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Change in the woody floristic composition, diversity and structure from protected to unprotected savannahs in Pendjari Biosphere Reserve (Benin, West Africa)

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Abstract

Savannahs are widespread vegetation type in Sudanian zone of Africa. As protected areas are often assumed to be the best way to conserve biodiversity, we assessed the effectiveness of the Pendjari Biosphere Reserve in Benin, for maintaining savannah woody species composition, diversity and structure. Square plots of 900 m^2 were randomly established in protected and surrounding unprotected savannahs, and all woody species (dbh $\geq$ 1 cm) were recorded and identified. Species composition, Importance Value Index, densities, basal area and diversity indexes were assessed in relation to conservation status. The results showed that DCA based on presence/absence species data did not separate clearly protected savannahs from unprotected ones. However, some species were prominent in unprotected savannahs while others showed the same scheme in protected ones. Diversity indexes indicated a good distribution of species in the two savannah types. The woody density showed a higher value in protected than unprotected savannah at shrub layer level. The basal area was significantly higher in the protected savannah than unprotected one at the two woody layer levels. It can be concluded that biodiversity conservation in surrounding unprotected areas should be of great importance to increase biodiversity conservation by protected area whether specific actions were implemented.

Key words: conservation, diversity, savannah, structure, woody species

Résumé

Les savanes sont un type de végétation très répandu dans la zone soudanienne de l'Afrique. Étant donné que les aires protégées sont supposées être la meilleure façon de préserver la biodiversité, nous avons évalué l'efficacité de la Réserve de biosphère de la Pendjari, au Bénin, pour ce qui est du maintien de la composition des espèces ligneuses de la savane, leur diversité et leur structure. Des parcelles carrées de 900 m furent établies au hasard dans l'aire protégée et dans les savanes non protégées voisines, et toutes les espèces ligneuses (dbh 1 cm) furent enregistrées et identifiées. La composition des espèces, l'Indice de valeur d'importance, la densité, l'aire basale et les indices de diversité furent évalués par rapport au statut de conservation. Les résultats ont montré que la DCA basée sur des données portant sur la présence/absence d'espèces ne séparait pas clairement les savanes protégées de celles qui ne l'étaient pas. Cependant, certaines espèces étaient prédominantes dans les savanes non protégées alors que d'autres l'étaient dans les savanes protégées. Les indices de diversité indiquent une bonne distribution des espèces dans les deux types de savane. La densité ligneuse montrait une valeur supérieure dans la savane protégée que dans la savane non protégée au niveau de la strate arbustive. L'aire basale était significativement supérieure dans la savane protégée que dans la savane non protégées aux deux niveaux des strates ligneuses. On peut en conclure que la conservation de la biodiversité dans les aires voisines non protégées devrait être considérée comme très importante pour améliorer la conservation de la biodiversité d'une aire protégée où des mesures spécifiques ont été appliquées.

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Introduction

All over the world, human survival depends on biodiversity (Singh, 2002) and therefore its conservation becomes fundamental. Several strategies such as the protected area setting, their effective management, the achievement of conservation measures outside the protected areas to restore biodiversity in degraded habitats, are fulfilled (Primack, 2008). Among these strategies, the most effective is probably the establishment of protected areas, due to the large amounts of biodiversity that it preserves (Maiorano, Falcucci & Boitani, 2008; Abellán *et al.*, 2011). However, this effectiveness is not always achieved. Moreover, many kinds of environmental changes influence or determine processes that can both increase and erode diversity (Sheil, 1999). Those changes mainly concern exploitation through selective harvest and commercial logging, seasonally set forest fires, fuel wood removal and charcoal production, grazing of cattle, pruning and land clearing for agricultural activities (Ramirez-Marcial, Gonzalez-Espinosa & Williams-Linera, 2001; Reyers, 2004; Banda, Schwartz & Caro, 2006). These disturbances are reported as influence factors of forest structure (Bhuyan, Khan & Tripathi, 2003; Sagar, Raghubanshi & Singh, 2003; Banda, Schwartz & Caro, 2006), its woody diversity (Sagar & Singh, 2005; Makana & Thomas, 2006) and woody species composition (Sagar, Raghubanshi & Singh, 2003) in tropical areas. In addition, quantification based on woody species is an important aspect when studying disturbance impact on forest structure. Indeed, woody species is a dominant life form which provides resources and habitat for many animal species and is easy to count (Condit *et al.*, 1996; Cannon, Peart & Leighton, 1998; Sagar, Raghubanshi & Singh, 2003).

Pendjari Biosphere Reserve in Benin like other National Parks in Africa was set up primarily to protect wildlife mainly the big mammals as these latter maximize the financial return of reserves. It is also assumed that protecting large mammals is an appropriate surrogate for conserving all biodiversity, including plants (Banda, Schwartz & Caro, 2006). Therefore, it might be necessary to test whether such protected area contributes effectively to conserve the forest attributes such as structure, woody species composition and diversity. Indeed, from some past studies (Vermeulen, 1996; Shackleton, 2000; Banda, Schwartz & Caro, 2006; Paré *et al.*, 2009), protected areas do not necessarily conserve the greatest diversity of plant species. While other studies (Bhuyan, Khan & Tripathi, 2003; Sagar, Raghubanshi & Singh, 2003; Sahu, Sagar & Singh, 2008) have proved the opposite.

In addition, savannahs constitute one of the largest biomes of the world, comprising about 20 per cent of the land surface and most of them occur in Africa (Shorrocks, 2007). Savannahs are a resource for food, medicine, timber and livestock breeding (Bellefontaine, Gaston & Petrucci, 1997). Thus, they are subjected to much degradation, and their conservation is important in the process of biodiversity conservation. To conserve them, it is required to know how its attributes such as woody species composition, diversity and structure behave facing degradation. Therefore, this study was carried out in order to check whether Pendjari Biosphere Reserve contributes to conserve effectively woody structural characteristics, diversity and species composition of savannahs.

Materials and methods

Study system

The study was carried out in the Pendjari Biosphere Reserve (10°30′–11°30′N and 0°50′–2°00′E), a protected area located in the extreme north-western part of Benin (West Africa) and in its surrounding land-use areas (Fig. 1). It was established since 1986 and covers 4666.4 km^2 including Pendjari National Park (2660.4 km^2), Pendjari hunting zone (1750 km^2) and Konkombri hunting zone (251 km^2). The climate is tropical with an average annual, unimodal rainfall of 1100 mm. The rainy season starts in April or May, followed by a dry season from November to March. In the PBR, savannahs are the widespread vegetation type, and anthropogenic activities are prohibited. However, savannahs, in surrounding open access land, are set up sometimes on unfit land for agriculture and are subjected highly to human disturbance such as selective logging and cutting; pruning and firewood extraction. Inside and outside the protected area, the soils are mainly ferruginous. The reserve is set up on a peneplain with a flat relief with the presence of large isolated hills and floodplains. The Atakora mountain chain (400–513 m above sea level) occupies its southern part, with stones and unfitted land for agriculture. Several large mammals are encountered in the PBR and benefited some particular attention. The main species are *Syncerus caffer planiceros*, *Hippotragus equines*,

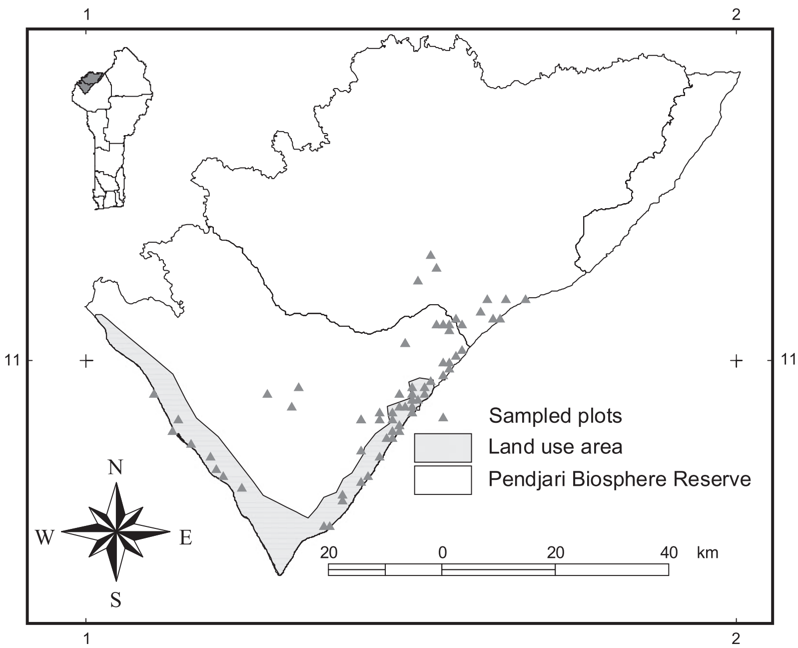

Fig 1 Localization of study area and sampled plots

Alcelaphus buselaphus major, Kobus kob, Sylvicapra grimmia, Ourebia ourebi, Tragelaphus scriptus, Phacochoerus aethiopicus, Papio anubis, Cercopithecus aethiops, Hippopotamus amphibius, Panthera leo, Acinonyx jubatus, Panthera pardus, Loxodonta africana etc. Some of these species could be encountered sometimes in surrounding unprotected zone. In this latter area, conservation activities focused on wildlife are implemented and aimed at controlling the small hunting.

Sampling and data collection

Thirty five square plots of 900 m^2 were established randomly in each savannah type (protected and unprotected). Within each plot, every woody individual with a diameter at breast height (dbh) dbh $\geq$ 1 cm was measured for dbh and identified. Plant names and authorities were checked in database of the International Plant Name Index (IPNI) through the link: www.ipni.org. Data were collected during the period from July to September.

Data analyses

For each plot, the number of species, stem density, basal area and diversity indexes were calculated. These indices were Shannon–Wiener's diversity index, Shannon's measure of evenness and Margalef's index (Magurran, 2004). As surveys based solely on large and medium-sized tree species were not able to always reflect the overall woody diversity (Tchouto *et al.*, 2006), we considered two woody layers (tree layer dbh $\geq$ 10 cm and shrub layer 10 cm > dbh $\geq$ 1 cm) when calculating the above-mentioned parameters. In the shrub layer, tree and shrub species were also recorded.

Two-way ANOVA was performed to examine whether the computed vegetation attributes vary in relation to savannah conservation status and vegetation layer. Thus, the number of species, the stem density and the basal area per plot were log-transformed before the analysis. The combinations of savannah conservation status variants (protected and unprotected) and those of vegetation layer (shrub and tree layer) were compared by a Tukey test. Univariate statistical analyses were performed with Statview.

Multivariate Detrended Correspondence Analysis (DCA) was used to explore the variation of woody floristic composition across savannah types in PCORD.5. From output of DCA, we calculated the Importance Value Index (IVI) for each inventoried species in each of group defined by DCA. IVI was calculated as the sum of relative dominance, relative density and relative frequency. The matrix obtained was subjected to Principal Component Analysis (PCA) using Community Analysis Package (CAP). Jaccard's similarity index was used for assessing

ß-diversity among the two savannahs (protected and unprotected).

Results

Woody species composition

The two savannah types yielded a total of 58 species representing 44 genera and 23 families. A complete list of species and their code are provided in appendix 1. The most abundant families are Combretaceae (17%), Mimosoideae (10%), Caesalpinioideae (10%), Rubiaceae (10%), Meliaceae (7%) and Anacardiaceae (7%). The two savannah types shared most of their common woody species, and the pattern of DCA (Fig. 2) indicated three groups of plots score (one group composed exclusively of plots from protected savannahs, one group composed exclusively of plots from unprotected savannahs and mixed group composed of plots from the two savannah types).The similarity in woody species composition between the two savannah types was 67%. Using IVI values of species, the first two axes of principal component analysis (Fig. 3) saved 95% (63.27% with axis 1 and 31.73% with axis 2) of variation in species composition. The projection of the three precedent groups defined by the DCA, in the axes system obtained from PCA showed that the first axis discriminated the groups of species with high IVI values from those of low ones in unprotected savannah. Thus, species such as *Parkia biglobosa* (Jacq.) R.Br. ex G. Don, *Lannea barteri* Engl., *Anogeissus leiocarpa Guill.& Perr.*, *Securidaca longepedunculata* Fresen., *Tamarindus indica* L., *Ximenia americana* L., *Ziziphus abyssinica* Hochst. ex A. Rich. and *Combretum nigricans Leprieur ex Guill. & Perr.* had high IVI values in unprotected savannahs, while *Acacia gourmaensis A. Chev*, *Pteleopsis suberosa* Engl. & Diels, *Lonchocarpus laxiflorus* Guill. & Perr., *Stereospermum kunthianum* Cham., *Grewia villosa* willd. and *Maytenus senegalensis (lam.)* Exell showed the opposite scheme in the same habitat. The second axis separated the group composed exclusively of plots of protected savannahs, from one mixed group. These plot groups are linked with species that had high IVI values in each of them. Thus, *Vitellaria paradoxa* C.F.Gaertn., *Bridelia scleroneura Müll. Arg.*, most of *Combretum species, Crossopteryx febrifuga Benth.*, *Piliostigma thonningii* (Schumach.) Milne-Redh, *Pseudocedrela kotschyi* Harms, *Terminalia avicennioides* Guill. & Perr. and *Pterocarpus erinaceus* Poir. had high IVI values in mixed plot group. However, *Afzelia africana Sm.*, *Burkea africana Hook.*, *Daniellia oliveri (Rolfe) Hutch. & Dalziel*, *Detarium microcarpum Guill. & Perr.*, *Ekebergia senegalensis Fuss.*, *Lannea barteri* Engl., *Ozoroa insignis* Delile, *Pericopsis laxiflora* (Benth. ex Baker) Meeuwen and *Syzygium guineense* Guill. & Perr. had high IVI values in protected savannahs.

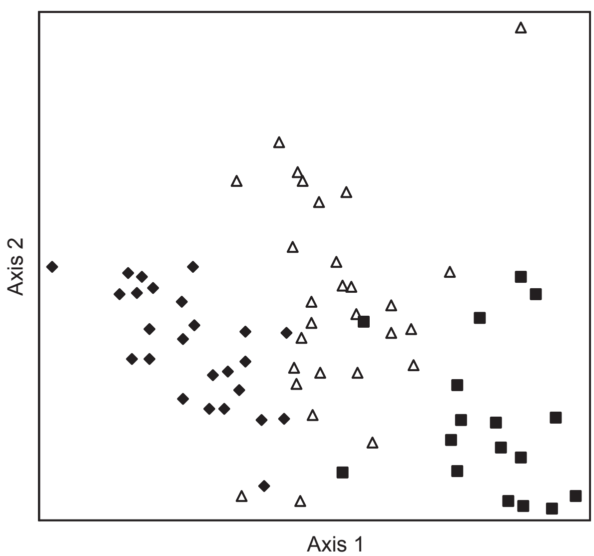

Fig 2 Plot scores projection onto axes 1 and 2 of Detrended Correspondence Analysis on woody species composition (from left to right : exclusive plots of unprotected savannas, plots of mixed group and exclusive plots of protected savannas). Total inertia: 3.3; Eigenvalue of Axis 1: 0.30; Eigenvalue of Axis 2: 0.18

Species diversity and structural characteristics

Species richness per plot did not differ significantly between savannah types while the difference was significant at layer level of each savannah type (Table 1). Diversity indexes indicated a good distribution of species in the two savannah types. However, in unprotected savannahs, the diversity was higher at shrub layer level than at tree one.

A total of 1106 and 916 woody individuals were recorded, respectively, in protected and unprotected savannahs. The woody density per plot was significantly higher in protected savannahs at shrub layer level while the difference was not significant at tree layer. As far as, the basal area is concerned significant higher values were found in the protected savannah compared with the unprotected one at the two layer levels (Table 1).

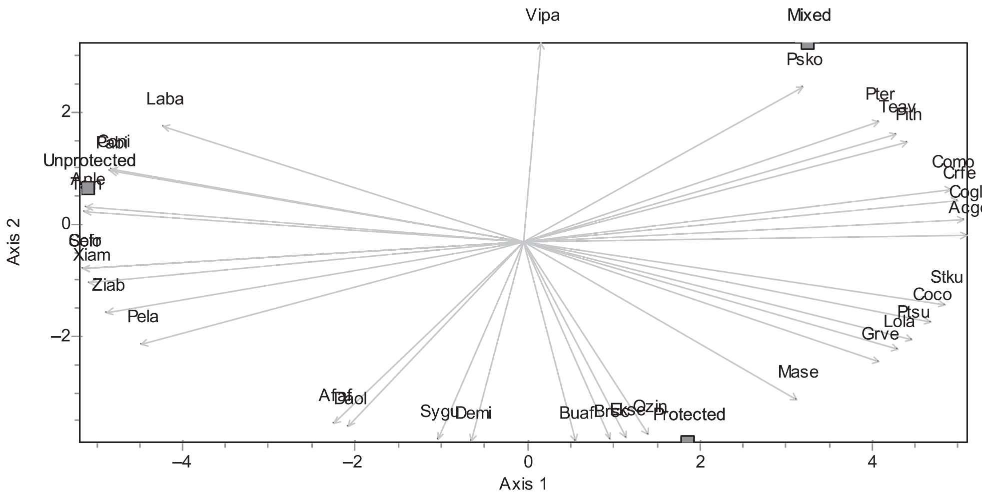

Fig 3 Projection of woody species and plot score group in the system axes of Principal Correspondence Analysis using Importance Value Index values of species. The plot score groups were defined previously by the DCA and were unprotected, mixed and protected groups. The meaning of abreviations and species list are provided by appendix 1

Table 1 Structural characteristics and diversity of savannahs (protected and unprotected) in relation to layer (tree and shrub) in Pendjari Biosphere Reserve. Values of a line, followed by a same letter (a or b), are not significantly different while those followed by different letters are significantly different. (in bracket, we are the number of plots)

	Protected savannahs (35)		Unprotected savannahs (35)		*P*-value		
	Shrub layer : dbh < 10 cm	Tree layer (dbh ≥ 10 cm)	Shrub layer : dbh < 10 cm	Tree layer (dbh ≥ 10 cm)	Savannah status (SS)	Vegetation layer (VL)	SS*VL
Species richness (S) per plot	8a	4b	8a	4b	0.771	<0.001	0.895
Shannon–Wiener's diversity index ($H' = -\sum pi*\log_2* pi$)	4.33a	4.30a	4.67a	2.87b	0.853	<0.001	0.313
Shannon's measure of evenness ($J' = H'/\ln S$)	0.79a	0.82a	0.87a	0.74a	0.780	0.441	0.107
Margalef 's index ($D_{Mg} = (S-1)/\ln N$)	7.18a	8.22a	8.10a	5.77b	0.663	<0.001	0.761
Density (plant/ha)	253.65a	95.87b	193.65ab	96.50b	0.129	<0.001	0.040
Basal area (m^2/ha)	2.03a	19.2b	1.3ba	16.60c	0.215	<0.001	0.883

Discussion and conclusion

The study revealed that the woody species richness was higher at shrub than tree layer level of each savannah type. However, the woody diversity showed the same trend in solely unprotected savannahs. This suggests disturbance effect on woody diversity at tree layer level. Such effect should be mostly linked to the firewood use that selects adult's tree individuals of some woody species and consequently decreases woody species richness and diversity. Similar results were reported elsewhere (Bhuyan, Khan & Tripathi, 2003; Sagar, Raghubanshi & Singh, 2003; Sagar & Singh, 2005; Makana & Thomas, 2006) where a significant decrease in woody diversity with the disturbance intensity were reported on various tropical ecosystems. However, we found that diversity indexes indicated a good distribution of species in the two savannah types at shrub layer level. This finding agrees with those one of Banda, Schwartz & Caro (2006) and Paré *et al.* (2009) and suggesting that

surrounding unprotected areas should be of great importance in biodiversity conservation.

The finding according to which, the mean density of woody was higher in conserved savannahs than in the unprotected ones at shrub layer level is consistent with others researches (Bhuyan, Khan & Tripathi, 2003; Sagar, Raghubanshi & Singh, 2003; Makana & Thomas, 2006) undertaken elsewhere. These authors found that the mean stem density of woody was higher in the least disturbed site than in the highly disturbed one. These disturbances concerned mostly the selective cutting of woody for fuel use in the case of our study area. If woody selective cutting have induced shrub density decreasing, this meant also that this activity (i.e. woody extraction for fuel use) threatens seriously biodiversity conservation in this open access land. Therefore, conservation strategies in this latter area must be oriented towards a sustainable use of firewood trees.

As far as the basal area is concerned, we found higher values in the protected savannahs than in the unprotected ones at the two vegetation layers level. This difference of basal area between the two savannah types can be explained by the combined effect of selective logging and cutting. Large size class diameters of some valuable trees are targeted for logging. At the same time, smaller individuals are cut for firewood use. This result is consistent with that of Banda, Schwartz & Caro (2006) who obtained higher value of basal area in Katavi National park (Tanzania) compared with the one in the human-inhabited area. Also Assogbadjo *et al.* (2010) found in Wari Maro forest reserve (centre of Bénin) a significantly higher basal area in woodlands of low anthropogenic pressure than in ones of high pressure.

The woody species richness recorded globally in the study showed the dominance of the Combretaceae, Mimosoideae, Caesalpiniodeae and Rubiaceae families. This floristic trend has been reported by Paré *et al.* (2009) in Burkina and is characteristic of African sudanian savannahs. Considering IVI values as indicator of species dominance, *A. africana, B. africana, D. oliveri, D. microcarpum, E. senegalensis, L. acida, O. insignis, P. laxiflora,* and *S. guineense* would be less prominent in unprotected savannahs. This may be explained by the fact that human pressure mostly threatens those woody species and prevent their prominence in unprotected area. Consequently, they should retain particular attention in biodiversity conservation process in this area. This result agrees partially with the finding of Paré *et al.* (2009) who found in Burkina Faso that *O. insignis* was rare in the unprotected dry forest. *A. africana, B. africana* and *D. microcarpum* have been also reported as prominent in woodland stands of low human pressure (Assogbadjo *et al.*, 2010). Other species have high IVI values in unprotected savannahs and may suggest that they are not mostly valued by local people (case of *S. longepedunculata, Z. abyssinica* and *C.*) or that these species support mostly human pressure despite their valorization (case of *P. biglobosa, L. barteri, A. leiocarpa, T. indica* and *X. americana*).

Analysis of change of woody species composition in relation with protection status of savannah showed that with increasing demographic pressure and consequently pressure on savannahs, their woody species composition may change. Similarly, Sagar, Raghubanshi & Singh (2003) indicated a variation of woody species composition in relation to disturbance gradient of a tropical dry forest in India.

In conclusion, this study showed that effectiveness of this protected area to conserve savannah structure and woody diversity depends on the woody layer. Woody species composition change in relation to savannah conservation status may be also evident according to interrelation specific-use-species. Thus, implementation of some specific actions could help woody vegetation conservation in surrounding unprotected areas. The main could be the introduction in unprotected area, rapid growth tree species that can be used by local communities for fuel use. Also, local communities could be encouraged to diversify their agroforestry parklands with woody species that are less prominent in unprotected areas.

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Appendix 1

A complete list of woody species with dbh >1 cm recorded in the all inventoried plots with their families and codes used in the PCA ordination.

Species	Family	Code
Acacia dudgeoni Craib	Leg-Mimosoideae	Acdu
Acacia erhembergiana A	Leg-Mimosoideae	Acer
Acacia gourmaensis A. Chev	Leg-Mimosoideae	Acgo
Acacia mellifera Benth	Leg-Mimosoideae	Acme
Afzelia africana Sm.	Leg-Caeslpinioideae	Afaf
Annona senegalensis Pers.	Annonaceae	Anse
Anogeissus leiocarpa Guill.& Perr.	Combretaceae	Anle
Balanites aegyptiacus Delile	Balanitaceae	Baae
Bombax costatum Pellegr. & Vuillet	Bombacaceae	Boco
Bridelia scleroneura Müll. Arg.	Euphorbiaceae	Brsc

(continued)

Burkea africana Hook.	Leg-Caeslpinioideae	Buaf
Combretum collinum Fresen.	Combretaceae	Coco
Combretum fragrans F. Hoffm.	Combretaceae	Cofr
Combretum glutinosum Perr. ex DC.	Combretaceae	Cogl
Combretum molle R. Br. ex G. Don	Combretaceae	Como
Combretum nigricans Leprieur ex Guill. & Perr.	Combretaceae	Coni
Crossopteryx febrifuga Benth.	Rubiaceae	Crfe
Daniellia oliveri (Rolfe) Hutch. & Dalziel	Leg-Caeslpinioideae	Daol
Detarium microcarpum Guill. & Perr.	Leg-Caesalpinioideae	Demi
Dichrostachys cinerea (L.) Wight & Arn.	Leg-Caesalpinioideae	Dici
Dombeya quinqueseta (Delile) Exell	Sterculiaceae	Doqu
Ekebergia senegalensis Fuss.	Meliaceae	Ekse
Gardenia aqualla Stapf & Hutch.	Rubiaceae	Gaaq
Gardenia erubescens Stapf & Hutch.	Rubiaceae	Gaer
Gardenia ternifolia Schumach.	Rubiaceae	Gate
Grewia lasiodiscus K. Schum.	Tiliaceae	Grla
Grewia villosa willd.	Tiliaceae	Grvi
Hannoa undulata Planch.	Simaroubaceae	Haun
Khaya senegalensis A.Juss.	Meliaceae	Khse
Lannea acida A.Rich.	Anacardiaceae	Laac
Lannea barteri Engl.	Anacardiaceae	Laba
Lannea velutina A. Rich.	Anacardiaceae	Lave
Lonchocarpus laxiflorus Guill. & Perr.	Leg-Papilionoideae	Lola
Maytenus senegalensis (lam.) Exell	Celastraceae	Mase
Mitragyna inermis (Willd.) Kuntze	Rubiaceae	Miin
Ozoroa insignis Delile	Anacardiaceae	Ozin
Parkia biglobosa (Jacq.) R.Br. ex G. Don	Leg-Mimosoideae	Pabi
Pericopsis laxiflora (Benth. ex Baker) Meeuwen	Leg-Papilionoideae	Pela
Piliostigma thonningii (Schumach.) Milne-Redh	Leg-Caesalpinioideae	Pith
Pseudocedrela kotschyi Harms	Meliaceae	Psko
Pteleopsis suberosa Engl. & Diels	Combretaceae	Ptsu
Pterocarpus erinaceus Poir.	Leg-Caesalpinioideae	Pter
Rhus natalensis Bernh. ex Krauss	Anacardiaceae	Rhna
Sarcocefalus latifolius (Sm.) E. A.Bruce	Rubiaceae	Sala
Securidaca longepedunculata Fresen.	Polygonaceae	Selo
Sterculia setigera Delile	Sterculiaceae	Stse
Stereospermum kunthianum Cham.	Bignoniaceae	Stku
Strychnos spinosa Lam.	Loganiaceae	Stsp
Syzygium guineense Guill. & Perr.	Myrtaceae	Sygu
Tamarindus indica L.	Leg-Caesalpinioideae	Tain
Terminalia albida Scott-Elliot	Combretaceae	Teal
Terminalia avicennioides Guill. & Perr.	Combretaceae	Teav
Terminalia macroptera Guill. & Perr.	Combretaceae	Tema
Tricalysia okelensis Hiern	Rubiaceae	Trok
Vitellaria paradoxa C.F.Gaertn.	Sapotaceae	Vipa
Vitex doniana Sweet	Verbenaceae	Vido
Ximenia americana L.	Olacaceae	Xiam
Ziziphus abyssinica Hochst. ex A. Rich.	Rhamnaceae	Ziab

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