Towards sustainable use of Marula (*Sclerocarya birrea*) in the Savannah woodlands of Zvishavane District, Zimbabwe

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DECLARATION

I hereby declare that this dissertation is a result of my own, unaided work except where acknowledged. It is being submitted in partial fulfilment of the requirements for the degree Master of Science in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.

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ABSTRACT

The aim was to determine the availability of marula (*Sclerocarya birrea*) (A.Rich.) Hochst. Subsp.cafra (Sond.) Kokwaro trees for the harvesting of nut oils, through determining abundance, population structure and regeneration capacity, within the context of the socio-economic and biophysical dimensions of villages in Zvishavane, Zimbabwe. Both arable and non arable lands in the study area were sampled within four randomly selected villages to measure species abundance, regeneration and population dynamics of the trees. The socio-economic factors influencing marula commercialisation were determined through participatory rural appraisal (PRA) and household questionnaire survey techniques. Vegetation characteristics were assessed through the point centre quarter (PCQ) method by placement of transects across sampled villages.

All households (100%) collected marula fruit for their household use, mainly for brewing marula beer, making jam and selling kernels for snacks or oil pressing. In 2005, the mass of marula harvest per household averaged 160 ± 18 (SD) kg, with a range of 50-800 kg within the study area. A linear regression analysis indicates no increase in mass of marula harvest with larger sizes of household (r^2 = 0.0089, d.f = 50, p = 0.4048). In addition, household interviews revealed that there was no association between level of household wealth status and the household's use of traditional medicine from marula trees (χ^2 = 0.2233, d.f = 2, p = 0.8944).

The vegetation survey indicated a relatively high density of marula within the study area of 8.03 ± 3.19 stems ha^{-1}**.** There was a significant difference in marula densities between arable and non arable land uses ($F_{1, 197}$ = 11.92, p=0.001). The arable land had 6.40 ± 5.29 stems ha^{-1} while non arable land had three times more at 19.63 ± 11.82 stems ha^{-1}. However there was no significant difference in densities between the villages in the study area ($F_{3, 195}$ =1.063, p= 0.366). There was a significant difference between marula tree diameters between arable and non arable land ($t_{92, 107}$ = 1.69, p = 0.0401). The arable land had generally bigger tree diameters (31.2 ± 25.3 cm) than non arable land (26.5 ± 20.8 cm), suggesting a form of domestication through allowing marula to grow around homesteads and crop fields.

The investigation of marula size class profiles shows a large proportion of smaller diameter trees and this indicates ongoing recruitment of trees into the population. A closer analysis of the smallest diameter class shows a higher proportion of saplings (> 6cm diameter) than of seedlings (< 4cm diameter). Fruit harvesting seems to have a low potential for any negative impact, compared to other uses of marula trees. However fruits have the highest economic return and therefore should be targeted for the commercialisation activities. The management of some destructive forms of marula tree use (such as harvesting for bark, firewood, and carving wood) however, do need to be monitored to limit negative impacts on the population. There is also a need to determine the annual quantity of harvestable marula fruits and also the sex ratio of marula trees (a dioecious species) on this particular site, as a prelude to developing sustainable harvesting quotas, so that harvesting rates do not exceed the capacity of populations to replace the individuals extracted.

There are some non governmental organisations (NGOs) and local institutions that are working towards natural resources conservation in the area. Zvishavane water project (ZWP) and Phytotrade Africa are assisting the rural producers in marula commercialisation activities through providing information on processing, packaging and marketing. At a current value of US$1 $kg^{-1}$of fruit, the 3200 ha study area is estimated to yield a total harvest of 1 120 000 kg of marula fruit per year, and this should translate to an approximate total value of $1 120 000 per year for the whole area. There is still a need to expand the supply of processed goods with added value to wider markets locally, nationally, and internationally. There is therefore an indication that marula products offer a promising economic alternative for the people in the rural areas of Zvishavane area and southern Africa as a whole. The cash injection earned from selling fresh marula products comes at a particularly crucial time of the year, when money is required for school fees, uniforms and books. However there is a need for long-term monitoring and evaluation of socio-economic and environmental impacts of marula commercialisation so as to achieve sustainable resource utilisation in the region.

Key words: regeneration, marula enterprise, commercialisation, and livelihoods

DEDICATION

To my mother and father, who worked so hard and made sure that, I got good education.

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1.0 INTRODUCTION

1.1 Background

Non-Timber Forest Products (NTFPs) such as those from marula (*Sclerocarya birrea* (A.Rich.) Hochst. Subsp.cafra (Sond.) Kokwaro), baobab (*Adansonia digitata,* L.), and monkey orange (*Strychnos spinosa,* Lam), feature prominently in the semi-arid, deciduous savannahs of Southern Africa, and constitute an essential part of the livelihoods, culture and spirituality of rural communities within their distribution ranges (Shackleton *et al*., 2002). Some uses of the tree species include food, oils, carving, firewood, fencing and medicine. Apart from the local markets, the demand for natural products from NTFPs has also increased on the international market (Ham, 2003).

The commercialisation of natural products in southern Africa brings a suite of opportunities for rural development and social upliftment, but also a number of challenges and threats for subsistence users, for the resource base, and for traditional cultures and customs (Peters, 1996). This is because the harvesting practices may have environmental impacts on both the bio-physical and socio-economic environment. Some extraction techniques can lead to the death of the individual plant, while the harvesting of fruits and flowers may have negative results on the whole population (Peters, 1996; Ticktin 2004). Some plant species are however more able to sustain continuous harvest than others (Arnold, 2001).

1.2 Problem Statement

Although marula has been traditionally useful to the people of Zvishavane, the products from the tree have recently gained far higher economic value due to the commercial demand for marula nut oil. In 2005 marula oil was being sold for US$16.00 per kg on the international market (PhytoTrade Africa 2005, personal communication) and this resulted in increasing demand for marula fruits in many parts of southern Africa. Sound ecosystem management depends on accurate, complete, and concise information regarding the extent, condition and productivity of natural resources (Peters, 1996), therefore there is a need to quantify the availability and harvesting levels of marula, in the past, at present and into the future to ensure that harvesting is sustainable.

1.3 Justification for the Study

Over long periods of time, woodlands can and do recover from even heavy use if allowed the time to do so without further disturbance, but this does not happen if there is repeated harvesting at short intervals relative to the species regeneration cycle. In some semi-arid tropical areas, increasing demand for NTFPs puts pressure on the vegetation (Lykke, 2000). There are also reports of unsustainable harvesting on traditional NTFPs, such as foods and medicines (Hanson, 1992; Campbell *et al*., 1997), but there appears to be few studies on the ecological impacts of harvesting on populations of NTFPs in the savannah environments (Boffa, 1999; Schreckenberg, 1999).

There is a need to consider regeneration of trees when assessing the sustainable harvesting levels of NTFPs (Hall and Bawa, 1993). Regeneration is best measured over a long period of time (Boot and Gullison, 1995), but an analysis of size structure of a population at one point in time can also provide valuable information in assessing the life history and signs of negative impacts of harvesting on regeneration (Hall and Bawa, 1993). Therefore a monitoring and control system is needed that provides a constant flow of information about the ecological response of marula to varying degrees of exploitation (Peters, 1996). In other words, the whole production cycle needs to be adaptively managed.

In 2004, some communities living in savannah woodlands of Zvishavane of Zimbabwe began the commercial use of *Sclerocarya birrea* (marula) to try to improve their livelihoods through oil pressing of the kernels. This present study was hence undertaken at the beginning of this new marula enterprise, and it provides a baseline scientific investigation on the impacts of the newly adopted commercial utilisation of this NTFPs. The marula enterprise is the organised trading of marula products in this area of Zimbabwe.

Some of the information required for the sustainable management of NTFPs includes species distribution, abundance, size structure, rate of regeneration, growth rate, and response to disturbances such as harvesting. This forms the baseline for studying the population dynamics of marula, subsequently providing adequate information for assessing and monitoring the impacts of harvesting.

At the time that this research was being undertaken, no other study had yet been done in Zvishavane to assess the patterns of resource use within the different land uses of the region. Arable and non arable land uses are the two major land use types, as in many traditional communal areas of Zimbabwe, and it is not clear if there is a difference in NTFPs harvesting between these two land uses (Chivaura-Mususa *et al.,* 2000; Mlambo and Huizing, 2004). People's houses are built closer to the arable lands (crop farming areas), while the non arable lands (wild lands) are used for cattle grazing, hunting, timber and fuel wood sourcing.

There is also a need to evaluate resource use in the context of the socio-economic dimensions of the area. This can be obtained through assessing the history of harvesting, addressing issues such as status of collecting and harvesting locations; time and seasonality of exploitation; institutional arrangements; and the impacts of different levels of exploitation. In addition, information on previous inventories and other environmental activities in the area; local identification and values of products, specific types of resources used, and efforts to sustain resource use (planted, domesticated or through selecting preferred or more productive genotypes) would be very useful (Shackleton, 2003).

An inventory of existing and future demand for the products, operational information, as well as tenure and institutional matters are also important contextual information within which the study was placed (Shackleton, 2003). An investigation of this nature can assist resource users towards sustainably harvesting marula through implementing appropriate principles of harvesting in the face of the new oil pressing business.

1.4 Marula (*Sclerocarya birrea*) description

The research was centred on *Sclerocarya birrea* (A.Rich.) Hochst. Subsp.cafra (Sond.) Kokwaro in the Anacardiaceae (mango) family. It is a medium-sized tree, 7-17m in height, with a rounded, spreading crown, which stands leafless for several months (winter) of the year. It occurs in medium to low altitude open woodland and bush. The bark is rough, flaking in patchy sections, which gives a mottled appearance. The leaves are imparipinnate, spirally arranged, and crowded near the ends of the branches, with 3-7 pairs of opposite to sub-opposite leaflets (Palgrave, 2002).

The species is primarily dioecious, with male and female flowers on different trees (Mojeremane *et al.,* 2004). The female flower is normally single or in small groups on stalks up to 3 cm long, with an almost spherical ovary. Flowering normally starts in September and ends in November, prior to producing the fleshy, up to 3 cm diameter fruits. Insects are generally responsible for pollinating the flowers. The tree grows easily from seed sown in washed river sand in spring (Palgrave, 2002).

Little is known about the silvicultural characteristics of *Sclerocarya birrea*; however, it regenerates naturally from seed, coppice, truncheons and gregarious root suckering. If the fruit operculum has been opened, germination is fast and uniform, reaching 70% after one week and 85% after two weeks from sowing (Mojeremane *et al.,* 2004). Marulas are frequently a community dominant and hence a keystone species in terms of community productivity. Marula trees are browsed by wild game and domestic livestock (Palmer and Pitman 1972). It is also a preferred host species for a number of parasitic plants (Dzerefos *et al*., 2003), as well as the larvae of several invertebrates (Shackleton, 2002 a). Marulas also appear to have short-term persistent seed banks (Witkowski, unpublished). Seed dispersal occurs largely through fruit consumption by mammalian herbivores, which disperse the nuts during eating and defaecation. Dispersal distances vary greatly and may be as far as several kilometres (Shackleton, 2003).

Traditional uses of marula

Marula is an important tree species in all the communities where it is found (Palmer and Pitman, 1972). This species has multiple uses, including consumption of the fruits, which are eaten fresh or fermented to make a beer, the kernels are eaten as snacks or the oil extracted, the leaves are browsed by livestock and have medicinal uses, as does the bark. The wood is carved into different products such as spoons, plates, and decorative animal figures (Shackleton and Shackleton, 2002). Because of these multiple uses and its significance in the landscape, several African cultures have specific beliefs and ceremonies associated with this species (Walker, 1989). Marula is widely distributed in many parts of the southern African countries such as Zimbabwe, South Africa, Malawi, Angola, Zambia, Swaziland, Botswana, Namibia and Mozambique (Figure 1).

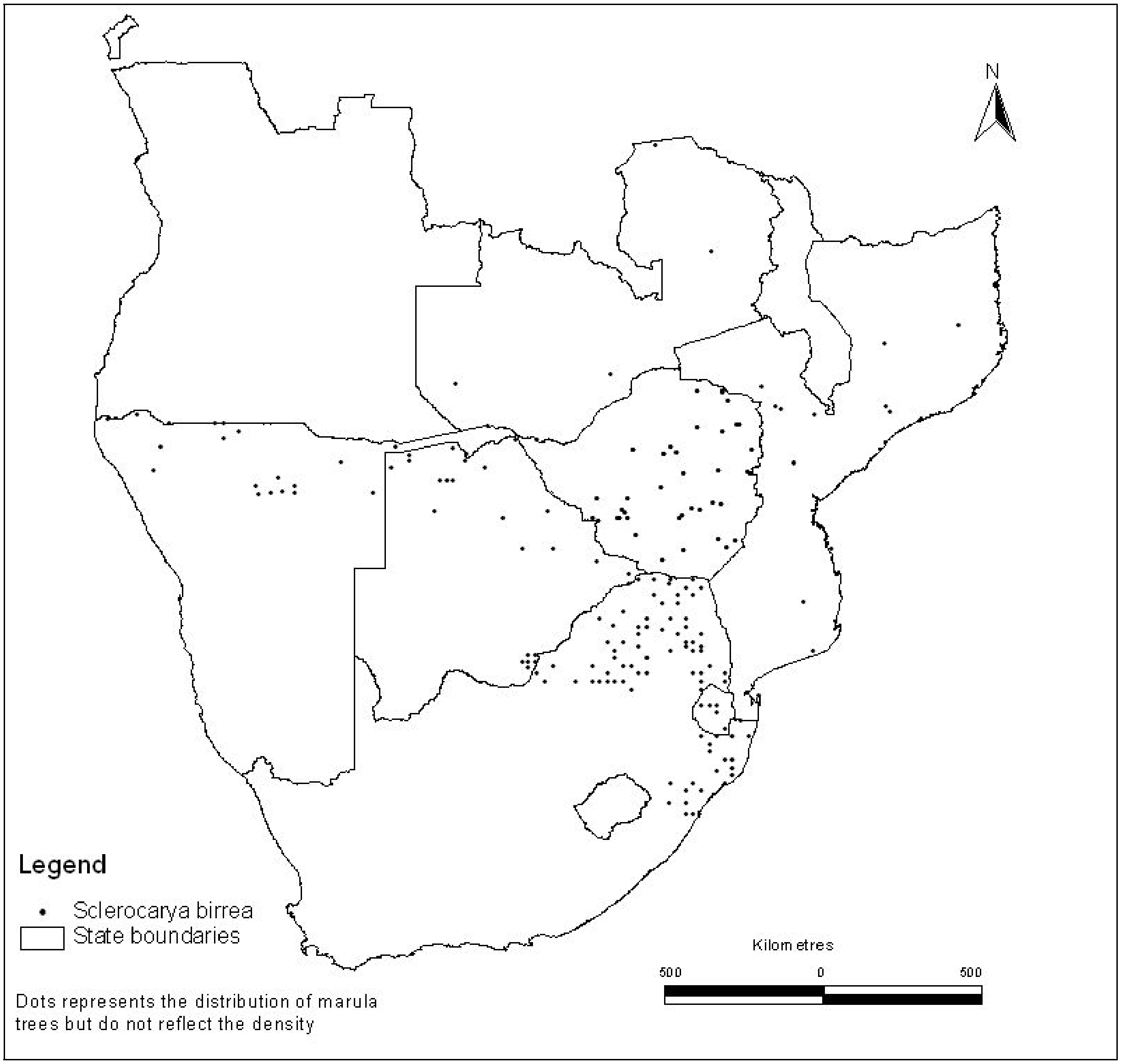

Figure 1: The distribution of marula in southern African countries (Source: PhytoTrade Africa 2005).

Because of the widespread occurrence (Figure 1) and use of marula, it has frequently been identified as a desirable species to support the development of rural communities based on the fruit, beer or nuts, and therefore as a species for potential domestication (Shackleton, 2002). Interest in this species was renewed in the 1990s after the development of a highly successful liqueur called Amarula in South Africa, which is produced using extracts from the fruit. This has developed further in southern Africa between 1995 and 2000, as commercialisation initiatives were oriented towards benefiting the rural poor in Botswana, Namibia and South Africa (Shackleton, 2002).

2.0 LITERATURE REVIEW

2.1 Woodland contributions to livelihoods in Zimbabwe

In Zimbabwe, in terms of income, woodlands resources have greater value for the poor members of society than for the richer classes. Amongst the poorest of Zimbabwean's population, woodland products account for 17% of income, while for the richest they account for only 4% of total household incomes. Similar to the inter-settlement variation in use of wild fruits, there is also a high variation of intra-settlement use and differences between households could be indicative of differences in wealth status. Poorer members of the community tend to use more fruits, and are more likely to sell fruits as an additional source of income at many sites across southern Africa (Cavendish, 2000; Shackleton and Shackleton, 2002). Wealthier households in South Africa collect less fruits from the woodlands themselves, and are more likely to buy a proportion of the fruits from other people, rather than collect their own (Lawes *et al.,* 2004). At the time of the study, there was no literature on how wealth status influences NTFPs use in Zvishavane district of Zimbabwe. This information is essential in order to determine the influence of wealth status in NTFPs use under different situations.

2.2 Uses of fruits and seeds from indigenous plant species

In terms of diversity, yields and extent of use of wild fruits and seeds in southern Africa, the savannah biome is the most important (Lawes *et al.,* 2004). Over the past 200 000 years, people have gathered tasty fruits from savannah trees and shrubs that are valued for their size, flavour and nutritional value. The most valued fruits are those with (a) large edible fruits such as *Adansonia digitata* and several *Strychnos* species (*S. cocculoides, S. pungens, S. madagascarensis, and S. spinosa*), (b) the medium size fruits (*Vangueria, Diospyros, Garcinia*) and (c) those with high yields and oil-rich nuts (*Sclerocarya birrea, Schinziophyton rautanenii, Trichilia emetica).* The savannah therefore has a great diversity of gathered plant foods that originate from one of the three categories listed above (Lawes *et al.,* 2004).

2.3 Demand for wild edible fruits

In a number of household level studies done in many parts of southern African countries, it was shown that wild edible fruits are among the most commonly used NTFPs (Lawes *et al.,* 2004). There is also evidence of spatial, age and gender differentiation in the importance of wild edible fruits for local livelihoods. The quantity harvested and the range of species used varies between (a) villages, (b) between households within a single village, and (c) between different individuals in a single household. Differences between villages are a reflection of cultural norms, local species availability and the climatic and economic conditions (Lawes *et al.,* 2004).

The interplay between supply and demand is most obvious in human modified environments, where residents preferentially maintain important fruit species around the homestead and within arable fields, a common practice throughout southern Africa (Campbell, 1987; Schreckenberg, 1999). This practice may well be regarded as the first stage of domestication (Lawes *et al*., 2004). These trees are usually the remnants of the original more continuous woodland, but many households also protect and nurture self-germinated individuals, or they alternatively plant seeds or truncheons of particularly favoured species such as *S. birrea* (Mwambo, 2000; Shackleton, 2003).

2.4 Domestication

People obtain certain benefits from seeds, nuts and fruits, but many large fruited trees also benefit from people through enhancing seed dispersal, protection from veld fire and animal damage, and also through domestication. Marula is a typical example. It is considered that in the past, marula was a scarce species when human population densities were low and the wildlife population size was still high (Lawes *et al.,* 2004). This general conclusion may also be verified by measuring tree densities between different land uses that have different histories of human modification within villages.

In some studies done in Namibia the tree gender affects population status of marula. In some investigations of adult trees (40-80cm) the number of female trees was more than the number of male stems (Nghitoolwa *et al*., 2003). This was caused by the deliberate elimination of male trees which do not produce fruits and this imbalance has potential to negatively impact the natural flow of pollen (Nghitoolwa *et al*., 2003). There is therefore a need to assess gender balances of marula when studying the sustainability of marula species commercialisation.

2.5 Evaluating people centered research methodology

Participatory rural appraisal (PRA) is an example of a people centered research methodology and has been used in many studies across Africa to gather information about the commercial use of fruit trees. The technique commonly used within the PRA include use of timelines, mapping (resource, tenure and control), resources flow diagrams, seasonal calendars, linkage diagrams, and pair-wise and matrix ranking (FAO, 1990; Anon, 1990; Campbell *et al*., 1995). Indigenous knowledge obtained through participatory research complements scientific information for the benefit of researchers (Goma *et al.,* 2001). Goma *et al.,* (2001) argues that in some instances participatory processes are able to generate traditional knowledge that is clearer than other scientific information. He concluded that participatory research is beneficial when it is well planned and farmers are made part of the investigation team. PRA has therefore been widely used by people studying natural resources in a livelihood context. This method can be useful in investigating the impact of marula resource harvesting as it helps to reveal useful indigenous knowledge.

Another important technique used for collecting socio-economic information is the use of household level administered questionnaires. Questionnaire surveys make it possible to quantify information and to draw comparisons between the needs of different communities (Shackleton and Shackleton, 2005). In order to get a clearer understanding of the socio-economic factors influencing marula use, it is therefore necessary to employ both PRA and household questionnaire methodologies.

2.6 Tree population dynamics in savannahs

There is still insufficient knowledge concerning the persistence and regeneration of African savannah trees (Wilson and Witkowski, 1998; Witkowski and Garner, 2000; Wilson & Witkowski 2003; Botha *et al*., 2004). Trees of the savannah woodlands of south-central and eastern Africa respruit from roots and stumps once the above ground parts have been removed or killed by harvesting or fire damage (Grundy 1995; Frost, 1996; Luoga *et al*., 2004; Neke in press). These shoots grow faster than newly established seedlings, because they already have a well-established root system with stored reserves (Chidumayo, 1993; Grundy, 1995).

Disturbances such as harvesting of trees by humans for fuel and building materials is likely to greatly change the size class distribution of harvested species and also result in increased mortality. The effectiveness of resprouting from stumps differs with species, plant size or age at time of cutting, stump height, and the proportion of the stand removed (Shackleton, 2000; Luoga *et al*., 2002; 2004). There is also a general tendency for tall stumps to produce a larger number of coppice shoots than short stumps (Mushove and Makoni, 1993). This tendency, has also been reported for South African trees, and is attributed to a larger surface area on stumps where buds can develop (Shackleton, 1997).

In South Africa, Shackleton *et al*., (2005) found that the density of marula was not related to distance from the village despite previous studies which indicated that tree density increases with distance from villages (Shackleton *et al.,* 2003 b). There is therefore a need to investigate whether there are any similarities or differences between studies already done in South Africa and those done in other parts of southern Africa. There will be however expected differences in methodology as homesteads in other parts of southern Africa like Zimbabwe are not confined to any one place but scattered across the whole landscape. The sampling units that are normally placed radiating from the villages in South African studies may need to be randomly selected in Zvishavane because of this uneven distribution of homesteads and other land uses.

The harvesting of seeds or fruits needs to be undertaken with caution, since heavy harvesting could have long-term detrimental effects on recruitment of new individuals. Unfortunately, however, there are few studies examining population degradation due to fruit harvesting. Peters (1996) and Boot and Gullison (1995) have reported on harvesting of fruits from tree species in South America, arguing that even species that produce fruit in abundance have shown significant reduction in recruitment and changes in size/age profile as a result of fruit harvesting. However recent studies on *S. birrea* from the Bushbuckridge area of South Africa shows that approximately 92% of marula fruit could be harvested without long-term negative impacts on future recruitment and overall population structure (Emmanuel *et al*., 2005). These findings from Bushbuckridge can also be expected for many parts of rural Zimbabwe due to similarities in the biophysical aspects of the environments.

In arid savannahs, recruitment of fleshy-fruited plant species not only depends on the general availability of favourable site conditions, but also on processes such as germination and dispersal of viable seeds distributed away from the parent plant in order to guarantee recruitment success (Tews *et al.,* 2004). Each dispersal agent is characterised by a specific fruit handling behaviour and consumption rate, and thereby produces a unique seed-dispersal pattern, which in turn has an influence on plant population dynamics (Bleher and Bohning-Gaese, 2000). For many fleshy-fruited plant species, there is a wide range of potential seed dispersers that depend on the abundance of dispersal agents and the composition of seeds by dispersal guilds (Tews *et al.,* 2004). Seed dispersal is therefore a crucial ecological process that maintains the diversity of plant communities (Christian, 2001).

There has already been much work in the Bushbuckridge lowveld and elsewhere on enterprises based on the use of *S. birrea* fruits (Shackleton *et al*., 2002; Wynberg *et al*., 2002), along with guidelines for future developments towards a sustainable industry (Wynberg *et al*., 2003). Many households already make jam for domestic consumption or sale, and most brew beer for home consumption alongside the growing trade of marula beer. Two large-scale marula enterprises operate in the Bushbuckridge (Wynberg *et al*., 2002), and these buy raw fruits and kernels from local rural villages. Based on previous studies in the area, there appears to be a sufficient density of fruit-bearing (female) marula trees, and high fruit yield per tree, to support both domestic consumption and commercial demand in the area (Shackleton *et al*., 2003; Shackleton and Shackleton, 2004; Shackleton, 2004). The research findings were based on vegetation measurements and also questionnaires to measure the household use of marula and therefore concluding that the marula enterprise has a potential to become a viable business with sustainable harvesting of fruits. The challenge however is to test these findings on a different site outside the Bushbuckridge and in addition to determine local harvesting quotas. The methods used seem to be suitable for similar studies in other parts of southern Africa where similar biophysical and socio-economic factors exist, such as the Zvishavane area of Zimbabwe.

In another investigation done in the Weverdiend area of the Bushbuckridge region of South Africa, the densities of adult *S. birrea* trees were similar to densities in other parts of region. It was concluded that there is sufficient fruit production for a marula enterprise in the short term. In the longer term, however, it was shown that the density of *S. birrea* declined significantly for 12 years in that area, and there are indications of resource depletion. If this were to continue, any marula enterprises would be jeopardized. Hence, the relative magnitude of the different determinants of marula population decline need to be monitored (Shackleton *et al*., 2005). There is therefore a need for measuring the abundance of marula in an area for the purpose of developing sustainable harvesting quotas especially in the context of a fast developing marula enterprise.

Studies done in West African moist forest by Poorter *et al.,* 1996 has shown that population structures differ widely between different tree species. They observed three major types of population structures that were, (a) a declining number of individual trees with size, the so called inverse J-shaped curve indicating sufficient regeneration to maintain the population in the long term, (b) an increase in number of individuals with size, indicating an absent or sparse regeneration, and (c) a variable distribution, composed of strongly fluctuating patterns (Poorter *et al.,* 1996). It therefore means population structures are static representations of a population composition at a certain moment in time. In almost similar studies by Obiri *et al.,* (2001) in the Eastern Cape Province of South Africa, all species assessed, except *Harpephyllum caffrum* and *Heywoodia lucens*, displayed the characteristic inverse J-shaped distribution and it was concluded that the populations were generally stable (Obiri *et al.,* 2001). It implies that regeneration can be assessed by looking at the population structures but this interpretation needs long term information in order to measure the potential for a sustainable resource harvesting.

Interpretation of size-class profiles is useful in assessing the state of populations for a variety of management purposes (Shackleton *et al.,* 1994; Witkowski *et al.,* 1994), as changes in the structure of a population often occurs before changes in species composition (Harper, 1977; Shackleton, 1993). The assessment of size class distributions is also a useful means of projecting population trends, and to a lesser extent, for historical population trend analysis (Harper, 1977).

2.6.1 Evaluating the vegetation survey technique

The point-centred quarter (PCQ) method can be used to gather some quantitative information in savannah woodland (Greig-Smith 1964). Density is the measure of number of trees per unit area and can be measured by the PCQ method (Greig-Smith, 1964). This method was selected by Vesey-Fitz Gerald (1973) because it is suitable for determining the density of sparsely spaced trees (Mueller-Dombois and Elenberg, 1974) such as those of savannah systems. In using the PCQ the distance from the sampling point to the nearest tree is measured. The orientation of the quadrants is fixed in advance before the vegetation survey. From the mean value of the measurements by this method, the mean area, and thus the density, of all individuals may be calculated.

The PCQ method is therefore useful and has the advantage of having no need to demarcate the sampling area of a certain size or shape. This is particularly necessary when the sampling intensity is intended to be high. Since collection of quantitative data is at best a time-consuming task, it is imperative that the samples taken should be such as give greatest amount of information in return for the effort and time involved (Greig-Smith, 1964). The essential feature of random sampling, which allows the observed variance of data to be used as the basis of tests for significance, is that any point within the area has an equal chance of being represented in the samples (Greig-Smith, 1964).

2.7 Aim and Objectives

2.7.1 Aim

The overall aim was to determine the availability of marula (*Sclerocarya birrea*) trees for the harvesting of nut oils, through determining abundance, population structure and regeneration capacity, within the context of the socio-economic and biophysical dimensions of villages in Zvishavane, Zimbabwe.

2.7.2 Objectives

1) To assess the relationships between household wealth status and use of non-timber forest products in general, and for marula in particular.
2) To assess the contribution that marula products makes towards people's incomes.
3) To describe and quantify the distribution, abundance and population structure of marula in the area.
4) To assess the impact of marula harvesting practices on the ability of the trees to regenerate (resprouting and reseeding).
5) To compare marula tree harvesting between the (a) arable and (b) non-arable land uses.

2.8 Key Questions

1) What is the level of marula harvesting by people in relation to economic status, gender, age, and levels of education?
2) How does distribution, composition and regeneration of marula change within villages between (a) arable and (b) non arable land uses?
3) How do the stem diameters of the trees vary between different land use types?

3. 0 METHODOLOGY

3.1 Description of Study area

The research was conducted at Mukwakwe (Figure 2) about 46 km east of Zvishavane town, towards the Buchwa chrome mine along the Zvishavane-Beitbridge Road ($19^{o}21^{'}$S; 29^{o} $31^{'}$ E) and located in Murowa and Mutambi Wards within Zvishavane district of Zimbabwe. It is at altitude of 750m and receives a mean annual rainfall of 500 mm and this rainfall is of high intensity and exceeds the infiltration rates of the inherently infertile sandy soils, resulting in high run-off losses from the fields. Mid-season droughts (between October and February) are common, compounding the effects of the persistent droughts, which occur three out of every five years. As communal farmers rely on their crops for their income and for their well-being, such environmental instability results in rampant livelihood insecurity (Source: Dry land farming in Zimbabwe: Africare and Midlands State University).

The soils are predominantly derived from granite and medium sandy loams light textured, with low agricultural potential due to low nutrient content, particularly nitrogen and phosphorus (Nyamapfene, 1991). The study area can be described as broadleaved savannah, dominated by tree species such as *Sclerocarya birrea*, *Albizia amara*, *Strychnos madagarscariences* and *Colosphermum mopane*. *C mopane* loses its leaves during the dry season and is favoured browse species by livestock and wildlife. Most arid savannah trees are relatively fire resistant; however, *C. mopane* vegetation is highly flammable because of the abundance of volatile oils. The most common smaller trees are *Dichrostachys cinerea* and *Termanalia sericea.* There is a perennial river that flows through the area and has few other seasonal tributary rivers in a terrain formed by a belt of hill outcrops with some flood plains in the southerly direction along the main river course.

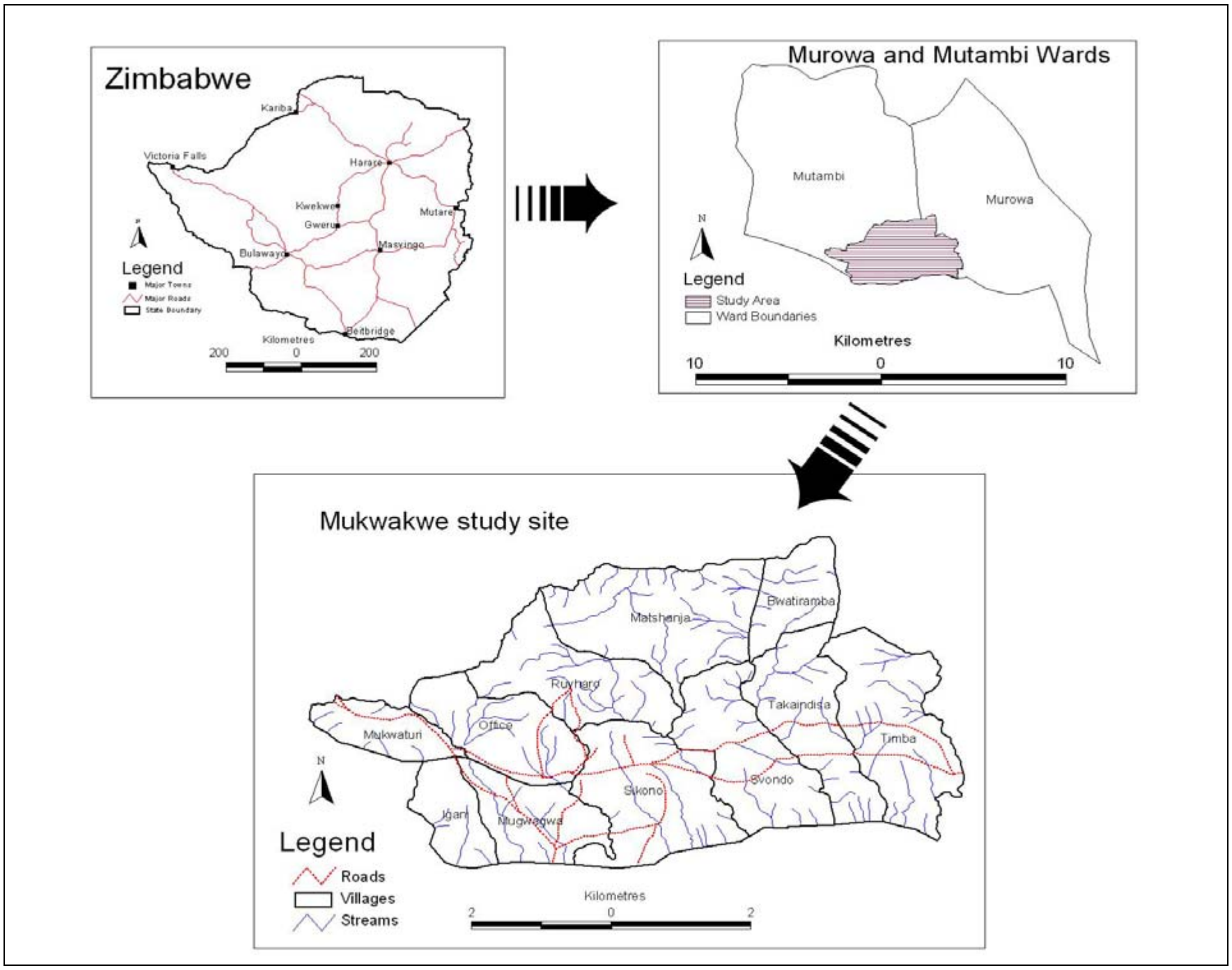

Figure 2: Map showing Zimbabwe, Zvishavane district and the study area within Murowa and Mutambi wards shown with the 11 villages (Source: Surveyor General: Zimbabwe, 2005)

The region is made up of 11 villages, namely Mukwaturi, Igani, Office, Ruvharo, Mugwagwa, Sikono, Matshanja, Svondo, Takaindesa, Bwatiringa and Timba (Figure 2**.** Four of the 11 villages in the Mukwakwe area were selected, based on a random number sampling procedure from the 11 villages in the region. These were Mugwagwa, Sikono, Svondo and Takaendesa (Figure 2). These four villages are located in a generally low-lying area and have similar altitudes (about 750 m above sea level). The vegetation composition of the area is similar except for some portions of Sikono village that have high densities of *Dichrostachys cinerea* because of disturbances during the construction of the rail line and from deposits of the old Buchwa chrome mine. There were approximately 40 households in each of the villages, but Mugwagwa had relatively higher numbers of people due to the school and the business shopping centres that are located in that village. Nearly 50% of the area is arable, although some land has been left fallow due to persistent water shortages in the area in recent years. People in the area are mainly of the Shona tribe and speak ChiKaranga, a dialect of the Shona language. Natural resources in the area are communally owned, but under the stewardship of traditional leadership, and operates within the by laws of the Runde Rural District Council. The other 50% of the land is not suitable for crop production because of the hilly terrain, but is used for cattle grazing.

3.2 Methods of Data collection

The size of the study area and respective villages were estimated by a Global Position System (GPS) receiver and with the aid of a 1:50 000 topographic map of the area. The approximate aerial extents (and percentages) of different land uses were determined from a 1:12500 aerial photograph of 1996 (flight height 4500m) with aid of a Laser Distance meter.

Data collection was done through a combination of, participatory rural appraisal (PRA), a questionnaire survey and a vegetation ground survey. These were done in order to collect both socio-economic and biophysical information regarding the use of marula in the four selected villages of the study area.

3.2.1 Socio-Economic Survey

Socio-economic information was collected through a combination of PRA and questionnaire administration techniques within each of the four villages. The specific techniques used within the PRA included use of timelines, mapping (resource, tenure and control), resources flow diagrams, seasonal calendars, linkage diagrams, and pair-wise and matrix ranking (FAO, 1990). Groups of about 30 people in each village were systematically sampled from a village list and asked the same questions through structured and semi-structured interviews in the vernacular Shona language by the researcher. There were a total of 12 questions for the focus group discussions (Appendix 2). In some instances the groups were divided into gender or age classes in order to assess differences in perception of natural resource issues. The questionnaire was vetted by the human ethics committee of the University of the Witwatersrand in August 2005.

The household questionnaire survey was administered through a systematic random sample of households from each village. Aspects investigated by the questionnaire included household information about livelihood activities, incomes, pattern of expenditure, education, use of NTFPs, institutional arrangements, and the socio-economic and environmental impacts of NTFPs commercialisation. Twenty people from each of the four villages sampled were interviewed individually, resulting in a total of 80 household questionnaire interviews which constituted a 20% sampling intensity from the estimated 400 households in the whole study area.

3.2.2 Vegetation Survey

Woody vegetation characteristics such as species composition, density, and size structure were measured through the placement of randomly positioned transects across the sampled villages. The purpose was to sample the representative woody vegetation characteristics of the whole study area and hence the two major land use types in the area, namely (1) arable fields, which include the homesteads and the croplands, and (2) non-arable land, which included all wild land and the grazing areas.

The point centre quarter (PCQ) method, a "plot-less" sampling technique, was used to assess species composition, density, and size structure, at points along transects across the sampled villages. The transect direction was determined randomly by selecting a bearing from the centre of a village, with another transect perpendicular to the first transect (i.e. two cross cutting transects at 90^o). A series of points were systematically located along each transect, 100 m apart, and spatially captured with the aid of a GARMIN GPS receiver. There were approximately 11 PCQ points in transects which were normally one kilometre in length. At every sampling point, four quadrants (90 degrees) were created, using the transect line and a line perpendicular to it. Measurements and recording of species in each quadrant was done in two parts. Firstly selecting the marula plant (all sizes were sampled) that was closest to the sampling point in each of the four quadrants and then measuring its distance from the central point. Tree diameters above the basal swell were also measured. This first part of assessment made it possible to measure marula trees in all sizes classes including seedlings, saplings and mature trees. The second part was selecting any woody plant species (including marula) >1.5

m in height, closest to the sampling point within each of the four quadrants, then measured the distances from the central point and tree diameter 30 cm above the basal swell. The names of all selected species in the quadrants were noted to determine the species composition. All the relevant data were recorded on the field sheet (Appendix 1).

The transect lines stretched throughout the village, across the arable fields and non-arable lands. All sampling points along transects were categorised as arable or non-arable. The field measurements were captured by means of a geographical information system (GIS, Arc View version 9.0), which produced maps of the study areas showing the surface areas of the major land uses of the villages. Field measurements were also supported by a combination of a 1: 12500 aerial photograph of 1996 (flight 4500m) and a 1:50 000 topographical map of Mukwakwe area to determine the vegetation characteristics.

The local people assisted in the field measurements because they are very knowledgeable on the identification and location of the resources in the woodlands. This was very important as the inventories included resources harvested from areas such as traditional reserves and sacred places. Species identity was further verified by Palgrave, (2002).

The measuring of individuals of the same species in different size classes was useful in determining marula tree population dynamics in the Mukwakwe area. Basal areas were calculated from the basal diameters using a Microsoft Excel spreadsheet. The diameter classes were grouped into 10 cm intervals and the results displayed in the form of a histogram. A separate histogram was drawn to show the recruit stage (<10cm diameter).

The PCQ method has the advantage of being plotless, so there is no need to demarcate the sampling area of a certain size or shape. This made the method easy to employ when the workforce was small, as three people were sufficient for this survey. It was also compliant with a GPS receiver, which helped in inputting the data into a GIS. The following calculations were done to determine marula densities from the PCQ collected data (Mitchell, 2005).

i) Determination of total distances between trees and sampling points

ii) The average distance, $\bar{d}$ was calculated.

iii) Determined the mean area using the formula $MeanArea = \left[\bar{d} \right]^2$

iv) Calculated the absolute density of all the tree species (trees per ha): $AbsoluteDensity = \dfrac{MeanArea}{10000m^2}$

v) The formulas below were used to determine the absolute and relative frequency respectively.

$$F_a = \frac{N_a}{n} \quad \text{and}$$

$$F_r = \left[\frac{F_a}{\sum F_{a_i}} \right] * 100\%$$

Where

F_a is the absolute frequency of the target species,

N_a is the number of points where at least one individual species occurs,

n is the total number of sampling points,

F_r is the relative frequency of the target species and

ΣF_{ai} is the total absolute frequencies of all the species in a transect.

vi) The relative density was determined by dividing the number of occurrence of target species by the total number of trees and is expressed as a percentage (Mitchell, 2005).

3.3 Data analyses

Analysis of the field data was done using SAS version 9.1, with the Windows-based Enterprise Guide. For the socio-economic survey, the general classifications was between the 1) poor, 2) average and 3) rich members of the community by the use of information from the consumer council of Zimbabwe (CCZ) that categorised people into these wealth levels with the aid of the poverty datum line. These values were further verified by information gathered during PRA, where the number of livestock and agricultural implements were used as indicators for determining the different wealth status of households within the study area (Appendix 3).

A two-way (factorial) ANOVA was used to determine the differences in vegetation characteristics between villages and land use types. Regressions analyses were also used to determine the relationships between levels of harvesting with various socio-economic factors, such as income level, size of household, alternative livelihood activities, and levels of education of household members. Contingency tables X^2 analyses were used to analyse economic benefits, perceptions of impact and possible solutions of any problems associated with NTFP harvesting. Student t –tests were used in analysing data such as tree density and tree diameter classes with respect to land use patterns. Marula species demographic characteristics were also assessed by Spearman's Correlation and Kolmogorov Smirnov Test. The tree population estimates were weighted relative to the size (hectares) of the different land uses within the study site. A 95% level of significance was used in this study.

4.0 RESULTS

4.1 Socio-economic factors

4.1.1 Household socio-economic profile

The households interviewed were mainly poor (30%), with an average cash expenditure of about US$192.00 per annum. About 42% of households were using cash less than US$125.00 per annum, which is far below the poverty datum line of Zimbabwe (Consumer Council of Zimbabwe, 2005). Average number of people per household in the study area was 7.2 ± 0.4 (mean ± standard error), and 88% of the household heads were resident in the area. The average age of household heads was 48.9 ± 1.8, and about 20% of the households were headed by women.

About 41% of households in Mukwakwe sourced water for household use from the communal boreholes, while 21% of households obtained water from either protected or unprotected wells close to their homesteads. However a further 38% of the households still relied on the streams and rivers as a source of domestic water, which they regarded to be unsafe. About 91% of households in this area made use of a local clinic for medical services and it was located at a distance of ± 5 km from most households. There was however a further 9% of household that still consulted either traditional healers or faith healers for health problems.

Although incomes were generally low and erratic, households had access to basic shelter and land for cultivation. About 56% of households had houses made of bricks under thatch, 36% had bricks under iron sheets or asbestos and 8% of households lived in thatched roofed houses with walls of sticks plastered with mud. The main livelihood activities in the area included crop production, animal rearing, and harvesting of NTFPs as all (100%) of the households sampled were involved in crop production, animal rearing and harvesting of NTFPs.

4.1.2 Households use of marula fruit and other NTFPs

All households collected marula fruit for own use, mainly for brewing *mukumbi* beer (90%), making jam (30%) and selling kernels for snacks (35%) or oil pressing (50%). About 43% of households sold NTFPs, while 34% of households were members of a NTFP enterprise group called Mukwakwe Watershed Group, which assisted them in product development and marketing of the marula oil. There appeared to be no association between the sex of the respondent and being a member of the enterprise (χ^2 = 0.3824, d.f = 1, p=0.5363), however there is a positive association between being a member of the enterprise group and selling NTFPs (χ^2 =16.62, d.f = 1, p = 0.0001). About 40% of respondent were members of the Mukwakwe watershed group and 60% were non-members. All the members of the Mukwakwe watershed group were selling marula products, but only 10% of non-members were selling marula kernels, mainly for snacks. This indicates the important role played by the enterprise group in developing the marketing of NTFPs in the area.

In 2004, the average mass per household of marula fruits harvested was 160 ± 18 kg, with a range of 50-800 kg. The mean number of harvesting months was 2 ± 1. Due to the 2004-2005 growing season drought in the area, there was a significant difference in the marula harvested between 2004 and 2005 (t = -3.78, d.f = 79, *p* = 0.0003). The mass for 2005 was much lower at only 120 kg ± 15kg. A linear regression analysis indicated no increase in mass of marula harvest with larger numbers of household members (r^2 = 0.0089, d.f = 50, SE = 0.1132, p = 0.4048).

There was no linear relationship between size of household and mass of marula harvest. This suggested a degree of specialisation of the activities within individual households. The PRA methodology indicated that marula nut cracking and beer brewing was done by elderly women and the number of such elderly women was about 2 per household and was similar in both small and large sized households.

4.1.3 Marula beer brewing

A marula beer locally known as m*ukumbi* was commonly brewed at Mukwakwe, from around January to April, when the fruits are ripe. People of all ages and sexes enjoy the beer as a means of fellowship with relatives and friends and beer drinking plays an important role in building and maintaining social ties. There is a less alcoholic marula juice called *dova*, which takes only one day to prepare and is popular with children. The “real” marula beer, *mupwa*, takes seven days to be brewed and is more alcoholic and popular with most adult men and women. Beer is processed from ripe and fresh marula fruits and allowed to ferment in a specially designed traditional clay pot. Traditionally marula beer was not sold locally, but more recently about 10% of households were involved in selling the beer at a cost less than the equivalent of US$ 0.30 per litre, and the maximum amount traded by a single household was about 200 litres in 2005. Almost 90% of households brewed marula beer, hence the low potential for beer trading in the area. The beer was also used in rituals for informing ancestors when the field crops are ready for harvesting. In some instances the beer is mixed with sorghum to make a more alcoholic and tastier beer, locally known as *kachasu*.

Apart from beer brewing, the nuts of the fruit are eaten as a snack food (50% of households), especially when drinking beer, or are ground to produce a tasty butter (20%). Marula fruits are also useful in processing jam (30%) that is prepared by boiling a mixture of the thick fruit juice with sugar. People in the area also enjoy a thick porridge (20%) that is a by-product of beer brewing. The seeds of marula fruits also contribute to the diet of livestock such as cattle and goats, especially during the winter when there are few feed sources, while the shells of marula kernels have been used as a cooking ingredient (15%) that works as bicarbonate of soda.

4.1.4 Uses for marula bark

The marula bark is a common source of medicine in the Mukwakwe area. From the household interviews, there appeared to be no association between level of household wealth status and the household's use of medicinal herbs (χ^2 = 0.2233, d.f = 2, p = 0.8944). The survey also indicated that 25% of the respondents use marula bark to cure some of the common diseases prevalent in the area. Marula bark medicine is taken both orally and externally to treat common health problems, such as toothache, stomach disorders and "loose anal problem" (*dzviti*). It is also useful for treating women's strained muscles after giving birth. In addition, oil is produced as a by-product of butter processing, and is used in treating influenza and ear problems in children. The bark also produces a nice dye used especially on crafts made of Ilala palm (*Hyphaene petersiana*).

4.1.5 Uses for marula wood

Marula wood is used in carving, for making traditional wooden plates, plough wheels, drums and mortars for processing maize, millet, and nuts for peanut butter. The wood is preferred over other species for its lightness and general good strength properties. However, carving was not common in the area as only 5% of households depended on carving as a source of livelihood, but 52.5% of households indicated use of marula wood for craft work. Quantitative data for harvestable stems per hectare were lacking, but the PRA indicated use of the branches of the marula tree for carving or craft purposes. This is consistent with only a few stumps (nearly 8%) of marula that was found during the vegetation ground survey stage of the study. All the households used firewood as the main fuel for cooking and also about 83% of the household disclosed that they sometimes used dry marula trunks/stems as fuel wood. Use of green marula wood is, however, forbidden in local traditional culture.

4.1.6 Traditional importance

About 35% of people sampled believed that the spirits of their ancestors rest under marula trees and hence many traditional beer rituals of praying for crop protection against wild animals are carried out under marula trees. About 59% of the households perceived that selling marula fruit had no negative impact on their culture and 10% of the respondents did not approve of the sale of marula products. The remainder of the people had no opinion on the possible negative impacts of marula harvest on their local traditional culture. Traditionally, the fresh ripe fruits were squeezed to remove the skin and pulp, which was used for beer brewing, or to make the traditional marula porridge and jam. The kernels were then covered by wild grape plant leaves, but nowadays people put the nuts onto rocks (*ruware*) for them to dry, and these are of better quality for oil pressing than the nuts that are left to dry with pulp.

4.1.7 Institutional framework of marula use

About 93.8% of respondents indicated that there are natural resources management institutions working in the area. These institutions included Zvishavane Water Project (ZWP), traditional leaders, Lutheran Development Agency and the Runde Rural District Council (RRDC). The council is contributing towards natural resource conservation through instituting by-laws that regulate the use of water, forests and soil resources. ZWP was the largest NGO working in the area with a total membership of ± 100 households and assisted people in water harvesting, soil conservation, permaculture, and sustainable agricultural techniques. The people in the area generally regarded these institutions to be effective in their delivery of services.

According to both household and PRA surveys, traditionally all fruit trees were not allowed to be cut down, especially the seed bearing (female) marula. The questionnaire survey indicated that 97% of respondents were aware of natural resources conservation rules and regulations instituted in the area. The perception of 62.8% of respondents was that the source of these rules was the local traditional leadership. About 18% of respondents perceived that the source of the rules and regulation was their local traditional culture. However only 14.3% and 3% thought the source of the rules were the central government and council respectively. There is therefore a reliance on the traditional authority for natural resource conservation in the area.

4.2 Vegetation Structure

4.2.1 Species composition and densities

Species occurrence was almost similar within the four villages, with eight species occurring in all the four villages (i.e. *Sclerocarya birrea*, *Piliostigma thonningi*, *Terminalia sericea*, *Colosphermum mopane*, *Diospyros mespiliformis*, *Combretum apicalatum*, *Dichrostachys cinerea* and *Acacia tortillis*) (Table 1).

Table 1: Tree species composition, including families, scientific & common names and densities (stems ha^{-1}) within the four villages at Mukwakwe area of Zvishavane District, Zimbabwe

Family	Scientific name & authority	Common name	Mugwagwa	Sikono	Svondo	Takaendesa	Mean ± SD
Anacardiaceae	***Lannea stuhlmanii*** Welw	Rusty-leaved lannea	0.67		0.43	1.3	0.8 ± 0.45
	Sclerocarya birrea, (A.Rich.) Hochst. Subsp.cafra (Sond.) Kokwaro	Marula	5.05	12.43	6.55	8.08	8.03 ± 3.19
Bignoniaceae	***Kigelia africana***, (Lam.) Benth.	Sausage tree	0.34		0.43		0.39 ± 0.06
Bombacaceae	***Adansonia digitata***, L.,	Baobab	0.34			0.32	0.33 ± 0.01
Caesalpinioidea e	***Afzelia quanzensis*** (Welw.) Pierre	Pod mahogany	0.34	0.78			0.56 ± 0.31
	Burkea africana, Hook.var. andongensis Oliv.	Burkea	0.34				0.34
	Colosphermum mopane, Kirk ex J. Leonard	Mopane	3.7	6.99	2.62	0.32	3.41 ± 2.77
	Piliostigma thonningi, Schumach. Milne-Redh. Subsp. Leutweinii (Schinz) Excell	Monkey bread	0.67	1.55	1.31	1.3	1.21 ± 0.38
Combretaceae	***Comberetum apicalatum***, Sond,	Pond mahogany	0.67	0.78	2.19	0.32	0.99 ± 0.82
	Comberetum adegonium, Steud. Ex A.Rich.	Four leaved Combretum	0.67	0.78		0.65	0.7 ± 0.07
	Terminalia sericea, Burch. exDC.	Sliver Terminalia	5.72	4.66	10.49	4.52	6.35 ± 2.81
Ebenaceae	***Diospyros mespiliformis***, Hochst,	Jackal-berry	1.01	0.78	1.75	0.65	1.05 ± 0.49
Euphorbiaceae	***Euphorbia ingens***, E. Mey. Ex Boiss	Giant Euphorbia	1.34	0.78		0.32	0.81 ± 0.51
Fabaceae	***Pseudolachnostylis maprouneifolia***, Pax var. dekindtii (Pax) Radd. –Sm.	Duikerberry	0.34		0.43	0.32	0.36 ± 0.06
	Xeroderris stuhlmnnii, (taub) Mendonca & E.C. Sousa	Wing pod	0.34		0.9	0.32	0.52 ± 0.33
Loganiaceae	***Strychnos madagarscariensis***, (Benth)	Hairy monkey Orange	2.02	0.78			1.4 ± 0.88
	Strychnos spinosa Lam	Spiny monkey orange	0.34				0.34
Malvaceae	***Azanza garckeana***, F. Hoffm	Snot apple	0.34		0.43	0.97	0.58 ± 0.34
Mimosaceae	***Acacia tortillis***, (Forssk.) hayne subsp. Heteracantha (Burch.) Brenam	Umbrella Thorn	0.34	8.55	0.9	0.65	2.61 ± 3.97
	Albizia amara, (Roxb.) Boivin subsp.sericocephala (Benth.) Brenan	Bitter Albizia	0.67	0.78		0.32	0.59 ± 0.24
	Dichrostachys cinerea, (L.) Wight & Arn. Subsp.african	Sickle bush	2.36	11.65	3.5	4.52	5.51 ± 4.19
Moraceae	***Ficus sycomorus,*** L. subsp. sycomorus	Sycomore fig	0.34				0.34
TOTAL			**27.95**	**51.29**	**31.93**	**24.88**	**34.01± 11.87**

The most common families were the Mimosaceae and Combretaceae, which had at least 3 different species. *S. birrea* had a high density of 8.03 ± 3.19 stems ha^{-1} and this showed the widespread occurrence of the species in the study area (Table 1). The other species which had generally high densities were *C. mopane* (3.41 stems ha^{-1}), *T. sericea* (6.35 stems ha^{-1}) and *D. cinerea* (5.51 stems ha^{-1}).

4.2.2 Marula abundance within villages

There was no significant difference in densities of marula between villages ($F_{3, 195}$ =1.063, p= 0.366) whereas the different land uses did not have significant differences in marula densities ($F_{1, 197}$ = 11.92, p=0.001), where non arable land had a higher density (19.63 ± 11.82) than arable land (6.40± 5.29) (Table 2).

Table 2: Proportions of arable and non arable land within villages, and respective marula densities (plants /ha) in Mukwakwe within Zvishavane district, Zimbabwe

Village	Percentage of arable	Percentage of nonarable	Transect Number in village	Arable land marula density	Non-arable land marula density
Mugwagwa	57	43	T1	2.39	0
			T2	6.24	8.88
Sikono	38	62	T1	18.30	22.30
			T2	4.08	39.04
Svondo	55	45	T1	8.35	17.15
			T2	1.32	15.82
Takaendesa	60	40	T1	5.70	19.73
			T2	4.83	26.67
MEAN±SD	52.5	47.5		6.40± 5.29	19.63±11.82

There was evidence of differential utilisation of marula between these two major land uses (Table 2). This was because young marula stems are cut down in the arable fields to allow for crop production. There was a high abundance of marula in the area, with an average absolute density of 8.03 ± 3.19 stems ha^{-1} and a relative density of 21.67% (Table 3). Calculating from the absolute density of marula (stems ha^{-1}) in villages and the respective size of villages (ha), the population of marula was also high (Table 3).

Table 3: Marula densities, and estimated population sizes within the two land uses in villages of Mukwakwe in Zvishavane district, Zimbabwe

Village	Size of village (ha)	Absolute marula density (stems ha^{-1})	Relative marula density (%)	*Weighted Number of stems per village in arable land	*Weighted Number of stems per village in non-arable land	Estimated total number of stems per whole village
Mugwagwa	396	5.05	18.30	1139.43	859.57	1999
Sikono	643	12.43	19.87	3036.96	4955.04	7992
Svondo	610	6.55	17.87	2177.45	1780.2	3995
Takaendesa	490	8.08	30.62	2375.40	1583.60	3959
Mean± S.D	535±113	8.03±3.19	21.67±6.03	2182±786	2295±1817	4477±2521

* Number of stems per village in proportion to the proportional size of the particular land use within a village

Sikono village had a higher marula population than in the other villages that resulted from a high absolute density of the species. However the relative marula density in that village did not differ much with the other 3 villages (Table 3). This probably indicated that tree populations of all species were generally high in this particular village. The whole study area of about 3200 ha was estimated to have about 29440 stems of marula, and this was calculated from an absolute density of about 8.03 stems ha^{-1}.

4.2.2 Population Dynamics

There was a significant difference in marula trees diameters between the different land uses of Mukwakwe area ($t_{92, 107} = 1.69$, $p = 0.0401$) with 31.23 ± 25.28 cm and 26.51 ± 20.76 cm diameters for arable and non-arable land respectively (Figure 3).

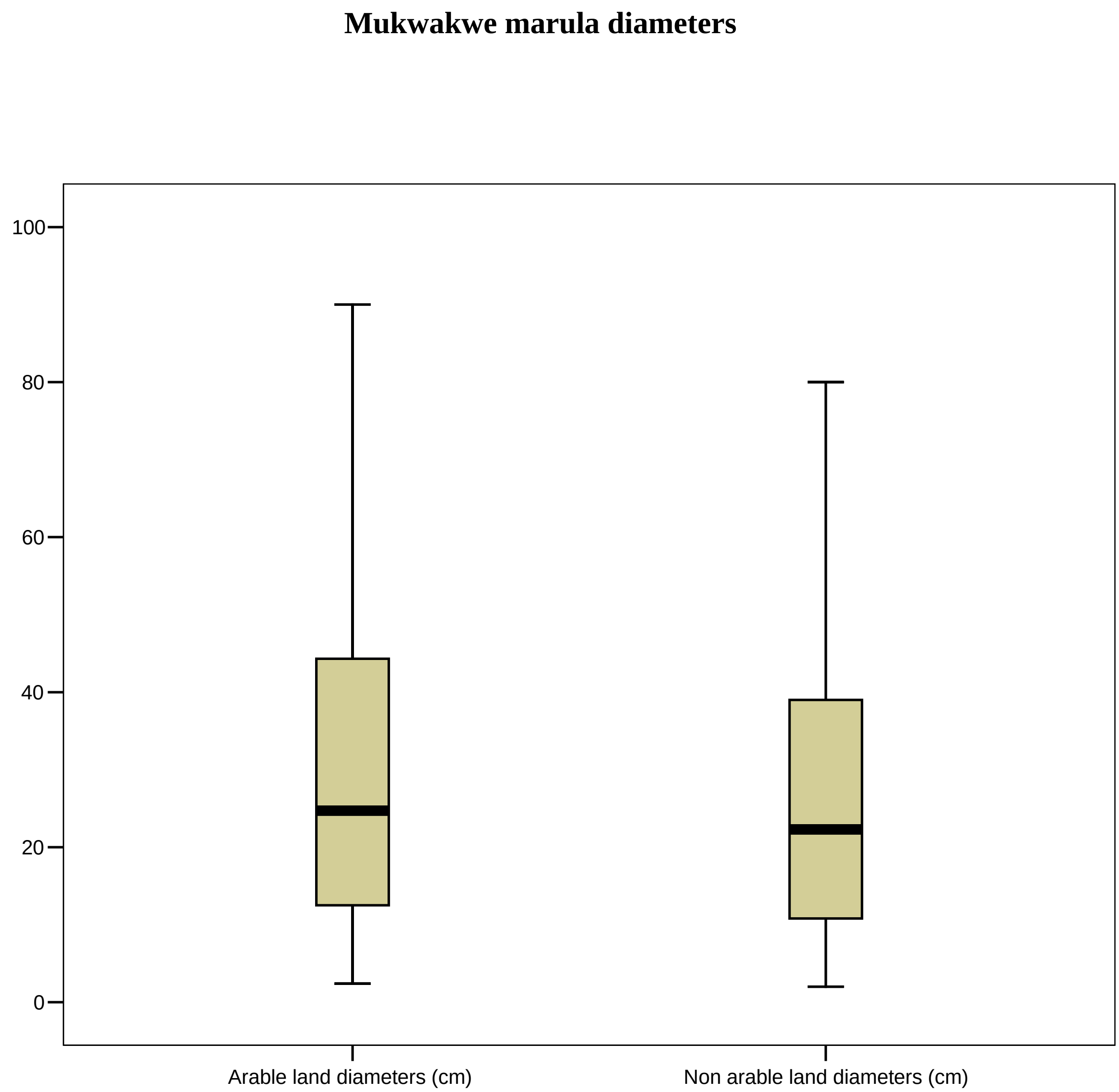

Figure 3: Box and whisker plot of differences in marula basal diameters (cm) between arable and non arable land uses in Mukwakwe of Zvishavane District, Zimbabwe

The difference in diameter sizes of marula between arable and non arable land uses (Figure 3) was small (4.72 cm), and only a large sample size was able to show this difference. There was also some evidence of differential resource use between these two major land uses either through protecting large trees in and around arable fields or through allowing regeneration within non arable lands.

4.2.3 Size class profile

An analysis using the Spearman's rank correlation of size classes with frequencies of trees in respective size classes indicated a large proportion of trees in the smaller size class groups. The overall size class distribution of the study area showed negative correlations (Table 4). A negative correlation indicated an inverse J- shaped curve (Poorter *et al.,* 1996), and this was the size distribution of marula in all the four villages of Mukwakwe (Table 4).

Table 4: Spearman's rank correlation to analyse trends in marula size class distributions within the four villages in Mukwakwe area of Zvishavane district, Zimbabwe.

Site	**Sample size**	**Spearman's Correlation**	**p-value**
Mugwagwa	62	-0.8572	0.0007[a]
Sikono	44	-0.8524	0.0148[a]
Svondo	44	-0.6640	0.0511[b]
Takaendesa	52	-0.72348	0.0078[a]
Whole Study Area	**202**	**-0.9085**	**0.0001[a]**

* Different superscripts indicates significant difference at P<0.05 significance level

The marula size distribution (Table 4) illustrated the presence of regeneration into the population as was shown by the negative value of the Spearman's rank correlation coefficient (-0.9085) (Poorter *et al*., 1996). The characteristic inverse J-shape was found in most villages but was most evident when assessing the trends in the whole study area (Figure 4). Although Svondo village had a negative slope (-0.72348) it did not show significance (p=0.0511), although it was very close.

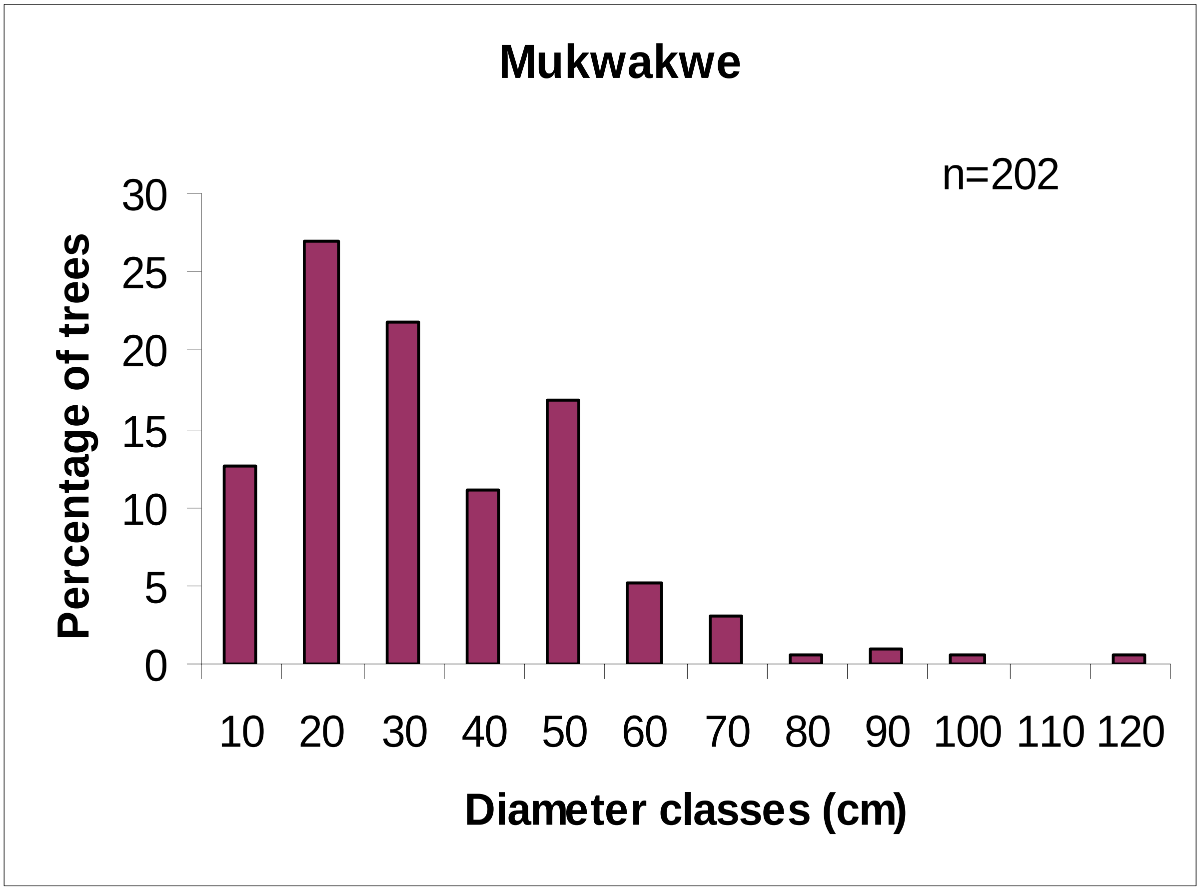

Figure 4: Size class distribution based on percentages, of marula trees in the Mukwakwe area of Zvishavane district, Zimbabwe.

Large proportions of smaller diameter trees were found, and this indicated ongoing recruitment into the population (Figure 4). However it was observed that the smallest diameter class had fewer individuals than the second one and this indicated a retarded movement from individuals in the recruit/suffrutex stage to the next stage. After individuals have moved through the first stage, there is a relatively uniform movement from one size class to the next, indicating a stable population (Shackleton, 2002). The recruitment stage was constituted by seedlings and saplings but with more saplings (Figure 5).

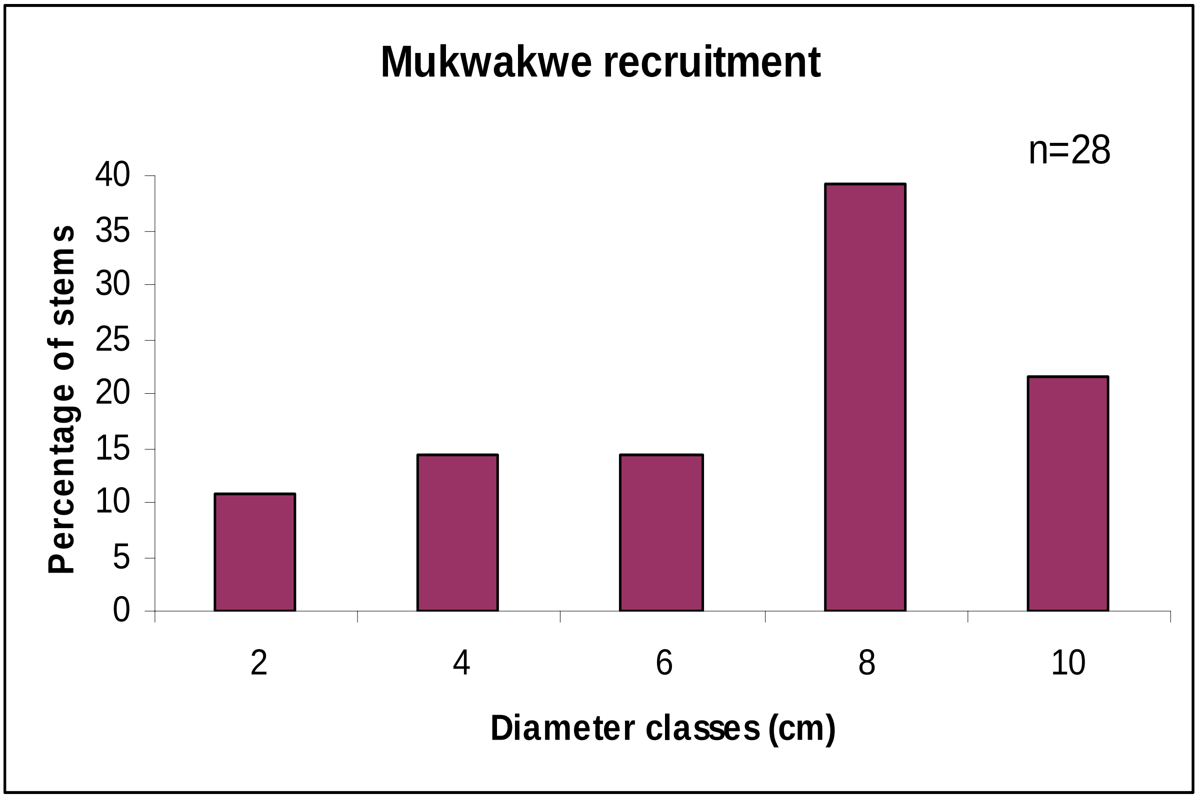

Figure 5: Size class distribution based on percentages, of marula stems in the recruit stages of marula (<10cm) in the Mukwakwe area of Zvishavane district, Zimbabwe

A closer analysis of the smallest diameter (<10cm) class showed a higher proportion of saplings (6, 8 and 10cm diameter classes) than seedlings (2, 4cm diameter classes), (Figure 5). The presence of the recruit stage is evidence of a population which is capable of regenerating but there is still a high mortality in the youngest age group. There was some variability in diameter class distribution between the four villages, but overall there were high proportions of smaller diameter trees (Figure 6)

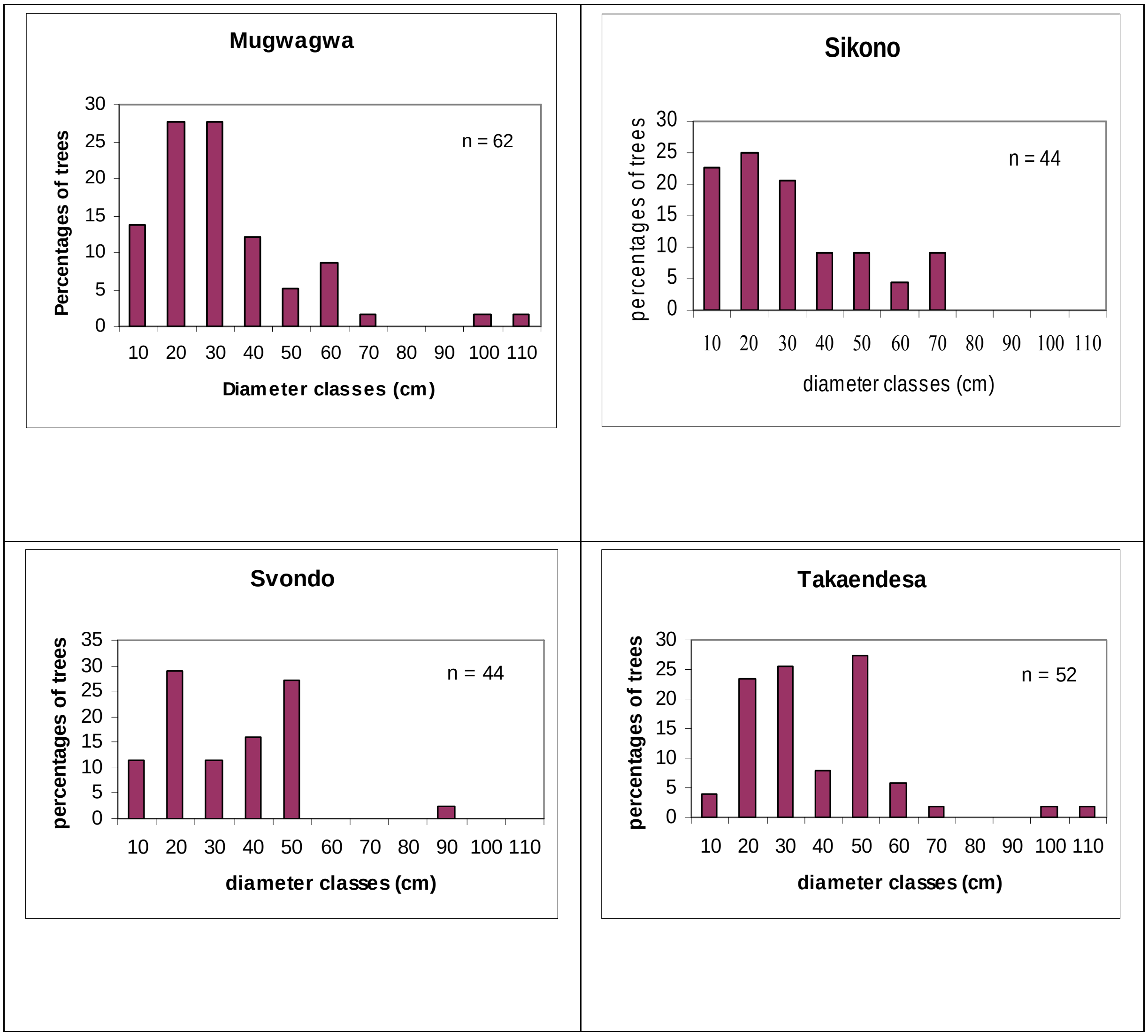

Figure 6: Diameter classes of marula in the four villages of Mukwakwe area of Zvishavane District, Zimbabwe.

In Figure 6 the diameter classes within villages also showed a bottleneck in individuals moving from the suffrex stage to the sapling and mature individuals stage, similar to the evidence for the whole study area (Shackleton, 2002). A disturbance in the size structure of marula was however evident in the Svondo village as there were a reduced number of 30 cm diameter trees.

The population structures of all marula subpopulations within both the arable and non-arable land uses were normally distributed according to the Kolmogorov Smirnov Test ($p<0.05$) (Figure 7).

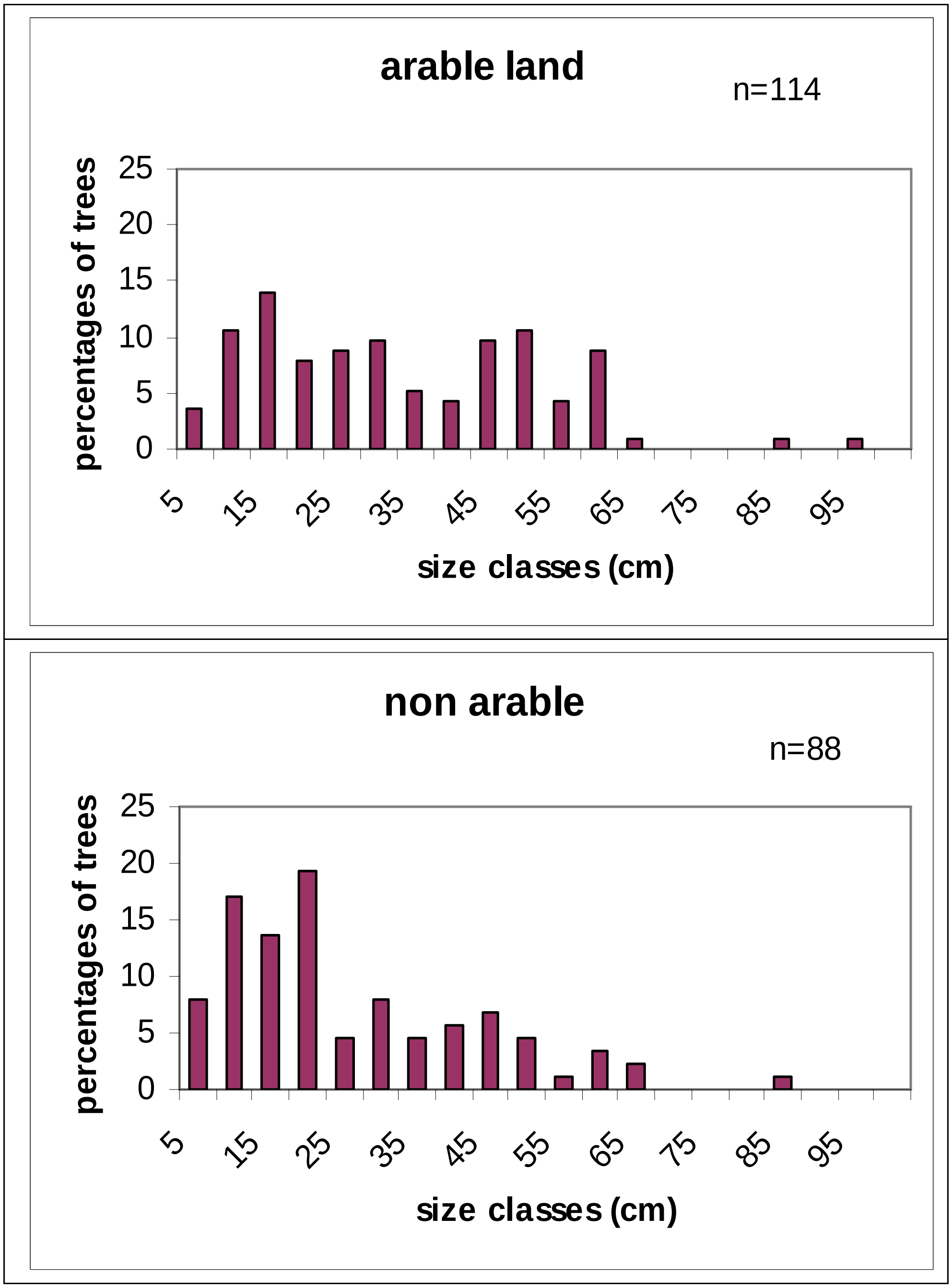

Figure 7: Size classes of marula between arable and non arable land uses in the Mukwakwe area of Zvishavane District, Zimbabwe.

The size classes between different land uses within the study area had slight differences (Figure 7). There were a higher proportion of smaller size classes within the non arable land uses than in the arable land uses, and this suggested that people tend to allow smaller marula trees to grow in the non arable land. The arable land however had generally much bigger tree diameters of 31.23 ± 25.28 cm than non arable land which had 26.51 ± 20.76 cm. This suggested a form of domestication through allowing marula to grow around homesteads and crop fields.

5.0 DISCUSSION

5.1 Socio Economic Factors

5.1.1 Households socio-economic profile

The size of households in the study area was 7.2 ± 0.4, and 88% of the household heads were resident in the area. Nearly 20% of the household heads were women. This is similar to studies done in Zimbabwe by Luckert *et al.,* (2001), where the size of the household was 7.9 and about 20.4% of household heads were female. There are therefore some similarities in the socio-economic profile of people between Mukwakwe area and some parts of eastern Zimbabwe where similar studies were done.

5.1.2 Comparison of household use of marula

The extent of household use of marula fruit in this present study were comparable to those obtained from similar studies in South Africa. Shackleton *et al*. (2000) found for a part of Bushbuckridge, that 59-77 % of households were using marula, whilst this study indicates that 100% of households were using marula. However the proportion of people in Mukwakwe and Bushbuckridge selling marula kernels was basically the same, being 43% and 40% respectively. The high proportion of households harvesting marula was similar to those cited in Shackleton *et al*. (2002) for Mozambique, Namibia, northern Kwazulu-Natal, and also Zimbabwe (McHardy 2002).

Although a higher proportion of people harvest marula at Mukwakwe, the volume of harvest was smaller (160 ± 18kg) than in Bushbuckridge (1207 ± 121kg), and this is because commercial use of marula at Mukwakwe has just started within the last two years (from 2004) (Shackleton and Shackleton, 2005). There was however a household at Mukwakwe that harvested 800 kg alone in 2005, and this indicates a potential increase in overall volume of marula harvest in the area.

Beer brewing at Mukwakwe is done between January and April and this is similar to other studies by Campbell *et al.,* (1997) in Zimbabwe that described a seasonal dimension to the collection of numerous savannah resources in Zimbabwe, which was closely linked to agricultural activities. The beer brewing coincides with the availlabity of ripe marula fruits between January and April and is the crop growing season of Zimbabwe. Marula beer is important in maintaining social networks within the community members (Shackleton *et al* 2000).

5.1.3 Institutional framework

From the PRA it appeared that people who do not observe the rules and regulations capitalise on the reluctance of the traditional leaders to exercise their authority provided in the Zimbabwe Traditional leaders Act of 1998. The community claims the traditional leaders' ineffectiveness began when role changes occurred during the period when Village Development Committees (VIDCOs) were formed in an independent Zimbabwe after 1980. The focus group discussions also showed that the Runde Rural District Council (RRDC) has instituted a number of by-laws that are being used in the area to conserve natural resources.

A number of non-governmental organisations (NGOs) were working in Mukwakwe area towards sustainable management of woodland and forest resources. These included, Lutheran Development Association, Zvishavane Water Project, ITDG and PhytoTrade Africa. An important function of NGOs in the area was to educate people on issues related to environmental management, including promoting national policies such as observing the national tree planting day, held every first Saturday of December of every year. The various training programmes by NGOs have increased the resource conservation awareness in the area especially through the anti-deforestation campaigns. SAFIRE[1] and PhytoTrade Africa play the biggest roles in assisting organisations in Zimbabwe to develop indigenous fruit commercialisation (Ham, 2003). These organisations assist the commercialisation activities through providing information on processing, packaging and marketing. Partnerships and networks facilitated by these organisations benefit communities through providing access to expertise and already developed markets. The partnerships also benefit commercial organisations through improved supply chains and access to raw materials (Ham, 2003).

All these institutions work closely with the Forestry Commission, a parastatal organisation responsible for forestry resource management and operate in the confines of the Forest Act (Chapter 19:05 revised in 1996) and Communal Land Forest Produce Act (1987). Related

[1] SAFIRE (Southern Alliance for Indigenous Resources) is a Zimbabwean NGO that is based in Harare.

legislation comprises the Communal Land Act (chapter 20:04), Natural Resources Act (chapter 20:13), and the National Parks and Wildlife Act (chapter 20:14) (Government Gazette - Zimbabwe, 2005).

There are also other local institutions which are involved in the management of natural resources in the area such as Rukwengweru, which works in collaboration with the Zvishavane Water Project in managing livestock grazing areas. These local groups are lead by local people and target the priority needs of the people and receive support from donor organisation like Oxfam of Australia.

5.2 Vegetation Characteristics

5.2.1 Population Density

The density of marula was much higher in non arable land than in arable land in the Mukwakwe area, despite the diameters of marula in arable land being much bigger. This is almost similar to case studies in South Africa, where in the Bushbuckridge district the density of marula trees was significantly higher in protected areas than the neighbouring communal lands, fields or homesteads (Shackleton, 2003). Also in the Bushbuckridge the trees in protected areas were small, while those in homesteads were much bigger and more mature. There is therefore a close similarity in density and tree sizes in both case studies. These characteristics suggest some degree of historical selection of the trees in the homesteads and fields. The deliberate conservation of indigenous trees in fields is a traditional agro-forestry practice in much of Africa (Ingram, 1990). In the smallholder sector of much of Africa, mature trees are often left in arable fields or in field margins (Chivaura-Mususa *et al.,* 2000), and in some studies done in Zimbabwe, edible fruit-bearing trees were left in fields and around homesteads (Campbell, 1987; Campbell *et al.,* 1991; Schrecbenberg 1999).

5.3 Ecological sustainability

The size class distributions were analysed by Spearman's correlation test and negative slopes generally indicated recruitment, since larger size-classes have fewer individuals (Poorter *et al*., 1996). This could be explained by the ability of savannah woodlands to resprout from roots and stumps once the above ground parts have been removed or killed by harvesting or fire damage (Grundy, 1995; Frost, 1996). These shoots grow faster than newly established seedlings because they already have a well-established root system with stored nutrients reserves (Chidumayo, 1993; Grundy, 1995).

It should however be emphasised that the obtained population histograms of basal diameter classes are size class distributions and not age class distributions. Poorter *et al.,* (1996) suggests that in general there is some relationship between size and age distributions but variability can be large in some instances. The size class distribution however shows the regeneration of marula at a particular time but the process can be inferred from the results. This means only long-term monitoring of population dynamics at Mukwakwe will clearly show the process of regeneration. Demographic studies of this nature are a cost effective means of providing useful data on the impact of forest utilisation, and this can lead to adoption of effective conservation strategies (Botha *et al.,* 2002; Wilson and Witkowski, 2003, Dhillion, 2004).

Population structures are affected by a variety of factors and for sustainable harvesting of marula there is a need to compare the amount of damage resulting from the various marula uses. The impacts of NTFPs extraction on any one species are determined by variation in site conditions over space and time (Ticktin, 2004). At the same time the sustainability of marula requires that harvest rates do not exceed the capacity of populations to replace the individuals' extracted (Hall and Bawa, 1993). The present study can be compared with similar studies done in the Bushbuckridge by Shackleton *et al.* 2005 on assessing the sustainability of marula harvest as the two sites have almost similar environmental conditions (Figure 8).

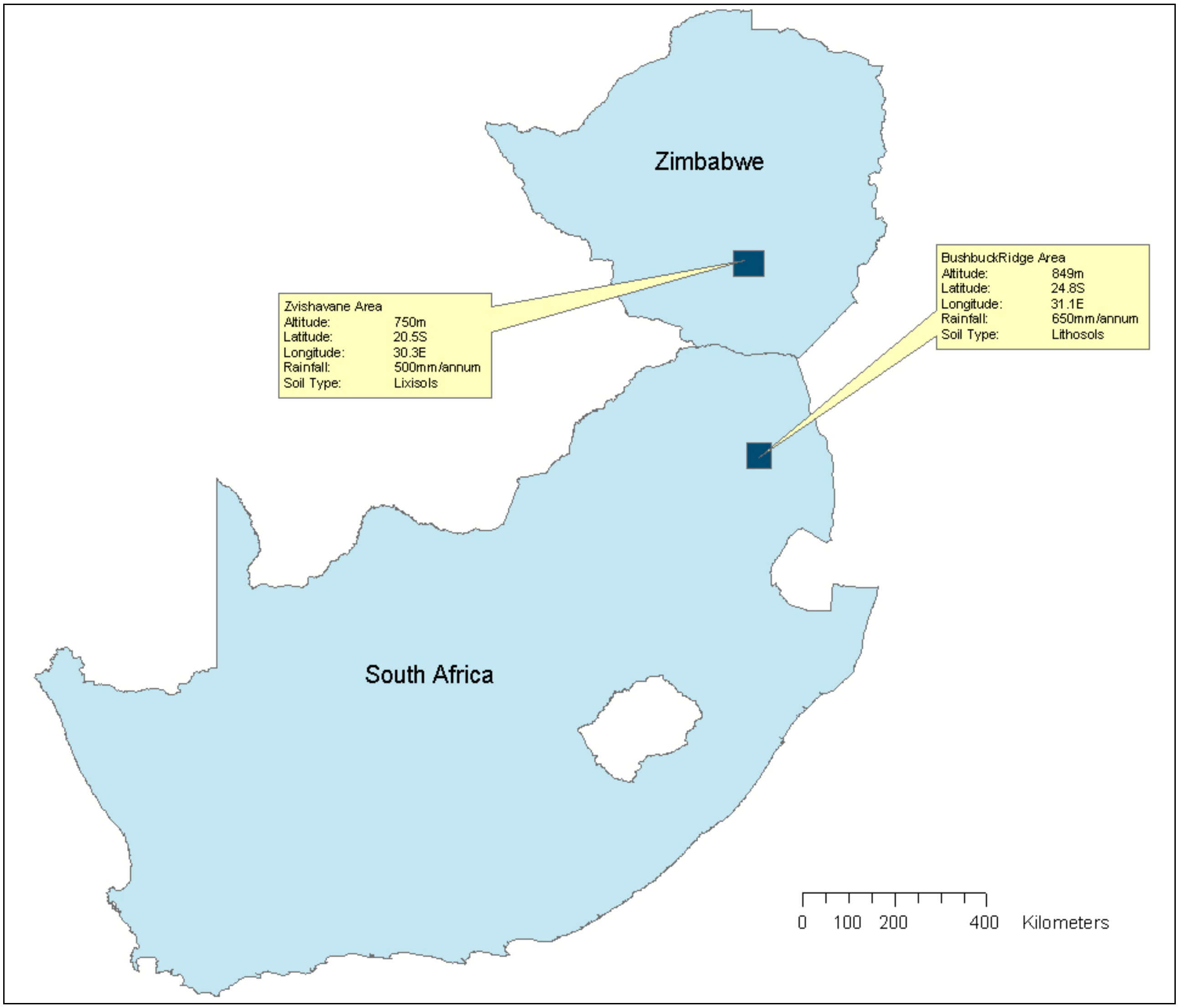

Figure 8: Map showing Zimbabwe and South Africa and indicating the similarities of environmental conditions of the Zvishavane and Bushbuckridge districts of the two countries

In a stage-based population matrix model in the Bushbuckridge, it was shown that 92% of marula fruits could be harvested without impacting the population profile (Shackleton, 2005). Also studies on marula from the same area showed that approximately 92% of marula fruit could be harvested without long-term impacts on future recruitment (Emmanuel *et al*., 2005). Although exact quantities of harvestable marula fruits in Mukwakwe are not known, a higher proportion of people harvest marula at Mukwakwe than the Bushbuckridge. However the volume of harvest at Mukwakwe was smaller (160 ± 18kg) than at Bushbuckridge (1207 ± 121kg). The lower volumes of marula fruits harvested at Mukwakwe, despite almost similar environmental conditions, were probably because the commercial use of marula is still a new business venture in the area.

It may be alleged that fruit harvesting to produce kernels has a potential impact on dispersal and establishment, but this has to be measured with regard to the quantities harvested. In some investigations done on annual maximum sustainable harvest limits proposed for NTFPs, it was recorded that the rates were above 80% when harvesting seeds and fruits (Peters, 1991; 1992; Zuidema and Boot, 2002). In the harvesting of whole plants, annual sustainable rates were 0 and 35% for *Euterpe precatoria* and *Aechmea magdalenae* respectively (Zuidema, 2000; Ticktin *et al.,* 2002). This is because tolerance to harvesting varies according to life cycles and the part of the trees that is harvested (Ticktin, 2004). This means that fruit harvesting has less impact on the persistence of the species than other uses that results in damage to the whole tree and hence should be promoted more than the other uses of marula trees at Mukwakwe.

Carving is a speciality of only 5% of the people and has a high economic benefit to these few individuals, but poses the greatest potential for population reduction because of the possibility of whole tree harvesting. At present the woodcarvers are only using tree branches but there is the potential for whole tree harvesting when demand for products increases. Wood carving should therefore be monitored and controlled so as to reduce the negative ecological impacts of this activity. Beer brewing is the most common use of marula in the area (90%), and it probably poses the least threat to regeneration as people only make use of fruit pulp, and the seeds are left in the environment to allow for regeneration. In some cases when people take the fruits to their homes for beer brewing, this may act as a form of seed dispersal and is important because seed dispersal is a crucial ecological process that maintains the diversity of plant communities (Christian, 2001). An obvious challenge to dispersal is the possibility of preferential cutting of male trees as the tree is dioecious. Hunter and Twine (2005) found that many people within Agincourt area of Bushbuckridge do not have a sex preference when cutting marula trees although other studies show a bias in harvesting between males and female marula trees (Shackleton *et al*., 2003). In this study the sex ratio was not determined because of the difficulties of differentiating the different sexes as field work was done outside the flowering and fruiting seasons however the few respondents asked were not able to differentiate between female and male marula trees. The sex ratio for this present study was therefore assumed to be 1:1 (Shackleton, 1996) but there is still need to further investigate the sex ratios in order to recommend more conservation strategies of marula in the study area.

Marula medicine is extracted from the tree bark and was used by 25% of respondents, but there is no local commercial trading of marula medicines. This medicine is mainly extracted by traditional healers and herbalists, and the vegetation ground survey did not show any evidence of trees with scars resulting from medicine extraction. In other words bark harvesting for medicinal purposes at present does not seem to have a negative impact on marula tree populations in Mukwakwe, although it is a common reason for degradation of tropical tree populations (Cunningham, 1997).

The low recruitment from seed in three of the four villages does not necessarily indicate over-harvesting and may be a result of other factors such as below average rainfall, increased predation by goats, or under-counts of seedlings due to sampling error. There is however a need to adapt conservation strategies for the young marula seedlings in order to ensure proper natural regeneration of the commercially important species.

5.4 Socio-economic sustainability

The cash income from marula oil sales contributed significantly towards overall incomes for the rural producers. The uses of marula kernels for oil pressing, butter making and marula food snacks together have the most economic benefit and are widely used in the Mukwakwe area. In this research the density of adult (>15cm diameter) trees was 7.0 stems ha^{-1} and assuming a sex ratio of 1:1, the density of fruit bearing trees is 3.5 stems ha^{-1}. An annual yield of 744 ± 338 kg tree^{-1} has been recorded in the Bushbuckridge (Shackleton, 1996). Taking a conservative estimate of fruit yield as 100 kg tree^{-1} and a 3.5 tree ha^{-1} tree density, this resulted in an average annual yield of 350 kg ha^{-1}. The value of the total crop at US$1 kg^{-1} is a good, being the price of marula kernels in 2005 (Nyarai Kurebgaseka[2], personal communication). The study area of about 3200 ha will have a total of 1 120 000 kg of marula per year and this can mean an approximate total marula value of US$ 1 120 000 per year.

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[2] Nyarai Kurebgaseka is the Technical Services Manager of PhytoTrade Africa

The estimations above clearly indicate the economic value of harvesting NTFPs. Moreover the approximations are based largely on the minimum harvest value of the raw indigenous resources. There is a need to add value to the marula by processing them, and this can be done by improving production technology. Due to the present low technological investment in some of the products, it will remain a home based process, thereby limiting the potential displacement of women from the production process, and creating economic empowerment as the business enterprise is developed. There is also a need for the facilitation of training communities in appropriate processing techniques (Kadzere *et al*., 2002). The next step will be to expand the supply of the processed goods with added value to wider markets, locally, nationally, regionally and internationally. The commercial production of NTFP products should be scheduled so that harvesting and processing are done in summer and winter respectively, and this will make the business an all year round activity. During summer when fruits are ripe, people can harvest the crops for beer brewing and other household uses, and then let the fruits dry to allow for kernel extraction in winter.

According to a PhytoTrade Africa (Gus Le Breton, personal communication), there are an estimated 2.5 million households in the region that harvest marula and there is a potential total output of about 877200 tonnes of marula fruit derived products. If total production is achieved, this can bring an annual turnover of about US$263 million to the whole southern African region. Conversion of the potential value to a real cash flow can be achieved through harvesting the NTFPs, and that increased cash flows within the local economy and will have large benefits for the whole region. The primary beneficiaries will be the harvesting entrepreneur from the local areas. This may have positive impacts, especially in the face of economic hardships, HIV/AIDS, unemployment and retrenchments of the poorest people of rural Zimbabwe and southern Africa at large. There is therefore an indication that marula products offer a promising economic alternative to the people in the rural areas of southern Africa (Trauernicht and Ticktin, 2005).

5.5 Management strategies

The management of some destructive forms of marula resources (such as harvesting of bark, firewood, carving wood), do need to be monitored to limit negative impacts on the population that may reduce fruit availability for regeneration or cropping. The uses of the fruits seems to have a low potential for any negative impacts, but these have the highest economic return and therefore are the ones that should be targeted for commercialisation activities. This is probably possible at Mukwakwe because of the already existing conservation strategies and the presence of a strong institutional framework, both in the form of organisations operating in the area and also because of the various rules and regulations stipulated by the Rural District Council and being enforced by the traditional leadership.

6 CONCLUSION AND RECOMMENDATIONS

There is no evidence at present of any negative impacts of marula harvesting on the species regeneration in the area because of a high proportion of plants in the smaller size classes, and thus indicating a generally stable population. There is however evidence of differential resource harvesting between arable and non arable land use areas, which may have developed through human selection and domestication of the valuable trees in homesteads and arable fields.

The study further shows that marula harvesting and selling is one of the few options available to generate income for the people in this part of Zimbabwe. Generally marula contributes to various forms of livelihood capital including human (health, nutrition and security), financial (cash from sales of fruit, kernels and beer), social (sharing of marula beer, cultural norms) and natural capital (trees returned, planting of trees, selection of favourable genotypes), (Shackleton and Shackleton 2005). The cash injection earned from selling fresh marula products comes at a particularly crucial time of the year, when money is required for school fees, uniforms and books. Its significant cultural value also means that this species provides a range of indirect livelihoods benefits and is important in building social capital.

There is therefore an indication that non-timber forest products offer a promising economic alternative that also meets resource conservation goals. High species abundance and the presence of regeneration may contribute to a viable and sustainable natural products commercialisation in the area, but long-term monitoring of population dynamics is needed to clearly verify the process of regeneration together with investigating the sex ratio of the marula tree. The socio-economic aspects influencing resource use should also be continuously monitored to avoid any major environmental and social impacts on commercial marula fruit harvesting.

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APPENDIX 1:Data Table for Point-Centered-Quarter Samples

Name of Focal Species: _______________ Country: _______________________ Village: _______________________ Date _____/_____/ ______ Transect Number: _____________________ Bearing _______________________

Point Code	Coordinates		Quad No.	Focal Species and Other Species				Focal Species Only		
	X	Y		Species Name	Distance	Diameter	Sex	Distance	Diameter	Sex
a			1							
			2							
			3							
			4							
b			5							
			6							
			7							
			8							
c			9							
m=			n=		Σd=					

APPENDIX 2: FOCUS GROUP DISCUSSION QUESTIONS

1) Can you tell me some of the traditional uses or beliefs about marula in the area? Anything else (new uses etc)?
2) Are NTFPs easy to find, or have they become more scarce/plentiful? Please explain.
3) What sort of people are involved in NTFP harvesting/ processing/ selling? Eg gender and age. List by species.
4) Are there any rules about the use of NTFPs (traditional or modern)? What do you think about them? Are they effective?
5) Is there anybody here such as natural resource management institutions (traditional or modern) who monitors the use of these resources? Please describe How effective?
6) Do you make money from NTFPs? How/where (describe?) Is this a good thing or a bad thing?
7) Does NTFP use/commercialisation affect the environment at all? How? Any strategies?
8) Do you use modern or traditional methods for harvesting and processing NTFPs? Please describe these methods. How are they different?
9) During which time of the year do you harvest these NTFPs?
10) Do you think NTFP use/commercialisation sustainable?
11) Do you have other natural resources besides the focal tree species? Do you utilise them?
12) Can you tell me the main income generating activities that you are involved? What is the contribution to household income?

Community Profile

Name	H/h head				Age (h/h).	Social Interaction			ES		Livestock ownership.				Wealth rank			No. of chn	sg	Other.		Income Sources	
	m	f	w	wr.		p	g	c	Y	N	c	g	d	ch	r	a	p			pre	post	f	of

H H - Household Head
M - Male
F - Female
W - Widow
Wr - Widower
Es - Education Status

Livestock: C - Cattle
G - Goats
D - Donkeys
Ch - Chickens

Wealth Ranking: R - Rich
A - Average
P - Poor

Sg - School going
Pre - Pre school