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Original research

Savanna woody plants and their provision of food resources to bees in southern Burkina Faso, West Africa

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Abstract
West African savanna ecosystems and biodiversity are threatened by intensified land use and increasing degradation of natural habitats. Despite the importance of bees for pollinating crops and native plant species, little information is available regarding the importance of savanna woody plant species to provide bees with food resources. This study was carried out in the Sahelo-Sudanian zone of Burkina Faso, West Africa. Three study areas (the Dano basin, the wildlife reserve of Bontioli and the Nazinga game ranch) were selected. Floristic inventories were carried out on 48 subplots laid out across three land-use types. The three study areas followed a gradient of land-use intensity from Nazinga (lowest intensity) to Bontioli and Dano (highest land-use intensity). The number of bee morphospecies and their abundance as flower visitors was recorded from inflorescences of plants during the different flowering periods. Out of a total diversity of 82 woody plant species, 53 species (64.63%) from 38 genera and 21 families were melliferous. These plants were visited by bees for foraging nectar and/or pollen. Species of Combretaceae were the most visited by bees in terms of individuals (53.85%). Combretum glutinosum alone accounted for 36% of visits. More than half of the melliferous plants (50.94%) were visited for both nectar and pollen. About 32.08% of plants were visited for nectar only (32.08%), while 16.98% were visited for pollen only (16.98%). The majority of savanna plants are flowering in the dry season, but few flowering species can be found throughout the whole year. Savanna woody plant species constitute important food resources for bees, therefore providing a wide range of applications for the development of beekeeping activities in the Sudanian region of West Africa.

Keywords
Melliferous plants; Pollen; Nectar; Foraging; Sudanian region

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Contents

1. Introduction

Increasing human population has led to an intensification of traditional land use. Especially in developing countries, the human population is growing fast, with many of the rural inhabitants being poor, undernourished, and living in a more and more degraded environment due to increasing demand for agricultural productivity (Chaplin-Kramer et al., 2014; Steward et al., 2014). Fallow periods have become shorter, or land is cultivated continuously because of land shortages (Şaul et al., 2003). As long as sufficient arable land was available, there was no need to use marginal habitats (i.e. those that were very far from human settlements or were difficult to work on due to unfavourable structure or exposition). Such idle land provided many habitats in which a highly diverse community of plants and animals could survive, among them important species that provide food, fodder, timber, and fuelwood. However, with increasing demand, fruit picking is intensive, and the harvest of fruits may take place before they are ripe, not leaving any seed to germinate in the fields (Ki, 1994). Also, livestock may browse more heavily on the vegetation as fallow areas become smaller. With some delay, a new problem has become evident, namely the lack of regeneration of e.g. economically most important trees such as *Vitellaria paradoxa* (karité or shea tree) and *Parkia biglobosa* (Ræbild et al., 2012).

Another problem in the context of biodiversity decline is the loss of ecosystem services such as insect pollination (Thompson et al., 2014). The preservation of the guilds of pollinators (bees in particular) would require their intimate knowledge; i.e. of their habitats and food resources. Pollination is fundamental in the sexual reproduction of plants (Barker et al., 1980; Buchmann and Nabhan, 1996). It is one of the most important mechanisms for the maintenance of biological diversity and dynamics, and thus for life on Earth. About 90% of angiosperm species depend on animals for pollination and sexual reproduction (Ollerton et al., 2006; Renner, 1998). Approximately 75% of agricultural crop species rely, to some degree, on animal pollination, and one-third benefit from cross-pollination by developing higher fruit quantity and/or quality (Klein et al., 2007). According to Biesmeijer (2006), one third of crops require pollination to improve the quality of seeds and fruits, and the great majority of them are pollinated by numerous bees estimated to comprise at about 25,000 species worldwide (Dias et al., 1999). In addition to the pollination service, some bee species produce honey and other highly appreciated products such as propolis, wax and royal jelly. This has promoted the practice of beekeeping worldwide, and particularly in Africa, where trading apiculture products considerably improves household incomes, especially in rural areas (Bradbear, 2011).

Bees mainly feed on nectar and pollen of flowers provided by melliferous plants. However, some of these plants are visited by bees either for their nectar (nectariferous plants) or for their pollen (polliniferous plants). Therefore, the survival of these insects strongly depends on the availability of plant resources in their environment. Unfortunately, bee populations have been declining due to intensified land use leading to habitat degradation (Ollerton et al., 2014), and hence a reduction in food resources provided by melliferous plants (Forrest et al., 2015). For keeping their nutritional balance, most bees need to forage for a wide variety of wild but also of agricultural and horticultural floral species. The preservation of these food resources is essential for maintaining bee diversity and thus ensure the continued delivery of their ecosystem services. This requires detailed knowledge of melliferous plants in their environment.

In fact, only a few studies on bees have been carried out in West Africa (Aizen and Harder, 2009), where the main source of livelihood is based on rain-fed agriculture. In the context of regional land use and global climate change, the documentation on melliferous plant species offers a wide range of ecological and economic applications (for example bee conservation, beekeeping industry, poverty reduction, plant domestication or biodiversity conservation). Hence, ecosystem services enhanced by biodiversity (such as biotic pollination) can create mutually beneficial environmental and food-supply scenarios (Garibaldi et al., 2016; Tittonell and Giller, 2013), improving the livelihood of smallholders through higher and more stable crop yields, while minimizing negative environmental impacts (Godfray et al., 2010; Herrero et al., 2010). Our study indirectly contributes to the conservation of bee species (honey bees and wild bees) by assessing their food plants. The specific objectives were

(i) to inventory all woody savanna species used by bees as food resources,
(ii) to observe bee activities on the inflorescences of different plant species and to identify the type of floral reward collected, and
(iii) to identify the plant species being most attractive to bees.

2. Methods and material

2.1 Study areas and study design

This study was carried out in the Sahelo-Sudanian zone of Burkina Faso, West Africa. This zone is characterized by two pronounced seasons per year: a rainy season from June to October and a dry season from November to May, with October being a transition month (Grote et al., 2009). Mean annual rainfall varies between 800 and 1000 mm (Hema et al., 2011), while the mean annual temperature ranges from 27 to 28 °C (MSP, 2010). Phytogeographically, the study areas belong to the Sudanian Regional Centre of Endemism (White, 1983). The vegetation is dominated by a mosaic of various savanna types including shrub and tree savannas. Three study areas (elevation ranges between 271 and 448 m a.s.l) were selected (Figure 1):

- the Dano basin (11°8′56.566″N, 3°3′36.446″W),
- the wildlife reserve of Bontioli (10°48′26.393″N, 3°4′39.564″W), and
- the Nazinga game ranch (11°6′34.998″N, 1°29′7.181″W).

The three study areas followed a gradient of land-use intensity from Nazinga (lowest intensity) to Bontioli and Dano (highest land-use intensity). Dano and Bontioli are characterized by a mosaic of farmlands, villages and vegetation fragments. Agricultural activities are intense in these areas, including some beekeeping. Dano area comprises a small city of about 50,000 inhabitants with a fast-growing community where mainly farmers expand their settlements more and more into the surrounding savanna. Hence, only a few, very small "near-natural" savanna habitats have remained and only economically relevant tree species such as karité (*Vitellaria paradoxa*) and neré (*Parkia biglobosa* [Jacq.] R.Br. ex G.Don) have been left, forming a so-called parkland landscape. Anthropogenic disturbance at the savanna sites of Dano was more intensive than at Bontioli, forming an agricultural landscape with degraded soils and intense grazing, fire and logging. Forest cover amounts to 52.9%, cropland to 37.2% (K. Dimobe, unpublished data). We therefore considered the disturbance intensity (DI) in the area of Dano as "high". Bontioli area is a protected area, but categorized as a "Nature Reserve" according to Burkina Faso's legislation (Tia, 2008). The Bontioli savanna spreads over an area of 25,000 ha and is characterized by the dominance of the trees *Terminalia laxiflora* Engl. & Diels and *Vitellaria paradoxa* C.F. Gaertn. The DI of this area was considered as "medium" due to human activities such as agriculture, grazing, fire, uncontrolled logging and timber extraction that were registered even inside the reserve. The reserve is surrounded by plenty of villages and a wide agricultural landscape. Forest cover amounts to 77.85%, cropland to 12.59% (Dimobe et al., 2015). Nazinga area is also a protected area, classified as "Wildlife Reserve" according to Burkina Faso's legislation. It spreads over an area of 97,536 ha (Hema et al., 2011) and is characterized by tree species typical of pristine savanna forests, such as *Terminalia macroptera* Guill. & Perr., *Detarium microcarpum* Guill. & Perr. and *Prosopis africana* (Guill. & Perr.) Taub. Human disturbance is low except for regular, managed fires at the beginning of the dry season and only small settlements with agricultural fields at the margin of the reserve. The forest cover amounts to 88.2%, cropland to 0.8% (Dimobe et al., 2017). We considered disturbance intensity in this area as "low."

2.2 Data collection and analysis

In each study area, four sampling plots within a grid of 60 m x 90 m, were set up randomly. Within each plot, subplots of 15 m x 30 m were laid out in the four corners, giving a total of 48 subplots. Inventories of woody plant species were then carried out on the 48 subplots during the rainy season. Melliferous trees and shrubs were identified through regular observation of bees' presence and foraging on the inflorescences from January to December 2015. Once bees were observed visiting the flowers, the respective plant species was classified as "melliferous". Plant species flowered at different times of a year and were grouped according to the seasons: dry season (November to May); beginning of the rainy season (June); rainy season (July to September); end of rainy season (October). Flowering plant species within the subplots were monitored for 10 days during alternating hours (6 am to 12 am, or 12 am to 6 pm) to assess the number of bee visitors. The monitored plant species were then divided into three groups: frequently visited plants (¿ 500 visits by bees in total; intensity of foraging "IF" = +++), moderately visited plants (100-500 visits; IF = ++), and scarcely visited plants (¡ 100 visits; IF = +). The intensity of foraging is equivalent to the number of bee visits and was chosen as a parameter to enhance the clarity of the results. To characterize the type of food resources primarily collected by visiting bees, we distinguished nectariferous plants (i.e. plants that were only visited for their nectar) from those that were visited by bees only for pollen and plants of which the bees collected both rewards. This distinction was based on the foraging behaviour of the bees at the flowers. Bees solely foraging at the base of the corolla and not touching the pollen-bearing anthers were assumed to collect nectar, whereas bees leaving the flowers with pollen easily visible in the "pollen baskets" on the hind legs were assumed to collect pollen. The combination of the two behaviours was accounted to the collection of both nectar and pollen. The analysis of variance (ANOVA) and Duncan's test at 5% level were used to compare the mean abundance of bees on the melliferous plant species. These statistical analyses were performed using STATISTICA software version 7.1.

3. Results

3.1 Diversity of melliferous plants

The vegetation inventories revealed 82 tree and shrub species belonging to 26 plant families (Table SI, Supporting infor-

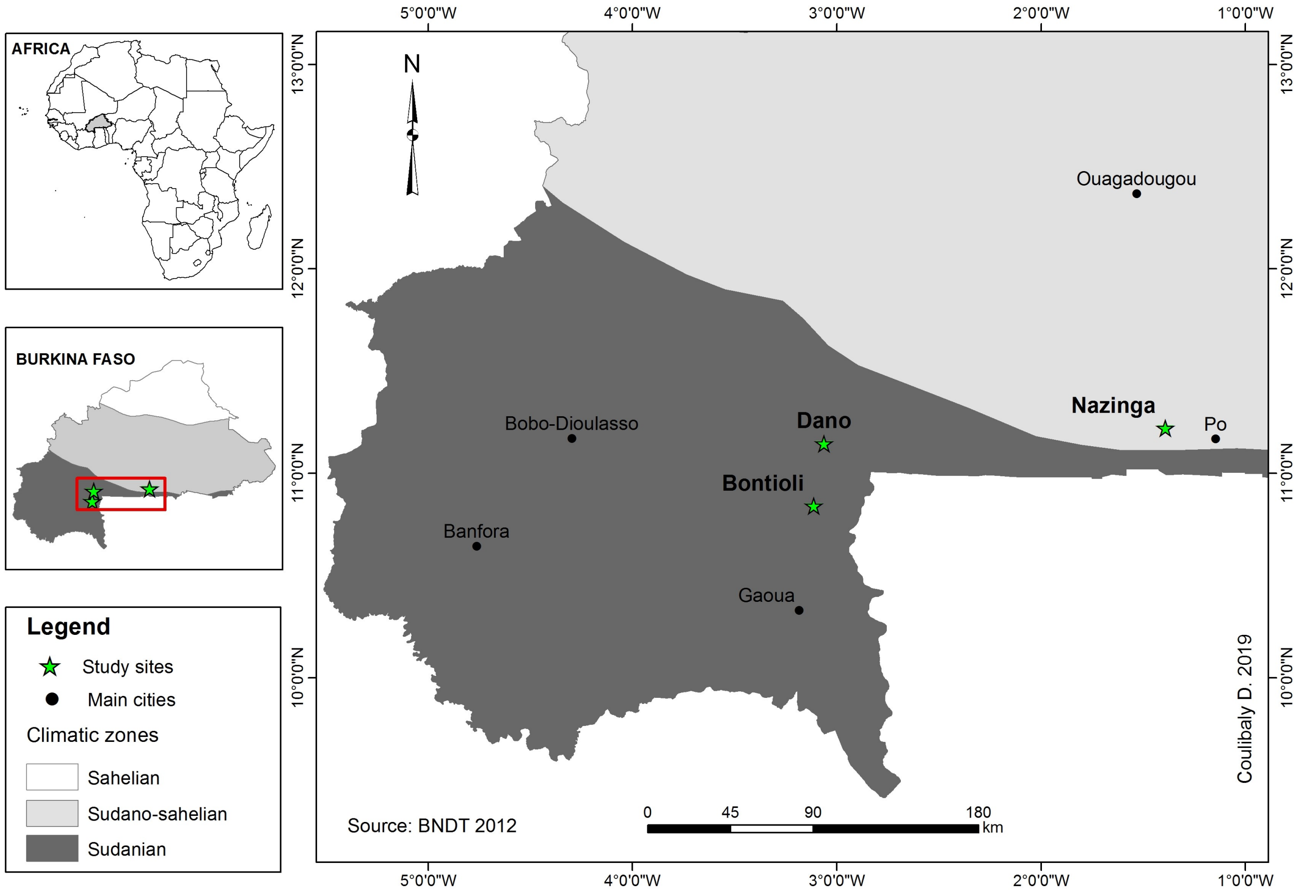

Figure 1. Location of study areas in southern Burkina Faso, West Africa

mation). Combretaceae was the most diverse family with 13 species (15.85%). It was followed by Fabaceae-Mimosoideae (11 species; 13.41%) and Fabaceae-Caesalpinioideae (9 species; 10.98%). A larger number of plant species was recorded at the study sites at Nazinga (52 species) compared to Bontioli (44 species) and Dano (43 species). A total of 53 melliferous plant species were identified, representing 64.63% of all woody plants inventoried in the study areas. These species belong to 38 genera and 21 families (Table 1). Nazinga comprises the highest number of melliferous plant species (44 species), accounting for 83.02% of all recorded species. In Bontioli and Dano, 30 (56.60%) and 24 (45.28%) melliferous plant species were recorded, respectively. Plant families attracting the highest number of bees were Combretaceae (53.85%), Fabaceae-Mimosoideae (9.58%) and Fabaceae-Caesalpinioideae (6.19%). The Combretaceae species such as Combretum glutinosum and C. collinum were most frequently visited by bees (36% of all bee visits for C. glutinosum and 9.87% for C. collinum). Acacia ataxacantha (Fabaceae-Mimosoideae), Flueggea virosa (Phyllanthaceae), Ximenia americana (Olacaceae), Combretum molle (Combretaceae), Pterocarpus erinaceus (Fabaceae-Faboideae) and Lannea microcarpa (Anacardiaceae) were moderately visited. All other melliferous plant species were scarcely visited by bees. The majority of bee visitors was observed during the dry season (on 34 species of visited plants) and at the beginning of the rainy season (on 22 species of visited plants). Visits of ten plant species were observed during the rainy season and of four plant species at the end of the rainy season (Table 1).

3.2 Comparison of the mean number of bee visits

A total of 5686 bee visits were recorded on the 53 melliferous plant species across the three study areas. The mean number of visits differed significantly ($F = 76.90$; $df = 2$; $P = 0.02$) between Nazinga, Bontioli and Dano. The highest mean number of visits was recorded in Nazinga, the lowest in Dano (Table 2).

3.3 Types of food resources collected by bees from plant species

More than half (50.94%) of the assessed melliferous plant species were visited by bees for both nectar and pollen, 32.08% were visited for nectar and 16.98% for pollen only (Table 3). Most of the plants visited by bees only for their pollen were Fabaceae-Mimosoideae species. The majority of Combre-

Table 1. Melliferous plant species recorded at three areas in southern Burkina Faso (B = Bontioli; D = Dano; N = Nazinga). Given are further the plant family, the flowering period (DS = dry season; BRS = beginning of rainy season; RS = rainy season; ERS = end of rainy season), the total number of bee visitors (n) and the intensity of foraging (IF). Plant species were assigned to frequently visited species (> 500 visits in total, IF +++, indicated in bold), moderately visited species (100 – 500 visits, IF ++), and scarcely visited species (< 100 visits, IF +).

Melliferous plants		Flowering period				Study sites (n bees)			Total	IF
Species names	**Family**	DS	BRS	RS	ERS	B	D	N	**(n)**	
Acacia dudgeonii Craib ex Holland	Fabaceae-Mimosoideae		x			0	0	19	19	+
Acacia macrostachya Rchb. ex DC.	Fabaceae-Mimosoideae		x			0	0	13	13	+
Acacia nilotica (L.) Willd. ex Delile	Fabaceae-Mimosoideae			x		0	0	11	11	+
Acacia seyal Delile	Fabaceae-Mimosoideae		x			0	0	22	22	+
Acacia sieberiana DC.	Fabaceae-Mimosoideae	x				0	20	22	42	+
Afzelia africana Sm.	Fabaceae-Caesalpinioideae	x				14	0	3	17	+
Allophylus africanus P.Beauv.	Sapindaceae		x			0	0	16	16	+
Annona senegalensis Pers	Annonaceae	x	x			6	12	28	46	+
Anogeissus leiocarpa (DC.) Guill. & Perr.	Combretaceae		x	x		12	0	0	12	+
Bombax costatum Pellegr. & Vuill	Malvaceae	x			x	0	0	6	6	+
Cassia sieberiana DC.	Fabaceae-Caesalpinioideae	x	x			35	49	4	88	+
Ceiba pentandra (L.) Gaertn.	Malvaceae	x				0	0	6	6	+
Combretum adenogonium Steud. ex A.Rich.	Combretaceae	x	x			2	0	4	6	+
Combretum collinum Fresen.	Combretaceae	x	x			208	99	254	561	+++
Combretum glutinosum Perr. ex DC.	Combretaceae	x				887	205	955	2047	+++
Combretum micranthum G.Don	Combretaceae	x				0	0	6	6	+
Combretum molle R.Br. ex G.Don	Combretaceae	x				33	28	92	153	++
Combretum nigricans Lepr. ex Guill. & Perr.	Combretaceae	x				0	13	66	79	+
Combretum paniculatum Vent.	Combretaceae	x				0	0	48	48	+
Daniellia oliveri (Rolfe) Hutch. & Dalziel	Fabaceae-Caesalpinioideae	x				84	0	0	84	+
Detarium microcarpum Guill. & Perr.	Fabaceae-Caesalpinioideae			x		26	2	24	52	+
Dichrostachys cinerea (L.) Wight & Arn.	Fabaceae-Mimosoideae		x			0	0	26	26	+
Diospyros mespiliformis Hochst. ex A.DC.	Ebenaceae	x				21	8	34	63	+
Entada africana Guill. & Perr.	Fabaceae-Mimosoideae	x				11	0	3	14	+
Feretia apodanthera Delile	Rubiaceae		x			0	9	3	12	+
Flueggea virosa (Roxb. ex Willd.) Voigt	Phyllanthaceae		x	x		0	0	227	227	++
Gardenia erubescens Stapf & Hutch.	Rubiaceae	x	x	x	x	17	6	3	26	+
Gardenia ternifolia Schumach. & Thonn.	Rubiaceae	x	x	x	x	7	17	6	30	+
Grewia bicolor Juss.	Malvaceae		x			0	0	107	107	++
Gymnosporia senegalensis (Lam.) Loes.	Celastraceae	x				42	23	16	81	+
Isoberlinia doka Craib & Stapf	Fabaceae-Caesalpinioideae	x				47	0	32	79	+
Khaya senegalensis (Desr.) A.Juss	Meliaceae	x				0	11	0	11	+
Lannea acida A.Rich	Anacardiaceae	x				49	21	22	92	+
Lannea microcarpa Engl. & K.Krause	Anacardiaceae	x				56	36	25	117	++
Lannea velutina A.Rich.	Anacardiaceae	x				37	18	8	63	+
Mitragyna inermis (Willd.) Kuntze	Rubiaceae			x		22	0	0	22	+
Parkia biglobosa (Jacq.) R.Br. ex G.Don	Fabaceae-Mimosoideae		x			34	14	0	48	+
Philenoptera laxiflora (Guill. & Perr.) Roberty	Fabaceae-Faboideae	x				0	0	31	31	+
Piliostigma thonningii (Schumach.) Milne-Redh.	Fabaceae-Caesalpinioideae		x	x		16	0	10	26	+
Psorospermum senegalense Spach	Clusiaceae	x				0	0	15	15	+
Pterocarpus erinaceus Poir.	Fabaceae-Faboideae	x				0	143	0	143	++
Saba senegalensis (A.DC.) Pichon	Apocynaceae	x				5	0	6	11	+
Sarcocephalus latifolius (Sm.) E.A.Bruce	Rubiaceae		x			0	0	127	127	++
Securidaca longipedunculata Fresen	Polygalaceae	x				0	0	28	28	+
Stereospermum kunthianum Cham.	Bignoniaceae	x				7	0	15	22	+
Tamarindus indica L.	Fabaceae-Caesalpinioideae		x	x		0	0	6	6	+
Tectona grandis L.f.	Lamiaceae		x			88	0	0	88	+
Terminalia laxiflora Engl. & Diels	Combretaceae	x				21	13	18	52	+
Terminalia macroptera Guill. & Perr.	Combretaceae	x	x			46	32	20	98	+
Vitellaria paradoxa C.F.Gaertn.	Sapotaceae	x				16	58	0	74	+
Ximenia americana L.	Olacaceae	x				35	25	129	189	++
Ziziphus mauritiana Lam.	Rhamnaceae			x	x	0	74	0	74	+

Table 2. Comparison of the mean number of bee visits between the three study areas. Different letters indicate significant differences (ANOVA followed by Duncan Test)

Bontioli	Dano	Nazinga
493.5 ± 9.25^b	234 ± 5.96^c	694 ± 11.43^b

taceae were visited for both food resources. Plant species belonging to other families were mostly visited for nectar.

4. Discussion

Melliferous plant species are essential for the conservation of bee species since they constitute their main food resources. Unfortunately, as in many other countries of West Africa, knowledge on melliferous plant species in Burkina Faso is still incomplete. Guinko et al. (1992) conducted the first inventory of melliferous plant species in Ouagadougou and its surroundings, in the centre of Burkina Faso. Their study revealed 159 melliferous plant species 77 of which were woody plants (48 flowering in the dry season and 29 in the rainy season). A similar study carried out in Burkina Faso (Nombré, 2003) reported 96 and 97 melliferous plant species in Garango (province of Boulgou, eastern centre) and Nazinga (province of Nahouri, southern centre), respectively. Among these melliferous plant species, 50 (Garango) and 56 (Nazinga) were woody species; the other plant species were herbaceous.

Our study recorded 53 melliferous woody species belonging to 38 genera and 21 families. These findings are in accordance with the study carried out by Nombré (2003). On the other hand, the number of melliferous plant species recorded during our study was lower than that recorded by Guinko et al. (1992). The lower number of melliferous plant species reported by Nombré and our study when related to the findings of Guinko et al. (1992) may highlight the stronger degradation of the natural landscape in West Africa during the past years, as widely supported by previous studies (Dimobe et al., 2015; Landmann et al., 2010; Leßmeister et al., 2019; Wegmann et al., 2010). However, our study allowed for completing the already existing list with some melliferous plant species such as *Acacia ataxacantha* (Fabaceae-Mimosoideae), *Allophylus africana* (Sapindaceae), *Cassia sieberiana* (Fabaceae-Caesalpinioideae), *Diospyros mespiliformis* (Ebenaceae), *Psorospermum senegalense* (Clusiaceae), and *Tectona grandis* (Lamiaceae). The knowledge of melliferous plants will allow envisaging other studies concerning bees such as pollination of crops.

A study conducted by Coulibaly et al. (2016) on the spatial distribution of bees at the identical study sites plus nearby cotton and sesame fields revealed high bee abundance in Bontioli and Dano. The finding was due to a high abundance of two bee species, namely Hypotrigona gribodoi and Apis mellifera. The stingless bee Hypotrigona gribodoi is generalist in terms of food and nesting resources. Apis mellifera is maintained at these study sites by the common practice of beekeeping. This finding contrasts with the present study that revealed a high abundance of bees in Nazinga compared to Bontioli and Dano. Several reasons could explain this variation: (i) the richness of melliferous plants recorded in Nazinga was greater compared to the two other study areas. This allowed for observing a wide range of plant species and hence more bee individuals in Nazinga; (ii) Bontioli and Dano are characterized by more intense agricultural activity compared to Nazinga. Both former areas are embedded in agriculture-bound landscapes with a heterogeneous small-scale matrix of fields, savanna fragments and home gardens that offer abundant and diverse floral resources to bees. Therefore, in addition to the wild plant species, the proliferation of cultivated plants leads to dispersion of bees between wild plants and cultivated plants during the rainy season. A study carried out by Stein et al. (2018) revealed that an across-habitat spillover of bees (mostly abundant social bee species) from savanna into crop fields was observed during the rainy season when crops are mass-flowering, whereas most savanna plants are not in bloom. Despite disturbance intensification, these findings suggest that wild bee communities can persist in anthropogenic landscapes and that some species even benefitted disproportionally.

West African areas of crop production such as for cotton and sesame may serve as important food resources for bee species in times when resources in the savanna are scarce, and receive at the same time considerable pollination service (Stein et al. 2018). Even during the dry season, in the absence of seasonal crops, the market gardening could also maintain a large community of bees able to visit woody plant species (Tuo et al., 2019). Due to more cultivated plants in Bontioli and Dano, the effect of bee dispersion between cultivated plants and wild plants in these areas could reduce the number of bee visits on woody plant species compared to Nazinga. For this reason, in Nazinga, where farming is moderately practised, bees have no other choice than to settle mostly on wild plants. The hypothesis highlights the role of wild flora in maintaining the abundance of bees, necessary to provide pollination service.

The greatest richness of woody plants was recorded in Nazinga because this area still benefits from natural vegetation undisturbed by human activities. Although Bontioli is a protected area, much of it is used for agricultural activities by the local population; which makes it a moderately disturbed environment. As for the community of Dano with its 50,000 inhabitants, the cutting of wood for local millet beer manufacture (38,000 t of fuelwood extraction per year, Dreyer Foundation Dano, pers. comm.) and for the needs of households added to the destruction of natural vegetation, making it seriously disturbed and poor in plant species diversity. The overall richness in melliferous plants accounted for 64.63% of all assessed woody species. This provides evidence of bees truly selecting between plant species. This selection could be influenced by floral morphology, phenology and general

Table 3. Plant species and types of food resources collected by bees

Melliferous plants	Food resource collected		
Species names	**Pollen**	**Nectar**	**Pollen + nectar**
Acacia ataxacantha DC.	x		
Acacia dudgeonii Craib ex Holland	x		
Acacia macrostachya Rchb. ex DC.	x		
Acacia nilotica (L.) Willd. ex Delile	x		
Acacia seyal Delile	x		
Acacia sieberiana DC.	x		
Afzelia africana Sm.		x	
Allophylus africanus P.Beauv.		x	
Annona senegalensis Pers			x
Anogeissus leiocarpa (DC.) Guill. & Perr.			x
Bombax costatum Pellegr. & Vuill.			x
Cassia sieberiana DC.	x		
Ceiba pentandra (L.) Gaertn.			x
Combretum adenogonium Steud. ex A.Rich.			x
Combretum collinum Fresen.			x
Combretum glutinosum Perr. ex DC.			x
Combretum micranthum G.Don		x	
Combretum molle R.Br. ex G.Don			x
Combretum nigricans Lepr. ex Guill. & Perr.		x	
Combretum paniculatum Vent.			x
Daniellia oliveri (Rolfe) Hutch. & Dalziel		x	
Detarium microcarpum Guill. & Perr.			x
Dichrostachys cinerea (L.) Wight & Arn.		x	
Diospyros mespiliformis Hochst. ex A.DC.	x		
Entada africana Guill. & Perr.			x
Feretia apodanthera Delile			x
Flueggea virosa (Roxb. ex Willd.) Voigt			x
Gardenia erubescens Stapf & Hutch.			x
Gardenia ternifolia Schumach. & Thonn.			x
Grewia bicolor Juss.		x	
Gymnosporia senegalensis (Lam.) Loes.		x	
Isoberlinia doka Craib & Stapf		x	
Khaya senegalensis (Desr.) A.Juss		x	
Lannea acida A.Rich.			x
Lannea microcarpa Engl. & K.Krause		x	
Lannea velutina A.Rich.		x	
Mitragyna inermis (Willd.) Kuntze			x
Parkia biglobosa (Jacq.) R.Br. ex G.Don			x
Philenoptera laxiflora (Guill. & Perr.) Roberty		x	
Piliostigma thonningii (Schumach.) Milne-Redh.	x		
Psorospermum senegalense Spach		x	
Pterocarpus erinaceus Poir.			x
Saba senegalensis (A.DC.) Pichon			x
Sarcocephalus latifolius (Sm.) E.A.Bruce			x
Securidaca longipedunculata Fresen		x	
Stereospermum kunthianum Cham.		x	
Tamarindus indica L.			x
Tectona grandis L.f.			x
Terminalia laxiflora Engl. & Diels			x
Terminalia macroptera Guill. & Perr.			x
Vitellaria paradoxa C.F.Gaertn.			x
Ximenia americana L.		x	
Ziziphus mauritiana Lam.			x

floristic composition (Lobreau-Callen and Damblon, 1994).

The consideration of flowering periods is important when studying the melliferous potential of plant species. They indicate the periods of nutrient availability for bees in each area since individuals of a certain plant species do not necessarily flower simultaneously at different sites (Guinko 1984). Flowering periods may vary in time, space and from year to year, and, depending on humidity conditions, individuals may flower in small quantities (Food and Agricultural Industries Service, 1986). In our study, the majority of melliferous plant species were flowering in the dry season and early rainy season. Abundantly flowering species belonged to the Fabaceae-Faboideae and Fabaceae-Mimosoideae and were mainly visited by leaf-cutting bees (Megachilidae). Despite the flowering intensity of woody plant species in the dry season, nutrient availability for bees was observed almost throughout the year. These results are in accordance with the work of Laflèche (1981) who observed a variation in the flowering periods of melliferous plant species. Similar observations have been made in the Sudano-Guinean area of central-western Benin (Yédomonhan et al., 2009). The availability of melliferous plant species throughout the year constitutes an important asset because it allows continuous foraging activity and therefore it is not compulsory to feed bees as is done in Europe during winter (Iritie et al., 2014).

Across all families, the Combretaceae were most important as food plants for bees. Similar findings were reported by Guinko (1984) in Burkina Faso. This result could also be explained by the abundance and dominance of Combretaceae in the study areas. In fact, in terms of plant family diversity, the predominance of Leguminosae, Rubiaceae and especially Combretaceae is a main characteristic of natural plant formations in Sudano-Guinean and Sudanian areas (Aloma, 200; Nombré, 2003; Sawadogo, 1993). The choice of Combretaceae species by many bees could also be due to the long flowering time of these species. In addition to being one of the most dominant families in the areas, Combretaceae may offer a more significant amount of nectar and pollen compared to other families.

The results of this study showed that more than half of the melliferous plant species were visited for both nectar and pollen, while the other species were visited either for nectar or for pollen. These findings contrast to those of Dongock et al. (2004) who indicated in a study carried out in the Sudano-Guinean highland area of western Cameroon that 41% of plants were visited by bees for pollen and 23% for nectar. Similarly, according to Nombré (2003), some flowering species were melliferous in the Sudanian area of Burkina Faso, whereas they were not in a study carried out in the Sudano-Guinean area in west-central Benin. These are, for example, *Piliostigma thonningii*, *Cochlospermum planchoni*, *Gardenia erubescens*, *Gardenia ternifolia*, *Pterocarpus erinaceus*, *Wissadula amplissima*, etc. This confirms the idea of De Layens and Bonnier (1991) that a species can be melliferous in one area and not in another area. The aforementioned taxa are, for the most part, visited in the Sudanian area for their nectar (Nombré, 2003), but the production of nectar by the plants would depend on several parameters. According to many authors (Crane, 1990; De Layens and Bonnier, 1991; Fluri et al., 2001a,b; O'Toole and Raw, 2004), the amount of produced nectar depends, among other things, on climate, soil and plant vigour.

5. Conclusion

This study contributed to filling scientific knowledge gaps on melliferous tree woody in the Sudanian region of West Africa. The findings revealed a high diversity of savanna woody plant species used by bees as resources of pollen and nectar. Species of Combretaceae were the most attractive for bees compared to other families. The melliferous plant species were flowering throughout the year in the study areas, although many more species flowered in the dry season. This is relevant for the development of beekeeping activities and for setting up agricultural itineraries. By controlling the food preferences (host plants) of each bee species, it could be possible to direct the choice of melliferous plant species in nearby agricultural areas.

However, to optimize data, it would be interesting to extend this study with an inventory of herbaceous plant species and their bee visitors. Furthermore "bee-friendly plants" are defined by the quantity of food they produce and the visitation rates of adult insects foraging for nectar. However, it is pollen nutritional quality that enables proper larval development of bees, affecting their populations. Not all plants produce pollen that satisfies the nutritional requirements of bee larvae, and we lack an understanding of how different plant pollens impact bee nutritional demands (Filipiak, 2019). Hence, further studies should assess the quantity and quality of food resources provided.

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References

Aizen, M. A. and Harder, L. D. (2009). The global stock of domesticated honey bees is growing slower than agricultural demand for pollination. *Current Biology*, 19(11):915–918, doi:10.1016/j.cub.2009.03.071.

Aloma, S. (200). *Etude des facteurs de production de miel dans deux zones écologiques différentes au sud du Togo: les sites d'Aképé et d'Agotimé-Nyitoé*. Mémoire de DEA. University of Benin, Cotonou.

Barker, R. J., Lehner, Y., and Kunzman, M. R. (1980). Pesticides and honey bees: nectar and pollen contamination in alfalfa treated with dimethoate. *Archives of Environmental Contamination and Toxicology*, 9(2):125–133, doi:10.1007/BF01055368.

Biesmeijer, J. C. (2006). Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands. *Science*, 313(5785):351–354, doi:10.1126/science.1127863.

Bradbear, N. (2011). *Le rôle des abeilles dans le développement rural : manuel sur la récolte, la transformation et la commercialisation des produits et services dérivés des abeilles*. Organisation des Nations Unies pour l'alimentation et l'agriculture, Rome.

Buchmann, S. L. and Nabhan, G. P. (1996). *The forgotten pollinators*. Island Press/Shearwater Books, Washington, DC.

Chaplin-Kramer, R., Dombeck, E., Gerber, J., Knuth, K. A., Mueller, N. D., Mueller, M., Ziv, G., and Klein, A.-M. (2014). Global malnutrition overlaps with pollinator-dependent micronutrient production. *Proceedings. Biological sciences*, 281(1794):20141799, doi:10.1098/rspb.2014.1799.

Coulibaly, D., Pauly, A., Konate, S., Linsenmair, E. K., and Stein, K. (2016). Spatial and seasonal distribution of bee pollinator species in a Sudanese agro-ecological system in Burkina Faso, West Africa. *Entomology and Applied Science Letters*, 3(4):1–11.

Crane, E. (1990). *Bees and beekeeping: Science, practice, and world resources*. Comstock Pub. Associates, Ithaca, N.Y., 1. publ edition.

De Layens, G. and Bonnier, G. (1991). *Cours complet d'apiculture et conduite d'un rucher isolé*. Collection des nouvelles flores. Belin, Paris.

Dias, B. S. F., Raw, A., and Fonseca, I. V. L. (1999). International pollinators initiative: the São Paulo declaration on pollinators: Report on the recommendations of the workshop on the conservation and sustainable use of pollinators in agriculture with emphasis on bees.

Dimobe, K., Goetze, D., Ouédraogo, A., Forkuor, G., Wala, K., Porembski, S., and Thiombiano, A. (2017). Spatio-temporal dynamics in land use and habitat fragmentation within a protected area dedicated to tourism in a Sudanian savanna of West Africa. *Journal of Landscape Ecology*, 10(1):75–95, doi:10.1515/jlecol-2017-0011.

Dimobe, K., Ouédraogo, A., Soma, S., Goetze, D., Porembski, S., and Thiombiano, A. (2015). Identification of driving factors of land degradation and deforestation in the wildlife reserve of Bontioli (Burkina Faso, West Africa). *Global Ecology and Conservation*, 4:559–571, doi:10.1016/j.gecco.2015.10.006.

Dongock, N., Foko, J., Pinta, J. Y., Ngouo, L. V., Tchoumboue, J., and Zango P. (2004). Inventaire et identification des plantes mellifères de la zone soudano guinéenne d'altitude de l'ouest Cameroun. *Tropicultura*, 22(3):139–145.

Filipiak, M. (2019). Key pollen host plants provide balanced diets for wild bee larvae: A lesson for planting flower strips and hedgerows. *Journal of Applied Ecology*, 56(6):1410–1418, doi:10.1111/1365-2664.13383.

Fluri, P., Pickhardt, A., Cottier, V., and Charrière, J. D. (2001a). La pollinisation des plantes à fleurs par les abeilles:

Biologie, Ecologie, Economie 2ème partie. *L'Abeille de France et l'Apiculteur*, 872:335–340.

Fluri, P., Pickhardt, A., Cottier, V., and Charrière, J. D. (2001b). La pollinisation des plantes à fleurs par les abeilles: Biologie, écologie, économie 1ère partie. *L'Abeille de France et l'Apiculteur*, 871:287–296.

Food and Agricultural Industries Service (1986). *Tropical and sub-tropical apiculture*, volume 68 of *FAO agricultural services bulletin*. Rome.

Forrest, J. R. K., Thorp, R. W., Kremen, C., and Williams, N. M. (2015). Contrasting patterns in species and functional-trait diversity of bees in an agricultural landscape. *Journal of Applied Ecology*, 52(3):706–715, doi:10.1111/1365-2664.12433.

Garibaldi, L. A., Carvalheiro, L. G., Vaissiere, B. E., Gemmill-Herren, B., Hipolito, J., Freitas, B. M., Ngo, H. T., Azzu, N., Saez, A., Astrom, J., An, J., Blochtein, B., Buchori, D., Garcia, F. J. C., Oliveira da Silva, F., Devkota, K., Ribeiro, M. d. F., Freitas, L., Gaglianone, M. C., Goss, M., Irshad, M., Kasina, M., Filho, A. J. S. P., Kiill, L. H. P., Kwapong, P., Parra, G. N., Pires, C., Pires, V., Rawal, R. S., Rizali, A., Saraiva, A. M., Veldtman, R., Viana, B. F., Witter, S., and Zhang, H. (2016). Mutually beneficial pollinator diversity and crop yield outcomes in small and large farms. *Science*, 351(6271):388–391, doi:10.1126/science.aac7287.

Godfray, H. C. J., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., Pretty, J., Robinson, S., Thomas, S. M., and Toulmin, C. (2010). Food Security: The Challenge of Feeding 9 Billion People. *Science*, 327(5967):812–818, doi:10.1126/science.1185383.

Grote, R., Lehmann, E., Brümmer, C., Brüggemann, N., Szarzynski, J., and Kunstmann, H. (2009). Modelling and observation of biosphere–atmosphere interactions in natural savannah in Burkina Faso, West Africa. *Physics and Chemistry of the Earth, Parts A/B/C*, 34(4-5):251–260, doi:10.1016/j.pce.2008.05.003.

Guinko, S. (1984). *Végétation de la Haute Volta (Burkina Faso), tome I*. Thèse de Doctorat d'Etat, Université Bordeaux III, France, Bordeaux.

Guinko, S., Sawadogo, M., and Guenda, W. (1992). Etudes des plantes mellifères de saison pluvieuse et quelques aspects du comportement des abeilles dans la région de Ouagadougou, Burkina Faso. *Etudes flor. Veg. Burkina Faso*, 1(2):27–46.

Hema, E. M., Barnes, R. F. W., and Guenda, W. (2011). Distribution of savannah elephants (Loxodonta africana africana Blumenbach 1797) within Nazinga game ranch, Southern Burkina Faso. *African Journal of Ecology*, 49(2):141–149, doi:10.1111/j.1365-2028.2010.01239.x.

Herrero, M., Thornton, P. K., Notenbaert, A. M., Wood, S., Msangi, S., Freeman, H. A., Bossio, D., Dixon, J., Peters, M., van de Steeg, J., Lynam, J., Parthasarathy Rao, P., Macmillan, S., Gerard, B., McDermott, J., Seré, C., and Rosegrant, M. (2010). Smart investments in sustainable food production: revisiting mixed crop-livestock systems. *Science*, 327(5967):822–825, doi:10.1126/science.1183725.

Iritie, B. M., Wandan, E. N., Paraiso, A. A., Fantodji, A., and Gbomene, L. L. (2014). Identification des plantes mellifères de la zone agroforestière de l'école supérieure agronomique de Yamoussoukro (Côte d'Ivoire). *European Scientific Journal*, 10(30):444–458.

Ki, G. (1994). *Etude socio-économique de la gestion de Parkia biglobosa (Jacq) R.Br. ex G.Don. (Néré) au Burkina Faso*. Université de Ouagadougou, Institut du Développement Rural, Ouagadougou, Burkina Faso.

Klein, A.-M., Vaissière, B. E., Cane, J. H., Steffan-Dewenter, I., Cunningham, S. A., Kremen, C., and Tscharntke, T. (2007). Importance of pollinators in changing landscapes for world crops. *Proceedings. Biological sciences*, 274(1608):303–313, doi:10.1098/rspb.2006.3721.

Laflèche, B. (1981). *Les abeilles: Guide pratique de l'apiculteur amateur*. Solarama. Solar, Paris (France).

Landmann, T., Machwitz, M., Schmidt, M., Dech, S., and Vlek, P. L. G. (2010). Land cover change in West Africa as observed by satellite remote sensing / Current state of Biodiversity in West Africa. In Thiombiano, A., Kampmann, D., Thiombiano, A., and Kampmann, D., editors, *Atlas de la biodiversité de l'Afrique de l'Ouest*, pages 92–97. Bundesministerium für Bildung und Forschung, Ouagadougou & Frankfurt/Main.

Leßmeister, A., Bernhardt-Römermann, M., Schumann, K., Thiombiano, A., Wittig, R., and Hahn, K. (2019). Vegetation changes over the past two decades in a West African savanna ecosystem. *Applied Vegetation Science*, 22(2):230–242, doi:10.1111/avsc.12428.

Lobreau-Callen, D. and Damblon, F. (1994). Spectre pollinique des miels de l'abeille *Apis mellifera* L. (Hymenoptera, Apidae) et Zones de Végétations en Afrique Occidental Tropicale et Méditerranéenne. *Grana*, 33(4-5):245–253, doi:10.1080/00173139409429006.

MSP (2010). *Meteorological Station of Pô, Burkina Faso*. Direction de la Météorologie du Burkina Faso, Ouagadougou, Burkina Faso.

Nombré (2003). *Etude des potentialités mellifères de deux zones du Burkina Faso: Garango (Province du Boulgou) et Nazinga (Province du Nahouri)*. Doctorat unique spécialité, Université de Ouagadougou, Burkina Faso, Ouagadougou, Burkina Faso.

Ollerton, J., Erenler, H., Edwards, M., and Crockett, R. (2014). Extinctions of aculeate pollinators in Britain and the role of large-scale agricultural changes. *Science*, 346(6215):1360–1362, doi:10.1126/science.1257259.

Ollerton, J., Johnson, S. D., and Hingston, A. B. (2006). Geographical variation in diversity and specificity of pollination systems. In Waser, N. M. and Ollerton, J., editors, *Plant-pollinator interactions*, pages 283–308. Univ. of Chicago Press, Chicago.

O'Toole, C. and Raw, A. (2004). *Bees of the world*. Facts on file, New York.

Ræbild, A., Hansen, U. B., and Kambou, S. (2012). Regeneration of *Vitellaria paradoxa* and *Parkia biglobosa* in a parkland in Southern Burkina Faso. *Agroforestry Systems*, 85(3):443–453, doi:10.1007/s10457-011-9397-0.

Renner, S. S. (1998). Dynamics of tropical communities. In D. M. Newbery, H. H. T. Prins & N. D. Brown, editor, *Dynamics of tropical communities: Effects of habitat fragmentation of plant pollinator interactions in the tropics.*, pages 339–360. Blackwell Science, London, UK, London, UK.

Şaul, M., Ouadba, J.-M., and Bognounou, O. (2003). The wild vegetation cover of western Burkina Faso: Colonial policy and post-colonial development. In Bassett, T. J. and Crummey, D., editors, *African savannas*, pages 121–160. Currey, Oxford.

Sawadogo, M. (1993). *Contribution à l'étude du cycle des miellées et du cycle biologique annuel des colonies d'abeilles Apis mellifera adansonii Latr. à l'ouest du Burkina Faso.* Thèse de Doctorat, Université de Ouagadougou, Burkina Faso, Ouagadougou, Burkina Faso.

Stein, K., Stenchly, K., Coulibaly, D., Pauly, A., Dimobe, K., Steffan-Dewenter, I., Konaté, S., Goetze, D., Porembski, S., and Linsenmair, K. E. (2018). Impact of human disturbance on bee pollinator communities in savanna and agricultural sites in Burkina Faso, West Africa. *Ecology and evolution*, 8(13):6827–6838, doi:10.1002/ece3.4197.

Steward, P. R., Shackelford, G., Carvalheiro, L. G., Benton, T. G., Garibaldi, L. A., and Sait, S. M. (2014). Pollination and biological control research: are we neglecting two billion smallholders. *Agriculture & Food Security*, 3(1), doi:10.1186/2048-7010-3-5.

Thompson, I. D., Okabe, K., Parrotta, J. A., Brockerhoff, E., Jactel, H., Forrester, D. I., and Taki, H. (2014). Biodiversity and ecosystem services: lessons from nature to improve management of planted forests for REDD-plus. *Biodiversity and Conservation*, 23(10):2613–2635, doi:10.1007/s10531-014-0736-0.

Tia, L. (2008). *Modeling of vegetation dynamics and its contribution to the water balance in semi-arid lands of west Africa*, volume No. 58 of *Ecology and development series*. ZEF, Bonn.

Tittonell, P. and Giller, K. E. (2013). When yield gaps are poverty traps: The paradigm of ecological intensification in African smallholder agriculture. *Field Crops Research*, 143:76–90, doi:10.1016/j.fcr.2012.10.007.

Tuo, Y., Coulibaly, D., Kone, M., Yao, G. F. K., and Koua, K. H. (2019). Contributory study to the assessment of bee's fauna in market gardening areas in northern Ivory Coast (case of Korhogo). *Journal of Research in Ecology*, 7(2):2534–2545.

Wegmann, M., Machwitz, M., Schmidt, M., and Dech, S. (2010). Fragmentation of rain forest-endanging biodiversity. In Thiombiano, A., Kampmann, D., Thiombiano, A., and Kampmann, D., editors, *Atlas de la biodiversité de l'Afrique de l'Ouest*, pages 86–91. Bundesministerium für Bildung und Forschung, Ouagadougou & Frankfurt/Main.

White, F. (1983). *The vegetation of Africa: A descriptive memoir to accompany the Unesco/ AETFAT/UNSO vegetation map of Africa*, volume 20 of *Natural resources research*. Unesco, Paris.

Yédomonhan, H., Tossou, M. G., Akeogninou, A., Demenou, B. B., and Traore, D. (2009). Diversité des plantes mellifères de la zone soudano-guinéenne: cas de l'arrondissement de Manigri (Centre-Ouest du Bénin). *International Journal of Biological and Chemical Sciences*, 3(2), doi:10.4314/ijbcs.v3i2.44514.

Table SI. Woody plants inventoried in the three study areas

Order	Species	Families	Order	Species	Families
1	*Acacia ataxacantha* DC.	Fabaceae-Mimosoideae	42	*Grewia bicolor* Juss.	Malvaceae
2	*Acacia dudgeonii* Craib ex Holland	Fabaceae-Mimosoideae	43	*Gymnosporia senegalensis* (Lam.) Loes.	Celastraceae
3	*Acacia macrostachy*a Rchb. ex DC.	Fabaceae-Mimosoideae	44	*Quassia undulata* (Guill. & Perr.) F.Dietr.	Simaroubaceae
4	*Acacia nilotica* (L.) Willd. ex Delile	Fabaceae-Mimosoideae	45	*Hexalobus monopetalus* (A.Rich.) Engl. & Diels	Annonaceae
5	*Acacia seyal* Delile	Fabaceae-Mimosoideae	46	*Isoberlinia doka* Craib & Stapf	Fabaceae-Caesalpinioideae
6	*Acacia sieberiana* DC.	Fabaceae-Mimosoideae	47	*Khaya senegalensis* (Desr.) A.Juss	Meliaceae
7	*Afzelia africana* Sm.	Fabaceae-Caesalpinioideae	48	*Lannea acida* A.Rich	Anacardiaceae
8	*Albizia chevalieri* Harms	Fabaceae-Mimosoideae	49	*Lannea microcarpa* Engl. & K.Krause	Anacardiaceae
9	*Allophylus africanus* Beauv.	Sapindaceae	50	*Lannea velutina* A.Rich.	Anacardiaceae
10	*Annona senegalensis* Pers	Annonaceae	51	*Mitragyna inermis* (Willd.) Kuntze	Rubiaceae
11	*Anogeissus leiocarpa* (DC.) Guill. & Perr.	Combretaceae	52	*Ozoroa obovata* (Oliv.) R.Fern. & A.Fern.	Anacardiaceae
12	*Azadirachta indica* A.Juss. [cult.]	Meliaceae	53	*Parkia biglobosa* (Jacq.) R.Br. ex G.Don	Fabaceae-Mimosoideae
13	*Balanites aegyptiaca* (L.) Delile	Zygophyllaceae	54	*Pericopsis laxiflora* (Benth.) Meeuwen	Fabaceae-Faboideae
14	*Bombax costatum* Pellegr. & Vuill	Malvaceae	55	*Philenoptera laxiflora* (Guill. & Perr.) Roberty	Fabaceae-Faboideae
15	*Bridelia ferruginea* Benth.	Phyllanthaceae	56	*Piliostigma thonningii* (Schumach.) Milne-Redh.	Fabaceae-Caesalpinioideae
16	*Bridelia scleroneura* Müll. Arg.	Phyllanthaceae	57	*Prosopis africana* (Guill. & Perr.) Taub.	Fabaceae-Mimosoideae
17	*Burkea africana* Hook.	Fabaceae-Caesalpinioideae	58	*Pseudocedrela kotschyi* (Schweinf.) Harms	Meliaceae
18	*Cassia sieberiana* DC.	Fabaceae-Caesalpinioideae	59	*Psorospermum senegalense* Spach	Hypericaceae
19	*Cassia singueana* Delile	Fabaceae-Caesalpinioideae	60	*Pteleopsis suberosa* Engl. & Diels	Combretaceae
20	*Ceiba pentendra* (L.) Gaertn.	Malvaceae	61	*Pterocarpus erinaceus* Poir.	Fabaceae-Faboideae
21	*Combretum aculeatum* Vent.	Combretaceae	62	*Saba senegalensis* (A.DC.) Pichon	Apocynaceae
22	*Combretum adenogonium* Steud. ex A.Rich.	Combretaceae	63	*Sarcocephalus latifolius* (Sm.) E.A.Bruce	Rubiaceae
23	*Combretum collinum* Fresen.	Combretaceae	64	*Sclerocarya birrea* (A.Rich.) Hochst.	Anacardiaceae
24	*Combretum glutinosum* Perr. ex DC.	Combretaceae	65	*Securidaca longipedunculata* Fresen	Polygalaceae
25	*Combretum micranthum* G.Don	Combretaceae	66	*Sterculia setigera* Delile	Malvaceae
26	*Combretum molle* R.Br. ex G.Don	Combretaceae	67	*Stereospermum kunthianum* Cham.	Bignoniaceae
27	*Combretum nigricans* Lepr. ex Guill. & Perr.	Combretaceae	68	*Strychnos innocua* Delile	Loganiaceae
28	*Combretum paniculatum* Vent.	Combretaceae	69	*Strychnos spinosa* Lam.	Loganiaceae
29	*Crossopteryx febrifuga* (Afzel. ex G.Don) Benth.	Rubiaceae	70	*Swartzia madagascariensis* = Bobgunnia madagascariensis (Desv.) J.H.Kirkbr. & Wiersema	Fabaceae-Faboideae
30	*Daniellia oliveri* (Rolfe) Hutch. & Dalziel	Fabaceae-Caesalpinioideae	71	*Tamarindus indica* L.	Fabaceae-Caesalpinioideae
31	*Detarium microcarpum* Guill. & Perr.	Fabaceae-Caesalpinioideae	72	*Tectona grandis* L.f.	Lamiaceae
32	*Dichrostachys cinerea* (L.) Wight & Arn.	Fabaceae-Mimosoideae	73	*Terminalia avicennioides* Guill. & Perr.	Combretaceae
33	*Diospyros mespiliformis* Hochst. ex A.DC.	Ebenaceae	74	*Terminalia laxiflora* Engl. & Diels	Combretaceae
34	*Entada africana* Guill. & Perr.	Fabaceae-Mimosoideae	75	*Terminalia macroptera* Guill. & Perr.	Combretaceae
35	*Feretia apodanthera* Delile	Rubiaceae	76	*Trichilia emetica* Vahl	Meliaceae
36	*Ficus abutilifolia* (Miq.) Miq.	Moraceae	77	*Vitellaria paradoxa* C.F.Gaertn.	Sapotaceae
37	*Ficus thonningii* Blume	Moraceae	78	*Xeroderris stuhlmannii* (Taub.) Mendonça & E.C.Sousa	Fabaceae-Faboideae
38	*Flueggea virosa* (Roxb. ex Willd.) Voigt	Phyllanthaceae	79	*Ximenia americana* L.	Olacaceae
39	*Gardenia aqualla* Stapf & Hutch.	Rubiaceae	80	*Zanthoxylum zanthoxyloides* (Lam.) Zepern. & Timler	Rutaceae
40	*Gardenia erubescens* Stapf & Hutch.	Rubiaceae	81	*Ziziphus mauritiana* Lam.	Rhamnaceae
41	*Gardenia ternifolia* Schumach. & Thonn.	Rubiaceae	82	*Ziziphus mucronata* Willd.	Rhamnaceae