

Research Article

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Checklist of Woody Plants Species and Their Uses in The Miombo Woodlands Of Western Zambia

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Received Date: July 12, 2019

Published Date: July 19, 2019

Abstract

Woody plant species were inventoried in the Miombo Woodlands of western Zambia. The checklist is based on a vegetation survey using vegetation plots of 1,000 m² and also includes records from botanical collections made elsewhere at the study site. 135 woody species belonging to 44 families were identified and presented according to their life form, places of occurrence, collection number(s) and uses. The Fabaceae family was most species rich (35 species). Woody under-growths were the most represented life form (81%). The majority of species identified had multiple uses, but none of the species are listed on the Plant Red Data List for Zambia. This study fills a gap for local plant species inventories in this region.

Keywords: Species occurrence; Threat status; Useful woody species; Vegetation surveys

Introduction

Woodlands in Africa are diverse vegetation formations [1] and sub-Saharan Africa holds centers of high plant species richness such as the mesic Miombo of south-central Africa [2]. Earlier efforts by White [3] documented the taxonomy of the flora of Northern Rhodesia (Zambia) and provided a checklist that comprised 1400 indigenous species and 250 introduced species. A more recent checklist of vascular plants in Zambia by Phiri [4] recorded a rich flora particularly in herbaceous and woody plants with 161 Pteridophytes, 2 Gymnosperms, 171 Monocotyledons and 4,046 Dicotyledons. This rich plant diversity is under threat through selective harvesting of valuable timber and deforestation. Consequently, with the deforestation rate of 1.5% per year Zambia is classified as one of the countries with high deforestation [5]. A key driver of this deforestation is the high demand for woodlands products, which in Zambia contributed already in 2005 5.2% to the total Gross Domestic Product [6]. Deforestation and selective timber harvesting vary geographically within Zambia. Deforestation rates range from 0.2% in Southern Province to 2.47% in Luapula Province [7]. Knowledge of the flora of a given area, its distribution and use, is an essential prerequisite to sound land-use policy in the management of biodiversity. Local or regional plant species

inventories and checklists that record the current state of the flora provide important baseline information for conservation and monitoring plans. Woodland plant inventories can therefore provide fundamental information for the assessment and prioritization of management measures towards woodland conservation. However, the published records of local or regional plant checklists southern Africa still need to be updated as large areas remain unexplored to date not only in Zambia but also other southern African countries [8-10].

From the literature cited above, there have been knowledge gaps in documenting species at the local level in Zambia. In this study, we provided a checklist of woody plant species at three sites (Luampa, Dongwe and Kafue) of the Miombo Woodlands of western Zambia.

Methods and Materials

Study site

The study sites Dongwe, Luampa and Kafue (Figure 1) in western Zambia are characterised by the tropical sub-humid climate with alternating dry and wet seasons [8], a mean annual temperature of 20.8 °C [11,12] and annual rainfall ranging from 875 to 990mm [13].

The landscape of western Zambia consists of an extensive sand-covered Pliocene plain whose recent geomorphological history has considerable bearing on the soil and vegetation of the area [14]. The soils consist of Kalahari Sands from the Tertiary to the recent period which according to JAICAF [15] covers the western and north-western Zambia. The classification of the main soil types

of western Zambia was described by the Survey Department of the Government of Zambia [16]. According to the classification scheme [16], these Kalahari Sands are Aerosols and Podzols, a formation of the parent Basement and Katanga rocks, with the accumulation of Karoo deposits (Figure 1).

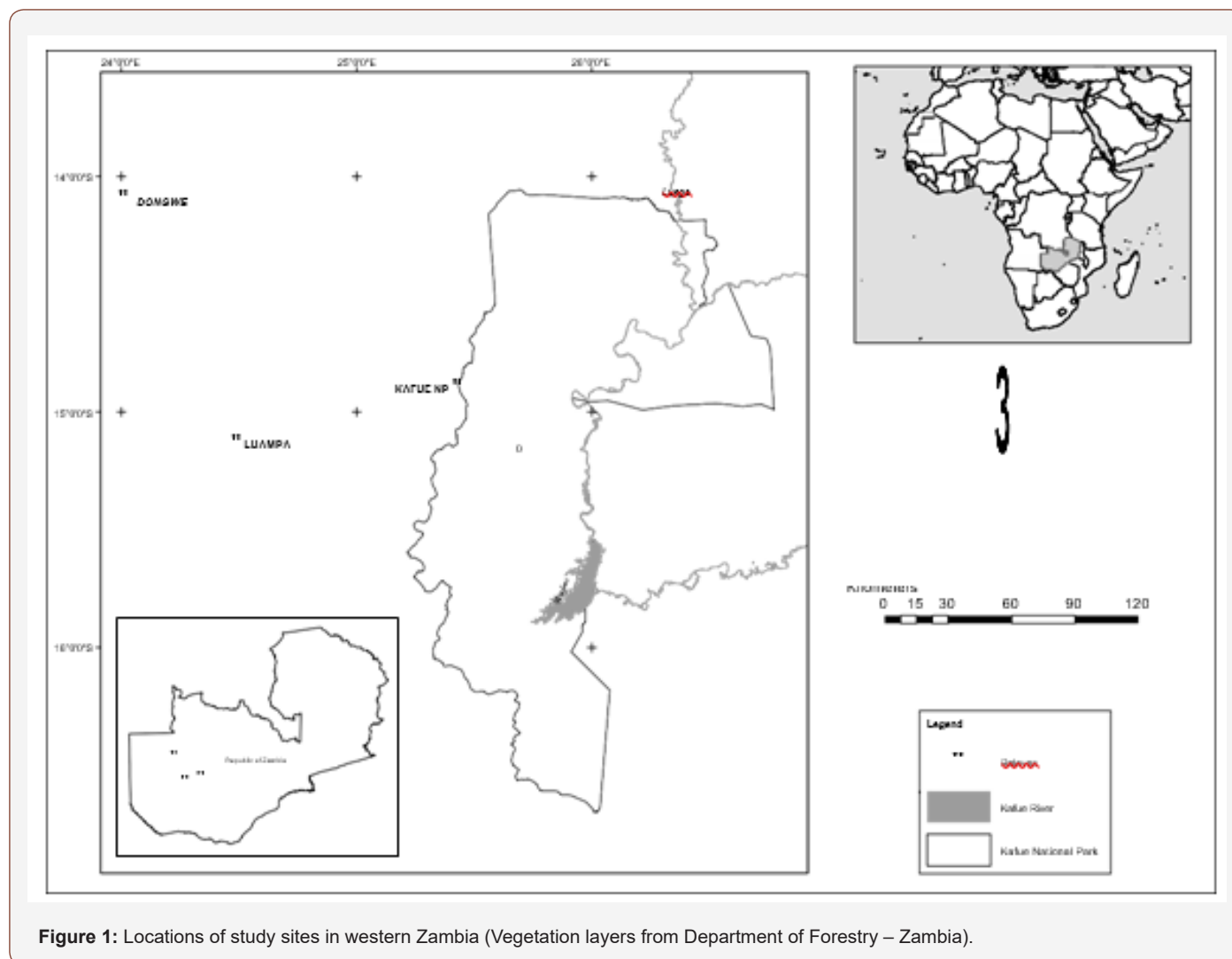


Figure 1: Locations of study sites in western Zambia (Vegetation layers from Department of Forestry – Zambia).

The study area falls within the vegetation zone of the Miombo Woodlands sensu White [17]. The Miombo Woodlands is dominated by tree species of the genera *Brachystegia* Benth., *Isoberlina* Craib & Stapf ex Holland. and *Julbernardia* Pellegr. of the family Fabaceae clustered in the subfamily Caesalpinioideae and the tribe Ahmerstieae [4,18,19]. It covers a vast area of about 3.6 million km² in southern and eastern Africa, encompassing ten countries namely: Angola, Botswana, Congo Democratic Republic, Malawi, Mozambique, Tanzania, Zambia and Zimbabwe [20].

Study design

This study was carried out as part of the ObservationNet (www.ObservationNet.org) activities of the “Southern African Science Service Centre for Climate Change and Adaptive Land Management” (SASSCAL; www.sasscal.org). One of the aims of the ObservationNet is to collect phytodiversity data (i.e. data on the diversity of plant

species in an area) through standardised biodiversity assessments within the southern African region and to monitor their changes over time.

The spatial layout of the sites followed the standards of the Biodiversity Observatories [21,22]. Based on a preliminary survey of vegetation types through searches of literature and the most recent Google Earth images, three Biodiversity Observatories of 1 km² in size were selected, situated approximately 100km apart in Luampa, Dongwe and Kafue National Park (Figure 1). The Observatories of 1 km² were divided into a grid of 100 hectares. In the centers of 20 randomly selected hectares, plots of 1000 m² (20m x 50m) in size were laid out. These plots were sampled during the rainy seasons (March–May) of 2014 and 2015. During both of these sampling seasons, the annual rainfall was 70% of the mean annual precipitation that ranges between 875 and 990 mm for the study area (www.earth-observation-monitor.net/map).

Data collection

For each of the plots, we recorded the presence and abundance of individuals per woody plant species. The abundance of species was assigned according to the number of individuals of each species observed in total: rare (1 or 2), occasional (3–5), frequent (6–10), and common (>11) species. Specimens were identified using morphological characteristics which included the vegetative parts, the flowers, and the fruits. Preliminary species identification was done first directly in the field using relevant field guides [3,23-26] and taxonomic studies [27-29] and finally confirmed at the herbarium of University of Zambia. Based on an arrangement with the herbarium of the University of Zambia (UZL) holotype and lectotype specimens were used for identification.

The specimens were dried and mounted following the routine herbarium practices 32. Plant nomenclature followed Phiri 4 for the majority of the identifications while in cases of ambiguity the Flora of Zambia (www.zambiaflora.com), the Global Plants JSTOR (www.plants.jstor.org) and The Plant List (www.theplantlist.org) were referred to. Voucher specimens were lodged at the Herbarium Hamburgense of the University of Hamburg (HBG) and duplicates will be deposited at the herbarium of the University of Zambia (UZL).

Results

Florist diversity

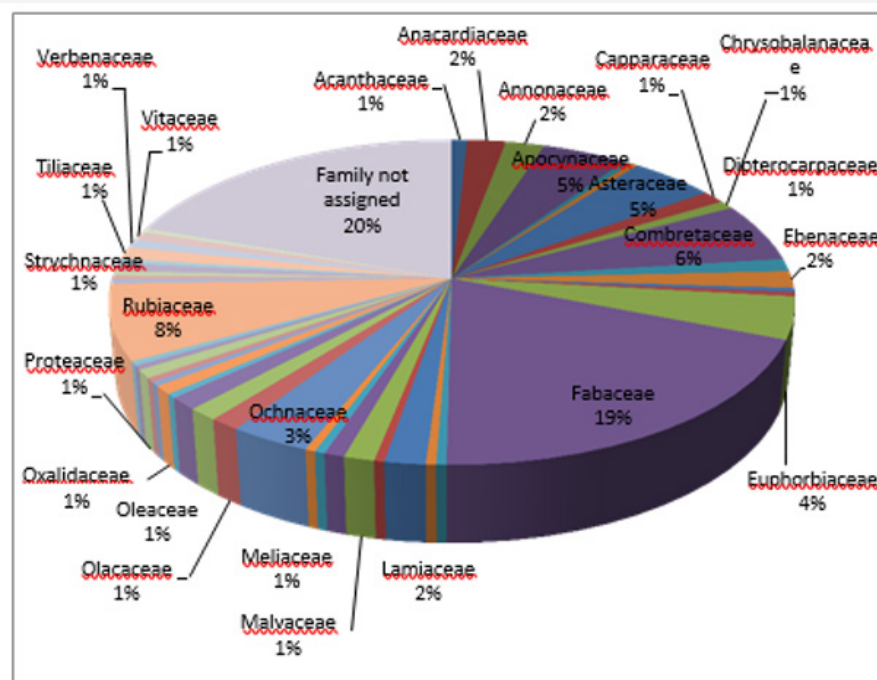


Figure 2: An illustration of the families identified in the three Observatories with the six families with the most recorded species indicated.

A total number of 239 woody plants species from 44 plant families were recorded for the three sites. Of the recorded species, 135 species were identified to species level with the remaining identified either to genus, family or morphotype (i.e., plants of identical morphology) level. The morphotypes that were not

The list of families presented in this study was arranged according to the Linear Angiosperm Phylogeny Group (LAPG) III (Haston et al. 2009), while subfamilies, genera, and species are arranged alphabetically within the families. Local names and uses were compiled based on information provided by local people and literature sources. The life forms considered in this study were trees = woody plants taller than 0.5m, shrubs = woody plants with a height between 0.25 - 0.5m, shrub/trees = woody plants that in some observations were between 0.25 - 0.5 m in height and in others taller than 0.5 m and belonged to the same species, dwarf shrubs = plants whose shoots are either woody or herbaceous and have a height below 0.25m, lianas = plants whose shoot system climbs or lies relatively flat on the ground surface and geoxyles = plants with reduction of the complete shoot system to storage organs that are imbedded in the soil. The different uses were coded as TI = timber production, PO = posts, pole and roundwood, WO = fuelwood and charcoal, PU = pulp and paper production, FD = fodder, FO = food, NW = other non-timber products (gums, medicines, dyes, tanning, etc.), AE=aesthetic and ethical values.

In order to undertake the field sampling and collection of specimens a permit was granted by the Zambia Wildlife Authority to conduct research on and collect voucher specimen of flora with permit number NP/8/27/1.

Asteraceae (5%) and Apocynaceae (5%). In terms of life forms, the woody under-growths (i.e., shrubs, dwarf shrubs, shrubs/trees) of the woodlands consisting of plants between below 0.25 and 0.5 meters in height represented the most common life form (81% of the species). Of the recorded woody under-growths group 39% of the species represented woody under-growths, 23% shrubs/trees and 19% dwarf shrubs (Table 1). About 46% of the species occurred occasionally, i.e., only 1 to 2 plants have been recorded for all plots. Among the all woody species only *Julbernardia paniculata* (Benth.) Troupin, *Brachystegia spiciformis* Benth., *B. boehmii* Taub., *Cryptosepalum exfoliatum* subsp. *pseudotaxus* De Wild

and *Guibourtia coleosperma* (Benth.) J.Leonard were commonly occurring (i.e., occurred at >10 recordings). These common species were also observed in all three study sites except for *C. exfoliatum* subsp. *pseudotaxus* (Figure 2).

A total of 101 of the woody species in the study were found to be locally useful either for non-timber products, fuelwood, timber production or other purposes as described in more detail below. Of the uses established, about 75% of these species are used in non-timber products as gums, medicines, dyes, tanning and many more (Table 1).

Table 1: List of woody plant species, their life form, collection number and location, arranged according to families.

Species Name	Life Form	Abundance	Uses	Voucher Number	Plate No.	Location
Acanthaceae						
<i>Duosperma quadrangulare</i> (Klotzsch) Brummitt	Shrub	rare	FO	138076		K
<i>Hypoestes forskalii</i> (Vahl) R.Br.	Shrub	rare		132148		K
Amaryllidaceae						
<i>Crinum macowanii</i> Baker	Shrub	rare	NW	132141		L, K
Anacardiaceae						
<i>Searsia quartiniana</i> A. Rich.	Shrub	Frequent	FO	131071, 142196	6c	L, D
<i>Sclerocarya birrea</i> (A.Rich.) Hochst.	Tree	rare	FO	132128		K
Annonaceae						
<i>Friesodielsia obovata</i> (Benth.) Verdc.	Shrub/Tree	occasional	FO, FD	142610		K
<i>Uvariastrum hexaloboides</i> (R.E.Fr.)	Shrub/Tree	occasional	FO	132107		L, K
<i>Xylopi odoratissima</i> Welw. ex Oiv.	Shrub	common	NW	131181	6d	L, D
Apocynaceae						
<i>Diplorhynchus condylocarpon</i> (Müll. Arg.) Pichon	Shrub/Tree	common	NW	140121		D, L, K
<i>Landolphia parvifolia</i> K. Schum.	Liana	frequent	FO	142505	6a, b	D, L
<i>Strophanthus welwitschii</i> (Baill.) K. Schum.	Liana	occasional		142649		D
Asparagaceae						
<i>Asparagus racemosus</i> Willd.	Dwarf shrub	occasional		142788		K
Asphodelaceae						
<i>Bulbine abyssinica</i> A.Rich.	Dwarf shrub	rare	NW	131355, 132214		D, K
Asteraceae						
<i>Conyza gouanii</i> (L.) Willd.	Dwarf shrub	occasional	NW	132207		K
<i>Crassocephalum rubens</i> (Jacq.) S. Moore	Dwarf shrub	rare	NW	131301	4b	K
<i>Dicoma anomala</i> Sond.	Dwarf shrub	occasional		138099		K
<i>Elephantopus scaber</i> L.	Dwarf shrub	frequent		131119	4a	D, L, K
<i>Erythrocephalum zambesianum</i> Oliv. & Hiern	Dwarf shrub	frequent	NW	142503		L, K
<i>Felicia welwitschii</i> (Hiern) Grau	Dwarf shrub	rare		142698		D
<i>Macledium poggei</i> (O.Hoffm.) S.Ortiz	Dwarf shrub	rare		142660		K
<i>Pleiotaxis eximia</i> O. Hoffm.	Dwarf shrub	occasional	NW	142665	4c	L, K
<i>Vernonia glabra</i> ssp. <i>laxa</i> (Seetz) Vatke	Dwarf shrub					L, K
<i>Vernonia melleri</i> Oliv. & Hiern	Dwarf shrub	occasional		131401		L
<i>Vernonia petersii</i> Oliv. & Hiern ex Oliv.	Dwarf shrub	frequent	FD	142678		L, K
<i>Vernonia poskeana</i> Vatke & Hildebr.	Dwarf shrub	rare		131157		L
Capparaceae						
<i>Capparis tomentosa</i> Lam.	Dwarf shrub	frequent	NW, FO, AE	138093		K
<i>Cleome hirta</i> (Klotzsch) Oliv.	Dwarf shrub	frequent		138076		K
<i>Maerua triphylla</i> ssp. <i>pubescens</i> A. Rich. (Klotzsch) DeWolf	Dwarf shrub	frequent		131358		K

Chrysobalanaceae						
<i>Parinari capensis</i> Harv.	Dwarf Shrub/ Geoxyle	frequent	NW, FO		7a	L
<i>Parinari curatellifolia</i> Planch. ex Benth.	Tree	frequent	NW, FO, WO	131213		L, K
Combretaceae						
<i>Combretum collinum</i> Fresen.	Tree	occasional	NW, TI	131113		D, L, K
<i>Combretum elaeagnoides</i> Klotzsch	Shrub/Tree	occasional		131403		D, L
<i>Combretum molle</i> R.Br. ex G.Don	Shrub/Tree	frequent	NW, TI	142578		D, L, K
<i>Combretum psidioides</i> Welw.	Shrub/Tree	occasional	NW	131402	7c, d	D
<i>Combretum zeyheri</i> Sond.	Shrub/Tree	common	NW, WO, NW	131183		L, K
<i>Pteleopsis anisoptera</i> (Welw. ex M.A.Lawson) Engl. & Diels	Tree	occasional	TI, WO	1320102	7e	D
<i>Terminalia brachystemma</i> Welw. ex Hiern	Tree	occasional	NW, FO, WO	131165		L, K
Commelinaceae						
<i>Cyanotis longifolia</i> Benth.	Dwarf shrub	frequent		131016		D, L, K
Dipterocarpaceae						
<i>Marquesia macroura</i> Gilg	Tree	occasional		140121		K
Gilg	Tree	occasional		132222		K
<i>Monotes glaber</i> Sprague	Tree	occasional	NW, WO	142639, 141189	7f	L
Ebenaceae						
<i>Diospyros batocana</i> Hiern	Tree	common	NW, FO, PU	140159	8a	D, L, K
<i>Diospyros mespiliformis</i> Hochst. ex A.DC.	Tree	frequent	NW, FO			K
<i>Diospyros virgata</i> (Gürke) Brenan	Dwarf Shrub/ Geoxyle	common	NW	131054, 131191, 140143		D, L, K
Ericaceae						
<i>Cleistanthus polystachyus</i> Hook. f. ex Planch.	Shrub	rare		132122		L
Erythroxylaceae						
<i>Erythroxylum emarginatum</i> Thonn.	Shrub/Tree	occasional		142649		K
Euphorbiaceae						
<i>Acalypha ornata</i> Hochst. ex A. Rich.	Shrub	occasional		132101		L
<i>Flueggea virosa</i> (Roxb. ex Willd.) Voigt	Shrub/Tree	occasional	NW, FO	142566		L, K
<i>Hymenocardia acida</i> Tul.	Shrub/Tree	common	NW	142526	D, L, K	
<i>Maprounea africana</i> Müll.Arg.	Shrub/Tree	frequent	NW			L
<i>Oldfieldia dactylophylla</i> (Welw. ex Oliv.) Léonard	Shrub/Tree	frequent		142693		D
<i>Pseudolachnostylis maprouneifolia</i> Pax	Tree	common	NW, FO	140131, 131047		D, L, K
<i>Sclerocroton oblongifolius</i> (Müll. Arg.) Kruijt & Roebers	Dwarf shrub	rare	NW	131056, 142172, 135679	8b	L, K
<i>Uapaca kirkiana</i> Müll. Arg.	Tree	occasional	NW, FO	142817		D, K
<i>Uapaca nitida</i> ssp. Nitida	Tree	occasional	NW, FO			L, K
Fabaceae						
<i>Azelia quanzensis</i> Welw.	Tree	frequent	NW, FO, TI, WO	131163		L, K
<i>Albizia antunesiana</i> Harms	Shrub/Tree	frequent	NW, WO	142766		D, L, K
<i>Albizia versicolor</i> Welw. ex Oliv.	Shrub/Tree	common	NW, WO	132156		D, K
<i>Anisophyllea boehmii</i> Engl.	Tree	occasional	NW, FO	132216		K
<i>Baphia massaiensis</i> var. obovata Taub.	Shrub/Tree	common	NW, FO, FD	131007	2c, d	D, L, K
<i>Bauhinia petersiana</i> Bolle	Shrub/Tree	frequent	NW, FO, FD	142520	1e, f	D, L, K
<i>Bobgunnia madagascariensis</i> (Desv.) J.H.Kirkbr. & Wiersema	Tree	common	NW, FO, TI	131191	2e	L, K
<i>Brachystegia boehmii</i> Taub.	Tree	common	TI, WO, PO, NW			D, L, K
<i>Brachystegia spiciformis</i> Benth.	Tree	common	TI, WO, PO, NW	131146		D, L, K

<i>Burkea africana</i> Hook.	Tree	common	WO, PO, NW		1c	D, L, K
<i>Cassia abbreviata</i> Oliv.	Shrub/Tree	occasional	NW	142622		K
<i>Chamaecrista mimosoides</i> (L.) Greene	Dwarf shrub	occasional	NW	131025, 142559	1j	D, K
<i>Copaifera baumiana</i> Harms	Shrub/Tree/ Geoxyle	common	NW	131085	1d	L, K
<i>Crotalaria alexandri</i> Baker f.	Dwarf shrub	occasional		142576		L, K
<i>Crotalaria anisophylla</i> (Hiern) Welw. ex Baker f.	Dwarf shrub	occasional		142774		L
<i>Crotalaria caudata</i> Welw. ex Baker	Dwarf shrub	occasional		131176		D, L
<i>Crotalaria cephalotes</i> Steud. ex A.Rich.	Dwarf shrub	occasional	NW	132180	2f	K
<i>Crotalaria laburnifolia</i> L.	Dwarf shrub	common		142570		K
<i>Crotalaria microcarpa</i> Hochst. ex Benth.	Dwarf shrub	rare		131099		D, L
<i>Cryptosepalum exfoliatum</i> ssp. <i>pseudotaxus</i> De Wild.	Tree	common	TI, NW, PO, NW, WO	142504	1a, b	D
<i>Dichrostachys cinerea</i> (L.) Wight & Arn.	Shrub/Tree	common			3a, b	D, L, K
<i>Erythrophleum africanum</i>	Tree	common	WO, PO, NW	131124	1g, h	D, L, K
<i>Guibourtia coleosperma</i> (Benth.) J.Leonard	Tree	common	TI, NW,	140151		D, L
<i>Indigofera demissa</i> Taub.	Dwarf shrub	occasional		131174		D, L
<i>Indigofera flavicans</i> Baker	Dwarf shrub	common		131130		L, K
<i>Isoberlinia angolensis</i> (Benth.) Hoyle & Brenan	Tree	occasional	TI, NW, AE			K
<i>Julbernardia paniculata</i> (Benth.) Troupin	Tree	common	TI, WO, PO, NW, FD	140155		D, L, K
<i>Keetia venosa</i> (Oliv.) Bridson	Tree	occasional		142561		K
<i>Lannea edulis</i> (Sond.) Engl.	Shrub/Tree	frequent	NW	131178		L, K
<i>Mucuna poggei</i> Taub.	Shrub/liana	occasional	NW	142564		K
<i>Pericopsis angolensis</i> (Baker) Meeuwen	Tree	occasional	TI, WO, NW, FD	138072		L, K
<i>Piliostigma thonningii</i> (Schumach.) Milne-Redh.	Shrub/Tree	occasional				K
<i>Pterocarpus angolensis</i> DC.	Tree/Geoxyle	common	TI, WO, NW		2a, b	D, L, K
<i>Rhynchosia caribaea</i> (Jacq.) DC.	Shrub/Tree	occasional	NW	131195		L, K
Flacourtiaceae						
<i>Flacourtia indica</i> (Burm.f.) Merr.	Shrub/Tree	frequent	NW, FO	131198		K
Hypericaceae						
<i>Psorospermum baumii</i> Engl.	Shrub/Tree	occasional	NW, FO	131162	7b	D
Lamiaceae						
<i>Ocimum africanum</i> Lour.	Shrub	rare				K
<i>Tinnea vestita</i> Baker	Dwarf shrub	occasional	NW, FO	131021, 142739		L, K
<i>Vitex doniana</i> Sweet	Shrub/Tree	occasional	TI, FO, NW, FD	140154	8c, d	L
<i>Vitex madiensis</i> Oliv. subsp. <i>Milanjiensis</i> (Britten) F. White	Shrub/Tree	rare		142638		L
Lauraceae						
<i>Cassytha pondoensis</i> ssp. <i>Pondoensis</i> Engl.	Shrub/Liana	occasional	NW	131134	5f	D, L
Malvaceae						
<i>Abutilon angulatum</i> (Guill. & Perr.) Mast.	Shrub/Tree	occasional	NW	142504		D
<i>Pavonia senegalensis</i> (Cav.) Leistner	Shrub/Tree	rare		131268		D, L
Meliaceae						
<i>Bersama abyssinica</i> Fresen.	Shrub/Tree	rare	NW, AE	142874		K
<i>Trichilia emetica</i> Vahl	Tree	rare	NW, AE			K
Myrtaceae						
<i>Syzygium guineense</i> (Willd.) DC.	Shrub/Tree	occasional	NW, FO	142200		L
<i>Ochna pulchra</i> Hook.	Shrub/Tree	common	NW	131059		D, L, K
Olacaceae						
<i>Olax obtusifolia</i> De Wild.	Shrub/Tree	occasional		142598		L

<i>Ximena americana</i> L.	Shrub/Tree	frequent	NW, FO	142523		L, K
<i>Ximena caffra</i> Sond.	Shrub/Tree	frequent	NW, FO	131047		K
Oleaceae						
<i>Olea capensis</i> L.	Shrub/Tree	occasional		138065		K
<i>Schrebera trichoclada</i> Welw.	Tree	rare		144524		L, K
Orobanchaceae						
<i>Striga asiatica</i> (L.) Kuntze	Dwarf shrub	occasional	NW	138077		L, K
Oxalidaceae						
<i>Biophytum abyssinicum</i> Steud. Ex A. Rich.	Dwarf shrub	occasional	NW		8f	D
<i>Biophytum umbraculum</i> Welw.	Dwarf shrub	occasional		131098		D, L
Passifloraceae						
<i>Paropsia brazzeana</i> Baill.	Shrub/Tree	frequent	NW	131080	8g	D, L, K
Polygalaceae						
<i>Securidaca longepedunculata</i> Fresen.	Tree	occasional	NW	131204		L
Proteaceae						
<i>Protea angolensis</i> Welw.	Tree	rare	NW	142795		K
<i>Protea gaguedi</i> J.F. Gmel.	Tree	frequent	NW			K
Ranunculaceae						
<i>Clematis chrysoarpa</i> Welw. ex Oliv.	Dwarf shrub	occasional		131351, 142755, 142609		L, K
Rhamnaceae						
<i>Ziziphus mucronata</i> Willd.	Shrub/Tree	occasional	FO, NW			K
Rubiaceae						
<i>Agathisanthemum bojeri</i> Klotzsch	Shrub/Tree	occasional	NW	142781		L, K
<i>Fadogia cienkowskii</i> Schweinf.	Shrub/Tree	occasional		142191		L
<i>Gardenia ternifolia</i> Schumach. & Thonn.	Shrub/Tree	occasional	NW, FO	132132		D
<i>Pavetta schumanniana</i> F. Hoffm ex K. Schum	Shrub/Tree	frequent		142749		D, K
<i>Rothmannia engleriana</i> (K.Schum.) Keay	Shrub/Tree	frequent	NW	131196	5c, d	D, L
<i>Spermacoce pusilla</i> Wall.	Shrub/Tree	occasional		131100		D, L
<i>Tricalysia longituba</i> De Wild.	Shrub/Tree	occasional		131255		L, K
<i>Vangueriopsis lanciflora</i> (Hiern) Robyns	Shrub/Tree	frequent	NW, WO	131180	5a, b	D, L
Sapindaceae						
<i>Zanha africana</i> (Radlk.) Exell	Shrub/Tree	occasional	WO	142751		K
Sapotaceae						
<i>Englerophytum magalismontanum</i> (Sond.) T.D.Penn.	Shrub	occasional	NW	131079	5e	D, L
Solanaceae						
<i>Solanum mauritianum</i> Scop.	Dwarf shrub	occasional				K
Strychnaceae						
<i>Strychnos cocculoides</i> Baker	Tree	frequent	NW, FO, AE, PO	131083	8h	D, L, K
<i>Strychnos pungens</i> Soler.	Shrub/Tree	frequent	NW, FO	140149		D, L, K
Thelypteridaceae						
<i>Christella chaseana</i> (Schelpe) Holttum	Dwarf shrub	occasional				D
Tiliaceae						
<i>Grewia flavescens</i> Juss.	Shrub	occasional	NW, FO	131013		D, L, K
<i>Triumfetta annua</i> L.	Dwarf shrub	occasional		131109		L, K
Verbenaceae						
<i>Endostemon obtusifolius</i> (E. Mey. ex Benth.) N.E.Br.	Dwarf shrub	occasional				D, L
<i>Lantana angolensis</i> Moldenke	Shrub	occasional	NW, FO, FD	142644	8e	L, K
Vitaceae						
<i>Cyphostemma junceum</i> Wild & R.B. Drumm.	Shrub/Liana	frequent	NW, FO	132169		D

<i>Cyphostemma princeae</i> Wild & R.B. Drumm	Shrub/Liana	frequent	NW, FO	131382		D, L, K
Zingiberaceae						
<i>Aframomum alboviolaceum</i> (Ridl.) K.Schum.	Shrub	occasional	NW, FO	4d		D

Abundance was assigned according to the frequency of observations of each wood plant species: rare (1 or 2 recordings), occasional (3–5 recordings), frequent (6–10 recordings) and common (>11 recordings) species. The locations where these species occurred in the study sites were abbreviated L = Luampa, D = Dongwe and K = Kafue National Park. The different uses were coded as TI = timber production, PO = posts, pole and Roundwood, WO = fuelwood and charcoal, PU = pulp and paper production, FD = fodder, FO=food, NW = other non-wood products (gums, medicines, dyes, tanning, etc.), AE = aesthetic and ethical values.

Owing to the rainy season when the field work was done, only some species had flowering and fruiting parts for identification while the rest were identified using vegetative parts, illustrated in

the Plates 1–8. With regard to the conservation status of the species, none of the recorded species are listed on the Plant Red Data List for Zambia [8] (Plates 1-8).



Plate 1: Some species found in the Miombo Woodlands of western Zambia from family Fabaceae subfamily Caesalpinioideae: (a)&(b) *Cryptosepalum exfoliatum* subsp. *pseudotaxus*; (c) *Burkea africana*; (d) *Copaifera bauhimiana*; (e)&(f) *Bauhinia petersiana*; (g)&(h) *Erythrophleum africanum*; (i)&(j) *Chamaecrista mimosoides*.



Plate 2: Some species found in the Miombo Woodlands of western Zambia from family Fabaceae subfamily Papilionioideae: (a)&(b) *Pterocarpus angolensis*; (c)&(d) *Baphia massaiensis*; (e) *Bobgunnia madagascariensis*; (f) *Crotalaria cephalotes*.



Plate 3: Some species found in the Miombo Woodlands of western Zambia from family Fabaceae subfamily Mimosoideae: (a)&(b) *Dichrostachys cineria*.



Plate 4: Some species found in the Miombo Woodlands of western Zambia from families. Asteraceae: (a) *Elephantopus scaber* subsp. *plurisetus*; and (b) *Crassocephalum rubens*; (c) *Pleiotaxis eximia*; & Zingiberaceae: (d) *Aframomum alboviolaceum*.



Plate 5: Some species found in the Miombo Woodlands of western Zambia from families Rubiaceae: (a)&(b) *Vangueriopsis lanciflora*; (c)&(d) *Rothmannia engleriana*; Sapotaceae: (e) *Englerophytum magalismontanum*; & Lauraceae: (f) *Cassytha pondoensis*.

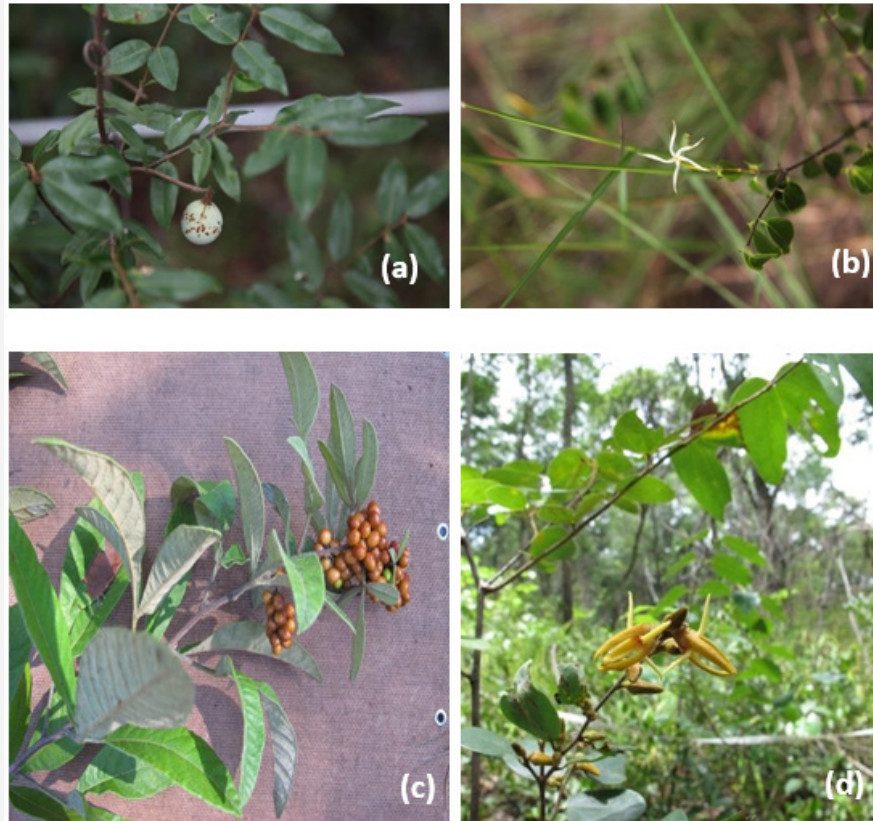


Plate 6: Some species found in the Miombo Woodlands of western Zambia from families Apocynaceae: (a)&(b) *Landolphia parvifolia*; Anarcadiaceae: (c) *Searsia quartiniana*; Annonaceae: (d) *Xylopia odoratissima*.



Plate 7: Some species found in the Miombo Woodlands of western Zambia from families Chrysobalanaceae: (a) *Parinari capensis* subsp. *capensis*; Hypericaceae: (b) *Psorospermum baumii*; Combretaceae: (c) *Combretum psidioides*; & Dipterocarpaceae: (d) *Monotes glaber*.



Plate 8: Some species found in the Miombo Woodlands of western Zambia from families Ebenaceae: (a) *Diospyros batocana*; Euphorbiaceae: (b) *Sclerocroton oblongifolius*; Lamiaceae: (c)&(d) *Vitex doniana*; Verbenaceae: (e) *Lantana angolensis*; Oxalidaceae: (f) *Biophytum umbraculum*; Passifloraceae: (g) *Paropsia brazzeana*; & Strychnaceae: (h) *Strychnos cocculoides*.

Brief description of the useful woody species

Fabaceae: *Cryptosepalum exfoliatum* subsp. *pseudotaxus* (Plate 1a&b) is referred to in the local languages Lozi and Mbunda as Mukwe. This tree is one of the subdominant species in the wetter Miombo Woodlands [34] which only occurred in the northern sites of our study area. A dwarf shrub relative, *C. exfoliatum* subsp. *suffruticans*; was recorded for Angola [30-34] and is reported to occur also in our study area has enormous woody underground biomass described as “geoxylic suffrutex” Finckh and Revermann [28]. According to Storrs [23], the bark of *C. exfoliatum* subsp. *pseudotaxus* is suitable for the construction of beehives.

Burkea africana (Plate 1c) is locally referred to in Lozi as Museshe and in Mbunda as Mubulwebulwe. This tree is one of the

dominant species on Kalahari Sands of southern and central Africa [31]. Elephants and other game animals as well as caterpillars browse on this species [35,36]. The pods and bark contain a saponin and are used as fish poison and the bark is used for tanning leather.

Bauhinia petersiana locally referred to in Lozi and Mbundu as Mupondopondo (Plate 1e&f). In Zambia, elephants browse on the leaves and pods of this tree/shrub. The seeds are roasted in some communities of western Zambia during periods of food scarcity.

Erythrophleum africanum locally referred to in Lozi as Mubako (Plate 1g&h). This tree was referred to by Le Roux & Müller 25 as another subdominant tree on Kalahari Sands of southern Africa. The reddish- brown wood is very hard and resistant to borers and

termites hence used for fancy furniture, flooring, and sleepers for the rail lines [23].

Chamaecrista mimosoides (Plate 1i&j). This dwarf shrub was one of the more abundant species in the plots at the sites Kafue and Dongwe where it showed signs of browsing by insects. The roots of this species are used to treat dysentery and stomach pains.

Pterocarpus angolensis locally referred to in Lozi as Mukwa (Plate 2a&b). This species occurred in the study site mostly as a tree but in some plots as a geoxylic suffrutex. The dual growth forms of this species in southern Africa has been also recorded by Shackleton [37]. The tree produces one of the best timbers in the southern African region [38-43] with the brown heartwood resistant to borers and termites [44]. The wood is also used for woodcarving and building of canoes and is valued for its medicinal purposes. The roots are usually ground into a powder used for colouring the huts in a number of communities in western Zambia.

Baphia massaiensis locally referred to in Lozi as Isunde and in Mbunda as Kayola (Plate 2c&d). This species was common in all the sites of the study. The wood of this tree is mostly used as firewood in western Zambia while the leaves and roots are used in the treatment of sores and rashes [23].

Bobgunnia madagascariensis locally referred to in Lozi and Mbunda as Mushakashela (Plate 2e). This tree produces wood used in carvings and the leaves and bark are used to treat headaches and slow down palpitations of the heart [40] while in the rural communities of western Zambia the bark is used for the production of pesticides.

Crotalaria cephalotes (Plate 2f) this erect, annual, dwarf shrub was mostly observed in Kafue and had signs of browsing by insects. However, no local use of the species has been recorded in western Zambia or in literature.

Dichrostachys cinerea locally referred to in Lozi as Muselesele (Plate 3a&b). In wetter parts of Zambia for example in the Kafue Flats *D. cinerea* has been considered a key species in the encroachment of grasslands [41]. The leaves, stem, bark, and roots of this tree/shrub have been recorded to be used to treat general sexually transmitted diseases in western Zambia [42].

Asteraceae: *Elephantopus scaber subsp. plurisetus* (Plate 4a). The leaves of this dwarf shrub are used to treat stomach ailments in western Zambia.

Pleiotaxis eximia (Plate 4c). This dwarf shrub was occasionally found in the sites in Kafue National Park and Luampa and was particularly conspicuous because of its catchy red flowers. In Luampa, the roots of this species are used for medicinal purposes in healing stomach upsets.

Combretaceae: *Pteleopsis anisoptera* locally referred to in Lozi as Mufunji and in Mbunda as Mufunga (Plate 7e). This species occurring as a tree was observed only in wetter, denser study sites of Dongwe. The wood of this tree species is hard and heavy with twisted grains hence only used for roofing poles in the construction

of huts, hoe handles and maize pounding sticks. Apart from the leaves and shoots being browsed on by wildlife according to Storrs (1979), this tree is used for medicinal purpose in most parts of Zambia.

Zingiberaceae: *Aframomum alboviolaceum* locally referred to in Lozi as Ishindwa and in Mbunda as Mutundundu (Plate 4d). This species was observed in the denser woodlands of the study site (Dongwe) as a shrub growing to a height of about 1.5m, while in the relatively open woodlands it occurred as a dwarf shrub. The leaves of *A. alboviolaceum* are known to be used as antibacterial remedies in most tropical countries of Africa [43]. In western Zambia, the inner fruit pulp is eaten whole including the seeds.

Rubiaceae: *Vangueriopsis lanciflora* locally referred to in Lozi as Muhole and Mbunda as Mumosomoso (Plate 5a&b). The bark, which when the plant is younger has a rusty-red appearance, is ground to a powder which is used to treat the swelling caused by mumps. The roots are used for medicinal purposes of fertility, potency, and childbirth.

Rothmannia engleriana locally referred to in Lozi and Mbunda as Mushimbangolwa (Plate 5c&d). In most communities in western Zambia the roots are used in the preparations of good luck charms and to dispel evil spirits.

Sapotaceae: *Englerophytum magalismontanum* locally referred to in Lozi as Mulumbilo and Mbunda as Mushombo (Plate 5e). In western Zambia, the fruits of *E. magalismontanum* are gathered and eaten.

Lamiaceae: *Vitex domiana* (Plate 8c&d). The semi-deciduous tree was occasionally found only in study sites of Luampa. In most of Zambia, this species is considered a good plank and used for building, boxes, interior fittings and furniture [32]. The bark is used for making clothing dyes and the fruit is used for making jam and wine. The leaves are browsed on by cattle and also used for medicinal purposes

Lauraceae: *Cassytha pondoensis* locally referred to in Lozi and Mbunda as Lwambu (Plate 5f). This parasitic twining dwarf shrub has stems used as an aphrodisiac in the study area especially in Luampa.

Apocynaceae: *Landolphia parvifolia* locally referred to in Lozi and Mbunda as Mumbongo (Plate 6a&b). This liana species had such a high abundance especially in the northern study site Dongwe where it sometimes formed an impenetrable mat. A similar study in Cussequ, Angola by Revermann et al. [34] also recorded an impenetrable mat formed by the related species *L. camptoloba*. The edible fruit is gathered from the wild for local consumption. It is a popular wild food, especially with children and travellers, which is sometimes also sold at local markets.

Annonaceae: *Xylopia odoratissima* locally referred to in Lozi as Muvuma and in Mbunda as Situnduwanga (Plate 6d). This species was abundant in all three study sites. The roots are used to dispel bad luck and witchcraft in western Zambia.

Anacardiaceae: *Searsia quartiniana* locally referred to in Lozi as Chikwekwe (Plate 6c). This species was abundant in Dongwe and Kafue study sites. The fruits are eaten as wild fruits and the roots are used for medicinal purposes in healing stomach ailments in western Zambia.

Chrysobalanaceae: *Parinari capensis subsp. capensis* locally referred to in Lozi and Mbunda as Kabulabula (Plate 7a). This geoxylic suffrutex has edible fruits. The oil is extracted from the seeds of this and a related species, *P. curatellifolia*, by most communities in Zambia.

Dipterocarpaceae: *Monotes glaber* locally referred to in Lozi as Mutembo and in Mbunda as Mulenga (Plate 7f). In contrast to [23] who described this species as occurring close to grasslands and wetlands, in our study it occurred in woodlands. *M. glaber* and another species from this genus that has been recorded in our study, namely *M. engleri*, has light reddish-brown coloured wood which is used for fence posts, door and window frames and hut building in western Zambia.

Ebenaceae: *Diospyros batocana* locally referred to in Lozi as Munjongolo and in Mbunda as Mufombwa (Plate 8a). This tree is sometimes mistaken for the geoxyle suffrutex species *D. chamaethamnus* that also occurs in western Zambia and has a similar appearance but different growth form. The bark, roots, and leaves are used for various medicinal purposes and as a snake repellent. The softwood is used for making cooking sticks and tool handles [23].

Verbenaceae: *Lantana angolensis* (Plate 8e). Unlike the more abundant invasive species *Lantana camara* found most in aquatic environments, this shrub (*Lantana angolensis*) was found in the woodlands in western Zambia as also cited by van Wyk & van Wyk [45]. Fruits of this species are eaten by humans as well as birds in western Zambia and other parts of the country.

Strychnaceae: *Strychnos cocculoides* locally referred to in Lozi as Muhuluhulu (Plate 6c). The cork from this species is generally thick and the bark with deep fissures. The edible fruit has a long storage life and has rapidly become an important cash in Windhoek and Swakopmund for the alcoholic drink fermented and distilled from it [30]. The wood is used in western Zambia for crafting handles while the shell of the fruit is used to store cosmetic ochre-clay.

Discussion

The family of Fabaceae had the highest species richness in this study. This concurs with most studies on Miombo Woodlands that describe these woodlands as being dominated by the family Fabaceae [9,13]. For the plates we subdivided the Fabaceae into only three subfamilies of Caesalpinioideae, Papilionoideae, and Mimosoideae based on earlier phylogenetic studies (Lersten et al. 1992; Wu et al. 2003). A more recent study by Azani et al. [45] however sub-classified Fabaceae into six subfamilies based on recent phylogenetic relationships in the family. Other families within our study with higher numbers of species were Rubiaceae,

Combretaceae, Asteraceae, and Apocynaceae. In a similar checklist of woody species in Cusseque, Angola, Revermann et al. [10] found also that Fabaceae was the species-richest but in contrast to our study, other species-rich families in Cusseque were Euphorbiaceae and Proteaceae.

Species with higher frequency, which were classified as common, were also more widespread and therefore recorded in all three sites, with the only exception of *C. exfoliatum subsp. pseudotaxus*, which was only recorded for Dongwe in the wetter part of the study area. *C. exfoliatum subsp. pseudotaxus* is known to occur as a subdominant species in the wetter Miombo Woodlands of northwestern Zambia [4]. The latter species, together with *Brachystegia spiciformis*, *B. boehmii* and *Guibourtia coleosperma*, all recorded as common species in our study, have been referred to as the dominant species in the three storey forest of western Zambia [34].

The woody under-growths (i.e., shrubs, dwarf shrubs, shrub/trees) of the woodlands, consisting of plants below 0.25 to 0.5 meters in height, represent the most common life form (81% of the species). Notable among the shrubs were the geoxyles referred to as 'underground trees' of southern Africa, one of the most distinctive growth forms characteristic of fire-prone savannas [46]. The geoxylic suffrutices such as *Parinari capensis subsp. capensis*, *Copaifera baumiana*, and *Diospyros virgata* contribute to a highly resilient shrub community withstanding not only frequent anthropogenic fires but also frost conditions [12,46,47].

Of the species recorded with different uses, about 75% are used in non-timber products as gums, medicines, dyes, tanning and many more. The high utilization of the woody species observed in this study is valuable information for conservation researchers and forest managers for effective management of the woodland conservation. In Zambia, a study by Phiri et al. [48] observed the challenge of overharvesting *Pterocarpus chrysothrix Taub.* (related to *Pterocarpus angolensis*, which has been recorded for our study area) accelerated by exporting timber leading to the species being threatened. Many species are under threat as long as levels of utilization are unregulated also due to the unknown threat status of species. None of the species observed in our study were threatened according to the IUCN Plant Red Data List for Zambia [8]. There is need to revisit the threat status of woody species in Zambia for the consideration of regulatory measures that entail conservation and protection of the threatened species [49-26].

The present checklist of woody species in the Miombo Woodlands of western Zambia has been compiled to make the information on the local distribution and use of woody species in Zambia more accessible. The study covers only a small part of this fragmented landscape and is therefore not exhaustive. However, this study will help to fill the gap of species-occurrence data that will feed into local inventories in the region and thus contribute to the update the National Red Species Data List [57-68]. The information on the local use of selected species, which is largely based on unpublished knowledge provided by members of the local

communities, sheds light on the economic value of woody plant species in western Zambia. The literature in this study area is much dispersed and is often difficult to access because most of the papers are relatively old or were published in regional or national journals, which are not readily available [69-80]. The study will therefore

facilitate further botanical research and biodiversity conservation planning for the Miombo Woodlands that form an important economic resource for the majority of the rural population [81-91] ([Appendixes I](#) and [Appendixes II](#)).

Table 2: Coordinates for the Plots.

Plot Number	Date	Lat	Long	R. Person	Vegetation. Type	Plot. Size	Country	Administration. Unit
27502	20140305	-15.13791	24.49613	P.Sichone	Miombo	1000	Zambia	Luampa
27504	20140308	-14.09577	24.0153	P.Sichone	Miombo (wet)	1000	Zambia	Dongwe
27506	20140320	-15.13873	24.48869	P.Sichone	Miombo	1000	Zambia	Luampa
27508	20140321	-15.13965	24.48961	P.Sichone	Miombo	1000	Zambia	Luampa
27510	20140322	-15.14055	24.4896	P.Sichone	Miombo	1000	Zambia	Luampa
27512	20140322	-15.14061	24.49518	P.Sichone	Miombo	1000	Zambia	Luampa
27514	20140323	-15.14151	24.49424	P.Sichone	Miombo	1000	Zambia	Luampa
27516	20140323	-15.14148	24.49238	P.Sichone	Miombo	1000	Zambia	Luampa
27518	20140324	-15.14143	24.48773	P.Sichone	Miombo	1000	Zambia	Luampa
27520	20140324	-15.14145	24.48959	P.Sichone	Miombo	1000	Zambia	Luampa
27522	20140324	-15.14237	24.49051	P.Sichone	Miombo	1000	Zambia	Luampa
27524	20140325	-15.14329	24.49236	P.Sichone	Miombo	1000	Zambia	Luampa
27526	20140324	-15.1433	24.49328	P.Sichone	Miombo	1000	Zambia	Luampa
27528	20140323	-15.14241	24.49423	P.Sichone	Miombo	1000	Zambia	Luampa
27530	20140324	-15.14507	24.48954	P.Sichone	Miombo	1000	Zambia	Luampa
27532	20140324	-15.14511	24.49326	P.Sichone	Miombo	1000	Zambia	Luampa
27534	20140324	-15.14603	24.49511	P.Sichone	Miombo	1000	Zambia	Luampa
27536	20140327	-15.13787	24.49242	P.Sichone	Miombo	1000	Zambia	Luampa
27538	20140327	-15.13785	24.49056	P.Sichone	Miombo	1000	Zambia	Luampa
27540	20140403	-14.0958	24.01807	P.Sichone	Miombo (wet)	1000	Zambia	Dongwe
27542	20140403	-14.09671	24.01806	P.Sichone	Miombo (wet)	1000	Zambia	Dongwe
27544	20140403	-14.09668	24.01621	P.Sichone	Miombo (wet)	1000	Zambia	Dongwe
27546	20140404	-14.09678	24.02361	P.Sichone	Miombo (wet)	1000	Zambia	Dongwe
27548	20140404	-14.09587	24.02362	P.Sichone	Miombo (wet)	1000	Zambia	Dongwe
27550	20140404	-14.09762	24.01897	P.Sichone	Miombo (wet)	1000	Zambia	Dongwe
27552	20140405	-14.09854	24.01989	P.Sichone	Miombo (wet)	1000	Zambia	Dongwe
27554	20140405	-14.0994	24.0171	P.Sichone	Miombo (wet)	1000	Zambia	Dongwe
27556	20140405	-14.09848	24.01526	P.Sichone	Miombo (wet)	1000	Zambia	Dongwe
27558	20140406	-14.10038	24.02264	P.Sichone	Miombo (wet)	1000	Zambia	Dongwe
27560	20140406	-14.10034	24.01986	P.Sichone	Miombo (wet)	1000	Zambia	Dongwe
27562	20140406	-14.10028	24.01524	P.Sichone	Miombo (wet)	1000	Zambia	Dongwe
27564	20140408	-14.10306	24.02075	P.Sichone	Miombo (wet)	1000	Zambia	Dongwe

27566	20140407	-14.10211	24.01706	P.Sichone	Miombo (wet)	1000	Zambia	Dongwe
27568	20140408	-14.10398	24.02167	P.Sichone	Miombo (wet)	1000	Zambia	Dongwe
27570	20140408	-14.10392	24.01704	P.Sichone	Miombo (wet)	1000	Zambia	Dongwe
27572	20140407	-14.1039	24.01519	P.Sichone	Miombo (wet)	1000	Zambia	Dongwe
27574	20140408	-14.10299	24.0152	P.Sichone	Miombo (wet)	1000	Zambia	Dongwe
27578	20140415	-14.8983	25.43676	P.Sichone	Miombo	1000	Zambia	Kafue
27580	20140416	-14.89783	25.43995	P.Sichone	Miombo	1000	Zambia	Kafue
27582	20140416	-14.89889	25.44361	P.Sichone	Miombo	1000	Zambia	Kafue
27584	20140419	-14.89701	25.44024	P.Sichone	Miombo	1000	Zambia	Kafue
27586	20140419	-14.8988	25.43744	P.Sichone	Miombo	1000	Zambia	Kafue
27588	20140419	-14.89703	25.44396	P.Sichone	Miombo	1000	Zambia	Kafue
27590	20140420	-14.90059	25.43557	P.Sichone	Miombo	1000	Zambia	Kafue
27592	20140420	-14.90151	25.43835	P.Sichone	Miombo	1000	Zambia	Kafue
27594	20140421	-14.89971	25.43836	P.Sichone	Miombo	1000	Zambia	Kafue
27596	20140421	-14.90062	25.44021	P.Sichone	Miombo	1000	Zambia	Kafue
27598	20140421	-14.90153	25.44114	P.Sichone	Miombo	1000	Zambia	Kafue
27600	20140421	-14.89975	25.44394	P.Sichone	Miombo	1000	Zambia	Kafue
27602	20140422	-14.90334	25.44019	P.Sichone	Miombo	1000	Zambia	Kafue
27604	20140422	-14.90425	25.44205	P.Sichone	Miombo	1000	Zambia	Kafue
27606	20140422	-14.90245	25.44299	P.Sichone	Miombo	1000	Zambia	Kafue
27608	20140423	-14.90515	25.44111	P.Sichone	Miombo	1000	Zambia	Kafue
27610	20140423	-14.90512	25.43739	P.Sichone	Miombo	1000	Zambia	Kafue
27612	20140423	-14.90421	25.43554	P.Sichone	Miombo	1000	Zambia	Kafue
28082	20150319	-15.14324	24.48771	P.Sichone	Miombo	1000	Zambia	Luampa
28084	20150320	-15.1397	24.49426	P.Sichone	Miombo	1000	Zambia	Luampa
28088	20150323	-14.10141	24.02333	P.Sichone	Miombo (wet)	1000	Zambia	Dongwe
28094	20150325	-14.902406	25.436483	P.Sichone	Miombo	1000	Zambia	Kafue
28096	20150326	-14.90394	25.4335	P.Sichone	Miombo	1000	Zambia	Kafue

Acknowledgement

This study formed part of the research portfolio of the BMBF-funded SASSCAL initiative (Task no. 159) promotion number: 01LG1201M. We are most grateful to field assistants that participated in the collection of the data namely Alex Liseli, Andrew Munshukulumbwe and Charles Sitali. Zambia Wildlife Authority granted us permission to undertake this study in their protected areas.

Authors contributions

Sichone, P – Data sampling, data analysis and drafting of the manuscript, Schmiedel, U – Study design, conceptual guidance and text editing, Phiri, P – Support with plant identification and taxonomical verifications. All authors contributed to the manuscript.

Conflict of Interest

No conflict of interest.

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