	<i>Maranthes</i>	<i>Maranthes polyandra</i> (Benth.) Prance	+
	<i>Parinari</i>	<i>Parinari curatellifolia</i> Planch. ex Benth.	+
Clusiaceae	<i>Garcinia</i>	<i>Garcinia ovalifolia</i> Oliv.	-
	<i>Anogeissus</i>	<i>Anogeissus leiocarpa</i> (DC.) Guill. et Perr.	+
	<i>Combretum</i>	<i>Combretum adenogonium</i> Steud. ex A.Rich.	+
		<i>Combretum micranthum</i> G. Don	+
		<i>Combretum molle</i> R. Br.	+
		<i>Combretum nigricans</i> Lepr. ex Guill. & Perr.	+
Combretaceae	<i>Guiera</i>	<i>Guiera senegalensis</i> J.F.Gmel.	+
	<i>Pteleopsis</i>	<i>Pteleopsis suberosa</i> Engl. et Diels	+
	<i>Terminalia</i>	<i>Terminalia avicennioides</i> Guill. et Perr.	+
		<i>Terminalia laxiflora</i> Engl. & Diels	+
		<i>Terminalia macroptera</i> Guill. et Perr.	+
Convolvulaceae	<i>Ipomoea</i>	<i>Ipomoea argentaurata</i> Hallier f.	-
		<i>Ipomoea dichroa</i> Choisy	-
Costaceae	<i>Costus</i>	<i>Costus afer</i> Ker-Gawl.	-
		<i>Costus lucanusianus</i> J.Braun & K.Schum.	+
		<i>Costus spectabilis</i> (Fenzl) K. Schum.	+
Cucurbitaceae	<i>Luffa</i>	<i>Luffa purgans</i> Mart.	- **
Cyperaceae	<i>Fimbristylis</i>	<i>Fimbristylis acicularis</i> R.Br	- **
	<i>Rhynchospora</i>	<i>Rhynchospora corymbosa</i> (L.) Britton	-
Dilleniaceae	<i>Tetracera</i>	<i>Tetracera alnifolia</i> Willd.	+
	<i>Dioscorea</i>	<i>Dioscorea bulbifera</i> R.Br.	+
Dioscoreaceae		<i>Dioscorea dumetorum</i> (Kunth) Pax	+
		<i>Dioscorea sagittifolia</i> Pax	-
Ebenaceae	<i>Diospyros</i>	<i>Diospyros mespiliformis</i> Hochst. ex A. DC.	+
	<i>Alchornea</i>	<i>Alchornea cordifolia</i> (Schumach. & Thonn.)	+
	<i>Antidesma</i>	<i>Antidesma venosum</i> E.Mey. ex Tul.	+
Euphorbiaceae	<i>Euphorbia</i>	<i>Euphorbia convolvuloides</i> Hochst. ex Benth.	+
		<i>Euphorbia hirta</i> L.	-
		<i>Euphorbia hyssopifolia</i> L.	-
	<i>Abrus</i>	<i>Abrus melanospermus</i> Hassk.	+
	<i>Acacia</i>	<i>Acacia ataxacantha</i> DC.	-
		<i>Acacia dudgeoni</i> Craib ex Holl.	+
		<i>Acacia macrostachya</i> Rchb.ex DC	+
	<i>Aeschynomene</i>	<i>Aeschynomene indica</i> L.	-
	<i>Afzelia</i>	<i>Afzelia africana</i> Sm. ex Pers.	+
	<i>Albizia</i>	<i>Albizia zygia</i> (DC.) J. F. Macbr.	+
	<i>Berlinia</i>	<i>Berlinia grandiflora</i> (Vahl) Hutch. et Dalziel	+
Fabaceae	<i>Burkea</i>	<i>Burkea africana</i> Hook.	+
	<i>Senna</i>	<i>Senna siamea</i> (Lam.) H.S.Irwin & Barneby	+
		<i>Senna singueana</i> (Delile) Lock	-
	<i>Crotalaria</i>	<i>Crotalaria sessiliflora</i> L.	-
		<i>Crotalaria gorensis</i> Guillemin & Perrottet	+
		<i>Crotalaria lachnophora</i> A. Rich.	- **
		<i>Crotalaria macrocalyx</i> Benth	+
	<i>Daniellia</i>	<i>Daniellia oliveri</i> (Rolfe) Hutchinson et Dalziel	+
	<i>Desmodium</i>	<i>Desmodium scorpiurus</i> (Sw.) Desv	- **
		<i>Desmodium velutinum</i> (Willd.) DC.	+

Families	Genera	Species	Guinko (2005)
	<i>Detarium</i>	<i>Detarium microcarpum</i> Guill. et Perr.	+
		<i>Detarium senegalense</i> J.F. Gmel.	+
	<i>Dichrostachys</i>	<i>Dichrostachys cinerea</i> (L.) Wight et Arn.	+
	<i>Entada</i>	<i>Entada africana</i> Guill. et Perr.	+
	<i>Indigofera</i>	<i>Indigofera dendroides</i> Jacq.	+
	<i>Mimosa</i>	<i>Mimosa pigra</i> L.	-
	<i>Parkia</i>	<i>Parkia biglobosa</i> (Jack.) R. Br. ex G. Don	+
	<i>Pericopsis</i>	<i>Pericopsis laxiflora</i> (Benth. ex Baker) Meeuwen	+
	<i>Philenoptera</i>	<i>Philenoptera laxiflora</i> (Guill. & Perr.) Roberty	+
	<i>Piliostigma</i>	<i>Piliostigma reticulatum</i> (DC.) Hochst.	-
		<i>Piliostigma thonningii</i> (Schumach.)	+
	<i>Prosopis</i>	<i>Prosopis africana</i> Taub.	+
	<i>Pterocarpus</i>	<i>Pterocarpus erinaceus</i> Poir.	+
		<i>Pterocarpus santalinoides</i> cHér. ex De.	+
	<i>Tamarindus</i>	<i>Tamarindus indica</i> L.	+
	<i>Tephrosia</i>	<i>Tephrosia bracteolata</i> Guill. & Perr.	-
		<i>Tephrosia elegans</i> Schum.	+
		<i>Tephrosia lebrunii</i> Cronquist	+
		<i>Tephrosia nana</i> Schweinf.	+
	<i>Uraria</i>	<i>Uraria picta</i> (Jacq.) DC.	+
Gentianaceae	<i>Anthocleista</i>	<i>Anthocleista djalonensis</i> A Chev	+
Hernandiaceae	<i>Gyrocarpus</i>	<i>Gyrocarpus americanus</i> subsp. <i>pinnatilobus</i> Kubitzki	-
	<i>Gmelina</i>	<i>Gmelina arborea</i> Roxb.	+
	<i>Hoslundia</i>	<i>Hoslundia opposita</i> Vahl	+
	<i>Plectranthus</i>	<i>Plectranthus monostachyus</i> (P.Beauv.) B.J.Pollard	-
Lamiaceae	<i>Tectona</i>	<i>Tectona grandis</i> L.f.	+
	<i>Tinnea</i>	<i>Tinnea barteri</i> Gürke.	-
	<i>Vitex</i>	<i>Vitex chrysocarpa</i> Planch. ex Benth.	-
		<i>Vitex doniana</i> Sweet	+
Loranthaceae	<i>Agelanthus</i>	<i>Agelanthus dodoneifolius</i> (DC.) Polhill & Wiens	-
	<i>Adansonia</i>	<i>Adansonia digitata</i> L.	+
	<i>Bombax</i>	<i>Bombax costatum</i> Pellegr. et Vuillet	+
	<i>Ceiba</i>	<i>Ceiba pentandra</i> (L.) Gaertn.	+
	<i>Cola</i>	<i>Cola cordifolia</i> (Cav.) R.Br.	-
		<i>Cola gigantea</i> A.Chev.	+
		<i>Cola laurifolia</i> Mast.	-
Malvaceae	<i>Grewia</i>	<i>Grewia barteri</i> Burret	+
		<i>Grewia mollis</i> Juss.	+
		<i>Grewia tenax</i> (Forssk.) Fiori	-
	<i>Hibiscus</i>	<i>Hibiscus cannabinus</i> L.	+
	<i>Sida</i>	<i>Sida linifolia</i> Juss. ex Cav.	-
	<i>Sterculia</i>	<i>Sterculia setigera</i> Delile	+
	<i>Triumfetta</i>	<i>Triumfetta pentandra</i> A. Rich	-
	<i>Wissadula</i>	<i>Wissadula rostrata</i> (Schumach.) Hook.f.	+
	<i>Azadirachta</i>	<i>Azadirachta indica</i> A.Juss.	+
	<i>Carapa</i>	<i>Carapa procera</i> DC.	+
Meliaceae	<i>Ekebergia</i>	<i>Ekebergia capensis</i> Sparrm.A. Juss.	+
	<i>Khaya</i>	<i>Khaya senegalensis</i> (Desr.) A.Juss.	+
	<i>Pseudocedrela</i>	<i>Pseudocedrela kotschyi</i> (Schweinf.) Harms	-
	<i>Trichilia</i>	<i>Trichilia emetica</i> Vahl	+
	<i>Ficus</i>	<i>Ficus sur</i> Forssk.	+
Moraceae		<i>Ficus sycomorus</i> L.	-
	<i>Milicia</i>	<i>Milicia excelsa</i> (Welw.) C.C.Berg	+
Myrtaceae	<i>Syzygium</i>	<i>Syzygium guineense</i> DC.	+
Nymphaeaceae	<i>Nymphaea</i>	<i>Nymphaea lotus</i> L.	+
Ochnaceae	<i>Lophira</i>	<i>Lophira lanceolata</i> Tiegh. ex Keay	-
Olacaceae	<i>Olax</i>	<i>Olax subscorpioides</i> Oliv.	+
Orchidaceae	<i>Calypstrochilum</i>	<i>Calypstrochilum christyanum</i> (Rchb. f.) Summerh	+
Passifloraceae	<i>Passiflora</i>	<i>Passiflora foetida</i> L.	-
Phyllanthaceae	<i>Bridelia</i>	<i>Bridelia micrantha</i> (Hochst.) Baill.	+
		<i>Bridelia scleroneura</i> Müll Arg.	+

Families	Genera	Species	Guinko (2005)
	<i>Flueggea</i>	<i>Flueggea virosa</i> (Roxb. ex Willd.) Voigt	-
	<i>Hymenocardia</i>	<i>Hymenocardia acida</i> Tul.	+
	<i>Margaritaria</i>	<i>Margaritaria discoidea</i> (Baill.) Webster	+
	<i>Phyllanthus</i>	<i>Phyllanthus muellerianus</i> (Kuntze) Exell	+
	<i>Andropogon</i>	<i>Andropogon chinensis</i> (Nees) Merr.	+
		<i>Andropogon gayanus</i> Kunth	+
	<i>Digitaria</i>	<i>Digitaria horizontalis</i> Willd.	-
	<i>Elionurus</i>	<i>Elionurus muticus</i> (Spreng.) Kuntze	-
	<i>Euclasta</i>	<i>Euclasta condylotricha</i> Stapf in Prain	+
	<i>Hyparrhenia</i>	<i>Hyparrhenia hirta</i> (L.) Stapf	- **
		<i>Hyparrhenia involucrata</i> Stapf	-
Poaceae	<i>Hyperthelia</i>	<i>Hyperthelia dissoluta</i> (Nees ex Steud.) Clayton	-
	<i>Loudetia</i>	<i>Loudetia togoensis</i> (Pilg.) C.E.Hubb.	+
	<i>Oplismenus</i>	<i>Oplismenus hirtellus</i> (L.) P. Beauv.	+
	<i>Oxytenanthera</i>	<i>Oxytenanthera abyssinica</i> (A. Rich.) Munro	+
	<i>Panicum</i>	<i>Panicum maximum</i> Jacq.	-
	<i>Pennisetum</i>	<i>Pennisetum pedicellatum</i> Trin.	+
		<i>Pennisetum polystachion</i> (L.) Schult.	+
Polygalaceae	<i>Schizachyrium</i>	<i>Schizachyrium sanguineum</i> (Retz.) Alston	+
Potamogetonaceae	<i>Securidaca</i>	<i>Securidaca longipedunculata</i> Fresen.	+
Ranunculaceae	<i>Potamogeton</i>	<i>Potamogeton octandrus</i> Poir.	+
Rhamnaceae	<i>Clematis</i>	<i>Clematis hirsuta</i> Guill. & Perr.	+
	<i>Ziziphus</i>	<i>Ziziphus mauritiana</i> Lam.	-
	<i>Crossopteryx</i>	<i>Crossopteryx febrifuga</i> Benth.	+
	<i>Fadogia</i>	<i>Fadogia agrestis</i> (Schweinf. Ex Hiern)	+
	<i>Feretia</i>	<i>Feretia apodanthera</i> Delile	+
	<i>Psychotria</i>	<i>Psychotria peduncularis</i> var. <i>hypsophila</i> (K. Schum. & K. Krause) Verdc.	- **
		<i>Psychotria psychotrioides</i> (DC) Roberty	+
		<i>Psychotria vogeliana</i> Benth.	+
Rubiaceae	<i>Sarcocephalus</i>	<i>Sarcocephalus latifolius</i> (Sm.) Bruce	+
	<i>Spermacoce</i>	<i>Spermacoce stachydea</i> DC.	+
	<i>Cremaspora</i>	<i>Cremaspora triflora</i> (Thonn.) K. Shum.	-
	<i>Gardenia</i>	<i>Gardenia erubescens</i> Stapf & Hutch.	-
		<i>Gardenia ternifolia</i> Schumach. et Thonn.	+
	<i>Ixora</i>	<i>Ixora brachypoda</i> DC.	+
	<i>Macrosphyra</i>	<i>Macrosphyra longistyla</i> (DC.) Hiern	+
	<i>Mitracarpus</i>	<i>Mitracarpus hirtus</i> (L.) DC.	-
	<i>Mitragyna</i>	<i>Mitragyna inermis</i> (Willd.) Kuntze	-
	<i>Pavetta</i>	<i>Pavetta corymbosa</i> F. M. Williams.	+
Rutaceae	<i>Zanthoxylum</i>	<i>Zanthoxylum zanthoxyloides</i> (Lam.) Watermann	-
Salicaceae	<i>Flacourtia</i>	<i>Flacourtia indica</i> (Burm.f.) Merr. Willd.	-
	<i>Oncoba</i>	<i>Oncoba spinosa</i> Forssk.	+
	<i>Allophylus</i>	<i>Allophylus africanus</i> P. Beauv.	+
Sapindaceae	<i>Lecaniodiscus</i>	<i>Lecaniodiscus cupanioides</i> Planch.	+
	<i>Paullinia</i>	<i>Paullinia pinnata</i> L.	+
Sapotaceae	<i>Pouteria</i>	<i>Pouteria alnifolia</i> (Baker) Roberty	+
	<i>Vitellaria</i>	<i>Vitellaria paradoxa</i> Gaertn.f.	+
Thelypteridaceae	<i>Thelypteris</i>	<i>Thelypteris striata</i> (Schumach.) Schelpe	+
Verbenaceae	<i>Stachytarpheta</i>	<i>Stachytarpheta indica</i> (L.) Vahl	-
	<i>Ampelocissus</i>	<i>Ampelocissus leonensis</i> (Hook.f.) Planch.	+
Vitaceae	<i>Cissus</i>	<i>Cissus populnea</i> Guill.et Perr.	+
		<i>Cissus rufescens</i> Guill. & Perr.	-
Ximeniaceae	<i>Ximenia</i>	<i>Ximenia americana</i> L.	+
Zingiberaceae	<i>Siphonochilus</i>	<i>Siphonochilus aethiopicus</i> (Schweinf.) B.L.Burt	-

Legend: + Present or - Absent in the flora of Kou classified forest (Guinko, 2005)

**species that are absent in the catalogue of vascular plants of Burkina Faso (Thiombiano *et al.*, 2012)

The flora of the KCF includes 122 woody species belonging to 38 families and 73 genera, and 85 herbaceous species belonging to 34 families and 68 genera. Floristic richness also varies according to the

type of plant formation or land use. It is higher in shrubby (107) and woody (102) savannas and in gallery forests (75). It is much lower in agrosystems (32), open forest (24) and the *Tectona grandis* L.f. plantation (13).

Biological spectrum of the flora

The biological spectrum of the flora of the KCF is mainly dominated by phanerophytes (64.6%) followed by therophytes (15.0%) (Fig. 2).

Chronological distribution of the flora

The phytogeographic spectrum (Fig. 3) of the species recorded shows a higher proportion of Sudano-

Zambeian species (21.2%) and Sudanian base-element species (18.5%).

They are followed by pantropical species (15.2%) and tropical African species (12.6%). We note the presence of an endemic species whose distribution is limited to the West African region. This is *Borassus akeassii* Bayton, Ouédraogo and Guinko.

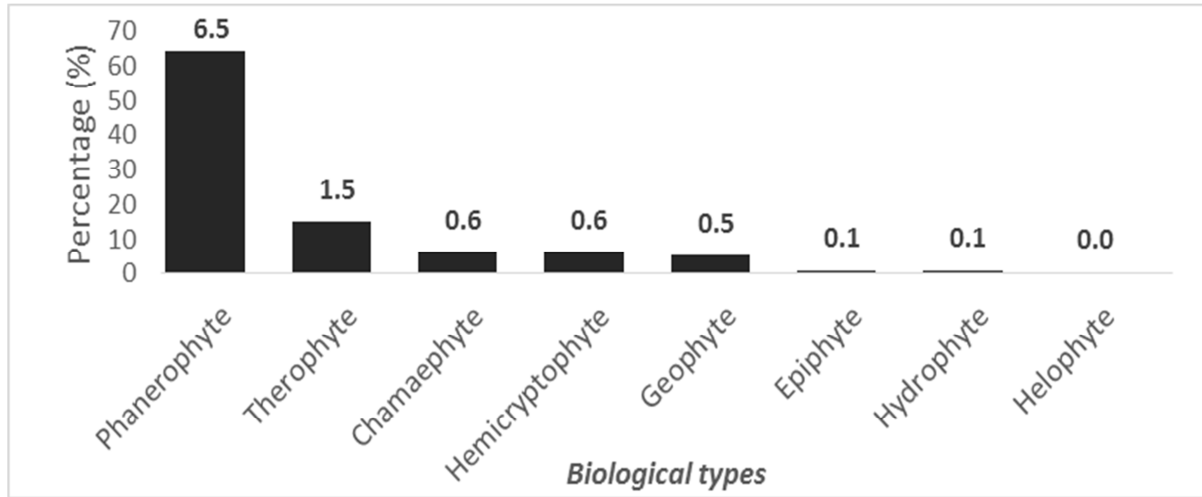
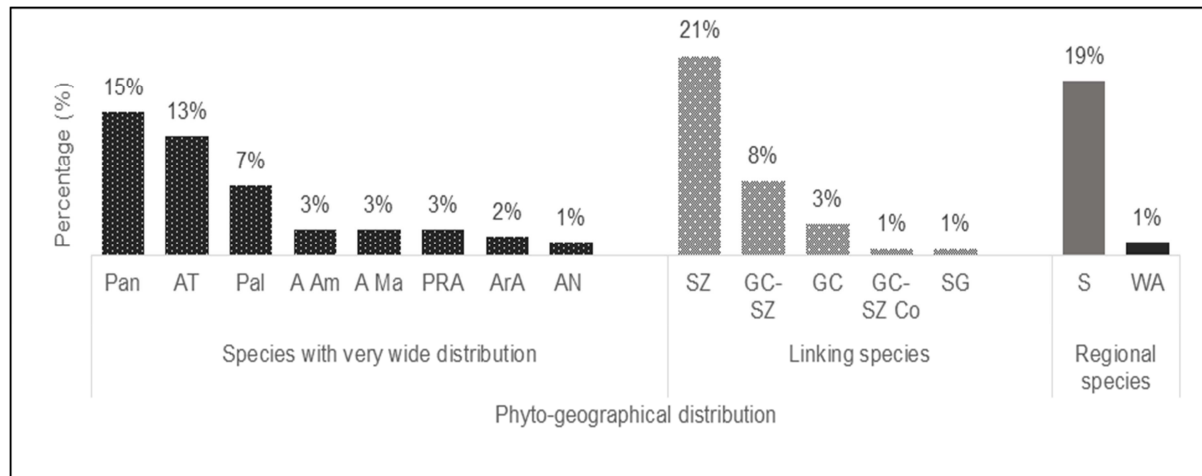


Fig. 2. Biological spectrum of the flora of the Kou Classified Forest



SZ: Sudan-Zambeian ; S: Sudanian ; Pan: Pantropical ; AT: Tropical Africa; GC-SZ: Guinean-Congolese and Sudan-Zambeian; Pal: Paleotropical; GC: Guinean-Congolese; A Am: Afro-American; A Ma: Afro-Malagasy; PRA: Pluri-regional African; ArA: Arab-African; WA: Endemic to West Africa; AN: Afro-Neotropical; GC - SZ Co: Guineo-Congolese Sudanese-Zambeian Comorian; SG: Sudano-Guinean

Fig. 3. Phytogeographic distribution spectrum of the Kou Classified Forest flora

Diversity indices

The diversity indices calculated and presented in Table 2 show that the flora of the KCF is diverse both at the woody plants level ($H' = 3.37$; $D' = 0.93$) as well as the

herbaceous plants level ($H = 3.23$; $D' = 0.94$), with a more or less equitable distribution of individuals within the species ($E = 0.73$ woody ; $E = 0.80$ herbaceous). However, these indices are low for the woody flora of the

Tectona grandis plantation ($R_{mg} = 2.32$; $H = 0.71$; $D' = 0.25$; $E = 0.28$) and for the herbaceous flora of the gallery forest ($R_{mg} = 1.53$; $H' = 2.11$).

Species rarity index

Analysis of the frequency of KCF species allowed us to calculate their rarity index which, according to the thresholds established by Traoré *et al.* (2011), shows that 87.86% of species (181 species) are rare against 9.71% moderately frequent and 2.43% very frequent (Fig.4).

Special status species of the Kou classified forest
Fifty-three species of special status or species of conservation value have been identified in the KCF.

Among them 42 species are threatened in Burkina Faso, i.e., 56.77% of the country's threatened species, and 22 species are on the IUCN red list, including *Borassus akeassii* endemic to the West African region, and *Calamus deerratus* G. Mann and H. Wendl., a rare species in the sudanian galleries.

Table 2. Indicators of woody and herbaceous diversity in the Kou classified forest.

Indicators of Diversity	Specific Richness S		Margalef absolute richness R_{mg}		Shannon's diversity H'		Simpson's dominance D'		Piélou's equitability E	
	W	H	W	H	W	H	W	H	W	H
Agrosystem	12	20	2.96	2.12	2.09	2.25	0.83	0.87	0.84	0.91
Clear Forest	24	/	4.68	/	2.38	/	0.86	/	0.75	/
Gallery Forest	37	35	7.16	1.53	3.11	2.11	0.94	0.86	0.84	0.92
Plantation	13	/	2.32	/	0.71	/	0.25	/	0.28	/
Woody savannah	66	36	8.89	4.10	2.85	3.00	0.87	0.94	0.72	0.90
Shrubby Savannah	64	44	6.23	4.28	3.09	3.09	0.94	0.94	0.89	0.90
KCF	121	85	13.61	7.85	3.36	3.80	0.93	0.97	0.74	0.92

W: Woody flora and H: Herbaceous flora

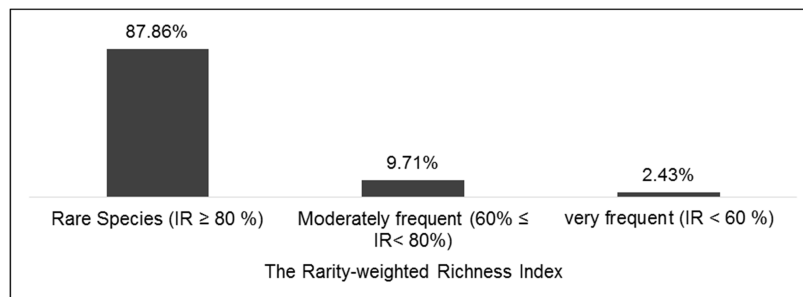


Fig. 4. Proportion of species according to rarity indices in the Kou Classified Forest

Structure and dynamics of the vegetation of the Kou Classified Forest

Density, basal area and overall vegetation cover

The average density of woody plants in the KCF is 45 ± 5 ft/ha with an average tree diameter of 14.34 ± 0.4 m. By land use type, it varies from 40 ± 6 ft/ha for agrosystems to 885 ± 325 ft/ha for

plantations (Table 3). The average basal area of the KCF is 15.73 ± 2.86 m²/ha and varies between 8.38 ± 0.44 m²/ha in open forest and 33.8 ± 14 m²/ha in shrub savanna. The average soil cover by the herbaceous cover is $22\% \pm 4\%$. It is higher in the shrub savanna ($62\% \pm 8\%$) and lower in the gallery forest ($7\% \pm 4\%$).

Table 3. Structural parameters of the vegetation of the Kou Classified Forest

Land Use Types	Average density (tree/ha)	Average basal (m ² /ha)	Average diameter (m)	Herbaceous cover (%)
Agrosystem	40 ± 6	12.6 ± 1.70	15.44 ± 1.68	9 ± 7
Clear Forest	685 ± 185	8.38 ± 0.44	14.33 ± 0.97	10 ± 8
Gallery Forest	444 ± 59	8.67 ± 1.94	18.98 ± 1.14	7 ± 4
Plantation	885 ± 325	9.16 ± 8.85	11.16 ± 0.47	23 ± 10
Wooded savannah	520 ± 63	26.34 ± 8.07	12.51 ± 0.64	45 ± 5
Shrubby Savannah	493 ± 57	33.8 ± 14.00	13.41 ± 0.94	62 ± 8
KCF	456 ± 51	15.73 ± 2.86	14.34 ± 0.40	22 ± 4

Mean \pm standard error

Horizontal structure of woody plants

Fig. 5 shows the diameter class distribution of woody trees in the KCF. Overall, it has an inverted « J-shape » and is characterized by a decreasing distribution in number of trees from small to large diameters. The value of the "shape" or "C" parameter of the Weibull curve is 0.7 for the KCF (Fig. 5a) and varies according to land use types (Fig. 5). It is less than one ($c < 1$) for the different types of occupation except for plantations where it is 1.1 (Fig.5d).

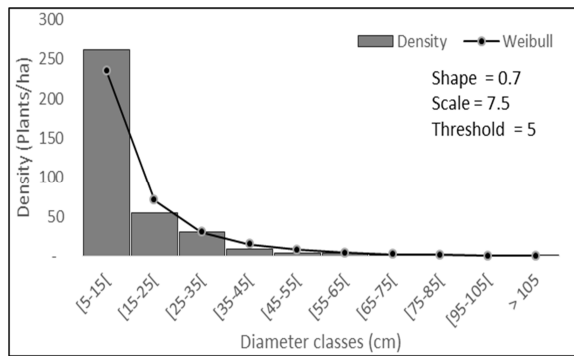


Fig. 5. A: Kou Classified Forest

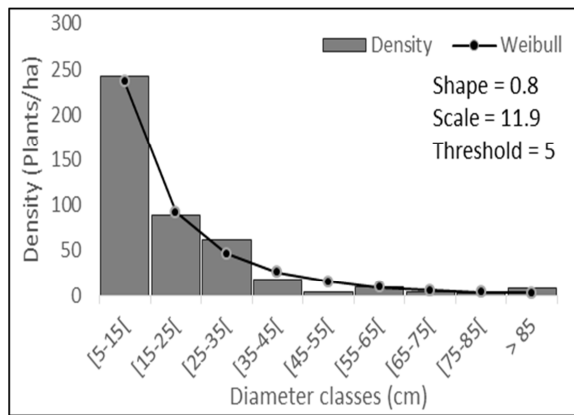


Fig. 5. B: Gallery Forest

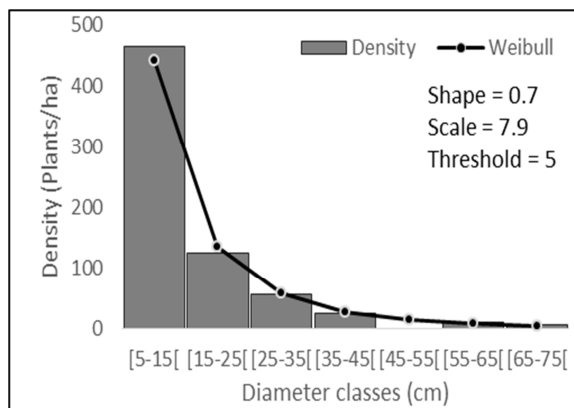


Fig. 5. C: Clear Forest

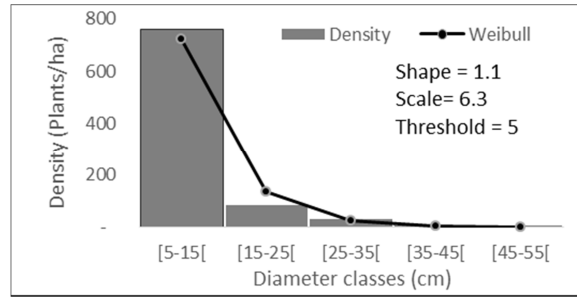


Fig. 5. D: Plantation

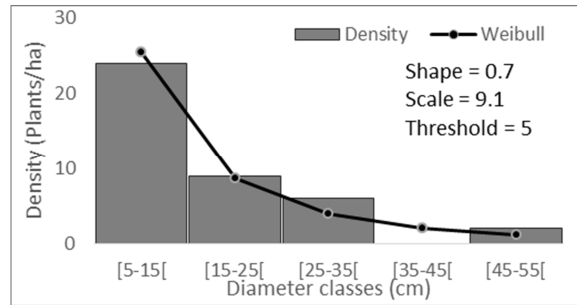


Fig. 5. E: Agrosystem

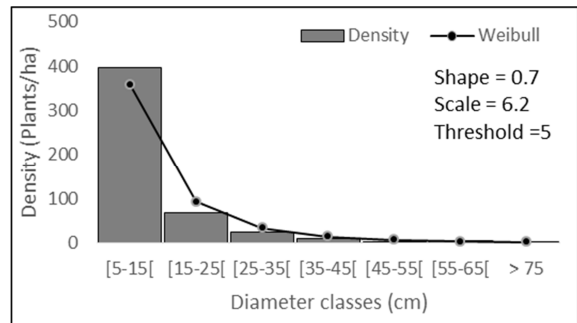


Fig. 5. F: Wooded savannah

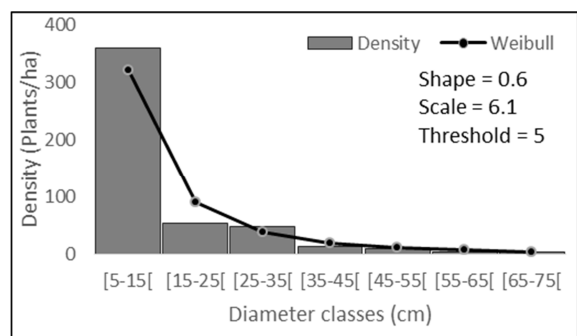


Fig. 5. G: Shrubby Savannah

Fig. 5. Demographic structure of woody species in the Kou Classified Forest

Regeneration potential of woody species

The regeneration assessment resulted in a list of 76 species with an overall density of 1280 seedlings/ha

and a regeneration rate of 236.37%. The highest regeneration rate was recorded in the gallery forest (370.76%). The distribution in height classes of the

regeneration shows that it is dominated mainly by seedlings of the [0-0.5 m] class and which represents 80.59% of the regeneration's seedlings (Fig.6).

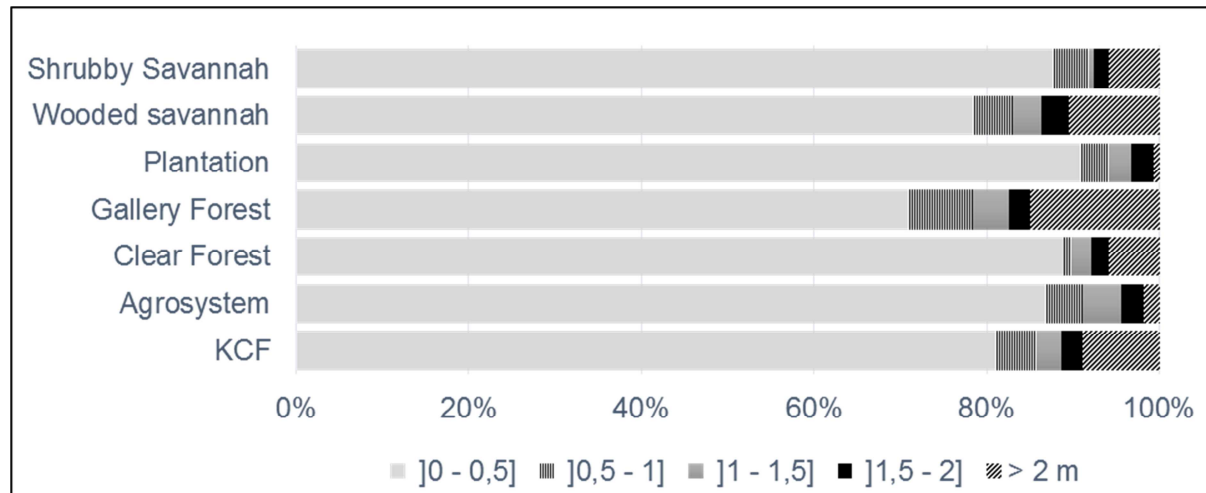


Fig. 6. Spectrum of regeneration distribution in height classes

Health status of woody plants

The analysis of the health status of woody plants in the KCF shows that 95.40% of inventoried woody plants are healthy, only 4.20% are partially dried out and 0.29% is cut.

Discussion

Biodiversity of the Kou Classified Forest

The flora of the KCF is rich in 207 species. This floristic richness is close to that of Coulibaly (2003) and lowers than that of Guinko (2005), who found 200 and 277 species in the KCF respectively. This difference is due to the fact that the work of Guinko (2005) went beyond angiosperms and even took into account the mycological flora of the KCF. However, this study identified 64 species that were not identified by Guinko (2005). Among these species, 8 species are not listed in the catalog of vascular plants of Burkina Faso (Thiombiano *et al.*, 2012), thus new to the flora of Burkina Faso. This makes it possible to estimate the overall flora of the KCF to date at least 341 species.

Compared to other classified forests in Burkina Faso, the woody flora of the KCF (121 species) has more species than that of the Pama Reserve (Mbayngone *et al.*, 2008), the Arly National Park (Ouédraogo *et al.*,

2008), the Gampèla (Achard, 1993), Toéssi (Bélem, 1993), Bansié (Ouédraogo, 2004), and Niangoloko (Ouoba, 2006) classified forests, which have 92, 109, 45, 80, 109, and 99 woody species respectively.

The diversity indices show that the woody and herbaceous flora of the KCF is diverse with the exception of the woody flora of the *Tectona grandis* plantation (Rmg = 2.32; H = 0.71; D' = 0.25; E = 0.28) and the herbaceous flora of the gallery forest (Rmg = 1.53; H' = 2.11). This is due to the fact that *Tectona grandis* plantations are nearly monospecific (Guinko, 2005) and that the water-saturated soils of the gallery allow only a small number of moist-adapted species to grow (N'Da *et al.*, 2008). In addition, the closed canopy in the forest gallery does not allow for good light penetration, thus limiting the development of understory and sun-loving plants.

The prominence of the Fabaceae (18.45%), Poaceae (7.77%) and Rubiaceae (6.80%) families is a characteristic of African savannas (Gnoumou, 2013) and highlights the importance of the savanna flora at the KCF. The predominance of Sudano-Zambezian transition species (21.2%) and species of Sudanian base element (18.5%) is the expression of the belonging of this ecosystem to the Sudanian domain

and shows a better conservation of the original phytodiversity (Mbayngone *et al.*, 2008). The predominance of phanerophytes (64.6%) is also a characteristic of the flora of the Sudanian zone of Burkina Faso (Thiombiano *et al.*, 2010) and also highlights the woody character and the high level of protection of the KCF. Indeed, several works have highlighted the predominance of phanerophytes in forests (Ouoba, 2006) and in woody savannas with absolute protection (Adjanooun, 1964). According to Ouédraogo *et al.* (2010b), the KCF is among the best maintained classified forests due to effective conservation actions (integral brick fencing, participatory management, daily presence of eco-guides, etc.). Due to these conservation actions the forest also assumes the protection of 53 species of special status, which is more than half of the threatened plant species of Burkina Faso (56.77%). But the high proportion of rare species (87.86%), i.e. species with a restricted distribution within the KCF (IR \geq 80%), shows the vulnerability of this flora which deserves special attention.

Vegetation structure and dynamics

The structure of the woody vegetation of the KCF in the inverted "J- shape" is a characteristic of tropical forests (N'Da, 2008) and expresses good health and ecological stability of the vegetation (Ouédraogo, 2006). The "C" values of the Weibull curve ($C < 1$) of savannas, forests, and agrosystems show that their vegetation is characterized by multispecific stands with high regeneration potential (Glèlè Kakaï, 2016). On the other hand, at the plantation level, the Weibull curve ($1 < C < 3.6$) expresses a characteristic distribution of a monospecific stand with a predominance of young or small diameter individuals (Glèlè Kakaï, 2016). This can be explained by the predominance of *Tectona grandis*, the high density of the stand (885 ± 325 ft/Ha) with individuals of average diameter of 11.16 ± 0.47 m.

The analysis of regeneration potential shows that more than half of the woody species identified are in regeneration (75 species out of 121) despite difficulties in identifying very young seedlings. The density (1280

seedlings/ha) and the regeneration rate (236.37%) indicate a good natural regeneration of species according to the Rothe scale (1964). In view of these parameters and the rate of healthy individuals recorded (95.40%), it can be concluded that the level of anthropization of this forest is extremely low, thus ensuring a perpetuation of its flora. Despite this, there is some fraudulent cutting of vegetation (0.29%) which could increase if the level of protection were to decrease.

Conclusion

The evaluation of the floristic diversity of the Kou classified forest shows that it harbors a diverse and rich flora of 207 species. This study completes the flora of the KCF with 64 new species and the flora of Burkina Faso with 8 new species. The list of flora obtained is far from being exhaustive and can therefore be further improved by other studies. We also noticed a better conservation of the original phytodiversity and an ecological stability of the vegetation that favors the presence of more than half of the threatened species of Burkina Faso. However, the high proportion of rare or restricted species within the KCF shows that this ecosystem deserves special and permanent attention. Despite its small size (115 ha), the KCF remains a bulwark for the floristic diversity of Burkina Faso and the sub-region.

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