EFFECTS OF HARVESTING SYSTEMS ON TREE SPECIES COMPOSITION, RECRUITMENT, AND POPULATION STRUCTURE IN MTANGATANGA FOREST RESERVE, MZIMBA DISTRICT, MALAWI

MASTER OF SCIENCE DEGREE IN FORESTRY AND ENVIRONMENTAL MANAGEMENT THESIS

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MZUZU UNIVERSITY

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BACHELOR OF SCIENCE IN FORESTRY

A THESIS SUBMITTED TO THE FACULTY OF ENVIRONMENTAL SCIENCES, DEPARTMENT OF FORESTRY, IN FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE DEGREE (MSc) IN FORESTRY AND ENVIRONMENTAL MANAGEMENT

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DECLARATION

I hereby declare that this thesis, titled "Effects of harvesting systems on tree species composition, recruitment and population structure in Mtangatanga Forest Reserve, Mzimba District", has been written by me and is a record of my research work. All citations, references, and borrowed ideas have been duly acknowledged. It is being submitted in fulfillment of the requirements for the award of degree of Master of Science (MSc) in Forestry and Environmental Management of the Mzuzu University. None of the present work has been submitted previously for any degree or examination in any other University.

	6th January 2026
Masozi Dorothy Shaba	Date

CERTIFICATE OF APPROVAL

I, the undersigned, certify that this is a result of the author's work, and that to the best of my knowledge, it has not been submitted for any other academic qualification within Mzuzu University or elsewhere. The Thesis is acceptable in form and content, and the candidate demonstrated satisfactory knowledge of the field covered by the thesis through an oral examination held on 28th November 2025.

	6th January 2026
Main Supervisor	Date
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Co-supervisor	Date
Associate Professor Lusayo Mwabumba	

DEDICATION

I dedicate this work to the Almighty God for his guidance, protection and everlasting love. I further dedicate this thesis to my father, Dr. Bina Huggins Shaba (late) and my mother, Mercy Chirwa Shaba, for their encouragement and moral support during my studies; my husband Chimwemwe, and my children, Ruth and Daniel Mhone, for enduring my absence. Lastly, I dedicate the thesis to my sister Thandiwe Shaba for taking care of my children.

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ACRONYMS

ADC	Area Development Committees
BA	Basal Area
DF	Degree of Freedom
DoF	Department of Forestry
DBH	Diameter at Breast Height
GoM	Government of Malawi
Ha	Hectare
Ha^{-1}	Per hectare
H'	Shannon Wiener Index
IPCC	Intergovernmental Panel on Climate Change
IVI	Importance Value Index
Ln	Natural Logarithm
M^2ha^{-1}	Square meters per hectare
MFR	Mtangatanga Forest Reserve
MZUNIREC	Mzuzu University Research Ethics Committee
N	Total Number of Individuals
Pi	Promotion of individuals
p-value	Probability Value
Ede	Relative Density
Rf	Relative Frequency
RDo	Relative Dominance
S	Species Richness
SD	Standard Deviation
SH	Selective harvesting

SFM	Sustainable Forest Management
SoPs	Standard Operating Procedures
SSA	Sub-Saharan Africa
Sj	Jaccard similarity Index (%)
t-value	Test Statistic
UH	Unregulated harvesting
VDC	Village Development Committees
α	Fisher's Alpha Diversity Index

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ABSTRACT

Forests and woodlands are among the most biodiverse and productive terrestrial ecosystems especially in tropics, yet they continue to face extensive degradation driven by unsustainable management. Harvesting systems strongly influence population structure, tree species composition, and recruitment dynamics. The removal of trees alters stand density and may subsequently modify species diversity and forest structure. In Mtangatanga Forest Reserve, both non-selective and unregulated harvesting are practiced with the latter often resulting from non-compliance in areas designated for strict conservation. Selective harvesting and clearcutting are mostly associated with the removal of immature and protected species, potentially undermining forest regeneration

This study evaluated the effects of selective and an unregulated harvesting system practised in Mtangatanga Forest Reserve on species composition, recruitment, and population structure. Twenty concentric nested circular sample plots (ten per harvesting type) were purposively established. Each plot comprised three nested subplots with a radii of 6m, 12m, and 20m, where all trees were identified, enumerated, and measured for diameter at breast height.

A total of 644 individual tree species were enumerated, representing 25 species in selectively harvested and 19 in unregulated harvesting areas. Dominant species were in the family of *Brachystegia, Julbernardia,* and *Uapaca.* Recruitment, there was no statistically significant difference between unregulated and selective with $p > 0.05$ in seedling, saplings, and poles. Diversity (Shannon-Wiener index) was significantly higher in selectively harvested areas ($H' = 2.65$) than in unregulated areas ($H' = 2.34$). There was a significant difference ($p < 0.001$)

with selective harvesting exhibiting a smooth reverse J-shaped size-class distribution, indicating stable recruitment, while unregulated harvesting showed a slightly disturbed pattern. The study concludes that regeneration is sufficient in selectively harvested areas but inadequate under unregulated harvesting. Strengthened forest law enforcement and sustainable management interventions are therefore, recommended to support long-term forest resilience to promote forest-based enterprises.

Keywords: Miombo woodland, Harvesting systems, Recruitment, Species diversity, population structure

CHAPTER 1: INTRODUCTION

1.1 Background of the study

Forests and woodlands are most biodiverse and productive terrestrial ecosystem, especially in the tropics (Montfort *et al*., 2021; Badu *et al.,* 2022), yet they continue to face intensive degradation driven by unstainable management. Globally, almost 60% of tropical forests are habitats for all the living things on the Earth. They play a vital role in regulating climate, weather patterns, and well as enhancing global carbon sequestration. They also moderate soil erosion and support the community's livelihoods (Chaudhary *et al*., 2016; Kacholi, 2019). Against all the roles tropical forests play on earth, they are depleting rapidly (Badu *et al*., 2022). Vancutsem *et al.* (2021) reported that between from 1990 and 2020, 219 million hectares equivalent to 17% of world's tropical forest cover present in 1990 were deforested, while 10% of the remaining 1,071 million hectares experienced degradation.

Chapman *et al.* (2022) described that recently, the African continent has been faced with environmental challenges due to overpopulation, second most populous continent and its population projected to quadruple by 21st century. Africa is the poorest continent, and its people depend on natural resources for a source of energy for heating and lighting, as well as a source of construction materials, medicines, fodder, and food, which leads to loss of biodiversity (Pelletier, *et al.*, 2019; Chapman *et al.*, 2022). The Malawi National Forest Policy (GoM, 2016) together with studies by Jew *et al.,* (2017); Muvengwi *et al.,* (2020); and Chapman *et al.,* (2022), indicates that most forest reserves and customary forests are heavily degraded due to high dependency on natural resources including encroachment for farming, unsustainable harvesting, poor ecosystem management of the ecosystem, and charcoal production.

In Sub-Saharan Africa (SSA) region, forest reserves, national parks and game reserves are increasingly failing to fulfil their natural ecological functions due to natural and anthropogenic pressures such as floods, climate change, soil erosion, forest fires, and the growing intensity of anthropogenic activities (Badu *et al*., 2022). The anthropogenic activities have risen over time with population growth and the associated demand for food, timber, and fibre (Appiah *et al.*, 2021; Badu *et al*., 2022). Miombo woodlands play a critical role in sustain livelihoods across SSA, 60% of the regional population (Pelletier *et al.*,2019). Millions of people in rural and urban areas depend on these ecosystems for construction materials (poles and timber), and for energy sources such as fuelwood and charcoal (Jew *et al.*, 2017; Muvengwi *et al.*, 2020). Jew *et al.* (2017) further project that by 2050, the population of the SSA region will double, exerting even great pressure on forest resources. Therefore, sustainable forest management is essential to curb the ongoing depletion of the forests and Miombo woodlands (GoM, 2016; GoM, 2017; Jew *et al.,* 2017; & Gondwe *et al.*, 2020; Muvengwi *et al*., 2020).

In Malawi, approximately 97% of households depend on unsustainable and often illegal sources of fuel energy, primarily firewood and charcoal (GoM, 2017). Holmes *et al.* (2019) and Gondwe, (2020) reported that about 85 % of Malawian lives in rural areas depend more on forest resource for domestic and industrial uses as their primary source of income. The dependency has accelerated deforestation, currently estimated at 2.8% per year, as reported in the Malawi National Forest Policy (GoM, 2016). However, GoM, (2024) reported that 115,650 hactares (ha) were deforested in Malawi from 2010 to 2020, which equates to the rate of 11,565 ha ± 1.067 ha y^{-1}, equivalent to a 0.66% ± 0.03% annual rate of deforestation with forests nationally. The report also revealed that 14,192 ha ± 1,323 ha were degraded annually. Further, Khendlo, *et al.* (2024) reported that Malawi experienced a significant loss of 224,000 ha of the tree cover, which representing 15% reduction in its overall tree cover between 2001 and 2023.

The high rate of forest degradation has compromised tree species composition, recruitment and population structure, due to anthropogenic activities such as illegal charcoal production, uncontrolled fires, unauthorised tree cutting, and collection for commercial firewood (Muvengwi et *al.*, 2020; Forest Landscape Restoration Action Plan for M'mbelwa District Council, 2021).

Ribeiro *et al.* (2015) described Miombo woodland regions as characterized wet and dry conditions, with drier interiors and wetter coastal areas. They further noted that rising temperatures may alter disturbance regimes such as fires, illegal harvesting, and shifting cultivation, hence affecting biodiversity. The continued loss of mature trees transforms the Miombo landscape, often converting woodlands into grasslands or scrub lands. According to Vyamana *et al.* (2021), studies by Chiteculo, V. and Surovy, P., (2018); Pelltier etal., (2019); Mambo, (2020); Nchimbi, (2022) have demonstrated that unsustainable wood harvesting is widespread in Miombo woodlands. Consequently, the extraction rates exceed natural regeneration through coppicing, root suckering and sprouting. Nonetheless, Miombo tree species possess regenerative capacity with pioneer species colonizing disturbed sites where human activities have been intense (Vyamana *et al.,* 2020; Badu *et al*., 2022).

Tree removal significantly alter stand density, which may potentially modify tree species diversity, composition and forest structure (Latterini, 2023; Workneh & Wanssie, 2024). The structure and composition of Miombo woodlands are strongly influenced by harvesting systems of charcoal production, timber sawing, and firewood collection (Orthmann, 2005; Chidumayo & Marunda, 2010; Gumbo *et al.,* 2018; Manjate *et al.,* 2025). The main harvesting systems practised are include clear cutting (complete coppice), coppice with standards, and selective harvesting (Chirwa *et al.,* 2009). Local communities often adopt clear-cutting when the production demands are high particularly for commercial firewood, charcoal production, pole and timber (Clarke & Shackleton, 2007).

Selective harvesting, on the other hand involves felling coppice thinning or branch lopping throughout the woodlands without a definite harvesting cycle (Pelletier *et al.,* 2019). While globally regarded as an efficient and biodiversity-friendly method (Poudyal *et al.,* 2018; Manjate, 2025). Selective harvesting has nonetheless contributed to forest degradation due to the absence of clear harvesting intervals variability in production rate (Clarke & Shackleton, 2007). Moreover, biomass loss Miombo woodlands remain largely unquantified because forest inventories are rarely conducted, given the low perceived commercial value of the ecosystems (Skole *et al.,* 2021).

This study, therefore, sought to assess the effects of different harvesting systems, namely selective and unregulated on the species composition, recruitment, and population structure within Mtangatanga Forest Reserve (MFR). Selective harvesting is defined as the removal of individual trees or small groups to maintain an uneven-aged forest structure (Smith *et al*., 1997; Arii *et al*., 2008; Falk *et al*., 2008). In contrast unregulated is the removal of trees targeting valuable species, without regard to size or quantity (Muboko *et al*., 2019).

Data was collected purposively areas where selective and unregulated harvesting occurred. This study, selective sites were those designated for limited firewood and poles collection, while unregulated sites were conservation areas where harvesting are done illegally due to weak enforcement.

According to Latterini *et al.* (2023), tree harvesting forest microclimate affecting humidity, wind speed and light intensity, thereby stressing forest species. The type and intensity of harvesting species density, composition and population structure (Fayolle *et al*., 2014). Mtangatanga Forest Reserve has not been spared degradation, particularly, from illegal charcoal production and firewood collection, leaving reserve with patchy forest cover. This study was therefore, carried out to compare the effects of selective and unregulated harvesting systems on tree species composition, recruitment and population structure, and how these influence species diversity within the reserve.

1.2 Statement of the problem

Despite the numerous ecological, economic, and social benefits derived from unsustainable management remain widespread across most parts of Malawi (Kachamba, 2016). Local communities continue to clear forests for agricultural expansion, charcoal production, and through the setting of bush fires activities that threaten the long-term survival of the ecosystems if sustainable management practices are not implemented (GoM, 2016). Malawi, approximately 88% of the population and 54% of urban households rely on charcoal as their primary source of biomass energy (GoM, 2017). This dependence on charcoal and firewood is one of the major drivers of deforestation and forest degradation, within negative implications for the environmental stability, social welfare and economic livelihoods GoM, 2017).

Anthropogenic disturbances within the Miombo woodlands significantly alter species composition and structure. Such changes often prolong the recovery process or even prevent forests from regaining their original species composition following severe disturbances (Giliba *et al.*, 2011; Kalaba *et al.*, 2013). Illegal tree harvesting mainly through selective logging and clearcutting is prevalent. Selective harvesting, particular, has resulted in overexploitation and biodiversity loss, while suppressing the regeneration of saplings (Gatti *et al*., 2015). Kamangadazi (2019) further notes that over-exploitation, charcoal production, and overgrazing collectively disrupt species recruitment within the Miombo ecosystem. Moreover, many degraded areas regenerates primary through coppicing from rom stumps or rootstocks, and because certain species have low dispersibility and short-lived seeds, recruitment, and population structures are negatively affected (Frost, 1996; Zimudzi *et al*., 2013).

Understanding the effects of these harvesting systems on the dynamics of the miombo woodlands of MFR is therefore crucial. The MFR is located between two rapidly growing urban centres, that is Raiply Trading Centre and Mzimba Boma. These centres exert immense pressure on forest resources. The market opportunities associated with growth of urban and peri-urban communities surrounding the Miombo woodland further intensify unregulated harvesting (Zulu *et al.*, 2020). Unsustainable practices with as the non-selective felling of trees and the harvesting of immature trees and protected species contribute to poor forest structure and declining species composition (Ribeiro *et al.,* 2020). Further, Hafico and Fleig (2015) indicated that anthropogenic activities, particularly illegal selective harvesting, play a significant role in shaping the dynamics of Miombo woodlands.

However, there is inadequate information on how different harvesting systems influence forest dynamics, especially in terms of tree species composition, recruitment and population structure within MFR. this study, therefore, aimed to evaluate the effects of selective and an unregulated harvesting system practised in MFR on species composition, recruitment, and population structure. The finding will contribute to improve forest and woodland management strategies that promote sustainable use and conservation of Miombo ecosystems.

1.3 Research objectives

1.3.1 Main objective

The main objective of this study was to evaluate the effects of selective and an unregulated harvesting system practised in Mtangatanga Forest Reserve on species composition, recruitment, and population structure.

1.3.2 Specific **objectives**

The specific objectives were;

1. To assess the effects of selective and unregulated harvesting systems on floristic tree species composition.
2. To compare the effects of selective and unregulated harvesting systems on tree species diversity.
3. To assess the effect of selective and unregulated harvesting systems on recruitment patterns.
4. To examine the effects of selective and unregulated harvesting systems on tree population structure.

1.3.3 Research hypotheses

The following were the research hypotheses;

1. There is no significant difference in tree species composition under selective and unregulated harvesting systems.
2. There is no significant difference in new tree species recruitment under selective and unregulated harvesting systems.
3. There is no significant difference in tree population structure under selective and unregulated harvesting systems.

4. There is no significant difference in tree species diversity under selective and unregulated harvesting systems.

1.4 Justification of the study

The study provides information on the dynamics of harvesting systems and their implications for sustainable forest management and conservation. The findings are expected to guide – evidence-based decisions that promote ecological integrity and long-term sustainability of forest resources. Specifically, the information generated will assist policy-makers, decision-makers and implementers in understanding the relative impacts of selective and unregulated harvesting systems on composition, recruitment and forest structure such understanding is crucial for adopting management strategies that enhance the sustainability of forest ecosystems. the forest resources and enables protection of the threatened and endangered species for economic, ecological and social values.

Moreover, the knowledge obtained from the assessment of species composition and structure forms a scientific basis for understanding forest resource conditions. This understanding is vital for protection and restoration of threatened and endangered species, which hold significant ecological, economic, and social values.

In addition, the study provides practical insights for policy formulation and planning. The findings will enable policy-makers to develop strategies that reflect actual conditions observed, thereby improving the effectiveness of forest governance and conservation interventions. The information generated will be particularly useful to the M'mbelwa District Council, the Forestry Department, local communities, and development structures such as the Area Development Committees (ADCs), Village Development Committees (VDCs). These institutions and stakeholders will benefit from having a reference document to guide sustainable forest management, conservation planning, and the equitable use of the natural resources within the district and surrounding areas.

1.5 Ethical consideration

Ethical clearance for this study was obtained from the Mzuzu University Research Ethics Committee (MZUNIREC), clearance number MZUNIREC/DOR/24/51 and an informed consent form was prepared to authorize the study (Appendices 6 and 7). The research did not involve direct interaction with human participants or animals; therefore, no additional consent procedures were required. All research activities were conducted in accordance with the approved ethical guidelines and institutional standards for responsible research conduct.

CHAPTER 2: LITERATURE REVIEW

2.1 Floristic tree species

Miombo woodlands are dominated by trees of the genera *Brachystegia, Julbernardia* and *Isoberlinia,* which make them floristically distinct from other woodlands in Africa (Frost, 1996). They are broadly categorized into wet and dry Miombo woodlands. Countries like Malawi, Mozambique and Zimbabwe have dry Miombo woodlands that receive less than 1,000mm of annual rainfall. These woodlands are characterized by trees less than 15m height and relatively low floristic diversity. The dominant deciduous species include *Brachystegia spiciformis, B. boehmii and Julbernardia globiflora*. The herbaceous layer varies considerably in composition, biomass, often with suppressed saplings beneath the canopy trees (Frost, 1996; Riberiro *et al.,* 2015; Kamangadazi, 2019).

In contrast, wet Miombo woodlands occur in eastern Angola, northern Zambia, southwestern Tanzania and central Malawi, where receive rainfall exceeds 1,000mm per year, and canopy height exceeds 15m. These areas posse deeper moist soils that support rich vegetation and vigorous growth. The dominant species include *Brachystegia floribunda, B. glaberrina, B. longifidia, B. wangermeeana, Julbernardi apaniculata, Isoberlinia angolensis* and *Marquesia macroura* (Frost, 1996; Nyirenda, 2022).

Although Miombo woodlands appear may uniform over large areas under the similar environmental conditions, variations exist due to factors such as past and present land use, edaphic factors, effects of fires, wildlife impacts, and other anthropogenic disturbances (Frost, 1996). These factors influence species composition and structure. Monitoring floristic tree species composition is there crucial for detecting environmental changes and assessing forest health and ecological sustainability (Chazdon, 2003; Pretzsch *et al.,* 2019).

Globally, forests are degrading at alarming rate estimated between 750 and 800 million hectares lost from a total of about 1.6 billion hectares (Muboko *et al.,* 2019). Illegal wood harvesting is widespread across many African countries, including, Congo, Ethiopia, Ghana, Kenya and Nigeria, contributing significantly to overexploitation (GoM, 2017; Muboko *et al.,* 2019). In Southern Africa, the illegal harvesting of high value species such as *Pterocarpus angolensis* (kiaat), *Afzelia quanzensis* (chamfuta), *Dalbergia melanoxylon* (African blackwood), *Combretum imberbe* (leadwood), *Diospyros mespiliformis* (African ebony), *Pericopsiselata* (African teak) and *Khaya anthotheca* (red mahogany), is increasing even in protected areas (Muboko *et al.,* 2019).

Asare *et al.* (2022) and Sessen *et al.* (2015) observed that illegal wood harvesting alters tree species composition and population structure leading to biodiversity loss. Overharvesting of indigenous species contributes to forest degradation and decline of preferred species, many of which become threatened or endangered (Gebeyehu *et al*, 2019). Selective harvesting systems, when properly managed, can mimic natural disturbances that promote regeneration enhance biodiversity (Latterin *et al.,* 2023).

However, widespread reliance on firewood and charcoal used by almost 90% of African and the majority of Malawians intensified illegal harvesting even in the protected areas (GoM, 2017; Asare *et al.,* 2022). By 2030, the demand for fuelwood in Africa is projected to reach 544.8 million m^3 for firewood and 46.1 million tons for charcoal (Asare *et al.,* 2022, cited in Arnold & Persson, 2003). Since many protected forests are treated open access sources, unregulated harvesting has degraded ecosystems and altered tree species composition, weakened recruitment and population (Sessen *et al.,* 2015; Asare *et al.,* 2022).

2.2 Tree Species diversity

Species diversity is multi-dimensional and thus include species richness, evenness and composition (Mambo, 2020). According to Atsbha *et al.* (2019) explained that Shannon diversity index (*H'*) value varies, the value ≥ 3.0 considered as high, when the value is between 2.0 and 3.0 considered as medium, low value is between 1.0 and 2.0, the lowest value is ≤ 1.0. Other studies on Miombo woodlands by Zimudzi *et al.* (2013), Kacholi (2019), Kamangadazi (2019), and Monfort *et al.* (2021), reported that H' commonly ranges from 1.5 to 3.5 and it rarely exceeds 4.5.

Mambo, (2020) reported high Shannon diversity index value (*H')* (3.31) in Dzalanyama Forest Reserve, Malawi. Similarly, Hafico and Fleing, (2015) in Mozambique recorded higher diversity ranged between 3.03 and 3.64. Studies, explained that high Shannon diversity index value could obtained due to previous disturbance, which opened tree canopy for light tolerant species like combretum to regenerate. Additionally, it also suggested that existing management practiced has been facilitated vigorously species regeneration in studied area. Mwakalukwa, *et al.* (2014) described high *H'* could attributed to very large sample size and also the presence of the riverine forest where likelihood of encountering rare species is high. Furthermore, also suggested that areas where receive average rainfall of 700 to 1000mm have high *H'* compared to areas received low rainfall.

In contrast, Shirima, *et al*. (2011) recorded low diversity (1.05) and (1.25) from Tanzania's woodlands. Lower diversity was attributed to different environment factors, intensity of anthropogenic disturbances, climatic conditions and limited sample size. Therefore, Species diversity in Miombo woodlands may differ depending on interaction of different factors that could encounter with.

2.3 Regeneration and species recruitment

Studies have shown regeneration significant differences in regeneration among seedlings, saplings and poles across land use disturbance categories in the land use (Nyirenda 2022). Badu (2020) explained that there are continuous regeneration and natural regrowth in the forest, though severe disturbances may lead to loss of tree species (Badu, 2020). A healthy regenerating population shows a reverse J-shaped, an indicator of profuse regeneration and recruitment curve (Gebeyehu *et al.,* 2019; Muvengwi *et al.,* 2020). Such population are common in natural forests, where external disturbances are limited (Gebeyehu *et al.,* 2019). Miombo woodlands regenerate in selective and unregulated harvesting systems, and this is mostly enhanced by anthropogenic activities (Vyamana *et al.,* 2020; Badu *et al.,* 2022; Solano *et al.*, 2023). Furthermore, Miombo woodlands colonize quickly after disturbances due to sunlight and reduced competition among the woody plants (Hafico and Fleig, 2015). Species recruitment in Miombo woodlands occur from soil seed bank and vegetative parts such as stems, roots, stumps and suckers (Missanjo *et al.,* 2014; Montfort *et al.,* 2021). There are several factors influence the ability of species to regenerate, such as climatic conditions (rainfall and light), size and age of the stem, forest types, and fire frequency (Montfort *et al.,* 2021).

In a study conducted in Liwonde Forest Reserve, Kamangadazi *et al.* (2016) determined the impact of selective harvesting on the tree species regeneration, richness, and diversity in the co-management blocks in Liwonde Forest reserve. Although no significant differences were found between treatments, the harvested area recorded higher regenerants compared to the unharvested area. Comparatively, Syampungani et *al*. (2016) compared land use practices involving charcoal production, slash-and-burn agriculture, and timber harvesting on Miombo woodland dynamics. The study showed that charcoal production and slash-and-burn agriculture have the potential to promote the establishment and regeneration of miombo species, whereas timber harvesting appeared to cause less disturbance to the forest and was not considered a sustainable management option for maintaining population.

Kacholi, (2019), indicated that species recruitment plays a great role in ecosystem dynamics and forest conservation. Healthy natural regeneration is determined by the high number of individual species found in each of the diameter classes showing forest sustainability (Zimudzi, *et al.,* 2013; Kacholi, 2019). Zonvo *et al.* (2021) found that seedling stage, there were a lot of abundant species than in other stages in the recruitment pattern. This happens because the seedlings are suppressed by fires and anthropogenic activities. According to Hall et al. (2003) stem mortality increased due to fire and livestock grazing. Fire affects the growth of the seedlings, whilst adult trees survive fire disturbance (Pelletier et *al*., 2019).

2.4 Species composition and structure

Species composition and population structure in woodlands have been calculated based on the species frequency, diversity and basal area, factors influenced by species abundance, size and number of individual species recorded (Kamangadazi, 2019; Gondwe, 2020; Nyirenda, 2022). High species diversity improves forest resilience to disturbances such as pests, diseases, fires and climate shocks (Chazdon, 2003; Pretzsch, 2009).

The floristic variations describe the differences in the tree species composition in the miombo woodlands. The tree species variations in woodlands are largely affected due to anthropogenic disturbances such tree harvesting, charcoal production, climatic conditions and agriculture expansion (Nyirenda, 2022). Tree species composition refers to the relative proportional contribution of individual tree species within the stand, often expressed as a percentage (Nchimbi, 2022). Composition and structure differ across sites depending on soil conditions, temperatures and rainfall patterns (Gondwe, 2020; Nchimbi, 2022).

According to Latterini *et al*. (2023), controlled tree removal can either facilitate a change in species composition or maintain the current forest structure. However, through unregulated harvesting interrupts forest structure and composition (Sahoo, *et al.,* 2020). Studies by Gondwe (2021) and Monfort *et al.* (2021) indicated that tree species richness and diversity differ in Miombo woodlands depending on the level of anthropogenic activities and climatic conditions.

Muvengwi *et al.* (2020) stated significant differences in shrub and tree composition between harvested and unharvested sites, with harvested showing higher species richness. Since trees are essential components in the ecosystem, assessing species diversity and abundance is critical (Gondwe, 2020; Nchimbi, 2022). Some species in these woodlands are critically endangered (Nyirenda, 2022). Illegal harvesting changes forest structure and composition and threatens preferred tree species at risk of extinction (Makalukwa, 2014; Kacholi, 2019; Asare *et al.,* 2022). Species composition influences the ecosystem structure, function and resilience. It determines the diversity of ecological niches, affects nutrient cycling, supports wildlife habitats, and enhances ecosystem services, such as carbon sequestration, water regulation and soil stabilization (Vermeulem *et al.,* 2020).

Stem density and basal area describe tree species composition and population structure in the woodlands. Stem density refers to number of stems per hectares (Ha) while basal area represents the cross-sectional area of trees at 1.3m above ground expressed in m^2ha^{-1} (Makalukwa, 2014; Nchimbi, 2022; Nyirenda, 2022). Differences in stem density often depicts the level of human disturbances and harvesting intensity within species and diameter class size in the Miombo woodlands (Gebeyehu *et al.,* 2019; Gondwe, 2020; Nchimbi, 2022). For example, in dry Afromontane forests of Awi Zone, northwestern Ethiopia, 60.8% of adult species in Kahatsa forest lacked seedlings and samplings, depicting poor regeneration (Gebeyehu *et al.,* 2019). Alternatively, Chidumayo (2002), reported that the stem density in Miombo woodlands increase because of the recruitment from coppices and seedling regeneration.

The studies conducted in different protected forests showed the history of human disturbance affected species composition and structure (Makalukwa, 2014; Gebeyehu *et al.,* 2019; Gondwe, 2020; Nchimbi, 2022; Nyirenda, 2022). Important Value Index (IVI) is used to examine species composition in Miombo woodlands by using their relative density and dominance (basal area) (Kamangadazi, 2019; Gondwe, 2021). The IVI for each species in each plot was calculated as the sum of relative density and dominance and expressed in percentage, as each IVI needs to be assessed in detail to know its frequency of occurrences (Makalukwa, 2014; (Gondwe, 2021).

Solano *et al.* (2023) indicated that the presence or absence of species composition in the sampling areas presents the inequalities in recruitment. However, there were no significant differences between management treatments, suggesting that they were ecologically sustainable. Furthermore, Solano et al. (2023), reported low species richness due to the environmental conditions.

CHAPTER 3: MATERIALS AND METHODS

3.1 Study area

The study area was Mtangatanga Forest Reserve, situated about 15 km north of Mzimba Boma and about 2 km from Raiply trading centre in the Northern region of Malawi. Mtangatanga Forest Reserve (MFR) is located at latitude 11^{0}56'S and 33^{0}42'E (Kachamba, 2016). MFR was gazetted in 1958 with an area of 8,443ha. The management regime for MFR is a co-management agreement. Forest co-management block is the size of the area within the FR for easy management for individual co-management agreement (GoM, 2005).

The study site lies in a relatively flat area at an altitude between 1,500 and 1,700 meters above sea level. The dominant soil type in the MFR is humic ferralitic. The annual precipitation ranges from 960 to 1050mm, with the rainy season occurring between December and April, followed by a dry period from May to November. Mean minimum and mean maximum annual temperatures vary from 6°C to 29°C, respectively (Hardcastle, 1978; Kachamba, 2016).

The study was conducted in the North-eastern part of MFR with 1,264.6ha. The site was purposively selected because it experiences selective and unregulated harvesting and located close to the road. This makes the illegal transportation of forest products easier. Furthermore, Mtangatanga forest reserve was selected over other reserves in Mzimba because the present study builds on a previous study by Kachamba *et al.* (2016) conducted in the same reserve. Kachamba *et al.* (2016) focussed on above and belowground biomass models for trees in the Miombo woodlands of Malawi. The current study examined the effects of different harvesting systems on tree species composition, recruitment and population structure. Figure 1 shows the study area.

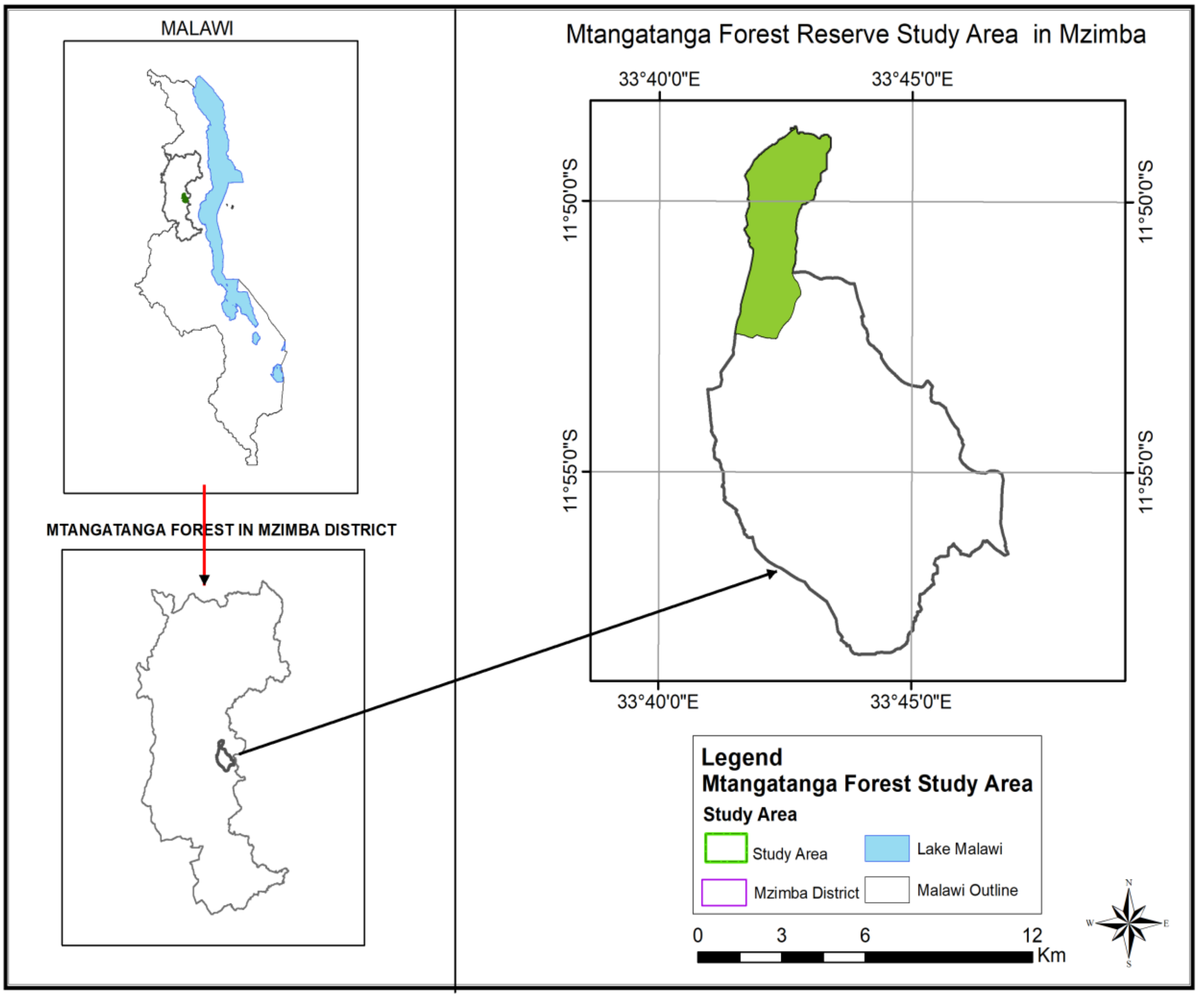


Figure 1: Map of the study area in Mtangatanga Forest Reserve in Mzimba District

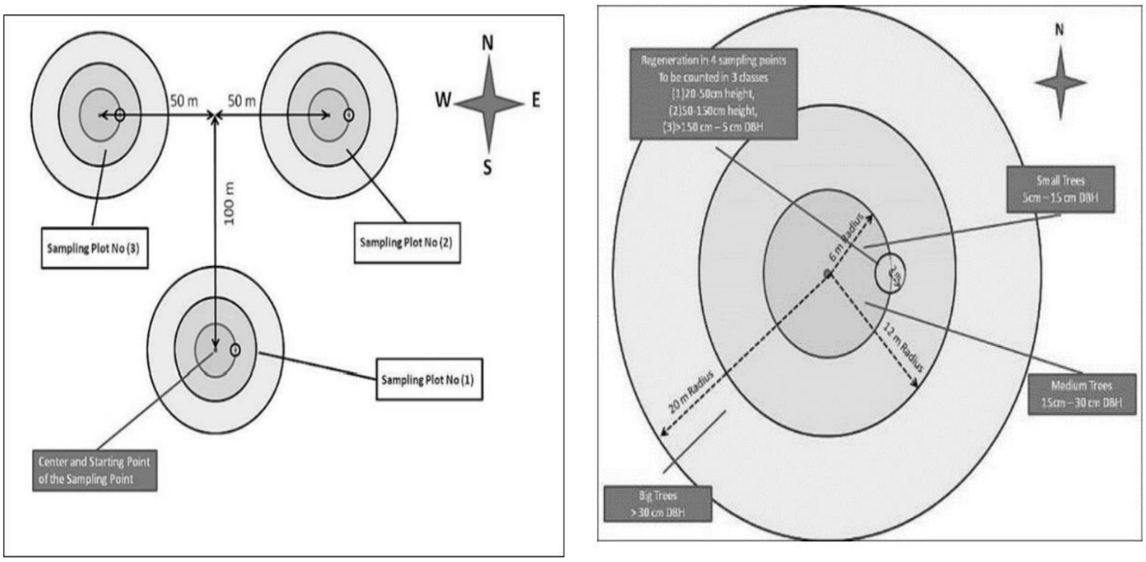
3.2 Research design

The study deployed a quantitative research method using a stratified cluster sampling based on the harvesting systems occurring within the forest (Nchimbi, 2022). Two harvesting systems were considered: selective and unregulated harvesting. For each treatment, ten plots were sampled resulting in total of twenty sample plots across the study area. The concentric nested sample plots were designed with various sizes that were laid purposively in both treatments. The concentric circular plot was used where a plot was divided into three subplots with radii of 6m, 12m and 20m (Figure 2 b). The forest sample clusters of nested fixed radius plots were also used (Figure 2 a). Sample allocation followed Intergovernmental Panel on Climate Change

(IPCC) approved method was used to determine the sample allocation, where the number and geographic location of sample plot clusters for a specific level of accuracy of 10% were determined (GoM, 2016; 2018). The concentric circular plots were laid linearly in a transect line of 1km. The use of nested concentric circular plots for conducting tree assessment gives a chance for every tree to be included to avoid edge effects (Nchimbi, 2022; Tomppo *et al.,* 2024).

3.3 Data collection

Data collection followed the Standard Operating Procedures (SoPs) for forest inventory, which describes the layout and measurement protocols for sample plots (GoM, 2018). All the stems within the plot were recorded and diameter at breast height (DBH) was measured at 1.3m above the ground, corresponding to the size categories defined within the nested design. The fixed radius concentric plots captured trees across size classes: 6m subplot for small trees (5 – 14.9 DBH), the 12m subplot for medium trees (15 – 29.9 cm DBH), and 20m subplot for large trees ≥ 30 cm DBH. To assess generation, a 2m radius clip plot established due to East of the plot centre of 6m (Figure 2). This micro-plot was used to recorded seedlings and saplings following procedures adopted from GoM, (2018); Kamangadazi, (2019).



(a) (b)

Figure 2: Illustration of diagram of a nested cluster plots (a) and a nested sample plot (b) used for collection of tree species parameters (GoM, 2018)

The first plot was generated randomly using a computer, after which subsequent plots were systematically established at 100m interval from the north of the initial plot (Kamangadazi *et al.,* 2016). The diameter at breast height (DBH) at 1.3m recorded for every tree stem within in the sampled plot using the callipers and diameter tapes. All the tree species were listed and identified by their botanical name by the taxonomist from Mzuzu Botanic Herbarium Garden. The height for each stem in the plot was measured using a vertex and transponder (Figure 3). The small plot of radius 2m in the subplot of 6m radius was laid to record the tree regeneration. Each subplot with a 2m radius was established within a 6m subplot to assess (count) natural regeneration. Within the microplot, all regenerants for each species were counted and recorded in three height classes. Small (20 to 49.9cm), medium (50 to 149.9cm), and large (150cm < 5m).

Figure 3**:** Data collection team (a), the materials used for data collection (measuring tape, diameter tape, transponder, calliper and vertex (b)) and setting the plot (c).

Field observations were done and the following human disturbances were noticed: tree debarking for bee hives, livestock grazing, fires, and charcoal production along the transect line (Figure 4). The study was conducted in October 2024 and March 2025.

Figure 4: Tree ring bark for beehive (a), charcoal production (b), fire (c), animal dung and animal foot track (d)

3.4 Data analysis

3.4.1 Floristic tree species composition

All tree species were identified and recorded by their botanical and family names in selective harvesting and unregulated harvesting. The total number of tree stem were listed on each plot (Appendix 1).

Jaccard Similarity Index was used to compute the percentage of similarity of the tree species composition between selective and control harvesting (Gebeyehu *et al*, 2019; Gondwe, 2021). Formula:

$Sj = a/(a+b+c)$ Equation 1

Sj = Jaccard Similarity index (%)

a = number of tree species common to site A and B (Selective and Control)

b = number of tree species recorded only in site A

c = number of tree species recorded only in site B

The Sj value ranged between 0 and 1; where

0 indicates dissimilarity and 1 indicates similarity in the species composition. An Sj index value of $\geq$ 50% was considered high.

3.4.2 Species diversity

Biological diversity, Species abundance and structural parameters and species richness (S) were used.

Species diversity was computed using Shannon-Wiener Index equation

$H' = -\sum_{i=1}^{s} pi\ lnpi$ Equation 2

Where, H' is Shannon-Wiener diversity index, $\sum$ is sum from species 1 to species S, S is the number of species in the area, ln is natural logarithm of the number pi=proportion of individuals as a particular species in a sample (pi = ni/N): ni is the number of individual stems for particular tree species in the given plot and N is the total number of individual species for the sampled plots. The values of H' range from 0 to 5, usually values range from 1.5 to 3.5, and the greater the value of H' the greater the diversity of the community (Kamangadazi, 2019; Nchimbi, 2022; Bienu *et al.,* 2023).

Tree species evenness

$J' = H'/\text{LnS}$ Equation 3

Where J' is evenness, H' is Shannon-Wiener Index, S is species richness, and Ln is natural logarithm (Nyirenda, 2022).

Species abundance and structural parameters. The species richness (S) used

Shannon Index:

$H' = \sum S\ i=1\ pi.\log(pi)$ Equation 4

Where pi represents the percentage of abundance of a given species (pi = ni/N): ni, the number of individuals counted for a species. N is the total number of counted individuals; all species combined. S is the total or cardinal number of the list of species (Kamangadazi, 2019; Bienu *et al.,* 2023).

3.4.3 Recruitment pattern

The height of the regenerates was recorded for all tree species on each plot. The number of recruits were subjected to t-test analysis to examine the differences in selective and unregulated harvesting. The Mintab statistical software version 20.3.0.0 was used and the tables and figures were generated using Microsoft Excel version 2019.

3.4.4 Population structure

The tree species composition and population structure within the forest were expressed in terms of stem density (ha^{-1}) and within different growth stages based on the diameter classes (DBH). Stem density was computed using Equation 5:

Stem density $=\frac{1}{n}\sum_{i}^{n} = 1(\frac{ni}{A})$ Equation 5

Where stem density is in terms of number of stems ha^{-1} in a given growth stage, ni is the number of stems in a given growth stage in a given plot, n is the number of plots, and A is the plot area (Nchimbi, 2022).

t-test of the stem diameter at breast height was analysed by comparing the stem diameter between selective and unregulated harvesting systems. The Mintab statistical software version 20.3.0.0 was used. The tables and figures were generated using Microsoft excel version 2019

The Important Value Index (IVI) for each species in each plot was calculated as the sum of relative density (RDe), relative frequency (Rf) and relative dominance (RDo) as described in the equation below;

IVI = Rf+RDe+RDo/3 (Thukral et al., 2019 ; Nyirenda, 2022) Equation 6

The basal area (BA) was computed (DBH in cm)

BA = 0.00007854*DBH^2 (Kacholi, 2019) Equation 7

T-test of the basal area was analysed by comparing basal area between selective and unregulated harvesting systems.

CHAPTER 4: RESULTS

4.1 Floristic tree species composition

Floristic tree species composition is key in miombo woodlands because it gives information about the structure, function and resilience of the ecosystems. It also reveals the diversity of ecological niches, affects nutrient cycling, provides wildlife habitats, and improves ecosystem services like soil stabilization, air and water regulation. Therefore, monitoring floristic tree species composition assists in observing the environmental changes in an area and, serves as an indicator for forest health and ecological sustainability.

4.1.1 Vegetation composition

A total of 644 individual trees representing 25 species were enumerated in selective harvesting, whereas 157 individual trees representing 19 species were recorded in the unregulated harvesting (Appendix 3). The most abundant species under selective harvesting included *Brachystegia floribunda, Brachystegia boehmii, Brachystegia spiciformis, Julbernardia paniculata* and *Uapaca kirkiana* (Figure 5). Similarly, in the unregulated harvesting areas, abundant species were *Brachystegia spiciformis, Brachystegia floribunda, Brachystegia boehmii, Julbernardia paniculata* and *Uapaca kirkiana* (Figure 6).

In total, tree species recorded in selective harvesting, belonged to 20 genera and 17 families, while those in the unregulated harvesting belonged to 15 genera and 12 families. Recruitment assessment revealed forty-eight (48) species were enumerated in the with 25 families (Appendix 1). The number of individual regenerants was 1,765 in selective harvesting, while 992 regenerants were recorded in unregulated harvesting (Appendix 4).

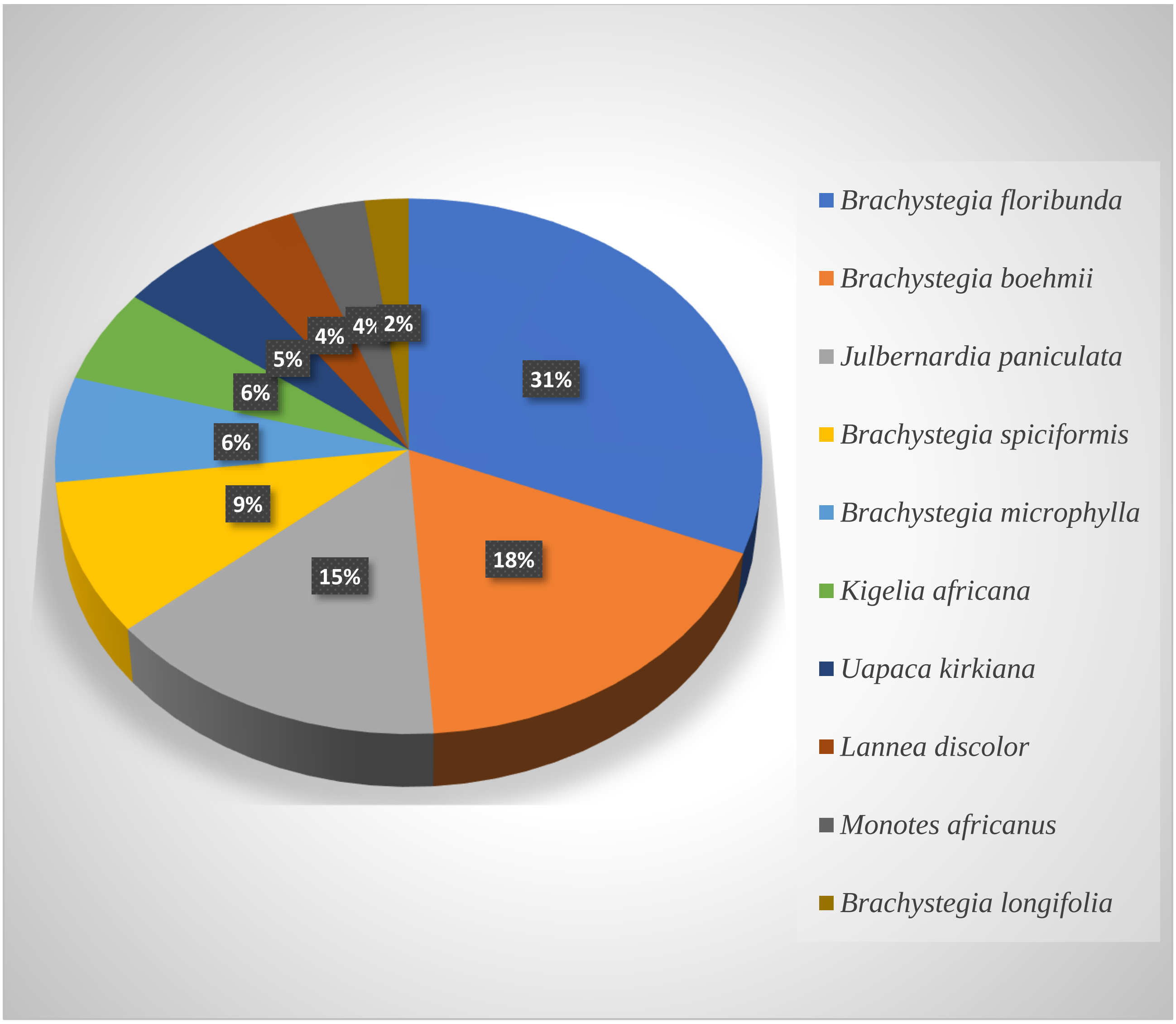


Figure 5: Abundance of tree species in unregulated harvesting in MFR, Mzimba District.

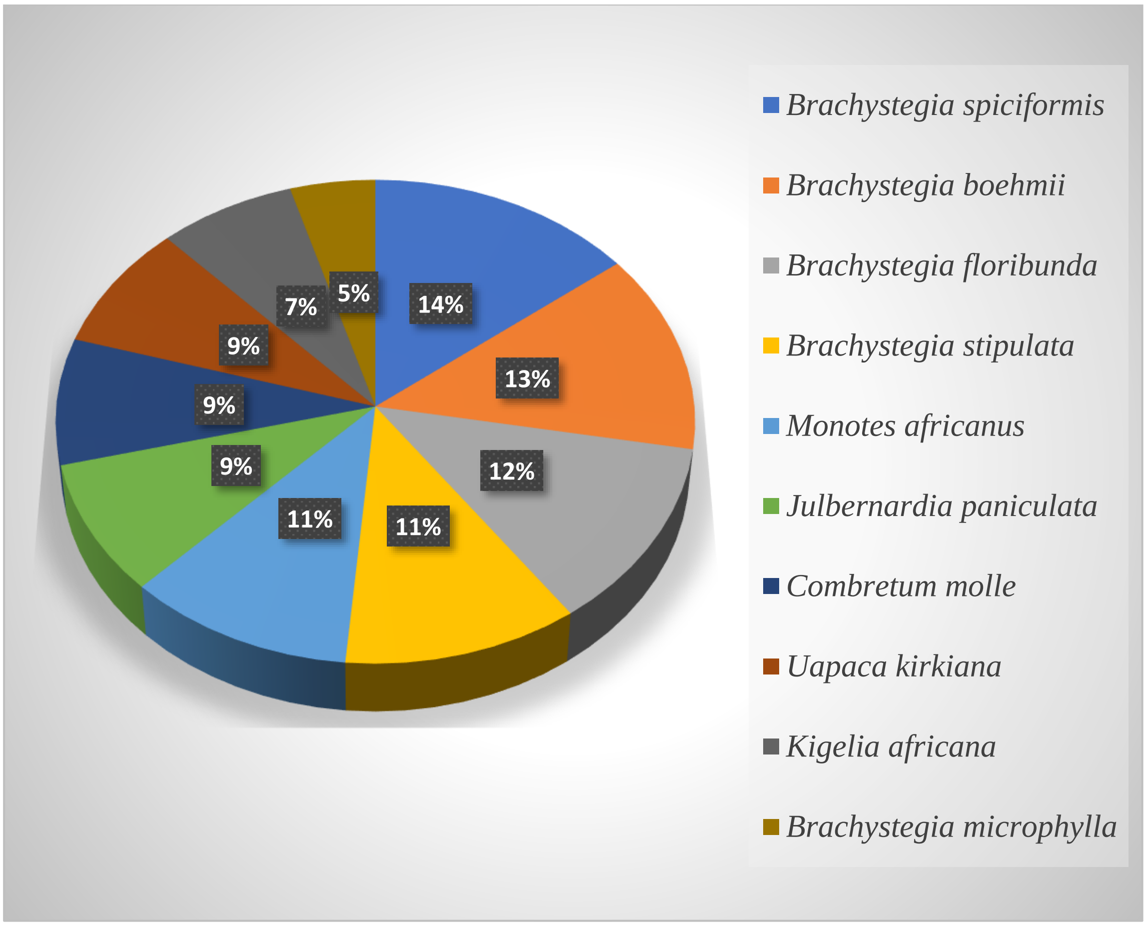


Figure 6**:** Abundance of tree species in selective harvesting in MFR, Mzimba District

The Jaccard similarity index of tree species between selective and unregulated harvesting in different DBH size classes is presented in Table 1. The number of tree species shared in recruitment was 21 out of 44 species (Table 1).

Table 1**:** Jaccard similarity index between selective and unregulated harvesting systems in MFR in Mzimba District.

Name of size class	**Unregulated harvesting**	**Selective harvesting**	**Common species**	**Jaccard Index**
Timber trees (≥30cm)	1	7	6	0.43
Pole timber trees (≥15 - 29.9cm)	4	12	12	0.43
Sapling trees (≥5 - 14.9cm)	2	12	10	0.42
Recruitment (<5 cm DBH)	8	15	21	0.48

Results from Table 1 revealed a Jaccard similarity (Sj) index of 0.43 for timber trees, 0.43 for pole timber, 0.42 for saplings, and 0.48 for recruitment. The value of Sj ranges from 0 to 1, where 0 indicates complete dissimilarity and 1 indicates complete similarity in species composition between two harvesting treatments. This, therefore, means that the two treatments have generated a species composition that is more dissimilar than they are similar.

4.1.2 Relative abundance and Importance Value Index

The relative abundance of tree species in selective harvesting was *Brachystegia spiciformis* (13%), *Brachystegia boehmii* (12%), *Brachystegia floribunda* (11%), *Brachystegia stipulate* (10%), *Monotes africanus* (10%), *Julbernardia paniculate* (8%), *Combretum mole* (7%), *Kigelia africana* (7%) and *Uapaca kirkiana* (7%), and the rest of the species were below 5% (Figure 7). In unregulated harvesting, abundant species were *Brachystegia floribunda* (28%), *Brachystegia boehmii* (16%), *Julbernardia paniculate* (13%), *Brachystegia spiciformis* (8%), *Brachystegia microphylla* (6%), *Kigeliaafricana* (5%), and the rest were below 5% relative abundance (Figure 8).

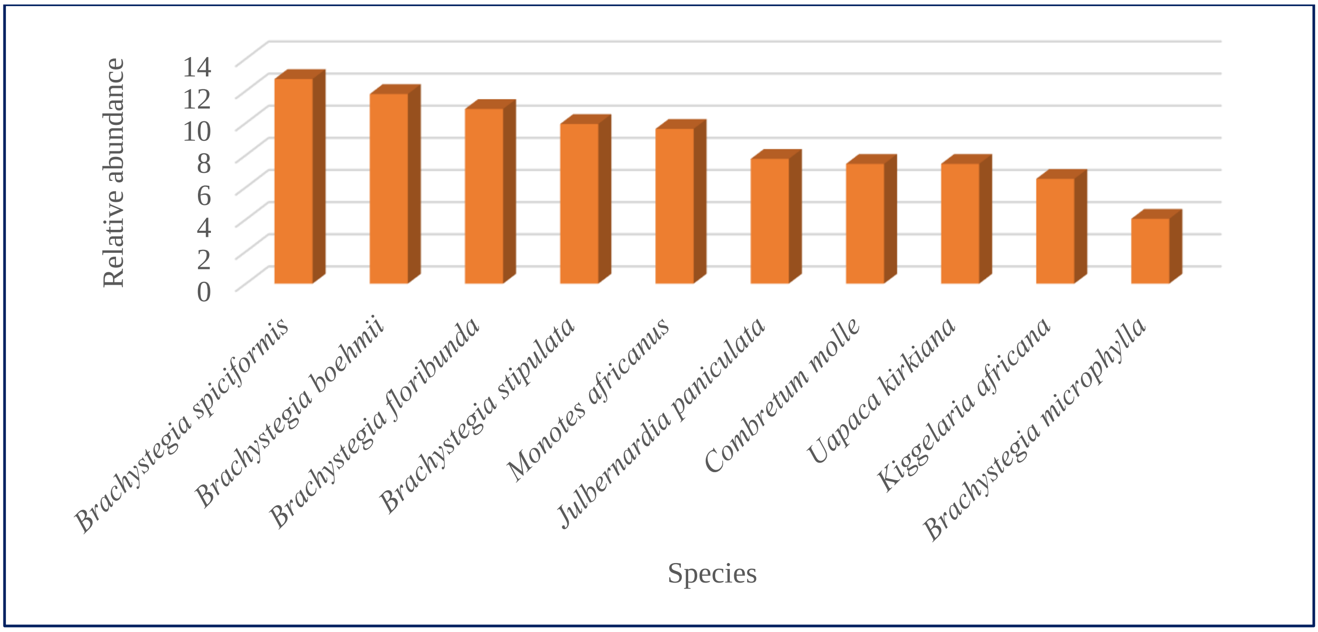


Figure 7: Relative abundance of tree species in selective harvesting system in MFR in Mzimba District.

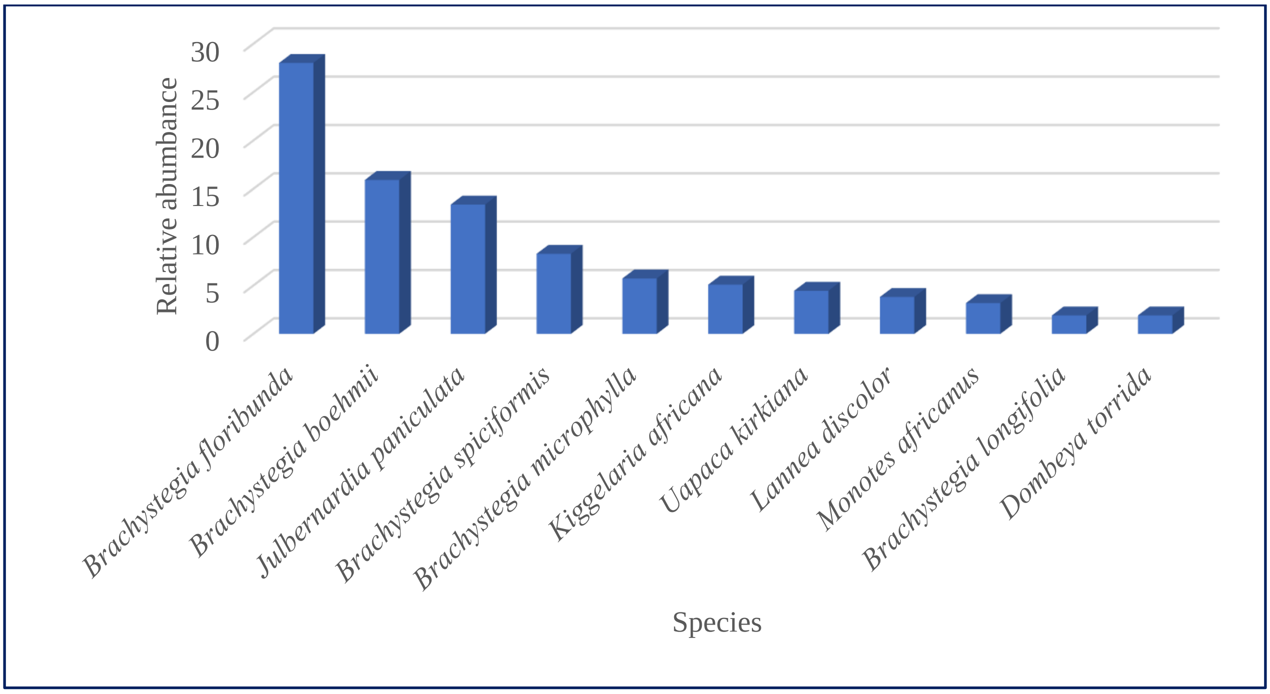


Figure 8: Relative abundance of tree species in unregulated harvesting system being practised in MFR in Mzimba District.

4.2 Species Diversity Indices

A total of 25 and 19 tree species were enumerated in selective and unregulated harvesting treatments, respectively.

Table 2: Species diversity index, species richness and species evenness of the unregulated and selective harvesting systems in MFR.

Diversity measure	**Selective harvesting**	**unregulated harvesting**
Shannon-Wiener diversity index	2.65	2.34
Species richness	25	19
Species evenness	0.41	0.46

The Shannon-Wiener index was higher (2.65) in selective harvesting than in unregulated harvesting (2.34) (Table 2). The species evenness was slightly higher (0.46) in unregulated harvesting as compared to the 0.41 of selective harvesting in Mtangatanga forest reserve. However, species richness was higher in selective harvesting (25) than in unregulated harvesting (19) system.

4.3 Tree species recruitment pattern

Species recruitments were categorised by height as seedlings (0 - 49.9cm), saplings (≥50 – 149.9cm) and poles (≥150cm<5m) (Appendix 4). The results revealed no significant difference ($p > 0.05$) in tree species recruitment between selective and/or unregulated harvesting treatments and across regeneration classes (Table 3).

Table 3*:* t-test statistical analysis of regeneration category between unregulated and selective harvesting systems in MFR.

Regeneration category	**Harvesting system**	**Mean±sd**	**t-value**	**p-value**
Seedlings	Unregulated	23.7±66.1	-1.58	0.121
	Selective	55.5±94.1		
Saplings	Unregulated	1.28±3.10	-1.71	0.093
	Selective	2.90±4.40		
poles	Unregulated	0.46±1.82	0.17	0.867
	Selective	0.4±1.22		

The results showed that there was no statistically significant difference between unregulated and selective harvesting, with $p = 0.121$ in seedling, $p = 0.093$ in saplings, and $p = 0.867$ in poles. However, Selective harvesting recorded numerically high generation numbers in seedlings and saplings (Appendix 4).

The abundance of species was different in regeneration categories in unregulated and selective harvesting treatments. The key tree species recorded in selective harvesting were *Combretum* *molle,* followed by *Uapaca kirkiana, B. stipulate, B. floribunda* and *B. spiciformis,* whilst in unregulated harvesting were *Uapaca kirkiana, B. floribunda, B. boehmii, B. microphylla* and *Julbernadia paniculata* (Figures 9 and 10).

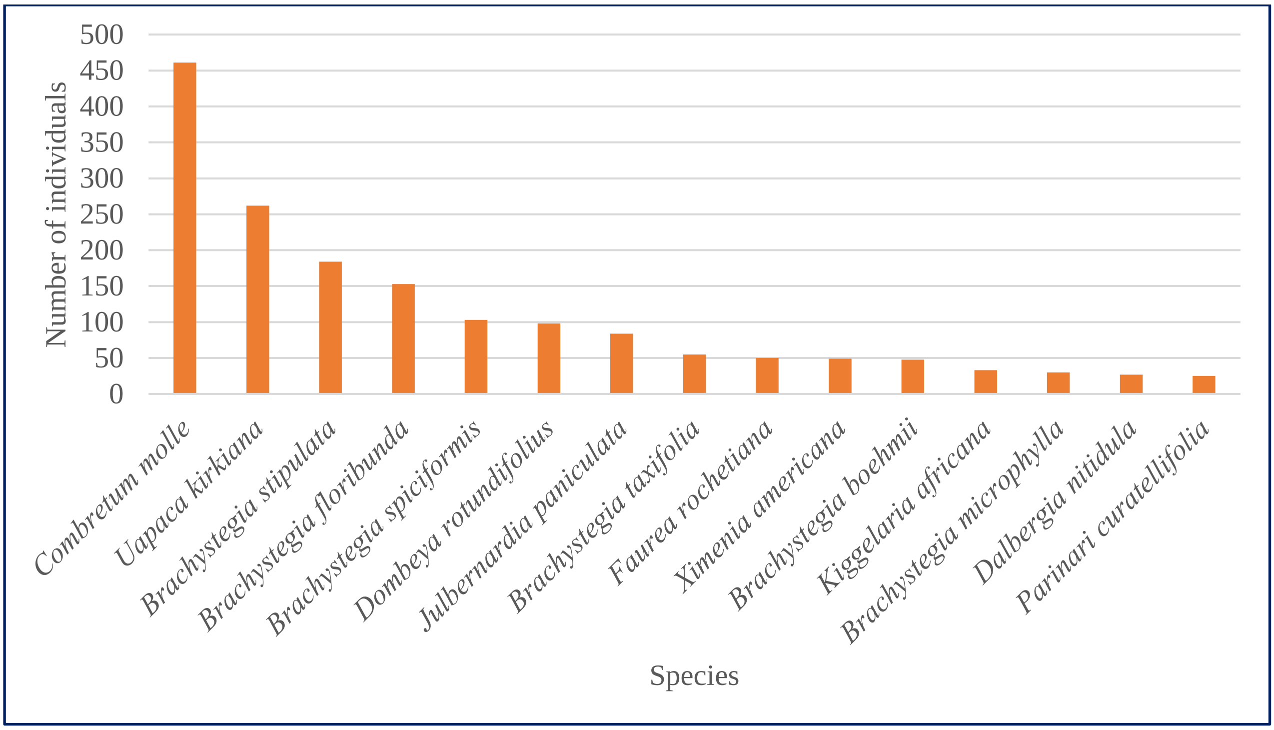


Figure 9: Regenerants species in selective harvesting in MFR

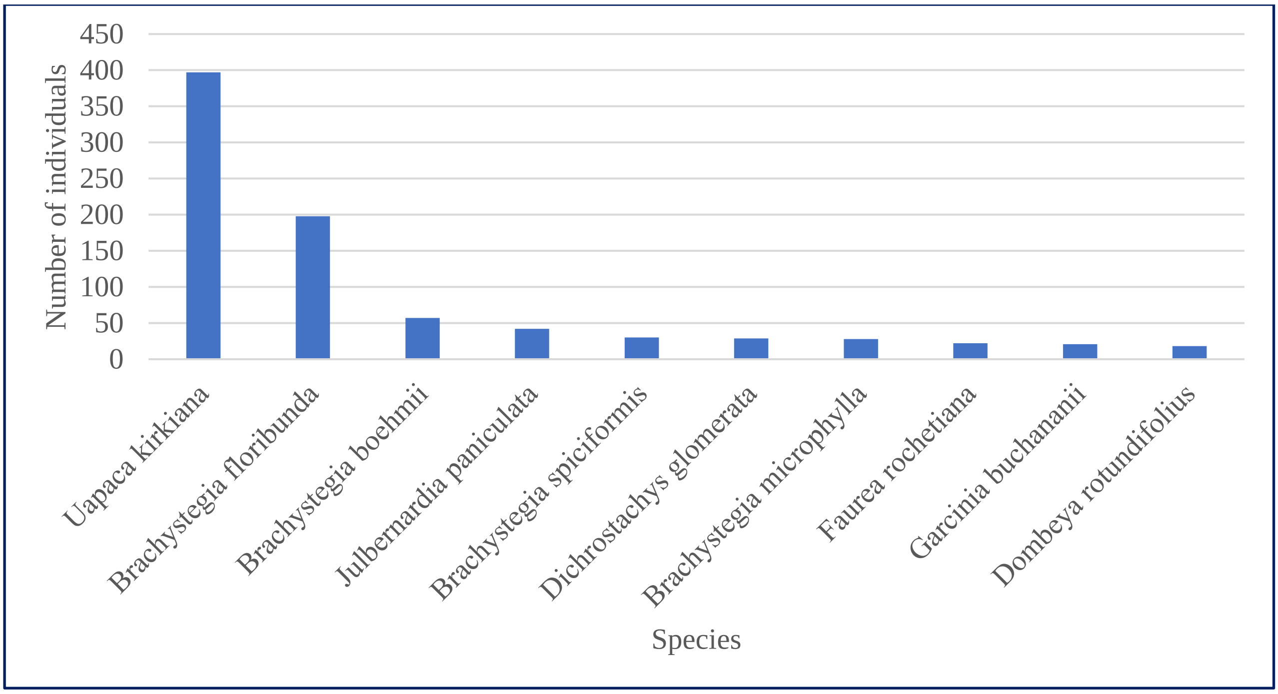


Figure 10: Regenerants species in unregulated harvesting in MFR

The results in Figures 9 and 10 indicate that the regenerants from miombo species still dominate the woodland in both harvesting treatments. This shows that the population structure of miombo woodlands largely remains undisturbed and is not replaced by pioneer species like *Uapaca kirkiana* and *Combretum molle*.

4.4 Population structure

4.4.1 Size classes distribution

Figure 11 presents the size classes distribution of tree species for recruitment (0 – 4.9 cm), saplings (≥5.0 – 14.9 cm), pole timber (≥15.0 – 29.9 cm), and timber trees (≥ 30cm) in terms of number of stems by diameter at breast height (DBH) in selective and unregulated harvesting.

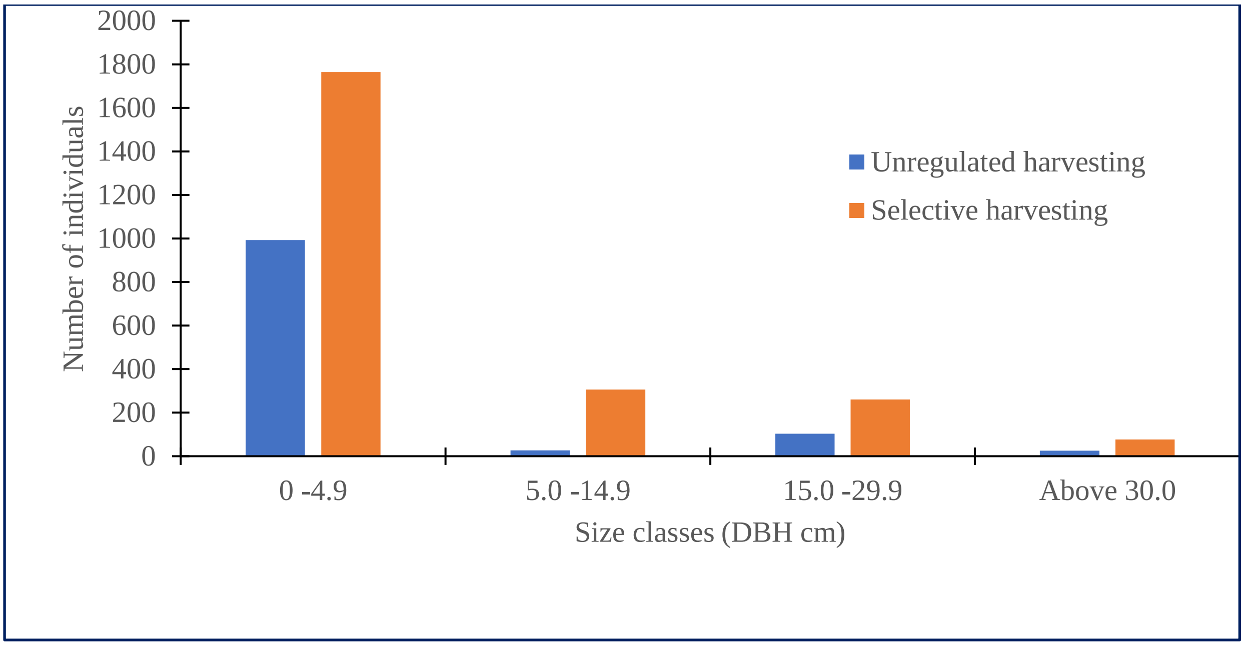


Figure 11: Stem diameter distribution of tree species in unregulated and selective harvesting in MFR.

The results show a smooth reverse J-shaped curve of the size class distribution in selective harvesting and a slightly disturbed reverse J-shaped curve of class distribution in unregulated harvesting. Furthermore, harvesting recorded consistently higher abundances for each of the classes compared to the selective harvesting treatment. Unregulated harvesting recorded more trees in ≥15.0 - 29.9 size classes than ≥5.0 – 14.9 and ≥30 size class, which was unexpected. Statistical analysis (Table 4) showed a highly significant difference in DBH between the selective and unregulated harvesting treatment ($P < 0.001$).

Table 4: T-test of the stem diameter at breast height of the selective and unregulated harvesting system in MFR, Mzimba District.

Harvesting system	**Observations**	**Mean±SD**	**t-value**	**df**	**p-value**
Unregulated	202	21.5±11.6	8.60	320	0.000
Selective	246	13.48±7.15			

4.4.2 Stem density

Selective harvesting had recorded high stem density per hectare for each species compared to unregulated harvesting (Figure 12).

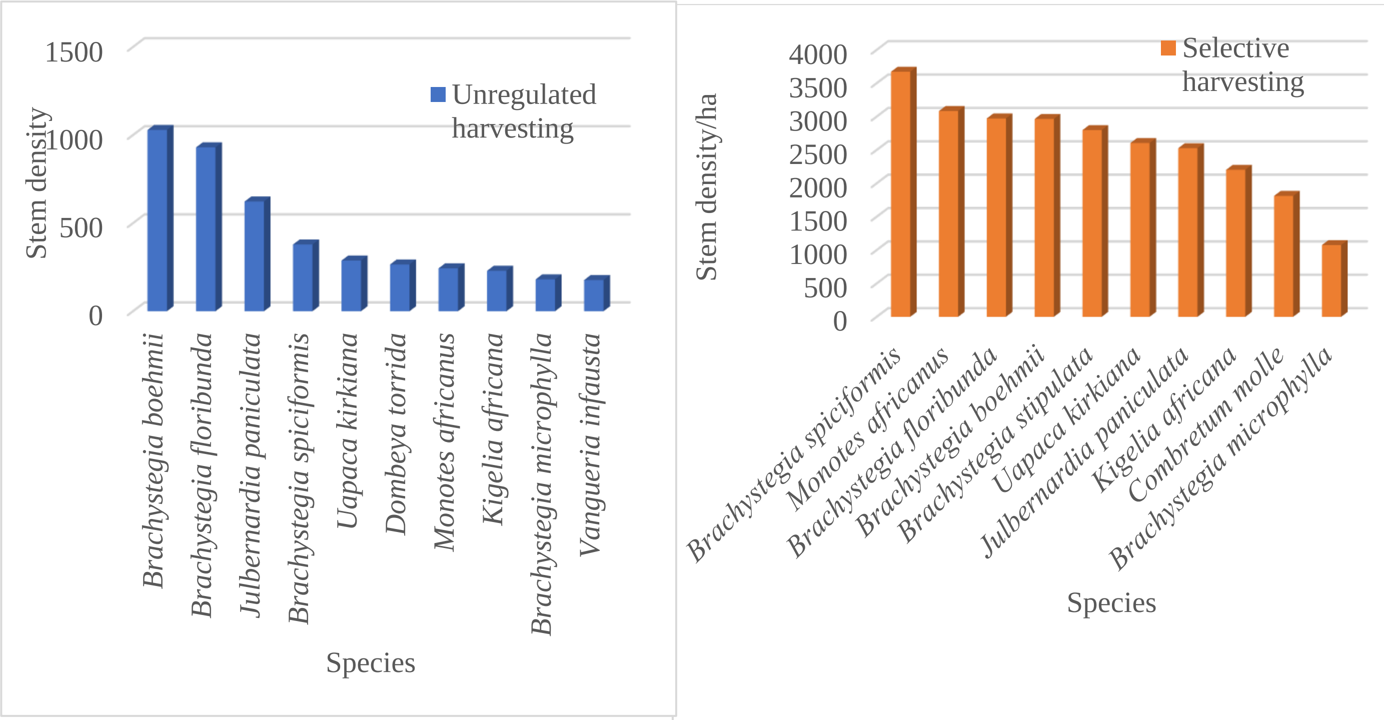


Figure *12:* Stem density ha^{-1} of the species in unregulated and selective harvesting in MFR

The results showed that stem density varied between 10 and 3673 stems/ha in selective harvesting, while in unregulated harvesting, it ranged between 8 and 1028.9 stems/ha (Appendix 2). Species that registered higher density in selective harvesting (3673 to 1075 stems/ha) were *B. spiciformis,* followed by *Monotes africanus, B. floribunda, B. boehmii,* and then *B. microphylla,* while in unregulated harvesting, species that recorded higher density (1029 to 177 stems/ha) were *B. boehmii, B. floribunda, Julbernardia paniculata*, and *Vangueria infausta* (Figure 12).

4.4.3 Basal area

Table 5 and Appendix 2 revealed a significant difference in the basal area for species between selective and unregulated harvesting (p-value = 0.016)

Table 5: t-test statistical analysis of basal area (m^2ha^{-1}) of the tree species between unregulated and selective harvesting systems being practiced at MFR in Mzimba District.

Harvesting system	Observations	Mean±SD	t-value	df	p-value
Unregulated	157	0.414±0.349	2.42	259	0.016
Selective	644	0.337±0.389			

Note: SD stand for standard deviation and df for degrees of freedom

The basal area distribution by species varied between 0.11 and 40.46 m^2ha^{-1}in selective harvesting, while in unregulated harvesting, it varied between 0.13 and 19.76m^2ha^{-1} (Appendix 2).

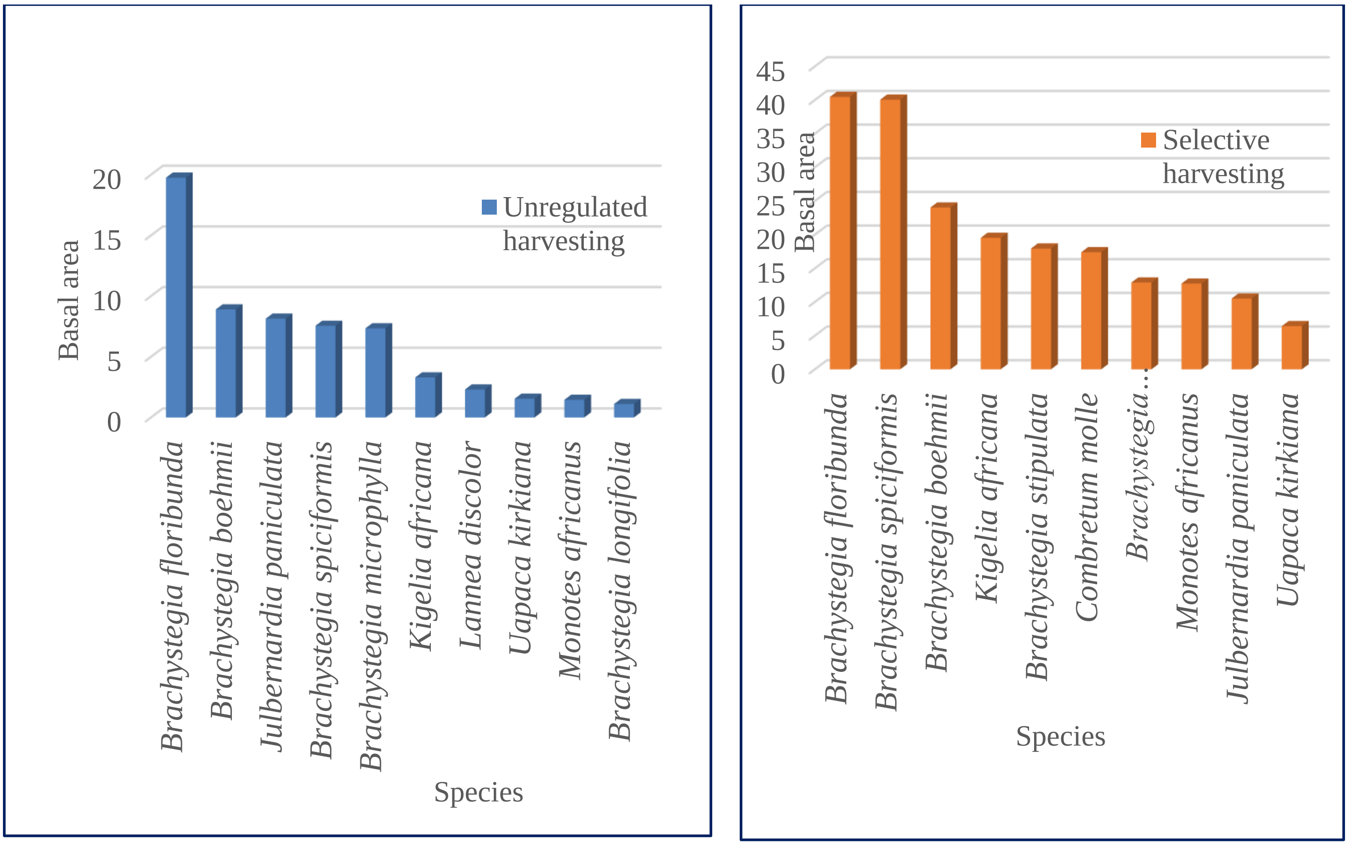


Figure 13:: Basal area m^{2}ha^{-1} of the species in unregulated and selective harvesting systems at MFR, Mzimba District.

Figure 13 revealed that *B. floribunda, B. boehmii, Julbernardia paniculata, B. spiciformis,* and *B. microphylla* species had high basal area (m^{2}ha^{-1}) in unregulated harvesting. Whilst in selective harvesting, *B. floribunda, B. spiciformis, B. boehmii, Kigelia africana* and *B. stipulata* had high basal area (m^{2}ha^{-1}). The selective harvesting produced consistently higher basal area for almost all species compared to unregulated harvesting.

CHAPTER 5: DISCUSSION

5.1 Floristic tree species composition

A total of 644 individual trees were enumerated in selective harvesting, consisting of 25 species, while 157 individual trees were recorded in unregulated harvesting, consisting of 19 species. These values show moderately high tree species richness for Miombo woodlands and are comparable to other findings in similar ecosystem. For example, a study conducted by Kamangadazi *et al.* (2016) recorded 21 tree species in Liwonde Forest Reserve. Kacholi (2019) reported that 24 species were enumerated in Nongeni Forest Reserve. However, all studies were within the same range of species number, corresponding to the global tropical rainforest range of 20 to 223 species/ha (Kacholi, 2019, cited in Whitmore, 1984). The vegetation composition showed that the ten most abundant tree species in both selective harvesting (SH) and unregulated harvesting (UH) were in the genera of *Brachystegia, Julbernardia,* and *Uapaca kirkiana. Brachystegia species, Julbernardia paniculate,* and *Uapaca kirkiana* were abundant in the selective harvesting compared to the unregulated harvesting systems. Unregulated harvesting was exposed to excessive harvesting, which led to a decrease in tree species, compared to selective harvesting. Therefore, selective harvesting supports more species and regeneration because of moderate disturbance which promotes structural heterogeneity (Falk, et al., 2008) and avoidance of widespread damage to root systems and soil structure

On the other hand, the results revealed that *Combretum mole* and *Uapaca kirkiana* was among the abundant tree species in both harvesting systems. This may suggest that *Brachystegia* species have dormant seed to germinate, while *Uapaca kirkiana* is easily established, since it is a pioneer species. On the other hand, *Brachystegia* species are good at coppicing from the stumps when they are cut at the right stump size (Luoga *et al.,* 2003). The current study agrees with Pelletier *et al.* (2019) in Zambia Miombo woodlands, where human activities affect the distribution of tree species, especially for timber, green wood collection and charcoal production.

The results also revealed that there was high dissimilarity (0.43) in tree species composition between SH and UH in all tree size classes, and tree species recruitment was 0.48. This is probably because of the differences in the level of disturbances in these two systems. The other suggested reason could be harvesting systems; unregulated harvesting attributed to dissimilarity, because more harvesting was done in sapling and timber trees. These results agree with Gondwe, (2020), who found almost similar results (0.45), which presented low tree species similarity between Co-managed (Perekezi and Liwonde Forest Reserves) and Government managed (Kaning'ina and Thambani). The tree species differences attributed due to landscape physiography and rainfall within the forest reserve (Frost, 1996). Haider *et al.* (2018) and Gebeyehu *et al.* (2019) also reported low similarity in tree species composition due to differences in the level of disturbances and the level of elevation gradient of the area. Further, tree species composition and structure vary in similar or different places due to soil conditions, temperatures, and rainfall (Gondwe, 2020).

5.2 Species Diversity

The total number of tree species enumerated in selective harvesting was 25 and 19 species in unregulated harvesting, respectively. The most of *Brachystegia* species are common in both systems and few unique in either of the two. It showed that intensity of different harvesting systems could not affect the existence of Miombo species. These observations are similar to studies by Nchimbi, (2022) in Marang' Forest, Tanzania, indicated that higher number of recruitments of pioneer species in both systems. The Shannon-Wiener diversity indices indicated a higher species diversity (2.65) in selective compared to unregulated harvesting

(2.34). The higher species diversity in selective harvesting was attributed to previous disturbance, which opened tree canopy for light tolerant species like *combretum* and *Uapaca* to regenerate. The excessive harvesting of indigenous trees may lead to forest degradation and loss of biodiversity (Chidumayo, 2010; Gebeyehu *et al*, 2019). Other studies on miombo woodland forests by Zimudzi *et al.* (2013), Kacholi (2019), Kamangadazi (2019), and Monfort *et al.* (2021), reported that H' commonly ranges from 1.5 to 3.5 and it rarely exceeds 4.5. The *H'* value (2.65 and 2.34) from the present study was lower than the value of 3.31 reported by Mambo (2020) for Dzalanyama Forest Reserve. This showed that opening space created by the SH and UH allowed the pioneer species to take over. In this particular study, the tree species diversity was higher in selective harvesting could be attributed to colonisation of *Combretum molle,* and *Uapaca kirkiana* due to open canopy and consequently availability of sunlight for germination, establishment and growth of trees. Another reason could be, as suggested by Kacholi (2019), that tree species diversity varies from one area to another due to various factors, including human disturbances, topography and climatic conditions.

5.3 Tree species recruitment pattern

This study found no statistically significant differences in tree species recruitment between selective and unregulated harvesting systems across the three regeneration categories (seedlings, saplings, and poles regeneration) (Table 3). However, seedlings were more abundant in SH than in UH (Appendix 2), demonstrating vigorous regeneration at early stages. The reduction in abundance from seedlings to saplings and poles suggests that mortality increases as individuals grow, likely due to fire, livestock grazing, shading by canopy species, and natural death. This pattern aligns with a reverse J-shaped curve showing continuous regeneration/recruitment but decreasing survival at later stages (Gebeyehu *et al.,* 2019).

Similar findings were observed in Chongoni Forest Reserve (Missanjo *et al.,* 2014) and (Kaning'ina, Thambani and Liwonde Forest Reserves (Gondwe, 2020) that where light-demanding species recruited showed more regeneration in disturbed/harvested areas. Anthropogenic activities such as fires, livestock grazing and wood collection play acritical in supressing saplings and poles (Hall, *et al.,* 2003; Zonvo, *et al.,* 2021). Nonetheless, Miombo woodlands in the family of *Caesalpiniaceae* and *Euphorbiaceae* possess adaptations that enable regeneration under disturbance which reduces abundance of tree species (Nyirenda, 2020; Vyamana *et al.,* 2020; Zonvo *et al.,* 2021; Badu *et al.,* 2022)

5.4 Population structure

The diameter at breast height (DBH) size class distribution revealed a smooth reverse J-shaped curve in selective harvesting, while as slightly disturbed reverse J-shaped curve in unregulated harvesting systems. A t-test revealed a highly significant difference ($P < 0.001$) in DBH between the selective and unregulated harvesting. The results showed that there was a stable distribution of trees in selective and continuity of population structure in selective. Whilst in unregulated, the population structure was slightly disturbed, especially in pole timber and timber (large) tree classes. The study observed that intensive harvesting occurred in pole timber and timber trees in unregulated compared to selective. This could be attributed to illegal harvesting of forest products for economic activities. Consequently, shrubs and trees composition differ significantly in Miombo woodlands (Muvengwi *et al*., 2020).

Comparatively, studies by Giiba *et al.* (2011) in Bereku Forest Reserve, Tanzania; Kalaba, (2013) in Zambia; Gondwe, (2020) and Nyirenda, (2022) in Malawi; Bienu *et al.* (2023) in Kuki Biosphere, Democratic Ruplic of Congo, reported that the history of anthropogenic activities affect species composition and structure, such as charcoal production, firewood collection, and timber sawing. These results agree with Muboko *et al.,* 2019) who indicated that high illegal wood harvesting occurred in Malawi, Tanzania, Zambia and Angola. The variation in species composition occurred due to the degree of harvesting in the woodlands (Gebeyehu *et al.,* 2019).

The Miombo woodland received pressure for wood products from Mzimba Boma and Raiply rural growth centre, since MFR is situated between these locations. These two sites create market opportunities for the surrounding communities which exert more pressure to the forest due to increased demand for the resources. These results are similar to the study done by Zulu *et al*. (2020), who found that the market opportunities created by the surrounding urban and peri-urban communities play a great role in unregulated harvesting in miombo woodlands. The human activities in Miombo woodlands have disproportionate effects on the present species population structure and composition (Nchimbi, 2022). Asare *et al*. (2022) reported that more illegal harvesting changes forest structure and composition. This threatens preferred species to extinction or become endangered species (Makalukwa, 2014; Kacholi, 2019; Asare *et al.,* 2022).

The results also showed more seedlings in both harvesting systems, which reveals active regeneration for stable and healthy tree species population (Nyirenda, 2022). Similar results were reported by other studies done by Zimudzi *et al.* (2013) in Mazowe Botanical Reserve in Zimbabwe; Kacholi, (2019) in Nongeni forest reserve in Tanzania, and Kamangadazi, (2019). In Perekezi, Ntchisi and Liwonde forest reserves in Malawi. These studies likewise observed that a greater number of seedlings supports positive species regeneration and recruitment. Muvengwi *et al.* (2020) further reported that the high proportion of juveniles (young trees) indicated a vigorously recruiting population structure, whilst a high proportion of adults (old/matured trees) may indicate a potentially ageing population. This means that in selective harvesting, the forest portrayed a healthy and even-aged population structure, where the young tree species recruited into adult classes. People use trees at different stages, and young ones are left to grow in unregulated harvesting, while the trees in young and old were highly cut for different purposes. This could suggest that they were used for poles and charcoal production.

Banas *et al.* (2018) explained that sustainable forest management (SFM) as utilization of forests should be continuously supply of forests products, biological diversity. resilience and resistance to disturbances and non-production function. Sustainability of the tree species in both harvesting systems are attainable by active regeneration, saplings and pole timber which have chance to supply forest products. However, Lewark, (2020) reported that SFM for harvesting timber from miombo woodlands had not been successful despite the efforts made by providing all silvicultural treatments. The implications of SFM, in high dissimilarity of tree species composition in unregulated harvesting is that the continuity of forest products supply would be decreased. The saplings were more than pole timber class. This may lead to discontinuity forests community and the productivity could be reduced. Gondwe, (2020) recommended selective harvesting should be allowed to simulate regeneration. However, unsustainable wood harvesting is widely spread in the miombo woodlands whereby wood harvesting is more than replenish which is unhealth for sustainability (Vyamana *et al.,* 2021). Although this is the case, Miombo species would not change to new forest types despites different harvesting systems applied.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

The study aimed to evaluate forest dynamics under different harvesting systems in miombo woodlands of Mtangatanga Forest Reserve. The study was looking into comparing the harvesting systems used in Miombo woodlands based on the following parameters: tree species composition, recruitment, and population structure. The study revealed that there was a high tree species abundance in *Brachystegia* species in selective harvesting and unregulated harvesting treatments, respectively. This shows that the Miombo woodlands could not be affected by the pioneer species.

The study also focused on the diameter at breast height (DBH) size class distribution that reveals a smooth reverse J-shaped curve in selective harvesting, while slightly disturbed reverse J-shaped curve in unregulated harvesting treatment. This implies that the number of seedlings and pole timber is abundant compared to timber trees in selective harvesting. It suggests that the young trees are enough to replace big trees. Unregulated harvesting needs close monitoring because the number of seedlings and pole timber is not sufficient to replace saplings and timber trees, while saplings are not abundant. This means that those areas will not adequately support the biodiversity and ecosystem. Therefore, forest sustainable management should be implemented to enhance steady and healthy forests.

The study also observed that Mtangatanga Forest Reserve has protected/endangered tree species that have been listed by the Government of Malawi, like *Julbernadia paniculate (Mtondo) (*Forest Act (Cap. 63:01) of the Laws of Malawi).

The study concludes that as long the dominant species are still existing, the forest would not change to a new forest type unless the land use is changed. Hence the forest will remain as a Miombo woodland. Therefore, Proper conservation and management is needed, especially for economically important tree species preferred for charcoal production such as *Julbernadia paniculate, Brachystegia spiciformis, Brachystegia floribunda* and *Brachystegia boehmii, while Combretum molle* is used for firewood.

6.2 Recommendations

Based on the findings of the present study, the following points are recommended to further characterise the forest dynamics under different harvesting systems for Mtangatanga Forest Reserve.

a. Recommendations;

1. In order to maintain and conserve tree species diversity, recruitment, population structure and associated ecological community in the MFR. The study recommending the empowerment/strengthen the local community governance structures that might take lead in protection of forest resources.
2. The study recommends that forest law enforcement be enhanced to curtail unregulated harvesting by reinforcing regular patrolling and promote forest-based enterprises. It was observed in the field that the bark of trees was removed for traditional bee hives.
3. Although, Miombo woodlands could not change to a new forest type despite heavy forest degradation. The study recommends close monitoring on the utilization of forest resources for future generation.
4. In order to have well conserved and rich biodiversity, the policy makers should provide incentives for communities surrounding the MFR.

b. Suggested further studies

1. The present study was limited to tree species abundance, but a further study should look into the effects of soil composition in recruitment pattern.
2. The present study was limited to tree species composition, but further ecological studies should look into differences in the level of disturbances and the level of elevation gradient of the area, like slope and altitude.
3. Further studies should be done on the analysis of carbon sequestration and storage in biomass and soil in Mtangatanga Forest Reserve to trade off carbon credits for the surrounding communities. This would enhance the protection and conservation of the forest.

REFERENCES

Appiah, J.O., Duah, W.A., Sobeng, A.K. and Kpienbaareh, D., 2021. 'Analysing patterns of forest cover change and related land uses in the Tano-Offin forest reserve in Ghana: Implications for forest policy and land management', *Trees, Forest and People,* 5, pp. 100-105.

Arii, K., Caspersen, J.P., Jones, T.A. and Thomas, S.C., 2008. *A selection harvesting algorithm for use in spatially explicit individual-based forest simulation models*.

Asare, F., Owusu, F.W. and Gazo, R., 2022. 'Sustainable charcoal production drive in rural communities in Ghana, West Africa', *Energy for Sustainable Development*, 68, pp. 364-372, ISSN 0973-0826, https://doi.org/10.1016/j.esd.2022.04.013.

Atsbha, T., Desta, A.B., and Zewdu, T., 2019. *Wood species diversity population structure, and regeneration status in Gra-Kahsu natural vegetation, Southrn Tigray of Ethiopia*. Heliyo 5(2019) e01120. doi: 10.1016/j.heliyon. 2019.e01120.

Badu, K.A, Anning, A.K., Eshun, B. and Mensah, G., 2022. 'Land use effects on tree species diversity and soil properties of the Awudua Forest, Ghana', *Global Ecology and Conservation* 34(2022): e02051.

Bienu, S.A., Lubalega, T.K., Khasa, D.P., Kaviriri, D.K., Yang, L., Yuhua, L., Eyul'Anki, D.M., Tango, E.K. and Katula, H.B., 2023. 'Floristic diversity and structural parameters on the forest tree population in the Luki biosphere reserve, Democratic Republic of Congo', *Global Ecology and Conservation*. Available at https://doi.org/10.1016/j.gecco.2023.e02489. (Sourced on 9th February, 2024).

Chapagain, U., Chapagain, B.P., Nepal, S. and Manthey, M., 2021. 'Impact of Disturbances on Species Diversity and Regeneration of Nepalese Sal (Shorearobusta) Forests Managed under

Different Management Regimes', *Earth*, 2, pp. 826–84 4. https://doi.org/10.3390/earth2040049

Chapman C.A, Abernathy K., Chapman L.J., Downs C., Effiom E.O., Gogarten J.F., Golooba M., Kalbitzer U., Lawes M.J., Mekonnen A., Omeja P., Razafindratsima O., Sheil D., Tabor G.M., Tumwesigye, C. and Sarkar D., 2022. 'The future of sub-Saharan Africa's biodiversity in the face of climate and societal change', *Front. Ecol. Evol.* 10:790552. doi: 10.3389/fevo.2022.790552.

Chaudhary, A., Burivalova, Z., Koh, L.P. and Hellweg, S., 2016. 'Impact of Forest Management on Species richness: Global meta-analysis and Economic trade-offs', *Sci Rep,* 6, pp. 1-10. https://doi.org/10.1038/Srep23954.

Chazdon, R.L., 2003. 'Tropical forest recovery: Legacies of human impact and natural disturbances', *Perspectives in Plant Ecology, Evolution and Systematics*, 6(1,2), pp. 51-71. https://doi.org/10.1078/1433-8319-00042.

Chidumayo, E. and Marunda, C., 2010. *Dry Forests and Woodlands in Sub-Saharan Africa: Context and Challenges. In Dry Forests and Woodlands of Africa*: Managing for Products and services, 1st ed.; Chidumayo, EN., Gumbo, D.J., (Eds.), Centre for International Forestry Research (CIFOR): London, UK; Washington, DC, USA, 2010; Chapter 1, pp.1-9.

Chirwa, P.W., Syampungani, S. and Geldenhuys, C.J., 2009. *The Ecology and Management of the Miombo Woodlands for Sustainable livelihoods in Southern Africa*: The case for non-timber forest products.

Chiteculo, V. and Surovy, P. 2018. *Dynamic Patterns of Trees Species in Miombo Forest and Management Perspectives for Sustainable Production*—Case Study in Huambo Province, Angola. Faculty of Forestry and Wood Sciences, Department of Forest Management, Czech

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Clarke, N., Gundersen, P., Belyazid, U.J., Kjonaas, O.J., Persson, T., Sigurdsson, B.D., Stupak, I. and Lesterdal, L., 2015. *Influence of different tree-harvesting intensities on forest soil carbon stock in boreal and northern temperate forest ecosystems*. Forest Ecology and Management.

Falk, K.J., Burke, D.M., Elliott, K.A., and Holnes, S.B., 2008. 'Effects of single-tree and group selection harvesting on the diversity and abundance of spring in deciduous forests in Southwestern Ontorio', *Forest Ecology Management*, 255(7) .https://doi.org/10.1016/j.foreco.2008.01.033. Sourced on 25th April, 2025.

Fayolle, A., Swaine, M.D., Bastin, J.F., Bourland, N., Comiskey, J.A., Dauby, G., Doucent, J.L., Gillet, J.F., Fleury, S.G., Handy, O.j., Kirunda, B., Kouame, F.N. and Plumptre, A.J. (2014). 'Patterns of tree species composition across tropical African forests', *Journal of Biogeography (J. Boigeogr.)* 2014. © John Wiley & Sons Ltd. https://wileyonlinelibrary.com/journal/jbi. Doi.org:10.1111/jbi.12382.

Forest Landscape Restoration Action Plan for M'mbelwa District Council, 2021. United States Agency for International Development and the United Kingdom Foreign, Commonwealth and Development Office by the Government of Malawi and Tetra Tech through USAID Contract No. 72061219C00005, Modern Cooking for Healthy Forests.

Frost, P., 1996. The Ecology of Miombo Woodlands. In: B Campbell (Ed.) *The Miombo in Transition: Woodlands and Welfare in Africa, pp. 11-57*. Centre for Internation Forestry Research, Bagor, Indonesia.

Gatti, C.R., Simona, C., Jeremy L., Marco, M., Mauro, M., Paola A.D., Francesco, P. and Riccardo, V. 2015. 'The impact of selective logging and clearcutting on forest structure, tree diversity and above-ground biomass of African tropical forests', *Ecological Research,* 30. 10.1007/s11284-014-1217-3.

Gebeyehu, G., Soromessa, T., Bekele. and Teketay, D., 2019 'Species composition, stand structure and regeneration status of the species in dry Afromontane Forests of AwiZone, northwestern Ethiopia', *Ecosystem Health and Sustainability,* 5(1),199-215. http://doi.org/10.1080/20964129.2019.1664938.

Giliba, R.A., Boon, E.K., Kayombo, C.J., Musamba, E.B., Kashiadye, A.M. and Shayo, P.F., 2011. 'Species Composition, Richness and Diversity in Miombo Woodland of Bereku Forest Reserve, Tanzania', *Biodiversity*, 2(1), pp. 1-7.

Gondwe, M.F., Choa, M.A., Chirwa, P.W. and Geldenhuys, C.J., 2020. *Land use land cover change and the comparative impact of co-management and government-management on the forest cover in Malawi (1999-2018)*. Taylor & Francis Group. https://doi.org/10.1080/1747423X.2019.1706654

Gondwe, M.F.K., 2020. *Influence of Miombo woodlands management, drivers on land use/Cover and Forest Change, woody composition/diversity, population structures in Malawi*. Available at http://hdl.handle.net/2263/75413. Sourced on 8th February, 2024.

Government of Malawi, 2017. *National Charcoal Strategy, 2017 – 2027*. The Ministry of Natural Resources, Energy and Mining.

Government of Malawi, 2016. *National Forest Policy:* Lilongwe Malawi: Forestry Department, Ministry of Natural Resources, Energy and Mining.

Government of Malawi, 2018. *Forest Carbon Inventory*: Standards of Operating Procedures. Forestry Department, Ministry of Mines, Natural Resources and Environment.

Government of Malawi, 2024. *Malawi's Second National REDD+ Forest Reference Level*. Republic of Malawi, the Ministry of Natural Resources and Climate Change.

Government of Malawi, 2005. *Standards and Guidelines for Participatory Forestry in Malawi*. Improving forest governance – improving rural livelihoods. Ministry of Mines, Natural Resource and Environment, Department of Forestry, Lilongwe.

Gumbo, D.J., Dumas-Johansen, M., Muir, G., Boerster, F. and Xia, Z., 2018. *Sustainable Management of Miombo Woodlands. Food Security, Nutrition and Wood Energy*; Food and Agriculture Organisation of the United Nation (FAO) Rome: Italy.

Haider, S., Kueffer, C., Bruelheide, H., Selpel, T., Alexander, J.M., Rew, L.J., Arevalo, J.R., Cavieres, L.A., McDougall, K.L., Milbau, A., Naylor, B.J., Speziale, K. and Pauchard, A., 2018. 'Mountain roads and non-native species modify elevational patterns and plants diversity', *Global Ecology and Biogeography*. Doi:10.1111/geb.12727.

Hall, J.S., Harris, D.J., Medjibe, V. and Ashton, P.M.S., 2003. 'The effects of selective logging on forest structure and tree species composition in a Central African Forest: implications for management of conservation areas', *Forest Ecology and Management*. https://doi.org/10.1016/s0378-1127(03)00107-5.

Hofico, N.S.A. and Fleig, F.D., 2015. 'Diversity and structure of Miombo Woodlands in Mozambique Using Range of Sampling Sizes', *Journal of Agricultural Science and Technology,* B5, pp. 679-690.

Kachamba D.J., Eid T. and Gobakken T., 2016. *Above- and Belowground Biomass Models for Trees in the Miombo Woodlands of Malawi*. Available at https://doi.org/10.3390/f7020038. Sourced on 4th February, 2024.

Kacholi, D.S. (2019). ‘Assessment of Tree Species Richness, Diversity, Population structure and Natural Regeneration in Nongeni Forest Reserve in Morogoro Region, Tanzania’, *Tanzania Journal of Science,* 45(3), pp. 330-345, 2019. ISSN 0856-1761, e-ISSN 2507-7961

Kalaba, F.K., Quinn, C.H., Dougill, A.J. and Vinya, R., 2013. *Froristic composition, species diversity and carbon storage in charcoal and agriculture Fallows and management implications in Miombo woodland of Zambia*. Forest Ecology and Management.

Kamangadazi, F., Mwabumba, L. and Missanjo, E., 2016. ‘The Potential of Selective Harvesting in Mitigating Biomass and Carbon Loss in Forest Co-management Block in Liwonde Forest Reserve, Malawi’, *Scholars Academic Journal of Biosciences* (SAJB). ©Scholars Academic and Scientific Publisher

Kamangadazi, F., 2019. *Analysis of tree community composition, diversity and natural regeneration in miombo woodlands of Malawi*.

Khendlo, J., Goodary, R., and Beeharry, R., 2024. *Deforestation Trends in Chikwawa District, Malawi: Geospatial Land Use Land Cover Change*. Available at SSRN: http://ssrn.com/abstract=5050231 or http://dx.doi.org/10.2139/ssrn.5050231.

Latterini F., Mederski P.S., Jaeger D., Venanzi R., Tavankar, F. and Picchio R., 2023. ‘The Influence of Various Silvicultural Treatments and Forest Operations on Tree Species Biodiversity’. *Current Forestry Reports,* 9, pp. 59–71. https://doi.org/10.1007/s40735-023-00179-0.

Mambo, E.M., 2020. Assessment of Woody Species Diversity, Biomass and Carbon Stock Pontial of Dzalanyama Forest Reserve, Malawi

Manjate, A., Zahabu, E., Ilstedt, U., Egas, A., and Goodman, R.C., 2025. 'Structure and Composition of Selectively Logged Miombo in Central Mozambique', *Forest*, 16, p. 569. https://doi.org/10.3390/F16040569.

Mbwambo, L.R., 2000. *Species utilisation preferences and resource potential of miombo woodlands: a case of selected villages in Tabora, Tanzania*. Stellenbosch: Stellenbosch University.

Missanjo, E., Thole, G.K., Mtambo, C. and Chisanga, O., 2014. 'Evaluation of Natural Regeneration and Tree Species Diversity in Miombo woodlands in Malawi', *Journal of Biodiversity Manage Forestry,* 3(3). doi: https//dx.doi.org/10.4172/2327.4417.1000127

M'mbelwa District Council, 2017. *Social Economic Profile* (2017 – 2022).

Montfort, F., Nourtier, M., Grinand, C., Maneau, S., Mercier, C., Roelens, J.B. and Blanc, L. 2021. 'Regeneration capacities of woody species biodiversity and soil-properties in miombo woodland after slash and burn agriculture in Mozambique', *Forest and Management,* 48(8). 119039. http://doi.org/10.1016/j.foreco.2021.119039.

Muboko, N., Zengeni, L., Mashapa, C., Chibememe, G., & Gandiwa, E., 2019. 'The Social Dynamics of Illegal Wood Harvesting on Indigenous Woody Vegetation: A Case Study of Chimanimani National Park, Eastern Zimbabwe', *Open Journal of Forestry*, 9, pp. 381-396. http://doi.org/10.4236/ojf.2019.94021.

Muvengwi, J., Chisango, T., Mpakairi, K., Mbiba, M. and Witkowski E.T.F., 2020. 'Structure, composition and regeneration of miombo woodlands within harvested and unharvested areas', *Forest Ecology and Management*, 458. 117792, ISSN 0378-1127, http://doi.org/10.1016/j.foreco.2019.117792.

Mwakalukwa, E.E., Meilby, H., and Treue, T., 2014. *Floristic composition, structure and species association of dry miombo woodland in Tanzania*. Handawi Publishing Corporation. ISRN Biodiversity. Volume 2014. Article ID 153278, 15 pages. http://dx.doi.org/10.1155/2014/153278.

Nchimbi, G., 2022. *Tree species diversity, composition, population structure and associated herbivore abundance in human-impacted and non-impacted areas of Marang' forest, northern Tanzania*. The Nelson Mandela African Institution of Science and Technology.

Njogu, K.P. and Kung'u, B.J., 2015. 'Factors Influencing Adoption of Woodfuel Energy Saving Technologies in Nakuru County, Kenya', *Int. J.SCI.Res.IJSR,* 4, pp. 1028-1036.

Nyirenda, H., 2022. *Changes in tree structure, composition and soil in different disturbance categories in Miombo and agroecosystems in Malawi, central Africa*. Elsevier. http://doi.org/10.1016/j.helliyon.2022.el10664. Sourced on 15th February, 2024.

Nyirenda, H., Assede, E.P.S., Chirwa, P.W., Geldenhuys, C., Nsubaga, F.W., 2019. 'The effect of land use change and management on the vegetation characteristics and termite distribution in Malawi Miombo woodland'*, agroecosystem.Syst.,* 93, pp. 2331-2343.

Orthmann, B., 2005. *Vegetation Ecology of a Woodland-Savanna Mosaic in Central Benin (West Africa): Ecosystem Analysis with Focus on the Impact of Selective Logging* (Doctoral dissertation, Rostock, Univ., Diss., 2005).

Pelletier, J., Chidumayo, E., Trainor, A., Siampale, A., and Mbindo, K., 2019. *Distribution of tree species with high economic and livelihoods value for Zambia*. Forest Ecology and Management.

Poudyal, B.H., Maraseni, T., Cockfield, G., 2018. 'Evolutionary dynamics of selective logging in the tropics: A systematic review of impact studies and their effectiveness in sustainable forest management', *Forest Ecology and Management,* 430, pp. 166-175. https://doi.org/10.1016/j.foreco.2018.08.006.

Pretzsch, H., 2009. *Forest dynamics, growth and yield* (vol.684). Berlin: Springer.

Pretzsch, H., delRTO, M., Bilber, K., Arcangeli, C., Beelak, K., Brang, P., Dudzinska, M., Forrester, D.T., Kladtke, J., Kohnle, U. and Ledermann, T., 2019. 'Maintenance of long-term experiments for unique insights and trends', *Review and perspectives of forest research*, 138(1), pp. 165-185.

Rampheri, M. B., Dube, T., Shoko, C., Marambanyika, T., and Dhau, I., 2022. 'Local community attitudes and perceptions towards benefits and challenges associated with biodiversity conservation in blouberg nature reserve, South Africa', *African Journal of Ecology*, 60(3), 1– 11. doi: 10.1111/aje.12989.

Ribeiro, N.S., Katerere, Y., Chirwa, P.W. and Grandy, I.M., 2020. *Miombo Woodlands in a Changing Environment:* Securing the Resilience and Sustainability of People and Woodlands. ISBN 978-3-030-50103-7. © Springer Nature Switzerland AG2020.

Ribeiro, N., Syampungani, S., Matakala, N., Nangoma, D. and Ribeiro, A., 2015. *Miombo Woodlands Towards the Sustainable Use of Ecosystem Services in Southern Africa*. http://dx.doi.org/10.5772/59288.

Sahoo, T., Acharya, L. and Panda, P.C., 2020. 'Structure and Composition of tree species in tropical moist deciduous forests of Eastern Ghats of Odisha, India. In response to human-induced disturbances', *Environmental Sustainability*, 3(1), 69-82. https://doi.org/10.1007/s42398-020-00095-0.

Sassen M., Sheil D. and Giller K.E., 2015. 'Fuelwood collection and its impacts on a protected tropical mountain forest in Uganda', *Forest Ecology and Management*. http://dx.doi.org/10.1016/j.foreco.2015.06.037

Shackleton, C.M. and Clarke, J.M., 2007. Genesis Analytics (Pty) Ltd. Paper I: *Research and Management of Miombo Woodlands for Products in Support of Local Livelihoods*, pp.1-58

Shirima, D. D., Munishi, P. K. T., Lewis, S. L., Burgess, N. D., Marshall, A. R., Balmford, A., Swetnam, R. D., and Zahabu, E. M. 2011. "*Carbon Storage, Structure and Composition of Miombo Woodlands in Tanzania's Eastern Arc Mountains*." © 2011 Blackwell Publishing Ltd. Afri. J. Ecol., 49 (3): 332-342. https://doi.org/10.1111/j.1365-2028.2011.01269.x

Skole, D.L., Samek, J.H., Mbow, C., Chirwa, M., Ndalowa, D., Tumeo, T., Kachamba, D., Kamoto, J., Chioza, A. and Kamangadazi, F., 2021. *Direct Measurement of Forest Degradation Rates in Malawi: Toward a National Forest Monitoring System to Support REDD+*. Forests 2021, 12, 426. https://doi.org/10.3390/f12040426.

Smith, D.M., Larson, B.C., Ketty, M.J., and Ashton, P.M.S., 1997. *The practice silviculture: Applied Forest Ecology* (9^{th} ed). John Wiley and Sons.

Solano, R.J., Samuel, A.G.G., Moreno, G. V.S., Álvarez, S.P., Calderón A.O.A. and Barraza, G.Q., 2023. 'Effect of silvicultural treatment of individual selection on the horizontal structure of a p horizontal structure of a pine-oak forest in northern Mexico in northern Mexico in northern Mexico', *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 51(2), Article number 13082 DOI:10.15835/nbha51213082.

Soliku, O. and Schraml, U., 2020. *Protected areas management: A comparison of perceived outcomes associated with different co-management types.* Available at https://doi.org/10.1016/j.forpol.2020.102258. Sourced on 9^{th} February, 2024

Syampungani, S., Geldenhuys, C.J. and Chirwa, P.W., 2016. 'Regeneration dynamics of miombo woodland in response to different anthropogenic disturbances: Forest characterisation for sustainable management', *Agroforest Syst.*, 90, pp. 563–576. https://doi.org/10.1007/s10457-015-9841-7

Vermeulen, W.J., Geldenhuys, C.J., Esler, K.J., Syampungani, S. and Meke, G., 2020. 'Conceptual decision-making framework for the sustainable harvesting of forest and woodland species for medicinal tree bark in southern Africa, Southern Forests', *Journal of Forest Science*, 82(1), pp. 32-46. DOI: 10.2989/20702620.2019.1686689

Vyamana, V.G., Chamshama, S.A.O. and Andrew, S.M., 2021. *Coppicing and productivity of two indigenous tree species under different forest management regimes in Tanzania*. https://doi.org/10.1016/j.tfp.2021.100088. Sourced on 21st February, 2024.

Wang, W., Wang. J. and Meng, J., 2023. 'A climate–sensitive mixed-effects tree recruitment model for Oak (Querus spp.) in Hunan province, South-central China', *Forest Ecology and Management*, 528.

Workneh, Y. and Wassie, D., 2024. 'Effects of selective harvesting on diversity, structure and regeneration of woody plants in mixed plantation of Mengagesha Suba Forest, Central Ethiopia', *International Journal of Forestry Research*, 2024(1), pp. 335-5857.

Zimudzi, C, Mapaura, A., Chapano, C. and Duri, W., 2013. 'Woody species composition, structure and diversity of Mazowe Botanical Reserve, Zimbabwe', *Journal of Biodiversity and Environmental Sciences,* 3(6), pp. 17-29,2013

Zulu, L.C., Kamoto, J.F.M., Djenontin, I.N.S., Mbanze, A.A., Kambanje, C. and Katerere, Y., 2020. *Governance and Institutional Arrangement for Sustainable Management of Miombo Woodlands*. ©Springer Nature Switzerland AG2020.

APPENDICES

Appendix 1: Family and species name found in species recruitment, selective, and unregulated harvesting in MFR, Mzimba District

Family	Recruitment	Selective harvesting	Unregulated harvesting
Anacardiaceae	*Lanneadiscolour*	*Lanneadiscolor*	*Lanneadiscolor*
	Ozoroa insignis	*Ozoroa insignis*	-
Balanitaceae	*Balanitesaegyptica*	-	-
Boraginaceae	-	*Cordia abyssinica*	-
Caesalpinioideae	*Brachystegia boehmii*	*Brachystegia boehmii*	*Brachystegia boehmii*
	Brachystegia floribunda	*Brachystegia floribunda*	*Brachystegia floribunda*
	Brachystegia glaucescens	*Brachystegia microphylla*	*Brachystegia longifolia*
	Brachystegia glaucescens	*Brachystegia spiciformis*	*Brachystegia microphylla*
	Brachystegia longifolia	*Brachystegia stipulata*	*Brachystegia spiciformis*
	Brachystegia microphylla	*Brachystegia taxifolia*	*Brachystegia stipulata*
	Brachystegia spiciformis	-	-
	Brachystegia spiciformis	-	-

	Brachystegia stipulata	-	-
	Brachystegia taxifolia	-	-
	Isoberliniaangolensis	-	*Isoberliniaangolensis*
	Julbernardia paniculata	*Julbernardia paniculata*	*Julbernardia paniculata*
Chrysobalanecae	*Parinaricuratellifolia*	*Parinaricuratellifolia*	-
Combretaceae	*Combretum molle*	*Combretum molle*	*Combretum molle*
Dipterocarpaceae	*Monotes africanus*	*Monotes africanus*	*Monotes africanus*
Ericaceae	*Phillipiahexandra*	*Philippiahexandra*	*Philippiahexandra*
Euphorbiaceae	*Brideliamicrantha*	-	*Brideliamicrantha*
	Brideliamollis	-	-
	Pseudolachnostylismaprouneifolia	*Pseudolachnostylismaprouneifolia*	-
	Uapaca guineensis	-	-
	Uapaca kirkiana	*Uapaca kirkiana*	*Uapaca kirkiana*
	Uapaca titida	-	-
Fabaceae	*Senna singueana*	*Senna singueana*	-
Flacourtiaceae	*Kiggelariaafricana*	*Kiggelariaafricana*	*Kiggelariaafricana*
	Flacourtiaindica	-	-
Guttiferae	*Garcinia buchananii*	-	-

	Psorospermumfebrifugum	-	-
Loganiaceae	*Sytrychnos spinosa*	-	-
Mimosoideae	*Acacia amythethophylla*	*Acacia amythethophylla*	-
	Dichrostachyscinerea	-	-
	Dichrostachysglomerata	-	-
Moreceae	-	-	*Ficussycomorus*
Myrtaceae	*Syzigiumawariense*	-	-
	Syzigiumcordatum	*Syzigiumcordatum*	-
Ochnacea	*Ochnaschweinfurthiana*	*Ochnaschweinfurthiana*	-
Olacaceae	*Ximeniaamericana*	-	-
Papilionoideae	*Dalbergianitidula*	-	-
Proteaceae	*Faurearochetiana*	*Faurearochetiana*	*Faurearochetiana*
Rhamnaceae	-	*Ziziphusmucronata*	-
Rubiaceae	*Gardenia ternifolia*	*Gardenia ternifolia*	*Vangueriainfausta*
	Psychotriaeminiana	-	-
Sapindaceae	*ZanhaAfricana*	-	-
Sterculiaceae	*Dombeya burgessiae*	-	-
	Dombeya torrida	*Dombeya torrida*	*Dombeya torrida*
	Dombeya rotundifolius	-	-
Umbelliferae	*Steganotaeniaaraliacea*	-	-

(-) Indicates the absence of species in harvesting system and species recruitment

Appendix 2: Species name, stem density, basal area and important value for SH and UH in MFR

Family	**Species Name**	**Selective**			**Unregulated**		
		Density	**BA**	**IVI**	**Density**	**BA**	**IVI**
Anacardiaceae	*Lanneadiscolor*	459.72	2.06	4.07	133.33	2.31	10.09
	Ozoroa insignis	238.29	0.86	2.14	-	-	-
Boraginaceae	*Cordia abyssinica*	221.44	0.39	1.56	-	-	-
Caesalpinioideae	*Brachystegia boehmii*	2964.23	24.03	33.01	1028.85	8.90	50.60
	Brachystegia floribunda	2972.31	40.46	39.69	930.27	19.76	77.41
	Brachystegia longifolia	-	-	-	66.67	1.11	4.98
	Brachystegia microphylla	1074.68	12.89	13.65	180.94	7.35	20.73
	Brachystegia spiciformis	3672.75	40.06	43.76	378.77	7.56	27.64
	Brachystegia stipulata	2797.71	17.94	27.77	88.50	0.13	2.64
	Brachystegia taxifolia	30.22	0.73	0.75	-	-	-

	Julbernardia paniculata	2526.72	10.51	21.24	622.82	8.14	38.6
	Isoberliniaangolensis	-	-	-	22.22	0.20	1.40
Chrysobalanecae	*Parinaricuratellifolia*	442.87	1.39	3.40	-	-	-
Combretaceae	*Combretum molle*	1812.15	17.39	21.67	44.44	0.43	2.84
Dipterocarpaceae	*Monotes africanus*	3083.78	12.73	26.04	243.66	1.46	10.39
Ericaceae	*Philippiahexandra*	221.44	0.11	1.43	44.44	0.61	3.12
Euphorbiaceae	*Pseudolachnostylismaprouneifolia*	332.15	0.68	2.38	-	-	-
	Brideliamicrantha	-	-	-	110.72	0.24	3.90
	Uapaca kirkiana	2603.74	6.42	19.308	288.1	1.54	12.70
Fabaceae	*Senna singueana*	110.72	0.16	0.76	-	-	-
Flacourtiaceae	*Kiggelariaafricana*	2202.76	19.53	23.06	229.83	3.30	14.86
Mimosoideae	*Acacia amythethophylla*	60.44	1.58	1.56	-	-	-
	Albizia versicolor	-	-	-	8.00	0.92	2.22
Moreceae	*Ficussycomorus*	-	-	-	22.22	0.25	1.48

Myrtaceae	*Syzigiumcordatum*	110.72	0.45	0.90	-	-	-
Ochnacea	*Ochnaschweinfurthiana*	97.35	0.29	0.78	-	-	-
Proteaceae	*Faurearochetiana*	335.63	2.19	3.40	22.22	0.23	1.44
Rhamnaceae	*Ziziphusmucronata*	30.22	1.14	0.94	-	-	-
Rubiaceae	*Gardenia ternifolia*	208.06	0.14	1.40	-	-	-
	Vangueriainfausta	-	-	-	176.99	0.16	5.12
Sterculiaceae	*Dombeya torrida*	664.31	2.64	5.35	265.49	0.33	7.83

Appendix 3: Tree species name, family name, number of stems per species of stems ≥ 5cm DBH and < 5cm DBH in UH and SH in Mtangatanga Forest Reserve in MFR.

Species name	**Family**	**Stems ≥ 5cm DBH**		**Stems <5cm DBH**	
		Unregulated	**Selective**	**Unregulated**	**Selective**
Acacia amythethophylla	Mimosoideae	0	4	0	1
Albizia versicolor	Mimosoideae	1	0	0	0
Balanitesaegyptica	Balanitaceae	0	0	6	0
Brachystegia boehmii	Caesalpinioideae	25	76	45	57
Brachystegia floribunda	Caesalpinioideae	44	70	134	194
Brachystegia glaucescens	Caesalpinioideae	0	0	0	9
Brachystegia longifolia	Caesalpinioideae	3	0	0	10
Brachystegia microphylla	Caesalpinioideae	9	26	25	27
Brachystegia spiciformis	Caesalpinioideae	13	82	98	29
Brachystegia stipulata	Caesalpinioideae	1	64	178	3

Brachystegia taxifolia	Caesalpinioideae	0	2	52	0
Brideliamicrantha	Euphorbiaceae	2	0	0	2
Brideliamollis	Euphorbiaceae	0	0	2	0
Combretum molle	*Combretaceae*	2	48	441	4
Cordia abyssinica	Boraginaceae	0	4	0	0
Dalbergianitidula	Papilionoideae	0	0	23	5
Dichrostachyscinerea	Mimosoideae	0	0	0	2
Dichrostachysglomerata	Mimosoideae	0	0	0	29
Dombeya burgessiae	Sterculiaceae	0	0	0	0
Dombeya rotundifolius	Sterculiaceae	0	0	98	16
Dombeya torrida	Sterculiaceae	3	12	2	0
Faurearochetiana	Proteaceae	1	8	47	19
Ficussycomorus	Moreceae	1	0	0	0
Flacourtiaindica	Flacourtiaceae	0	0	3	2
Garcinia buchananii	Guttiferae	0	0	0	21
Gardenia ternifolia	Rubiaceae	0	4	2	4
Isoberliniaangolensis	Caesalpinioideae	1	0	0	1
Julbernardia paniculata	Caesalpinioideae	21	50	74	38
Kiggelariaafricana	*Flacourtiaceae*	8	42	31	3
Lanneadiscolor	*Anacardiaceae*	6	10	18	0

Monotes africanus	*Dipterocarpaceae*	5	62	9	6
Multidentiacrassa		0	0	0	1
Ochnaschweinfurthiana	Ochnacea	0	2	13	9
Ozoroa insignis	Anacardiaceae	0	6	0	0
Parinaricuratellifolia	*Chrysobalanecae*	0	8	24	5
Phillipiahexandra	Ericaceae	2	4	7	0
Pseudolachnostylismaprouneifolia	Euphorbiaceae	0	6	1	0
Psorospermumfebrifugum	Guttiferae	0	0	1	2
Psychotriaeminiana	Rubiaceae	0	0	0	9
Rytianiamonatitha		0	0	0	0
Senna singueana	*Fabaceae*	0	2	11	4
Steganotaeniaaraliacea	Umbelliferae	0	0	8	0
Sytrychnos spinosa	Loganiaceae	0	0	3	1
Syzigiumawariense	Myrtaceae	0	0	0	10
Syzigiumcordatum	Myrtaceae	0	2	0	5
Uapaca guineensis	Euphorbiaceae	0	0	0	2
Uapaca kirkiana	Euphorbiaceae	7	48	260	376
Uapaca titida	Euphorbiaceae	0	0	0	12
Vangueriainfausta	Rubiaceae	2	0	0	0
Ximeniaamericana	Olacaceae	0	0	49	4
Zanhaafricana	Sapindaceae	0	0	0	2
Ziziphusmucronata	Rhamnaceae	0	2	0	0

	Total number of stems	157	644	1665	924
Number of species		20	25	29	36

Appendix 4: Number of regenerates in different sizes in unregulated and selective harvesting treatments in MFR

Name of Species	Seedlings		Saplings		Poles		Total of seedlings	Total of saplings	Total of poles
	UH	SH	UH	SH	UH	SH			
Acacia amythethophylla	1	-	2	-	-	-	1	2	-
Balanitesaegyptica	-	-	-	-	-	-	6	-	-
Brachystegia boehmii	57	45	-	2	-	1	102	2	1
Brachystegia floribunda	194	134	4	13	-	6	328	17	6
Brachystegia glaucescens	9	-	-	-	-	-	9	-	-
Brachystegia longifolia	10	-	-	-	-	-	10	-	-
Brachystegia microphylla	27	25	-	5	1	-	52	5	1
Brachystegia spiciformis	29	98	1	4	-	1	127	5	1
Brachystegia stipulate	3	178	-	6	-	-	181	6	-
Brachystegia taxifolia	-	52	-	3	-	-	52	3	-
Brideliamicrantha	2	-	-	-	-	-	2	-	-
Brideliamollis	-	2	-	-	-	-	2	-	-
Combretum molle	4	441	1	20	-	-	445	21	-
Dalbergianitidula	5	23	-	4	-	-	28	4	-

Dichrostachyscinerea	2	-	-	-	-	-	2	-	-
Dichrostachysglomerata	29	-	-	-	-	-	29	-	-
Dombeya burgessiae	-	-	7	-	-	-	-	7	-
Dombeya rotundifolius	16	98	2	-	-	-	114	2	-
Dombeya torrida	-	2	-	-	-	-	2	-	-
Faurearochetiana	19	47	2	3	1	-	66	5	1
Flacourtiaindica	2	3	-	4	-	-	5	4	-
Garcinia buchananii	21	-	-	-	-	-	21	-	-
Gardenia ternifolia	4	2	-	-	-	-	6	-	-
Isoberliniaangolensis	1	-	2	-	-	-	1	2	-
Julbernadiapanuculata	17	-	2	-	1	-	17	2	1
Julbernardia paniculata	21	74	1	9	-	1	95	10	1
Kiggelariaafricana	3	31	-	2	-	-	34	2	-
Lanneadiscolor	-	18	1	3	-	-	18	4	-
Monotes africanus	6	9	1	3	-	3	15	4	3
Multidentiacrassa	1	-	3	-	-	-	1	3	-
Ochnaschweinfurthiana	9	13	1	-	-	-	22	1	-
Ozoroa insignis	-	-	-	1	-	-	-	1	-
Parinaricuratellifolia	5	24	-	1	-	-	29	1	-
Phillipiahexandra	-	7	-	-	-	-	7	-	-
Pseudolachnostylismaprouneifolia	-	1	-	-	-	-	1	-	-
Psorospermumfebrifugum	2	1	-	-	-	-	3	-	-
Psychotriaeminiana	9	-	-	-	-	-	9	-	-
Rytianiamonatitha	-	-	-	-	11	-	-	-	11

Senna singueana	4	11	-	2	-	-	15	2	-
Steganotaeniaaraliacea	-	8	-	-	-	-	8	-	-
Sytrychnos spinose	1	3	-	-	-	-	4	-	-
Syzigiumawariense	10	-	-	-	1	-	10	-	1
Syzigiumcordatum	5	-	-	-	-	-	5	-	-
Uapaca guineensis	2	-	-	-	-	-	2	-	-
Uapaca kirkiana	376	260	18	2	3	-	636	20	3
Uapaca titida	12	-	-	-	-	-	12	-	-
Ximeniaamericana	4	49	1	-	-	-	53	1	-
Zanhaafricana	2	-	1	-	-	-	2	1	-
Grand Total	**924**	**1665**	**50**	**87**	**18**	**12**	**2589**	**137**	**30**

Appendix 5: : Presence of tree species in both harvesting system and recruitment in MFR

Species Name	**Selective Harvesting**	**Unregulated harvesting**	**Species recruitment**
Acacia amythethophylla	√	×	√
Balanitesaegyptica	×	×	√
Brachystegia boehmii	√	√	√
Brachystegia floribunda	√	√	√
Brachystegia glaucescens	√	√	√
Brachystegia glaucescens	√	√	√
Brachystegia longifolia	√	√	√
Brachystegia microphylla	√	√	√
Brachystegia spiciformis	×	×	√
Brachystegia spiciformis	×	×	√
Brachystegia stipulata	×	×	√
Brachystegia taxifolia	×	×	√
Brideliamicrantha	×	√	√
Brideliamollis	×	×	√
Combretum molle	√	√	√
Cordia abyssinica	√	×	×
Dalbergianitidula	×	×	√
Dichrostachyscinerea	×	×	√
Dichrostachysglomerata	×	×	√
Dombeya burgessiae	×	×	√
Dombeya rotundifolius	×	×	√

Dombeya torrida	√	√	√
Faurearochetiana	√	√	√
Ficussycomorus	×	√	×
Flacourtiaindica	×	×	√
Garcinia buchananii	×	×	√
Gardenia ternifolia	√	√	√
Isoberliniaangolensis	×	√	√
Julbernardia paniculata	√	√	√
Kiggelariaafricana	√	√	√
Lanneadiscolor	√	√	√
Monotes africanus	√	√	√
Ochnaschweinfurthiana	√	×	√
Ozoroa insignis	√	×	√
Parinaricuratellifolia	√	×	×
Phillipiahexandra	√	√	√
Pseudolachnostylismaprouneifolia	√	×	√
Psorospermumfebrifugum	×	×	√
Psychotriaeminiana	×	×	√
Senna singueana	√	×	√
Steganotaeniaaraliacea	×	×	√
Sytrychnos spinosa	×	×	√
Syzigiumawariense	×	×	√
Syzigiumcordatum	√	×	√
Uapaca guineensis	×	×	√
Uapaca kirkiana	√	√	√

Uapaca titida	×	×	√
Ximeniaamericana	×	×	√
Zanhaafricana	×	×	√
Ziziphusmucronata	√	×	×

(×) shows the species that were absent and (√) indicates species that were present in the harvesting system.

Appendix 6: MZUNIREC Approval

MZUZU UNIVERSITY

DIRECTORATE OF RESEARCH

Mzuzu University
Private Bag 201
Luwinga
Mzuzu 2
MALAWI
TEL: 01 320 722
FAX: 01 320 648

MZUZU UNIVERSITY RESEARCH ETHICS COMMITTEE (MZUNIREC)

Ref No: MZUNIREC/DOR/24/51 **12/08/2024.**

Masozi Dorothy Shaba,,
Mzuzu University,
P/Bag 201,
Luwinga,
Mzuzu 2.

Email: masozidorothyshaba@yahoo.com

Dear Masozi,

RESEARCH ETHICS AND REGULATORY APPROVAL AND PERMIT FOR PROTOCOL REF NO: MZUNIREC/DOR/24/51: EFFECTS OF HARVESTING SYSTEMS ON TREE SPECIES COMPOSITION, RECRUITMENT AND POPULATION STRUCTURE IN MTANGATANGA FOREST RESERVE, MZIMBA DISTRICT

Having satisfied all the relevant ethical and regulatory requirements, I am pleased to inform you that the above referred research protocol has officially been approved. You are now permitted to proceed with its implementation. Should there be any amendments to the approved protocol in the course of implementing it, you shall be required to seek approval of such amendments before implementation of the same.

This approval is valid for one year from the date of issuance of this approval. If the study goes beyond one year, an annual approval for continuation shall be required to be sought from the Mzuzu University Research Ethics Committee (MZUNIREC) in a format that is available at the Secretariat. Once the study is

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finalised, you are required to furnish the Committee with a final report of the study.

The Committee reserves the right to carry out compliance inspection of this approved protocol at any time as may be deemed by it. As such, you are expected to properly maintain all study documents including consent forms.

Wishing you a successful implementation of your study.

Yours Sincerely,

Wanangwa K. Msowoya

MZUNIREC Secretariat
FOR: MZUNIREC CHAIRPERSON

Mzuzu University Research Ethics Committee
Directorate of Research
Mzuzu University
P/Bag 201
Luwinga
Mzuzu 2
Email: mzunirec@mzuni.ac.mw

MZUZU UNIVERSITY RESEARCH ETHICS COMMITTEE
12 AUG 2024
PRIVATE BAG 201, LUWINGA
MZUZU 2

DISTRICT COMMISSIONER
M'MBELWA DISTRICT COUNCIL
12 SEP 2024
MZIMBA, MALAWI

THE DISTRICT FORESTRY OFFICER
DEPARTMENT OF FORESTRY
12 SEP 2024
P.O. BOX 129
MZIMBA

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Appendix 7: Informed consent form

Mzuzu University Research Ethics Committee (MZUNIREC)

Part I: Informed Consent Form for Research in

Effects of Harvesting Systems on tree Species Composition, Recruitment and Population Structure in Mtangatanga Forest Reserve, Mzimba District

Introduction

I am **Masozi Dorothy Shaba** from **Mzuzu University**. We are doing research on Effects of harvesting systems on tree species composition, recruitment and population structure in Mtangatanga forest reserve, Mzimba district. This consent form may contain words that you do not understand. Please ask me to stop as we go through the information and I will take time to explain. If you have questions later, you can ask me or another researcher.

Purpose of the research

This research aims to **evaluate forest dynamics under different harvesting systems in**

Mtangatanga Forest Reserve.

Type of Research Intervention

This research will involve your participation in a group discussion and/or individual interview.

Participant Selection

You are being invited to take part in this research because your involvement in this research will help collect right data and information that will address the research hypothesis.

Voluntary Participation

Your participation in this research is entirely voluntary. It is your choice whether to participate or not. If you choose not to participate nothing will change. You may skip any question and move on to the next question.

Duration

The research takes place for a period of **2 months**.

Risks

You do not have to answer any question or take part in the discussion/interview/survey if you feel the question(s) are too personal or if talking about them makes you uncomfortable.

Reimbursements

You will not be provided any incentive to participate in the research.

Sharing the Results

The knowledge that we get from this research will be shared with you and your community before it is made widely available to the public. Following, we will publish the results so other interested people may learn from the research.

Who to Contact

If you have any questions, you can ask them now or later. If you wish to ask questions later, you may contact: Prof. **Lusayo Mwabumba**, Lecturer, Mzuzu University, P/Bag 201, Luwinga, Mzuzu 2, Phone: 0880809035 and Mr Kennedy Masamba, Postgraduate Coordinator, Mzuzu University, P/Bag 201, Luwinga, Mzuzu 2, Phone: 0995754512

This proposal has been reviewed and approved by Mzuzu University Research Ethics Committee (MZUNIREC), a committee whose task is to ensure that research participants are protected from harm. If you wish to find out more about the Committee, contact Faith Mwangonde, Mzuzu University Research Ethics (MZUNIREC) Administrator, Mzuzu University, P/Bag 201, Luwinga, Mzuzu 2, Phone: 0886103419

Do you have any questions?

Part II: Certificate of Consent

I have been invited to participate in research about Effects of Harvesting Systems on tree Species Composition, Recruitment and Population Structure in Mtangatanga Forest Reserve, Mzimba District.

I have read the foregoing information, or it has been read to me. I have had the opportunity to ask questions about it and any questions I have asked have been answered to my satisfaction. I consent voluntarily to participate in this study

Print Name of Participant__________________

Signature of Participant ___________________

Date ___________________________

Day/month/year

If illiterate [1]

I have witnessed the accurate reading of the consent form to the potential participant, and the individual has had the opportunity to ask questions. I confirm that the individual has given consent freely.

Print name of witness____________

Thumb print of part

Signature of witness _____________

Date ________________________

Day/month/year

[1] A literate witness must sign (if possible, this person should be selected by the participant and should have no connection to the research team). Participants who are illiterate should include their thumb print as well.

Statement by the researcher/person taking consent

I have accurately read out the information sheet to the potential participant, and to the best of my ability made sure that the participant understands the research project. I confirm the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

Signature of Researcher /person taking the consent__________________________

Date ___________________________

Day/month/year

Appendix 8: Field Data Collection Material

No.	Data type	Data collection method	Materials/tools/equipment	Responsible person
1	Species name (botanical)	Identification and recording	Botanical book, recording materials (note pad, field form)	Taxonomist Student
2	Number of species	Counting and recording	Chalk, recording materials (note pad, field form)	Student
3	Regeneration counts	Counting and recording	Recording materials (note pad, field form)	Student
4	DBH (cm) (at 1.3m above the ground)	measurement	Diameter tape and calliper, recording materials (note pad, field form)	Student
5	Height (m)	measurement	Vertex and transponder, recording materials (note pad, field form)	Student
6	UTM coordinates	Recording	GPS	Student
7	Plot condition	observation	Recording materials (note pad and field form	Student
8	Ground distance	measurement	Linear tape	Student

Appendix 9: Data Collection Form

Tree Inventory Data | Recorder: ____________________

Sampling plot No._____ | Date: ___________________

XCoord: ____________ | Sub-Plot radius: 6____ 12____ 20____

YCoord: ____________

Tree ID	Species Name	DBH (cm)	Height (m)	Comments

Appendix 10: Regeneration Count Form

Regeneration count Data Recorder: __________________

Sampling Unit: _______ Date: ___________________

XCoord: _____________ Sampling plot No.: 1____ 2____ 3____

YCoord: _____________ Regeneration circle (2m radius at 6m east from centre)

Small Regeneration 20-49.9cm			Medium Regeneration 50-149.9cm			Big regeneration 150cm<5m DBH		
Species code	Tally	Count	Species code	Tally	Count	Species code	Tally	Count