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Woody species composition, structure and diversity of Mazowe Botanical Reserve, Zimbabwe

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Abstract

This study assessed woody species diversity, composition and vegetation structure in a dry forest Miombo woodland at Mazowe botanical reserve. All woody species were systematically identified and measured in 45 sample plots. Analysis of inventory data was done using Microsoft Excel. Four vegetation communities identified along the river, anthills, hills and slope areas of the reserve were demarcated. Relative Density, dominance, frequency, and species and family importance values were computed to characterize the species composition. A total of 108 woody species belonging to 78 genera and 41 families were recorded. Members of the Fabaceae subfamily Caesalpinoideae were dominant with 6 genera and 9 species. Stem densities/ha were high ranged from 572 on the anthills to 2040 along the river valley. The dbh distribution showed an inverse "J" shaped curve, meaning that there is active regeneration and recruitment in the woodlands. Shannon-Wiener Index of diversity values ranged from 1.85 in the slope area to 3.42 on the anthills showing high species diversity in the reserve. This study reveals that the Mazowe botanical reserve has a high species richness and diversity. This is mainly due to the diversity of habitats like river valleys, anthills, streams, hills and slopes for species establishment. A number of anthropogenic activities have been recorded in the reserve notably fire and tree cutting. These require further detailed assessment to evaluate their impact on the woodland dynamics.

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Introduction

Mazowe botanical reserve lies within the deciduous Miombo savanna woodland vegetation type (Wild and Barbosa, 1968). Miombo woodland is the most common type of savanna in southern Africa stretching from Angola and the Democratic Republic of Congo in the west to Mozambique and Tanzania in the east covering an area of approximately 2.7 million km^2 (Campbell *et al*., 2006). Miombo woodlands have been variously described throughout their distributional range, but much still remains to be understood in terms of regional variation in community composition, diversity, and spatial structure of these forests (Banda *et al*., 2008). Classically, Miombo woodlands are commonly assumed to be dominated by species in the genera *Brachystegia, Julbernardia,* and *Isoberlinia* (Banda *et al*., 2008; Burgess *et al*., 2004). Such a simple description does not adequately describe variation in species diversity across this vast geographical range. Other tree species such as *Pseudolachnostylis maprouneifolia, Diplorhynchus condylocarpon, Acacia sp, Combretum sp* also commonly occur (Ribeiro *et al.,* 2008), many of which may be locally dominant (Frost, 1996).

In recent years, many parts of sub-Saharan Africa have witnessed changes in the extent of savanna woodland mainly as a result of the burgeoning human population growth and subsequent land-use conversion (Walpole *et al*., 2004). The composition and diversity of plant species in the woodlands are management issues of great concern today due to the impact of several anthropogenic disturbance factors like wood harvesting for fuel and construction materials, land conversion into agriculture and settlement, fire and overgrazing.

In Zimbabwe, as in many other countries Miombo woodlands provide a wide range of products and services to the majority of the population, but they are being lost at an alarming rate. Zimbabwe, has for the last few years undergone a land reform exercise which has resulted in massive re-settlement of people on farmland including the opening up of new settlements on unoccupied woodland areas. The conversion of woodlands to agricultural land is likely to cause large-scale impacts on the hydrology, soils and general climate unless the dynamics are fully understood, and mitigation measures are designed (Gwali *et al*., 2010). A successful assessment and monitoring of impacts on savanna species dynamics will largely depend on the establishment of baseline inventory data on species composition, diversity and distribution of the woodlands. The Mazowe Botanical reserve is an ideal study site for establishing baseline data as it has escaped the worst of the anthropogenic disturbance factors due to its protection status.

Despite its status, little quantitative information exists on the vegetation structure and composition of the botanical reserve. Tsvuura and Nyamhanga (2002) produced a checklist of the reserve, and while informative, their study was largely qualitative and descriptive. Recent studies by Mujawo (2005) and Chapano (2012) focussed on the assessment of the drivers of floristic composition and remain largely unpublished.

In order to guide the management and policy decisions of the Mazowe Botanical reserve in terms of its conservation, there is need for quantitative data on the composition, distribution and abundance of its woody species.

This study aims to contribute to a better understanding of the dynamics and distribution of tree species in the Mazowe botanical reserve and to assess the human footprints in this protected area. The results will also provide an important baseline for monitoring the impact of land conversion on biodiversity in the neighbouring newly resettled areas.

Materials and methods

Description of study area

Mazowe Botanical Reserve is located in the Mazowe District, some 30 km N of Harare in Mashonaland Central province, next to Christon Bank Township in Zimbabwe (17° 39 S, 31° 31E, Figure 1). The reserve forms part of the catchment area of the Mazowe dam and covers an area of 48 ha with an altitudinal range of 1300-1400 m above sea level. It is bordered to the north by the Spelonken Estate, to the west by the Christon bank Township, to the south by the foot of the Shiva Hills and to the east by the Mazowe river. The Mazowe Botanical reserve is listed as a botanical reserve under the National Parks and Wild Life Act (1975) and is an outstation of the National Herbarium and Botanic gardens.

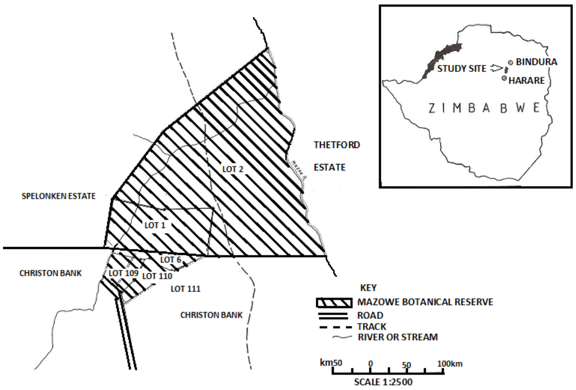

Fig. 1. Location of the Mazowe Botanical Reserve.

Mean monthly temperatures recorded at the nearby Henderson Research meteorological station range from 20-30 °C and annual rainfall averages 880 mm (Ngongoni *et al.,* 2008). The soils are kaolinitic and consist largely of well drained and heavily leached granite derived coarse grained sands which are relatively low in fertility. The soils on the termite mounds are, however, more fertile with higher concentrations of macronutrients. The vegetation of the reserve lies within the deciduous Miombo savanna woodland (Wild and Barbosa, 1968) which can be broadly divided into riverine, hilltop and slope vegetation (Tsvuura and Nyamhanga, 2002). A preliminary checklist of plants of the reserve recorded a total of 305 species and identified *B.spiciformis, B.glaucescens, B.boehmii, J.globiflora, Monotes glaber* and *C.africana* as among the dominant woody plants (Tsuura and Nyamhanga, 2002). In a later study Mujawu (2005), recorded 37 woody plants and confirmed the same species as dominants elements of the Mazowe botanical reserve.

Sampling and data collection

Field work was conducted in January 2013. The inventory was preceded by a study of the satellite images of the study area and by a field reconnaissance survey to establish transects lines and plot sizes. The reserve was divided into 4 main vegetation areas i.e. the riverine, slope, hill and anthill vegetation. A systematic sampling design was adopted with transect lines laid in a north-south direction. One transect was laid along the riverine vegetation and sample plots measuring 10x10 m were laid at 50 m intervals along the transect line. In the slope and hill areas, two transect lines were each laid approximately 100 m apart and sample plots measuring 20x20 were laid at 50 m intervals. Ten anthills were randomly sampled in the study area. A total of 45 quadrats representing a sampling intensity of 2.5 % were sampled in the whole study area.

In each sample plot, all woody trees were identified in situ and specimens were collected for those which could not be readily identified. These were later identified at the National Herbarium. Following Anderson and Ingram (1993), tree height was visually estimated and the circumference at 1.3 m was measured using a tape for only those plants with a circumference ≥ 8 cm. For multi-stemmed plants, the circumference for each individual stem was measured separately. A Garmin 12XL Global Positioning System was used to take readings of the approximate locations of each of the sample plots. Indicators of human disturbances such as trees cut and burning were noted.

Data analysis

Microsoft Excel was used for data analysis. The species composition of the plots was described using Importance Value Index (Curtis and McIntosh, 1951), which is commonly used to describe vegetation structure and species composition of forests (Ferreira and Prance, 1999; van Andel, 2001). The following parameters were measured:

1. Relative dominance = (total basal area for a species/total basal area of all species) x 100.
2. Relative density = (number of individuals of a species/total number of individuals) x 100.
3. Relative frequency = (frequency of a species/sum of all frequencies) x 100.
4. Relative diversity = (number of a species in a family/total number of species) x 100.
5 The importance value index (IVI) = relative dominance + relative density + relative frequency.
6. The family importance value (FIV) = relative dominance + relative density + relative diversity.

In general the relative dominance, relative frequency, relative density and relative diversity vary in the range 0 – 100%, so the species and importance value indices

(IVI and FIV) vary between 0 and 300%.

Community groupings for the sample plots were established using Two-way indicator species analysis (TWINSPAN). TWINSPAN is a classification system that separates plots into groups, or communities, on the basis of their species composition (Hill, 1979). To compare diversity within each community, the Shannon-Wiener's index of diversity was computed using the following formula:

$$H = - \sum_{i=1} pi \ln pi$$

Where pi= *ni* /N; *ni is* the number of individual trees present for species *i, N* is the

total number of individuals, and S is the total number of species. This index is widely employed to measure biological diversity (Magurran, 2004).

Results

Species composition

The TWINSPAN classification of all the vegetation sample plots in the reserve shows the existence of four distinct clusters here described as the hill, slope, anthills, and river valley floristic communities (Figure 1). The classification was done using weighted species composition data with weighting achieved using the number of stems measured in each plot. The majority of plots measured in each vegetation community clustered together. All the fifteen slope plots clustered into group 5, nine of the ten anthill plots clustered into groups 7 and 8, seven of the eleven hill plots clustered into groups 1, 2 and 3 and all ten riverine plots clustered into groups 9 and 10 (Figure 1). However, there are a few plots that have clustered outside their communities like plot 44 which separate early due to the presence of *Maerua angolensis and Zanha africana*. The plots 17, 19 and 21 are hill plots which have clustered together (group 4) with the slope plots because of the presence of *B. spiciformis* and *Monotes glaber* and absence of *Margaritaria discoidea*. Another hill plot 25 has been classified together with slope plots due to absence of *Brachystegia glaucescens* and *Margaritaria discoidea*.

Table 1. Summary of species composition and structural characteristics of trees ≥2. 5 cm dbh for each vegetation community.

Diversity measure	Riverine	Slope	Hill	Anthill
Number of Families	24	13	30	27
Number of Genera	31	24	45	43
Number of species	40	32	57	51
Stem density/ha	2040	815	764	572
Average dbh(cm)	8.65±9.8	8.39±6.6	10.27±8.7	6.25±6.7
Basal area $m^2 ha^{-1}$	70.24	12.51	18.58	20.74
Mean height (m)	7.1±4.3	5.4±3.6	6.6±3.9	6.5±3.0
Mean circumference (cm)	30.1±30.6	28.5±20.9	34.4±27.1	26.4±20.6
Shannon index	3.16	1.85	3.31	3.42

A total of 108 woody species representing 78 genera and 41 families were found in the Mazowe Botanical reserve, of which 40, 32, 57, and 51 species were identified in the riverine, slope, hill, and anthill parts, respectively (Appendix 1). A total of 1872 stems ≥ 2.5 cm dbh were counted. Stem density and basal area were highest in the riverine, followed by the anthills, then the hill and lastly the slope areas (Table 1). The average diameter of all individual trees was highest in the hill, almost similar in the slope and riverine areas and least on the anthills.

The species with the highest importance value index in the botanical reserve were *Monotes glaber* (88.95%), *Brachystegia spiciformis* (76.67%), *Brachystegia glaucescens* (48.33%), *Flueggea virosa* (40.51%), *Julbernardia globiflora* (38.19%) and *Olea europaea* (33%) (Table 2). The four vegetation types identified in Figure 1 are each characterised by a suite of species. Only two species, *Combretum molle* and *Peltophorum africanum* were found in all the four vegetation types. Other common species occurring on at least three communities are *Brachystegia spiciformis, Julberndia globiflora, Dichrostachys cinerea, Poulzozia mixta, Grewia flavescens, Ximenia americana, Terminalia stenostachya, Combretum collinum, Pterocarpus rotundifolius* and *Gymnosporia senegalensis*. The species importance value indices (Table 2) show that the most distinctive community is on the slope area which is largely dominated by two species *Monotes glabe*r and *Brachystegia spiciformis*, the two constituting slightly 55.2% of the total importance value of all the woody species in that community. The vegetation on the hill area comprises mainly of the three Fabaceae species *Brachystegia glaucescens, Julbernardia globiflora* and *Brachystegia boehmii*. *Flueggea virosa had* the highest importance value on the anthills and *Olea europaea, Brachystegia spiciformis, Celtis africana* and *Combretum erythrophyllum* showed large importance values on the riverine vegetation.

Table 2. The five most abundant species in each vegetation community according to decreasing order of the species importance value index (IVI).

Woodland type	Species	Relative dominance (%)	Relative density (%)	Relative frequency (%)	IVI/300
Riverine	*Olea europaea*	17.98	9.31	5.71	33
	Brachystegia spiciformis	14.79	5.39	5.71	25.9
	Celtis africana	6.55	13.24	5.71	25.5
	Combretum erythrophyllum	12.18	3.92	5.71	21.82
	Diospyros lycioides	1.8	11.27	4.76	17.83
Slope	*Monotes glaber*	23.41	51.12	14.42	88.95
	Brachystegia spiciformis	50.18	12.07	14.42	76.67
	Julbernardia globiflora	14.05	14.52	9.62	38.19
	Burkea africana.	5.35	3.27	6.73	15.35
	Dichrostachys cinerea	1.27	5.32	8.65	15.24
Hill	*Brachystegia glaucescens*	26.84	16.67	4.83	48.33
	Julbernardia globiflora	14.02	14.29	5.52	33.82
	Brachystegia boehmii	14.30	3.27	2.76	20.34
	Lannea discolor	2.68	7.74	5.51	15.93
	Pouzolzia mixta	1.11	4.76	4.82	10.70

Anthill	*Flueggea virosa*	22.90	10.68	6.93	40.51
	Markhamia obtusifolia	9.16	12.14	0.99	22.28
	Strychnos potatorum	7.92	6.80	4.95	19.67
	Boscia salicifolia	8.47	3.40	5.94	17.81
	Ziziphus mucronata	7.91	4.37	3.96	16.23

The Fabaceae subfamily Caesalpinoideae was the most taxonomically diverse with the largest number of genera and species in all the vegetation types (Table 3). The Caesalpinoideae genera recorded were *Brachystegia* with a total of 4 species and *Burkea, Julbernadia and Peltophorum* all with one species. This subfamily has the largest FIV values in the hill and slope areas showing its dominance in the two areas. The other Fabaceae subfamilies Mimosoideae and Papilionoideae were important only in the slope area. The Combretaceae showed high FIV in the riverine and adjacent slope areas, the Euphorbiaceae in the anthill and adjacent hill areas and the Anacardiaceae in the hill and riverine areas. The Ebenaceae and Oliaceae showed importance only in the riverine area, the Dipterocarpaceae in the slope area, the Moraceae and Rubiaceae in the hill area and the Capparaceae and Sapindaceae on the anthills.

Table 3. The five most important families in each vegetation type in decreasing order of family importance value (FIV).

Woodland type	Family	Genera	Species	Number/ha	FIV/300
Riverine	Combretaceae	1	4	180	34.00
	Fabaceae-Caesalpinoideae	3	4	140	32.36
	Ebenaceae	2	3	270	30.10
	Oleaceae	1	1	190	29.79
	Anacardiaceae	1	2	180	24.65
Slope	Fabaceae-Caesalpinoideae	4	6	252	119.54
	Dipterocarpaceae	1	1	417	77.66
	Fabaceae-Mimosoideae	3	4	60	21.95
	Combretaceae	2	5	12	17.20
	Fabaceae-Papilionoideae	2	3	15	14.17
Hill	Fabaceae-Caesalpinoideae	4	7	300	111.62
	Anacardiaceae	3	3	73	18.96
	Euphorbiaceae	4	4	43	18.69
	Moraceae	1	3	21	12.91
	Rubiaceae	3	3	41	12.74
Anthill	Euphorbiaceae	3	3	69	41.00
	Bignoniaceae	1	1	69	23.25
	Sapindaceae	3	3	56	23.25
	Capparaceae	3	3	28	19.52
	Fabaceae-Caesalpinoideae	5	5	22	17.44

Table 4. The rarest species in each vegetation community according to increasing species importance value index (IVI).

Woodland type	Species	Relative dominance (%)	Relative density (%)	Relative frequency (%)	IVI/300
Riverine	*Rotheca myricoides*	0.007	0.490	0.952	1.450
	Combretum collinum	0.007	0.490	0.952	1.450
	Grewia flavescens	0.007	0.490	0.952	1.450
	Flueggea virosa	0.009	0.490	0.952	1.452
	Pterocarpus rotundifolium	0.022	0.490	0.952	1.465
Slope	*Combretum molle*	0.007	0.205	0.962	1.173
	Psydrax livida	0.009	0.205	0.962	1.175

Hill	*Hexalobus monopetalus*	0.009	0.205	0.962	1.175
	Combretum apiculatum	0.027	0.409	0.962	1.177
	Vaungueriopsis lanciflora	0.015	0.205	0.962	1.181
	Diospyros kirkii	0.006	0.298	0.690	0.993
	Faurea rochetiana	0.008	0.298	0.690	0.995
	Strychnos spinosa	0.0010	0.298	0.690	0.997
	Rhoicissus tridentata	0.014	0.298	0.690	1.001
	Turrea nilotica	0.019	0.298	0.690	1.006
Anthill	*Lannea discolor*	0.007	0.48	0.99	1.482
	Senna singuena	0.007	0.48	0.99	1.482
	Flacourtia indica	0.011	0.49	0.99	1.486
	Julbernadia globiflora	0.011	0.49	0.99	1.486
	Gymnosporia maranguensis	0.015	0.49	0.99	1.490

Some species are poorly represented in the botanical reserve represented only by a single individual in each of the vegetation communities. Such species have been characterised as rare (Table 4). Some rare species are confined to only one community like *Flacourtia indica* and *Senna singueana* which are confined to anthill and *Diospyros kirkii* and *Strychnos spinosa* to hill areas. Others may be rare in one community, but quite abundant in others like *Faurea rochetiana* rare in hill but not so on slope, *Julbernadia globiflora* and *Combretum molle* rare on slope but not on anthills, hill and riverine, *Rotheca myricoides* rare in riverine but not on anthills, *Combretum collinum* rare on riverine but not on slope and anthills.

Structure

Table 1 shows that stem density varied between 572-2040 stems/ha whilst basal area varied between 12.51-70.24. Stem density and basal area were highest in the riverine area and lowest in the slope area. The dbh were variable throughout the vegetation communities, but generally trees had largest dbh values in the hill area and least values on the anthills. The number of species and individuals varied from 3 to 22 species and 10-65 individuals per quadrat, and a majority of quadrats had 6-12 species and 16-44 individuals indicating a dense distribution of species and individuals in the reserve at each site.

The diameter class distribution of trees in all vegetation communities produced reverse "J" shaped curves (Fig. 2). Most individuals, 75% in the slope, 61.4 % in the hill, 72.1% in the riverine and 64.9 % in the anthills, were in the 0–10 cm dbh classes.

One individual of *Brachystegia spiciformis* on the slope and two of *Brachystegia glaucescens* on the hill reached >45 cm dbh whilst two individuals one each of *B.spiciformis* and *Olea europeaea* reached >60 cm dbh on the riverine. An individual of *Olea europea* had a dbh greater than 70 m on the riverine. On the anthills 2 individuals of *Boscia salicifolia* had dbh >35 m.

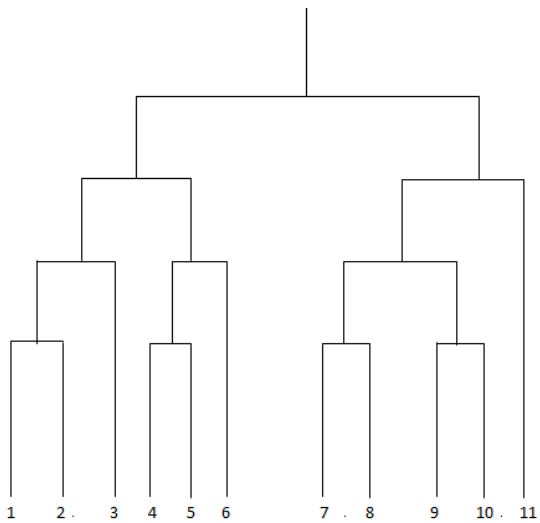

Fig. 2. TWINSPAN classification of the sample plots at Mazowe Botanical reserve.

The height class distribution of trees produced a skewed bell shaped curve for all the vegetation communities in the reserve (Fig. 3). As a whole, the height of trees >2.5 cm dbh ranged from 1.5 to 21 m. The tallest emergent trees were species of *Brachystegia spiciformis* , one in the riverine (21 m, 63.7 cm dbh) and the other in the slope (21m, 34.1 cm), followed by two *Brachystegia glaucescens* individuals (20m tall each, 38.2 cm and 49.7 cm dbh) in the hill. Majority of the trees between 1.5-8 m tall on slope, 4-12 on hill, 4-8 on riverine and 4-10 on anthills.

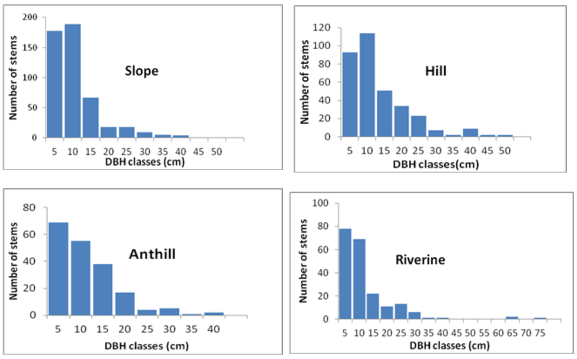

Fig. 3. Diameter class distribution of individuals ≥ 2.5 cm dbh in four vegetation types.

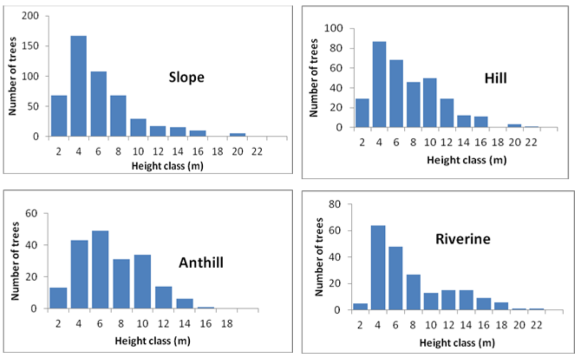

Fig. 4. Height class distribution of individuals ≥ 2.5 cm dbh in four vegetation types.

Species diversity

The Shannon-Wiener's index (Table 1) indicated that the anthills were the most diverse (3.42), closely followed by the hills (3.31), while the slope was the least diverse (1.85). Species noted to have contributed to high species diversity include *Markhamia obtusifolia* (0.256) and *Flueggea virosa* (0.239) in the anthills; *Brachystegia glaucescens* (0.299) and *Julbernadia globiflora* (0.278) in the hills; *Celtis africana* (0.268), *Diospyros lycioides* (0.246) and *Olea europeaea* (0.221) in the riverine; and *Monotes glaber* (0.343) and *B.spiciformis* (0.255) in the slope area.

Human footprints in the reserve

The reserve has many pedestrian tracks allowing free access to different destinations. The human impacts and activities observed in the reserve were wood cutting and dead wood collecting, illegal gold panning along the Mazowe river, bush fires, foot paths, mushroom and fruit gathering, tourist visits and religious ceremonies.

Discussion

The woody species richness of Mazowe Botanical reserve is high and compares well with similar studies carried out elsewhere in the Miombo region. In Tanzania Giliba *et al.* (2011) recorded 83 species in Bereku forest. In Zambia, Kalaba *et al.* (2012) recorded 83 species in the Copperbelt region and in Uganda Okiror *et al.* (2012) recorded 50 species in Kibale National park. This relatively high species richness could be attributed to the protection status of the reserve and also due to habitat heterogeneity, which has been found to increase tree diversity of woodlands and savannas in Africa (Menaut *et al.*, 1995). The differences in species composition among the different communities are often explained as due to micro-site factors. Frost (1996) pointed out that tree growth in Miombo ecosystems is generally determined by edaphic factors, principally nutrient and moisture availability, landscape position, the effects of fire, and anthropogenic disturbances.

A diversity of habitats including anthills, river valleys and streams, hills and slopes exist at the Mazowe botanical reserve. These, coupled with significant variability in soil physicochemical properties reported by Mujawo (2005) provide variable micro-habitats for the growth of a multitude of species.

The several human activities noted in the reserve constitute forms of pressure on the plant resources in the protected area. It is noteworthy that although human use inevitably alters the appearance and size class profile of Miombo, there are contrasting studies on the human impacts on woody plant species richness. Several studies indicate no decrease in species richness (Vermeulen, 1996; Malimbwi *et al.*

2005; Banda *et al.*, 2006), whilst others (Giliba *et al.,* 2011; Mwase *et al.*, 2007) show a significant decrease. However, there is need for a thorough assessment of these impacts on species richness and diversity within the reserve.

The dry Miombo woodland has historically been defined by species of the Fabaceae subfamily Caesalpinioideae, particularly the genera *Brachystegia and Julbenardia* (Timberlake and Chidumayo, 2011). In this study the dominance of the Caesalpinoideae in terms of the number of genera and species in all the four vegetation types is confirmed (Table 3).

In mature woodlands, the inverse J-shaped distribution of dbh size classes (Figure 2) showing more trees in the juvenile classes is indicative of a healthy and expanding population, in which young trees will recruit into adult size classes (Lykke, 1998). Accordingly, active regeneration and recruitment in Miombo woodland of Mazowe Botanical reserve as portrayed in this study is a good sign of sustainability of the woodland. Other studies within the Miombo have reported similar size class distributions (Kalaba *et al*, 2012, Chidumayo, 1987, Shirima *et al.*, 2011). However, caution should be exercised in the use of inverse J-distribution as stock control in management since the distribution assumes equal mortality rates among size classes which Isango (2007) regarded as biologically unrealistic.

The Shannon-Wienner index values obtained in this study (Table 1) fall between 1.5 and 3.5. This is the expected range for tropical woodlands (Savadogo, 2007). The values show that the anthills, hill and riverine areas have high biodiversity and the slope has low biodiversity. Shannon index values greater than 2 are indicative of medium to high diversity (Barbour *et al.*, 1999). The highest biodiversity was, however, obtained on the anthills. This is not surprising as termite mound soils are known nutrient rich micro-sites for plant establishment (Fleming and Loveridge, 2003) with high pH, moisture, organic matter and minerals, including nitrogen, carbon, calcium, magnesium, potassium and phosphorous. The low diversity of 1.85 in the slope area is mainly due to the dominance of only two species *Brachystegia spiciformis* and *Monotes glaber*. Based on the distribution of fire tolerant species in the reserve it appears as if fire has had a significant impact on the vegetation of the reserve. *Pterocarpus angolensis, Uapaca nitida, Parinari curatellifolia, Uapaca kirkiana* and *Diplorhynchus condylocarpon* are reported to be fire tolerant species (Frost, 1996) and in the Mazowe reserve they are only found in the slope and hill areas where fires are more intense than in the riverine and anthills. Our results further show that the Mazowe botanical reserve is biologically more diverse than comparable Miombo regions in Tanzania (Shannon 1.05) (Shirima *et al.*, 2011), Mozambique (Shannon 1.25) (Williams *et al.*, 2008) and Zambia (Shannon 2.7) (Kalaba *et al.*, 2012).

The presence of rare species represented by a single or a few individuals should not be cause for worry at the Mazowe botanical reserve taking into consideration the small size of the reserve (only 48 ha) and that none of the rare species is listed in the national or IUCN red data lists. Furthermore the majority of the rare species are known to be of wide distribution elsewhere in the country.

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Appendix 1. List of woody species recorded at Christon Bank botanical reserve.

Species	Family	Slope	Hill	Riverine	Anthill
Acacia karroo Hayne	FABACEAE - MIMOSOIDEAE	+		+	
Acacia polyacantha Willd. subsp. campylacantha (A.Rich.) Brenan	FABACEAE - MIMOSOIDEAE	+		+	
Albizia amara (Roxb.) Boivin subsp. sericocephala (Benth.) Brenan	FABACEAE - MIMOSOIDEAE				+
Albizia antunesiana Harms	FABACEAE - MIMOSOIDEAE	+	+		
Allophylus africanus P.Beauv.	SAPINDACEAE		+		+
Boscia angustifolia A.Rich. var. corymbosa (Gilg) DeWolf	CAPPARACEAE		+		
Boscia salicifolia Oliv.	CAPPARACEAE				+
Brachylaena discolor DC. var. rotundata (S.Moore) Beentje	ASTERACEAE		+		
Brachystegia boehmii Taub.	FABACEAE - CAESALPINIODEAE		+		
Brachystegia glaucescens Burtt Davy & Hutch.	FABACEAE - CAESALPINIODEAE	+	+		
Brachystegia spiciformis Benth.	FABACEAE - CAESALPINIODEAE	+	+	+	
Brachystegia spiciformis Benth. x glaucescens Burtt Davy & Hutch.	FABACEAE - CAESALPINIODEAE	+	+	+	
Bridelia cathartica G.Bertol. subsp. melanthesoides (Baill.) J.Léonard var. lingelsheimii (Gehrm.) Radcl.-Sm.	EUPHORBIACEAE		+		
Burkea africana Hook.	FABACEAE - CAESALPINIODEAE	+	+		
Cassia abbreviata Oliv.	FABACEAE - CAESALPINIODEAE				+
Celtis africana Burm.f.	CELTIDACEAE			+	+
Clerodendrum eriophyllum Gürke	LAMIACEAE				+
Combretum apiculatum Sond. subsp. apiculatum	COMBRETACEAE	+			
Combretum collinum Fresen. (incl. subspp.)	COMBRETACEAE	+		+	+
Combretum erythrophyllum (Burch.) Sond.	COMBRETACEAE			+	
Combretum hereroense Schinz subsp. hereroense	COMBRETACEAE			+	+
Combretum molle G.Don	COMBRETACEAE	+	+	+	+
Combretum zeyheri Sond.	COMBRETACEAE	+			
Commiphora marlothii Engl.	BURSERACEAE		+		
Commiphora mollis (Oliv.) Engl.	BURSERACEAE		+		+
Commiphora pyracanthoides Engl.	BURSERACEAE				+
Cussonia arborea A.Rich.	ARALIACEAE		+		
Dalbergia nitidula Baker	FABACEAE - PAPILIONOIDEAE		+		
Dichrostachys cinerea (L.) Wight & Arn.	FABACEAE - MIMOSOIDEAE	+	+		+
Diospyros kirkii Hiern	EBENACEAE		+		
Diospyros lycioides Desf. subsp. lycioides	EBENACEAE			+	
Diospyros natalensis (Harv.) Brenan	EBENACEAE		+	+	
Diospyros natalensis (Harv.) Brenan	EBENACEAE				
Diplorhynchus condylocarpon (Müll.Arg.) Pichon	APOCYNACEAE	+	+		
Dombeya rotundifolia (Hochst.) Planch. var. rotundifolia	STERCULIACEAE			+	+
Dovyalis zeyheri (Sond.) Warb.	FLACOURTIACEAE			+	
Ehretia obtusifolia DC.	BORAGINACEAE				+
Elephantorrhiza goetzei (Harms) Harms subsp. goetzei	FABACEAE - MIMOSOIDEAE		+		
Englerophytum magalismontanum (Sond.) T.D.Penn.	SAPOTACEAE			+	
Erythrina abyssinica DC.	FABACEAE - PAPILIONOIDEAE		+		
Erythrococca trichogyne (Müll.Arg.) Prain var. trichogyne	EUPHORBIACEAE			+	
Euclea divinorum Hiern	EBENACEAE			+	+
Faurea rochetiana (A.Rich.) Pic.Serm.	PROTEACEAE	+	+		
Faurea saligna Harv.	PROTEACEAE	+	+		
Ficus glumosa Delile	MORACEAE		+		
Ficus natalensis Hochst. subsp. natalensis	MORACEAE		+		
Ficus sur Forssk.	MORACEAE		+	+	
Flacourtia indica (Burm.f.) Merr.	FLACOURTIACEAE				+
Flueggea virosa (Willd.) Voigt subsp. virosa	EUPHORBIACEAE			+	+
Flueggea virosa (Willd.) Voigt subsp. virosa	EUPHORBIACEAE				
Friesodielsia obovata (Benth.) Verdc.	ANNONACEAE			+	+
Grewia flavescens Juss.	TILIACEAE		+	+	+
Grewia inaequilatera Garcke	TILIACEAE				+
Gymnosporia maranguensis (Loes.) Loes.	CELASTRACEAE			+	+

Gymnosporia senegalensis (Lam.) Loes.	CELASTRACEAE	+		+	+
Hexalobus monopetalus (A.Rich.) Engl.& Diels var. obovatus Brenan	ANNONACEAE	+	+		
Hoslundia opposita Vahl	LAMIACEAE				+
Hymenodictyon floribundum (Hochst.& Steud.) B.L.Rob.	RUBIACEAE		+		
Julbernardia globiflora (Benth.) Troupin	FABACEAE - CAESALPINIODEAE	+	+		+
Kirkia acuminata Oliv.	KIRKIACEAE		+		
Lannea discolor (Sond.) Engl.	ANACARDIACEAE		+		+
Maerua angolensis DC.	CAPPARACEAE				+
Maerua triphylla A.Rich. var. pubescens (Klotzsch) De Wolf	CAPPARACEAE				+
Margaritaria discoidea (Baill.) G.L.Webster var. nitida (Pax) Radcl.-Sm.	EUPHORBIACEAE		+		+
Markhamia obtusifolia (Baker) Sprague	BIGNONIACEAE				+
Mimusops zeyheri Sond.	SAPOTACEAE			+	
Monotes engleri Gilg	DIPTEROCARPACEAE		+		
Monotes glaber Sprague	DIPTEROCARPACEAE	+	+		
Mystroxylon aethiopicum (Thunb.) Loes.	CELASTRACEAE			+	+
Ochna pulchra Hook. subsp. pulchra	OCHNACEAE		+		
Ochna schweinfurthiana F.Hoffm.	OCHNACEAE		+		
Olea europaea L. subsp. cuspidata (G.Don.) Cif.	OLEACEAE			+	+
Ozoroa reticulata (Baker f.) R.& A.Fern.	ANACARDIACEAE		+		
Pappea capensis Eckl.& Zeyh.	SAPINDACEAE				+
Parinari curatellifolia Benth.	CHRYSOBALANACEAE	+	+		
Pavetta gardeniifolia A.Rich.	RUBIACEAE			+	+
Peltophorum africanum Sond.	FABACEAE - CAESALPINIODEAE	+	+	+	+
Pittosporum viridiflorum Sims var.	PITTOSPORACEAE		+	+	
Pouzolzia mixta Solms	URTICACEAE		+	+	+
Protea welwitschii Engl.	PROTEACEAE	+			
Pseudolachnostylis maprouneifolia Pax	EUPHORBIACEAE	+	+		+
Psydrax livida (Hiern) Bridson	RUBIACEAE	+		+	+
Pterocarpus angolensis DC.	FABACEAE - PAPILIONOIDEAE	+			
Pterocarpus rotundifolius (Sond.) Druce subsp. rotundifolius	FABACEAE - PAPILIONOIDEAE	+		+	+
Pterolobium stellatum (Forssk.) Brenan	FABACEAE - CAESALPINIODEAE			+	+
Rhoicissus rhomboidea (Harv.) Planch.	VITACEAE		+		+
Rhoicissus tridentata (L.f.) Wild & R.B.Drumm.	VITACEAE		+		
Rhus lancea L.f.	ANACARDIACEAE			+	
Rhus leptodictya Diels	ANACARDIACEAE		+		+
Rhus longipes Engl. var. longipes	ANACARDIACEAE			+	+
Rotheca myricoides (Hochst.) D.A.Steane & Mabb.	LAMIACEAE			+	+
Senna singueana (Delile) Lock	FABACEAE - CAESALPINIODEAE				+
Steganotaenia araliacea Hochst. var. araliacea	APIACEAE				+
Strychnos madagascariensis Poir.	LOGANIACEAE	+	+		
Strychnos potatorum L.f.	LOGANIACEAE			+	+
Strychnos spinosa Lam.	LOGANIACEAE		+		
Swartzia madagascariensis Desv.	FABACEAE - PAPILIONOIDEAE	+			
Syzygium guineense (Willd.) DC.	MYRTACEAE		+		
Terminalia stenostachya Engl.& Diels	COMBRETACEAE	+	+		+
Tetradenia riparia (Hochst.) Codd	LAMIACEAE		+		
Tricalysia niamniamensis Hiern subsp. nodosa (Robbr.) Bridson	RUBIACEAE		+		
Turraea nilotica Kotschy & Peyr.	MELIACEAE		+		
Uapaca nitida Müll.Arg.	EUPHORBIACEAE	+	+		
Vangueria infausta Burch. subsp. infausta	RUBIACEAE	+	+		
Vangueriopsis lanciflora (Hiern) Robyns	RUBIACEAE	+			
Vepris rogersii (Mendonça) W.Mziray	RUTACEAE			+	
Ximenia americana L. var. microphylla Oliv.	OLACACEAE		+	+	+
Ximenia caffra Sond. var. caffra	OLACACEAE			+	+
Zanha africana (Radlk.) Exell	SAPINDACEAE		+		+
Ziziphus mucronata Willd.	RHAMNACEAE			+	+