



A commented checklist of woody plants in the Northern Republic of Congo

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Aim – This paper aims to provide the first exhaustive list of woody species present in the northern part of the Republic of Congo, describing the vegetation types, characterizing the ligneous forest stands and explaining the distribution range of characteristic species.

Location – The 1.23 million ha of the logging concession of ‘Congolaise Industrielle des Bois’, situated in the North of the Republic of Congo (1.41°N 16.32°E), were prospected during six years. The study area is bordered by the Sangha River to the west and by the Likwala-aux-Herbes swamps to the east.

Methods – The checklist, given as an electronic appendix, documents 702 woody species. Each species is annotated with the following headings when the information is known: scientific, pilot and local names, life-form, preferential habitat, distribution, seed dispersal type, human use, abundance and foliage phenology. Field observations have been augmented with existing bibliography.

Results – A total of 392 genera and 79 families are presented. *Ficus* is the largest genus with seventeen species. 73% of taxa are endemic to the Guineo-Congolian Region centre. The sarcochorous functional diaspore type represents 71%. Eleven percent of the species are anemochorous and are mostly emergent trees. Forty-four species newly recorded for the Republic of Congo are especially commented.

Main conclusions – Terra firma forests are characterized by deciduous, light-demanding and wind-dispersed emergent tree species. Evergreen stands are mainly found at the confluence of the Sangha River and Likwala-aux-Herbes swamps. This forest could be regarded as equivalent to the other interfluvial forest blocks of the Major Fluvial Refuge in the Congo basin.

Key words – Woody species, Congo, Sangha River Interval, Likwala-aux-Herbes, refuge, endemism, functional diaspore type.

INTRODUCTION

The northern part of the Republic of Congo is by far the largest forest area of the country (fig. 1) but few studies are available on its floristic composition. Considered by White (1983) as a complex mosaic of semi-deciduous moist tropical forest, it includes the largest areas of open canopy Marantaceae forests (de Namur 1990).

Northern Congo vegetation is reported to have some similarities with the SE Cameroon (Letouzey 1968), SW of Central African Republic (Yongo & de Foucault 2001, Brncic 2002), NE of Gabon (Dowsett-Lemaire 1996), the Congo basin part of the Democratic Republic of Congo (Lebrun & Gilbert 1954, Evrard 1968, Lubini & Mandango 1981, Mosango & Lejoly 1990, Lubini & Kusehuluka 1991) and with the forests of West Africa (Gibert 1984).

Previous botanical studies in Congo Republic were conducted by Sita & Moutsamboté (1988) who published the Catalogue of Plants from Congo. They explored especially the centre and the south of the country. Champluvier & Dowsett-Lemaire (1999) supplemented this catalogue with 84 vascular plant species, collected in the Odzala National Park in NW of the country. A further 64 species (a number of them from Odzala) were added by Lachenaud (2009). Other studies deal with the Odzala National Park (Hecketsweiler et al. 1991, Dowsett-Lemaire 1996, Lejoly 1996, Kouka 2000, Van Asbroeck et al. 2000).

Moreover, Bouquet (1966) also provided the first inventory of medicinal plants in the country. Next to our study zone, Harris (2002) raised a list of 1090 vascular plant species in the Dzanga-Sangha Reserve located in the south-west of the

Central African Republic. Harris & Wortley (2008) have published an identification manual focusing on 522 tree species of the Sangha Tri-national Landscape including Noua-bale-Ndoki National Park in the northern Republic of Congo.

About 60% of the Northern Congo is under a logging concession due to the high abundance of valuable timber species, mainly belonging to the Meliaceae family (Fickinger 1992).

The objectives of this study were: (1) to provide the first exhaustive list of woody species of a floristically unknown area located in northern Republic of Congo (CIB's (Congolaise Industrielle des Bois) logging concession, 1.23 million ha), (2) to describe the species newly recorded for the country and (3) to characterize the ligneous stand.

MATERIAL AND METHODS

Study area

In the North of the Republic of Congo, the study site is located at the north-western limit of the Congo Basin (0.5–2.5°N 16–17.5°E), which is a wide and flat continental depression. Altitudes are lower than surrounding districts, reaching 350 m on average. Several forest types occur, swamp and swampy clearings covering a third of the area (Whitmore 1997). The site is bordered to the west by the Sangha River and to the east by the Likwala-aux-Herbes swamps, one of the biggest swamps in the world (Vandeweghe 2004). Lake Tele lies in the centre of the swamps. Savannas are absent in the study area and the current human population is concentrated at the boundaries of the area (fig. 1).

The three Forest Management Units (FMU) of the logging concession of the CIB Company totalling 1.23 million ha were prospected. These FMU's are located east of the Sangha River. The Loundoungou–Toukoulaka FMU is in the Likwala department, Pokola and Kobo FMU are in the Sangha department. Altitudes range between 330 and 460 m a.s.l.

The northern Congo climate is equatorial (Vennetier 1963). The average monthly temperatures fluctuate slightly around 25°C, with a minimum in August and a maximum in March. Day temperature differences are low (below 10°C). The mean annual relative humidity is 85% with a minimum in February and a maximum in October (Paget & Desmet 2003). The average annual precipitation in Ouesso (1.616°N 16.318°E) is between 1547 mm (1945–1965) and 1685 mm (1961–1990, from ASECNA in Paget & Desmet 2003). The rainfall pattern shows two peaks, one in May and one in September–October. A distinct decrease of rainfall from December to February and a little drier period centred in July are perceived.

Precambrian schistoquartzitic Complex (series of Nola) occurs around the Kobo site (Vennetier 1963). The extreme north of Kobo and the west of Loundoungou FMU are composed of Mesozoic sandstones (SCETAGRI 1983). Apart from these small areas, the site is mainly covered by Quaternary alluvial deposits (Schwartz & Lanfranchi 1993; fig. 1).

Data collection

Field work was carried out from October 2003 to March 2009. The collecting of botanical samples targeted the woody species. A total of 714 voucher specimens were deposited in the Herbarium (BR) of the National Botanic Garden of Belgium. Of these, 212 are botanical samples and 502 other are botanical pictures; 703 were collected by J.-F. Gillet, seven by E. Vautravers and four by G. Kossa Kossa.

The main publications consulted to identify plants and to get information about their distribution and other ecological traits were the 'Flore du Gabon' (1961–1992), 'Flore du Congo belge et Ruanda-Urundi' (1948–1963) and Aubréville (1959). This bibliographical information was consolidated by the examination of herbarium material at BR.

Under each listed species (electronic appendix) the following headings are used. If the information is not available, the corresponding category is not mentioned.

Scientific name and synonymy – The accepted name is mentioned with the species authority according to Brummitt & Powell (1992). Name status is derived from the African Plants database of 'Conservatoire et Jardin Botaniques de la Ville de Genève'. Synonyms (Syn.) are given in case confusion might arise. Subspecific name (subsp.) or variety name (var.) is also given if the determination has been made to these taxonomic levels.

If the genus is identified and the species determination is uncertain, 'cf.' is indicated before the species name. If the species is not known, 'sp.' is used. If the complete name of the species is in doubt, 'vel sp. aff.' is added after the scientific name. In these cases, more complete samples (fertile) are needed in order to confirm the identifications.

Pilot name (PN) – The pilot name is commonly used in forest or management inventories. It is a commercial name in French, a local or common name of different ethnic groups (Bantu people, mostly Bakwele) or simply the genus of the scientific name. It changes with the region and exists mainly for large and middle-sized trees.

Local name (LN) – The local name originates from the Aka dialect called Mbendjele (Bahuchet 2006), a semi-nomadic population (pygmies). Woody species having the same Mbendjele name have botanical similarities: same genus or family. Most plants have a Mbendjele name and are used traditionally (medicines, food, construction, magico-religious...). The oral tradition is the only way to perpetuate their extensive knowledge of the forest from generation to generation. To write the Mbendjele names, the International Phonetic Alphabet is used (Thomas & Bahuchet 1991), but with no tonic stress.

Life-form (LF) – The woody life-forms are divided into ten categories (table 1, inspired from Letouzey 1982). The diameter is measured at 1.3 m height or immediately above the buttresses or other trunk deformations (dbh: diameter at breast height).

Preferential habitat (PH) – The different vegetation types described below are taken into account at different levels to characterize the preferential habitat of the woody species encountered.

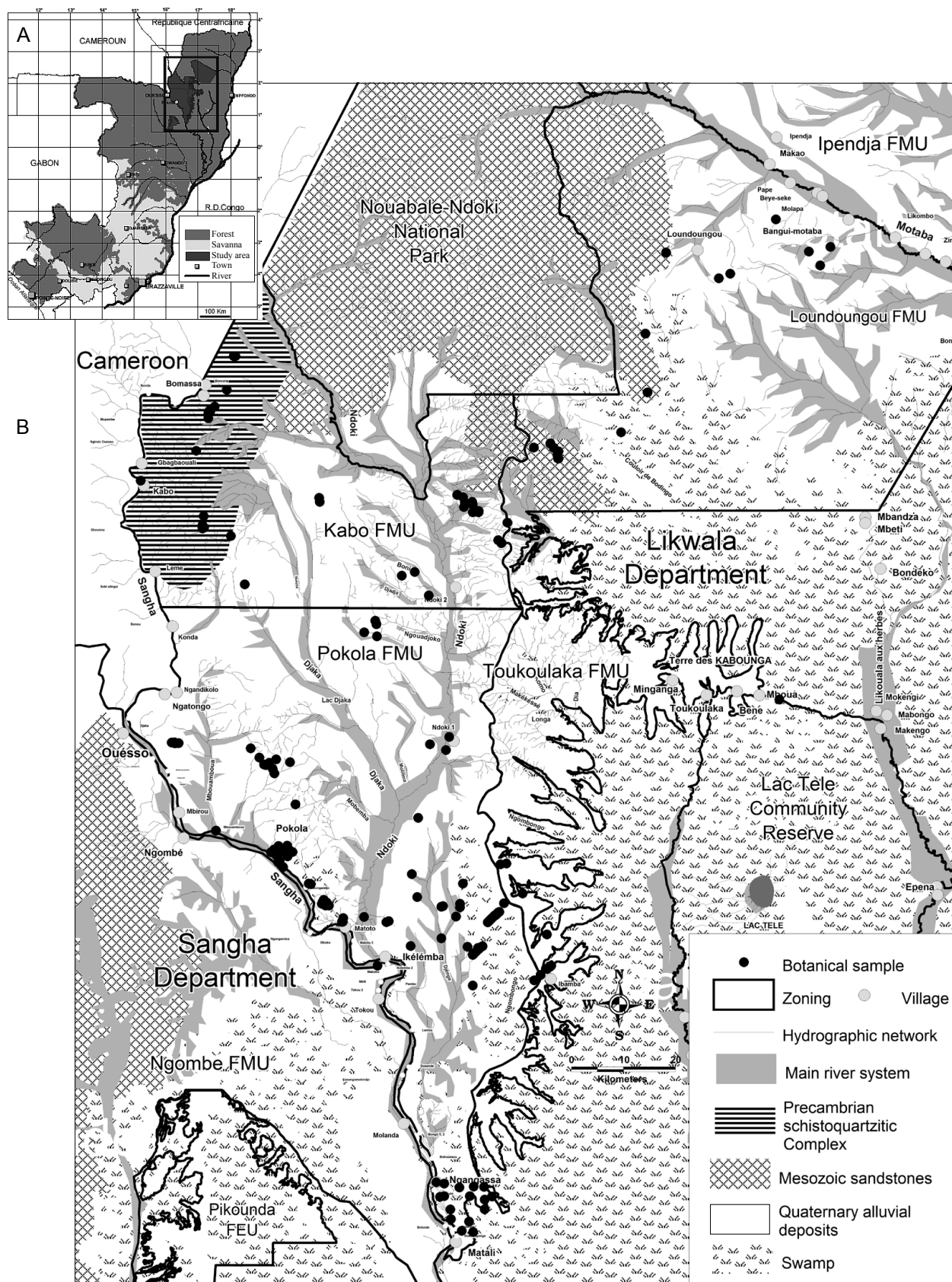


Figure 1 – A, location of the study area and distribution of the forest /savanna in the Republic of Congo (from CIB-management cell); B, close-up of the study area and its geology (from Dadet 1969, Vennetier 1963 and SCETAGRI 1983), and location of herbarium specimens collected.

Table 1 – Description of the seven most important woody life-forms encountered (based on Letouzey 1982).

The three other life-forms, often more specific, are: Strangler, lianescent species which uses the trunk of a tree as support and eventually kills it by suffocation (only the *Ficus* genus); Vine, sub-ligneous species with only a woody stem at the base, creeping or climbing plant; Semi-parasite, photosynthetic woody species which grows on and penetrates the tissues of its host plant (Viscaceae family).

Vegetal type	Height	Diameter
Large tree	30–40 m	1,5–2 m
Middle(-sized) tree	20–30 m	60–100 cm
Small tree	10–20 m	10–30 cm
Shrub (sarmentose or not)	2–10 m	≤ 10 cm
Suffrutescent plant	≤ 1 m	-
Large liana	20–40 m	≥ 10 cm
Liana/woody climber	-	≤ 5 cm

The **mixed terra firma forest** (Evrard 1968) forms a heterogeneous mosaic with locally dominant species and vegetation types. Within this complex pattern five most important vegetation types can be distinguished:

(1) open vegetation type with Marantaceae (Gillet 2006): The few tall trees are scattered, other woody elements are scarce, except in places with creeping and/or climbing lianas. The ground of this open vegetation is always covered by giant herbs (Marantaceae and Zingiberaceae) forming a dense herbaceous understorey higher than 3 m. The density of wood is less than 100 stems per hectare (dbh ≥ 5 cm) and the tree cover is around 20%. It is therefore not considered as a forest vegetation type. This vegetation type is mainly abundant in the south-east of the study zone (6 000 ha). However it can be also found elsewhere as small inclusions.

(2) sparse forest with Marantaceae (Kouka 2000): The canopy is still discontinuous but less than in the previous type, mid-storey trees and shrubs become visible, but the dense herbaceous understorey is always present.

(3) dense forest with Marantaceae (Gillet 2006): The canopy is most often closed, mid-storey trees and shrubs are relatively abundant. A dense herbaceous understorey is always present but gaps in the thicket are observed.

(4) moist semi-deciduous dense forest with Sterculiaceae and *Celtis* spp. (Letouzey 1968): The canopy is most often continuous, several woody layers are present, mid-storey trees and shrubs are abundant. The giant herbs do not form large patches in the understorey.

(5) young secondary forest (Lebrun & Gilbert 1954): In large clearings, the monodominant evergreen *Musanga cecropioides* forest is found preferentially in wetter places, and appears directly after logging or slash-and-burn agriculture.

The **monodominant *Gilbertiodendron dewevrei* forest** is defined by the presence of this gregarious, evergreen species. *G. dewevrei* forests have a continuous canopy. Several woody layers are observed; in particular *G. dewevrei* is present at different stages of development. The understorey

is usually open. In most cases, this forest is located along forest streams. Two variants can be separated according to soil drainage conditions (Gillet 2004): (6) *G. dewevrei* forest on dry land and (7) temporarily flooded *G. dewevrei* forest.

The **hydromorphic vegetation types** are: (8) The swampy forest extends along forest streams with small trees like *Lasiiodiscus palustris*. (9) The *Raphia* swamps are mainly composed of *Raphia hookeri* stands (Letouzey 1968). (10) The temporarily flooded forest of the Sangha River comprises the association of *Uapaca heudelotii* and *Irvingia smithii* (Harris 2002). (11) The swampy clearings, circular swampy depressions characterised in the centre by hydromorphic herbaceous vegetation. (12) Two kinds of swampy clearings are usually distinguished according to the presence (baïs) or not (eyanga) of a permanent or seasonal water course. Woody vegetation surrounding includes stands of *Lophira alata* for eyangas and *Hallea stipulosa* for baïs. *Guibourtia demeusei* is ubiquitous in the hydromorphic vegetation types. (13) The floating meadow is characterized by Poaceae and Cyperaceae.

Distribution (Di) – White's studies (1983, 1986) of African phytogeography defined the Guineo-Congolian regional centre of endemism as the great African forest region from Sierra Leone to the east of the Democratic Republic of Congo. Natural ranges related to Guineo-Congolian Regional Centre of Endemism (White 1979, 1986, Doucet 2003) are presented in table 2.

If the species was introduced (invasive, ornamental, for planting or for its edible fruits), 'introduced' is added after the distribution.

Seed dispersal type (SDT) – Species have been classified into six functional diaspore types (Doucet 2003, Gillet 2006): (1) Sarcocorous: diaspore with soft and fleshy ripe fruit (drupes, berries and false fruits) or seed covered at their base as far as a certain height by a fleshy coloured envelope (aril), (2) Ballochorous: diaspore directly ejected by the producer plant (podes and follicles without arils or wings), (3) Pleochorous: diaspore with a floating device, (4) Pterochorous: diaspore with wing-like appendage (samara), (5) Pogonochorous: diaspore with plumose appendages, hairs or aigrets and (6) Sclerochorous: diaspore with a lack of distinctive character and with a weight lower than one gram (dry fruit).

One seed dispersal type can correspond to several dispersion guilds. Four distinct dispersion guilds are found: (1) Autochorous: species with no external agent for dispersal (ballochorous, sclerochorous) and (2) Heterochorous: intervention of an external agent: (2.1) Zoochorous: dispersion by animals, mainly by birds, bats and mammals (sarcocorous, sclerochorous) (2.2) Anemochorous: dispersion by wind (pterochorous, pogonochorous) and (2.3) Hydrochorous: dispersion by water (pleochorous).

Human use (HU) – Many species are used for their edible fruit, traditional medication, poison for hunting or fishing... Information comes from personal field observations and bibliography compilation, essentially from Bouquet (1966), Fay (1997), Vautravers & Kossa Kossa (2008) and the PROTA database. Only the most common uses are listed.

Table 2 – Typology and classification of natural range in three main categories for the species of the study area (from White 1979, 1986 and Doucet 2003).

CAR = Central African Republic, RC = Republic of Congo and DRC = Democratic Republic of Congo.

Category	Typology	Range
Species with a large distribution	Linking species	species linking several centres of endemism
	Panafrican	species present in all tropical Africa
	Afro-Malagasy	widespread species in continental Africa and in the islands of the Malagasy region (mainly the Madagascar Island)
	Afro-American	species present in Africa and tropical America
	Afro-Asian	species present in Africa and Asia
Species with a related Guineo-Congolian Regional Centre of Endemism range	Pantropical	widespread species in Africa, Asia and tropical America
	Upper and lower Guinean	Sierra Leone, Liberia, southern part of Ivory Coast, Ghana, Nigeria and Cameroon, Equatorial Guinea, Gabon and RC
	Central-guineo-congolian	southern Nigeria and Cameroon, South-western CAR, Equatorial Guinea, Gabon, RC and DRC without Katanga and North-Oriental provinces
	Omni-guineo-congolian	upper and lower Guinean and DRC without Katanga and North-oriental provinces
	Sub-guineo-congolian	omni-guineo-congolian and peripheral Transition Zones (TZ) : Sudania Regional TZ in the North and Zambezia Regional TZ in the South of the regional Guineo-Congolian regional centre of endemism
Species with restricted range	Congolian	includes northern RC and south-western CAR
	Cameroonian-Congolian	northern RC, south-eastern Cameroon and south-western CAR
	Cameroonian-Gabonese-Congolian	includes semi-deciduous forest of northern RC, north-eastern Gabon, south-eastern Cameroon and south-western CAR
	Lower Guinean	Southern Nigeria and Cameroon, Equatorial Guinea, Gabon and RC

Deciduous character (DC) – The phenology of adult foliage is also specified: deciduous or evergreen, mainly for abundant tree species. For this part, field observations have been completed with bibliography, essentially from Lebrun & Gilbert (1954), Aubréville (1959) and the PROTA database.

Status (S) – If the species is rarely encountered in our study site, the status ‘rare’ is added.

Samples collected (Sp) – Regarding the herbarium voucher specimens, at least one specimen of each species was deposited at BR.

For species without risk of confusion, a picture of the sample served as voucher specimen. Sample pictures come from the herbarium assembled by the first author at the site of Pokola (RC), his field herbaria or characteristic fresh materials (slice, fruit, flower and/or seedling).

In both cases (herbarium sample and picture), numbering is used (Sp: collector’s initial, number). A label with description and georeferencing of the sample is associated with each herbarium specimen. For image samples, ‘pict’ is added in the checklist between the collector’s initials and the number.

RESULTS

Characterization of the ligneous stand

Species are listed by alphabetic order of family and species. The checklist is available in pdf format as an electron-

ic appendix (<http://www.ingentaconnect.com/content/botbel/plecevo/supp-data>).

The list includes 702 woody taxa. The number of genera is 392 and the number of families is 79.

The most important genus is *Ficus* with seventeen species, especially stranglers. Other species-rich genera are mainly shrubs and small trees belonging to the following genus: *Drypetes*, *Diospyros*, *Bertiera* and *Macaranga* or lianas such as *Clerodendrum*, *Combretum* and *Strychnos* (table 3).

The most species-rich family represented is Fabaceae with 89 species of the three subfamilies, followed by Rubiaceae (82 species) and Euphorbiaceae (64 species) (table 4).

Phytochorology and endemism – A total of 68% of the taxa (480 species) have a range related to the Guineo-Congolian regional centre of endemism (table 2, fig. 2). Twenty-three percent of taxa (162 species) have a wider distribution and include 33 introduced species (see checklist) often sub-spontaneous. A more strict endemism (Lower Guinean part of the Guineo-Congolian regional centre of endemism) applies to at least 5% of the taxa (36 species). The distribution of 4% of the taxa remains unknown (fig. 2).

Functional diaspore and seed dispersal types – The sarcochorous type, dispersed by animals, is the most important with 71% of species (fig. 3).

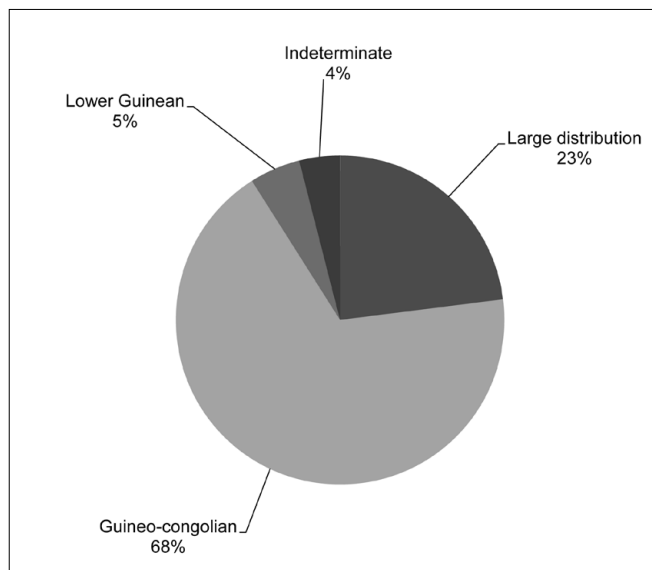
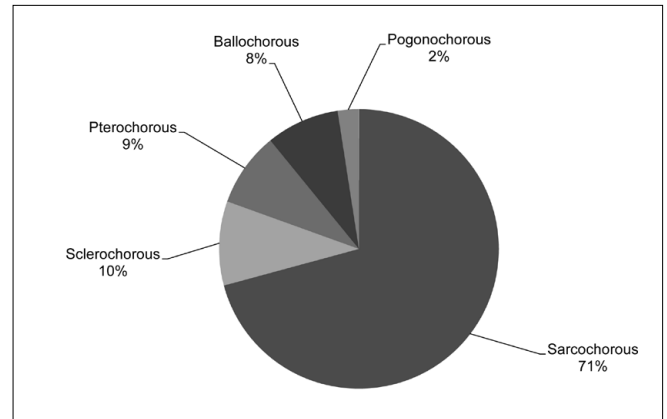
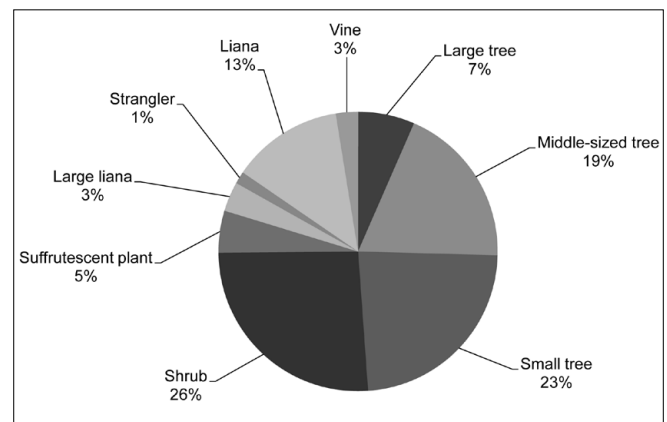
Table 3 – The number of species per genus for the nine most speciose genera, 393 genera collected.

Genus	Number of species
<i>Ficus</i>	17
<i>Drypetes</i>	12
<i>Diospyros</i>	12
<i>Clerodendrum</i>	8
<i>Combretum</i>	8
<i>Cola</i>	7
<i>Bertiera</i>	7
<i>Macaranga</i>	7
<i>Strychnos</i>	7

Table 4 – The number of species per family for the twelve most speciose families of the 79 families collected.

Detailed numbers are given for the Fabaceae family (Caesalpinioideae, Mimosoideae and Papilionoideae).

Family	Number of species
Fabaceae	89
Caesalpinioideae	31
Mimosoideae	24
Papilionoideae	34
Rubiaceae	82
Euphorbiaceae	64
Annonaceae	31
Moraceae	26
Apocynaceae	23
Sapotaceae	22
Sapindaceae	21
Flacourtiaceae	18
Meliaceae	18
Sterculiaceae	18
Tiliaceae	16

**Figure 2 – Phytochorological spectra of the 702 species collected.****Figure 3 – Functional diaspore type of the 702 species collected.****Figure 4 – Life-form of the 702 species collected.**

Life-form – The three most common life-forms are shrub (26%), small tree (23%) and middle-sized tree (19%) (fig. 4).

Human use – At least 184 of the listed species (26%) are useful to humans in the study area. Medicinal bark and edible fruit are the two most common uses. The families most used are Euphorbiaceae, Meliaceae, Fabaceae and Sterculiaceae (see checklist).

Species newly recorded for the Republic of Congo

The 44 species commented here by alphabetic order of families and species are those not yet cited in Bouquet (1966), Sita & Moutsamboté (1988), Champluvier & Dowsett-Le-maire (1999) and Lachenaud (2009). Introduced species are not mentioned. The life-form (LF) and the preferential habitat (PH) are given as in the checklist. In addition, location of the collected samples and more detailed distribution (Di) are presented here.

Ancistrocladaceae

Ancistrocladus letestui Pellegr.

JFG pict 299: Sangha department, Kabo FMU, 2.161°N 16.199°E.

LF: Liana. PH: Secondary *Gilbertiodendron dewevrei* forest on dry land. Di: Gabon, Cameroon.

Annonaceae

Hexalobus sp. 1

JFG 172: Sangha depart., Pokola FMU, 1.448°N 16.211°E.
LF: Middle-sized tree. PH: Temporarily flooded forest of the Sangha River. Di: Cameroon, CAR.

Note – Probably the same new species of *Hexalobus* mentioned by Harris (2002).

Xylopia cupularis Mildbr. Syn. *X. chrysophylla* Louis ex Boutique

JFG 175: Likwala depart., Toukoulaka FMU, 1.215°N 16.789°E; JFG 177: Sangha depart., Kabo FMU, 2.168°N 16.199°E.

LF: Small tree. PH: Open canopy Marantaceae forest. Di: Gabon, Cameroon, CAR, DRC, Angola (Cabinda).

Xylopia gilbertii Boutique

JFG 94: Sangha depart., Pokola FMU, 1.304°N 16.695°E.
LF: Small tree. PH: Open canopy Marantaceae forest. Di: Gabon, DRC.

Apocynaceae

Hunteria ballayi Hua

JFG 62: Sangha depart., Kabo FMU, 1.970°N 16.189°E.
LF: Shrub. PH: Moist semi-deciduous dense forest. Di: Gabon, Cameroon.

Landolphia villosa J.G.M.Pers.

JFG pict 598: Sangha depart., Pokola FMU, 0.808°N 16.648°E.

LF: Large liana. PH: Moist semi-deciduous dense forest with hydromorphic soil and *Gilbertiodendron dewevrei* forest on dry land. Di: Gabon, DRC.

Note – Edible fruit sold in markets, medicinal bark.

Capparaceae

Cleome afrospina Iltis

JFG pict 388: Sangha depart., Kabo FMU, 2.266°N 16.245°E.
LF: Suffrutescent plant. PH: Secondary swampy clearing (eyanga). Di: Nigeria, Gabon, Cameroon, CAR, D.

Ebenaceae

Diospyros ferrea (Willd.) Bakh.

JFG 110: Sangha depart., Kabo FMU, 2.014°N 16.640°E.
LF: Shrub. PH: Hydromorphic vegetation types and moist semi-deciduous dense forest. Di: Africa, Asia, Australia.

Diospyros melocarpa F.White

JFG pict 411: Sangha depart., Pokola FMU, 0.827°N 16.649°E.
LF: Small tree. PH: Open canopy Marantaceae forest. Di: Nigeria, Gabon, Cameroon, Equatorial Guinea, DRC.

Fabaceae Caesalpinioideae

Cynometra oddonii De Wild.

JFG pict 370: Sangha depart., Pokola FMU, 0.772°N 16.619°E.
LF: Small tree. PH: Temporarily flooded forest of the Sangha River. Di: Gabon, DRC.

Dialium zenkeri Harms

JFG pict 375: Sangha depart., Kabo FMU, 2.032°N 16.617°E.
LF: Middle-sized tree. PH: Mixed terra firma forest. Di: Cameroon, CAR, DRC.

Fabaceae Mimosoideae

Adenopodia scelerata (A.Chev.) Brenan

JFG pict 565: Sangha depart., Pokola FMU, 1.271°N 16.622°E.
LF: Liana. PH: Open canopy Marantaceae forests, roadside vegetation. Di: Liberia to DRC.

Fabaceae Papilionoideae

Erythrina droogmansiana De Wild. & T.Durand

JFG 141: Sangha depart., Kabo FMU, 2.266°N 16.245°E.
LF: Small tree. PH: Mixed terra firma forest. Di: Cameroon, Gabon, CAR, DRC.

Ostryocarpus riparius Hook.f. Syn. *Millettia micrantha* Harms

JFG 202: Sangha depart., Pokola FMU, 1.241°N 16.662°E.
LF: Large liana. PH: Temporarily flooded *Gilbertiodendron dewevrei* forest and swamp. Di: Guinea to DRC.

Flacourtiaceae

Dovyalis zenkeri Gilg

JFG pict 490: Sangha depart., Pokola FMU, 1.811°N 16.485°E.
LF: Small tree. PH: Roadside vegetation. Di: Guinea-Bissau to Uganda.

Oncoba crepiniana De Wild. & T.Durand

JFG 125: Sangha depart., Kabo FMU, 2.103°N 16.177°E.
LF: Small tree. PH: Moist secondary forest. Di: CAR, DRC, Sudan.

Scottellia klaineana Pierre Syn. *S. coriacea* A.Chev.

JFG pict 499: Sangha depart., Kabo FMU, 2.160°N 16.200°E.
LF: Middle-sized tree. PH: Dense forest with Marantaceae. Di: Sierra Leone to DRC.

Scottellia orientalis Gilg

JFG pict 500: Sangha depart., Pokola FMU, 1.790°N 16.490°E.
LF: Small tree. PH: Hydromorphic vegetation types. Di: Nigeria, Cameroon, CAR, DRC.

Lauraceae

Beilschmiedia variabilis Robyns & Wilczek

JFG pict 514: Sangha depart., Pokola FMU, 1.241°N 16.661°E.
LF: Small tree. PH: *Guibourtia demeusei* swampy forest. Di: DRC.

Linaceae

Hugonia micans Engl.

JFG pict 520: Sangha depart., Pokola FMU, 2.008°N 16.654°E.
LF: Liana. PH: Swamp. Di: Cameroon, Gabon, CAR.

Hugonia spicata Oliv. var. *glabrescens* Keay

JFG pict 522: Sangha depart., Kabo FMU, 2.052°N 16.384°E.
LF: Liana. PH: Moist semi-deciduous dense forest. Di: Nigeria, Gabon, CAR, DRC.

Moraceae

Ficus variifolia Warb.

JFG pict 618: Sangha depart., Pokola FMU, 1.323°N 16.394°E.
LF: Large tree. PH: Moist semi-deciduous dense forest. Di: Sierra Leone to Uganda.

Rubiaceae

Keetia tenuiflora (Hiern) Bridson

JFG 256: Sangha depart., Kobo FMU, 2.230°N 16.233°E.

LF: Liana. PH: Moist semi-deciduous dense forest. Di: Sierra Leone to Uganda.

Psychotria brevipaniculata De Wild.

JFG pict 687: Sangha depart., Pokola FMU, 0.770°N 16.643°E

LF: Suffrutescent plant. PH: Moist semi-deciduous dense forest. Di: Cameroon, CAR, DRC, Uganda.

Tricalysia longituba De Wild. var. *longituba*

JFG 255: Sangha depart., Kobo FMU, 2.205°N 16.203°E.

LF: Shrub. PH: Swampy clearing (baïs). Di: Cameroon to Zambia.

Rutaceae

Zanthoxylum lemairei (De Wild.) P.G. Waterman Syn. *Fagara lemairei* De Wild.

JFG pict 693: Sangha depart., Pokola FMU, 1.340°N 16.740°E.

LF: Small tree. PH: Secondary forest. Di: Ivory Coast to Uganda.

Sapindaceae

Chytranthus carneus Radlk.

JFG 101: Sangha depart., Pokola FMU, 1.325°N 16.395°E.

LF: Shrub. PH: Moist semi-deciduous dense forest. Di: Sierra Leone to DRC and Angola.

Chytranthus mortehanii (De Wild.) De Voldere ex Hauman

JFG pict 701: Sangha depart., Kobo FMU, 2.161°N 16.195°E.

LF: Shrub. PH: Mixed terra firma forest with hydromorphic soil. Di: Cameroon, Gabon, CAR, DRC.

Note – Edible grilled seed.

Chytranthus setosus Radlk.

JFG 103: Sangha depart., Kobo FMU, 2.027°N 16.628°E.

LF: Shrub. PH: Moist semi-deciduous dense forest with hydromorphic soil. Di: Ivory Coast to DRC.

Eriocoelum dzangensis D.J. Harris & Wortley

JFG pict 703: Likwala depart., Toukoulaka FMU, 1.205°N 16.778°E.

LF: Shrub. PH: Mixed terra firma forest. Di: CAR.

Eriocoelum paniculatum Baker

JFG 263: Likwala depart., Toukoulaka FMU, 2.115°N 16.788°E.

LF: Middle-sized tree. PH: Mixed terra firma forest. Di: Cameroon, Gabon, CAR.

Laccodiscus pseudostipularis Radl. ex Engl.

JFG pict 705: Sangha depart., Pokola FMU, 1.320°N 16.400°E.

LF: Small tree. PH: Hydromorphic vegetation types, mixed terra firma forest with hydromorphic soil. Di: Cameroon, Gabon, CAR, DRC.

Sapotaceae

Brevia sericea Aubrév. & Pellegr. Syn. *Brevia leptosperma* (Baehni) Heine

JFG pict 714: Sangha depart., Pokola FMU, 1.309°N 16.417°E.

LF: Large tree. PH: Moist semi-deciduous dense forest. Di: Ivory Coast to DRC.

Chrysophyllum ubangiense (De Wild.) D.J. Harris Syn. *Donella pentagonocarpa* (Engl. & K. Krause) Aubrév. & Pellegr.

JFG pict 715: Sangha depart., Kobo FMU, 2.263°N 16.242°E.

LF: Large tree. PH: Moist semi-deciduous dense forest. Di: Ivory Coast to DRC.

Englerophytum iturense (Engl.) L. Gaut. Syn. *E. vermoesenii* (De Wild.) Aubrév. & Pellegr.

JFG 169: Sangha depart., Kobo FMU, 1.783°N 16.489°E.

LF: Shrub. PH: Temporarily flooded *Gilbertiodendron dewevrei* forest and swamp. Di: DRC.

Manilkara maboqueensis Aubrév.

JFG pict 722: Likwala depart., Loundoungou FMU, 2.502°N 17.177°E.

LF: Large tree. PH: Moist semi-deciduous dense forest with hydromorphic soil. Di: Cameroon, CAR.

Note – Edible fruit and medicinal bark.

Pradosia spinosa Ewango & Breteler

JFG pict 726: Sangha depart., Pokola FMU, 0.773°N 16.643°E.

LF: Small tree. PH: Moist semi-deciduous dense forest with hydromorphic soil. Di: DRC.

Solanaceae

Solanum anguivi Lam.

JFG pict 735: Sangha depart., Kobo FMU, 2.266°N 16.245°E.

LF: Suffrutescent plant. PH: Secondary and hydromorphic vegetation types. Di: Afro-Malagasy.

Note – Edible cooked fruit.

Sterculiaceae

Cola gigantea A. Chev.

JFG pict 743: Sangha depart., Pokola FMU, 1.448°N 16.211°E.

LF: Middle-sized tree. PH: Mixed terra firma forest, secondary forest along the Sangha River. Di: Ivory Coast to Sudan and Uganda.

Cola urceolata K. Schum.

JFG 100: Sangha depart., Kobo FMU, 1.944°N 16.703°E.

LF: Shrub. PH: Hydromorphic vegetation types. Di: Cameroon, Gabon, CAR, DRC.

Note – Edible fruit.

Strychnaceae

Strychnos boonei De Wild.

JFG pict 529: Sangha depart., Pokola FMU, 1.323°N 16.395°E.

LF: Liana. PH: Moist semi-deciduous dense forest. Di: Nigeria to Uganda.

Thymelaeaceae

Dicranolepis pulcherrima Engl. & Gilg

JFG 132: Sangha depart., Kobo FMU, 1.998°N 16.660°E;

JFG 133: Sangha depart., Kobo FMU, 1.973°N 16.188°E.

LF: Shrub. PH: *Gilbertiodendron dewevrei* forest. Di: Cameroon, Gabon, CAR, DRC.

Verbenaceae

Clerodendrum excavatum De Wild. Syn. *C. grandifolium* Gürke

JFG 191: Sangha depart., Kobo FMU, 1.973°N 16.188°E.

LF: Liana. PH: Moist semi-deciduous dense forest. Di: Cameroon, Gabon, CAR, DRC.

Clerodendrum poggei Gürke Syn. *C. angolense* Gürke

JFG 155: Sangha depart., Pokola FMU, 1.269°N 16.782°E.

LF: Shrub. PH: Secondary and Marantaceae forest. Di: Cameroon to Ethiopia and Angola.

DISCUSSION

Characterization of the ligneous stand

The natural range of 73% of taxa corresponds to the Guineo-Congolian regional centre of endemism, including the Lower Guinean species (fig. 2). This percentage is similar to those obtained in the sub-region which also includes a large majority of Guineo-Congolian related species (Doucet 2003, Dauby et al. 2008, Lubini & Kusehuluka 1991, White 1979). The species with a more limited distribution (Lower Guinean species) are poorly represented in the study area (5%, fig. 2) compared to central Gabon with nearly 30% (Doucet 2003). Conversely the proportion of the widely distributed species is more than twice as high (23%, fig. 2) as in Gabon (10%, Doucet 2003).

The evergreen Gabonese forests contain a high rate of species endemic to Gabon – close to 10% of the species (Sosef et al. 2006). In contrast, in our inventories in

the northern Republic of Congo only one species seems to be truly endemic: *Diospyros whitei*, recently described by Dowsett-Lemaire & Pannell (1996). For the Dja region in Cameroon, Sonké (1998) also found a very low rate of Cameroonian endemic species (0.3%). In the lowland forests of Central Africa, the rates of narrow endemism are therefore much lower in continental semi-deciduous forests than in Atlantic evergreen forests. Conversely, the species with a wide distribution are better represented. Senterre (2005) has also shown that species with limited distribution gradually increase with the proximity of the Atlantic Ocean to the detriment of Guineo-Congolian wide range species.

The sarcochorous type is the most important seed dispersal type occurring in 71% of the species collected (fig. 3). In other parts of Central Africa, sarcochorous species are also well represented (Doucet 2003, Lubini & Kusehuluka 1991, Senterre 2005, Sonké 1998).

In Northern Congo, 11% of species are anemochorous (pterochorous and pogonochorous) (fig. 3). This functional type seems to be more important in semi-deciduous forests due to the abundance of anemochorous large trees of the genera *Albizia*, *Alstonia*, *Amphimas*, *Anopyxis*, *Ceiba*, *Entandrophragma*, *Funtumia*, *Khaya*, *Lophira*, *Lovoa*, *Markhamia*, *Nesogordonia*, *Pericopsis*, *Petersianthus*, *Piptadeniastrum*, *Prioria*, *Pteleopsis*, *Pterocarpus*, *Pterygota*, *Stemonocoleus*, *Terminalia* and *Triplochiton*. This dominance implies a higher frequency and magnitude of the opening of the tree cover (Senterre 2005) than in evergreen forests, except for the monodominant *Aucoumea klaineana* forests which are dominated by the only anemochorous species of the Burseraceae family (Doucet 2003). The extensive open canopy Marantaceae forests in the mosaic of semi-deciduous forests seem to be relics of former openings. These would be caused by paleo-fires (Brncic 2002, Gillet et al. 2008).

Among a total of 44 new species for the Republic of Congo, surprisingly some are relatively common large trees such as the Sapotaceae *Brevia sericea*, *Chrysophyllum ubangiense* and *Manilkara maboensis*; this is exemplary for the lack of botanical knowledge of the study area. Others are very rare such as the thorny Sapotaceae *Pradosia spinosa* (fig. 6) recently described by Ewango & Breteler (2001) and previously only known in north-eastern DRC, and in Gabon's Mayombe (Gillet et al. 2003).

Original vegetation types with limited distribution

The most unusual terra firma forest in the study area is encountered in the extreme south, close to the confluence of the Sangha River and the Likwala-aux-Herbes swamps (fig. 5). Indeed this is the only place where stands of *Schefflerodendron gilbertianum* are observed. This rare species was previously known only in islands of Lake Tumba in DRC (Evrard 1968) and along the northern bank of the Lekoli River in Odzala NP in Congo (Dowsett-Lemaire 1996). This fragmented and highly localized distribution of *S. gilbertianum* on both sides of the Congo River could be the remnant of a previously wider range. In the study area, *S. gilbertianum* is accompanied by other rare tree species of evergreen forest such as *Pradosia spinosa* and *Diospyros melocarpa*, new records for the country.

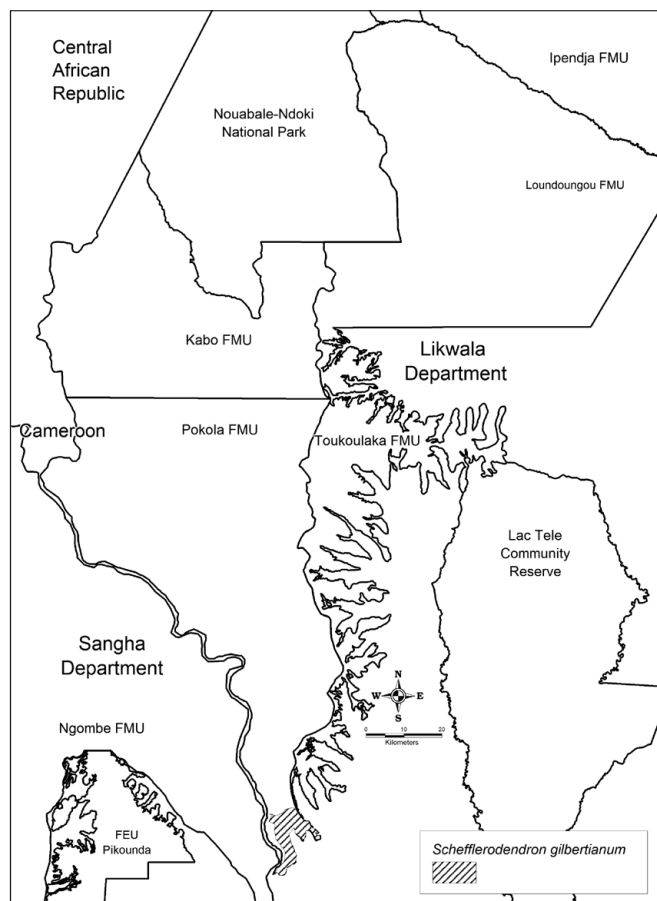


Figure 5 – Distribution map of *Schefflerodendron gilbertianum* from personal observations.

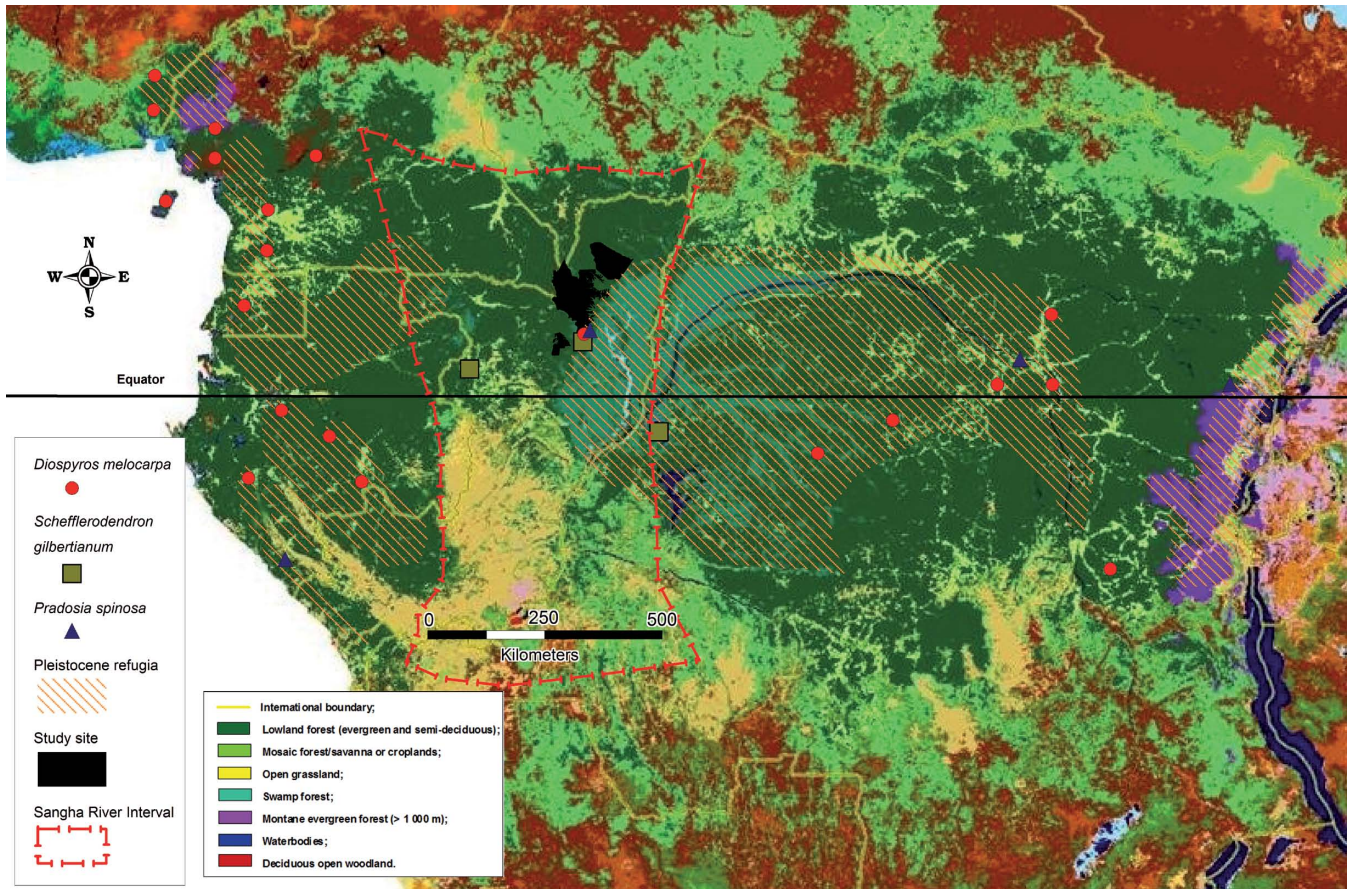


Figure 6 – Vegetation map of Central Africa (from Mayaux et al. 2004) with the distribution of *Diospyros melocarpa* (Doucet 2003, Senterre 2005), *Schefflerodendron gilbertianum* (Evrard 1968, Dowsett-Lemaire 1996) and *Pradosia spinosa* (Ewango & Breteler 2001, Gillet et al. 2003), and the location of the three main postulated Pleistocene rainforest refugia (Bahuchet 1996, Colyn et al. 1991, Maley 2002). The smallest fluvial refugia, e.g. the lower Congo River (Robbrecht 1996, Wieringa 1999), are not shown.

The temporarily flooded forest of the Sangha River includes a specific evergreen vegetation (Harris 2002). The association between *Uapaca heudelotii* and *Irvingia smithii* is characteristic of riparian forests of the Congo basin (Léonard 1947). *U. heudelotii* settles on the river banks, in contrast to other taxa that indicate the age of the vegetation such as the Caesalpinoideae, Chrysobalanaceae and Scytropetalaceae (Lebrun & Gilbert 1954, Doucet 2003). This family is endemic to the Guineo-Congolian Region (White 1986), especially *Brazzeia congoensis* and *Scytropetalum pierreanum* are endemic of the main rivers of the Congo basin (Letouzey & White 1978). This particular vegetation is actually extended to the main river system of the Congo Basin (Lubini 1985).

Phytogeographic considerations

Our study site lies in the central part of the Sangha River Interval (SRI), defined by White (1979) as a large floristically poor area (14–18°E) which seems at least 400 km wide separating the Lower Guinean and Congolian subcentres of endemism. In White's time, however that area was one of the least well-collected parts of Africa. A little further north in SW CAR, Harris (2002) reassessed White's hypothesis of a SRI. The author listed sixteen species considered by White (1978, 1979) as absent from the interval but present to the

East and West; Harris reported three of them in his checklist (*Diospyros ferrea*, *Psychotria minuta* and *Strychnos talbotiae*). Three of those sixteen species were observed in the present study: *Diospyros ferrea*, *D. melocarpa* and *Parinari congensis*. The first is present in hydromorphic vegetation types and in some terra firma forests, the second in terra firma forest and the last in temporarily flooded forest of the Sangha River. Other species listed by White (1979) are from two genera especially difficult to identify at the species level: *Psychotria* and *Strychnos*, mainly suffrutescent plants and lianas respectively, probably under-sampled in our study.

Concerning *Diospyros* species, a genus used by White (1978) to highlight Guineo-Congolian phytochoria, three other species previously unknown in the interval have been reported by Dowsett-Lemaire (1996) in its west part, on terra firma forests near main rivers (Lekoli, Mambili): *D. boala*, *D. hoyleana* and *D. zenkeri*. Dowsett-Lemaire (1996) discovered fourteen species of Ebenaceae, *D. whitei* being the most abundant. This species seems to be an endemic of the Northern forest part of the Sangha River Interval (Dowsett-Lemaire & Pannell 1996). Senterre (2005) highlighted *Diospyros* coastal species that seem ecological and chorological transgressors (White 1979) in the Congolian riparian forests. Our distribution map of one of them, *D. melocarpa* (fig.

6) includes additional records. *D. melocarpa* has a very fragmented central Guineo-Congolian natural range. In addition it is also present in terra firma forests of the Congo basin but never far from the major rivers where soil conditions appear favourable for it (fig. 6).

Figure 6 also represents the particular distribution of two other rare species in our study area. *Schefflerodendron gilbertianum* has a range restricted to the forest part of the SRI and *Pradosia spinosa* has a central Guineo-Congolian wider range but limited to the edges of postulated refugia (fig. 6). Both are found in edaphically favourable conditions: near rivers and swamps or on islands (Evrard 1968, Ewango & Breteler 2001, Dowsett-Lemaire 1996, pers. obs.).

The presence of these numerous new species of Lower Guinea and/or Congolian as well as in the SRI suggests that the floristical poverty of the SRI was overestimated by White (1978, 1979), due to a lack of exploration of the area. The northern forest part of the SRI is actually the phytogeographic region of moist semi-deciduous dense forests in Atlantic Central Africa (de Namur 1990). The southern part, at the south of Mambili River, includes savanna vegetations, mainly from the Bateke tablelands (fig. 6).

The original terra firma forest highlighted above, close to the confluence of the Sangha River and the Likwala-aux-Herbes swamps (fig. 5), is discussed in the context of the theory of the forest refugia. In Central Africa, two major Pleistocene rainforest refugia are currently postulated (Colyn et al. 1991, Maley 2002, Plana 2004); the first would be located in Western Gabon and Cameroon and the second in Eastern DRC (fig. 6). Both centres of species endemism and richness coincide with hill formations (Robbrecht 1996), altitudinal variation (Plana 2004) and greater rainfall patterns (Linder 2001). The most arid periods would have resulted in fragmentation of forests and formation of forest refugia (Plana 2004). Nevertheless, clusters of lowland forests populations would have also survived in several places within the Congo basin and many patches remained near the main river systems (Colyn et al. 1991). These climatic refuges would be characterized by climatic stability over longer periods of time; continually high degree of humidity and shade, edaphically favourable conditions (water, nutrients), such as gallery forests in lowland areas and along mid-altitude region of Africa's montane region (Plana 2004, Robbrecht 1996).

The suggestion that lowland forest patches remained in several areas within interfluvial forest blocks in the Congo basin is supported by the current restricted range of simian primates (Colyn et al. 1991), Rubiaceae (Robbrecht 1996) and Begoniaceae taxa (Sosef 1996), Caesalpinioideae evergreen forest trees (Wieringa 1999) and vascular plant species endemism in DRC (Ndjele 1988) and also by palaeobotanical records (Laraque et al. 1997, Maley 2002). The current distribution of pygmy populations is also revealing (Bahuchet 1996). This postulated 'quaternary Major Fluvial Refuge of the Congo basin' divided into several adjacent areas, developed from these studies, is empirically illustrated in figure 6.

CONCLUSION

The study site in the north-western part of the Congo basin is a complex mosaic of overlapping vegetation types. Lowland terra firma forests are dense to sparse, often with an understorey of giant herbaceous plants. The hydromorphic vegetation types are ubiquitous and characterized by specific species of old evergreen forests (Caesalpinioideae, Scytopetalaceae).

The composition and the evergreen character of terra firma forests seem also linked to drainage and soil water availability at all levels; changes in vegetation are observed around small swamps and swampy clearings, along main rivers like the Sangha River and close to the huge Likwala-aux-Herbes swamps.

On drier land, the large emergent trees are mostly deciduous, light-demanding and wind-dispersed. Distribution of the genera *Alstonia*, *Lophira*, *Pericopsis*, *Terminalia* and *Triplochiton* is probably derived from anthropogenic past clearing and fires combined with paleoclimatic fluctuations (Brncic et al. 2007, Gillet et al. 2008, van Gemerden et al. 2003). Nevertheless, in the north of the study area, on poor sandy soils, shade tolerant species (*Manilkara maboekensis*, *Prioria oxyphylla*) substitute these light-demanding species. This could indicate older forests with less anthropogenic impacts. But it may not be prudent to draw too many conclusions and complementary studies are definitely needed.

Finally, the Sangha River Interval (White 1979) is definitely richer than expected, especially the northern forest part. Therefore the SRI does not appear to be a distinct phytochoria. Stands of rare species (e.g. *Schefflerodendron gilbertianum*) are found close to the confluence of the Sangha River and the Likwala-aux-Herbes swamps. Numerous other interfluvial forest blocks are defined by the high specific richness and endemism in the DRC part of the Congo basin. They seem to be contiguous or linked by the river network and the whole could form the Major Fluvial Refuge of the Congo basin.

SUPPLEMENTARY DATA

Supplementary data are available at *Plant Ecology and Evolution*, Supplementary Data Site (<http://www.ingentaconnect.com/content/botbel/plecevo/supp-data>), and consist of a checklist of 702 woody species in the Republic of Congo (pdf format).

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