Influence of Illegal Selective Harvesting of *Colophospermum mopane* J. Kirk Ex Benth On Woody Vegetation Structure And Composition: A Case Of Ward 8, Mbire District, Mid-Zambezi Valley Region Of Zimbabwe

By

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Dedication

This thesis is dedicated to Makanaka, my daughter whose birth inspired me to enrol for the Master of Science in Conservation Biology.
Acknowledgments

I wish to appreciate my lecturers at Bindura University of Science Education, Zimbabwe notably Mrs Z. Jiri the project and programme coordinator and Mr A. Kundhlande my project supervisor whose enthusiasm for this thesis and for my authorship deserves and indeed receives my gratitude. Special thanks also go to my work place supervisor Mr B. Ncube for granting me the permission to frequently go out of station for the project commitments. I also wish to thank Mr T. Bope my colleague for editorial work whose contribution ensured that the whole document complied with the APA format. I also wish to acknowledge the University of Concordia staff for mentoring me in scientific writing and argumentation and APA tutorials, the National Herbarium in Harare for identification of some tree species. Lastly, I would want to thank my wife Anna for the emotional and social support and patience she exhibited throughout the whole course work and thesis. Her contribution to the success of this thesis could not go unmentioned.
Declaration

I, Obey Rwatiringa, declare the research project herein is my own work and has not been copied or lifted from any source without the acknowledgement of the source.

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Signed         Date
Abstract

Savanna woodlands are a priority for conservation as they are a habitat for many species. However, most of the savanna ecosystems are under threat from anthropogenic activities like agriculture, urbanization and over-harvesting. Charcoal production has been pointed out as one of the key causes of deforestation in sub-Saharan Africa causing local extinctions of some native species. The aim of this study was to investigate the effect of the illegal selective harvesting of Colophospermum mopane J. Kirk ex Benth on the woody vegetation structure and composition of natural woodlands of Ward 8 in Mbire district, Mashonaland Central Province of Zimbabwe. The study objectives were to determine the effects of selectively harvesting C. mopane for charcoal production on woody species diversity, relative abundance, evenness and vegetation structure. The study site was stratified into a disturbed area (with evidence of excessive harvesting) and undisturbed area (relatively intact forest). Within each site, 10 plots each measuring 20m × 20m were randomly selected for sampling. The following data were recorded per plot: name and number of species present, height, circumference at breast height, canopy depth and canopy length (two greatest diameters) were measured using tape measures and a graduated 3 m stick. The number of tree species and their type were used to calculate species diversity and evenness. Circumference at breast height was converted to diameter at breast height (DBH) using the formula for the circumference of a circle. The two greatest diameters and canopy depth were used to calculate canopy volume. Data were then analysed using a student t-test in SPSS version 21. The two communities significantly differed in their species composition with the disturbed site having lower abundance and species richness than the undisturbed site. Although Shannon-Wiener indices were not different between the two sites, evenness was significantly higher in the undisturbed site than the disturbed site. In structure, the undisturbed site had higher DBH values, basal area and height compared to the disturbed site. The results indicate that there has been significant loss of species and change in vegetation structure. There also is empirical evidence that there has been selective harvesting of big trees which has contributed to the reduction in size classes in the disturbed site. This has implications for conservation and therefore a need for promulgation of more stringent legislation and strict law enforcement against rampant poaching and indiscriminate cutting down of trees in these important natural woodlands of Zimbabwe.
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Chapter 1
Introduction

1.1. Background to the study

Savanna woodlands make up most of the tropical and sub-tropical woodland cover in sub-Saharan Africa and provide a wide range of benefits and products to local and national production (Venter & Witkowski, 2011). They provide the major source of energy for many households (Millenium Ecosystem Assessment, 2009). The main sources of energy derived from forests are firewood and charcoal. Savannas are also the focus of numerous livelihood activities in marginalized communities (Venter & Witkowski, 2011), the majority of which are found in Africa. These savanna woodlands have numerous wild plant species that are important in the subsistence sector, both for meeting a wide range of household needs and through increasing commercialization, thereby generating the much needed incomes (Dovie, Witkowski & Shackleton, 2008). Savanna woodlands are however under threat due to many anthropogenic activities that include logging, human induced climate change, invasive species and over-exploitation of resources.

Two factors may be attributed to the rapid decline in the savanna woodland. Firstly, demand for fuel wood and charcoal has increased due to the relatively high cost of electricity and petroleum-based fuels as well as rapid human growth, particularly in urban areas (Chidumayo, 2013). Secondly, there is increasing pressure on the woodlands arising from rapid human growth which necessitate clearing land for agriculture to enhance adequate food supply. In addition, the national economies of the savanna have, in the past been growing slowly with per capita income growth rate as low as 1% between 1990 and 1999 (Kaimowitz, 2003), yet poverty levels remain
high in these countries even in later years. As a result, there is increased dependence on forest resources and natural woodlands for human survival which invariably exerts pressure on these forests.

The charcoal industry targets woody species that yield great biomass and calorific values such as *Colophospermum mopane*. Most southern African countries are engaged in charcoal production, with a value of around 2–3% of GDP (Malimbwi *et al.*, 2010). Charcoal is primarily supplied from rural areas and provides affordable energy to 70–90% of the urban population, as well as income-generating opportunities in rural areas (Malimbwi *et al.*, 2010). The process of charcoal production can reduce standing woody biomass through selective harvesting of trees, which is the prevalent practice in most African woodlands (Chidumayo & Gumbo, 2013). Clear-cutting for charcoal can occur, particularly on the ‘frontier’ of charcoal production around large cities, where harvesting rates can greatly exceed regrowth (Woollen *et al*., 2016). Charcoal production is thus likely to impact the woodland resource base, and there may be trade-offs between charcoal production and other ecosystem services from woodlands (Chidumayo & Gumbo, 2013). However, a recent review concluded that few studies have assessed the links between charcoal production and their impact on the structure of Zimbabwean woodlands.

Forests in Zimbabwe play an important role in the conservation of biodiversity as they reduce land degradation and stabilize the environment. Forests also provide habitat for majority of the world’s wildlife species and enable the supply of clean water due to the roots of the trees which purify ground water. However, due to an increase in population these valuable services are not being met, this is so because of anthropogenic activities such as agriculture and illegal harvesting of *C. mopane* for charcoal production which depletes the valuable forests. The most dominant types of vegetation found in Zimbabwe are mopane, miombo, acacia, teak and
terminalia and they occupy land that is about two thirds of the country. FAO (2010) estimates that about 0.6 % of forests in Zimbabwe are lost every year as a result of agricultural activities which accounts for 70,000 ha per year.

Anthropogenic disturbances such as clearing for agriculture and harvesting of trees can alter vegetation structure and diversity (Mashapa & Gandiwa, 2013). Accordingly, the frequency and intensity of disturbances in an area will influence the vegetation structure and diversity of such ecosystems. Studies on anthropogenic disturbances such as tree harvesting and resultant effects on vegetation in rural areas are seldom quantified or assessed yet it is a critical challenge in conservation (Balme, Slotow & Hunter, 2010). Thus, for successful conservation and intervention there is need for knowledge of ecological processes and variation in species composition and diversity as well as structure in the face of disturbance (Mashapa & Gandiwa, 2013)

This study therefore aimed at assessing the impact of selective harvesting of mopane on community composition and structure in Northern Zimbabwe.

1.2. Problem statement

Due to the rising demand for charcoal, *C. mopane* trees are being illegally harvested to produce this charcoal. The extent to which this harvesting affects woody vegetation structure, species diversity and species abundance is poorly understood and it remains an area of concern in Ward 8 of Mbire district to conservationists. Although there are other species, *C. mopane* is being preferred for its high calorific value and if the trend continues it can trigger local extinction of the species. Harvesting of the mopane trees is being done illegally without the permission from responsible authorities such as the Forestry Commission hence the cutting is indiscriminate and in some areas extremely unsystematic. This is threatening the survival of the species.
Another problem is that people are not harvesting only dry mopane tree species but also fresh standing trees thus eliminating plants that will produce seed for the next generation. This study assessed the extent of damage so far.

1.3. Justification

There is a need to identify the effects of illegally harvesting mopane for charcoal production on the natural forest and to determine the extent to which woody vegetation structure, species diversity and abundance have been affected by illegally harvesting *C. mopane*. Trees play an important role in the conservation of the environment through stabilizing the environment and providing services such as carbon sequestration and purifying water. The harvesting of mopane trees impinges on theses ecosystem services thus the need to conduct this research to determine the extent to which the forest ecosystem has been disturbed. Mbire district is one of the communities that host high abundance of *C.mopane* but the species abundance is being threatened by evident selective harvesting due charcoal production as contrasted to other Zimbabwean districts. The findings from this study will help inform the relevant environmental authorities in Zimbabwe and policy makers alike to formulate applicable conservation strategies for the mopane woodlands based on the empirical evidence provided by this study. This study also hopefully provides a baseline for similar studies that can be carried out in other comparably affected woodlands across the country.

1.4. Aim

To investigate the influence of selectively harvesting *C. mopane* for charcoal production on woody vegetation structure and composition in Ward 8 of Mbire District in the mid-Zambezi valley region of Zimbabwe.
1.5. Objectives

1.5.1. To determine the effects of selectively harvesting *C. mopane* for charcoal production on woody species diversity in Ward 8 of Mbire District in the mid-Zambezi valley region of Zimbabwe.

1.5.2. To determine the effects of selectively harvesting *C. mopane* for charcoal production on woody vegetation species relative abundance and evenness in Ward 8 of Mbire District.

1.5.3. To determine the effects of selectively harvesting *C. mopane* for charcoal production on woody vegetation structure in Ward 8 of Mbire District.

1.6 Research questions

1.6.1. What are the effects of selectively harvesting *C. mopane* for charcoal production on woody species diversity in Ward 8 of Mbire District in the mid-Zambezi valley region of Zimbabwe?

1.6.2. What are the effects of selectively harvesting *C. mopane* for charcoal production on woody vegetation species relative abundance and evenness in Ward 8 of Mbire District?

1.6.3. What are the effects of selectively harvesting *C. mopane* for charcoal production on woody vegetation structure in Ward 8 of Mbire District?
Chapter 2

Literature Review

2.1 Deforestation Statistics

Deforestation is a phenomenon in which a forested area is converted into a non-forested area due to human or natural activities (Dimobe, Ouédraogo, Soma, Goetze, Porembski, & Thiombiano, 2015). Over-exploitation of species has been found to be one of the major cause of deforestation in the world (FAO, 2010). A number of forests in the world have been exposed to the problem of deforestation especially the Amazon forest due to rapid increase in logging. Research has shown that the cutting down of trees in the Savanna for charcoal production, firewood and timber, contributes a total of 68% of the perpetrators of deforestation in Africa, 89% in Asia and 51% in America (Geist & Lambin, 2001). Of the 68% in African the bulk of this is concentrated in the tropics. In a study by the World Bank in six West African states, charcoal production was shown to be the major cause of deforestation in protected areas (Dimobe et al., 2015). It is alarming that at the moment intensity of deforestation in protected areas is becoming higher than in unprotected areas (Castro-Luna, A, Castillo-Campos, G., Sosa, V., 2011). In China, the excessive consumption of charcoal which goes with the population growth is the main source of deforestation (Zhai, Cannon, Dai, Zhang, & Xu, 2015). In Uganda, the high request for charcoal has an incessant pressure on the forest, which leads to a deforestation rate of 600 km² per year (Call et al., 2017) in Uganda. Call et al (2017) observed that 75% of the destroyed forests are attributable to the consumption of ligneous energy (charcoal and firewood) in Tanzania.

About 30% of the land on earth is forested which translates to an estimated six billion hectares (FAO, 2010). Tropical deforestation recently became popular in the new millennium.
FAO (2010) projections show that deforestation has been taking place in the world from 1990 to 2002 at a rate of 15% per year and is projected to reach 23% by year 2020.

2.2 An overview Of Charcoal Production

2.2.1 History of charcoal production and trends.

The use of natural wood charcoal is approximately dated back to 30,000 years ago commonly in cave drawings (Van Beukering et al., 2010). Over 2 billion people globally rely on fuel wood as their main energy supply, especially rural households in developing countries (FAO, 2010). Wood charcoal production globally was in the year 2009, estimated at 47 million metric tons; 9% increase since 2004 (FAO, 2010). Fuel wood and charcoal, provides more than 14% of the world’s total primary energy and more significant in developing countries. This demonstrates the importance wood-fuel plays in meeting the energy requirements of developing countries. Due to this demand, it has pressed a huge demand on forests which are dwindling day by day. This trend can cause a destruction of preferred species which can become locally extinct.

Wood products are extracted from the forests mainly for use as wood fuel, for charcoal production, construction materials and for commercial enterprises such as curing tobacco and drying fish (Madoffe et al., 2012). Wood fuel is one of the primary sources of energy for domestic use and processing, as in the case of curing tobacco and drying fish, throughout the region (Sedano et al., 2016). It accounts for high percentages of the total household energy requirements. However, the consumption varies across countries ranging from 85% in Mozambique, 91% in Tanzania, 76% in Zambia and 14% in South Africa (Chidumayo & Gumbo, 2013). Agro-processing operations such as tobacco curing require large quantities of fuel wood, some 9 to 37 m³ and 19 to 33 m³ of wood per tonne of tobacco is required for flu and fire-cured tobacco, respectively (Manyanhaire & Kurangwa, 2014)
2.2.2 Trade in charcoal.

Trade in fuelwood and charcoal represents a source of cash income and employment for many rural poor. In Zambia, out of a total of 45,500 people engaged in the industry full-time, about 41,000 are engaged in charcoal production (Syampungani, Chirwa, Akinnifesi, Sileshi, & Ajayi, 2009). There are considerable trade networks moving the wood, or more usually the charcoal, from rural areas to urban areas (Malimbwi et al., 2010). Consequently, proximity to markets and transport routes is a significant factor in the harvesting levels and the resulting impacts on miombo woodland structure and productivity (Malimbwi et al., 2010). However, commercial demand for fuelwood may pose a serious challenge to the contribution of the industry to the well-being of local communities. This is because entrepreneurs, not necessarily residents in the rural community, tend to undertake harvesting for the commercial markets (Shackleton & Clarke, 2007).

2.3 Charcoal Production And Deforestation.

2.3.1 Effects of charcoal production on forests.

Charcoal production tends to have high environmental impacts, consuming huge areas of woody vegetation annually in some areas. For example, it is estimated that at least 3 million to 4 million cubic meters of wood is cut per annum to supply residents of the city of Dares Salaam in Tanzania (Malimbwi et al., 2010), with at least some of this coming from lower parts of the hotspot (Kitulang’halo Reserve near Morogoro). In a Ugandan forest in the Albertine Rift, charcoal producers had the most direct negative impact of five user groups extracting natural products from the forested landscape around Kibale National Park, whereas local firewood use for cooking was probably sustainable (Naughton-Treves, Kammen, & Chapman, 2007).
The production of charcoal using *C. mopane* tree species is one of the main causes of woodland change in the forests in Southern Africa. A number of southern African countries are involved in the production of charcoal and they usually gain a value which ranges from 2 to 3 % of GDP (Woollen *et al.*, 2016). According to Malimbwi *et al.*, (2010), charcoal is generally delivered to urban residents from rural areas and it provides a good source of energy to almost 70 -90 % of the urban residents and it is also a source of income for rural inhabitants. Charcoal making can result in the reduction of standing woody biomass through the process of selective harvesting of trees, (Chidumayo, 2013). Hence the production of charcoal is likely to have high impacts on the woodland resource base (Woollen *et al.*, 2016). Previous studies have often looked at the link between charcoal production and species diversity in other regions but little information is known on how it can impact local Zimbabwean forests.

**2.3.2 Effects charcoal production on species diversity and composition.**

Large-scale charcoal production, primarily in sub Saharan Africa, has been a growing concern due to its threat of deforestation, land degradation and climate change impacts. It is cited as the most environmentally devastating phase of this traditional energy supply chain, and despite increasing per capita income, higher electrification rates, and significant renewable energy potential, charcoal still remains the dominant source of cooking and heating energy for eighty percent of households in Sub Saharan Africa (Zulu & Richardson, 2013). The same authors note that charcoal use in Sub Saharan Africa is predicted to double by 2030, with over 700 million Africans relying on it as a durable, preferred, and cheap source of energy. Low process efficiencies, combined with unregulated actions of many producers, cause large volumes of wood to be harvested from nearby forests. These areas are often sections of communally-owned land in rural areas but can also make up large portions of nationally protected forests. As
a result of weak, unenforced or disjointed forest policies, many countries in Sub Saharan Africa are experiencing increased rates of deforestation from charcoal production in protected areas (Zulu, 2010). Unlike the use of fuelwood for cooking and heating, which is often supplied from ground harvesting and has no major impact on environmental degradation current methods of charcoal production require vast amounts of resources for relatively little return.

In a study on the effects of charcoal production on plant species in West Africa, Kouami, Yaovi, & Honan, (2009) showed that diversity indices significantly differed between exploited and unexploited areas due to selective cutting of species. The study revealed that species of the family *Combretaceae* and *Fabaceae* are mostly preferred and some have even become locally extinct. Similarly, Nock, Paquette, Follett, Nowak, & Messier (2013) found a change in species diversity with an increase from an urban area due to over exploitation near the town as people cut trees for urban charcoal consumption. Exploitation of resources near human dwelling usually lead to significant change in forests.

**2.3.3 Effects of charcoal production on vegetation structure.**

Selective harvesting of trees for charcoal making results simplification of the habitat linked with observed thinning of woodlands (Mashapa & Gandiwa, 2013; Sedano et al., 2016). For instance, a tree species can support many plant and animal species on an obligatory basis and one fruit tree can provide food for many birds and mammals. To maximize on profits, species of large size classes are preferred, as a result only shrubs will be left in the forest.

In a study by Naughton-Treves et al. (2007) they found that charcoal production had an effect of species structure. Similarly, (Kouami et al., 2009) found that charcoal production has resulted in a decrease in DBH of vegetation in harvested sites as compared to unexploited sites. This was attributed to selective pressure exerted on those species with diameter classes of 25 to
45 cm which are preferred in African savannas. In a study to assess the effects of human activities on woody vegetation structure in the woodlands of Maputaland (Gaugris & Rooyen, 2014) found that the woodland stem diameter class distribution and structure did not change when compared to a rural area where small woody plants dominated. Such results indicate that structure may not significantly change in a mature forest when compared to a young forest. However, if the pressure increases it has the effect of eliminating big trees leaving a community dominated by shrubs.

2.4. Species Diversity.

Measurement of community structure is usually achieved by calculating diversity indices which incorporate two aspects: different number of taxa (richness) and the distribution of individuals among taxa (evenness). Most diversity indices depend on the quality and availability of habitats (Barbour, 2010). They reflect the impact of all investigated stressors independent of ecoregion boundaries. Diversity indices reflect species richness and abundance of each species. There are different diversity indices that are sensitive to both the number of species and relative abundances of the species, such as the Shannon-Wiener and Simpson indices (Krebs, 2009), as well as indices that estimate the homogeneity of distribution of abundances among species (evenness). Krebs, (2009) points out that there are six factors that cause diversity gradients, one of which is disturbance. If we consider that the disturbance acts locally and can be represented by the environmental impacts, then diversity indices may reflect changes resulting from these impacts, and then, diversity indices allow us to assess easily the state of forest ecosystems. Communities with high scores of diversity indices show good environmental conditions, whereas those with low scores show environmental impacted conditions.
2.4.1 Limitations the indices of diversity.

The Shannon index is the best known and most used diversity index (Magurran, 2013). However, recently it has faced widespread criticism due to its sensitivity to the taxonomic level of the identification, as well as the area sampled, the sampling method and sampling season (Magurran, 2013). Shannon index gives a measure of both species numbers and the evenness of their abundance; the resulting figure does not give an absolute description of a site’s biodiversity. It is particularly useful when comparing similar ecosystems or habitats, as it can highlight one example being richer or more even. The problems caused by using Shannon index to measure diversity were recognized by (Jost et al., 2010). They arise because these measures are nonlinear with respect to species addition, even when all species are equally common. All else being equal, each added species leads to a smaller increment in ‘diversity’ than the species added before it (Jost et al., 2010).

The first and most fundamental problem of the traditional additive approach of Shannon or Simpson index is its premise that Shannon entropy or the Simpson index quantify conservation biology’s concept of diversity. Conservation biologists treat diversity as something that can be conserved or lost, but Shannon entropy and the Simpson index are logically inconsistent when used in this way (Jost et al., 2010). To conserve as much of Earth’s biodiversity as possible, sites with high diversity and high differentiation from others should be given conservation priority. These are exactly the systems which produce the strongest mathematical artefacts when Shannon entropy and the Simpson index are equated with diversity and additively partitioned. As a result, these two indices can present challenges in using them for measuring diversity. Despite these criticism Shannon Wiener index remains one of the most
popular and widely used diversity index in the scientific community due to its robustness and was used here to delineate the effects of charcoal production on species diversity.

2.4.2 Scales Of Diversity.

There are several scales at which biodiversity can be measured. All of them depend on the purpose and design of the research but generally fall into alpha diversity, beta diversity and gamma diversity (Tuomisto, 2010). Alpha diversity is defined as the diversity within a habitat or at local scale (Tuomisto, 2010). The same author defines beta diversity as the rate of compositional turnover along a habitat gradient within one geographical region, and gamma diversity as the rate of compositional turnover with geographical distance within one habitat. Tuomisto (2010) and Whittaker (1977) proposed a hierarchical nomenclature in which alpha diversity refers to within-habitat diversity, beta diversity to among-habitat differentiation in a landscape, gamma diversity to total within-landscape diversity, delta diversity to among-landscape differentiation in a region, and epsilon diversity to total within-region diversity. The use of these different scales is important in conservation because it affects the purpose of the study (Pasari, Levi, Zavaleta & Tilman, 2013).

2.5 Conclusion

There is a close link between charcoal production and biodiversity loss. This include change in species composition, diversity and structure. Exploitation target the big trees and select those with high heat content which invariably can dramatically change community structure and composition. Different researchers use different scales of diversity depending on the purpose of the study. This study was concerned with alpha diversity. Shannon Wiener index has been recommended for use in measuring alpha diversity and so will was used in this study.
Chapter 3

Methodology

3.1 Description Of The Study Area

Mbire district forms the major part of the low-lying mid-Zambezi Valley in Zimbabwe’s Mashonaland Central Province, and it is a semi-arid remote area described in the country’s agro-ecological zones IV and V specifically located 30° 25' E and 16° 30'S, and encompassing an area of about 2 700 km$^2$ (Tambara, Murwira, & Torquebiau, 2011). It is bordered by Mozambique to the north, Zambia to the north-west, Mashonaland West district to the west, Guruve rural district to the south and Muzarabani rural district to the east and has 17 wards/local administrative geographical boundaries (Figure 3.1). It is characterised by temperatures of up to 40°C in summer and low and increasingly irregular rainfalls averaging between 450-650-mm annually. There are two clearly defined seasons in the area – a rainy season from December to March and a long dry season from April to November (Baudron, Corbels, Andersson, Sibanda & Giller, 2011).

The mid-Zambezi valley is host to an estimated 700 plant species (Timberlake, 2000). On a broader note, the natural vegetation cover of the area is deciduous, dry savannah, and is dominated by *Colophospermum mopane* (Figure 2.2), with associations of *Acacia nilotica*, *Adansonia digitata*, *Combretum elaeagnoides*, *Diospyros kirkii*, *Kirkia acuminata*, *Sclerocarya*
birrea, Terminalia brachystemma, Terminalia sericea, Terminalia stuhlmanni and Ziziphus mucronate (Fritz, Said, Renaud, Mutake, Coid, & Monicat, 2003; Timberlake, Drummond, & Maroyi, 1988). Other dominant woodland types in the area include: the Diospyros kirkii/Combretum apiculatum low open woodland (Figure 2.3), commonly occurring on shallow sandstone soils, Brachystegia allenii C. mopane open woodlands on stony and deep soils, and Julbernardia/Combretum/mopane woodland on rocky sandstone slopes.

The area still hosts an important diversity of mammals, several of which are emblems of big African game (Fritz et al., 2003), with more than 40 species of large mammals and 200 bird species. Invertebrate groups partially studied for the area include Arachnids (127 species from 27 families), Coleoptera and Lepidoptera (90 species listed, mainly from Nymphalidae, Papilionidae and Lycaenidae families). The area includes an abundance and diversity of invertebrates of economic importance such as the mopane worm, Ambrasia belina (Timberlake, 2000; Timberlake et al., 1988).
3.4 Research Design.

A stratified random design was used where two strata were determined: a disturbed site and an undisturbed site. The disturbed site was considered to be an area where extensive harvesting of *C. mopane* is done while the undisturbed was a protected area nearby where little or no harvesting was taking place in it. Within each site 10 plots each measuring 20 m x 20 m were established. This plot size was considered adequate for surveys in savanna vegetation by Walker, (1976) it includes at least 15-20 trees of the most important species in the study plot.
3.5 Species Identification

Within each sample plot all woody species encountered were grouped into three classes and recorded: Tree species were defined as rooted, woody, self-supporting plants ≥3 m high with a basal stem diameter ≥6 cm. Shrubs were defined as rooted, self-supporting <3 m high and <6 cm in stem basal diameter (Ben-Shahar, 1998). Stumps were defined as woody plants with a height less than 0.5 m and has been cut. In each plot, these woody species were identified to species level either by using local names or botanical names following the nomenclature of Coates-Palgrave, (1997). Where the species were not easy to identify, samples were pressed and taken to the National Herbarium in Harare for identification. All species which were recorded using local names were subsequently converted to their botanical names following a checklist by Maroyi, (2013) and from www.zimbabweflora.co.zw.

3.6 Vegetation Structure.

To determine tree density (stems/ha) the following formula was used:

\[
\text{Density (stems/ha)} = \frac{\text{number of trees} \times 10000 \text{ m}^2}{\text{Plot area (m}^2\text{)}}
\]

All trees were sampled for growth traits using the following methods. The height of woody vegetation was measured by placing a calibrated 6m pole against a tree. For trees >6m, the pole was manually uplifted or height visually estimated by observing it at a distance away from the tree. On multi-stemmed plants, only the height of the tallest stem was considered. The basal circumference of each stem was measured just above the buttress swelling (to the nearest centimetre) using a flexible 5m tape measure. The basal circumference was then used to
calculate basal area using the following formula: \[ \text{Basal area (m}^2) = \frac{C}{4\pi}, \] where \( C \) = circumference in metres and \( \pi = 3.14 \)

Canopy depth of every living tree in the plot was measured using a calibrated 6m pole held against a tree. For taller trees (>6m), it was visually estimated or calculated from the height. Greatest canopy diameters (D1 and D2) were measured at 90° using a 30m tape measure. Canopy depth and the two canopy diameters were used to calculate canopy volume using a formula by Anderson (1973), as cited in van Beukering et al (2010): \[ \text{Canopy volume (m}^3) = 0.25 \cdot CD \cdot D1 \cdot D2. \]

Where CD = canopy depth in metres and D1 and D2 are the greatest canopy diameters in metres.

Individual woody biomass was calculated using an allometric equation developed by Mugasha and Chamshama (2002) for savanna woodlands with similar edaphic and climatic conditions: \[ WB = b_0 \cdot N \cdot DBH^{b_1} \]

Where \( WB \) = woody biomass (kg/tree), \( b_1 \) and \( b_0 \) = regression coefficients (\( b_1 = 0.0625 \) and \( b_0 = 2.553 \)).

The level of disturbance was also assessed by counting the number of \( C.mopane \) stumps in each plot. The stumps were classified as dead, freshly cut or live.

3.7 Methods Of Data Analysis.

Changes in community structure were assessed using several community metrics (Magurran, 2013). Richness (S), was measured as the different types of species present. Species diversity was measured using Shannon-Wiener diversity index (H) while equity was measured using evenness (J). The metrics were calculated for the two study sites using relative frequencies.
of the identified trees in the package ESTIMATES (Colwell, 2013). Data were then tested for normality using the Kolmogorov-Smirnov test. Since data were normally distributed an independent samples t-test was used to compare for differences between the two sites.

The structure of the communities (height, basal area, DBH, biomass, density and canopy volume) were compared between the two sites using an independent sample t-test since data were also normally distributed after testing with a Kolmogorov-Smirnov test. All statistical tests were carried out in SPSS version 21.

Changes in community composition were examined with the level of disturbance using Analysis of similarity (ANOSIM) and SIMilarity PERcentage analysis (SIMPER). The R-statistic generated by ANOSIM is a relative measure of separation among the treatments, with a 0 indicating no differences among treatments and a 1 indicating all samples in a treatment are more similar to one another than any sample belonging to another treatment. When ANOSIM revealed significant differences between the two sites, SIMPER was used to identify those tree species contributing most to the differences observed (key species). For SIMPER analyses, the Bray-Curtis distance was used to measure and compare each sample with every other sample to identify the species that are primarily responsible for the differences between the sample groups (i.e. disturbed vs undisturbed plots). ANOSIM and SIMPER tests were carried out in PAST (Hammer, Harper, & Ryan, 2001).
Chapter 4

Results

4.1 Species Abundance.

A total of 36 woody species belonging to 19 families (Appendix 1) were recorded. In total, the undisturbed site exhibited more abundance (164 individuals) than the disturbed site (125 individuals) (Appendix 1). The Fabaceae family was by far the most represented with 12 species.

Community structure changed due to disturbance (ANOSIM Global R = 0.88; P = 0.004). Some taxa were abundant in disturbed sites while others were abundant in undisturbed sites (Appendix 1). Further analysis with SIMPER revealed that the differences between the two communities was mainly driven by 9 species with an overall contribution of 100 % to dissimilarity (Table 4.1). The species with the highest contribution to dissimilarity was C. mopane at 28.73 % contribution and 16.74 average dissimilarity. The species with the lowest contribution to dissimilarity was Pseudolachnostylis maprouneifolia at 1.992 %. The abundance between the two sites were also significantly different for this species (t = 8; p = 0.0001; Table 1; Appendix 1).
Table 4.1. Woody species abundance of key families identified by SIMPER at disturbed and undisturbed site.

<table>
<thead>
<tr>
<th>Species botanical name</th>
<th>Av. Dissimilarity</th>
<th>Contribution %</th>
<th>Cumulative %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colophospermum mopane</td>
<td>16.74</td>
<td>28.73</td>
<td>28.7</td>
</tr>
<tr>
<td>Brachystegia spiciformis</td>
<td>10.05</td>
<td>17.25</td>
<td>45.9</td>
</tr>
<tr>
<td>Burkea Africana</td>
<td>7.687</td>
<td>13.19</td>
<td>59.1</td>
</tr>
<tr>
<td>Brachystegia boehmii</td>
<td>6.91</td>
<td>11.86</td>
<td>71.0</td>
</tr>
<tr>
<td>Combretum apiculatum</td>
<td>6.644</td>
<td>11.4</td>
<td>82.4</td>
</tr>
<tr>
<td>Friesodielsia abovata</td>
<td>5.167</td>
<td>8.867</td>
<td>91.3</td>
</tr>
<tr>
<td>Parinari curatelifolia</td>
<td>2.503</td>
<td>4.296</td>
<td>95.6</td>
</tr>
<tr>
<td>Peltophorum africanum</td>
<td>1.405</td>
<td>2.412</td>
<td>98.0</td>
</tr>
<tr>
<td>Pseudolachnostylis maprouneifolia</td>
<td>1.16</td>
<td>1.992</td>
<td>100</td>
</tr>
</tbody>
</table>
4.2 Species diversity.

The undisturbed site had more species compared to the disturbed site (t=2.5, p=0.045). Only 21 species were common between the two sites (Appendix 1). 21 (or 57%) of the species were common to both areas while only 4 species were absent in the undisturbed sites (Albizia amara, Lannea discolor, Lecaniodiscus fraxinifolius and Pseudolachnostylis maprouneifolia). The undisturbed site had more trees (average 817.55 stems/ha) compared to the disturbed site (average 492.76 stems/ha) (t=3.8; p=0.004). In terms of diversity the only measure that was significant was evenness while Shannon Wiener was not (Table 4.2).

Table 4.2: Species richness, density and evenness

<table>
<thead>
<tr>
<th>Index</th>
<th>Disturbed</th>
<th>Undisturbed</th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Species richness</td>
<td>22</td>
<td>32</td>
<td>2</td>
<td>0.045</td>
</tr>
<tr>
<td>Species Density (stems/ha)</td>
<td>492.76±67.23</td>
<td>817.55 ± 72.11</td>
<td>-4.218</td>
<td>.014</td>
</tr>
<tr>
<td>Shannon Wiener (H)</td>
<td>0.81 ± 0.35</td>
<td>1.61 ± 0.29</td>
<td>0</td>
<td>0.432</td>
</tr>
<tr>
<td>Pielou’s Evenness (J)</td>
<td>0.95 ± 0.33</td>
<td>0.89 ± 0.32</td>
<td>5</td>
<td>0.001</td>
</tr>
</tbody>
</table>

4.3 Vegetation structure.

The height of trees was significantly high in undisturbed site (average = 6.7 m) than on the disturbed site (average = 3.4 m) (t = 4.7; p =0.002). In terms of DBH, trees in the undisturbed
sites had a higher DBH compared to those in the disturbed areas ($t = 5.6; p=0.001$). The basal area was significantly higher in undisturbed sites than the disturbed sites ($t=6.7; p= 0.0001$). Lastly, woody biomass was higher in the undisturbed site at 5.9 kg/m$^2$ compared to the disturbed site (2.96 kg/m$^2$) ($t = 7.1; p =0.0001$). Only canopy volume remained constant between the two sites ($t=2.3; p=0.08$) (Table 4.3).

**Table 4.3: Summary of stand structure.**

<table>
<thead>
<tr>
<th>Index</th>
<th>Disturbed</th>
<th>Undisturbed</th>
<th>$t$</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (m)</td>
<td>3.4 ± 0.04</td>
<td>6.7 ± 0.08</td>
<td>4.7</td>
<td>.002</td>
</tr>
<tr>
<td>DBH (cm)</td>
<td>3.4 ± 0.002</td>
<td>7.2 ± 0.07</td>
<td>5.6</td>
<td>.001</td>
</tr>
<tr>
<td>Basal area (m$^2$)</td>
<td>0.71 ± 0.03</td>
<td>2.3 ± 0.08</td>
<td>6.7</td>
<td>.0001</td>
</tr>
<tr>
<td>Canopy volume (m$^3$)</td>
<td>4.2 ± 0.02</td>
<td>5.6 ± 0.11</td>
<td>2.3</td>
<td>.08</td>
</tr>
<tr>
<td>Woody biomass (kg/m$^3$)</td>
<td>2.96 ± 0.03</td>
<td>5.9 ± 0.05</td>
<td>7</td>
<td>0</td>
</tr>
</tbody>
</table>
Chapter 5

Discussion

Vegetation changes due to anthropogenic activities like selective harvesting remain one of the challenges in conservation today (Mashapa & Gandiwa, 2013) The impacts are usually destructive, often resulting in permanent vegetation structure and composition alterations as have been indicated in this study. Results from this study showed that the community structure changed due to disturbance as witnessed by the dissimilarity between the two communities. This dissimilarity in communities was mainly driven by low abundances of *C. mopane* in the disturbed site compared to the undisturbed site. The study also demonstrated that species evenness was higher in undisturbed site than the disturbed site while Shannon Wiener diversity remained constant. It terms of structure, height, DBH, basal area and woody biomass were significantly different between the two sites while canopy volume remained constant.

5.1 Woody Species Abundance And Richness.

Results indicate that the undisturbed site was more abundant in species compared to the disturbed site. The high abundance of species observed in the undisturbed site during this study are attributed to selective harvesting of *C. mopane*. It has been shown that species from the *Fabaceae* and *Combretaceae* family are sought after for charcoal production because of their high calorific value (Kouami,Yaovi,& Honan, 2009). *C. mopane* especially is preferred because of its high heat content value and that it lasts longer in burning. This has resulted in the selectivity of this species for charcoal burning. However, due to continuously increasing demand for charcoal and depletion of priority species such as *mopane* the harvesting methods are no longer segregatory (Chidumayo, 2013). There is a tendency of cutting down trees because of
availability as opposed to its calorific value. The effect of this selected exploitation varies with the community. It leads to more structural changes in savanna communities like in the current situation where in addition to exploitation of species for charcoal production, bushfires also contribute to the degradation. Personal observation in this study showed that even though *C. mopane* is preferred species in areas where it has been depleted certain species in the *Fabaceae* family are also being cut especially the genus *Brachystegia* and other miombo species.

The undisturbed community was richer in species compared to the disturbed site. Only 4 species were absent in the undisturbed sites (*Albizia amara, Lannea discolor, Lecaniodiscus fraxinifolius* and *Pseudolachnostylis maprouneifolia*) but present in disturbed sites. However, a total of 14 species found in undisturbed sites are absent in the disturbed site. Although this may be due to variation in other environmental variables, the major reason is logging as witnessed by the presence of stumps in the study site. The presence of these species in disturbed sites could be because these species are not selectively harvested for charcoal production. These species do not produce good charcoal and so they are not preferred for charcoal production.

Findings from this study corroborates with that of Kouami, Yaovi & Honan, (2009) who found that pressure on trees for charcoal production reduced species abundance in a Togo forest. In addition, Naughton-Treves, Kammen & Chapman, (2007) highlighted the negative impact of the intensive woody species exploitation in a national park in Uganda through the production and marketing of charcoal. In the study, they discovered that tree densities were higher in unexploited areas than exploited areas which agrees with the present study.
5.2 Woody Species Diversity.

Measurement of community structure is usually achieved by calculating indices which incorporate two aspects: different number of taxa (richness) and the distribution of the individuals among the taxa (evenness). These two aspects may be used in isolation or combined together to come up with different diversity indices. In this study Shannon-Wiener diversity indices, Pielou’s Evenness index and species richness were used to delineate the effects of mopane degradation in the current study. The Shannon index is the best known and most used diversity index (Magurran, 2013). It is affected by the taxonomic level of the identification, as well as the area sampled, the sampling method and sampling season. Identification to species level makes the Shannon Index more useful. In the current study, all species were identified to species level thus the index was based on species. Thus, study findings are more reliable coupled with the fact that an adequate area was sampled that making the results robust.

Most diversity indices depend on the quality and availability of habitats (Barbour, 2010). They reflect the impact of all investigated stressors independent of ecoregion boundaries. In the current study, Shannon Weiner H diversity values were low and similar in the two study sites despite the evidence of degradation in the disturbed site. Thus, this index failed to delineate the degradation gradient between the stations. However, the undisturbed site had higher evenness index than the disturbed site. The Shannon Wiener diversity index is sensitive to both the number of species and relative abundances (Krebs, 2009), while the evenness index estimate the homogeneity of distribution of abundances among species. This shows the number of species (abundance) was more important in shaping the community than the combination of the combined effect of abundance and richness. According to Magurran (2013), the Shannon Wiener index is particularly useful when comparing similar ecosystems or habitats, as it can
highlight one example being richer or more even. The differences in evenness shows that each community is dominated by different species. In this study about 30% of the species in undisturbed site were absent in the disturbed site. It has been shown the removal of certain dominant species in a community can have a negative effect on the remaining species because dominant species tend to create habitat and facilitate the growth of other species (Shirima, Totland, Munishi & Moe, 2015). This study was carried out in a mopane dominated woodland and its selective harvesting may have contributed to the reduction in community evenness in the disturbed site. Thus, this study has shown that the homogeneity of distribution of abundances among species (evenness) was important in structuring the community than the diversity of species.

According to Peter (1999), species diversity index for actual communities vary from 1.5 to 3.5 but indices above 1 are considered diverse by other authors (Madoffe et al., 2012). In this study however, only the undisturbed site falls within this range (1.61). Savanna ecosystems are generally species rich and their indices of diversity are usually above one in intact ecosystems. The low diversity in the disturbed site shows that there has been high logging of species which affected mostly the abundance of the species.

Research findings compare fairly with those of other studies on effects of disturbance on vegetation. However results contrast with those of Tambara et al. (2011) in the mid Zambezi valley who found that species diversity was higher on a disturbed site than undisturbed site. In their study however, the disturbance was due to agricultural activity rather than logging. They suggested that the removal of mopane woodland allowed other species to establish thus increasing species diversity. However, such results should be treated with caution because their diversity was high because if the dominance of pioneer species which tend to disappear in a
mature community. The community studied was mature which may explain the differences in our observations. In a comparative study Kimaro & Lulandala (2013) also found higher species diversity in disturbed sites because of continuous disturbance which tended to establish other species in favour of the dominant species.

5.3 Woody Vegetation Structure.

In terms of structure, the two communities were significantly different. The diameter at breast height (DBH), basal area and height in undisturbed sites was higher compared to the disturbed sites. When people are harvesting trees for charcoal production they usually target bigger trees (tall with bigger girth) as they produce more charcoal and energy on average as contrasted to small trees. Thus, over time bigger trees will begin to disappear in logged sites and be replaced by shrubs. The short trees with lower DBH in disturbed sites demonstrate that there has been selective harvesting species.

The research findings corroborates well with those of Naughton-Treves, Kammen & Chapman. (2007) who demonstrated that charcoal production affected woody species structure. Similarly, Kouami, Yaovi & Honan, (2009) found that charcoal production has resulted in the decrease in DBH and height of harvested sites as compared to unharvested sites. This was attributed to pressure exerted on those species with diameter classes of 25 to 45 cm which are preferred in African savannas. However, contrary to research findings, in a study to assess the effects of human activities on woody vegetation structure in the woodlands of Maputaland, Gaugris & Rooyen (2014) found that the woodland stem diameter class distribution and structure did not change when compared to a rural area where small woody plants dominated. Such results demonstrate that structure may not significantly change in a mature forest when compared to a young forest. However, if the pressure increases it has the effect of eliminating big trees leaving
a community dominated by shrubs. It is therefore important to study both mature and young forest to assess changes.

Considering the fact that harvesting tends to select certain species with high heat content and large trees it means the remaining community will only be dominated by shrubs. Such a community will have reduced basal area and overall reduced height classes.

5.4 The future of Mbire Forests.

As a result of weak forest policies in Mbire deforestation continues unabated. Unlike the use of fuelwood for cooking and heating, which is often supplied from ground harvesting and has no major impact on environmental degradation current methods of charcoal production require vast amounts of trees for relatively little return. This is putting unnecessary pressure on the forests and accelerates rates of deforestation.
Chapter 6

Conclusions And Recommendations

6.1 Conclusions.

Results of this study have demonstrated that illegal harvesting *C. mopane* charcoal has had negative impact on the forest composition and structure of Mbire. There is enough evidence to show that the abundance and richness of woody species has been altered with few species now left in the disturbed site. In addition, some species found in the disturbed site are no longer present in the undisturbed site which may suggest that species are slowly becoming locally extinct. Of note is that many species from the *Fabaceae* and *Combretaceae* are also increasingly being exploited. This observation means that the selected species *C. mopane* has been depleted and people could be now harvesting alternatives.

It can be concluded that Shannon Wiener diversity indices failed to delineate the differences in diversity while Pieolu’s Evenness showed differences. This suggest that the homogeneity of distribution of the species was more important than the diversity in explaining community composition. SIMPER analysis showed a high dissimilarity between the two communities with the abundance of *C. mopane* contributing more to the dissimilarity. This suggest that there has been increasing pressure for the harvesting of *C. mopane* for the production of charcoal. If the trend continues then *C. mopane* may become locally extinct.

In terms of structure, results showed that the two communities were different. DBH, basal area and height were higher in undisturbed site than in disturbed site. This demonstrate that there has been selective cutting of bigger and taller trees as they produce more charcoal. As a result the
disturbed site is now dominated by small trees and saplings which shows the extent of damage has been big.

6.2 Recommendations.

Based on these results the following recommendations are made:

- Mbire Rural District Council should come and halt the destruction of forests in the area because if this remain uncurbed some species will become locally extinct. This is because most of the cutting is actually illegal. Environmental custodian organizations such as EMA and Forestry Commissions should also enforce laws and legislation on the exploitation of woodlands. Arrest and fines or jail terms should be imposed on all perpetrators. Promulgation of more stringent Statutory Instruments against illegal exploitation of forests is recommend.

- There is also need for policies that allow for sustainable use of forest wood resources in Mbire so as to allow intergenerational equity in exploitation.

- Alternative sources of energy such as biogas and solar should be seriously considered since most of the logging is for the purpose of energy.

- There is need for environmental education to teach people on sustainable use of energy resource utilization.

The study also recommends further studies on the following aspects:

- Characterization of the species that are being logged besides *C. mopane*. This helps in identifying conservation hot spots and species that need urgent protection.
• A GIS based research can also be done to determine the extent of deforestation due to illegal harvesting of C. mopane temporally and spatially in Mbire.
References


Retrieved from
https://books.google.com/books?hl=en&lr=&id=fljsaxmL_S8C&oi=fnd&pg=PT7&dq=functonal+diversity+in+woodlands&ots=ayhP-31z9&sig=p2K_twvbUe-dk-WZz5VRXCS9PFw


biomass use by commercial and subsistence groups in western Uganda’s forests.


Appendices

Appendix 1-List of species identified in the plots.

<table>
<thead>
<tr>
<th>Species’ botanical name</th>
<th>vernacular name</th>
<th>family</th>
<th>undisturbed site</th>
<th>disturbed site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acacia hebeclada</td>
<td></td>
<td>Fabaceae</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Acacia nigrescens</td>
<td>Muungu, chinanga</td>
<td>Fabaceae</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Adansonia digitata</td>
<td>Muuyu</td>
<td>Bombacaceae</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Afzelia quanzensis</td>
<td></td>
<td>Fabaceae</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Albizia amara</td>
<td>Muora</td>
<td>Fabaceae</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Azanza garkeana</td>
<td>Mutohwe</td>
<td>Malvaceae</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Brachystegia boehmii</td>
<td>Mupfuti</td>
<td>Fabaceae</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>Brachystegia spiciformis</td>
<td>Musasa</td>
<td>Fabaceae</td>
<td>18</td>
<td>7</td>
</tr>
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<td>Burkea Africana</td>
<td>Mukarati</td>
<td>Fabaceae</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Colophospermum mopane</td>
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<td>Fabaceae</td>
<td>42</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Combretum apiculatum</td>
<td>Mubondo</td>
<td>Combretaceae</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Combretum hereroense</td>
<td>Mutechani</td>
<td>Combretaceae</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Commiphora marlothii</td>
<td>Munyera</td>
<td>Burseraceae</td>
<td>8</td>
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<td>Common Name</td>
<td>Family</td>
<td>Index</td>
<td>Status</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>---------------</td>
<td>-------------------</td>
<td>-------</td>
<td>--------</td>
</tr>
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<td>Crossopteryx febrifuga</td>
<td>Mukombigo</td>
<td>Rubiaceae</td>
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<td>0</td>
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<tr>
<td>Dichrostachys cinerea</td>
<td>Mupangara</td>
<td>Fabaceae</td>
<td>3</td>
<td>4</td>
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<td>Ebenaceae</td>
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<td>7</td>
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<td>1</td>
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<td>Julbernadia globiflora</td>
<td>Mutondo</td>
<td>Fabaceae</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Lannea discolor</td>
<td>Muganyacha</td>
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<tr>
<td>Lecaniodiscus fraxinifolius</td>
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<td>Sapindaceae</td>
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<td>5</td>
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<td>Munyunya</td>
<td>Dipterocarpaceae</td>
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<td>0</td>
</tr>
<tr>
<td>Elephantorrhiza goetzei</td>
<td>Mundorani</td>
<td>Fabaceae</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Vernonia colorata</td>
<td>Munyatera</td>
<td>Asteraceae</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Musungamhuru</td>
<td></td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Parinari curatelifolia</td>
<td>Muchakata</td>
<td>Chrysobalanaceae</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>Peltophorum africanum</td>
<td>Muzeze</td>
<td>Fabaceae</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Pseudolachnostylis maprouneifolia</td>
<td>Mushozhowa</td>
<td>Phyllanthaceae</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Rauvolfia caffra</td>
<td>Mukomasani</td>
<td>Apocynaceae</td>
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<td>0</td>
</tr>
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<td>Species</td>
<td>Common Name</td>
<td>Family</td>
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<td>-----------------------------</td>
<td>---------------</td>
<td>----------------------</td>
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<td>Munzvirimombe</td>
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<td>4</td>
</tr>
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<td>Vitex payos</td>
<td>Mutsubvu</td>
<td>Lamiaceae</td>
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<td>6</td>
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<td>Mukundanyoka</td>
<td>Rutaceae</td>
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<tr>
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<td>Muchecheni</td>
<td>Rhamnaceae</td>
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<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td>164</td>
<td>1</td>
</tr>
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</table>

**Appendix 2. Statistical output on species diversity.**

<table>
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<tr>
<th>Statistical Measure</th>
<th>Levene's Test for Equality of Variances</th>
<th>t-test for Equality of Means</th>
<th>Confidence Interval of the Mean Difference</th>
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<td></td>
<td>F</td>
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<td>t</td>
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<td>richness</td>
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**Appendix 3. Statistical output on structure.**
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<td></td>
<td>F</td>
<td>Sig.</td>
<td>t</td>
<td>df</td>
<td>Mean Diff</td>
<td>Std. Error</td>
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