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LONG DATABASE REPORT

ECOINFORMATICS

First vegetation-plot database of woody species from Huíla province, SW Angola

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Abstract

Angola is a country in south-central Africa, particularly rich in biodiversity. Despite the efforts recently made to document its biodiversity, there is a need for standardized sampling methods to document and compare the variety of ecosystems and plants occurring in the country. With this database report we aim to document the abundance and diversity of woody species in the woodlands of Huíla province. The database hosts the results of a standardised plot-based vegetation survey, consisting of 448 vegetation plots distributed throughout the 14 municipalities and Bicuar National Park. In total, 40,009 individuals belonging to 44 plant families were recorded and measured, belonging to 193 woody species. Species richness per municipality ranged from 32 to 126. The mean stem diameter (DBH) was 10.9 cm ± 7.5 cm. Small-size classes are increasingly dominated by few species, while the largest trees come from a wider range of species; miombo key-species dominated almost all size classes. Our study represents the first plot-based vegetation survey of any Angolan province and constitutes a useful source of information for conservation and management. Additionally, may constitute a powerful dataset to support future studies on biodiversity patterns and vegetation change over time and facilitate the elaboration of vegetation maps.

Taxonomic reference: Checklist of Angolan Plants (Figueiredo and Smith 2008), The African Plant Database (version 3.4.0) and A new classification of *Leguminosae* (LPWG 2017).

Abbreviations: DBH = Diameter at Breast Height; GIVD = Global Index of Vegetation-Plot Databases; LUBA = Acronym of the Herbarium of Lubango

Keywords

Angola, *Baikiaea-Burkea* woodland, database, Huíla province, miombo, woodlands/forests, woody species, vegetation survey

GIVD Fact Sheet: Vegetation-Plot Database of Woody Species from Huíla Province

GIVD Database ID: AF-AO-001			**Last update:** 2021-05-17
Vegetation-Plot Database of Woody Species from Huíla Province		**Web address:** http://www.givd.info/ID/AF-AO-001	
Database manager(s): Francisco Gonçalves (francisco.goncalves@isced-huila.ed.ao); António Chisingui (valter.chissingui@isced-huila.ed.ao); José Tchamba (jose.tchamba@isced-huila.ed.ao)			
Owner: ISCED-Huíla, Rua Sarmento Rodrigues, N.º 2, C.P. 230, Lubango-Angola			
Scope: The database contains information on diversity, abundance and diameter (DBH>5 cm) of woody species from the woodlands of Huíla province, Angola. The species were locally identified based on familiarity of team members with local/regional flora or using the available field guides.			
Availability: according to a specific agreement		**Online upload:** no	**Online search:** no
Database format(s): Excel		**Export format(s):** Excel, CSV file	
Plot type(s): nested plots		**Plot-size range (m²):** 100 to 1000	
Non-overlapping plots: 448	**Estimate of existing plots:** 448	**Completeness:** 100%	**Status:** completed and continuing
Total no. of plot observations: 448	**Number of sources (biblioreferences, data collectors):** 0		**Valid taxa:** 193
Countries (%): AO: 100			
Formations: Forest: 100% = Terrestrial: 100%			
Guilds: woody vascular plants: 100%			
Environmental data (%): altitude: 100 slope inclination: 100; surface cover other than plants (open soil, litter, bare rock etc.): 100; land use categories: 100; soil depth: 100; other attributes: At least one soil sample per plot was collected, depth depends on soil characteristic.			
Performance measure(s): presence/absence only: 100%; number of individuals: 100%; measurements like diameter or height of trees: 100%			
Geographic localization: GPS coordinates (precision 25 m or less): 100%			
Sampling periods: 2010-2019: 100%			
Information as of 2021-05-17; further details and future updates available from http://www.givd.info/ID/AF-AO-001			

Introduction

Africa's total forest area is estimated at 675 Mha, or about 23% of land area (PROFOR 2012). Globally, the value of forests to society is becoming increasingly evident, as they play an important role in the livelihoods and economic development of many communities and countries which depend on intact forests (Mayaux et al. 2005, FAO and UNEP 2020). Despite the global importance of forests and woodlands, there is an increasing pressure on forest resources and the situation in Angola is no exception. Replacement of forests by agriculture, urbanisation, or construction of infrastructure, charcoal production, timber exploitation of valuable tree species and human-ignited fires are among others the main causes for deforestation and forest degradation in Africa. Together, these drivers of change have contributed to an estimated loss of 13.7% of intact forests in Angola over the last decade (Schneibel et al. 2016, Potapov et al. 2017).

According to the preliminary results of the National Forest Inventory, Angola has an estimated forest cover of about 69.3 Mha, corresponding to 55.6% of the national territory (FAO 2018). Unfortunately, this document only provides a general overview of the state of forest resources in Angola; important data to understand the social-ecological dynamics of the woodland ecosystems are still lacking. Adding to that are unpredictable effects of climate change, which is expected to bring more frequent and intense droughts to some parts the country (Catarino et al. 2020). In fact, the southern and south-eastern parts of Angola are currently experiencing severe droughts, posing additional threats to forest resources, as local populations are driven to explore the available natural resources even more to meet their daily needs.

In Angola, several vegetation studies have been conducted, aiming to document the diversity of plants and to map the vegetation (Gossweiler and Mendonça 1939, Barbosa 1970, Stellmes et al. 2013). However, most of the early studies lack detailed descriptions of the species composition and plant diversity (Revermann et al. 2016). An approach based on the quantitative analysis of woody species was introduced by Monteiro (1970); this study conducted on the Bié plateau provided an excellent first overview of the composition of woody species in the woodlands of the Bié province. Over the last decade, relevant research projects in Angola have adopted plot-based surveys in their vegetation studies; most of them rely on standard plot sizes of either 10 × 10 m or 20 × 50 m, e.g., the Future Okavango Project (TFO) and the Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL). Other initiatives, however, have introduced other survey approaches,

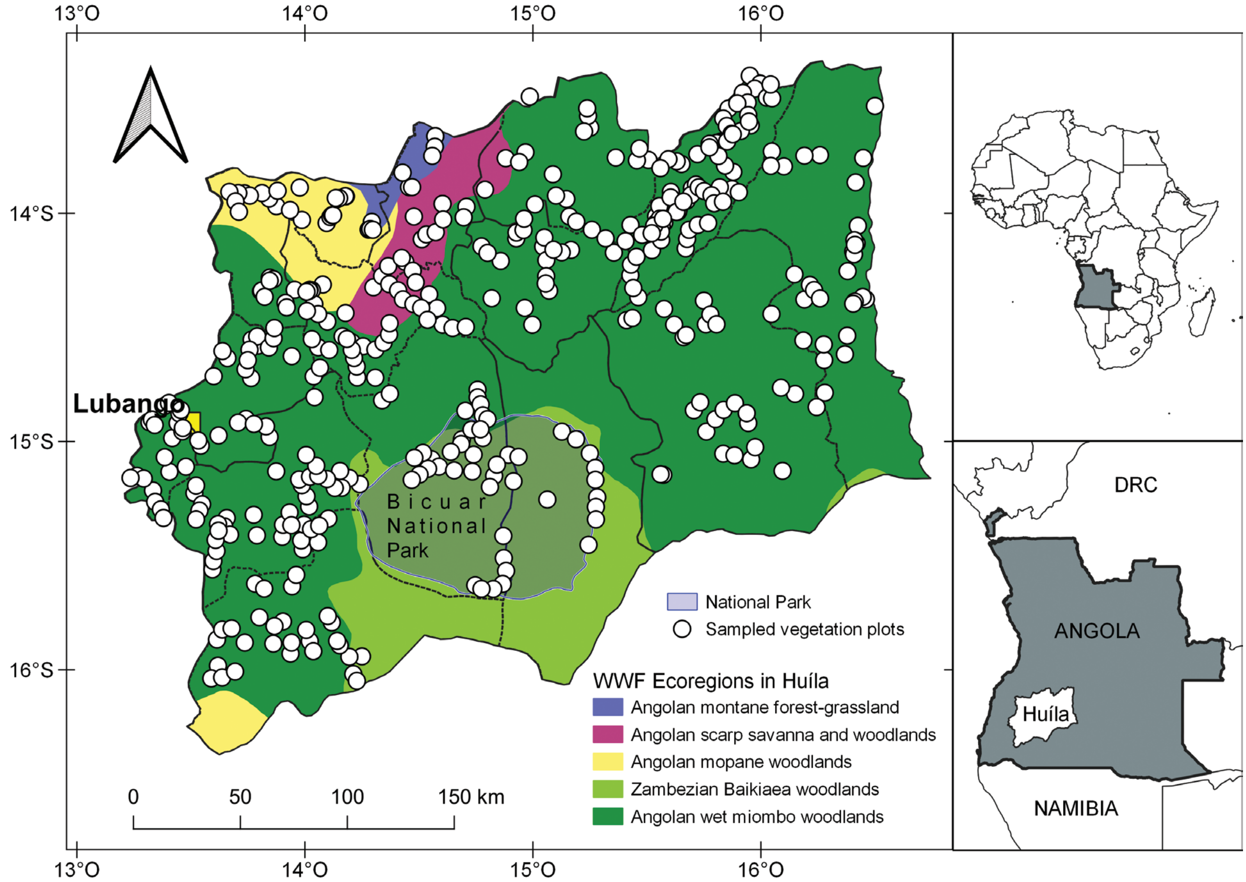

Figure 1. Map of Huíla province with municipalities (sub-polygons), ecoregions (color surfaces), and the location of the vegetation relevés (white dots) stored in the database.

looking in more detail at vegetation structure and strata, in order to allow for structural and functional analyses of these woodlands (FAO 2009, SEOSAW partnership 2021).

The studies which resulted from the mentioned research initiatives have greatly contributed to understand the diversity and composition of species at national and regional scale and provided powerful datasets (Revermann et al. 2016, Godlee et al. 2020). Despite these pioneer studies, systematic biodiversity surveys based on a standard plot design are still lacking for large parts of the forests and woodlands in Angola. Therefore, further plot-based vegetation surveys are of crucial importance to quantify forest resources and to provide data to support a sustainable management and conservation of woodland resources in Angola.

Our study represents the first vegetation-plot database of Huíla province, Angola, and contains data on diversity, abundance and DBH of woody species in the woodlands of the region. Using the data from this vegetation database, we provided the first classification of the woodlands of the Huíla province (Chisingui et al. 2018) and a comparative assessment of above-ground biomass in the western miombo region (Sichone et al. 2018).

Study area

The database covers the entire territory of Huíla province located in the highlands of southwest Angola. The province is divided into 14 municipalities and has an area of 78,879 km^2. The region falls within the Dry Winter Temperate bioclimate (Cwb) according to the Köppen-Geiger classification, being predominantly characterized by a warm temperate climate with a dry winter (Kottek et al. 2006). Mean annual temperature varies between 18 and 20°C and mean annual precipitation varies from about 700 mm in the southwest to ca. 1000 mm in the east. The province is inhabited by approximately 2.4 million people, belonging to various ethnic groups, being the second most populated province of Angola, after the capital province of Luanda (INE 2016). Apart from agriculture and livestock, extractive industries and tourism are the principal socio-economic activities (CESO 2010). Barbosa (1970) described eight vegetation units within Huíla province, while Chisingui et al. (2018) recently reported 14.

Data collection

The database comprises data about the woody vegetation sampled in 448 vegetation plots, distributed in the five ecoregions which extend into Huíla (Dinerstein et al. 2017) (Figure 1).

Vegetation sampling was based on the plot design adapted from the BIOTA Biodiversity Observatories (Jürgens et al. 2012). Each plot had a rectangular design of 20

× 50 m with one 10 m × 10 m nested subplot in the centre (Figure 2).

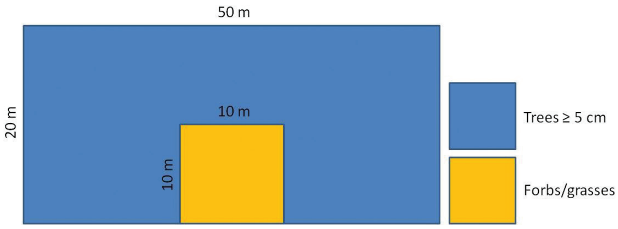

Figure 2. Plot design used in the vegetation surveys of the woodlands of Huíla province, note that we used the entire 1000 m² plot for tree measurements.

The vegetation relevés were carried out over approximately four years (2014–2018), mostly during the rainy season to ensure correct identification of plants, as many of the woody species in the region are deciduous. Since we had no a priori knowledge about the occurring woodland types (and associated plant communities), we aimed to standardise the sample coverage, trying to locate a comparable number of plots per municipality. Additionally, a slightly greater sampling effort was made in remote and sparsely populated areas, like Bicuar National Park, to integrate woody vegetation of little disturbed areas in our approach.

Plots were sited in areas of homogenous vegetation, the plots location was occasionally adjusted due to problems of accessibility, habitat fragmentation and dense or thorny vegetation. Plots were located at least 5 km apart, to minimize spatial autocorrelation and to capture spatial variation. In the entire 1000 m² plot, all tree species with DBH ≥ 5 cm were measured and identified on site to species or at least genus level, using the expertise on regional flora of the team members, and available field guides (Palgrave 2005). If on-site identification was not possible, a voucher was collected for identification at the Herbarium of Lubango [LUBA], based on other specimens deposited there, and on online resources (e.g. http://coicatalogue.uc.pt/; http://powo.science.kew.org/; http://theplantlist.org/; http://www.worldfloranoline.org/). Using the extended Braun-Blanquet cover-abundance scale (Dengler 2017), we estimated the cover for each woody as well as forb and grass species within the 100 m² subplot for the description of the overall plant community. Besides DBH, we also measured canopy height of the tallest and smallest tree using digital clinometers (Haglöf Vertex). Other environmental and site characteristics, including soil samples were also collected in each vegetation plot.

Database content

The vegetation-plot database of woody species from Huíla province **AF-AO-001** is registered at the GIVD – Global Index of Vegetation Databases (http://www.givd.info/ID/AF-AO-001). Overall, the database contains a total of 40,009 individuals of 193 tree species (incl. eight subspecies and five varieties), 40 tree taxa were only identified to genus, while 42 are yet to be confirmed. For consistency in the taxonomy of plants we used the Checklist of Angolan Plants as reference (Figueiredo and Smith 2008). To clean the data and to avoid any errors in the general database we used the "OpenRefine" tool (http://openrefine.org). To avoid misspelling of scientific plant names we standardized the names using the package "Taxonstand" version 2.2 (Cayuela et al. 2019) in R v3.4.3 (R Development Core Team 2021). Some tree species were preliminarily identified by their local names and we used various bibliographical sources to assign the scientific name (dos Santos 1972, Figueiredo and Smith 2012, Gonçalves et al. 2019). The family names followed mostly the African Plants Database (http://www.ville-ge.ch/musinfo/bd/cjb/africa/recherche.php). However, we decided in some cases to adopt recent changes in family assignments, in particular for *Aloe* – *Asphodelaceae*; *Cochlospermum* – *Bixaceae*; *Bridelia*, *Hymenocardia*, *Phyllanthus*, *Pseudolachnostylis*, and *Uapaca* – *Phyllanthaceae*; *Adansonia* and *Grewia* – *Malvaceae* and *Ptaeroxylon* – *Rutaceae*. Similarly, we adopted the most recent classification of the *Fabaceae* subfamilies (LPWG 2017).

The municipalities of Matala and Quipungo show fewer plot numbers, as most of their administrative territories falls within Bicuar National Park. The heavily fragmented woodlands in the municipality of Caluquembe made it difficult to allocate vegetation plots and are, thus, also represented by fewer plots. In Humpata woodlands are very patchy since geoxyle grasslands dominate vast areas, so that we only assessed the 100 m² subplots. A total of 44 families of vascular plants (including *Fabaceae* subfamilies) were recorded. The ten most dominant families in terms of individual records were: *Fabaceae*, subfamilies *Detarioideae* (58%), *Papilionoideae* (6%) and *Caesalpinioideae* (5%), followed by *Combretaceae* (13%), *Phyllanthaceae* (5%), and *Euphorbiaceae* (5%) other families showed only few individuals (Figure 3).

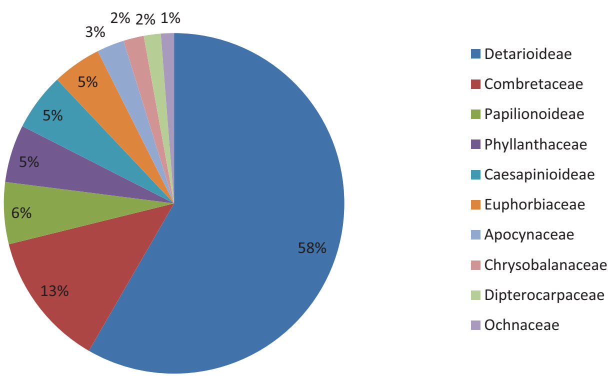

Figure 3. The ten most abundant families of vascular plants in the woodlands of Huíla.

Table 1. The ten most abundant woody species in terms of numbers of recorded individuals, including the families they belong to, municipalities in which they have been recorded and their respective mean DBH in cm plus Standard deviation (mean±sd).

Species (No. of Individuals)	Botanical family	Sites (municipalities)	DBH (cm)
Julbernardia paniculata (6691)	Detarioideae*	All municipalities, except in Gambos	11.5 ± 5.8
Brachystegia spiciformis (4547)	Detarioideae*	Except in Bicuar, Chicomba, Cuvango, Gambos, Humpata, and Matala	14.7 ± 10.6
Brachystegia longifolia (2259)	Detarioideae*	Except in Bicuar, Cacula, Chibia, Gambos, Humpata, and Matala	10.5 ± 5.2
Brachystegia boehmii (2133)	Detarioideae*	All municipalities	11.4 ± 6.1
Combretum collinum (1628)	Combretaceae	All municipalities	8.5 ± 4.1
Cryptosepalum exfoliatum subsp. *pseudotaxus* (1520)	Detarioideae*	Except in Bicuar, Cacula, Caluquembe, Chicomba, Gambos, Humpata, Matala, and Quipungo	9.2 ± 5.1
Colophospermum mopane (1369)	Detarioideae*	Recorded in Chibia, Gambos and Quilengues only	12.3 ± 8.4
Spirostachys africana (1222)	Euphorbiaceae	Except in Caconda, Caluquembe, Chicomba, Chipindo, Cuvango, Jamba, Matala, and Quipungo	9.6 ± 6.2
Pteleopsis anisoptera (1010)	Combretaceae	All municipalities, except in Caconda	9.4 ± 5.4
Diplorhynchus condylocarpon (930)	Apocynaceae	Recorded in all municipalities, except in Gambos, Humpata, and Matala	11.4 ± 9.4

*refers to the subfamily (*Detarioideae*) of the larger *Fabaceae* family.

Trees belonging to the *Fabaceae* subfamily *Detarioideae* were the most frequent across the sites. *Brachystegia spiciformis* exhibited the highest mean DBH, while *Combretum collinum* had the lowest mean DBH (Table 1).

Tree species richness calculated from the total number of taxa per municipality varied between 32 in Matala and 126 in Quilengues. The overall Shannon-Wiener diversity index (H'), calculated from the abundance of tree species per municipality, revealed also highest diversity of tree species in the municipality of Quilengues compared to others. The exceptional diversity of tree species found in Quilengues can be explained by the fact that this municipality includes parts of four important ecoregions and, thus, harbours many different vegetation units and species (Table 2).

Table 2. Overview of the study sites (the 14 municipalities and Bicuar NP), number of plots per site, total number of individuals, number of taxa and diversity (H') calculated from the abundance of tree species.

Municipalities	No. of plots	Taxa	No. Individuals	Shannon diversity (H')
Bicuar National Park	34	53	1782	2.71
Caconda	20	63	2760	2.54
Cacula	36	94	1744	3.15
Caluquembe	16	69	1498	3.08
Chibia	40	100	3124	3.29
Chicomba	20	78	2858	2.83
Chipindo	80	103	9465	2.93
Cuvango	34	86	4187	2.68
Gambos	30	57	2547	2.42
Humpata	15	60	1109	2.43
Jamba	30	51	2940	2.57
Lubango	31	99	2367	3.23
Matala	9	31	619	2.64
Quilengues	39	125	2690	3.79
Quipungo	14	56	714	2.85

It is a well-known phenomenon that the species richness increases with increasing sampling effort. This is particularly true for the municipality of Chibia for instance. However, in some places like Caluquembe also exhibited high-species richness, although the number of plots was lower due to fragmentation, caused by expanding agriculture. The influence of habitat fragmentation on biodiversity has been discussed by ecologists for a long time (Fahrig 2003). Recent studies indicate that habitat loss and fragmentation may have complex effects on species diversity, suggesting that variation in species diversity can be influenced by the total amount of habitat (Rybicki et al. 2020). Aguirre-Gutiérrez (2014) argues that the effect of fragmentation is dependent on the vegetation type and that these are not strongly related to species richness and diversity. From our point of view, the high species richness observed in Caluquembe can also be related to vegetation plots covering forest patches of the scarp savanna and woodlands ecoregion, considered of high diversity of vegetation types and significant levels of endemism (Goyder and Gonçalves 2019).

The mean DBH in the vegetation plots was 10.9 cm (±7.5), ranging from 5 cm to 218.7 cm. Small-size classes are increasingly dominated by few species, the five most dominant tree species are different for each size class, except for *Julbernardia paniculata* and *Brachystegia spiciformis*, which occur everywhere and in every size class (Figure 4). In general key-species of miombo woodlands were the most dominant trees across size classes, only interrupted by the presence of *Baikiaea plurijuga* and *Colophospermum mopane* in the intermediate and larger size classes. Size classes (+50 cm) were mostly dominated by individuals of *Brachystegia spiciformis* recorded in Gambos and Quilengues, and *Diplorhynchus condylocarpon* together with *Adansonia digitata* all from the woodlands of Quilengues, *B. plurijuga*, recorded only in the less disturbed areas of Bicuar and Gambos, exhibited also larger diameter.

Conclusion

The Huíla vegetation plot database (AF-AO-001) represents the first plot-based dataset of woody species in Huíla province. It comprises information from all 14 municipal-

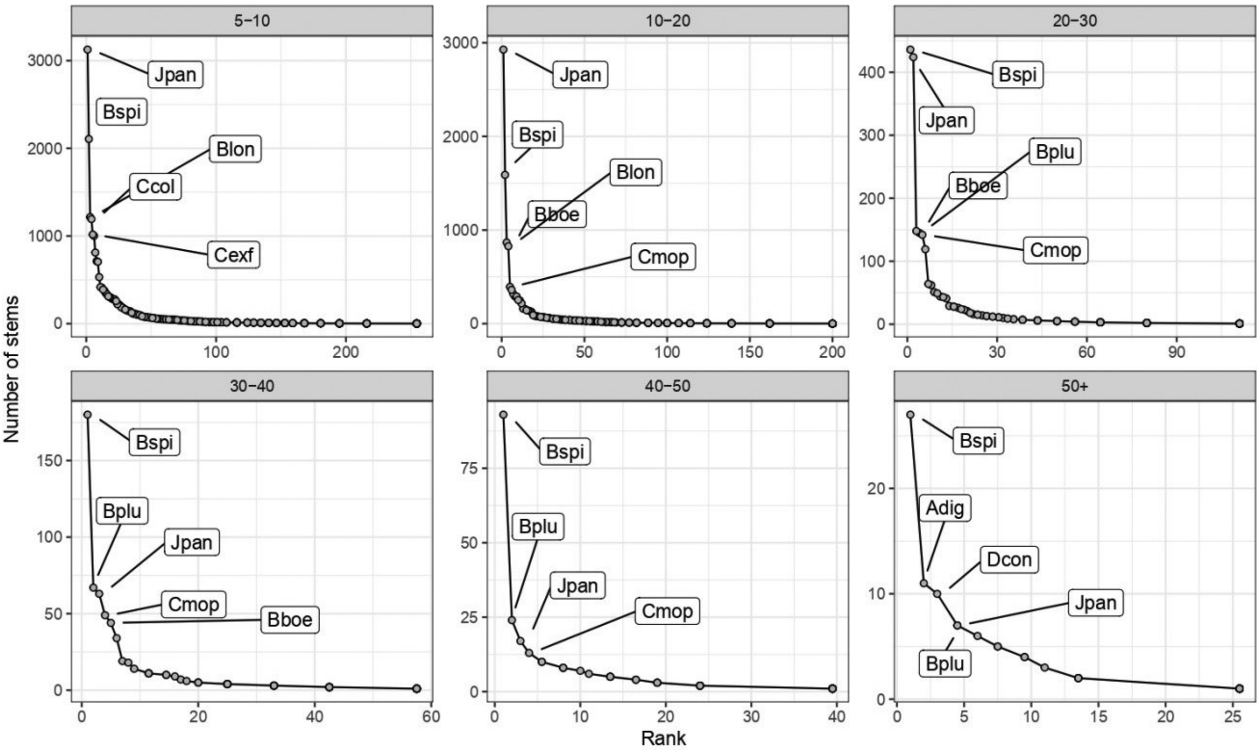

Figure 4. Rank abundance curve for the ten most abundant tree species per size class, as shown on the curves by their abbreviaton: *Adansonia digitata* (Adig), *Baikiaea plurijuga* (Bplu), *Brachystegia boehmii* (Bboe), *B. longifolia* (Blon), *B. spiciformis* (Bspi), *Colophospermum mopane* (Cmop), *Combretum collinum* (Ccol), *Cryptosepalum exfoliatum* subsp. *pseudotaxus* (Cexf), *Diplorhynchus condylocarpon* (Dcon) and *Julbernardia paniculata* (Jpan).

ities and Bicuar National Park. The information provided here constitutes a useful tool for management and conservation actions and may serve as a baseline for subsequent studies to analyse biodiversity patterns and assess changes in vegetation.

Future perspectives

This database may also provide the foundation for the elaboration of an envisaged vegetation map of this region. In addition to this work, we intend to explore additional information related to shrub and herbaceous plants, based on the identification of the botanical vouchers, field notes and photograph records collected during the field campaigns, to produce a preliminary checklist of the vascular plants of Huíla. The database of woody species from Huíla province may also be used for comparable studies with other plot data, using the same standard sampling plots in the African continent.

Authors contribution

F.M.P.G. conducted field work (incl. data collection, collection and identification of plants), conceptualized the MS and provided overall supervision to assure the quality of the database. A.V.C. conducted field work, project and database management. J.C.L. and M.F.F.R. conducted field work, conception and curation of the database. J.J.T. conducted field work combined with plant identification, J.L.M.A. helped with the conceptual design of the manuscript. H.D.J., I.M.C.C., B.R.B., M.D.G.C. and M.J.C. did field work and data collection. S.K.A.M. participated in the conceptualization and curation of the database. M.F. and P.M. helped with data collection in Bicuar National Park and with data analysis, N.J. contributed to study design, R.R. participated in field work in the municipalities of Cuvango and Jamba. All authors critically revised the final manuscript.

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