

RESEARCH PAPER**OPEN ACCESS****Baseline floristics and above-ground biomass in permanent sample plots across miombo woodlands in different land tenure systems in Hwedza, Zimbabwe****Edwin Nyamugadza^{*1}, Sara Feresu¹, Billy Mukamuri², Casey Ryan³, Clemence Zimudzi¹**¹*Department of Biological Sciences and Ecology, University of Zimbabwe, Harare, Zimbabwe*²*Department of Community and Social Development, University of Zimbabwe, Harare, Zimbabwe*³*School of GeoSciences, University of Edinburgh, Edinburgh EH9 3FF, UK***Key words:** Sustainable land management, Land-use, Carbon stocks, Species composition, DisturbanceDOI: <https://dx.doi.org/10.12692/jbes/27.4.65-79>**[Published: October 13, 2025]****ABSTRACT**

This study aims to present baseline data on species diversity, forest structure and above-ground biomass (AGB) in different land tenure systems in miombo woodlands of Hwedza District, in Zimbabwe. One-hectare permanent sample plots were established in Communal Area, Small-Scale Commercial Farms (SSCF), Old Resettlement Area, New Resettlement Area and Protected area (Imire Game Park). Tree measurements were taken at the standard 1.3 m diameter at breast height for individual trees with diameters ≥ 5 cm. A total of 215 stems representing 87 species from 37 families, were assessed. Species composition differed with disturbance intensity across land tenure systems. The sub-family, Fabaceae-Detarioideae was the most abundant with *Brachystegia spiciformis* emerging as the dominant species across all land tenure systems. The SSCF recorded the highest species richness (40 species) and plant density (0.0693 plants-m²), while Communal Area had the lowest species richness (13 species) and plant density (0.0063 plants-m²), indicating significant anthropogenic pressure. Species diversity was highest in New Resettlement Area (Shannon index = 2.92) whilst the lowest diversity was recorded at Imire Game Park (Shannon index = 1.41). Stem diameter distribution showed an inverse J-shaped pattern, with Old Resettlement Area displaying strong regeneration. The Imire Game Park had the highest number of larger sized trees. Biomass was highest in Imire Game Park (28.2 ha⁻¹) and SSCF (21.7 ha⁻¹) and lowest in Communal area (0.26 t/ha). The study revealed the effects of land tenure on diversity, structure and biomass of miombo woodlands which stands as a strong baseline for future studies in these woodlands for better sustainable land management.

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INTRODUCTION

Miombo woodlands are predominantly distributed in several southern and central African countries including Angola, Democratic Republic of Congo, Zambia, Zimbabwe, Mozambique, Malawi and Tanzania (Frost, 1996). Covering an estimated 1.9 million km², these woodlands are characterized by the dominance of tree species in the family Fabaceae, subfamily Detarioideae, particularly the genera *Brachystegia*, *Julbernardia*, and *Isoberlinia* (Bulusu *et al.*, 2021; Ribeiro *et al.*, 2020). In Zimbabwe, miombo woodlands cover approximately 42% of the woodlands (Nyoka *et al.*, 2011).

Miombo woodlands provide social and environmental services which sustain both humanity and nature. Social services include provision of firewood, timber, food and medicines for both rural and urban communities (Yannick *et al.*, 2024). Environmental services emanate from the woodlands' ability to act as carbon sinks; sequestering greenhouse gases from the atmosphere through various carbon pools that include Above-Ground Biomass (AGB), Below-Ground Biomass (BGB), litter, soil carbon and dead wood (Lupala *et al.*, 2014). Well established miombo woodlands also help to reduce soil erosion thereby promoting the growth of the amount of soil organic carbon (Shelukindo *et al.*, 2014). In addition to carbon storage, these woodlands provide vital ecosystem services including biodiversity preservation and conservation, soil protection, water retention and regulation.

Unfortunately, the capacity of these woodlands to provide services is increasingly under threat because of continued degradation and deforestation, from anthropogenically-driven land-use changes. Land Use Land Cover (LULC) changes alter the composition of carbon pools, contributing to increased carbon dioxide emissions into the atmosphere. For instance, the conversion of a woodland to a cropland in Uganda led to a reduction of (AGB) by 35.4% due to cutting down

of standing trees and branches (Zhang *et al.*, 2017); while conversion involving uprooting of standing stems and stumps disturbed BGB, and soil carbon by 26.5% and 0.21% respectively (Zhang *et al.*, 2017). Such conversions, result in increased carbon dioxide emissions to the atmosphere from disturbed carbon pools. Species composition and diversity in miombo woodlands is usually affected and influenced by land-use intensity within different land-tenure types. For example, in Zambia, Kalaba *et al.* (2013) reported that tree species composition and diversity were largely influenced by different agricultural practices like shifting cultivation. In a different study in Angola, Godlee *et al.* (2020) found out that tree species diversity was more pronounced in areas of higher disturbance compared to undisturbed areas. This means that, conversion from one land-tenure type to another has an impact on biodiversity (Walker and Desanker, 2004).

Generally, changes in land cover and use including forest clearance for agriculture and settlements, disrupt ecosystem biodiversity, alter ecosystem functioning and reduce carbon storage capacity. Unlike many other districts in Zimbabwe that are dominated by a single land tenure type, Hwedza is distinguished by a diverse and complex mosaic of land tenure types, that include communal area, small scale commercial farming area, new resettlement area, old resettlement area and large-scale commercial farming (Imire game park). Within these complex tenure types lie various land use practices that influence and affect various ecological parameters including above ground biomass, and biodiversity. These various land management practices have led to widespread cases of degradation, deforestation and disturbances of ecosystem services, making Hwedza an important study area to understand human-environment dynamics within miombo woodlands.

Despite the social, ecological and economic importance of miombo woodlands in Hwedza

district, there is notable absence of comprehensive long-term baseline data on tree species composition, structure and above ground biomass particularly in light of the district's diverse land tenure systems. Previous studies in Hwedza have largely focused on one-time assessments of small forest plots within a single land tenure, making them inadequate as baseline for future research and monitoring studies. For example, Pritchard *et al.* (2019) used once off circular plots of radius 20 m while Makumborenga *et al.* (2022) used once off circular plots of radius 15m in various land tenure systems including Protected area, communal area and old resettlement area in Hwedza. By establishing permanent sample plots (PSPs) in all the different land tenure types, the study provides a critical foundation for long-term monitoring of AGB and vegetation dynamics. Permanent sample plots play a very important role in forest monitoring especially in forest carbon dynamics, ground ecological monitoring and validation of forest degradation and deforestation over time (Wheeler *et al.*, 2021). This kind of long-term monitoring is essential for understanding how our landscapes are evolving whether due to natural changes, climate impacts, or anthropogenic activities. A well-established baseline enables the detection of meaningful ecological trends over time beyond seasonal or short-term fluctuations. This approach, will enhance our ability to assess how different land uses within tenure types affect ecosystems' health and their carbon storage capacity.

The specific objectives of this study were to (a) assess and compare species composition and diversity of miombo woodlands across five different land tenure systems, (b) estimate AGB of woody vegetation across permanent sample plots in different land tenure systems of Hwedza

MATERIALS AND METHODS

Study area

This study was conducted in Hwedza district of the Mashonaland East Province, south central

Zimbabwe, situated about 160 kilometers from Zimbabwe's Capital City, Harare (Fig. 1). The district is located at -18.616667 and 31.566667 latitude and longitude, respectively. With a population of 84 371 people, Hwedza is predominantly inhabited by farmers who rely on rain fed agriculture (Food and Nutrition Council, 2022). Hwedza district spans three agro-ecological regions: IIb, III and IV of Zimbabwe. Region IIb located in the northern part of the district, is the most agriculturally productive zone, while less productive areas in regions III and IV are situated south of Hwedza mountain (Manatsa *et al.*, 2020). The district is broadly classified into different land tenure systems that include Communal Area, Small-Scale Commercial Farming Area, Old Resettlement Area, New Resettlement Areas, and the Protected area (Imire game park) a protected area.

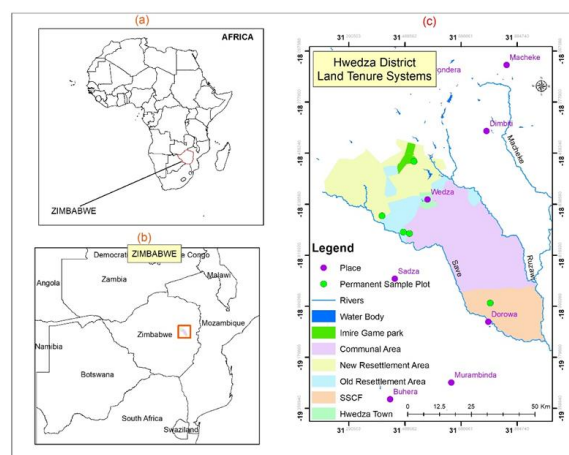


Fig. 1. The location of Hwedza district. The SSCF is the Small-Scale Commercial Farming area found in southern part of the district

Communal Areas are the oldest and most densely populated land-tenure category in the district. They date back to the colonial era, when the Land Apportionment Act of 1930 was introduced. Land in communal areas is held under customary tenure, meaning it is not privately owned but shared collectively and land size is approximately 0.3-1.3 hectares per household (Muchetu, 2019). Traditional leaders such as chiefs and headmen, working with Rural District Councils, oversee land allocation and

natural resource management (Macheka, 2021). This system has, however, faced increasing strain due to high population growth, unplanned settlement expansion, and limited livelihood alternatives apart from rain-fed agriculture. In communal land, the main land uses present include agriculture, settlement and grasslands which are used as grazing land by communities. As such, deforestation is widespread, driven by the high demand for firewood (Pritchard *et al.*, 2018). Trees are also frequently harvested for construction materials and fencing poles, often with little or no planting of replacement trees. In addition, uncontrolled grazing by livestock has led to the degradation of landscapes and reduced regeneration of woody species.

Small-scale commercial farming area

Represented in this study by Zviyambe were created by the colonial government in the 1930s. Initially named Native Purchase Areas, they were earmarked for a small number of African farmers; who had to first acquire land on lease from the government and eventually be allowed to purchase the farms (Scoones *et al.*, 2018). These farms were larger than fields allocated to individual farmers in communal areas and privately owned. In Zviyambe, for example, households' own farms averaging 90 hectares (Shonhe and Mtapuri, 2020). Main activities in the SSCF include growing of rain fed crops and rearing livestock. Livestock in SSCF, graze in paddocks belonging to the farm owner unlike in the communal, old resettlement and new resettlement areas where grazing lands are communal. The SSCF areas have generally maintained healthier vegetation, including well-established miombo woodlands because of more land per household, private ownership and use of rotational paddocks.

The Old Resettlement tenure was introduced in the 1980s, as part of the Zimbabwean government's first land reform programme aimed at reducing overcrowding in the communal areas through subdivision of large-scale commercial farms (Muringa and Zvaita, 2022). Each household had

improved access to land and was allocated about five hectares (Tatsvarei *et al.*, 2018; Tom, 2025). However, this was not accompanied by resources and support to improve livelihoods, which affected how the land was used and managed over time. Agriculture and settlements are the main land uses similar to communal land where communities are peasant farmers who rely on rainfed agriculture. Places like Rundu and Sengezi villages included in the study were part of this early resettlement effort. Major crops grown in this land tenure include tobacco as the main cash crop which is cured using firewood. The old resettlement area is dominated by key miombo species mainly *Brachystegia spiciformis* (Pritchard *et al.*, 2019) and associated species including *Monotis engleri* and *Burkia africana*.

New resettlement areas like Beta Village included in this study, were established during the Fast-Track Land Reform Programme (FTLRP) of the 2000s. In this programme large-scale commercial farms were subdivided into smaller plots where each household typically received about six hectares of land (Muchetu, 2019). While this programme expanded land access significantly, it also led to extensive clearing of forests for construction of homes and farming, often with little oversight on environmental impact (Jombo *et al.*, 2017). Some farmers in parts of Beta village, engage in winter cropping as they have access to water for irrigation, thereby improving their livelihoods. Nearby mountains in the new resettlement area are dominated by various miombo species including *Brachystegia glaucescens*, *Brachystegia spiciformis* and *Julbernardia globiflora*. Associate species like *Monotis engleri* are dominant just beneath the mountains.

A protected area (Imire game park)

Started off as a privately owned large scale commercial farm growing tobacco and maize. Since the 1970s, the farm has employed an integrated land-use system, combining game ranching and cattle grazing. Wildlife roams freely throughout the

property, contributing to biodiversity and eco-tourism opportunities, while cattle are allowed to graze and browse in designated areas. Imire's vegetation is predominantly miombo woodland, dominated by *Brachystegia spiciformis*. Firewood collection and other activities including harvesting poles for various use are prohibited in the park.

Plot establishment and sampling

Vegetation was sampled across the five land-tenure categories, included in the study. We first identified woodland patches using Google Earth imagery and then visited the sites to confirm their suitability and to obtain permission to establish plots from landowners. Five one-hectare permanent sample plots (PSP) were established following the method by Ryan *et al.* (2011) where plots were purposively selected using a stratified non-random approach. These forest monitoring plots will serve as a baseline for future studies in Hwedza miombo woodlands.

All woody trees with a diameter at breast height (DBH) ≥ 5 cm in each plot were identified, tagged, and measured at 1.3 m point of measurement using a diameter tape (Ryan *et al.*, 2011). For multi-stemmed tree branching below 1.3 m, each stem was measured separately as an individual tree. Species were identified in the field, with those difficult to identify collected as samples and taken to the National Herbarium in Harare for identification.

Data analysis

The following indices of biodiversity were calculated for each of the five sample plots in Hwedza:

Species richness was calculated as the total number of species in a particular plot (Kalaba *et al.*, 2013). Species diversity was measured using the Shannon-Wiener index (H'), which was calculated as follows for each land tenure type:

$$H' = -\sum p_i \ln(p_i)$$

Where, p_i represents the sum of individual species divided by the total number of species in a particular plot or land tenure type; Σ is the sum of the calculations; and $\ln$ is the natural logarithm (Lemi *et al.*, 2023).

Another measure of diversity called the Simpson index was measured using the following formula:

$$D = 1 - \sum_{i=1}^S p_i^2$$

Where D is the Simpson's diversity index; S is the sum of species per plot; and p_i is the proportion of the sum sample belonging to the i^{th} species (Gonçalves *et al.*, 2017).

Species evenness estimates the abundance of different species within an ecological unit or community (Gonçalves *et al.*, 2017). It was calculated based on the formula:

$$Evenness = H / \log(S)$$

Where H represents the Shannon index and S is species richness.

Plant density refers to the sum of all individual plant species per unit area within a plot and was calculated as follows:

$$Plant\ density = N/A$$

Where N , the total number of individual plants in the plot and A is area of the plot in square metres.

Relative Density (RD) shows the number of individuals of a species per unit area compared to the sum of all individual species. The following formula was used to calculate RD:

$$Relative_Density = Count / \sum(Count) * 100$$

Relative Dominance represents the proportion of a species' basal area in relation to the total basal area of all species. It is calculated using the formula:

$$\text{Relative_Dominance} = \frac{\text{Total_BA}}{\text{total_basal_area}} * 100$$

Above ground biomass: It was calculated using the following allometric equation developed by Ryan *et al.* (2011):

$$AGB = \exp((2.601 * \log(dbh)) - 3.629)$$

Where AGB is the Above Ground Biomass and DBH is the diameter at breast height measured in the field. Biomass of all trees per plot were summed up to get total biomass in kg before conversion to tonnes per ha (ha⁻¹).

RESULTS

Species composition and dominance patterns by land tenure

A total of 2 215 individual trees belonging to 87 species across 37 families were assessed across the five studied land tenure types. The results on species richness and plant density across the different land tenure types are presented in Table 1. The SSCF area had the highest species richness (40 species) among the five land tenure types. Imire game park displayed a moderate species richness (26 species), while the Communal Area had the lowest species richness (13 species). The SSCF area (0.07) and Imire game park (0.07) had similar values of plant density higher than those from other land tenure types. The Old Resettlement area showed a moderate (0.05) plant density, followed by the New Resettlement area (0.02) which had a lower plant density. The Communal area had the lowest plant density (0.0) which indicated less dense vegetation cover. Fig. 2 presents the relative dominance of species in each land tenure type. *Brachystegia spiciformis* was the dominant species in the Imire game park and Old Resettlement Areas, whilst *Julbernardia globiflora* was dominant in the SSCF and New Resettlement areas (Table 2). *Monotes engleri* consistently appeared across all studied land tenure types, with its relative density and dominance varying. Species such as *Burkia africana*, *Lannea discolor*, and

Euclea natalensis appeared in multiple land tenure types, contributing to the overall species richness in each land tenure type.

Woody species diversity

Species diversity indices across different land tenure types were calculated (Table 3). The New Resettlement Area had the highest Shannon index (2.92) followed by the SSCF area (2.64). The Old Resettlement (2.39) and Communal areas (2.27) had moderate species diversity; while Imire game park (1.42) exhibited the lowest diversity.

The Simpson's index followed a similar pattern, with values ranging from lowest in Imire Game Park (0.52) and highest in the New Resettlement area (0.90). The SSCF, Communal and Old Resettlement areas had intermediate species diversity values (0.87, 0.87 and 0.81 respectively). Species evenness was highest in the Communal Area (0.89) while New Resettlement (0.80) and SSCF areas (0.72) showed moderate uneven distributions. The Old Resettlement Area and Imire game park recorded lowest evenness of 0.67 and 0.43 respectively.

Stem diameter distribution

Smaller stems with a diameter at breast height (DBH) range of 5–10 cm were more dominant in the Old Resettlement area (468) than in any other land tenure type (Fig. 3). The Communal area had the lowest (54) number of stems in this category. The Imire game park had the highest number (343) of stems in the 10–20 cm DBH range. Furthermore, the results indicate that higher DBH stems (>20 cm) were found more commonly in the Imire game park than in any other land tenure type. Only two DBH categories- the 5–10 cm and the 10–20 cm were observed in the Communal and Old Resettlement areas. The distribution and variation of stems in both the SSCF and the New Resettlement areas show the presence of many smaller stems that indicate a high recruitment of species. The distribution of stem DBH showed an inverse J curve across the study area (Fig. 4).

Table 1. The number of species and the density of plants in each category of land tenure system per square meter

Land tenure system	Species richness(N)	Plant density (m ²)
Protected area (Imire game park)	26	0.07
Communal	13	0.00
Small scale commercial farming (SSCF)	40	0.07
Old resettlement	36	0.05
New resettlement	39	0.02

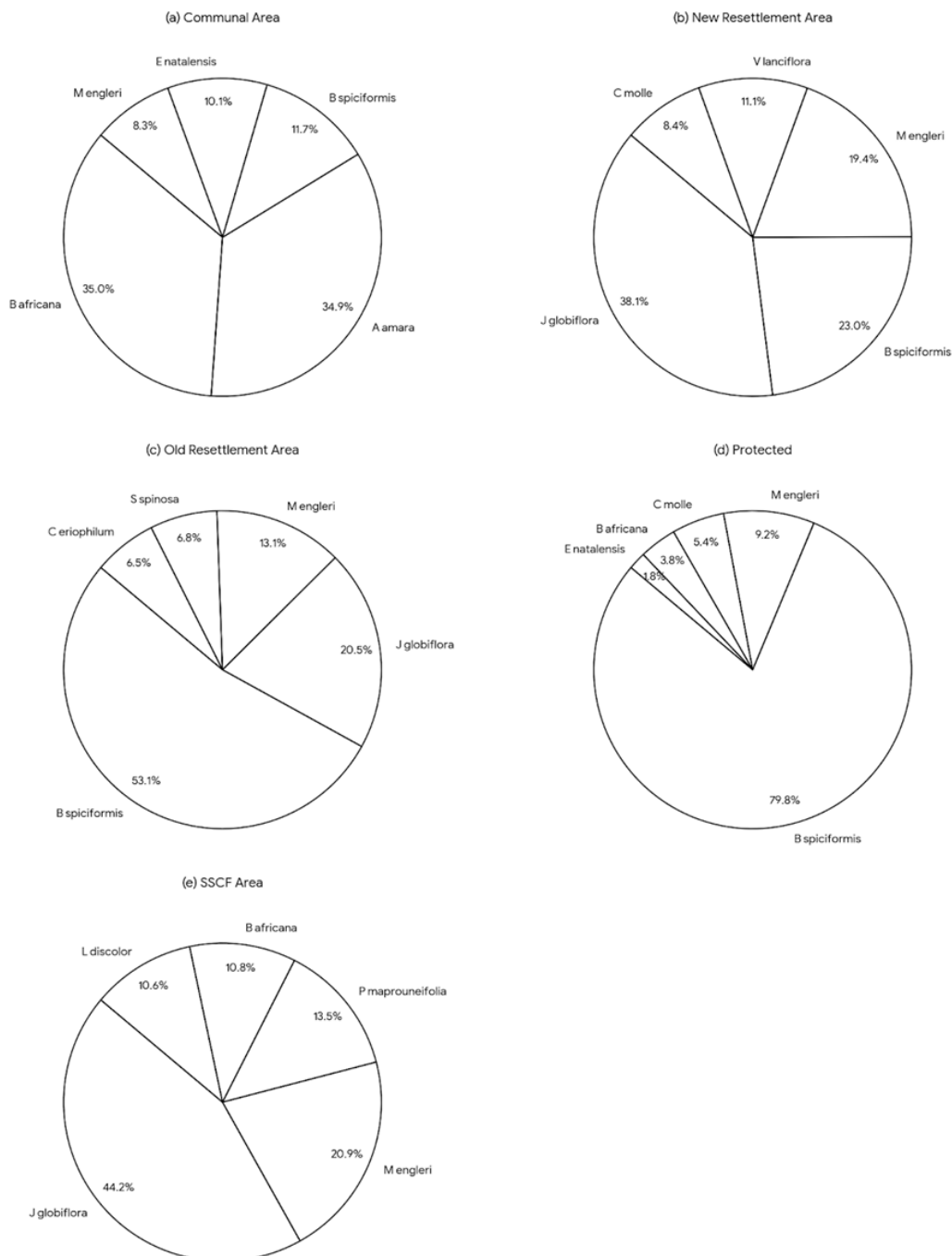


Fig. 2. Five dominant species in five different land tenure systems. (e) denoted as SSCF is the Small-scale Commercial farming area, (d) denoted as Protected is Imire game park. Major species on this figure include *Brachystegia spiciformis*, *Monotis engleri*, *Albizia amara*, *Burkea Africana*, *Julbernadia globiflora*, *Strycnos spinosa*, *Lanea discolor*, *P maprouneifolia* (*Pseudolachnostylis maprouneifolia*), *C eriophyllum* (*Clerodendrum eriophyllum*), *E natalensis* (*Euclea natalensis*), *V lanciflora* (*Vangueriopsis lanciflora*)

Table 2. Relative densities and relative dominance of tree species in the different land tenure system

Land tenure system	Species	Relative density (%)	Relative dominance (%)
Protected area (Imire game park)	<i>Brachystegia spiciformis</i>	20.72	32.92
	<i>Monotes engleri</i>	2.52	3.81
	<i>Combretum molle</i>	1.80	2.20
	<i>Burkia africana</i>	1.35	1.56
	<i>Diospyros lycioides</i>	0.76	0.70
Communal	<i>Burkia africana</i>	0.58	0.201
	<i>Albizia amara</i>	0.45	0.201
	<i>Brachystegia spiciformis</i>	0.40	0.06
	<i>Monotes engleri</i>	0.27	0.04
	<i>Euclea natalensis</i>	0.22	0.05
Small scale commercial farming (SSCF)	<i>Julbernardia globiflora</i>	8.39	10.19
	<i>Monotes engleri</i>	4.55	4.82
	<i>Lannea discolor</i>	3.06	2.43
	<i>Burkia africana</i>	2.34	2.49
	<i>Pseudolachnostylis maprouneifolia</i>	1.67	3.09
New resettlement	<i>Julbernardia globiflora</i>	2.34	2.36
	<i>Brachystegia spiciformis</i>	1.30	1.43
	<i>Monotes engleri</i>	1.26	1.20
	<i>Lannea discolor</i>	0.81	0.40
	<i>Combretum molle</i>	0.63	0.52
Old resettlement	<i>Brachystegia spiciformis</i>	9.02	2.45
	<i>Julbernardia globiflora</i>	3.74	0.94
	<i>Monotes engleri</i>	2.75	0.60
	<i>Clerodendrum eriophyllum</i>	1.35	0.29
	<i>Euclea natalensis</i>	0.72	0.25

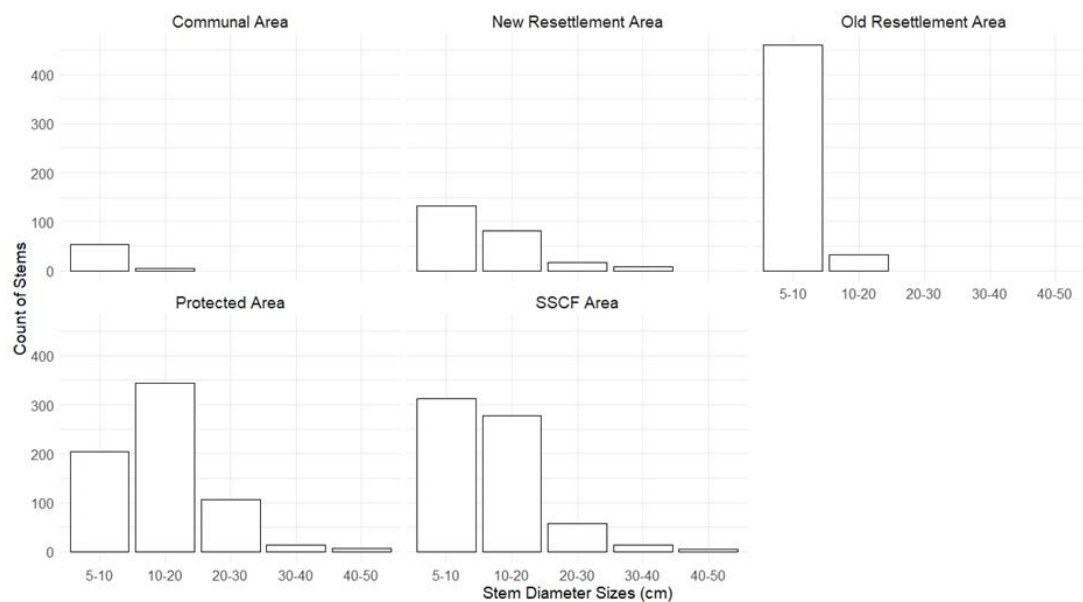
**Fig. 3.** Distribution of stems diameter range per land tenure systems**Above ground biomass (AGB)**

Table 4 shows distinct variations in AGB across the five-land tenure types. The Imire game park recorded 28.2 t ha⁻¹ of AGB which is the largest amount of AGB among the five-land tenure types of Hwedza. This was followed by the SSCF area where ABG reached 21.7 t ha⁻¹.

In contrast, much lower biomass values were observed in the two resettlement areas and communal areas. The New Resettlement area had an AGB of 6.83 t ha⁻¹, while the Old Resettlement area recorded 2.32 t ha⁻¹. The Communal area had the lowest biomass of land tenure types, with just 0.26 t ha⁻¹.

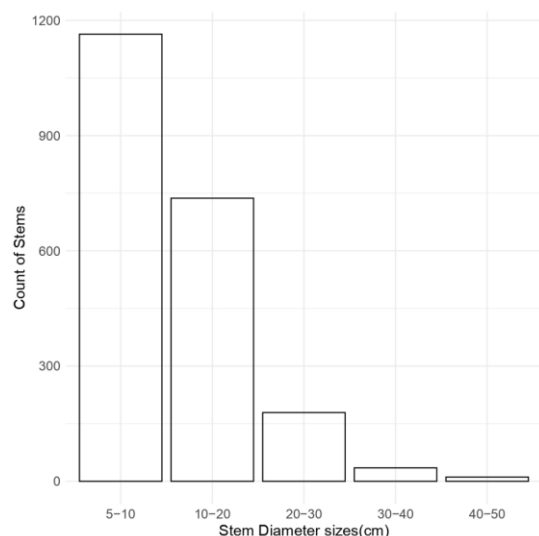


Fig. 4. Inverse J shaped, showing distribution of stems-based diameter sizes per land tenure system

Table 3. Species indices across land tenure systems including the Shannon, species richness and species evenness

Land tenure system	Shannon	Simpson	Evenness
Communal	2.27	0.87	0.89
New resettlement	2.92	0.90	0.80
Old resettlement	2.39	0.81	0.67
Protected area (Imire game park)	1.42	0.52	0.43
Small scale commercial farming	2.64	0.87	0.72

Table 4. The table shows the distribution of AGB per land tenure system

Land tenure system	AGB t ha ⁻¹
Communal	0.26
New Resettlement	6.83
Old Resettlement	2.32
Protected area (Imire game park)	28.2
Small scale commercial farming	21.7

Table 5. AGB distribution by DBH category across all land tenure system

Diameter range	AGB t/ha	Percentage contribution (%)
10-20	19.9	33.56
20-30	19.01	32.05
30-40	9.35	15.75
5-10	5.26	8.87
40-50	5.8	9.77

Table 5 highlights the distribution of AGB across different DBH categories, showing how tree size contributes to overall biomass accumulation. Trees in the medium range of the DBH category 10–20

cm contributed the most to AGB and total biomass followed closely by the 20–30 cm category. When combined, these two categories contributed approximately 65.6% of the total AGB, indicating that medium-sized trees were the primary biomass contributors. The 30–40 cm diameter trees contributed approximately 16% of total AGB while the 40–50 cm and 5–10 cm categories contributed 9.6% and 8.8%, respectively.

DISCUSSION

Tree species composition and dominance

The baseline assessment revealed clear differences in woodland composition, diversity, and structure across the five land-tenure types in Hwedza. The study documented 87 species belonging to 37 plant families distributed among the five land tenure types, showing high species richness across the study sites. This richness highlights the ecological significance of miombo woodlands, which provide essential ecosystem services that sustain local livelihoods (Ribeiro *et al.*, 2020). Similar findings have been reported on miombo woodlands in Domboshawa, Zimbabwe (Zimudzi and Chapano, 2016) and in Kaning'ina and Thambani forests in Malawi (Gondwe *et al.*, 2021). Such comparisons with other miombo woodlands indicate these forests form part of a wider regional biodiversity pattern, offering valuable insights for monitoring long-term ecological trends. The differences in species composition across land tenure types, largely reflect varying levels of disturbance and land use intensity. Agriculture is dominant activity in the Communal, New Resettlement and Old Resettlement areas, leading to greater disturbance and a shift in species assemblages.

In contrast, less disturbed areas such as the large and small-scale commercial farms support richer woodland communities. These patterns highlight the strong influence of land management on woodland diversity and emphasize the need for long-term monitoring to track how continued agricultural pressure may alter species composition and ecosystem health. The dominance of the subfamilies

Detarioideae and Caesalpinioideae of the Fabaceae shows that their ecological adaptability is high. These plants can fix nitrogen thereby improving soil fertility (Gonçalves *et al.*, 2018; Muboko *et al.*, 2013; Ribeiro *et al.*, 2020). This gives them a competitive advantage over other species in nutrient-poor soils. Their success can also be attributed to their deep root systems which not only help them access water and nutrients but to resprout vigorously after disturbance (Orwa *et al.*, 2009). The findings provide an important floristic baseline data which provides the basis for tracking long term ecological changes in Hwedza. This is important as it plays an important role in informing conservation and restoration efforts and strategies in Hwedza, especially given a mix of land uses practiced in the district.

Species richness and plant density

The SSCF area recorded the highest species richness and population density than in other land tenure types. This could be explained by possible use of sustainable land management practices in this land-use type such as controlled or rotational grazing through use of paddocks, and prescribed burning methods, as well as preservation of large trees. These approaches help prevent destructive wildfires and improve rainwater absorption, creating the right conditions for plants to recover and grow back naturally in case of disturbance. As a result, the woodland in this area remains vibrant and healthy. Additionally, land use in SSCF is largely forests and there is limited conversion of forests to other land uses.

In contrast, the Communal area showed the lowest values of both species' richness and population density probably because of intense anthropogenic pressure from activities such as overgrazing, deforestation, frequent wild fires and forest and land degradation. These anthropogenic occurrences cause runoff thereby decreasing chances of water infiltration that promotes species regeneration and growth of small stems into medium and large sized stems.

The higher prevalence of *Brachystegia spiciformis* and *Julbernardia globiflora* in Imire game park and the SSCF areas suggests that current conservation

efforts in these land-tenure types are having a positive effect. These two species are ecologically significant, as they are among the dominant and defining tree species of miombo woodlands. Their presence is often associated with healthier, and intact woodland ecosystems (Frost, 1996). Interestingly, SSCF areas, though not officially protected, still had a high number of these key miombo species.

These areas had relatively low population pressure, with farmers establishing woodlots and leaving parts of their land in a natural state. Many farmers in SSCF were observed to deliberately retain indigenous trees on their land because such trees provide useful benefits like shade, improved soil health, and other ecosystem services. Similar patterns have been observed elsewhere in southern Africa, where smallholder farming and agroforestry systems have been shown to support rich plant biodiversity (Dewees *et al.*, 2011).

Apart from the dominant miombo species, other well-known miombo associate species such as *Monotes engleri*, *Burkea africana*, *Lannea discolor* and *Euclea natalensis* were recorded across the five land tenure types. These species were found in both disturbed and less disturbed areas which suggests that they might be adaptable to land degradation. They seem to be able to cope with a wide range of conditions which might be coupled with their fast growth rate, flexible regeneration, and greater tolerance to disturbance. Plant densities were, much lower in the communal areas, which adds to the evidence that these areas are under significant ecological stress (Chipika and Kowero, 2000). This is because of increased resource pressure by villagers as communal land is communally owned and is common property

Species diversity and evenness

The New Resettlement area had the highest plant species diversity compared to other land tenure types in Hwedza, a pattern likely linked to its moderate levels of disturbance as the population levels are still lower compared to Communal land and Old

Resettlement While parts of the land are cleared for farming in the New Resettlement, patches of indigenous vegetation have been retained, creating a variety of habitats that can support a range of plant species. The observation aligns with the Intermediate Disturbance Hypothesis which predicts that species diversity is highest under conditions of moderate disturbance as neither competitive exclusion nor local extinctions dominate community dynamics (Buramuge *et al.*, 2023). A study in Tanzania, had similar results (Jew *et al.*, 2016), that showed that miombo woodlands with moderate disturbance often support the highest plant diversity.

Species diversity in the SSCF area was also relatively high, likely reflecting the benefits of sustainable land management practices. These include rotational grazing and prescribed burning practiced by farm owner. In contrast, the Imire game park had a lower species diversity, with a few species dominating and with limited regeneration opportunities likely because of over- grazing by livestock. The communal areas displayed a higher species evenness, indicating a balanced species distribution, a pattern similar to that observed in miombo woodlands in Angola by Gonçalves *et al.* (2017). This balanced species distribution could be a result of disturbance regimes like grazing which tend to affect fast colonizers while maintaining other species

The New Resettlement and SSCF areas showed moderately uneven distribution of species, which reflect the presence of dominant species alongside a diverse set of subordinate species.

Imire game park showed the lowest species evenness which was similar to that observed in an undisturbed woodland with a strong dominance of a few woody species, in south-central Angola by Gonçalves *et al.* (2017) The results of this study differ from those of similar studies carried out in Zimbabwe, for example by Gotore *et al.* (2021) and Zinyowera *et al.* (2021) who found that disturbance and land-tenure type had no effect on species diversity. This discrepancy could have been caused by the land-use history, habitat

characteristics, intensity of the different disturbance types, and variations in sampling methods used among the different study sites.

Species structure and stem diameter distribution

Variation in stem diameter distribution highlighted clear differences in forest structure and regeneration potential across the five land tenure types. Small sized stems were more predominant in the Old Resettlement area suggesting active regeneration, possibly because of previous intensive cutting down of trees and woodland degradation. In the Imire game park medium sized stems were most common, indicating a well-established tree population, with proportions even higher than those reported in similar land-use types in Tanzania (Shirima *et al.*, 2011). The largest trees were mainly found in the Imire game park and SSCF areas where protection and limited logging have allowed older trees to persist. In contrast, the Communal and Old Resettlement areas, lacked large trees indicating extraction of such stems for various purposes. The inverse J-shaped DBH distribution of stems-based diameter sizes observed across all the land-use types suggests healthy and regenerating forests, with many small stems gradually transitioning into fewer larger trees (Gotore *et al.*, 2021; Zimudzi and Chapano, 2016). The Imire game park, however had mostly trees with larger stem diameter probably because of competition and herbivory. Such observations establish a robust baseline for future monitoring, enabling the detection of changes in species composition, forest structure, and regeneration dynamics in response to land-use practices and environmental pressures over time.

Above ground biomass

Above-ground biomass (AGB) patterns mirrored the structural and compositional trends. The Imire game park had the highest AGB which could be attributed to the presence of well-established trees and minimal to no human disturbance. These findings are consistent with those of studies on protected miombo woodlands in Tanzania (Jew *et al.*, 2016, Shirima *et*

al., 2011). The SSCF area also recorded substantial AGB possibly because of the sustainable land management practices used in these areas including selective logging and fire management practices that promote biomass growth and accumulation.

In contrast, the Resettlement areas had moderate to low AGB. The Old Resettlement area in particular had low biomass due to excessive harvesting of trees for tobacco curing, garden poles, and other household needs (Stewart *et al.*, 2025) which has led to a landscape dominated by small trees. The situation was more critical in the Communal area where the lowest AGB was recorded because of the intense extraction of trees for firewood, construction and daily use, over grazing and frequent fires that have greatly reduced the woodland's biomass. Most of the biomass (over 65%) was stored in trees with a DBH between 10 and 30 cm consistent with results of a similar study in southern Malawi by Kuyah *et al.* (2014). The AGB recorded in the Resettlement areas as well as in the Communal area were lower than what was found in similar, heavily used landscapes in Tanzania (Jew *et al.*, 2016); while the AGB obtained in the SSCF and Imire game park were comparable to those reported in other well managed woodlands throughout the region (Ryan *et al.*, 2011, Ryan *et al.*, 2016). Overall, these baseline observations provide a reference for long-term monitoring and illustrate how land-use intensity and management practices influence species diversity, forest structure, as well as amount of biomass, and will allow future studies to track changes in regeneration, species composition, and carbon stocks over time, providing critical insights for sustainable woodland management and conservation planning.

CONCLUSION

The study highlights the critical role of land-use in different tenure systems in shaping species and vegetation composition and structure of Miombo woodlands. The results provide a robust baseline for long-term monitoring because they capture key structural, compositional, and biomass characteristics across a range of land-tenure types. They illustrate

how land-use intensity and management practices influence species diversity, forest structure, and biomass, and will allow future studies to track changes in regeneration, species composition, and carbon stocks over time, providing critical insights for sustainable woodland management and conservation planning. Permanent sample plots and recorded metrics (species richness, DBH distributions, AGB) will allow detection of future changes due to land-use practices, disturbances, or climate impacts. Stem size distributions, species diversity, evenness, and AGB emerge as reliable indicators to track woodland health and regeneration over time. Areas showing low biomass or skewed size classes can be targeted for intervention or restoration, while areas with high diversity and biomass can serve as reference sites. High biodiversity and plant density within SSCF areas point to sustainable land-use management that clearly support biodiversity conservation. In Imire game park, moderate species richness, indicates that conservation areas play an important role in maintaining stable and dense vegetation communities. Low biodiversity and plant populations in the Communal area indicate environmental degradation which requires the introduction of community-based initiatives that promote ecosystem conservation and sustainability of these woodlands.

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