An ecological assessment of the sustainable utilization of the woody vegetation in the Lowveld Bushveld, Mpumalanga province

by

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ABSTRACT

This study was done in the communal area surrounding Makoko village and in the adjacent conservation area within the Kruger National Park, Mpumalanga province, South Africa. The structure of the woody vegetation within the two areas were compared in terms of species diversity, density, size structure distribution and biomass to determine the impact of fuel wood harvesting within the communal area upon the woody vegetation. There was no difference in woody plant species richness between the conservation and communal areas, but there was a difference between the uplands and lowlands. The conservation area uplands had the highest woody plant density and woody plant biomass. There were differences between areas in terms of the woody size class structure. The socio-economic status of Makoko village was determined by interviewing 100 households within the village. The use of fuels including wood, paraffin, candles and electricity was determined. Community and Kruger National Park issues such as advantages and disadvantages of living adjacent to the Kruger National Park were also noted. The demand for fuel wood within Makoko village was 338.9 kg per person per year, but the supply of fuel wood in the communal area was only 54.6 kg per person per year, if harvested sustainably. A conservation area of equal size could provide 270.0 kg of fuel wood per person per year on a sustainable basis. Management recommendations were made towards achieving sustainability in the use of the woody plant resources.

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CHAPTER 1

INTRODUCTION

Historically, environmental issues and rural development were considered mutually exclusive, and as conflicting needs within society (Department of Environmental Affairs and Tourism 2002). However, as early as the 1960s, the approach to conservation in developing countries broadened from the past emphasis on strictly policed protected areas, to one of sustainable resource use and the maintenance of ecological processes and genetic diversity (Cunningham 2001). This broader approach involves land-users in bioregional management at an ecosystem level.

Throughout the world, wild, naturalized or non-cultivated plants provide a “green social security” to billions of people in the form of low-cost building materials, fuel, food supplements, herbal medicines, basketry and income. Despite the immense importance of these plant resources, their value is rarely taken into account in land-use planning. Although many ecosystems and harvested species populations are resilient and have a long history of human use, they can be pushed beyond recovery through habitat destruction and overexploitation (Cunningham 2001). These effects have been amplified by the rapid increase in the human population over the past 200 years (Population Reference Bureau 2004).

The global human population in the year 2000 was 6.1 billion people, with a population growth rate of 1.4% or 85 million people per year. From 2000 to 2030, almost all the annual growth in the human population will occur in the less developed countries in Africa, Asia and Latin America, with predicted annual growth rates of ≥1.9% in these countries (Population Reference Bureau 2004). An increase in the human population is inevitably accompanied by an increase in the pressure placed on the environment for delivery of the essential natural resources upon which most rural people are dependent for survival (Research and Development 2000; Butler 2004).

As global warming and global environmental changes become more apparent, the world's poor and marginalized people increase simultaneously and become more vulnerable because the environments that support them become progressively more degraded. Assessment of environmental problems, risk and vulnerability are critical components of development at the local community and individual level. Unless the way in which humans use their resources changes at the local level, environmental quality and the quality of life of these communities and individuals cannot be sustained.

The term sustainable development implies an end point or something that we can or have achieved. We live in a world that is dominated by a capitalist global market and private profit. However, market expansion is not always compatible with sustainable development (Oelofse 2003). It is difficult, if not impossible, to achieve sustainable development in our current global system. It is therefore more useful to think in terms of sustainability or the wise use of natural resources (Tooley 1996). Sustainability is a pathway or direction that we have to move along to achieve greater balance between the social, economic and ecological environment. It is about applying the goals and principles of sustainable development aimed at achieving a better quality of life while protecting the integrity of the ecosystems (Department of Environmental Affairs and Tourism 2002). Sustainability is also about improving what we are doing while at the same time seeking to transform society so that we may live in a world that is socially and ecologically just. This will require a radical shift in the way that we do things in the future.

The concept of sustainability is necessarily broad because it embraces economic, social and ecological principles. This often leads to wide-ranging and conflicting interpretations (Tooley 1996). Different interest groups place different emphases on economic, social or ecological aspects and compromises are necessary. The degree to which compromises can be made without jeopardizing the integrity of an ecosystem or resource base, or without neglecting to provide for people's basic needs, is not a simple matter to determine. Economic sustainability refers to economic viability and integrity and focuses on economic growth that is viable and fair, and which occurs at a rate that does not exceed the ability of natural and social systems to support this growth (Department of Environmental Affairs and Tourism 2002).

Social sustainability refers to social justice and equity and stresses community participation and social justice, paying particular attention to the most vulnerable people in society. Value is attached to social capital and social networks that supporting the use of appropriate technology, and meet the basic needs of people without degrading ecological systems (Department of Environmental Affairs and Tourism 2002).

Ecological sustainability involves the conservation of biodiversity and the maintenance of ecological integrity. The integrity of the environment refers to the healthy functioning of natural ecological systems. Ecological sustainability limits the use of natural resources to a level that allows them to regenerate and it minimizes the use of non-renewable resources. Ecological sustainability also aims to reduce the amount of waste and pollution released into systems and to maintain the capacity of ecosystems to support life at the global scale (Department of Environmental Affairs and Tourism 2002).

Cultural systems are even more dynamic than biological ones and the shift from a subsistence economy to a cash economy has, along with cultural change and an increase in human needs, contributed to a weakening of 'traditional' conservation practices often leading to an overexploitation of natural resources. In some cases, 'islands' of remaining vegetation created by habitat loss through urbanization and agricultural clearance, become focal points for harvesting pressure and are sources of conflict over rights and ownership of the remaining land and resources (Cunningham 2001). In South Africa, human settlement patterns were strongly controlled by dominant political ideologies in the past. Certain laws stipulated that native Africans had legal tenure only in designated regions. Many of the original wildlife reserves in South Africa were set up in remote parts of the country, receiving public support from those in power because the land was regarded as worthless. Presently, in the central Lowveld, two key features dominate the landscape: a large area under wildlife conservation (the Kruger National Park) that is juxtaposed with densely populated, economically impoverished communities of the former homelands of Gazankulu and Lebowa (Du Toit *et al*. 2003).

Households in the communal lands of the Lowveld rely on their immediate natural environment for several resources, including fuel wood, fruits, thatching grass, mushrooms, medicinal plants, reeds and other construction material (Shackleton 2000a). Studies have shown variable impacts of land use on biodiversity within the Lowveld system (Shackleton *et al.* 1994a; Shackleton 1998; Higgins *et al.* 1999) although there is a general perception of widespread land degradation in this area. There has been a marked decline in the woodland resources, a decline that seems to be accelerating (Du Toit *et al*. 2003) with the majority of South Africa's rural population remaining dependent upon fuel wood for their primary source of domestic energy (Griffin *et al.* 1993; Shackleton 1994a; Shackleton 1994b). It is likely that many rural households will continue to be partially or wholly dependent on fuel wood for a further 20 – 30 years despite that approximately 300 000 South African households receive new electricity connections annually (Shackleton 1994b; Price 1998).

Current extraction levels for many natural resources in the communal areas appear to be unsustainable. Harvesting has increased due to increases in the local populations, the commercialization of harvesting practices and the disintegration of local controls. The growing commercialization of resource-use provides much needed cash for local households but the decline of these resources undermines livelihood security in the long term (Du Toit *et al.* 2003). A loss of biodiversity in areas that form buffer zones between the urban world and the national parks is also cause for concern. Buffer zones have the potential to act as corridors for essential gene flow within species and without them, species may become isolated or fragmented within the conservation islands (Batary and Baldi 2001; Berry 2001; Bergren *et al.* 2002).

The primary focus of the present study is to test the hypothesis that the use of woody plant resources within a communal area adjacent to the Kruger National Park is unsustainable. It is predicted that these harvesting practices have resulted in severe impacts on woody plant parameters and processes within the communal area. The above hypothesis has been tested by examining the following questions:

- What is the impact of past and present harvesting of woody plants on woody plant species diversity, density, size class structure and biomass?
- What is the socio-economic demand for fuel in the study area and how is this demand linked to household income?

- How does fuel wood demand by the chosen village compare to the supply of fuel wood that is available for harvesting on a sustainable basis?
- What is the potential maximum fuel wood harvest in a non-disturbed environment?
- What practical steps can be taken towards achieving sustainability of fuel wood harvesting and use in the long term?

CHAPTER 2

STUDY AREA

INTRODUCTION

The fieldwork for the present study was done from October 2000 to September 2001. The study area is located in the eastern section of the Mpumalanga province of South Africa. The communal area forms a part of the Mdluli tribal land, within the Nsikazi district, on the western border of the Kruger National Park. After consultation with the local forum[1], the village of Makoko (hereafter simply referred to as Makoko) was selected as the specific study site. According to the local forum, Makoko had been used for a water quality study during 1999, and the people of Makoko were therefore familiar with questionnaires and research surveys. A second and more important reason for the choice of Makoko was because Chief Izak Mdluli, Chief of the Mdluli tribe, is a resident of Makoko and it was regarded as most appropriate that the chief's village was the one to be selected for the study. The tribal offices are also located in Makoko. Since research of this nature in the area was uncommon, the forum was interested and excited by the prospect of this study.

Makoko is situated in the Lowveld of Mpumalanga, south of Hazyview, being located from longitudes 31º12'18'' to 31º14'22'' E, and latitudes 25º13'55'' to 25º14'02'' S (Figure 2.1).

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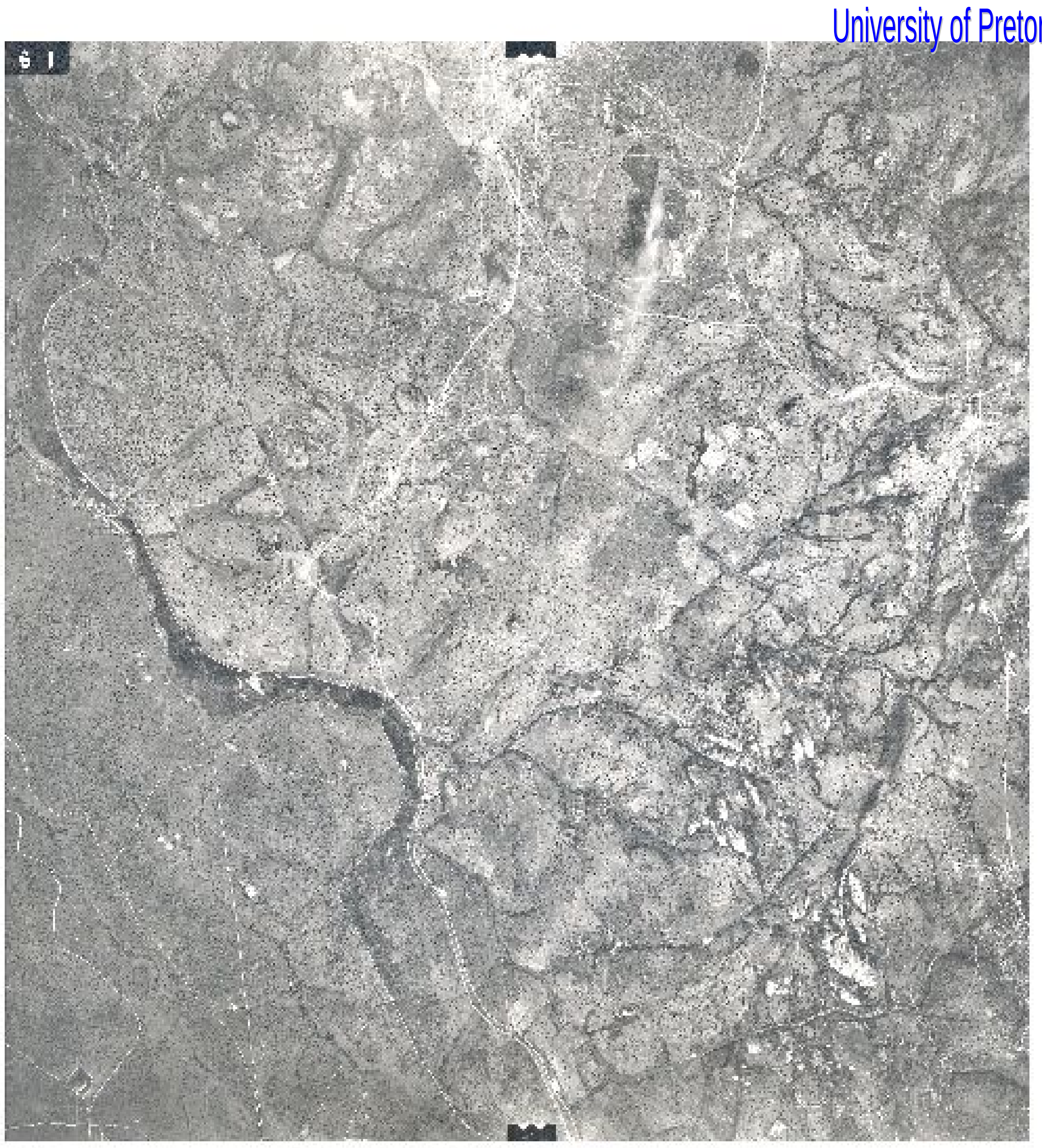
[1] Lubambiswano Forum, Tribal Office, Makoko, P.O. Box 2079, Kabokweni, 1245.



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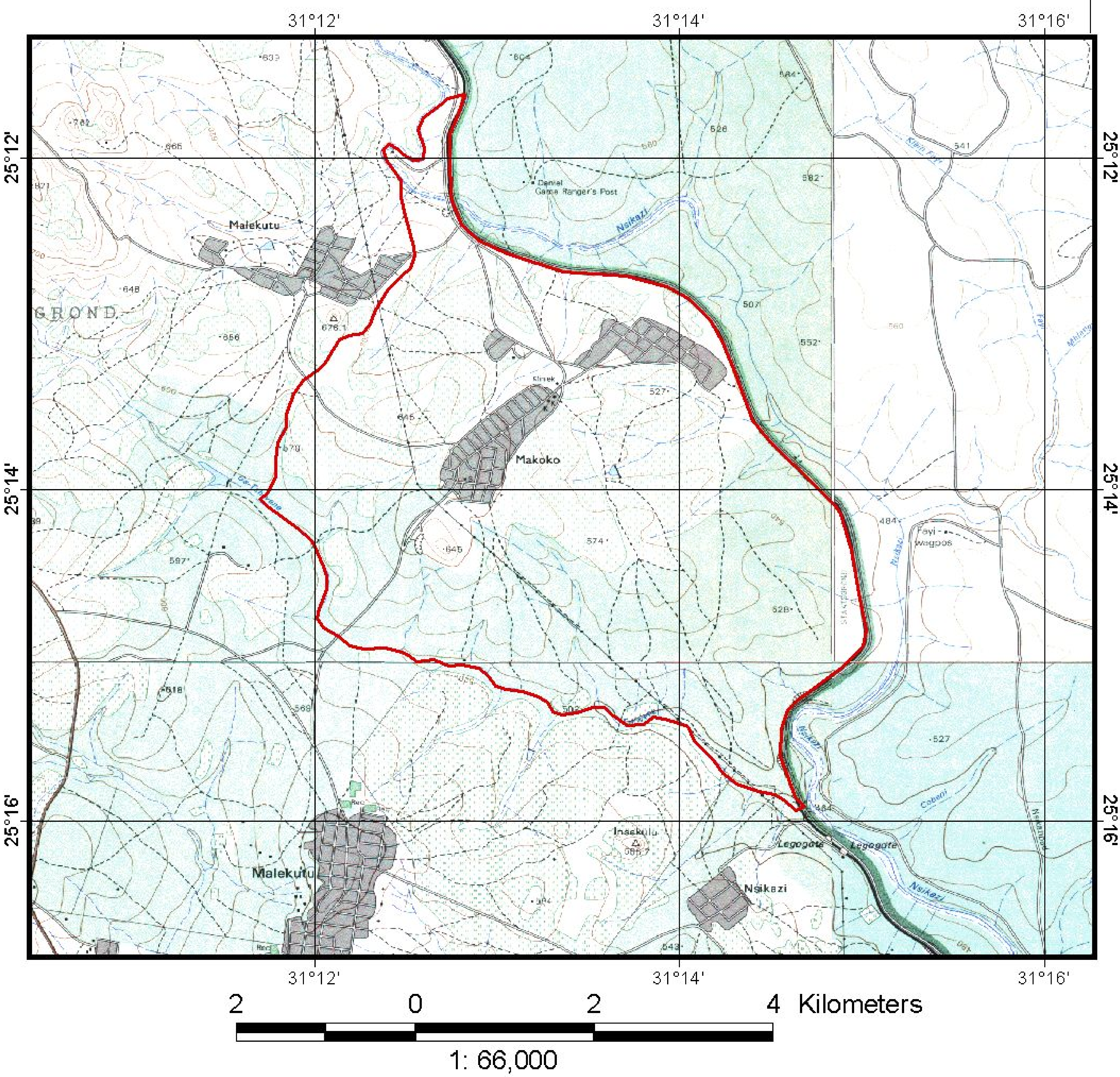


Figure 2.1 : The location of the study area in the Nsikazi district of the Mpumalanga province in South Africa relative to the Kruger National Park boundary.

Proclamation 1291 in the Government Gazette of 17 August 1962 (Republic of South Africa 1971) describes the boundaries of the Mdluli Tribal Authority, within the Nsikazi district as follows:

> "From the cement beacon situated on the boundary of the Kruger National Park and approximately 15 yards to the south of the provincial bituminized road at Numbi Gate; thence in an easterly and southerly direction along the boundary of the Kruger National Park to the point where it joins the Nsikazi River to its confluence with the Nsikazi Spruit; thence upstream along the Nsikazi Spruit to the middle of the wall of the Nsikazana Dam; thence in a straight line in a north-easterly direction to the summit of Mpameni Kop; thence in a straight line in an easterly direction for approximately 2765 yards to a cement beacon on the bank of the Nsikazi River at a point where three spruits flow into the said river at approximately the same place; thence upstream along the Nsikazi River to its confluence with an unnamed spruit on Lot no 155; thence in a straight line in a north-westerly direction across Mahushu Kop to a cement beacon situated 15 yards to the south of the provincial bituminized road from Pretorius Kop at the point where the said road joins the bituminized road between Bosbokrand and White River; thence in a south-easterly direction approximately 15 yards south of the provincial bituminized road from Pretorius Kop and parallel to the said road to the point of commencement."

The basis for the present study is a comparison of various parameters of the woody plants between the communal area of Makoko and the adjacent conservation area in the Kruger National Park. It was essential that these two areas be as similar in topography, vegetation, soil and geomorphology as possible, to avoid variation in the factors affecting the vegetation. Stereo aerial photographs of the two areas were closely examined to aid in the final selection of an appropriate study site. A suitable area within the Kruger National Park was chosen proximal to the western fence that closely resembled the environmental conditions in the communal area. The selected conservation area lies from longitudes 31º14’44’’ to 31º15’48’’ E and latitudes 25º12’36’’ to 25º14’02’’ S.

Since many of the issues that will be dealt with in this dissertation have to do with ownership of land and resources, it is important to understand the background to both study areas in terms of the movement of people, land occupancy and culture over the last few decades. Ownership issues are compounded by perceptions of ownership that vary between stakeholders. For this reason, it was deemed necessary to discuss the history of both the communal and conservation areas in detail.

HISTORY

Before European colonization, the San people who were the Stone Age inhabitants of the African subcontinent utilized the natural environment for shelter, food and subsistence (Hilton-Barber and Berger 2002). The practicalities of life combined with cultural taboos ensured that overexploitation of natural resources did not occur (Carruthers 1995). These hunter-gatherer communities were nomadic, existing in small family groups of about 15 to 25 people (Oakes 1992). Their constant movement resulted in sustainable resource-use and the survival of sufficient plant and animal life to feed succeeding generations (Cunningham 2001). In such a Stone Age society, there was no political hierarchy, wealth or trade, and food could not be stored for long periods or transported for long distances. A strong sharing ethic meant that there was no incentive to consume more than what was required immediately by a small band of people at any one time. San rock paintings show that these hunter-gatherers had the utmost respect for wildlife and that the hunt was a significant part of their spiritual life (Carruthers 1995).

From about 10000 BC up to approximately 0 AC, the lifestyle of the San hunter-gatherers remained unchanged in southern Africa (Oakes 1992). However, about 2000 years ago, migrants from central Africa began moving southwards, bringing metal-working skills with them. These Early Iron Age people are believed to have co-existed with the hunter-gatherers for at least 500 years. However, they disappeared from the archeological record around 600 AD. Although there is evidence that the original hunter-gatherer communities continued to live in the area after 600 AD, the next wave of migrants, usually referred to as the Late Iron Age people and with direct links to the ancestors of the modern Sotho and Tswana speakers, only arrived in the area sometime after 1000 AD, bringing with them cattle and the ability to cultivate crops (Hilton-Barber and Berger 2002). These skills contributed to the success of the Late Iron Age societies, resulting in rapid population increases during this time. In the early nineteenth century, European explorers came across individual settlements that were populated by 16000 to 30000 people who lived in the area known today as the North West Province (Hilton-Barber and Berger 2002).

At the beginning of the nineteenth century, the then Zulu king Shaka rose to power, starting off a chain reaction of violent disruption across the African subcontinent scattering and depleting tribes and causing wholesale destruction over most of southern Africa south of the Limpopo River. This state of continual war, known as the Mfecane, was initiated by Shaka, in an attempt to create a black empire that was militarily and territorially stronger than any chiefdom that existed then in Africa (Walton 1984). Ironically the consequences of the Mfecane were the complete breakdown of social and political structures within the tribes, leaving vast areas of the South African interior deserted and making it easier for European settlers to claim the land (Hilton-Barber and Berger 2002).

From 1836 onwards, bands of settlers of Dutch descent moved into the interior of the country, being dissatisfied with the British administration that ruled the Cape colony at that time. They set up their farms mainly in the area that was left abandoned after the Mfecane, and developed the land for agriculture (Hilton-Barber and Berger 2002).

By about 1860 the then Transvaal Republic had become divided into two distinct economic regions: settled agriculture in the south, and a hunting frontier in the north. In the southern region, African communities had generally been conquered and dispersed, or incorporated into the labour structure of British and Dutch societies. In the north, however, many African groups fought to retain a measure of independence and used access to wildlife in order to achieve this. One way to do this was to collaborate with Europeans in hunting, initially making the white settlers of the then northern Transvaal dependent on their African partners for the success of their efforts. These successful hunting partnerships had a detrimental effect on the number of wild animals in the then Transvaal Republic, and it was not long before the adverse economic effects of extravagant commercial hunting became apparent (Carruthers 1995).

By early 1860s, the economy began to suffer, bringing about the first hunting legislation. The objective of this legislation was to ensure a sustainable yield of wild animals and to perpetuate the economic welfare and security of the state. However, although not stated explicitly, the main thrust of the law was to control and restrict African access to wildlife because African people were only allowed to hunt if they were trusted servants in possession of passes and were accompanied by white people who were in charge of the firearms (Carruthers 1995).

By 1881, the above hunting legislation was still not enforced. This lead to many petitions from the citizens to the government demanding improved wildlife conservation laws as it had become abundantly clear that the wildlife of the region were in danger of disappearing altogether. The wildlife legislation of the former Transvaal Republic was finally updated in 1891, imposing some new regulations such as hunting licenses and the ownership of wildlife on private property. However, these regulations also were difficult to enforce and few people obtained hunting licenses. By the mid-1890s wildlife reduction was so apparent that the possibility of the extinction of all the wildlife in the Transvaal Republic became a real concern (Carruthers 1995).

This possibility was enhanced with the rinderpest epidemic in 1896, resulting in the loss of most of the domestic livestock and large populations of wildlife in the Transvaal Republic. The government suspended all hunting restrictions allowing free public access to wildlife to aid the destitute citizens as drought and a locust plaque had deteriorated the survival situation considerably. In addition, and because wildlife was implicated in the spread of rinderpest, its destruction was condoned officially and it was encouraged actively (Carruthers 1995).

After the rinderpest epidemic and the consequent extermination of much of the wildlife, the government closed many tracts of government land to hunters for five years. This was accompanied by a shift in emphasis from protecting wildlife countrywide through legislation to the protection of wildlife in certain special sanctuaries that were created especially for this purpose. This meant the abandonment of the conservation principle of sustainable use and the introduction of rigorous preservation in areas from which the public was excluded. Although wildlife reserves were seen as a more effective protection structure, their creation had the effect of removing the wildlife resources of certain areas from the economy (Carruthers 1995).

In 1913, the new South African Union Parliament passed the Natives Land Act (Act No 27 of the Union of South Africa), which clearly demarcated areas amounting to 8.5% of the country's total area where black people comprising 67% of the population were able to purchase land and live. These areas were referred to as Native Reserves up to 1948, where after they were called homelands. They were small and fragmented and in 1936, the Native Trust and Land Act (Act No 18 of the Union of South Africa) provided for the enlargement and consolidation of these Native Reserves by adding 6.3 million ha to the originally demarcated area creating a total area of about 16.8 million ha that was then allocated to about 6.5 million black people. Black people were required to move from white areas to these Native Reserves, with the Act giving the State the legal right to enforce the removal of whole population groups. The forced removals reached their peak between 1960 and 1980, with an estimated 3.5 million people being uprooted and resettled in new areas by 1984. Approximately 73% of the western boundary of the Kruger National Park was adjacent to these homelands (Walton 1984). This has lead to the large number of people who are occupying these areas today.

The Bantu Authorities Act of 1951 (Act No 68 of the Union of South Africa) introduced tribal systems of government for the homelands. The Transkei was the first homeland to achieve self governance and sovereign independence by 1976, followed by Boputatswana, Venda and Ciskei in 1977, 1979 and 1981 respectively. By 1984, the following six additional homelands were self-governing: Gazankulu, Kangwane, KwaNdebele, KwaZulu, Lebowa and Qwaqwa (Walton 1984). These were all integrated back into the national government by 1994.

The Kruger National Park

The first section of land to be proclaimed to later become the Kruger National Park was the small Sabi Game Reserve that was established in 1898. The original surface area was approximately 460 000 ha, with the addition of a further 1 million ha in 1904. The National Parks Act of 1926 (Act No 56 of the Union of South Africa) was adopted unanimously in 1926, adding millions of hectares of land north of the Sabie River to the area that then became known as The Kruger National Park (Fourie 1980).

James Stevenson-Hamilton was appointed as Head Ranger of the original conservation area in 1902. He noted the widespread use of snares and traps by the local people. Deadfalls, weighted falling spears, hunting dogs and other means to kill wild animals for their meat, hides and horns were prolific, leading him to conclude that under the existing circumstances, wild animals and people could not live together. The tribal people resident in the area were consequently told to return to their home areas, implying a move back into the domains of their tribal chiefs, before they planted their next crops. In compensation, they were released from paying taxes for one year. They were also told that if they had to travel in the reserve, they could only follow specific routes (Paynter and Nussey 1992).

Their exclusion from this vast conservation area meant that these rural people now lived in large communities adjacent to the reserve. In addition to the existing high population density of people that was already present in these former homelands, the additional forced removals from the reserves placed a greater pressure on the remaining areas to provide the necessary basic natural resources for survival. The results of this having happened over decades are evident today, especially when the status of the vegetation in these buffer zones is compared with that of the conservation area where there has been no public access to collect wood and other natural resources, for a period of at least 50 years (Higgins *et al*. 1999; Shackleton 1993a, b, 2000a)

Makoko village

The village of Makoko falls under the Mdluli Tribal Authority, that has jurisdiction over four separate villages: Makoko, Bekiswayo, Nyongani and Salubindza. The Swazi tribe is dominant under the Mdluli Tribal Authority, forming part of the Nguni group of people in southern Africa. They originally migrated from the Great Lakes area in the region of what is today Kenya, Tanzania and Uganda in central Africa, to settle in Swaziland in the sixteenth century (Herbst 1984). From 1969 to 1970 the Kaapmuiden-Phalaborwa railway line was built on the western border of the Kruger National Park. At that time, there were Mdluli people living at Mkhukhu, a village within the current borders of the Kruger National Park. These people were moved by officials of the South African National Parks to be resettled at Nyongani, a settlement close to the current Hazyview Station, approximately 20 km from Makoko. The name Makoko was derived from Makoko Shabangu who lived in the area earlier (Van Jaarsveld 2000).

Relationship to the Swazi of Swaziland

The relationship of this Swazi community of the Mdluli Tribal Authority to those of Swaziland, is interesting. These two communities share the same history up to the middle of the 19th century. During the reign of King Mswati I, a number of Swazi princes moved out of Swaziland to settle in the current KwaZulu-Natal and Mpumalanga. Prince Somcuba, who settled near the Crocodile River in Mpumalanga was later killed by King Mswati I but his surviving sons fled to Sekhukhuniland. Prince Bhevula also fled from Swaziland during the reign of King Mswati I and settled near White River after the Anglo-Boer war. Prince Nyamayenja and his followers settled near Piet Retief in KwaZulu-Natal (Van Jaarsveld 2000).

King Mswati I died in 1868. His son Ludvonga who was 17 years old at the time, succeeded him. However, the eldest son Mbilini of King Mswati I, from an affair, contested this accession and had to flee from Swaziland, but was given asylum by King Cetshwayo in Zululand (Herbst 1984). Some of Mbilini's followers did not go back to Zululand and settled in what are today Barberton, Nelspruit, Carolina and Ermelo. Another prince, Prince Mabhedla, and his followers also contested Ludvonga's reign and had to flee to Sekhukhuniland in the current Limpopo province. Prince Dantji of the Mpakeni tribe, settled in the Barbeton area after a dispute with one of his brothers. The exodus of all these Swazi princes from Swaziland during and after the reign of King Mswati I is the main reason for the great number of Swazi people who currently live outside Swaziland (Van Jaarsveld 2000).

Political development

The border between Swaziland and the former Zuid-Afrikaansche Republiek was settled from 1866 to 1884. This resulted in all the Swazi chieftains in South Africa falling under the authority of the then Union of South Africa after 1910, and under the Republic of South Africa after 1961. With the establishment of the Swazi Territorial Authority in 1976, and later the KaNgwane Legislative Assembly in 1977, the Swazi of South Africa became a self-governing people within the context of the former homelands, with their own central authority within KaNgwane (Van Jaarsveld 2000).

The Swazi Territorial Authority was given control over three existing regional authorities. They are the Nkomazi Regional Authority near Barberton, the Nsikazi-Legogote Regional Authority in the Nelspruit district and the Mlondozi Regional Authority in the Carolina district. Six Tribal Authorities fell under the Nsikazi-Legogote Regional Authority. They are the Mdluli Tribal Authority, the Gutswa Tribal Authority, the Nkambeni Tribal Authority, the Mpakeni Tribal Authority, the Masoyi Tribal Authority and the Mbuyane Tribal Authority. The village of Makoko in the present study is situated within the Mdluli Tribal Authority. A Tribal Chief rules each Tribal Authority. A Tribal Authority may consist of a number of Community Authorities (usually one per village) that are ruled by Headmen. These Headmen report directly to the Chief of the Tribal Authority.

The KaNgwane Legislative Assembly was established in accordance with Article 1 of the Constitution of Self-governing Territories (Act 21 of 1971 of the Republic of South Africa). It became part of the then Eastern Transvaal Province after the 1994 elections. The name of the Eastern Transvaal Province was changed to Mpumalanga in 1995 (Van Jaarsveld 2000).

Constitutional development

The first official acknowledgment of the position of Tribal Chiefs in the then Union of South Africa came with the acceptance of the Native Administration Act (Act 38 of 1927 of the Union of South Africa). The interim Constitution of the Republic of South Africa (Act 200 of 1993 of the Republic of South Africa) states that all former self-governing territories and independent territories in South Africa were to be united and regarded as national territory. Traditional Authorities are acknowledged by the Constitution and, according to Article 182 of the Constitution, the leader of a Traditional Authority whose area falls within the boundaries of a local government is an *ex officio* member of such a local authority and can be elected to any position within such a local authority (Van Jaarsveld 2000).

The history of the Mdluli ruling lineage

The Mdluli Tribe consists of baPai, Nhlanganu and Swazi-speaking people. However, the language that is used most often, is siSwati. Pai as a language is almost dead and the Nhlanganu who live among the Mdluli are reported to have abandoned their own language, Tsonga. The people of the Mdluli Tribe predominantly practice the Swazi culture today (Van Jaarsveld 2000).

The oldest record of the ruling lineage of the Mdluli dates back to a man named Silimanyama Mdluli who was born in northern KwaZulu-Natal. He settled in the area of Pretoriuskop in the current Kruger National Park in the Mpumalanga province. Silimanyama was killed at Pretoriuskop during a Swazi raid and his people then fled and were scattered (Van Jaarsveld 2000).

Silimanyama’s son and successor, Bashise, moved to the Soutpansberg in the Limpopo province where he and his followers lived under the protection of Joao Albasini. In 1864, Bashise and his people moved to Sekhukhuniland in the now Limpopo province to settle under Sekhukhune. Later, Sekhukhune became involved in warfare with European pioneers, and Bashise and his followers resettled along the Sabi River in the Mpumalanga province.

Bashise's son, Jacob Mdluli, succeeded his father in 1897 and led the Mdluli to resettle again at kaNyandaza in the Mpumalanga province. In 1926 the Mdluli moved again to the area where they live at present and where Jacob Mdluli died in 1941. After the death of his two oldest sons, Jacob's third son, Mqoshwa Zephonia Mdluli, was appointed Chief in 1964 in accordance with a subarticle of Article 2 of the Black Administration Act (Act 38 of 1927 of the Union of South Africa) as defined in the Amendment of Government Notice Number 1291 of 17 August 1962. Mqoshwa Zephonia Mdluli died on 27 October 1998. His eldest son, Izak Mdluli, was then appointed as his successor and reigns as Chief of the Mdluli Tribe today (Van Jaarsveld 2000).

The Mdluli Indigenous Authority System

The central authority within the Mdluli Tribal Area rests with the Chief and his Council. The Council consists of the Ward Headmen of each of the four settlements of the Mdluli Tribal Area, and their respective councilors. Each Headmen's Council consists of members of his settlement who are chosen by the residents of the settlement. The Council meets with the Chief every Monday at the Tribal Offices in Makoko village to discuss the week's events of each Headman's settlement. All matters concerning internal tribal politics and issues are discussed and decisions on these matters are made. Apart from the Headmen, the Chief also has one principal advisor. This man is the Chief's secretary and has a superior advisory position with the Chief (Van Jaarsveld 2000).

In the past, the Chief's family played an important role in the decisions made by the Chief. In the present day, however, the Chief's family does not necessarily live in close proximity to the Chief and therefore coming to the Monday meetings is not always possible. For this reason, the Council has largely taken over this role.

The Council also has the important task of assisting the Chief in court matters. According to the Black Administration Act (Act 38 of 1927 of the Union of South Africa) the jurisdiction of a Chief's court includes "all civil claims and disputes arising out of black law and custom between black people within his area of jurisdiction".

The land tenure system

Before 1980, stands in Makoko village were 150 x 150 m in size. Since then, and largely due to population growth, stand sizes have been reduced to 30 x 25 m. The decision regarding the size of a stand rests with the Department of Agriculture of the former KaNgwane. Settlements are now divided into streets, with stands on both sides in the form of a grid. All the stands are numbered, and each stand owner's name is recorded against the stand number in a book that is used specifically for this purpose. The book is kept at the tribal office. The portion of the land of each settlement that is considered to be the most fertile agriculturally is set aside for horticulture. The remaining portion within the settlement serves as a wood collection area and for grazing livestock (Van Jaarsveld 2000).

The procedure that a new resident must follow when applying for a stand in Makoko village is first to introduce himself or herself to the Headman, and to inform the Headman of a desire to acquire a stand. The Headman then introduces this person to the Chief as a new resident. If the resident has moved from a settlement in another tribal area to resettle in the Mdluli Tribal Area, a transfer letter from the previous Chief or Mayor of the township must be provided. This letter contains a report on the person's character and reasons for leaving the settlement or township of origin. The resident must then pay a single introductory *khonta* fee of R100 whereafter an annual payment of R6 is made. The word *khonta* literally means "to pay allegiance to" and *khonta* fees are symbolic of the resident's loyalty towards the Chief. All the residents pay the annual fee of R6, consisting of two combined payments. The *khonta* fee is R3 and an additional R3 is paid as *masimini. Masimini* is a fee that is paid for the right to practice horticulture and to graze livestock in the Tribal Ward. The Chief of the Tribal Area holds the land of the settlement in trust. Therefore the residents must pay for the right to use the Chief's land (Van Jaarsveld 2000).

Because of rapid population growth the residents of Makoko village are restricted to one stand each, except if a second stand is required for business purposes. If a man has more than one wife, the whole extended family therefore has to live on the same stand. Exceptions are made in some cases, for example to prevent quarrels between different wives of the same husband who do not want to share the same stand (Van Jaarsveld 2000).

Polygamy is not generally practiced in the area. It has been suggested that polygamy was a Swazi custom that added status to a man in the eyes of his peers. This tradition has been decreasing since the early twentieth century due to the influence of missionaries, the weakening of family and tribal customs and economic pressures. It has also been suggested that the Swazi women do not like polygamy, mainly because it causes friction within the household. However, the women do not normally prevent their husbands from having other wives (Van Jaarsveld 2000).

A young, single man is not permitted to live on his own stand before he is married. This is to avoid the problem of excessive parties. Until such time as he is married, a young man must live on his father's stand and be under his father's authority. The same rule applies to unmarried women. A woman only lives without a husband (or her father or brother) if she is divorced with children or is widowed. If the divorce is caused by the husband's behaviour, the woman and her children can remain on the original stand and the husband must get a new stand. The principle is that the original stand that is owned by the husband will one day belong to his children and that they can contact him whenever they need anything. If the divorce is caused by intolerable behaviour of the wife, she must move back to her father's stand while the children stay with their father and his people (Van Jaarsveld 2000).

Traditional rules are no longer followed with regard to adult children after their marriage. Consequently, they can choose where they want to live. Young, married couples often share a stand with their parents, but eventually they move to their own stand (Van Jaarsveld 2000).

The residents of Makoko village currently include a number of refugees from Mozambique. They are treated as normal residents and no hostility is shown towards them. Refugees who want to reside in a settlement must visit the Headman on a regular basis. The Headman will only approve such residency once he has come to know the individual over a period of time. The resident will be expected to pay *khonta* fees like all the other residents. There has been a decrease in the number of refugees coming into the Makoko village over the last few years, due to frequent police raids to remove illegal immigrants from the area as well as increasing stability and improved economic conditions in Mozambique (Van Jaarsveld 2000).

Population density

Makoko village had an estimated population of 5600 people in 1996 (Makoko Needs Assessment 1996) at the time when the population of the entire Nsikazi district was estimated at 310160 by the Central Statistics Bureau.

CLIMATE

Rainfall

In the Kruger National Park, precipitation decreases from south to north, except for the area around Punda Maria, which is situated at a higher altitude than the rest of the Park. There is a minor decrease in rainfall from west to east with a corresponding decrease in altitude. This gradient becomes more pronounced towards the escarpment on the western boundary of the Park (Gertenbach 1980). The Nsikazi district is situated in a subtropical zone with the rainy season starting in September or October and lasting until March or April. This is followed by a period of little or no rainfall. Some 80% of the precipitation occurs as quick, erratic thundershowers (Fourie 1980). The annual rainfall in the Nsikazi district ranges from 600 to 1000 mm with a long-term mean of 743.6 mm. The relatively high rainfall and absence of frost allows the grass to grow during the winter, providing green pasture out of season (Gertenbach 1983). The rainfall of the Kruger National Park oscillates between periods of above and below mean rainfall.

Rainfall cycles last approximately ten years each (Venter and Gertenbach 1986). The difference between the mean annual rainfall and a wet or dry cycle is ±26% (Venter and Gertenbach 1986).

Temperature

The mean daily maximum temperature is 30ºC in January and 23ºC in July. The mean daily minimum (early morning temperature) is 18ºC for January and 8ºC for July. Extreme minimum temperatures can fall to 7ºC in January and 4.2ºC in July (Fourie 1980).

GEOMORPHOLOGY, GEOLOGY AND TOPOGRAPHY

The main part of the study area is a flat bush and parkland savanna. There are occasional rocky inselbergs or outcrops of erosion-resistant granite (Fourie 1980). Gertenbach (1983) describes the study area as the Lowveld Sour Bushveld of Pretoriuskop, covering approximately 530 km^2 (2.8%) of the surface of the Kruger National Park. Archaean granite and gneiss form the underlying material creating an undulating landscape with distinct uplands and bottomlands.

The study area lies within the Skukuza Land System in the Pretoriuskop Land Type. The geology and geomorphological processes that have been dominant in the area have played an important role in shaping the general soil and vegetation patterns. The geology of the area consists mainly of granitoid rocks associated with the Basement Complex. These include granite, gneiss, migmatite, amphibolite and schist, of which the former three are dominant. In a small section of the area granitoid rocks belonging to the

Nelspruit Granite Suite occur, while the remainder of the area is underlain by Orpen gneiss. Mafic dykes of both pre- and post-Karoo Age occur throughout the area as intrusions in the Basement Complex. Variations in the density of the dykes as well as the granitoid rocks, which contain relatively large amounts of ferromagnesian minerals such as migmatite and amphibolite, play an important role in determining soil and vegetation patterns, and thus land types. Where these dykes occur abundantly, they have depressed the formation of typical granitic soil catenas (Venter 1990).

Rocky granite koppies and deep incisions that form seasonal streams are characteristic. Drainage occurs northwards via the Phabene and Mtshawu Streams to the Sabie River, and south and eastwards via the Nsikazi and Mbyamide Streams to the Crocodile River. The altitude varies from 550 to 650 m above sea level (Gertenbach 1983).

According to Venter (1990) the area is characterized by slightly to moderately undulating plains with a typical convex or concave land surface. The undulations become gentler towards the river valleys. The plains lie at altitudes varying from 250 to 750 m. From Pretoriuskop, the area with the highest elevation in the Land System, the plains slope gently towards the east. The plains are dissected and drained by numerous small and medium-sized seasonal streams and show a dendritic drainage pattern with two perennial rivers, the Crocodile River and the Sabie River. Small granitic hills occur in clusters at low densities.

SOILS

The strong correlation between geology and soils accentuates the geogenetic nature of the soils, which is to be expected of a relatively young erosion surface such as the

Lowveld (Venter 1986). The terrain is flat to undulating, except immediately adjacent to the Drakensberg Escarpment. The most extensive soil types are shallow, sandy lithosols, except towards the base of the catena where deeper duplex soils are common. Closer to the escarpment, deep apedal soils prevail (Shackleton 2000a). The soil pattern of the landscape corresponds with its position in the topography. The soils on the uplands are red to yellow-brown, deeply leached and varying from sand to sandy loam (6 to 15% clay). The soils are classified into the Hutton and Clovelly Forms with Portsmouth/Moriah and Paleisheuwel/Denhere respectively as the dominant Series. A characteristic feature of the landscape is that the sandy soils occur from the uplands almost to the drainage channels. This creates narrow lowlands that are relatively inconspicuous. Clay and minerals have accumulated in the lowlands, and therefore the soils in these areas are clayey with a strongly developed structure. In the vallys the Estcourt, Wasbank, Valsrivier and Sterkspruit Forms are dominant. On the banks of streams soils occur that have been deposited in recent times and have undergone little or no soil-forming processes. Such soils at times show clear layers of unconsolidated material and mainly belong to the Oakleaf and Dundee Forms (Gertenbach 1983).

Venter (1990) describes the soils of this land type as a reflection of the relatively high rainfall regime under which they have developed. They are mostly >1 m deep, and are well-developed on the crests and midslopes, and often display plinthic subsoil horizons, even in crest positions. The red and yellow apedal soils of the crests and upper midslopes (Hutton, Bainsvlei, Clovelly and Avalon Forms) occur along the footslopes of the hills leaving only narrow, inconspicuous footslopes that are dominated by duplex soils of the Kroonstad and Estcourt Forms along the drainage lines.

Many different hydromorphic soil types occur along the lower midslopes where predominantly wet or saturated soil conditions are found. Grey sand usually overlies either soft or hard plinthite, weathered rock or gleycutanic clay. Hard plinthite sometimes occurs in the solum but it is found too deep to be a diagnostic horizon. This is also true in the case of the Kroonstad Form, where hard plinthite sometimes underlies the gleycutanic B-horizon, indicating that different climatic conditions existed previously (Venter 1990).

VEGETATION

The vegetation of this portion of the Lowveld is diverse with more than 2000 plant species consisting of more than 200 tree, 600 shrub and 230 grass species. The study area partly falls in the Tropical Bush and Savanna Type Lowveld Bushveld that was described as Vegetation Type 10 and partly in the Lowveld Sour Bushveld that was described as Vegetation Type 9 by Acocks (1988). The latter occurs mainly in the communal areas. According to Low and Rebelo (1996) the study area falls in the Lowveld Bushveld, being further subdivided into areas of Mixed, Sweet and Sour Lowveld Bushveld.

Gertenbach (1983) described the vegetation structure of the uplands as an open tree savanna with relatively few low shrubs. The woody component is dominated by *Dichrostachys cinerea* subsp. *nyassana* and *Terminalia sericea*. Other dominant associated woody species include *Annona senegalensis, Antidesma venosum, Combretum apiculatum, Combretum collinum* subsp. *suluense, Combretum molle, Combretum zeyheri, Gymnosporia buxifolia, Parinari curatellifolia, Peltophorum africanum, Sclerocarya birrea, Strychnos madagascariensis*, *Strychnos spinosa* and

Ximenia caffra. This landscape is unique because many of the less common species of trees in the Kruger National Park occur abundantly in the area. Other woody species occurring within the study area include *Acacia sieberiana* var. *woodii, Albizia versicolor, Ficus sycomorus* common in the riverine vegetation but also present in the uplands of this landscape*, Lannea discolor, Piliostigma thonningii* and *Pterocarpus angolensis.* The vegetation on the small hills is comparable to that of the Malelane Mountain Bushveld.

The herbaceous layer is 1 to 2 m tall, dense (70% crown cover) and is dominated by the more sour grass species such as *Aristida congesta* susp. *congesta, Diheteropogon amplectens, Elionurus argenteus, Eragrostis atrovirens, Eragrostis lappula, Heteropogon contortus, Hyparrhenia filipendula, Hyparrhenia hirta, Hyperthelia dissoluta*, *Melinus nerviglumis*, *Pogonarthria squarrosa, Schizachyrium sanguineum*, *Setaria flabellata and Setaria perennis*. *Vernonia natalensis* is the dominant forb in the field layer. The physiognomic dominance of *Hyperthelia dissoluta* is typical of the landscape. The grass composition of the mid-slopes of the landscapes changes with grasses such as *Andropogon huillensis*, *Digitaria longiflora*, *Eragrostis capensis, Eragrostis gummiflua* and *Loudetia simplex* occurring more frequently there than in either the uplands or lowlands (Gertenbach 1983).

The lowlands in the landscape are narrow, and when they are present they form an open savanna with single trees and sparse shrubs and a dense grass cover. Dominant woody species are *Acacia gerrardii, Acacia nigrescens, Acacia nilotica* subsp. *kraussiana*, *Acacia tortilis* subsp. *heteracantha*, *Bolusanthus speciosus, Combretum hereroense*, *Diospyros mespiliformis, Euclea divinorum, Euclea natalensis, Grewia bicolor*, *Grewia hexamita*, *Grewia monticola, Mystroxylon aethiopicum, Rhus pyroides, Schotia brachypetala* and *Ziziphus mucronata*. Grasses that occur in the lowlands are *Aristida* *congesta* subsp. *barbicollis, Cymbopogon plurinodis*, *Digitaria eriantha* var. *pentzii, Eragrostis superba*, *Heteropogon contortus*, *Panicum maximum, Sporobolus fimbriatus*, *Themeda triandra* and *Urochloa mosambicensis*. Because of the sweet nature of the grasses in the lowlands they are selected by grazing herbivores and it is usually these areas that show the first signs of overgrazing (Gertenbach 1983).

Stream and riverbanks are densely vegetated, and mostly evergreen plants occur there. *Acacia robusta, Bauhinia galpinii, Diospyros mespiliformis*, *Euclea natalensis, Ficus sycomorus, Mystroxylon aethiopicum, Olea europaea* subsp. *africana, Schotia brachypetala*, *Spirostachys africana, Syzygium cordatum* and *Syzygium guineense* are the dominant woody species. The grass cover is sparse and is dominated by *Panicum maximum*. The palm *Phoenix reclinata* occurs in the sandy beds of the larger streams (Gertenbach 1983).

According to Venter (1990), the vegetation also reflects the high rainfall of the area in that hydrophilic species such as *Diospyros mespiliformis* and *Ficus sycomorus* that are associated with either drainage lines or seepage areas in the drier parts of the Land System, frequently occur on crests in the Pretoriuskop Land Type. *Terminalia sericea,* usually only dominant along hydromorphic midslopes in the drier parts of the Land System, is abundant on the crests and midslopes.

CHAPTER 3

WOODY PLANT PARAMETERS

INTRODUCTION

Conservation of biodiversity has been identified as one of the key aspects of sustainable land-use practices. It is generally believed that the human impact in non-protected areas have resulted in a decrease in biodiversity relative to protected areas, although many agro-ecosystems have an extremely rich species diversity (Shackleton 2000a). Woody plant density is affected by management practices, with some studies reporting a significant reduction in the number of woody plant stems in a communally managed as opposed to conservation area (Shackleton 1993b). An increase in woody plant stem density as a result of bush encroachment has also been reported (Skarpe 1990; Van Vegten 1993). The impact of natural resource harvesting on the woody plant height structure class has also been studied with some studies reporting a significant difference between harvested and unharvested sites (Shackleton 1993b; Higgins *et al.* 1999). Changes in the woody plant density and height structure class have a direct effect on woody plant biomass (Rutherford 1979). The woody plant species diversity, density, height structure classes and biomass will therefore be compared in the present study between sites in Makoko communal area and the Kruger National Park, to quantify the human-induced impacts on the relevant characteristics of the woody plant communities.

Species diversity

Attempts at understanding the patterns of species richness (number of species per unit area) and the factors controlling these are made difficult by problems on both a temporal and a spatial scale. It is therefore convenient to recognise components of diversity that are independently controlled. Three spatial scales of diversity can be distinguished. Alpha diversity refers to the number of species within a homogeneous community, and is usually explained in terms of equilibrium models of niche relations and governed by biological interactions such as competition. Beta diversity incorporates the concept of species turnover, or the rate at which species are replaced by others along habitat gradients, or between different communities in a landscape and gamma diversity that is independent of habitat differences. The concept of ecologically equivalent species (species that occupy the same habitat in different geographical localities) is also used. The size of the regional species pool is a function of the interaction between the alpha, beta and gamma diversities, which are variously controlled by predictable ecological and stochastic historical processes (Huntley 1991).

Whittaker (1977) distinguished between species diversity and richness. He assessed species diversity at point, alpha, gamma (landscape) and epsilon (regional) scales. Point diversity is species richness within a 1 m^2 area. Alpha diversity is described as the within-area diversity, being measured as the number of species occurring within local communities. Gamma diversity is also a measure of within-area diversity, but it usually refers to the overall diversity within a large area at the landscape scale. Epsilon diversity is a further measure of within-area diversity but at an even larger scale (for example across latitudinal gradients). He also introduced the concept of differentiation diversity or compositional turnover. Beta diversity was introduced to measure the degree of species change along a given habitat or physiographic gradient. It is therefore a measure of between-area diversity, lying between the point and alpha diversity scales, or between the alpha and gamma ones. Delta diversity is a further differentiation diversity index that lies between the gamma and epsilon diversity scales.

There are relatively few studies of the southern African savannas that have attempted to quantify the patterns of alpha and beta biodiversity within an area and that have compared the plant diversity between protected and non-protected areas (Shackleton *et al*. 1994; Lykke 1998; Shackleton 2000a). Such a comparison would provide a measure of the success or failure of protected areas as a strategy to help prevent the decline of biodiversity world-wide (Shackleton 2000a).

One of the goals of the present study is therefore to determine the impact that uncontrolled natural resource utilization has had on the woody plant species diversity of the communal area in comparison with the conservation area. It is hoped that the results from this part of the study will provide useful insight into the dynamics of woody vegetation under contrasting management practices in a savanna ecosystem.

Density

Knowledge of the density of the woody plants within an area is important for a number of reasons that are usually related to the type of land-use in the area under investigation. The presence of a plant influences the environment of its neighbours and may alter their growth rate and form. The degree to which this competitive effect will influence the plant usually depends upon the proximity of the individuals. The basis of such competition is the consumption of resources that are in limited supply. This includes the production of toxins and changes in conditions such as protection from wind and influences on the utilization by and behaviour of herbivores. Plants that grow at high densities experience stress from their neighbours early in their development, whereas plants growing at lower densities do so only when they have become mature. Any influence that reduces the rate of plant growth might be expected to delay the onset, and in turn reduce the intensity of density stress between plants. There is a linear relationship between the reciprocal of mean plant mass and density. The mass of an individual plant is a function of its starting capital (embryonic mass and endospermic reserves), relative growth rate within the environment, length of growing time and restrictions on growth rate that are imposed by the presence, character and arrangement of neighbours in the population (Harper 1979).

Density-dependent mortality or self-thinning refers to an increasing risk of death that is associated with an increasing density of the population (Silverton and Charlesworth 2001). Alien-thinning refers to situations where mortality in one plant species can be ascribed to the stress that is derived from the density of an associated plant species. Occasionally, population density may actually enhance seedling establishment, although such a positive density effect usually involves only the early stages of germination and seedling establishment. A mortality risk that increases with increasing density has regulating properties. It is a negative feedback that acts to constrain population size within narrower limits than the range of starting densities. It also is a buffer that can maintain populations at more constant levels than would be produced by natural variations in seed production and dispersal only (Harper 1979).

There is an inverse relationship between tree density and grass production and the greater the tree density, the lower the grass yield. This is particularly noticeable in savannas that are utilized by indigenous and domestic grazing ungulates in combination. However, it seems that grass yield is affected by tree density only when the tree density increases beyond a certain limit. In the False Thornveld of the Eastern Cape Province the density of *Acacia karroo* individuals that become limiting to grass production is in the region of 1000 trees per hectare. The maximum yield of edible forage (grass and browse) was shown to increase as the tree density increases up to this limit, but it declines as tree density increases further because of the negative effect of the denser tree populations on grass growth (Tainton 1999).

In the present study, both the total tree density (trees per hectare) and the number of woody stems per hectare were used to compare woody plant density between the communal and conservation areas. The influence of wood harvesting on woody plant seedling density was also determined so as to compare the success of recruitment of the woody plants between the two land-use types.

Size class structure

Communal lands offer an ideal opportunity to investigate the response of savannas to prolonged and intense disturbance and herbivore use. Knowledge of the structure of woody plant communities and populations is important for the practical management of the land, and can be used as a direct indication of recruitment success or failure of the vegetation under alternative management practices (Rathogwa 2000). Changes in the population structure of the woody plant species usually occur before changes in the species composition become apparent (Shackleton 1993a). The former are therefore useful warning indicators of mismanagement before losses of valuable plant species actually occur. Description and analysis of community structure along a utilization gradient can provide considerable insight into the dynamics of disturbance (Shackleton *et al.* 1994). Several studies have used size class structure to gain an insight into the dynamics of woody vegetation. For example, Higgins *et al*. (1999) examined changes in woody community structure under contrasting land-use systems in a semi-arid savanna of South Africa, Condit *et al.* (1998) used stem size distribution to predict population trends in a tropical tree community and Lykke (1998) assessed species composition change by means of woody plant size class distributions in savanna vegetation.

Harper (1979) described the study of trees as a study of short cuts because the long life-span and large size of a tree make many of the conventional studies of plant biology, including population dynamics, impossible or unrealistic. He discusses three short cut options to analysing the population dynamics of a forest or woodland:

- A detailed census procedure can be applied to a strictly defined age-class in a population. In practice, this usually means concentrating on the behaviour of seedlings and saplings that can be mapped and often aged by counting the apical bud scars. The information from such an age-class can sometimes be projected to account for some of the behaviour of older trees in the community.
- The dating of trees to obtain an indication of the age of the trees. If the age structure is known, both past and future states of the population can be inferred. The characteristics of growth rings can reveal more detail about the past history of the individuals, and this approach is useful in predicting past perturbances but fails to quantify the actions of the present and past management regimes.
- The assumption can be made that size reflects age. It is relatively easy to obtain a measure of the size of the trees in a population. If this assumption were true, it becomes easy to determine the age structure of forests and woodlands.

> Unfortunately, the assumption proved to be false in most cases, with even-aged forests showing marked differences between the sizes of individual trees. The use of size as a measure of age is only justified if the relationship has been formally proved by the use of some independent accurate measure of age. The temptation to use size as an index of age is strong in the tropics where annual rings are not formed and no other method of ageing a stand seems available. However, the size structure of a population of trees gives some measure of its future and can be used to make predictions about yield or to plan harvesting operations. In this case, the real ages of the trees may not be as important as the size classes. Just as the concept of a balanced age distribution can be applied to an animal population so a balanced size distribution can be envisaged as a comparable condition in a forest. In practice most forests do not have a balanced size distribution, although they may always tend to converge towards it.

In the arid savannas, an understanding of the regeneration strategies of different woody plant species could improve the resource extraction methods that are being used by rural communities. Many savanna trees regenerate vegetatively by producing sucker shoots from buds developing on the roots and stem bases (Rathogwa 2000).

If harvesting of resources by local people is sustainable, it is hypothesized that woody populations would have similar size class distribution patterns under contrasting management regimes and utilization pressure. The aim of this part of the present study was to determine the impact that past harvesting practices have had upon the woody plant community structure within the communal area. The structure of the woody plants within the communal area was compared with that of the woody plants within the conservation area. The size structure of the communities can then be used as an indication of the past and future population dynamics of the woody plants involved.

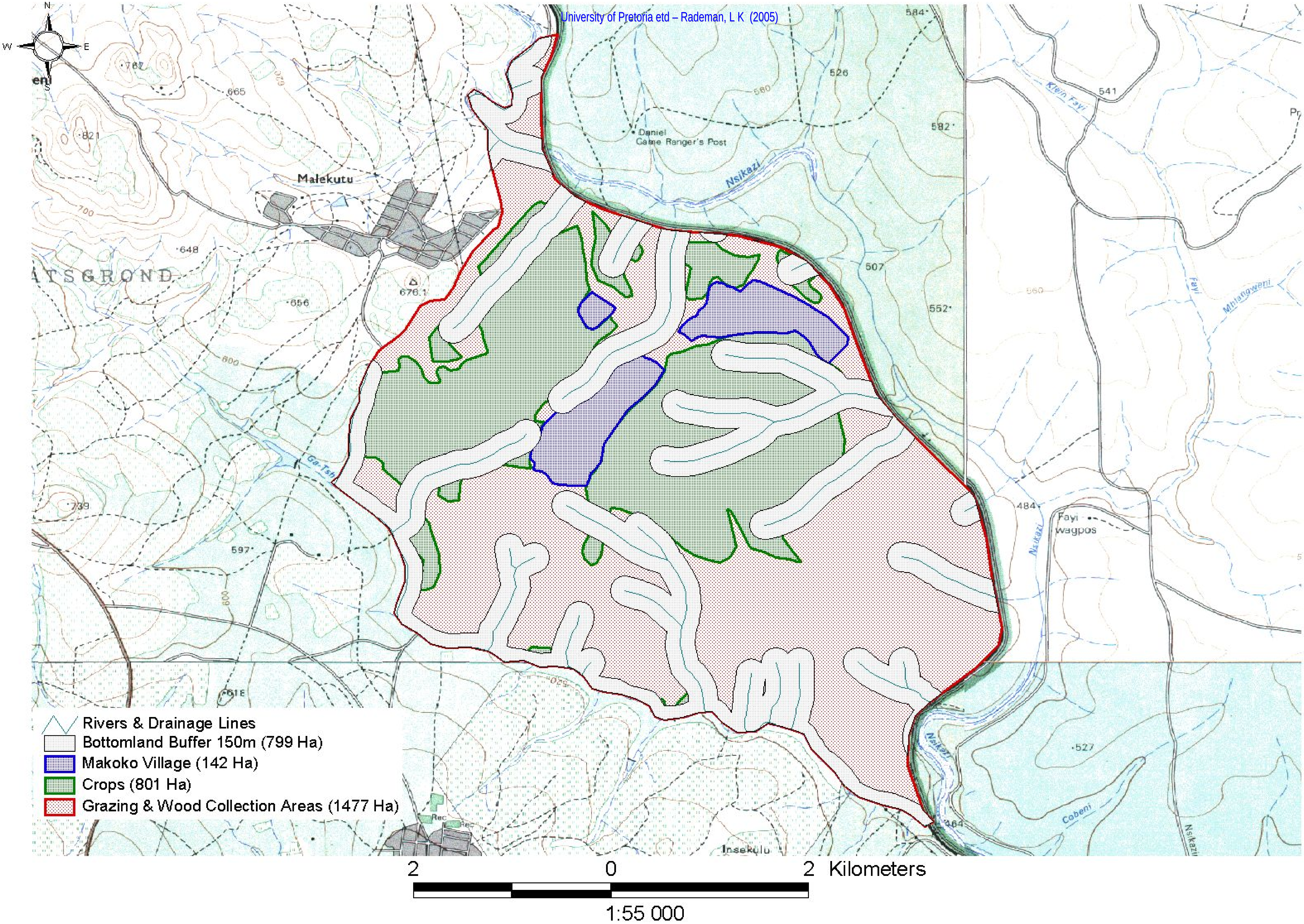
Biomass

A number of studies have used woody plant biomass to quantify the standing crop of woody plants in an area (Rutherford 1979; Shackleton *et al*. 1994; Higgins *et al*. 1999). For research on sustainable harvesting methods, it is important to have basic information on the total standing crop before the potential harvestable quantities can be determined. Based on stem diameter measurements (Rutherford 1979) this part of the present study will determine the woody plant biomass in both the communal and conservation lands in order to quantify the effect that harvesting of woody plant material has had upon the standing crop to date.

METHODS AND MATERIALS

Data collection

Granite is the dominant underlying rock formation in the study area, and because of its easy weathering characteristics, it forms the basis for the deep, red, sandy soil horizon of the region (Chapter 2). It also gives rise to the characteristic undulating landscape of the Pretoriuskop sourveld, with the uplands being clearly distinct from the lowlands, each with their own distinct vegetation. For this reason, the vegetation surveys were split into two sections: the uplands consisted of surveys done on the mid- to upperslopes, while the lowlands were surveys that were done on the lower half of the slopes (Figure 3.1).


N
W
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Malekutu
Daniel
Game Ranger's Post
Nsikazi
Klein Fayi
Fayi
Mhlangweni
Fayi wagpos
Ga-Tsh
Cabeni
Insekulu
Rivers & Drainage Lines
Bottomland Buffer 150m (799 Ha)
Makoko Village (142 Ha)
Crops (801 Ha)
Grazing & Wood Collection Areas (1477 Ha)
2
0
2
Kilometers
1:55 000

Figure 3.1: A 1:55000 topographical map of Makoko village and the Kruger National Park showing the division between the crop and wood collection areas and the up- and lowlands that were surveyed from 2001 to 2002.

For each of the two study areas, six transects were surveyed, with three being located on the uplands and three on the lowlands. The transects were positioned according to the topography of the area as based on 1:50000 aerial photographs and 1:50000 topographical maps. For the communal area surrounding Makoko, each of the six transects started from the edge of the village and radiated outwards. This was done to detect possible changes in the vegetation along a distance gradient away from the village. The first plot of each transect was located 100 m away from the last stand or planted crop on the village periphery. The transects were set out in a similar way within the conservation land, but they started from a central point with the first plot in each transect being located 100 m away from the central point.

Each transect consisted of a set of 15 plots that were spaced 100 m apart (Figure 3.2). This resulted in the fifteenth plot of each transect being approximately 1400 m away from the first one. Each plot was 5 x 50 m in size and was marked out by means of a rope and metal pegs. The rope was marked in 5 m intervals along its length. Each 5 m marker formed a subplot of 5 x 5 m. Hence each 5 x 50 m plot consisted of 10 smaller subplots. These subplots were numbered consecutively from 1 to 10. The co-ordinates for each plot were taken on site with a Magellan 300 Geographical Positioning System (GPS) instrument for later mapping. General information with regard to each plot was estimated visually and recorded manually onto the field data form. This information included aspect and slope (flat: 0 to 3°, gradual: 4 to 8°, average: 9 to 16°, steep: 17 to 26° and extreme: 27 to 45°), topography (upslope, midslope, footslope), geomorphology (flat, concave, convex) and soil type.

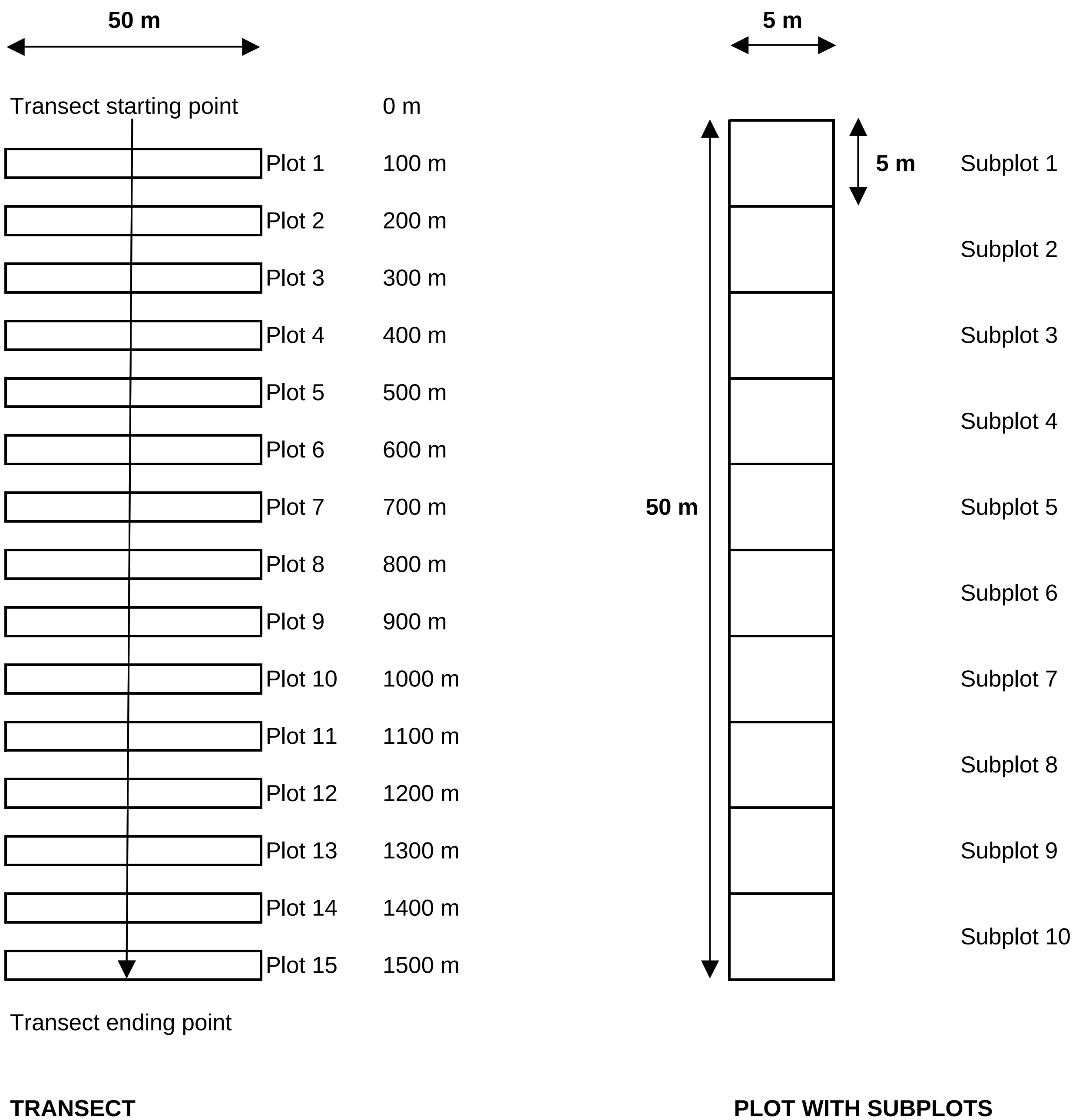

Figure 3.2: Schematic representation of a transect as surveyed during the present study in the Makoko village communal area and the Kruger National Park, Mpumalanga, South Africa from 2001 to 2002 to show the plot positioning and a plot enlargement to show the subplots (drawing not to scale).

Within every subplot, several measurements and observations were taken regarding the woody plants present. Each plant was identified, and the number of stems was noted. The stem diameter was measured in mm at a point just above the basal swelling. The height of the tree (Figure 3.3) was measured in m by using a calibrated 2 m measuring stick. In the case of trees >5 m tall, the tree height was estimated by mentally turning the tree around horizontally and then marking the location of the tallest point on the ground. The height of the tree was then measured with the measuring stick. The height at which the tree canopy was at its broadest (maximum canopy) was measured in m in a similar way to the tree height. The width of this maximum canopy was measured in two perpendicular directions. The height of the narrowest section of the canopy (minimum canopy) was also measured in m as was the diameter of the width of this minimum canopy that was measured in two directions. The proportion of dead woody material for each tree was estimated on a scale of 1 to 10 as 1: 0 to 10%, 2: 11 to 20%, 3: 21 to 30%, 4: 31 to 40%, 5: 41 to 50%, 6: 51 to 60%, 7: 61 to 70%, 8: 71 to 80%, 9: 81 to 90% and 10: 91 to 100%.

For the communal area, additional information regarding chopping damage was noted. The proportion of the whole stem that had been removed by chopping was estimated on a scale of 1 to 10, where 1 = 10% and 10 = 100% chopped. The status of these chopped stems was determined as chopped or non-chopped, dead or alive and coppiced or non-coppiced. These data aided in the interpretation of the impact of uncontrolled use of this natural resource on woody vegetation structure, density and composition.

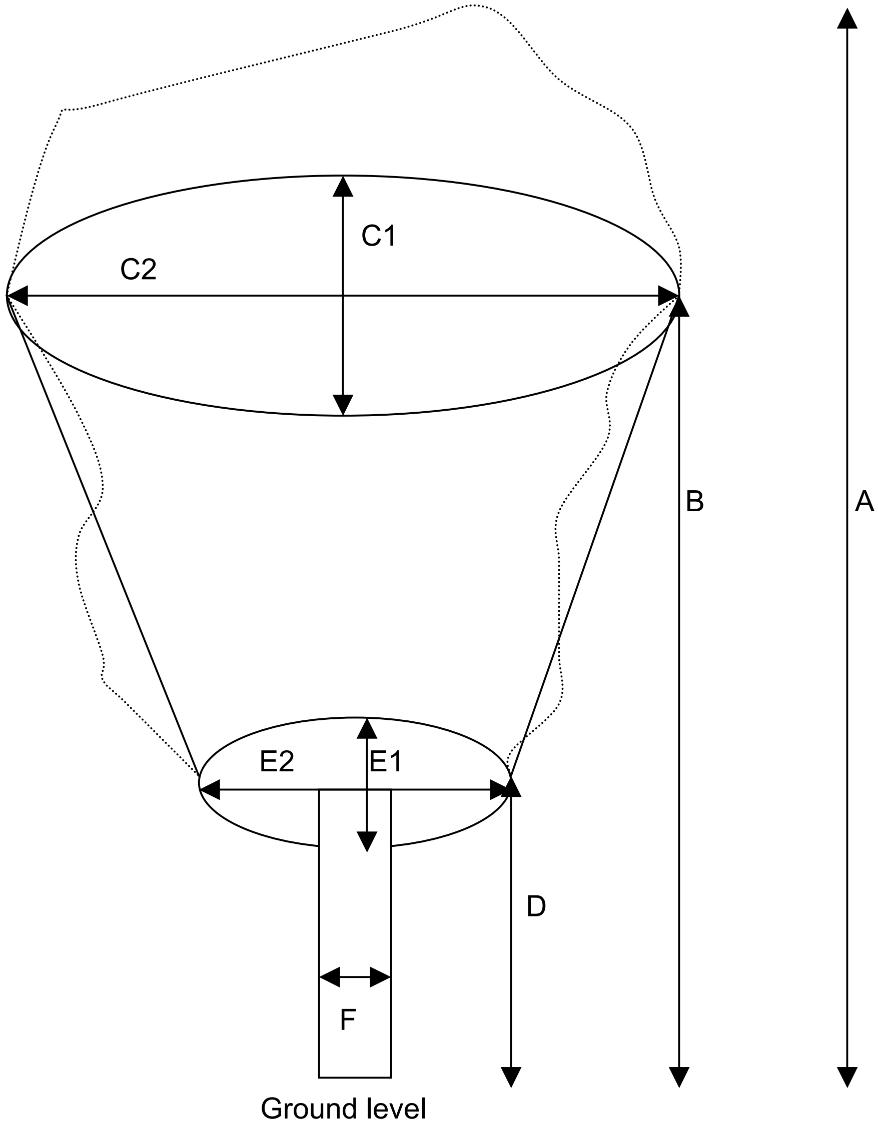

Figure 3.3 : Schematic representation of the measurements taken of a hypothetical woody plant shape, indicated by the broken lines, in the Makoko communal area and the adjacent Kruger National Park from 2001 to 2002 based on Rutherford (1979)

A	=	Full plant height (m).
B	=	Plant height at maximum canopy diameter (m).
C1 and C2	=	Maximum canopy diameter in two directions (m).
D	=	Plant height at minimum canopy diameter (m).
E1 and E2	=	Minimum canopy diameter in two directions (m).
F	=	Stem diameter (mm).

Data analysis

The field data were captured in a customised MS EXCEL® (1998) spreadsheet. The vegetation data were grouped in such a way that a combined value for each plot position, slope and land-use type could be calculated. This resulted in one value per plot position (1 to 15 plot positions) per slope (uplands or lowlands) per land-use type (communal or conservation area).

Species diversity

As used in the present study, alpha diversity or species richness refers to the total species count for a specified area. A species count for each plot position per slope per land-use type was done. A second species count was done for each transect per land-use type. A third species count was done per slope position for each land-use type. The species composition for the communal and the conservation areas were compared to judge the degree of similarity of the species. Sorensen's Similarity Index, a qualitative measurement when using presence or absence of species, was used to do this. The index is defined by the following equation of Mueller-Dombois and Ellenberg (1974):

$$SI_{sor} = [2c / (A + B)] \times 100$$

Where:	SI_{sor}	=	Sorensen's Similarity Index
	c	=	Number of common species between two relevés
	A	=	Total number of species in relevé 1
	B	=	Total number of species in relevé 2

As used in the present study, the term relevé in the previous equation refers to plot position, slope position or land-use type.

Since species presence does not give an indication of the evenness of species distribution in an area, the Shannon-Wiener Index was used to combine both components of diversity into one index by using the following equation of Mueller-Dombois and Ellenberg (1974):

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

Where: H' = Shannon-Wiener Index

p_i = the ratio of species i in the whole sample.

For the purposes of the present study, alien species refer to any species that were introduced by man into South Africa. Indigenous species include all species that have not been introduced by man.

Density

Woody plant density was expressed as the number of woody plants per hectare, the number of stems per hectare and the cumulative stem diameter per hectare (Shackleton 1993a; Higgins *et al*. 1999; Enslin *et al*. 2000). All the analyses were done separately for the two sets of data. The first data set consisted of all records, while the second data set consisted only of the records of individuals with a stem diameter ≥20 mm. For the purposes of this study, woody plants with a stem diameter of <20 mm were classed as saplings. These density values were compared between the two land-use types to judge their similarity by using Jaccard's Similarity Index. This index is a quantitative measure of similarity for any quantitative value, and is defined by the following equation of Mueller-Dombois and Ellenberg (1974):

SI_{jac} = [Mc ÷ (Ma + Mb + Mc)] x 100

Where: SI_{jac} = Jaccard's Similarity Index

Mc = Sum of density of species present in relevés 1 and 2

Ma = Sum of density of unique species in relevé 1

Mb = Sum of density of unique species in relevé 2.

Woody plant density was also expressed as the cumulative stem diameter (CSD). The cumulative stem diameter of multi-stemmed individuals was calculated by multiplying the number of stems of the individual by its mean stem diameter (mm).

Size class structure

In order to determine the size class distribution of the woody plants present, the following size classes, adapted from Westfall *et al.* (1996) were distinguished:

Class 1 : Stem diameter <20 mm : sapling

Class 2 : Height 0> to ≤1 m : dwarf shrub

Class 3 : Height 1> to ≤2 m : shrub

Class 4 : Height 2> to ≤5 m : multi–stemmed tall shrub

Class 5 : Height 2> to ≤5 m : single-stemmed medium tree

Class 6 : Height >5 m : tall tree.

The woody plants were divided into these size classes according to their stem diameter (class 1), full height measurement (classes 2 to 6) and number of stems (classes 4 and 5). The number of individuals present in each size class was calculated per plot position and per slope for the two land-use types. These values were then compared and tested for similarity by using Jaccard's Similarity Index as was explained in the previous section, but by replacing density with size class.

In addition, the woody plants were divided into classes that were based purely on their stem diameter. There were 40 stem diameter classes that were graded in 20 mm increments. Class 1 consisted of all the woody plants with a stem diameter from 0 to 20 mm, followed by the other classes in consecutive increments up to class 40 with a stem diameter from 781 to 800 mm. The size classes and number of individuals within each size class were log-transformed, and regressions were plotted. The slope and intercept of the regression lines were used as an indication of the dynamic state of the woody plant communities involved (Lykke 1998; Niklas *et al*. 2003).

Biomass

As in Shackleton (1994a), Banks *et al*. (1996) and Higgins *et al*. (1999), stem diameter was used to determine the woody plant biomass (Rutherford 1979). In the case of multi-stemmed individuals, each stem was treated as an individual plant and its biomass was calculated separately. The subset of saplings, defined as all individuals with a stem diameter of <20 mm, were not included in the biomass calculations because the diameter of their stems was not measured in the field.

Woody plant biomass was calculated by using the allometric linear regressions of Rutherford (1979). Woody plant biomass refers to the biomass of dry material of an individual and it consists of the sum of the stem, branch, twig, leaf and dead wood. It was calculated by using the following equation:

$$\ln Y = -8.5997 + 1.0472X$$

Where:	Y	= Woody plant biomass
	X	= ln $(SD)^2$. H
And where:	SD	= Stem diameter (cm)
	H	= Full plant height (cm)

The woody plant biomass was calculated for each individual and the wood biomass was calculated from the woody plant biomass. The wood biomass refers to the biomass that is contained only in the branches and stems. The difference between woody plant biomass and wood biomass is the presence of leaves, flowers, fruit and small twigs. The proportion of each individual that consists of branches and stems differs greatly among species because of structural differences. For the purposes of this study, the individual species differences were not incorporated into the calculations of biomass but growth form differences were. Working at Nylsvley Nature Reserve in the Limpopo province of South Africa, Rutherford (1979) reported a difference between woody plants in the proportion of the woody plant biomass that is constituted by the wood biomass: trees contain 93.7% wood biomass, while shrubs contain only 77.4%. In the above study, he estimated that when a combination of trees and shrubs are analysed, the wood biomass will constitute 91.8% of the woody plant biomass. In the present study, for the purposes of calculating the wood biomass, each woody plant was classified as a shrub or as a tree based on it's height size class: Classes 2 to 4 were shrubs, while Classes 5 and 6 were trees. A cumulative wood biomass (kg per ha) was calculated for each slope position (uplands and lowlands) for both land-use types (Rutherford 1979).

The quantity of fuel wood that can be harvested from the environment on a sustainable basis is known as the fuel wood supply. The calculation of the annual fuel wood supply is based upon an annual wood production rate of 3% of the standing wood biomass (Rutherford 1979; Shackleton 1994a; Banks *et al.* 1996). The surface area that is covered by each appropriate land-use type was used to convert the wood biomass values that were obtained per ha to a wood biomass value for each land-use type and slope position. The surface area of the land-use types was calculated with Geographical Information System software using a 150 m buffer around drainage lines demarcating the border between the uplands and lowlands (Figure 3.1).

Utilization

For each woody plant surveyed in the communal area the damage that was caused by chopping was quantified by making an estimation of the percentage of material, if any, that had been removed by chopping. The total number of woody plants that had been subjected to any form of chopping damage was calculated for each position along a disturbance gradient, and the data were then combined to derive a total for for each slope position. The mean percentage chopped material per woody plant was determined. For the chopped woody plants, the status of the chopped stems was also determined. The percentage of the chopped stems that were dead, alive and non-coppiced, or those that were alive and coppiced was also calculated. These values were compared by using Jaccard's Similarity Index. The relationship between the distance away from the starting point and the number of trees that were chopped (expressed as a percentage) was examined between plot positions 1 to 15, and the topographical slope positions (uplands and lowlands). A regression was used to determine the relationship between the distance away from the starting point of the transect and the mean percentage of stems chopped per individual.

Correlations, t-tests, Z-tests and one-way ANOVA were performed using SAS®[2] and linear regressions fitted in MS EXCEL®(1998). The editorial format of this dissertation follows that used by the South African Journal of Botany.

RESULTS AND DISCUSSION

Species diversity

A total of 69 woody plant species were recorded within the surveyed plots of the study area (Table 3.1). The species richness count for each of the 15 plot positions along the transects is shown in Table 3.2. For the conservation area, the highest species counts per plot position were 23 and 22 for the uplands and lowlands respectively. The communal area had a higher woody plant species diversity than the conservation area with maximum species counts of 31 and 32 per plot position for the uplands and the lowlands respectively. The number of common species between the communal and the conservation areas varied, but it was usually approximately 50% of the total species count (Table 3.2).

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[2] SAS® Version 8.2 from SAS Institute Inc., SAS Campus Drive, Cary, NC, 27513

Table 3.1: Woody plant species that were recorded in Makoko village communal area and the Kruger National Park, Mpumalaga, South Africa from 2000 to 2001 (Van Wyk and Van Wyk 1997)

Scientific name	English name	Scientific name	English name
Acacia grandicornuta	Horned thorn	*Ficus sur*	Broom cluster fig
Acacia nilotica	Scented thorn	*Ficus sycomorus*	Common cluster fig
Acacia robusta	Ankle thorn	*Grewia monticola*	Silver raisin
Acacia sieberiana	Paper bark thorn	*Gymnosporia buxifolia*	Common spike-thorn
Acacia tortilis	Umbrella thorn	*Gymnosporia mossambicensis*	Black forest spike-thorn
Albizia versicolor	Large-leaved false thorn	*Gymnosporia senegalensis*	Red spike-thorn
Annona senegalensis	Wild custard apple	*Heteropyxis natalensis*	Lavender tree
Antidesma venosum	Tassel berry	*Hippobromus pauciflorus*	False horsewood
Bauhinia galpinii	Pride-of-De-Kaap	*Lannea schweinfurthii*	False marula
Carissa bispinosa	Forest num-num	*Lantana camara*	Lantana
Catunaregam spinosa	Thorny bone-apple	*Olea europaea*	Wild olive
Combretum apiculatum	Red bushwillow	*Pappea capensis*	Jacket plum
Combretum collinum	Variable bushwillow	*Philenoptera violacea*	Apple-leaf
Combretum hereroense	Russet bushwillow	*Psidium guajava*	Guava
Combretum imberbe	Leadwood	*Rhoicissus tridentata*	Bushman's grape
Combretum molle	Velvet bushwillow	*Rhus dentata*	Nana-berry
Combretum zeyheri	Large-fruited bushwillow	*Rhus leptodictya*	Mountain karee
Dalbergia melanoxylon	Zebrawood	*Rhus chirindensis*	Red currant
Dichrostachys cineria	Sicklebush	*Rhus pyroides*	Common wild currant
Diospyros lycioides	Bluebush	*Syzygium cordatum*	Water berry
Diospyros mespiliformis	Jackal-berry	*Terminalia sericea*	Silver cluster leaf
Dombeya rotundifolia	Wild pear	*Trichilia emetica*	Natal mahogany
Ehretia amoena	Sandpaper bush	*Vangueria infausta*	Wild medlar
Erythroxylum delagoense	Small-leaved coco tree	*Vernonia colorata*	Lowveld bitter-tea
Erythroxylum emarginatum	Common coco tree	*Ximenia americana*	Blue sourplum
Euclea crispa	Blue guarri	*Ximenia caffra*	Sourplum
Euclea divinorum	Magic guarri	*Zanthoxylum capense*	Small knobwood
Euclea natalensis	Natal guarri	*Ziziphus mucronata*	Buffalo-thorn

Table 3.2: Woody plant species richness of the uplands and lowlands of the Makoko village communal area and the Kruger National Park, Mpumalanga, South Africa as surveyed from 2000 to 2001 to show the plots and transects used and Sorensen's Similarity Index (%) for each

Plot position	Species count				Common species		Sorensen's similarity index (%)	
	Conservation area		Communal area					
	Up-lands	Low-lands	Up-lands	Low-lands	Up-lands	Low-lands	Up-lands	Low-lands
1	23	18	18	19	12	8	59	43
2	16	22	23	15	11	8	56	43
3	20	15	20	21	11	6	55	33
4	17	21	17	26	9	11	53	47
5	21	21	28	19	11	9	45	45
6	16	17	18	23	10	9	59	45
7	12	18	19	27	7	11	45	49
8	19	22	25	27	11	11	50	45
9	14	21	26	23	10	13	50	59
10	11	17	24	29	8	11	46	48
11	14	17	29	32	10	14	47	57
12	14	16	26	27	9	12	45	56
13	21	15	30	22	14	8	55	43
14	16	21	24	20	9	12	45	59
15	15	11	31	23	12	8	52	47
Transect 1	27	31	43	37	17	20	49	59
Transect 2	29	28	36	39	22	24	68	72
Transect 3	31	31	29	38	20	24	67	70
All transects	46	45	47	49	37	37	80	79

This proportion is reflected by the similarity indices that were calculated for these areas (SI_{sor} = 33 to 59%). On a transect scale, the conservation area had a maximum alpha diversity of 31 species in each of the uplands and lowlands, whereas the communal area had values of 43 and 39 respectively. The number of common species between the two land-use types showed similarity indices ranging from a low of 49% to a high of 72% between the transects (Table 3.2). Overall, there were 37 common species between the two land-use types, with similarity indices of 80% and 79% for the uplands and lowlands respectively (Table 3.2). The conservation area uplands and lowlands contained nine and eight species on the up- and lowlands respectively that were not found within the communal area. However, the communal up- and lowlands contained ten and twelve species respectively that were not found within the conservation area. In total, the conservation area has 11 unique species and the communal area 16 (Table 3.3). Of the unique woody plant species in the communal area, only the two alien invasive species *Lantana camara* and *Psidium guajava* (Henderson 2001) occurred at a frequency of >1% of all the woody plant individuals in both the uplands and the lowlands. The communal uplands contained *Psidium guajava* at a frequency of 1.3% and *Lantana camara* at one of 17.6%, while the lowlands contained *Psidium guajava* at a frequency of 3.8% and *Lantana camara* at one of 10.0%. Shackleton (1993b) found that of the species unique to a harvested site, only *Lantana camara* formed >0.5% of the total number of stems in the area.

There was a significant increase in woody plant species richness along a disturbance gradient in the communal area for both the uplands (r^2 = 0.50, t = 3.64; P<0.01) and lowlands (r^2 = 0.17, t = 1.61; P<0.01) although neither were strong correlations, especially in the case of the lowlands.

Table 3.3: Woody plant species unique to the conservation area of the Kruger National Park, or communal area of Makoko village, Mpumalanga, South Africa as surveyed from 2000 to 2001 showing uplands and lowlands

	UPLANDS		LOWLANDS	
	Conservation area	Communal area	Conservation area	Communal area
** Acacia grandicornuta*				*Y*
** Acacia nilotica*		*Y*		
# Albizia versicolor			*Y*	
# Bauhinia galpinii			*Y*	
# Combretum collinum			*Y*	
Combretum zeyeri	*Y*			*Y*
** Diospyros lycidoides*				*Y*
# Lycioides rotundifolia	*Y*		*Y*	
** Erythophylum delagoense*		*Y*		*Y*
** Erythrophylum emaginatum*				*Y*
# Euclea crispa			*Y*	
Ficus sur	*Y*			*Y*
** Ficus sycomorus*		*Y*		
# Grewia monticola	*Y*			
Heteropyxis natalensis		*Y*	*Y*	
# Lannea schweinfurthii	*Y*		*Y*	
*~*Lantana camara*		*Y*		*Y*
# Philenoptera violacea	*Y*			
** Olea europae*				*Y*
# Piliostigma thonningi	*Y*		*Y*	
~ Psidium guajava*		*Y*		*Y*
** Rhoicissus tridentata*		*Y*		
# Rhus dentata	*Y*			
** Syzygium cordatum*				*Y*
** Trichilia emetica*				*Y*
** Vangueria infausta*		*Y*		
** Vernonia colorata*		*Y*		
** Ximenia americana*		*Y*		
# Ximenia caffra	*Y*			
** Zanthoxylum capense*				*Y*

*# unique to conservation area * unique to communal area ~ exotic species*

There was no significant difference between the woody plant species richness of the conservation and communal areas ($t = 0.58$; $P>0.05$). However, there was a significant difference in woody plant species richness between the uplands and lowlands of both areas combined ($t = 6.14$; $P<0.01$). These results for species richness alone may suggest that topography plays a dominant role over land-use type in determining the species diversity of the study area. Similar studies in savannas have concluded that differences in land-use are secondary correlates of vegetation pattern and that topography and geomorphology are of primary importance (Venter *et al.* 1989; Coughenour and Ellis 1993). A study by Higgins *et al.* (1999) did not provide convincing evidence of this view, but did suggest that there is some interaction between natural hierarchical determinants and human impact influences on vegetation pattern.

Alternatively, the Shannon-Wiener Index, when combining both species richness and evenness indicates that both the communal uplands and lowlands are more diverse (H' = 2.91; H' = 3.00) than the conservation uplands and lowlands (H' = 1.80; H' = 2.17). Overall, the lowlands have the higher evenness of species, suggesting that the lowlands are less patchy in terms of species distribution than the uplands. However, the larger difference in the H'-value between the uplands and lowlands in the conservation area was not observed in the communal area. This would suggest that homogenization is taking place within the woody vegetation in the communal areas. These results also suggest that within the communal area the human impact effects are paying a larger role than topographical position. However, the difference in the H'-values within the conservation up- and lowlands is approximately half the difference between the mean H'-values between land-use types. This would suggest that the land-use is playing a larger role in characterizing the species diversity than the topographical position.

There have been numerous studies that compared woody plant species diversity of protected areas with communal ones. These studies seem to have contradictory results with some showing almost no change and some showing several differences. Shackleton (1993a) investigated the demography and dynamics of the dominant woody species in a communal and protected area of Mpumalanga province, South Africa and found that the communal area had 20 species fewer than the protected area. Shackleton (1993b) also investigated fuel wood harvesting and its sustainable use in Mpumalanga. He found that most species were common to both the communal and protected lands. However, their relative abundance was markedly different. In the above study 27 species were recorded in the unharvested site that were not present in the harvested one. Six species were found in the harvested site, but not in the unharvested one. They confirmed positive harvesting selection for particular woody plant species through the examination of fuel wood bundles and informal interviews. Most of the respondents stated that they did not chop wood from wild fruit trees, although not all the people who were questioned shared this respect. In addition, it was reported that some respondents, especially the younger ones, failed to recognise the less common wild fruit tree species.

Shackleton *et al.* (1994) studied the vegetation community structure and woody plant species composition along a disturbance gradient in a communally managed South African savanna. Their work showed that harvesting and other impacts that are associated with communal area management have caused a significant reduction in woody plant species richness with increasing proximity to human settlements. Despite this, their results did not indicate a clear use-based difference when comparing near, mid and far plots. It was suggested in the above study that the floristic composition was still primarily a result of local environmental determinants. It was also clear that certain woody plant species responded strongly to disturbance, as was evident from a significant gradient in species richness away from human settlements. They termed those woody plant species that exhibited trends of use obligate sensitive species. These species showed a marked decline in abundance with increasing proximity to a human settlement and were considered to be at risk of local extinction within the area studied.

Higgins *et al*. (1999) also examined the changes in woody plants in terms of community structure and species composition under contrasting land-use systems of subsistence farming, wildlife conservation and cattle ranching in Mpumalanga, South Africa. They found the subsistence farms had an altered species composition and decreased species richness of woody plants. These reductions translated into a reduced distributional range and the quantity of useful plant products for rural inhabitants. The mean woody plant species richness per transect ranged from 13 to 33 species, with land-use significantly influencing species richness. The communal grazing lands had fewer species than the other two land-uses. These results were more apparent on the uplands than the lowlands. Shackleton (2000a) compared the woody plant diversity in protected and communal areas of the Lowveld Savanna of South Africa and showed that the vegetation in the communal lands had more bare ground but not fewer species than the protected areas. The above study reported that at the point scale (1 m^2), the communal area had 17% more plant species than the conservation area. At the plot scale (1000 m^2) the communal area also had significantly higher plant species richness than the adjacent conservation area, containing 11% more plant species. However, the beta diversity reflected a turnover of approximately 40% in plant species along the catenal gradient from the uplands to the lowlands with no difference in species richness between the communal and protected areas.

Intense harvesting pressure on the woody vegetation around human settlements may cause a change in the micro-environment in localised areas within the harvesting zone, creating small islands or niches for the establishment of new species and resulting in increased patchiness in the environment (beta diversity).

The introduction of domesticated fruit trees into communal areas is a contributing factor towards creating a higher woody plant species diversity there. Most homes have at least one paw-paw tree *Carica papaya*, a litchi tree *Litchi chinensis*, a mango tree *Mangifera indica*, and a guava tree *Psidium guajava* in their gardens (Foxcroft *et al.* 2001). The fruit from these trees provide a valuable food source for the rural people living in these areas providing a continual food supply to human and animal seed dispersal vectors. The occurrence of other non-fruit tree alien invasive species such as *Lantana camara* is also associated with these communal areas, further adding to the species count there. Alien species tend to establish and flourish in disturbed, overgrazed lands where they are able to outcompete the natural vegetation for available resources (Henderson 2001).

Density

The communal area contained 22% fewer woody plants per ha on the uplands ($Z = 13.33$; $P<0.01$) but 15% more woody plants per ha in the lowlands ($Z = -5.98$; $P<0.01$) when compared to the conservation area (Table 3.4, Figure 3.4). However, when saplings were excluded from the sample, the up- and lowlands of the communal area had 61% and 13% fewer woody plants per ha than the conservation area respectively ($Z = 20.53$; $P<0.01$) ($Z = -5.57$; $P<0.01$).

Table 3.4: The density in plants per ha and stems per ha for woody plants of the uplands and lowlands of the communal area around Makoko village and the conservation area within the Kruger National Park, Mpumalanga, South Africa from 2000 to 2001 when including and excluding saplings

Item	Uplands		Lowlands		Mean	
	Conservation area	Communal area	Conservation area	Communal area	Conservation area	Communal area
Woody plants per ha:						
Saplings included	5748	4477	2983	3435	4366	3956
Saplings excluded	2816	1084	1539	1343	2177	1214
Stems per ha:						
Saplings included	8841	6276	4080	4982	6461	5629
Saplings excluded	5909	3376	2220	2959	4065	3168
Saplings per ha	2932	3393	1444	2092	2188	2743

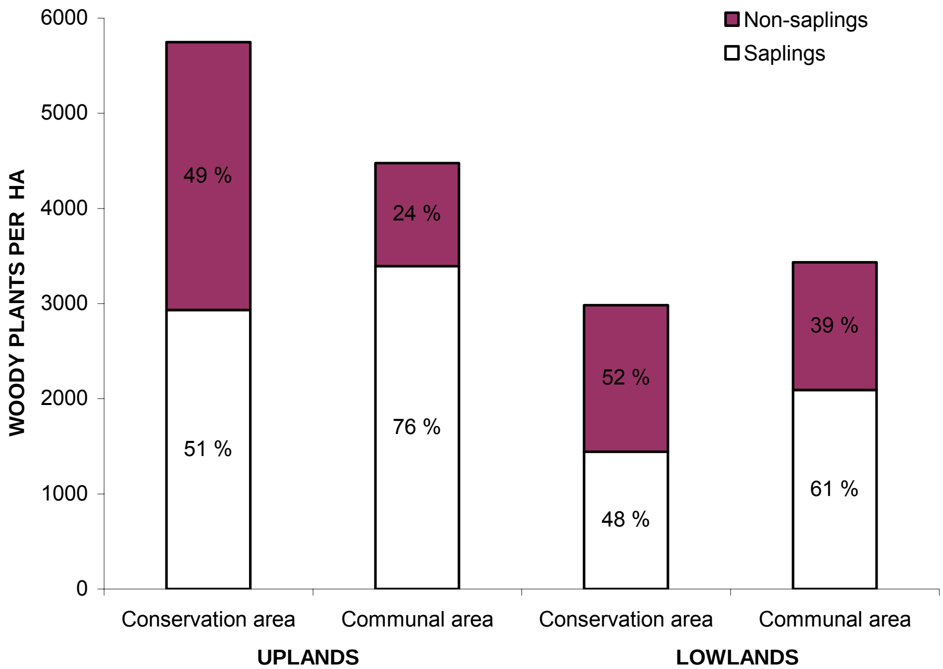

Figure 3.4: Woody plant density in plants per ha for the uplands and lowlands of the communal area of Makoko village and the conservation area within the Kruger National Park, Mpumalanga, South Africa from 2000 to 2001 showing percentage contribution of saplings (stem diameter <20 mm) and non-saplings (stem diameter ≥20 mm).

There was a significantly higher woody plant density on the uplands than the lowlands in both the conservation ($Z = 31.39$; $P<0.01$) and communal areas ($Z = 12.43$; $P<0.01$). When the number of woody plants per hectare was plotted against the distance away from the settlement, a significant linear relationship ($r^2 = 0.42$; $t = 3.90$; $P<0.01$) was found for the uplands when including saplings, and one of $r^2 = 0.31$ ($t = 4.85$; $P<0.01$) when excluding the saplings. The lowlands also showed similar significant linear relationships for all the woody plants ($r^2 = 0.13$; $t = 4.22$; $P<0.01$) and when excluding the saplings ($r^2 = 0.21$; $t = 4.98$; $P<0.01$).

It is well documented that the uplands of the sourveld generally have a significantly higher woody plant density than the lowlands (Gertenbach 1983; Venter 1990). In the present study the woody plant density in the conservation area when including saplings, is similar to that reported by Shackleton (1993a) who found a density of 5547 woody plants per ha for a protected site. He also showed that the mean density of each of seven woody plant species differed greatly between the two types of sites, with the density curves for the protected area being generally higher than those for the communal area. The communal area in the above study had a density of 5211 stems per ha which is higher than that found in the present study. Shackleton (1993b) found a density of 5583 and 5070 woody stems per ha respectively for unharvested and harvested sites. He also found that these densities were related to the distance away from a settlement (degree of disturbance) ranging from 2367 woody stems per ha closest to a settlement, to 9000 woody stems per ha at the furthest point away from a settlement. Higgins *et al*. (1999) found no consistent significant differences in woody stem density between land-use classes or slope position but within a communally managed area, there was a clear trend of increasing woody plant density with increasing distance away from a human settlement.

In the present study, the relative proportion of saplings between the two land-use types is marked, with the uplands and lowlands of the conservation area consisting of 51 and 48% saplings versus 76% and 61% in the communal area respectively (Figure 3.4). The high number of saplings found in the communal area seems to be an indication of recruitment or of increased coppicing by the woody plants after harvesting. Although the increased number of saplings after harvesting may be interpreted as the initial stages of bush encroachment (Shackleton 1993a), Shackleton (1993b) demonstrated that the regeneration capacity of a harvested woody plant community remains strong after harvesting and when the harvesting pressure was reduced or stopped then the community had the potential to revert back to a structure of an unharvested community in a relatively short time. In the above study, it was hypothesised that the greater sapling density in the harvested area was related to grass cover and height. In the communal areas, the grass is kept relatively short by livestock grazing that consequently reduces the competition for woody plant seedlings.

An important determinant of woody plant seedling establishment is intra- and interspecies competition from other plants, both woody and herbaceous (Smit *et al*. 1996). In certain species seedling establishment is unaffected by tree canopy cover while in others it is limited to between-canopy environments (Smit *et al*. 1996). In the Eastern Cape region, shading increased the density of surviving *Acacia karroo* seedlings (O'Connor 1995) while at Nylsvlei in the Limpopo province, shading decreased the density of surviving *Acacia tortilis* seedlings (Smith and Shackleton 1988). Smith and Goodman (1986) found that *Euclea divinorum* has the ability to establish under canopies, while seedlings of several *Acacia* species are distinctive in that they fail to establish under the canopy of any established woody plant regardless of species.

It is generally believed among the range and forage scientists that overgrazing induces bush encroachment (Van Vegten 1983; Skarpe 1990). Skarpe (1990) found that the increase in shrub abundance with heavy grazing was generally accounted for by shallow rooted species, suggesting that they are favoured by an increase in water availability in the soil surface following overgrazing of the grass layer. The importance of competition from herbaceous plants as a determinant of woody plant seedling establishment is reflected in several studies. Knoop (1982) observed that on a site that was dominated by *Acacia* species, large numbers of woody plant seedlings germinated and survived in a plot cleared of herbaceous vegetation, while only a few were found in a control plot. Smit *et al*. (1996) reported that *Colophospermum mopane* seedlings cannot establish on soil with a good grass cover, but high rates of *Prosopis* emergence and establishment on long-term protected plots with good grass cover were also recorded. In the above study, the eradication of mature trees in the Eastern Cape province did not prevent the establishment of *Acacia karroo* seedlings. This counters the widespread generalised assumption that long-term and/or heavy grazing is a pre-requisite for increased rates of woody plant establishment (Smit *et al*. 1996). However, Smit and Rethman (1992) indicated that while woody plants increased in Sourish Mixed Bushveld that was lightly grazed in the dormant season over a period of 52 years, the rate of increase in paddocks that were subjected to more severe grazing was considerably higher.

The lowlands of the communal area of the present study are utilized by large numbers of domestic grazing livestock. The difference in grass species composition between the uplands and lowlands of the study area is marked, with more palatable grass species being found on the lower slopes where the soil contains more clay (Gertenbach 1983; Venter 1990). The livestock feed selectively in this zone, resulting in overgrazing of this sweeter type of grassland. The overutilization of the grass in this area can cause bush encroachment because the grass cannot outcompete the woody plant seedlings that establish there at a greater rate than the grasses. In addition, the reduction in the grass biomass would result in more resources being made available for woody plant growth. The lowlands are closer to the water sources that are used by the people living in the village. Consequently, they contain more footpaths than the uplands. The resultant extensive trampling affects the vigour of the grasses in the area negatively, and encourages the establishment of woody plant seedlings.

Terminalia sericea and Dichrostachys cinerea

The number of stems per ha of *Terminalia sericea* is higher on the uplands within the conservation area than in the uplands of the communal area ($Z = 39.32$; $P<0.01$). The difference in number of stems per ha for *Terminalia sericea* on the lowlands within the communal area when compared with that in the conservation area was not significant ($Z = 2.44$; $P>0.05$). The mean number of stems per ha for T*erminalia sericea* on the up- and lowlands of the conservation area respectively are 185.54 stems per ha (range: 129.78 to 304.89; SD: 52.04) and 39.53 stems per ha (range: 3.56 to 95.11 stems per ha; SD: 30.323. When the number of stems of *Terminalia sericea* was plotted along the disturbance gradient there was a significant increase in number of stems per ha with a decrease in disturbance for both the uplands ($r^2 = 0.57$; $t = 3.22$; $P<0.01$) (Figure 3.5) and the lowlands ($r^2 = 0.40$; $t = 3.35$; $P<0.01$) (Figure 3.6).

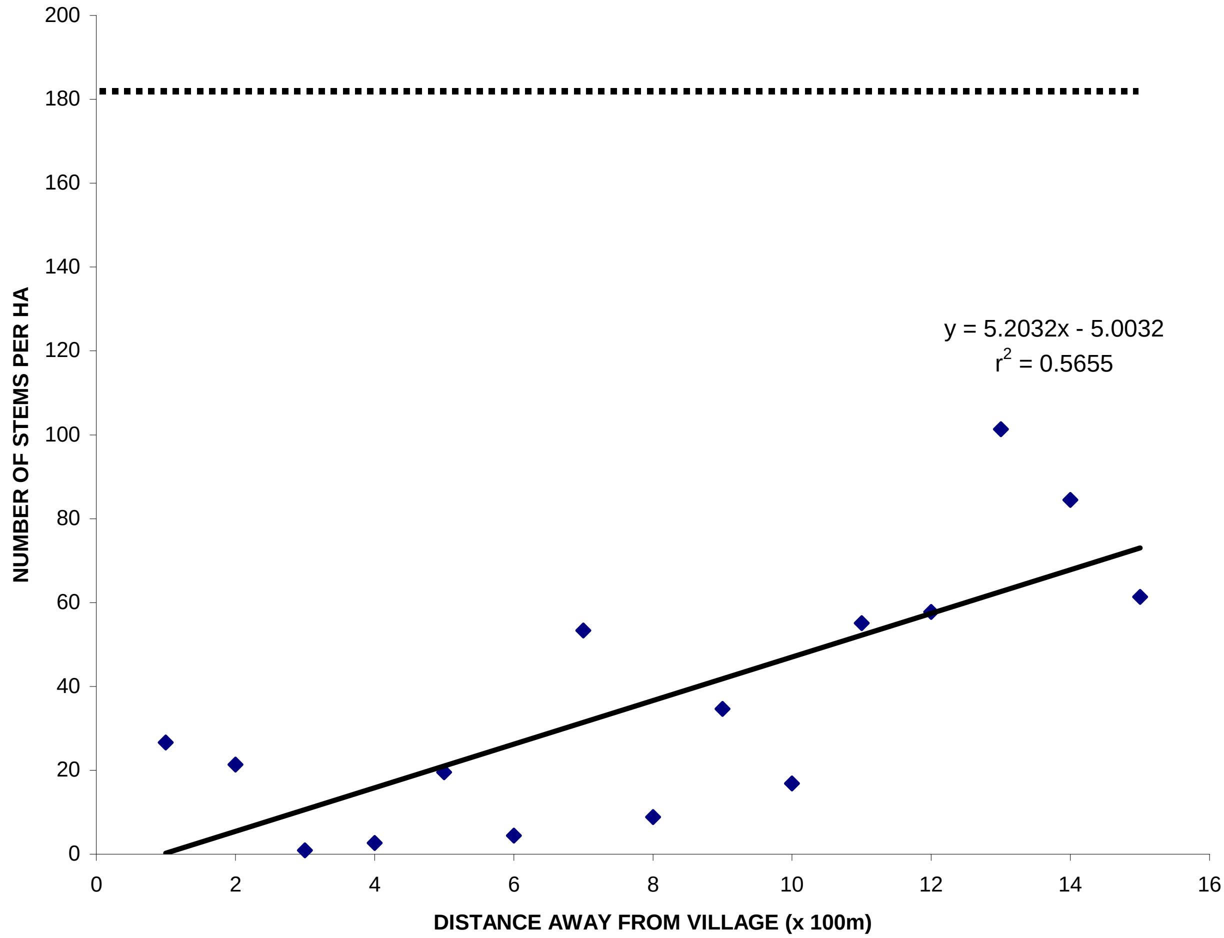

Figure 3.5: Linear regression of the density of *Terminalia sericea* expressed as number of stems per ha along a disturbance gradient (distance away from the village: 1 = 100m) in the uplands of the communal area surrounding Makoko village, Mpumalanga, South Africa from 2000 to 2001 (........ perforated line indicates the mean number of *Terminalia sericea* stems per ha for the conservation area uplands)

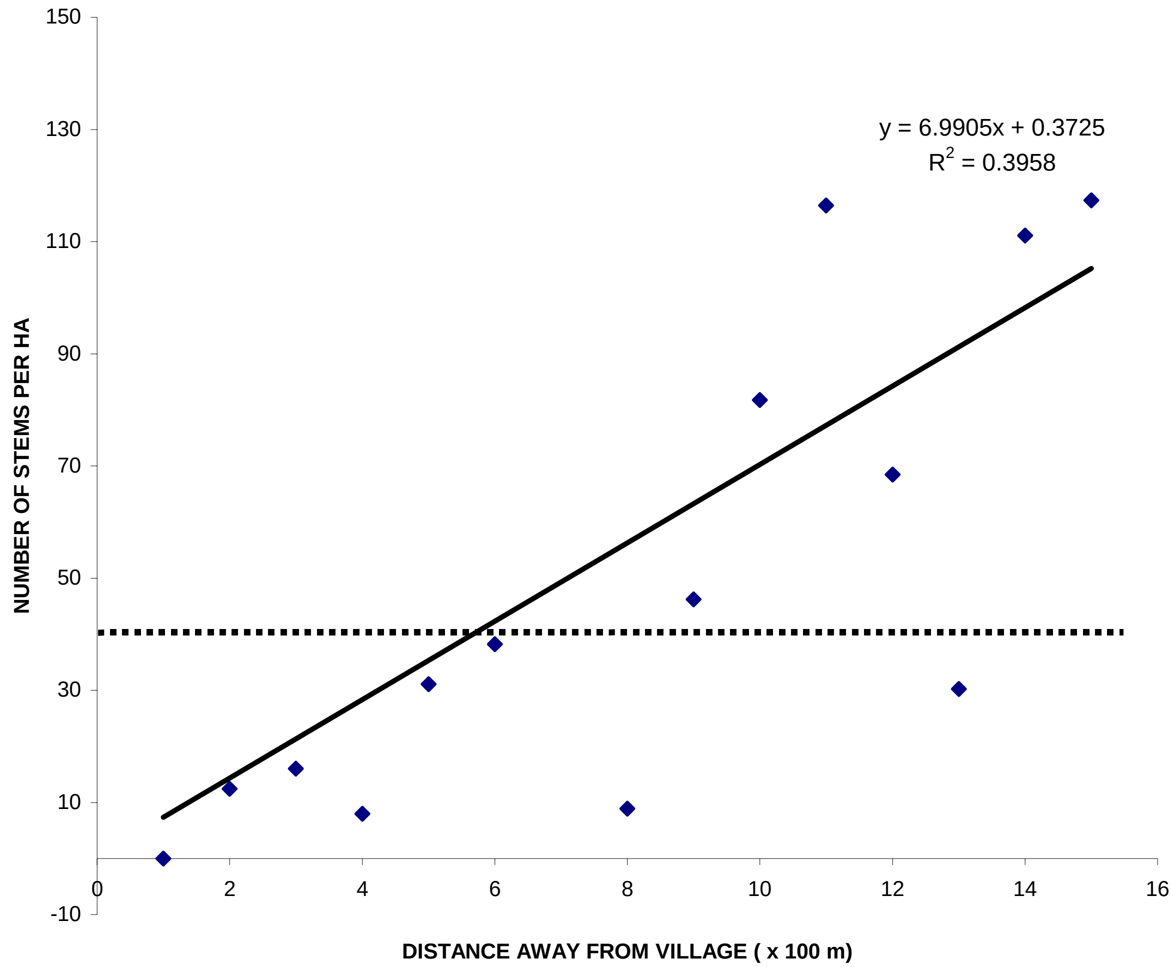

Figure 3.6: Linear regression of the density of *Terminalia sericea* expressed as number of stems per ha along a disturbance gradient (distance away from the village: 1 = 100m) in the lowlands of the communal area surrounding Makoko village, Mpumalanga, South Africa from 2000 to 2001 (.......... perforated line indicates the mean number of *Terminalia sericea* stems per ha for the conservation area lowlands)

The mean number of plants per ha for T*erminalia sericea* on the up- and lowlands of the conservation area respectively are 145.30 plants per ha (range: 92.44 to 235.56 plants per ha; SD: 42.04 plants per ha) and 30.10 plants per ha (range: 3.56 to 76.44 plants per ha; SD: 22.55. There was a significant linear relationship between number of plants per ha of *Terminalia sericea* and distance away from the village on both the up- and lowlands respectively ($r = 0.52$; $t = 3.78$; $P<0.01$) ($r = 0.49$; $t = 3.54$; $P<0.01$) (Figures 3.7 and 3.8). The mean cumulative stem diameter per ha for T*erminalia sericea* on the up- and lowlands of the conservation area respectively are 692.8 cm per ha (range: 400.89 to 1024 cm per ha; SD: 174.59) and 128.53 cm per ha (range: 23.11 to 300.44 cm per ha; SD: 87.75 cm per ha). The communal area uplands show a significant linear increase in cumulative stem diameter with an increase in distance away from the village, and hence with a decrease in disturbance ($r^2 = 0.59$; $t = 3.51$; $P<0.01$) (Figure 3.9). The lowlands show a similar trend but with larger fluctuations than the uplands ($r^2 = 0.40$; $t = 3.11$; $P<0.01$) (Figure 3.10).

The significant decrease in the density of T*erminalia sericea* expressed as the number of stems per ha, the number of plants per ha and the cumulative stem diameter per ha in the communal area shows that this is a species that is indeed sensitive to high levels of harvesting damage. This was not expected because *Terminalia sericea* is generally found in sourveld areas that are characterised by tall grass and annual fires (Gertenbach 1983). It is prone to coppicing rapidly after a fire and would hence be considered to have a rapid post-harvesting recovery. *Terminalia sericea* is not a species that is readily found on the lowlands, but when it is found there it tends to form uneven clumps or stands (Venter 1990). The significant, positive linear relationships between number of stems per ha, number of plants per ha and cumulative stem diameter per ha and a decrease in harvesting pressure supports the above results that indicate that *Terminalia sericea* is

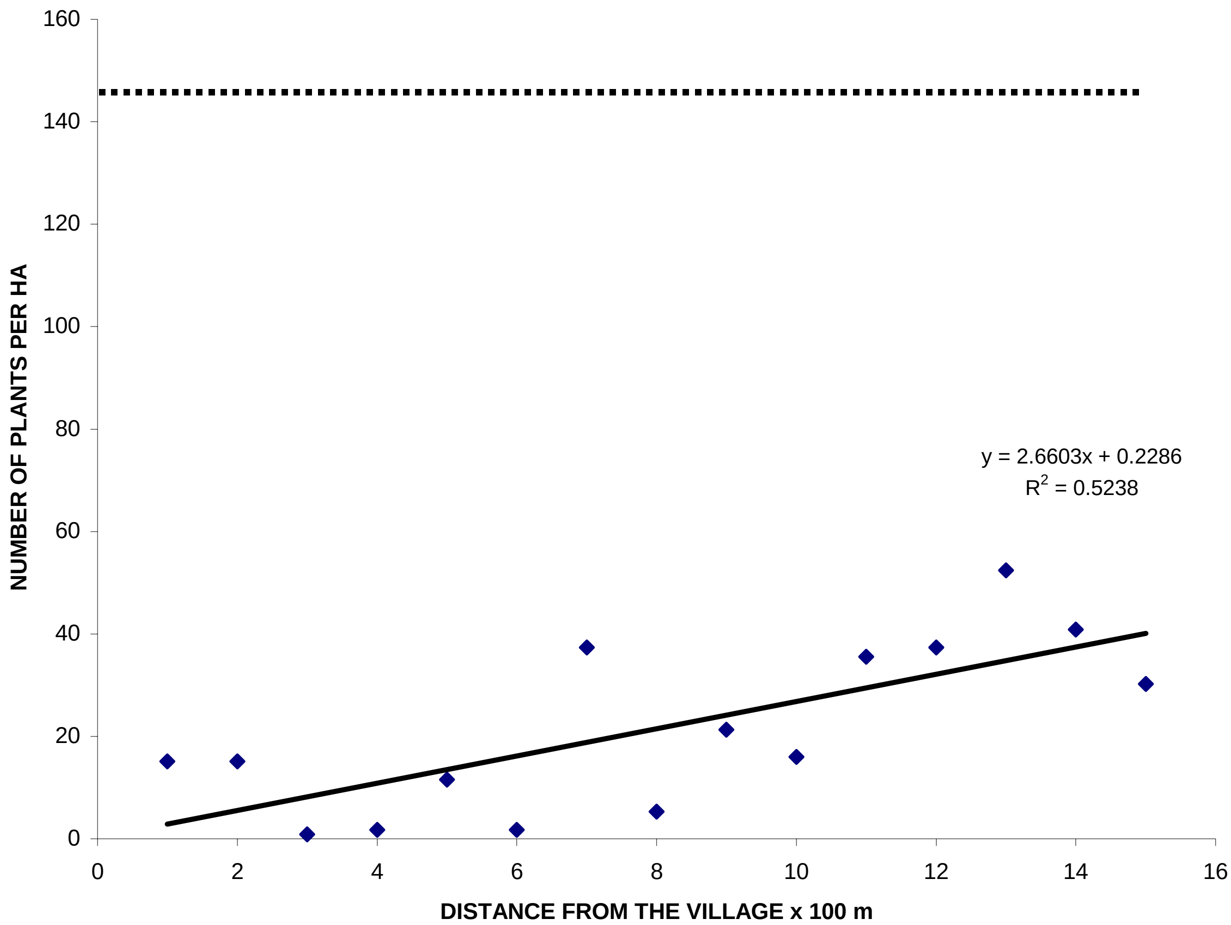

Figure 3.7: Linear regression of the density of *Terminalia sericea* expressed as number of plants per ha along a disturbance gradient (distance away from the village: 1 = 100m) in the uplands of the communal area surrounding Makoko village, Mpumalanga, South Africa from 2000 to 2001 (▪▪▪▪▪▪▪▪▪▪ perforated line indicates the mean number of *Terminalia sericea* plants per ha for the conservation area uplands)

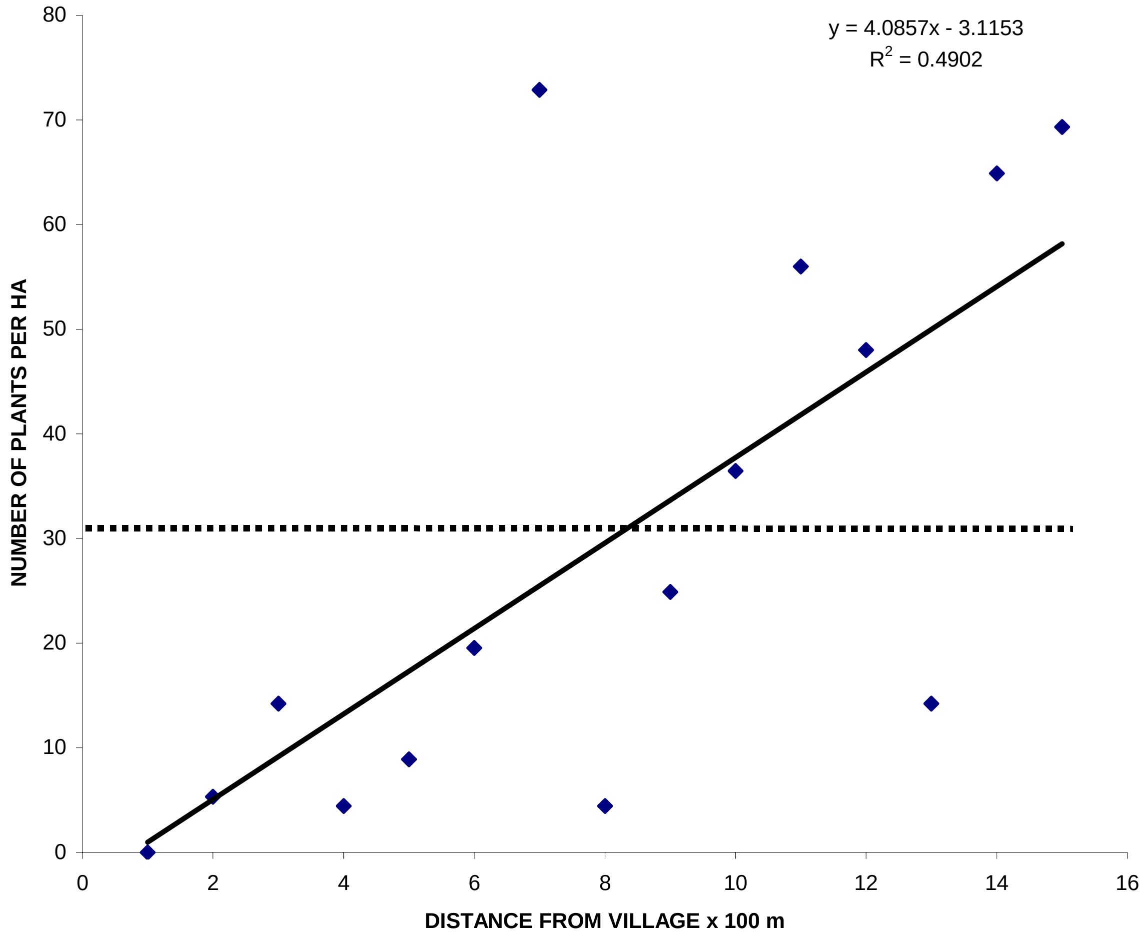

Figure 3.8: Linear regression of the density of *Terminalia sericea* expressed as number of plants per ha along a disturbance gradient (distance away from the village: 1 = 100m) in the lowlands of the communal area surrounding Makoko village, Mpumalanga, South Africa from 2000 to 2001 (............ perforated line indicates the mean number of *Terminalia sericea* plants per ha for the conservation area lowlands)

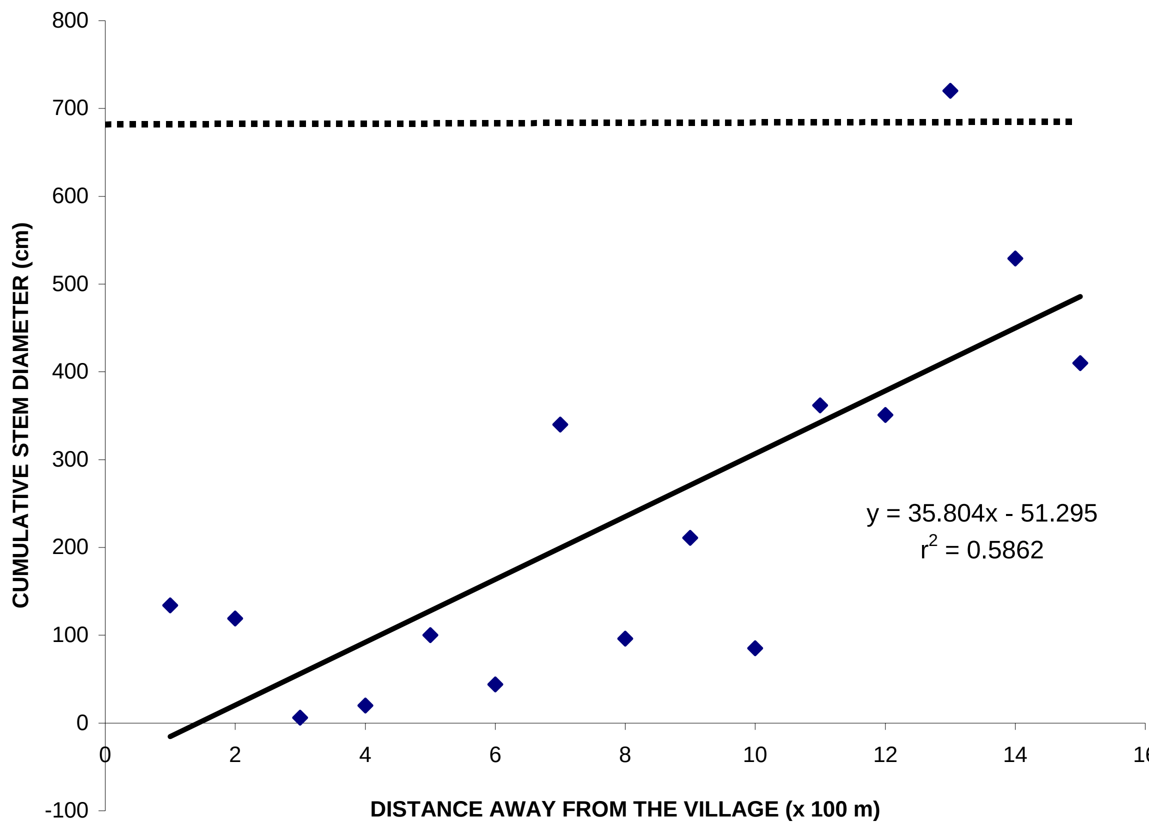

Figure 3.9: Linear regression of the cumulative stem diameter (cm) per hectare of *Terminalia sericea* along a disturbance gradient (distance away from village: 1 = 100 m) on the uplands of the communal area surrounding Makoko village, Mpumalanga, South Africa from 2000 to 2001 (...... perforated line indicates the cumulative stem diameter of *Terminalia sericea* per ha for the conservation area uplands)

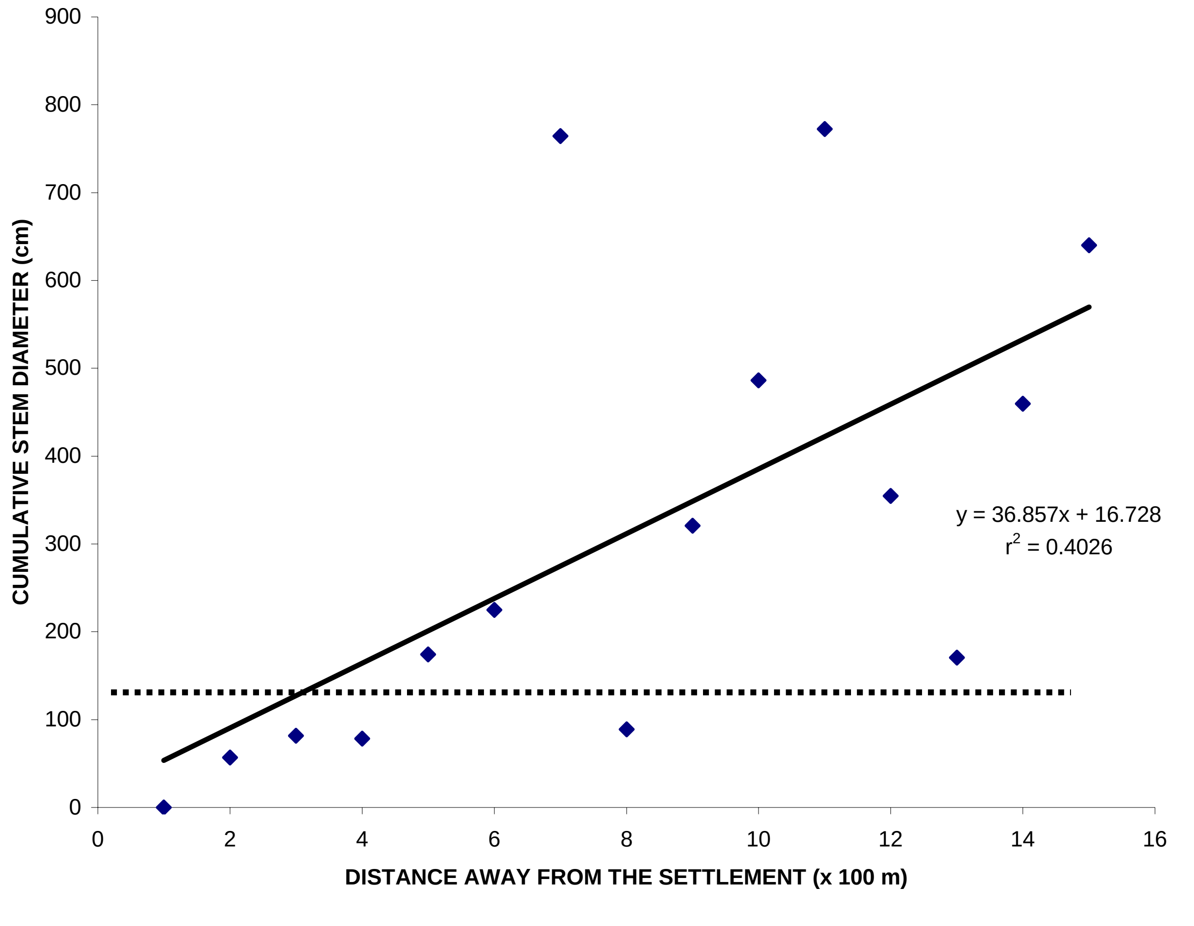

Figure 3.10: Linear regression of the cumulative stem diameter (cm) per hectare of *Terminalia sericea* along a disturbance gradient (distance away from the village: 1 = 100 m) in the lowlands of the communal area surrounding Makoko village, Mpumalanga, South Africa from 2000 to 2001 (▪▪▪▪▪▪▪▪▪▪ perforated line indicates the mean cumulative stem diameter for *Terminalia sericea* per ha for the conservation area lowlands)

sensitive to high levels of harvesting. The relative numbers of stems per ha and numbers of plants per ha in the upland far plots (from 1200 to 1400 m away from the village) are between two and four fold less than the mean for these measurements taken in the conservation area. This indicates that although the far plots were located at approximately the end of the Makoko communal area, the harvesting pressure was is high in these areas. However, the cumulative stem diameter per ha for the upland far plots was almost equivalent to that of the mean cumulative stem diameter of the conservation area uplands. This suggests that although number of stems and number of plants per ha may have changed considerably under harvesting in these far plots, the standing biomass is almost comparable to that in the conservation area. This would suggest that there are a number of *Terminalia sericea* individuals with wider stem diameters in these far plots, although overall there are fewer individuals there. This may be because as the distance from the village increases, the people harvesting wood are less able to carry larger size classes of woody plants back to the village.

In the communal area, both up- and lowlands have a significantly lower density (number of stems per ha) of *Dichrostachys cinerea* than in the conservation area respectively ($Z = 33.80$; $P<0.01$) ($Z = 20.36$; $P<0.01$). The mean number of stems per ha for the conservation area up- and lowlands respectively are 271.05 (range: 169.78 to 457.78 stems per ha; SD: 77.10 stems per ha) and 140.68 (range: 45.33 to 274.67; SD: 65.59). There was no significant linear relationship between the number of stems per hectare of *Dichrostachys cinerea* plotted against the distance away from the settlement for the uplands ($r^2 = 0.16$; $t = 1.22$; $P>0.05$) but there was for the lowlands ($r^2 = 0.49$; $t = 6.16$; $P<0.01$) (Figures 3.11 and 3.12). The mean number of plants per ha for the conservation area up- and lowlands respectively are 132.39 (range: 83.56 to 209.78 plants per ha:

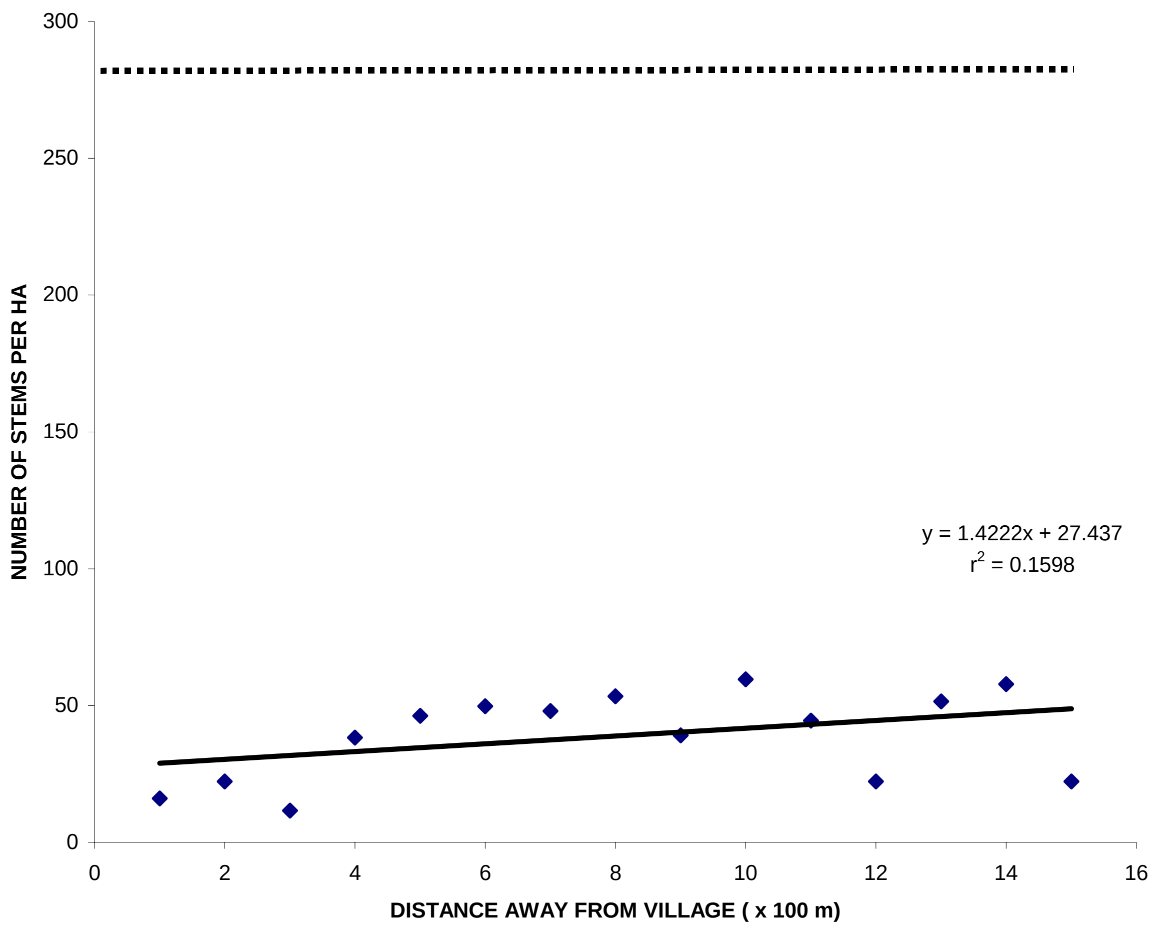

Figure 3.11: Linear regression of the density of *Dichrostachys cinerea* expressed as number of stems per ha along a disturbance gradient (distance away from the village: 1 = 100m) on the uplands of the communal area around Makoko village, Mpumalanga, South Africa from 2000 to 2001 (▪▪▪▪▪▪▪▪▪▪ perforated line indicates the mean number of stems of *Dichrostachys cinerea* per ha for the conservation area uplands)

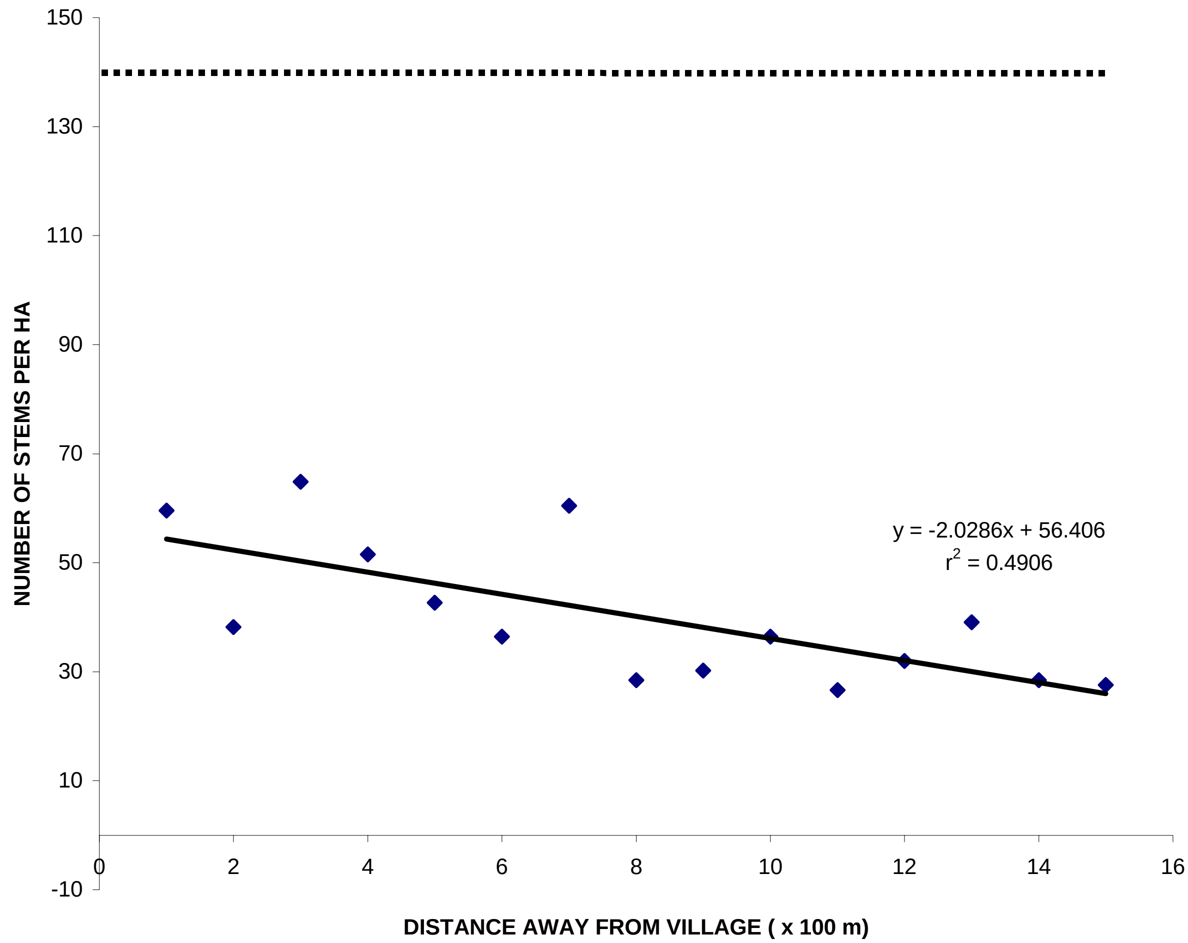

Figure 3.12: Linear regression of the density of *Dichrostachys cinerea* expressed as number of stems per ha along a disturbance gradient (distance away from the village: 1 = 100m) on the lowlands of the communal area around Makoko village, Mpumalanga, South Africa from 2000 to 2001 (·········· perforated line indicates the mean number of stems of *Dichrostachys cinerea* per ha for the conservation area lowlands)

SD: 34.57 plants per ha) and 78.64 (range 25.78 to 137.79 plants per ha; SD: 30.40 plants per ha). There was no significant relationship between number of plants per ha of *Dichrostachys cinerea* plotted against the distance away from the settlement for the uplands (r^2 = 0.17; t = 1.61; P>0.05) (Figure 3.13) but it was significant for the lowlands (r^2 = 0.69; t = -5.41; P<0.01) (Figure 3.14). The mean cumulative stem diameter for the conservation area up- and lowlands respectively are 768.47 cm per ha (range: 497.78 to 1333.33 cm per ha; SD: 228.26 cm per ha) and 423.47 cm per ha (range: 174.22 to 781.33 cm per ha; SD: 194.14 cm per ha). *Dichrostachys cinerea* shows a weak but significant positive linear response in cumulative stem diameter with relation to an increase in harvesting along a disturbance gradient away from the village for the uplands (r^2 = 0.09; t = 2.20; P≤0.05) (Figure 3.15) of the communal area and a negative one for the lowlands (r^2 = 0.04; t = 2.92; P≤0.05) (Figure 3.16).

On the uplands of the communal area, there is a six-fold difference in the number of stems per ha of *Dichrostachys cinerea* between the communal and conservation areas, but a four-fold difference in number of plants. This indicates that *Dichrostachys cinerea* is harvested at high pressure throughout the communal area and suggests that there is an overall increase in the number of stems per individual plant in the communal area under severe harvesting. There are no significant strong relationships between the number of stems per ha, number of plants per ha and cumulative stem diameter per ha with distance away from the village for *Dichrostachys cinerea* on the uplands of the communal area. In the conservation area uplands, the density of *Dichrostachys cinerea* is variable between plot positions indicating a bunched spatial distribution. However, in the communal area it seems more homogenous throughout the transects. This could further be indicative of *Dichrostachys cinerea* encroachment in the communal area.

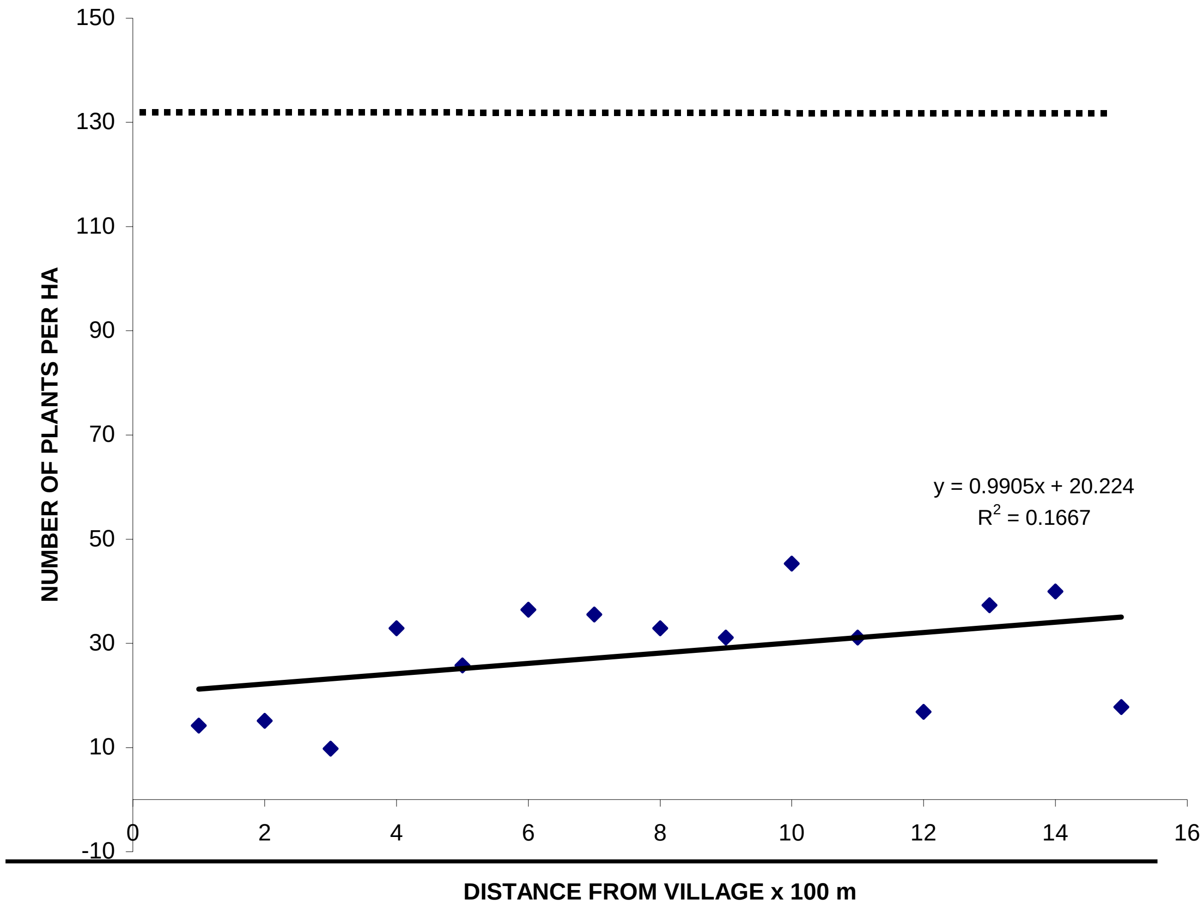

Figure 3.13: Linear regression of the density of *Dichrostachys cinerea* expressed as number of plants per ha along a disturbance gradient (distance away from the village: 1 = 100m) on the uplands of the communal area around Makoko village, Mpumalanga, South Africa from 2000 to 2001 (.......... perforated line indicates the mean number of plants of *Dichrostachys cinerea* per ha for the conservation area uplands)

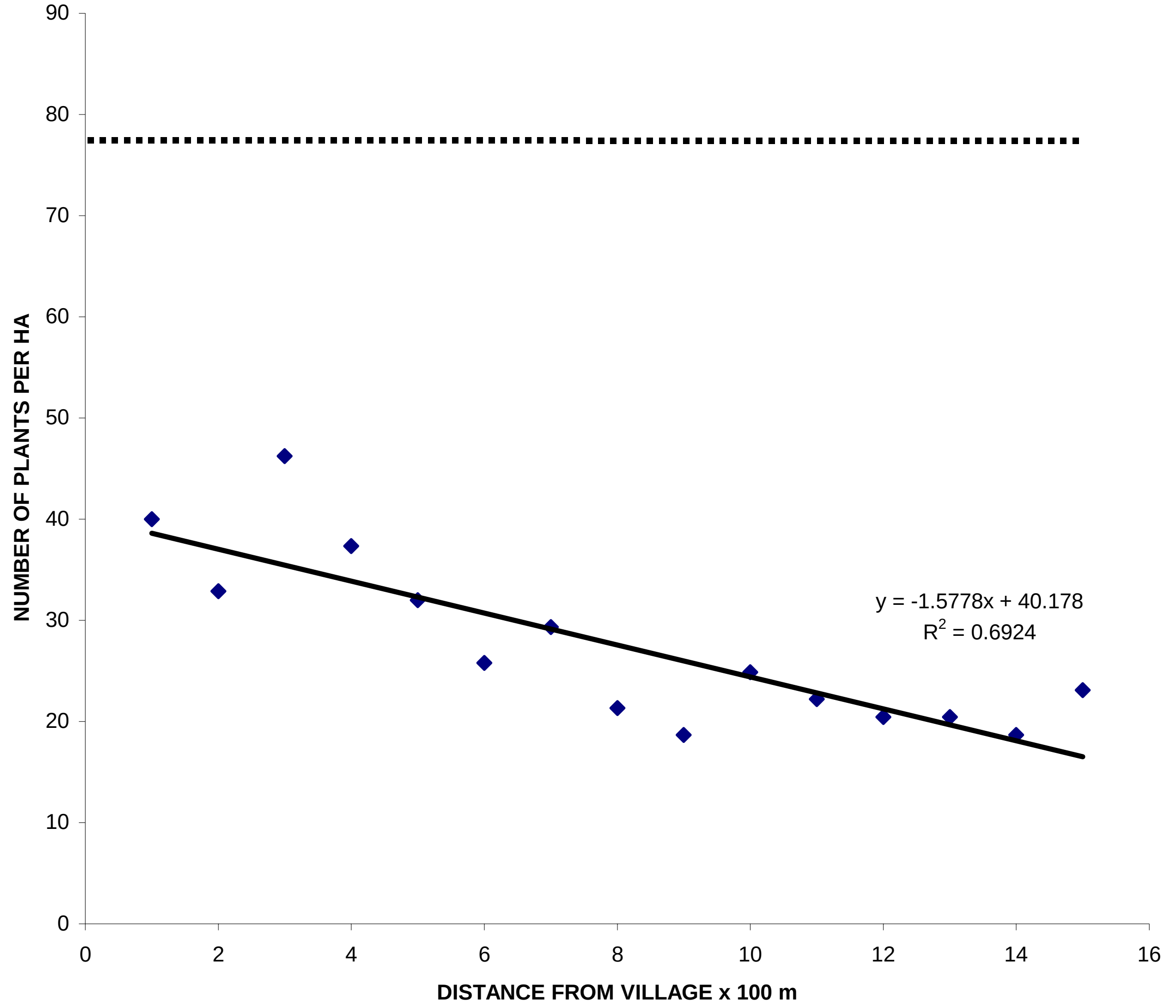

Figure 3.14: Linear regression of the density of *Dichrostachys cinerea* expressed as number of plants per ha along a disturbance gradient (distance away from the village: 1 = 100m) on the lowlands of the communal area around Makoko village, Mpumalanga, South Africa from 2000 to 2001 (...... perforated line indicates the mean number of plants of *Dichrostachys cinerea* per ha for the conservation area lowlands)

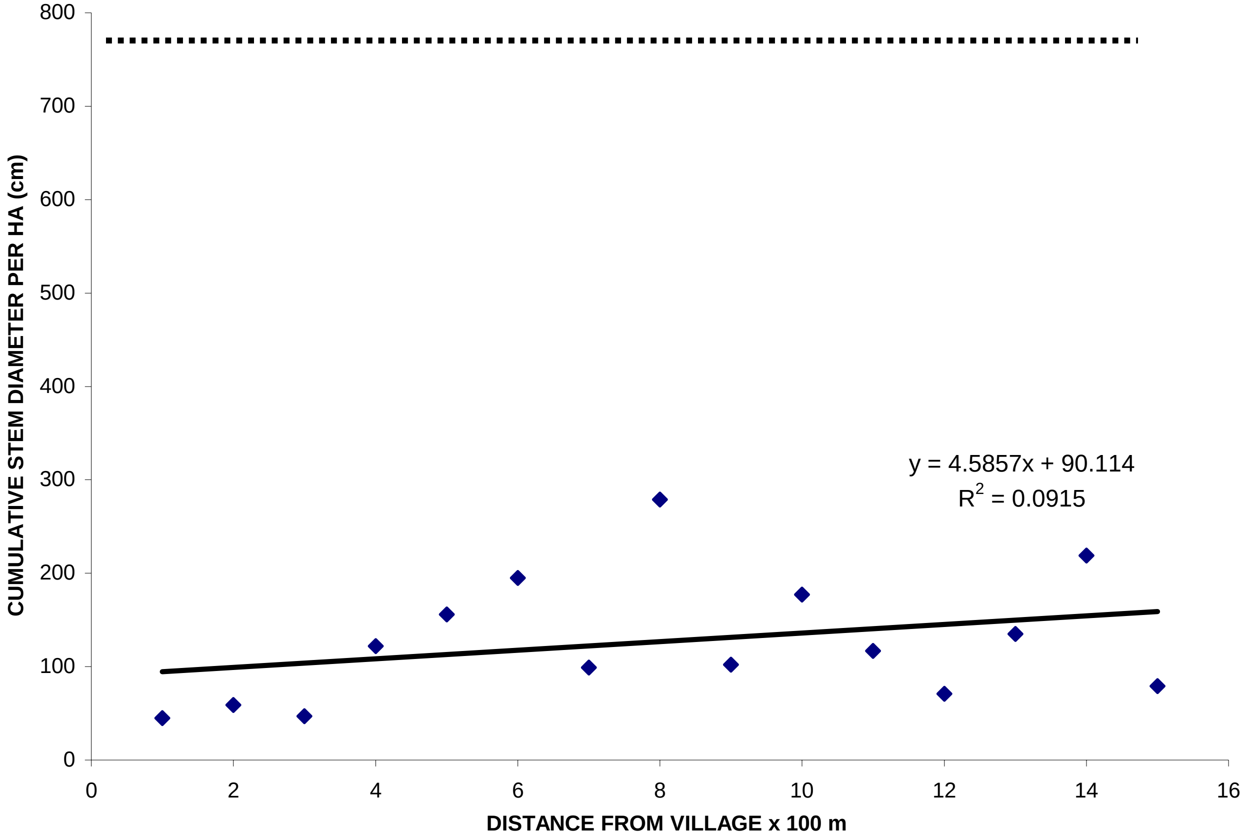

Figure 3.15: Linear regression of the cumulative stem diameter (cm) per hectare of *Dichrostachys cinerea* along a disturbance gradient (distance from village 1 = 100 m) on the uplands of the communal area surrounding Makoko village, Mpumalanga, South Africa as surveyed from 2000 to 2001 (........ perforated line indicates the mean cumulative stem diameter of *Dichrostachys cinerea* per ha for the conservation area uplands).

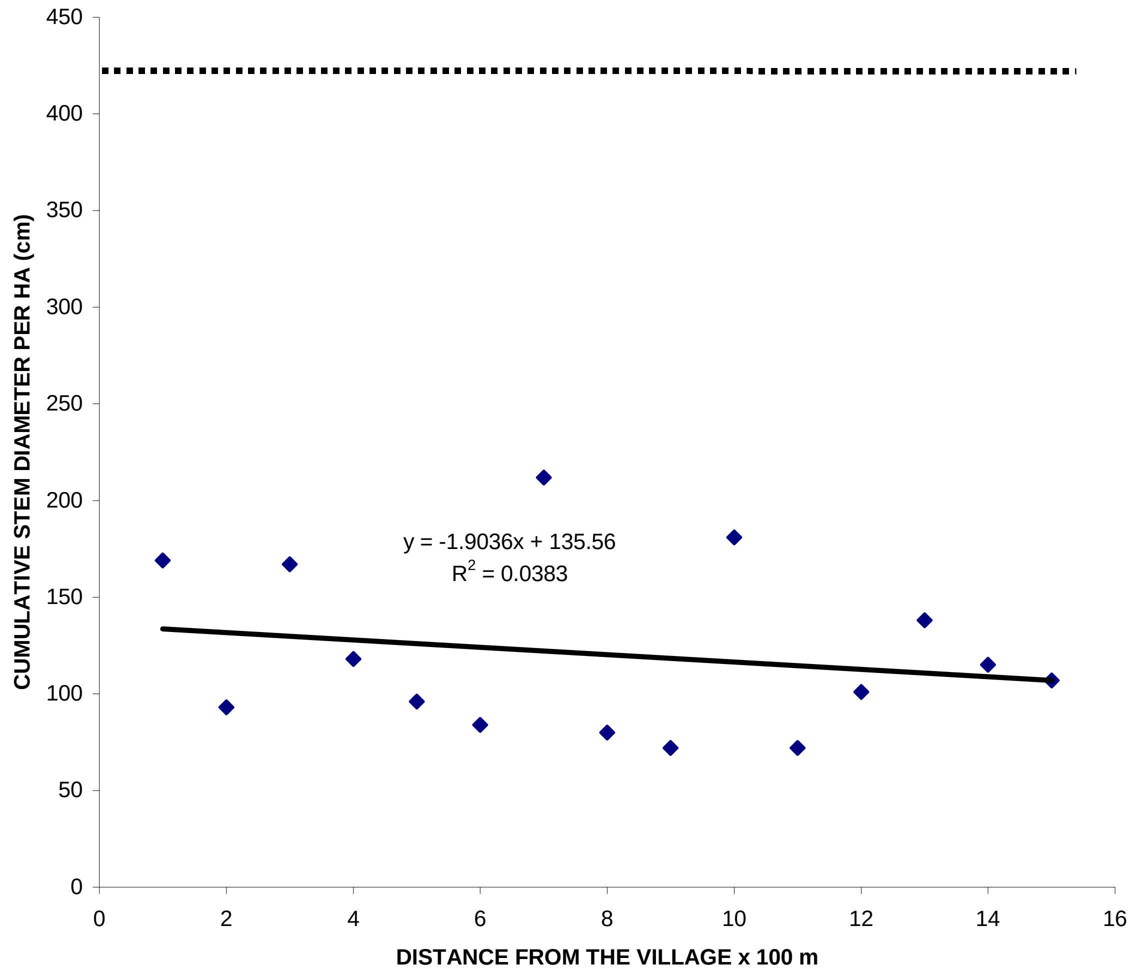

Figure 3.16: Linear regression of the cumulative stem diameter (cm) per hectare of *Dichrostachys cinerea* along a disturbance gradient (distance from village 1 = 100 m) on the lowlands of the communal area surrounding Makoko village, Mpumalanga, South Africa as surveyed from 2000 to 2001 (▪▪▪▪▪▪▪▪▪▪ perforated line indicates the mean cumulative stem diameter of *Dichrostachys cinerea* per ha for the conservation area lowlands)

In the lowlands, there is a stronger relationship between the number of individuals per ha for *Dichrostachys cinerea* when plotted against distance away from the village, than for the cumulative stem diameter per ha. This would suggest that there are more *Dichrostachys cinerea* individuals of the smaller size classes present closer to the village. This could be a result of higher grazing pressure closer to the villages, reducing the ability of the grass to compete with the woody plants. On the uplands, the density of *Dichrostachys cinerea* increases with a decrease in disturbance. However on the lowlands, the density decreases with a decrease in disturbance. *Dichrostachys cinerea* is been well documented as a bush-encroachment species increasing in abundance under conditions of high grazing pressure (Pratt 1971; Roques *et al.* 2001; Bond 2003). The results of the present study support the above studies. The success of *Dichrostachys cinerea* in terms of the response to the disturbance gradient away from the village on the lowlands could be attributed to increased seedling establishment opportunities or the increased opportunity for vegetative recruitment via root suckering (Euston-Brown pers.comm[3].) in the low grass biomass environment, since the lowlands are heavily grazed closer to the village.

Size class structure

The percentage of woody plants in each of six size classes was used as an indication of the differences in woody plant structure between slope positions in the communal and conservation areas (Table 3.5).

[3] Euston-Brown, D., Botanical consultant, Department of Botany, University of Cape Town, Private bag, Rondebosch, 7701.
Date: 19 October 2004

Table 3.5: Percentage and total number of woody plant individuals within each size class in the conservation area of the Kruger National Park and the communal area around Makoko village, Mpumalanga, South Africa from 2000 to 2001

Size class*	Uplands				Lowlands			
	Conservation area		Communal area		Conservation area		Communal area	
	Number	%	Number	%	Number	%	Number	%
1	3298	51	3262	65	2093	63	2276	60
2	160	3	356	7	246	7	307	8
3	1434	22	843	17	715	22	785	21
4	735	11	304	6	116	4	244	7
5	681	11	226	5	122	4	174	5
6	158	3	2	0	21	1	1	0
Total	6466	100	4993	100	3313	100	3787	100

*Notes

Class 1: saplings (stem diameter <20 mm)

Class 2: dwarf shrubs (height 0> to ≤1 m)

Class 3: shrubs (height 1> to ≤2 m)

Class 4: multi-stemmed tall shrubs (height 2> to ≤5 m)

Class 5: single-stemmed medium trees (height 2> to ≤5 m)

Class 6: tall trees (height >5 m).

For the uplands, saplings and dwarf shrubs formed 54% of the number of plants in the conservation area, and 73% in the communal one (Table 3.5; Figure 3.17). There was no significant difference in sapling counts between the conservation and the communal areas ($Z = 0.44$; $P>0.05$). There were significantly more dwarf shrubs in the communal upland than in the conservation one ($Z = -8.63$; $P<0.01$). However, there were significantly more shrubs ($Z = 12.39$; $P<0.01$), multi-stemmed tall shrubs ($Z = 13.37$; $P<0.01$), single-stemmed medium trees ($Z = 15.11$; $P<0.01$) and tall trees ($Z = 12.33$; $P<0.01$) in the conservation uplands than in the communal ones (Table 3.5; Figure 3.17).

The lowlands consisted of 70% saplings and dwarf shrubs in the conservation area and 68% in the communal one. There were significantly more saplings ($Z = -2.77$; $P<0.01$), dwarf shrubs ($Z = -2.59$; $P<0.01$), shrubs ($Z = -1.81$; $P<0.01$), multi-stemmed tall shrubs ($Z = -6.75$; $P<0.01$) and single-stemmed medium trees ($Z = -3.02$; $P<0.01$) in the communal lowlands compared to the conservation ones. However, the conservation area had significantly more tall trees ($Z = 4.26$; $P<0.01$) compared to the communal area (Table 3.5; Figure 3.18). The uplands of the communal area consisted of 21% exotic saplings namely *Lantana camara* and *Psidium guajava*, while the saplings in the communal lowlands consisted of 16% of these exotics species.

The results include the entire sampled population of all the woody plant species. When the two most common woody species are considered separately, the results show varying trends.

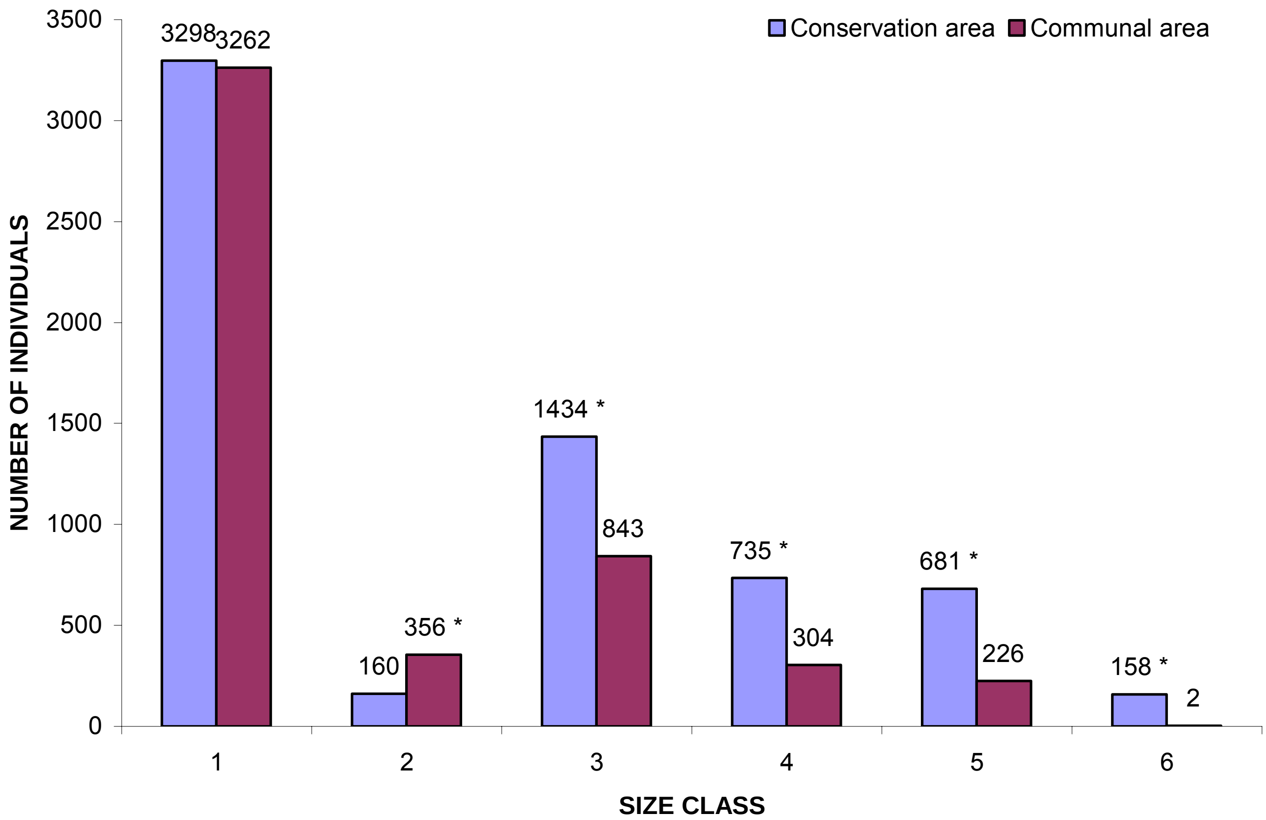

Figure 3.17: Frequency of occurrence of each size class of woody plants in the uplands of the conservation area of the Kruger National Park and the communal area around Makoko village, Mpumalanga, South Africa, as surveyed from 2000 to 2001. Significant differences between frequencies are marked with an asterix.

<u>Notes</u>

Class 1: saplings (stem diameter <20 mm)

Class 2: dwarf shrubs (height 0> to ≤1 m)

Class 3: shrubs (height 1< to ≤2 m)

Class 4: multi-stemmed tall shrubs (height 2> to ≤5 m)

Class 5: single-stemmed medium trees (height 2> to ≤5 m)

Class 6: tall trees (height >5 m).

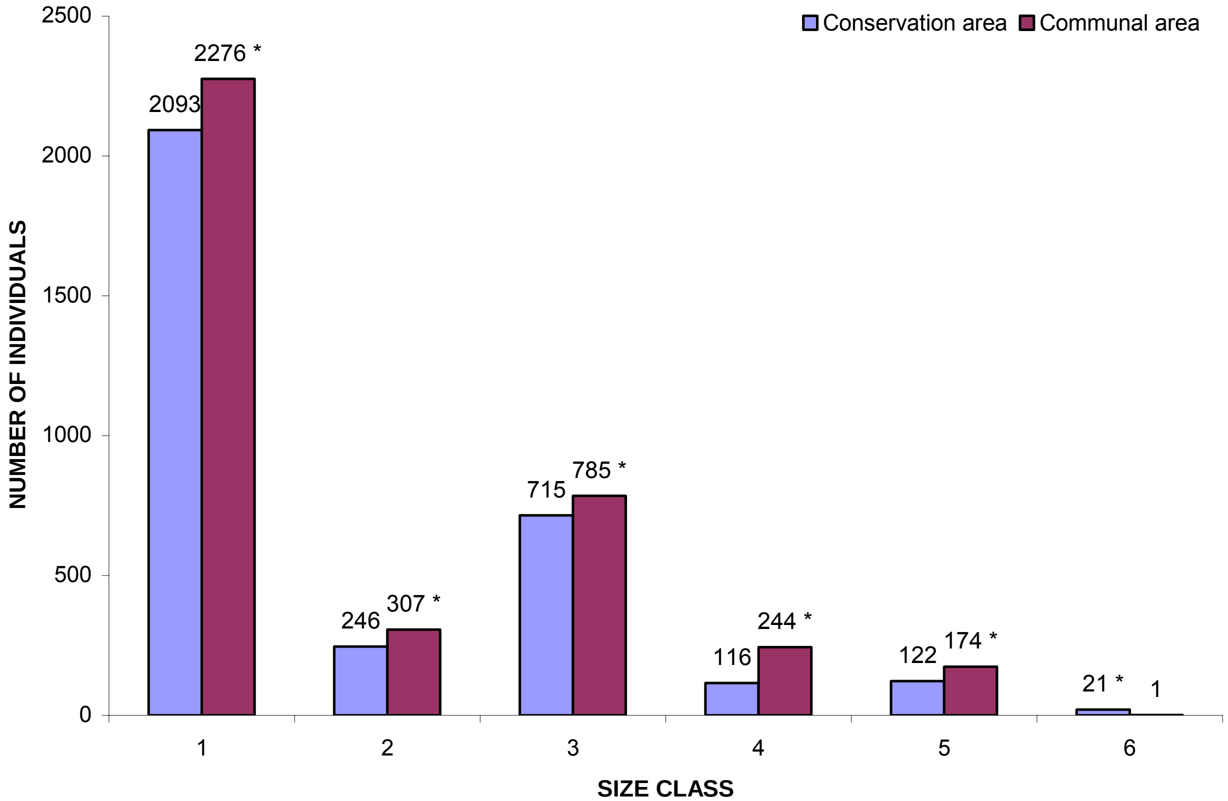

Figure 3.18: Frequency of occurrence of each size class of woody plants in the lowlands of the conservation area of the Kruger National Park and the communal area around Makoko village, Mpumalanga, South Africa, as surveyed from 2000 to 2001. Significant differences between frequencies are marked with an asterix.

Notes

Class 1: saplings (stem diameter <20 mm)

Class 2: dwarf shrubs (height 0> to ≤1 m)

Class 3: shrubs (height 1< to ≤2 m)

Class 4: multi-stemmed tall shrubs (height 2> to ≤5 m)

Class 5: single-stemmed medium trees (height 2> to ≤5 m)

Class 6: tall trees (height >5 m).

There were significantly more *Terminalia sericea* plants on the uplands of the conservation area than in the communal area in the following size classes: saplings (Z = 30.10; P<0.01), shrubs (Z = 12.12; P<0.01), multi-stemmed tall shrubs (Z = 12.22; P<0.01), single-stemmed medium trees (Z = 19.47; P<0.01) and tall trees (Z = 11.67; P<0.01) (Figure 3.19). However, there were more dwarf shrubs in the communal area than the conservation area (Z = -3.92; P<0.01). The conservation area lowlands contained more *Terminalia sericea* saplings (Z = 11.46; P<0.01), single-stemmed medium trees (Z = 2.03; P≤0.05) and tall trees (Z = 3.61; P<0.01), than the communal area lowlands, but there were more dwarf shrubs (Z = -4.04; P<0.01), shrubs (Z = -5.82; P<0.01) and multi-stemmed tall shrubs (Z = -5.79; P<0.01) within the communal lowlands than in those of the conservation area (Figure 3.20).

Dichrostachys cinerea seemed to be more abundant in all six size classes on the uplands of the conservation area when compared with the communal area, but this difference was only significant for the saplings (Z = 15.13; P<0.01), shrubs (Z = 23.21; P<0.01), multi-stemmed tall shrubs (Z = 18.54; P<0.01) and multi-stemmed medium trees (Z = 12.14; P<0.01) (Figure 3.21). The conservation area lowlands had significantly more *Dichrostachys cinerea* than in the communal area lowlands in each size class: saplings (Z = 8.96; P<0.01); dwarf shrubs (Z = 7.97; P<0.01); shrubs (Z = 16.44; P<0.01); multi-stemmed tall shrubs (Z = 5.46; P<0.01) and single-stemmed medium trees (Z = 2.85; P<0.01) except for tall trees (Z = 1.41; P>0.05) (Figure 3.22).

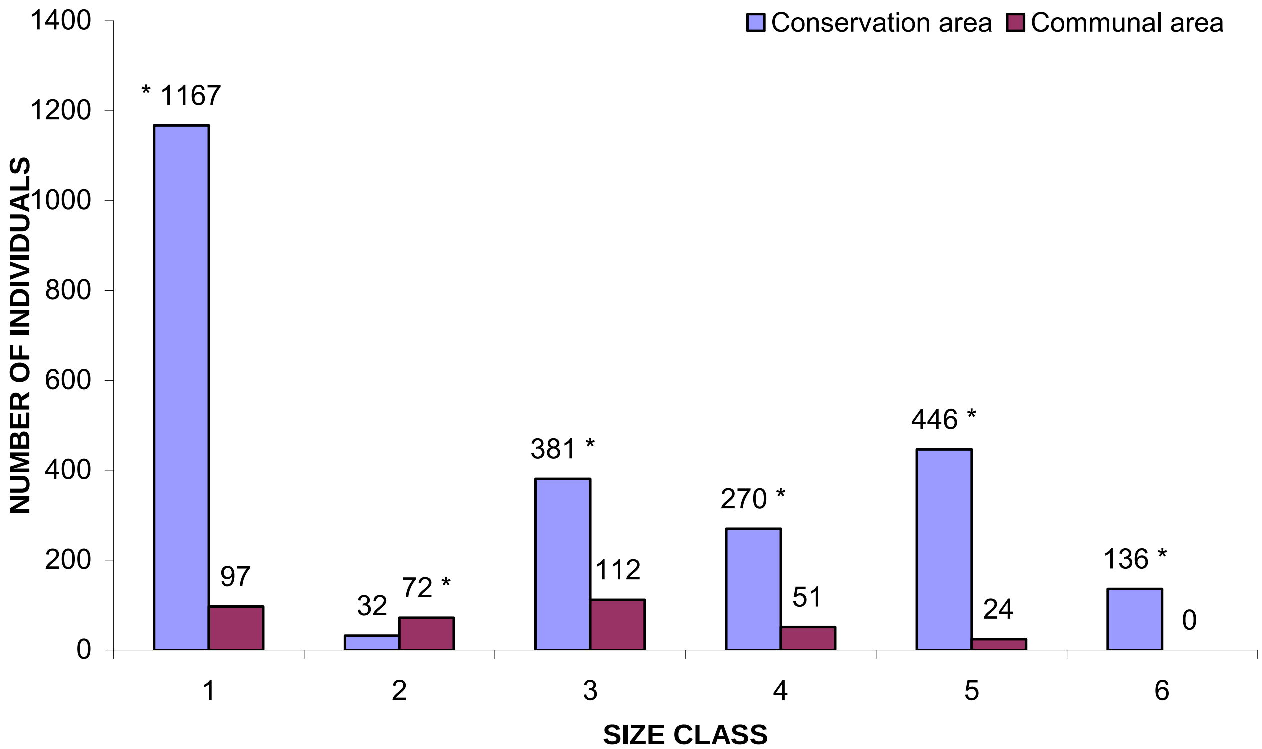

Figure 3.19: Frequency of occurrence of each size class of *Terminalia sericea* found in the Uplands of the conservation area of the Kruger National Park and the communal area around Makoko village, Mpumalanga, South Africa, as surveyed from 2000 to 2001. Significant differences between frequencies are marked with an asterix.

<u>Notes</u>

Class 1: saplings (stem diameter <20 mm)

Class 2: dwarf shrubs (height 0> to ≤1 m)

Class 3: shrubs (height1< to ≤2 m)

Class 4: multi-stemmed tall shrubs (height 2> to ≤5 m)

Class 5: single-stemmed medium trees (height 2> to ≤5 m)

Class 6: tall trees (height >5 m).

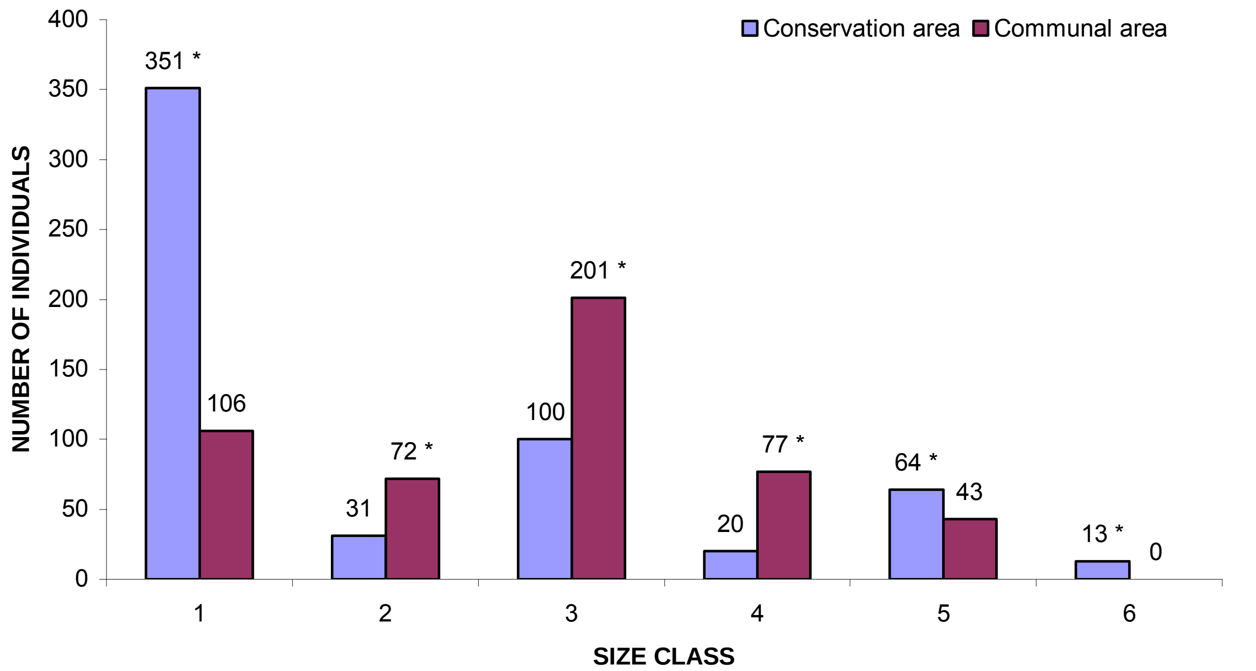

Figure 3.20: Frequency of occurrence of each size class of *Terminalia sericea* found in the lowlands of the conservation area of the Kruger National Park and the communal area around Makoko village, Mpumalanga, South Africa, as surveyed from 2000 to 2001. Significant differences between frequencies are marked with an asterix.

<u>Notes</u>

Class 1: saplings (stem diameter <20 mm)

Class 2: dwarf shrubs (height 0> to ≤1 m)

Class 3: shrubs (height 1< to ≤2 m)

Class 4: multi-stemmed tall shrubs (height 2> to ≤5 m)

Class 5: single-stemmed medium trees (height 2> to ≤5 m)

Class 6: tall trees (height >5 m).

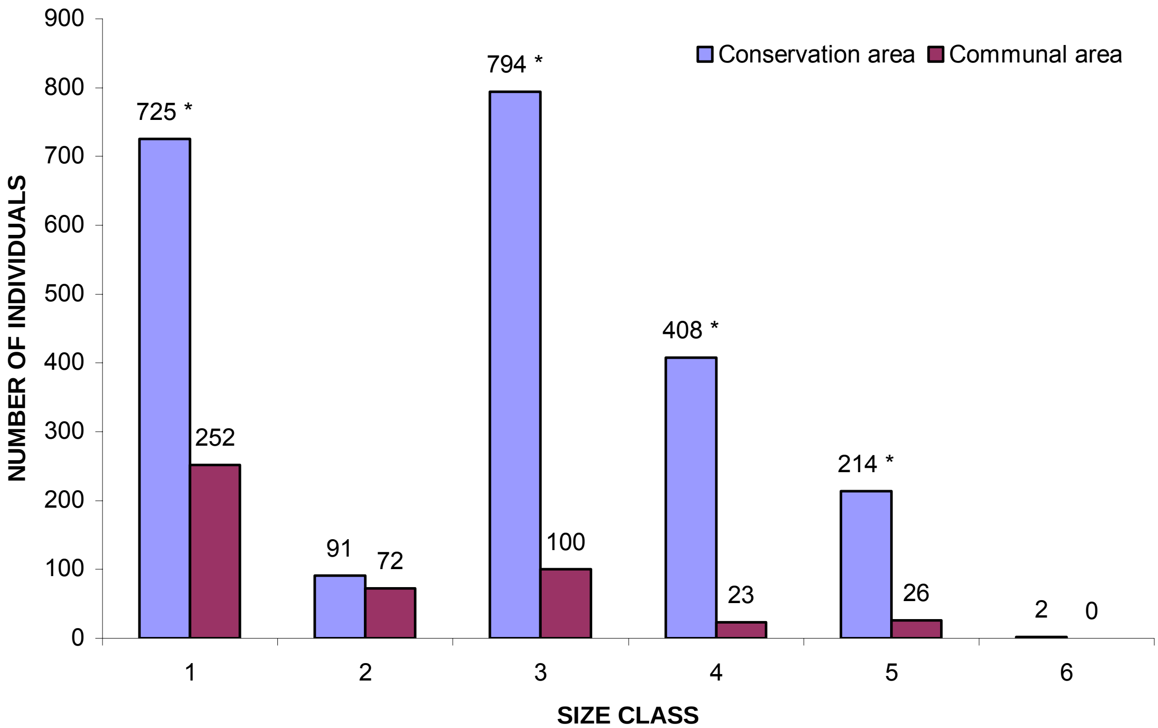

Figure 3.21: Frequency of occurrence of each size class of *Dichrostachys cinerea* found in the uplands of the conservation area of the Kruger National Park and the communal area around Makoko village, Mpumalanga, South Africa, as surveyed from 2000 to 2001. Significant differences between frequencies are marked with an asterix.

<u>Notes</u>

Class 1: saplings (stem diameter <20 mm)

Class 2: dwarf shrubs (height 0> to ≤1 m)

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Class 6: tall trees (height >5 m).

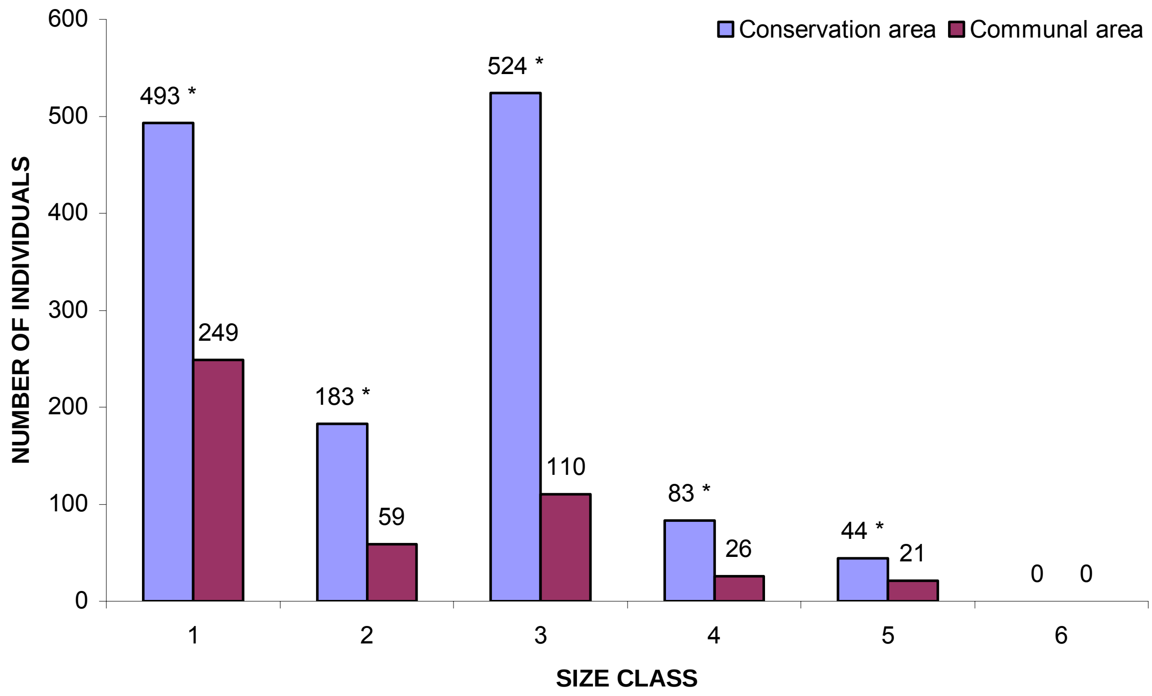

Figure 3.22: Frequency of occurrence of each size class of *Dichrostachys cinerea* found in the lowlands of the conservation area of the Kruger National Park and the communal area around Makoko village, Mpumalanga, South Africa, as surveyed from 2000 to 2001. Significant differences between frequencies are marked with an asterix.

Notes

Class 1: saplings (stem diameter <20 mm)

Class 2: dwarf shrubs (height 0> to ≤1 m)

Class 3: shrubs (height 1< to ≤2 m)

Class 4: multi-stemmed tall shrubs (height 2> to ≤5 m)

Class 5: single-stemmed medium trees (height 2> to ≤5 m)

Class 6: tall trees (height >5 m).

All 15 plot positions in the upland transects within the conservation area contained tall trees, but only two of the possible 15 plot positions within the communal area had individuals of this size class. A similar trend was found in the lowlands with 10 of the 15 plot positions in the conservation area having tall trees whereas only 1 of those in the communal area did so.

Shackleton (1993a) found clear differences in woody size class distribution between a communal and a conservation site in the Limpopo province, South Africa. In his study, he showed that the stability of the woody plant population was high only in those specific species that contained large woody plants. In general, seedling density was higher in the communal area than the conservation one, which could be an indication of potential bush encroachment. Overall, the woody plant density showed a linear decrease with increasing intensity of utilization, resulting in fewer size classes and a reduced proportion of the population of larger woody plants. Shackleton *et al*. (1994) also found that there was a strong increase in seedling density with increasing distance away from a human settlement. This would suggest that the disturbance gradient has a marked effect on structural characteristics of the woody plants. Higgins *et al.* (1999) showed that the vegetation structure in savanna ecosystems could be strongly influenced by land-use pattern. Based on the size structure of the woody plant communities, it was suggested in the above study that the communal grazing lands had a reduced capacity for woody plant regeneration and that future species losses could be expected.

In the present study, the higher density of woody plants on the uplands of the conservation area as opposed to the communal area, can be attributed to the obvious effect of the harvesting of wood by the human inhabitants of the area. The effect of harvesting is expected to be greater in the uplands where the woody plant densities are naturally higher than in the lowlands. In the lowlands, woody plant density generally increases in most size classes with utilization. A key attribute of the resilience of savannas is the ability of woody plants to coppice from the remaining stumps after having been harvested. Survival of the cut stems and the growth rates of the resultant coppice shoots are influenced by the tree size and height of cutting (Rathogwa 2000). Replacement occurs more rapidly through coppice growth than through seedling recruitment because coppice shoots grow more rapidly than stems that are recruited from seedlings. Coppice growth also has a lower mortality rate than seedlings (Scholes 1990). The resultant expected increase in the proportion of multi-stemmed individuals can be interpreted as a first step towards bush encroachment.

In the present study, there is a clear decrease in tall trees within the communal area compared with the conservation one. The removal of large trees to produce arts and crafts, fuel wood and construction material is possibly the main contributor to the decrease in tall trees. In addition, constant harvesting pressure over the past few decades on medium-sized woody plants could now be preventing these individuals from growing taller. Ludwig (2001) showed that large woody plants play an important role in maintaining the tree:grass ratio in savannas in East Africa. He also showed how savanna trees can reduce grass growth by competing with grasses for water and nutrients, and by decreasing light availability. In addition, he reported that trees can also improve the growing conditions for grasses by increasing soil moisture through hydraulic lift, by reducing evapotranspiration and by increasing soil nutrient availability. This in turn has an effect on the available forage quantity and quality.

In the present study, the effect that the harvesting of wood has on woody vegetation structure is amplified in the case of the lowlands of the communal area that have become increasingly dense and multi-stemmed when compared with the unharvested sites. In contrast, the uplands have become less dense with harvesting. This suggests that under conditions of severe woody plant utilization, the vegetation will eventually reach a relatively homogeneous state, with lower heterogeneity and hence a decrease in biodiversity (du Toit *et al.* 2003). Changes to both the homogeneous state and the microclimatic patterns will not be sustainable in the long-term.

Although the differences in the woody plant size class frequency of abundance are significant for all the woody species combined, individual species are much more dynamic in their response to severe harvesting. For example the number of individuals of *Dichrostachys cinerea* in each size class in the conservation area is at least double that in the communal area. This suggests that although this species is often regarded as an invasive and bush encroaching plant under poor habitat management, severe harvesting in combination with severe grazing of the herbaceous vegetation, may lead to a decline in it's abundance. This may be further caused by the severe browsing of coppice shoots by goats (Rathogwa 2000). The densities of *Terminalia sericea* trees that are found within the communal area are generally low, with the total absence of this species in the tall trees size class (>5 m: tall trees). The single-stemmed, medium tree class (2 m< class 5 ≤5 m:) were present in modest densities at 21.3 trees per ha on the communal uplands in comparison with the 396.4 trees per ha in the conservation area. In contrast to the uplands, the communal lowlands in some cases have a greater density of *Terminalia sericea* individuals than in the conservation ones. This may be a response to a change inn the environment in the lowlands under this type of harvesting pressure.

When considering a size class division that is based on the stem diameter of the woody plants, the regression equations show that the conservation uplands have relatively fewer individuals in the small size classes and more in the larger ones (slope= -2.28) relative to the communal uplands (slope= -2.58) (Figs. 3.23 and 3.24). The lowlands of the conservation areas (slope= -2.55) and the communal ones (slope= -2.57) show similar size class distributions (Figs. 3.25 and 3.26). This is substantiated by the stem density data that indicate that many more saplings occur within the uplands of the communal area than in the conservation ones. There also were significantly more tall trees (Class 6) in the conservation area than in the communal ones. Steeper regression lines are also said to indicate younger communities (Lykke 1998). Both the uplands and lowlands of the communal area have steeper slopes relative to the conservation area, suggesting that the woody plant communities in these communal areas are not stable or in a climax state. The similarity in the slopes between the communal area uplands and lowlands seems to indicate that the difference in size class structure between the two slope positions has become less under conditions of woody plant harvesting. According to Lykke (1998), the more gradual the slope of the size class distribution, the less rejuvenation there may be. This will result in a declining population. However, more gradual slopes can also be caused by other factors such as rapid growth in small size classes and high survival rates overall.

Biomass

The greater height and diameter of stems in the uplands relative to the lowlands indicate a significantly higher woody plant biomass there (Table 3.6).

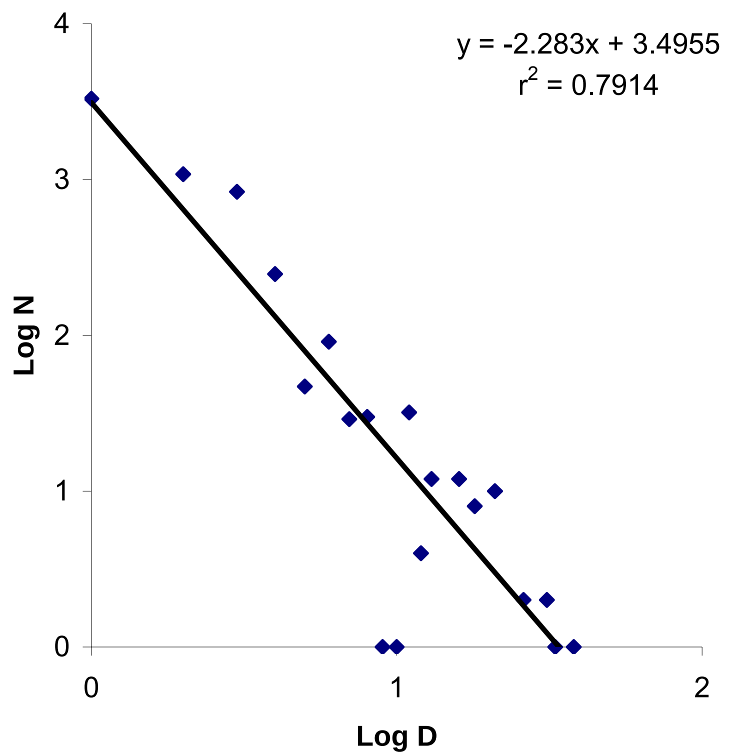

Figure 3.23: Log linear regressions of woody plant stem diameter classes (D = 20 mm increments) against woody plant density (N = number of individuals per ha) for the uplands of the conservation area within the Kruger National Park, Mpumalanga, South Africa, surveyed from 2000 to 2001.

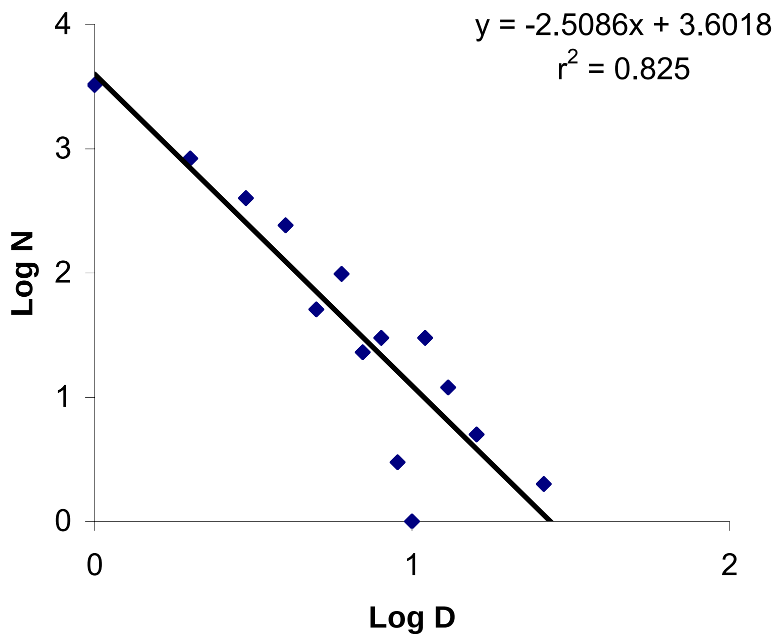

Figure 3.24: Log linear regressions of woody plant stem diameter classes (D = 20 mm increments) against woody plant density (N = number of individuals per ha) for the uplands of the communal area around the Makoko village, Mpumalanga, South Africa, surveyed from 2000 to 2001.

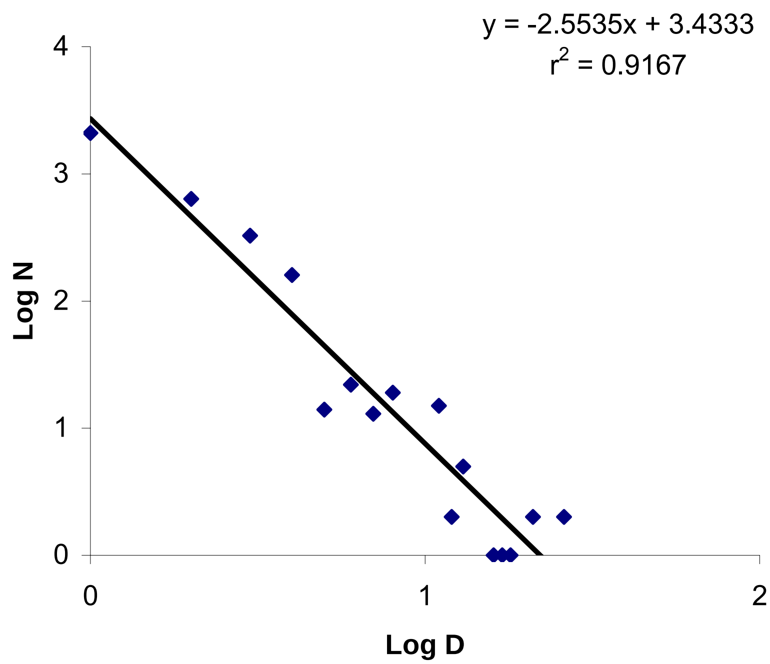

Figure 3.25: Log linear regressions of woody plant stem diameter classes (D = 20 mm increments) against woody plant density (N = number of individuals per ha) for the lowlands of the conservation area within the Kruger National Park, Mpumalanga, South Africa, surveyed from 2000 to 2001.

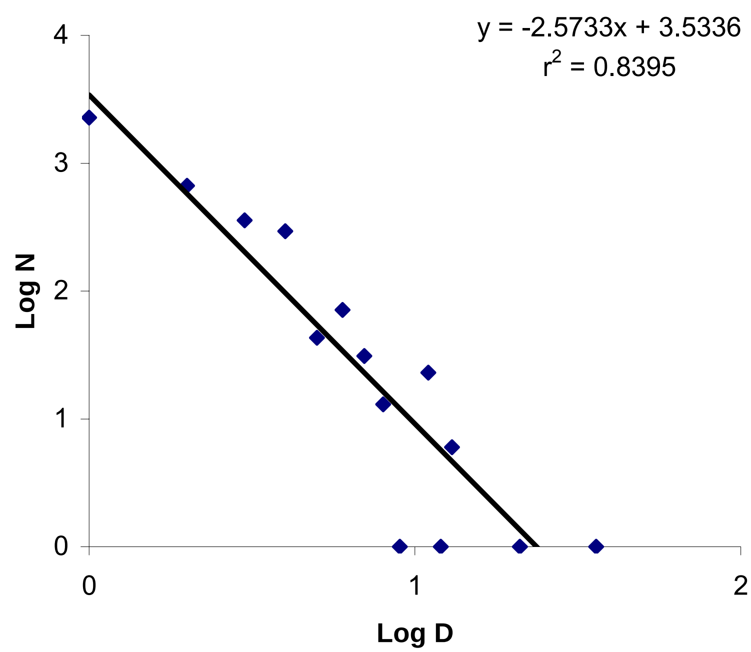

Figure 3.26: Log linear regressions of woody plant stem diameter classes (D = 20 mm increments) against woody plant density (N = number of individuals per ha) for the lowlands of the communal area around the Makoko village, Mpumalanga, South Africa, surveyed from 2000 to 2001.

Table 3.6: Woody plant biomass (kg per ha), wood biomass (kg per ha), wood biomass (metric tonnes) and harvestable wood biomass (metric tonnes) for the uplands and lowlands of the conservation area within the Kruger National Park and the communal area surrounding Makoko village, Mpumalanga, South Africa from 2000 to 2001

Biomass		Uplands		Lowlands	
		Conservation area	Communal area	Conservation area	Communal area
Woody plant biomass (kg per ha)	Class 2	30.80	246.98	85.62	181.69
	Class 3	593.17	908.58	452.76	852.79
	Class 4	1680.94	1263.71	318.70	778.77
	Class 5	3629.65	2703.83	1236.21	2029.00
	Class 6	25225.46	230.68	2937.25	82.85
	Total	31160.02	5353.78	5030.54	3925.10
Wood biomass (kg per ha)	Class 2	23.84	191.16	66.27	140.63
	Class 3	459.11	703.58	350.44	660.06
	Class 4	1301.05	978.11	246.68	602.77
	Class 5	3400.98	2533.49	1158.33	1901.17
	Class 6	23636.25	216.14	2752.20	77.63
	Total	28821.23	4622.48	4573.92	3382.97
Wood biomass		46741.41	7496.63	3653.14	2701.94
Harvestable wood biomass		1402.25	224.90	109.60	81.06

Notes

Class 1: saplings (stem diameter <20 mm)

Class 2: dwarf shrubs (height 0> to ≤1 m)

Class 3: shrubs (height 1< to ≤2 m)

Class 4: multi-stemmed tall shrubs (height 2> to ≤5 m)

Class 5: single-stemmed medium trees (height 2> to ≤5 m)

Class 6: tall trees (height >5 m)

For the uplands, the woody plant biomass on the conservation area was the greatest at 31160 kg per ha, with that in the communal area only 5354 kg per ha. The lowlands had a woody plant biomass of 5031 kg per ha for the conservation area and 3925 kg per ha for the communal area. The upland wood biomass for the conservation area was 28821 kg per ha and the communal area 4623 kg per ha. The lowlands had a wood biomass of 4574 kg per ha in the conservation area and 3383 kg per ha in the communal area.

Shackleton (1993b) showed that the wood biomass per ha was not significantly greater at an unharvested site than a harvested one in Mpumalanga, South Africa. The volume of dead wood available for harvesting in the communal grazing land was significantly less than in the unharvested area. Sticks on the ground in the harvested area were only half the size of those in the unharvested area. The above study reported a wood biomass of 18907 kg per ha on an unharvested site and 17413 kg per ha on a harvested one. The above study also reported a wood biomass of 16909 kg per ha for *Combretum* communities on granitic soils in the Kruger National Park and a mean woody plant biomass estimate of 16273 kg per ha at Nylsvlei in the Limpopo province. Shackleton (1994a) examined the possibility of growing more trees for fuel wood in the Limpopo province, South Africa and found a wood biomass of 20400 kg per ha in a conservation area, 17500 kg per ha in a commercial cattle ranching land and 4800 kg per ha in a communal area. Banks *et al*. (1996) found that wood biomass increased significantly with distance away from a settlement, varying from less than 2000 kg per ha adjacent to the settlement to >15000 kg per ha in plots located from 450 to 3100 m further away. Higgins *et al*. (1999) found that basal area of woody plants increased significantly with increasing distance away from settlements. They found a significantly lower woody plant biomass (<1600 kg per ha) on communal grazing lands than on the other land-uses (>4300 kg per ha). The total woody plant biomass differed between the human settlements and with distance away from the human settlements. The smaller and less formal settlements had greater masses of wood available than the two larger settlements. The increase in wood biomass with distance away from a settlement was significant, with plots closer to the villages having less than 17% of the wood biomass than the further plots.

In the present study there was a significant increase in wood biomass with distance away from the village in the uplands of the communal area (r^2 = 0.45; t = 3.24; P<0.01) but not in the lowlands (r^2 = 0.16; t = 1.57; P>0.05). There was a significant increase in wood biomass of *Terminalia sericea* with distance away from the settlement in both the uplands (r^2 = 0.30; t = 2.36; P≤0.05) and the lowlands of the communal area (r^2 = 0.46; t = 3.30; P<0.01). There was no significant relationship between the wood biomass of *Dichrostachys cinerea* and distance away from the settlement either in the uplands (r^2 = 0.001; t = 0.15; P>0.05) or in the lowlands of the communal area (r^2 = 0.02; t = -0.51; P>0.05).

The sizes of the uplands and lowlands within the wood collecting area in the communal area in the present study were 1621.78 ha and 798.69 ha respectively. The wood biomass in the uplands of the conservation area was the highest at 46741 metric tonnes (Table 3.6). Of this biomass the harvestable wood biomass comprised 1402.3 metric tonnes (3%) per year. This is a crude indication of the potential of an area, if managed on a sustainable basis, to provide wood as a fuel source on a long-term basis. However, the communal land in it's current condition had 224.9 metric tonnes of harvestable wood biomass under sustainable harvesting.

Of the wood biomass in the conservation uplands, the contribution of class 6 (trees >5 m tall) accounts for 81%. The absence of these large trees in the communal area creates a major reduction in woody plant biomass there. When considering height classes or densities alone, it is difficult to quantify the effect of the harvesting practices on the wood biomass values since stem diameter is the major determinant for the calculations of wood biomass (Rutherford 1979). The lowlands of the conservation area only have 16% of the woody plant biomass of the uplands, but in the communal lands they have 73% of the woody plant biomass of the uplands. It seems that harvesting pressure has resulted in an almost comparable standing crop of woody plant biomass in both the up and lowlands of the communal area. These results indicate that a homogenisation of the vegetation and probably also of the habitat may occur under high levels of utilization within the communal lands.

Utilization

The results from the present study show that of the woody plants on the lowlands and uplands of the communal area, 23% and 20% had been subjected to chopping respectively (Tables 3.7 and 3.8). There was a significant linear positive relationship between percentage harvesting damage per chopped woody plant relative to the distance away from the settlement for the uplands (r^2 = 0.70; t = 5.52; P<0.01) and lowlands (r^2 = 0.57; t = 4.12; P<0.01). In terms of chopping damage, Shackleton (1993b) found that only 6.4% of the stems in the communal areas he studied showed some signs of chopping, while only 5.7% showed signs of severe chopping. This indicates that when chopping does occur, it is often severe.

Table 3.7: Chopping damage along a disturbance gradient away from the settlement in the uplands of the communal area of Makoko village, Mpumalanga, South Africa surveyed from 2000 to 2001.

Distance away from village (m)	Number of chopped woody plants	Total number of woody plants	Percentage chopped	Reaction of stems to chopping (%)		
				Dead	Alive and non-coppicing	Alive and coppicing
100	10	76	13	60	0	40
200	12	96	13	25	25	50
300	6	109	6	83	0	17
400	9	73	12	89	11	0
500	20	178	11	30	0	70
600	10	82	12	30	0	70
700	25	92	27	24	0	76
800	17	105	16	65	0	35
900	18	123	15	56	6	39
1000	16	88	18	44	0	56
1100	22	119	19	41	0	59
1200	28	106	26	17	0	68
1300	53	183	29	38	0	62
1400	45	145	31	49	0	51
1500	48	156	31	19	0	81
Total	339	1731	20	40	1	59

Table 3.8: Chopping damage along a disturbance gradient from the settlement in the lowlands of the communal area of Makoko village, Mpumalanga, South Africa form 2000 to 2001.

Distance away from village (m)	Number of chopped woody plants	Total number of woody plants	Percentage chopped	Reaction of stems to chopping (%)		
				Dead	Alive and non-coppicing	Alive and coppicing
100	3	102	3	67	0	33
200	6	55	11	67	0	33
300	7	91	8	43	0	57
400	12	119	10	25	0	75
500	8	59	14	63	0	38
600	15	77	20	47	0	53
700	46	141	33	67	0	33
800	11	63	17	55	0	46
900	28	80	35	39	0	61
1000	38	121	31	42	0	58
1100	45	138	33	38	0	62
1200	32	130	25	44	0	56
1300	14	91	15	36	0	64
1400	38	100	38	32	0	68
1500	43	144	30	47	0	53
Total	346	1511	23	45	0	55

In the present study, there was a greater proportion of chopped woody plants in both the uplands (20 %) and the lowlands (23 %) than was found by Shackleton (1993b). Although the two study areas support different human populations, the differences in chopping damage could be a reflection of the increase in harvesting pressure on woody plants over time, because Shackleton's study was done eight years before the present one. The above study also reported a significant selection for particular size classes with stems with a circumference of >100 mm being favoured over those with smaller ones. He reported that of the stems with a circumference of >160 mm, 35.9% had been chopped with a biomass loss of >50%, but 77.3% of these did have coppice growth. In the present study there were a total of 1731 woody plants were recorded in the uplands and 1511 in the lowlands of the communal area. Of these, there were 339 (19.6%) as opposed to 346 plants (22.9%) with chopping damage respectively (Tables 3.7 and 3.8).

CONCLUSIONS

Although having a similar total woody plant species count, the conservation area has fewer species within the individual plots compared to the communal area. This was supported by the results of the Shannon-Wiener Index that which combined species richness and evenness and showed both the communal uplands and lowlands to be more diverse than in the corresponding conservation area. Within the conservation area, there was a significant difference in species diversity between the uplands and lowlands, but this was not so in the communal area. These results support the intermediate disturbance hypothesis, which states that species diversity will be highest at sites that have had an intermediate frequency of disturbance because it prevents competitive exclusion, and will be lower at sites that have experienced high or low disturbance frequencies (Schwilk 1997).

The 11 woody plant species that were found only within the conservation area indicate that there is real possibility of potential and past species loss within the communal area under the current wood harvesting management practices. This could be due to excessive harvesting of a specific species by choice, leading to its local extinction. Alternatively, the change in the local environment or microclimate due to overutilization, could result in habitats that are no longer suitable for the germination, establishment or survival of those species. The local extinction of species in these communal areas could contribute towards the existing problem of habitat fragmentation. Through the process of habitat fragmentation, natural areas are becoming separated from one another by the loss of linking corridors, thereby negatively affecting ecological processes that rely on such corridors for pollination, seed dispersal or migration.

The 16 woody plant species that were found only within the communal area may also be cause for concern, as this might indicate the colonisation of the area by species that were not originally found in this area. Among these, the most abundant are the alien plants. The higher the concentration of alien plants on the borders of the conservation area, the higher is the threat of them spreading into the park, and the more difficult the management of alien plants within the Kruger National Park will become. Some of the other woody plant species that were found only within the communal area are alien to it, although they are not classed as invasive plants. Although there will be natural differences in species composition between areas, the above is still a cause for concern because these species are colonising an area that has been modified by man. Knowing the invasive potential of all species, whether alien or indigenous, could be useful in order to assess the severity of the risk of the presence of these species. This will form the basis for determining the realistic possibility of implementing a sustainable management solution for the future. The density results indicate a general reduction in number for all the woody plant species, both in the conservation and the communal areas. This is especially pronounced in the uplands.

Terminalia sericea is sensitive to wood harvesting pressure. The density of *Terminalia sericea* in the high-intensity harvesting zones is low compared with the conservation area. *Terminalia sericea* is the dominant woody plant species of the area and it is an indicator of a specific vegetation type. A major change in the density of this species will therefore have a significant effect on the associated vegetation, making way for the invasion by other possibly alien and non-endemic species into the area. In the Kruger National Park, the sourveld area around Pretoriuskop rest camp has been designated as a botanical reserve due to having a high density of all plant species, including rare and endangered ones. High harvesting pressure in the communal area has resulted in major changes in the comparable vegetation type. Based on similar geology, topography and soil, the conservation area and the adjacent communal area would once have had a similar vegetation structure and composition. The communal area adjoining the botanical reserve around Pretoriuskop would have played a valuable role in maintaining the integrity of the ecosystem of that area within the park and may well still do so. The two areas function as parts of one ecosystem within which valuable ecological processes, such as migration, pollination and seed dispersal take place continually.

The greater density of *Dichrostachys cinerea* in the conservation area indicates that it is not necessarily a species that is resistant to harvesting. However, there is a lack of a response in density along a disturbance gradient. *Dichrostachys cinerea* is a preferred species for fuel wood. In the conservation area uplands, *Dichrostachys cinerea* shows a relatively even density distribution along the transects, but on the lowlands it shows a patchy distribution. In the communal area it also shows an even density along the transect but at a lower density. It is possible that the distribution of *Dichrostachys cinerea* in a stable ecosystem will remain fragmented and patchy. However, in a disturbed ecosystem, as will be found in a communal area, it seems to be able to establish and exist in an even and homogeneous state with the other woody plants. It would seem that this state is what eventually leads to bush encroachment, unless *Dichrostachys cinerea* is exposed to a high harvesting pressure as has happened in the communal area. Since *Dichrostachys cinerea* is a root suckering type plant, reproducing vegetatively by growing new shoots form the root stock it is likely that fire alone will not control *Dichrostachys cinerea* encroachment, but that a combination of high intensity fires and simultaneous harvesting by man or browsing by goats after fire may be required.

By combining density and height class structure data, some interesting observations were made. The two most obvious of these are the higher density of saplings within the communal uplands in comparison with that of the conservation area, and the almost total absence of large trees within the communal uplands. The lack of large trees in the communal area has contributed towards the 12-fold higher woody plant biomass that occurs in the conservation area uplands. This is a good indicator to the local human community of the potential quota of fuel wood if harvesting is to be practised in a sustainable way. However, the low available wood biomass in the communal area at present would mean that the area would require an extended recovery period of extremely low or no utilization, to allow the woody plants to recover before a sustainable harvesting programme can be implemented.

CHAPTER 4

THE SOCIO-ECONOMIC DEMAND FOR FUEL WOOD

INTRODUCTION

Energy source and consumption patterns are two of the primary differentiating characteristics between developed and undeveloped communities. People in developed urban areas generally derive their energy from bulk power supplies. In underdeveloped regions people use a range of energy sources often derived from their immediate natural surroundings. In South Africa, as in most of Africa, the most widely used source of domestic energy in rural areas is indigenous wood from naturally occurring woodlands (Griffin *et al*. 1992).

With the large increase in human population of the world since 1980 (U.S. Census Bureau 2004), there has been a predictable increase in the demand for fuel to sustain this rapidly growing population. In urban areas, the direct effect of this demand on the environment is less obvious, because the people are less dependent upon their immediate natural environment for fuel (UPPAP 2002). In contrast, the degradation of the local vegetation surrounding rural settlements as a result of fire wood collection cannot be ignored.

Rehabilitation of degraded land will require a clear understanding of the needs of the people who live there. Current demands and supply need to be quantified to determine the deficits or surpluses. Only then can a sustainable fuel wood management approach be considered.

Several studies have already been done to quantify the demand for fuel wood in rural settlements (e.g.: Griffin *et al*. 1992, Griffin *et al*. 1993, Shackleton 1994a and Banks *et al*. 1996). From the above studies, it was clear that it was not valid to allocate a standard per capita value of fuel wood utilization throughout a number of settlements because the sociological development of a community has a direct bearing on the degree of fuel wood utilization by that community (Griffin *et al*. 1992). Hence, the degree of socioecological development is an important consideration when determining the supply and demand for fuel wood in a specific community.

Shackleton (1994b) states that even under the most optimistic forecasts within the evolving socio-political situation in South Africa and the current electrification drive, it is likely that rural households in South Africa will continue to be partially or wholly dependent on fuel wood for a further 10 to 20 years from the time of the present study. In terms of the use of wood for construction purposes relative to the fuel wood demand, the volume of wood for construction is small, but it could make the difference between an overal surplus or deficit (Shackleton 1994a). This scenario requires that the current national estimates of wood requirements be increased by 2 to 5% to account for construction timber. In the above study that was done in Mpumalanga province of South Africa, the demand for construction timber amounted to 4.2% of the total wood demand, as opposed to 2.7% in Rwanda. In five villages in Mpumalanga, another study reported construction wood amounting to 3.3 to 4.0% of the total wood demand (Griffin *et al*. 1993).

The objectives of the present study were first to determine if the amount of wood used per family in Makoko is related to the mean household income of that family. If this were true, households with a small monthly income should be more dependent upon the natural environment for resources, and hence use a larger volume of fuel wood, as opposed to those with a medium to high monthly income. A second objective was to determine the use of household fuel wood as a basis to calculate the per capita wood consumption for the village. Data relating to supplementary non-wood fuel use were also collected on a per household basis. These data were then related to the economic status of each household to test if the choice of fuel source was related to household income.

Communities that surround the Kruger National Park are important stakeholders in the Kruger National Park and play a significant role in assisting the park management in controlling poaching along the park boundaries. It is therefore essential for the park officials and neighbouring communities to work together in building a sustainable future. An additional objective of the questionnaire survey was therefore to get some indication of the attitudes and perceptions of the Makoko village community towards the Kruger National Park so as to use this information to develop a framework for tackling some of the associated socio-ecological issues that face the park management. In doing so it could play an integral role in promoting the management of the park in a sustainable way.

METHODS AND MATERIAL

The method that was used in the present study to determine the fuel wood demand for the village of Makoko was similar to that of Griffin *et al*. (1992 and 1993) and Banks *et al*. (1996). Data on fuel wood utilization were collected by way of a questionnaire (Appendix

A) that was given to a randomly selected sample of the households in Makoko village. The questionnaire was only compiled once the researcher had spent time in the village and had become familiar with the people living there and with their way of life. This approach was essential because initially the questionnaire contained questions that were not specifically relevant to this particular village and were subsequently omitted. The statistical framework of the questionnaire was developed with the Department of Statistics of the University of Pretoria before distribution.

Data collection

The quality of data that are based on questionnaires is directly dependent on the justifiability of the research method that is followed (Van Jaarsveld 2000). For obtaining data on value judgments, questionnaires are not necessarily the most appropriate approach, since the questions are pre-written and the answers often staged and open-ended. In this case, the ideal would be to do a pre-survey by using qualitative methods before setting up a questionnaire (Els 1996). When doing questionnaire analysis, it is also important to train the interviewers adequately in terms of understanding why the study is being done, how the questions are to be asked and how the answers to the questions should be interpreted and noted. This is done to avoid having the interviewers and respondents answering in a way that they perceive the questions should be answered, which may not necessarily reflect the situation accurately.

There were an expected 473 households in Makoko village at the time of the study according to information received from the Hazyview Town Council. However, a total of 529 households was obtained by systematically counting each individual household that was marked on a 1:10000 map of the village. On consultation with the University of

Pretoria Department of Statistics it was decided to select 100 households from the sample of 529 households to represent the community. Working in the former Gazankulu district, in Mpumalanga, South Africa, Griffin *et al*. (1993) used a sample size of 80 randomly chosen households, on the assumption that this was the maximum number that could logistically be dealt with.

The households that were included in the sample were selected in a stratified random way from all the households. The households in Makoko village are arranged in blocks of approximately eight houses each. A network of roads separates the blocks. To stratify the households randomly for the survey, the blocks were numbered from 1 to 62. Within each block, each household was then given a household number ranging from 1 to 12. Each household was then referred to by a code that corresponded to its position on the map (for example, household 2209 in the sampling procedure would refer to household 9 in block 22). The sampling strategy stratified the area according to street block size. The blocks were divided into three types based on the number of households within the block. The first block type contained from four to six households per block, the second from seven to nine and the third from ten to 12. A total of 11, 25 and 13 blocks were randomly selected for the sample from the three block types respectively. The number of households that were selected from each block depended on the block type, with one, two and three households being selected per block from block types 1,2 and 3 respectively. Primary stratification was done according to block size to provide the clusters from which the primary units (households) were randomly selected proportionally.

The survey was done by way of an interview with a particular household member. The language used was *siSwati,* the language of the indigenous Swazi people of the study area. Two trained interviewers that were selected from the local community conducted the interviews. Each interviewer did 50 interviews. It was essential for the interviewers to come from Makoko village, so that they could find their way around the village. It also meant that the residents knew them, contributing to each respondent feeling relaxed about answering the questions honestly and without bias.

The two interviewers were chosen according to their command of both English and *siSwati*, their competency to understand the concept behind the questionnaire and their ability to read and write. Only applicants with proof of a Matriculation Certificate were considered. The interviews were done by Virginia Sihlangu, who is a trained teacher, and by Mduduzi Zwane, who is her friend and neighbour.

A detailed training session was held first with both interviewers. Initially, each question in the questionnaire was translated and explained carefully, making sure that the interviewers understood clearly what type of answer was sought. The importance of not asking the questions in a leading way or prompting the respondents to answer in a specific way, was stressed by making the techniques used for answering questionnaires clear. The interviewers were also told that there were no wrong answers, especially in the section dealing with the perceptions of the people towards the Kruger National Park. Therefore, they were instructed to record the answers exactly as given by the respondents. Each interviewer was also given a map of Makoko village and was trained how to read and follow the map accurately.

The 50 households per interviewer were grouped according to their proximity to each other, so as to avoid the interviewers having to walk unnecessary long distances between the households to conduct the interviews. On each interviewer's map, only the

50 households in that survey were clearly marked so as to avoid them going to the wrong households.

At the training session, each interviewer was given two files. One contained the 50 incomplete questionnaires and the other was for keeping the completed questionnaires. The incomplete questionnaires were pre-coded, each with a unique household number and the enumerator code. The coding allowed for revisiting the correct household at a later stage in case of an incomplete or inaccurately completed questionnaire. This allowed the completion of inadequate questionnaires instead of discarding them.

In the case of an empty household, the enumerators were instructed to visit a household on the immediate left of the selected household when facing the household. If this household was also empty, they were to go to the house immediately to the right of the originally selected household. If this house was also empty, they were instructed to return to the original household at a later time. If a household other than the original household was interviewed, the enumerators had to mark the new household on the map. The researcher then changed the coding on that particular questionnaire accordingly. This was done to avoid gaps in the data and to remain within the time and sampling framework.

The enumerators were paid a set fee per completed questionnaire. They completed between four and seven questionnaires per day, depending on the distance of the sample households that were selected for a given day from their own houses. As an incentive, they were each paid a bonus once all the questionnaires were completed, provided that they had been done properly and according to an acceptable standard.

They were told this in advance to encourage the completion of as many high quality questionnaires as possible.

The enumerators were instructed to explain to each respondent that this was a voluntary survey, that they were not obliged to complete the questionnaire, but that their co-operation would be greatly appreciated. It was defined as a research questionnaire for the University of Pretoria and there were no promises of compensation made by the nature of the questions of by the act of replying to the questions. This was important to avoid creating false expectations that could not be carried out by the University of Pretoria or the Kruger National Park. The respondents were also informed that their chief, Chief Mdluli, would receive a copy of all the research that was conducted and that this would be available in future to any of the residents who were interested in the results.

Each questionnaire consisted of four sections. However, because each section related to a different aspect, it was unlikely that the same person would be an authority on each of the four topics. For example, the head of the household would perhaps be the best person to ask about other people in the household, but may have nothing to contribute on the wood collection patterns for that household. It was therefore decided that to ensure the most reliable replies to all the questions in each section, the questions would be directed at the most appropriate person in a household who deals with that specific activity.

Section A contained questions on basic household information. In order of preference the persons who were interviewed for this section were the head of the household, the spouse of the head of the household, an elderly person, a sibling to the head of the household, a sibling to the spouse of the head of the household, the oldest child of the head of the household, the second oldest child of the head of the household, the third oldest child of the head of the household, the fourth oldest child of the head of the household and the fifth oldest child of the head of the household. The people living in the household and their respective ages, genders and monthly incomes were noted. Other data included the number of rooms in the household, the status of the electricity connection, the monthly electricity expenditure, the major uses of electricity in the household, the monthly gas expenditure and its major uses, the monthly paraffin expenditure and its major uses and the number of candles purchased and used per month.

Section B related to questions on wood collection. In order of preference the person interviewed for this section were the wood collector, the cook, the head of the household, the spouse of the head of the household, an elderly person, a sibling of the head of the household, a sibling of the spouse of the head of the household, the oldest child of the head of household, the second oldest child of the head of the household and the third oldest child of the head of the household. The respondents were first asked if they used wood for fuel. If they did not do so they were asked about the method in which they acquired this wood. If some of the wood was purchased, they were asked the reason for and price of purchasing wood as opposed to collecting it in the field. Those respondents who collected wood were then asked how frequently they did so, and where the wood was collected.

Section C of the questionnaire addressed the utilization of wood within the household. In order of preference the persons interviewed were the cook, the wood collector, the head of the household, the spouse of the head of the household, an elderly person, a sibling of the head of the household, a sibling of the spouse of the head of the household, the oldest child of the head of the household, the second oldest child of the head of the household or the third oldest child of the head of the household. The respondents were also asked to estimate the volume of wood that they used on a daily basis by placing the estimated amount of wood in a pile. This wood volume was then placed inside a large woven plastic bag. The interviewer then weighed the wood to the nearest 250 g on a hanging scale from a tree or horizontal post near to the household. The respondents were also asked to indicate the main purposes for which the wood were used within the household.

Section D of the questionnaire addressed questions on the general perception of the people of Makoko village of the Kruger National Park. In order of preference, the person who was interviewed was the same as in section A. The respondents were asked to indicate if they had ever heard of the Kruger National Park. If they replied affirmatively, they were then asked whether they had ever visited the Kruger National Park. The respondents were also asked to indicate what they perceived the greatest advantages and disadvantages to living adjacent to the Kruger National Park to be and what was understood by them to be the main reason for the existence of the Kruger National Park. The latter question consisted of two sections. The respondents were first required to choose from a set of ten possible reasons and three open options to say what they perceived the reasons for the existence of the Kruger National Park to be. Therefore the respondents could indicate any number or combination of reasons. They were also asked not to rank their choices in any order of priority. After they had completed this section of the question, the next question required the respondents to indicate which one of the above reasons were considered to be most important. This question was designed to give an indication of the perceptions of the people towards the primary objectives of the Kruger National Park. The final question was an open one in which they were asked to suggest what interactions or developments should be started or changed between their village and the park. The respondents were finally thanked cordially for their co-operation.

Data analysis

The data on the written questionnaire were first transcribed into a numeric code. The information on the completed questionnaires was then captured electronically and correlations, t-tests, Z-tests, F-tests and one-way ANOVA analysed by using SAS®. An initial printout of the data in electronic format was used for detailed checking and correcting of the data to ensure that the data had been properly encoded and accurately captured. The initial results were displayed as frequency tables based upon the initial questionnaire data. However, more advanced programming was necessary to analyse some of the results, especially where more than one variable was involved.

Several approaches were taken to examine the possibility of establishing correlations between the variables that were used in the study. However, the main topic of interest was the relationship between the income of a specific household and its fuel use, but particularly its fuel wood use. The procedures that were used included the Pearson Correlation Coefficient and the Wilcoxon Scores Method. The Pearson Correlation Coefficient is based on the assumption that both X and Y values are sampled from populations that follow a Gaussian distribution (Motulsky 1999).

The Wilcoxon Scores Method was used for ranking the data. It is commonly used in situations where there may be a possible correlation between a graded variable, such as household income, with a two-option variable such as electricity status (Motulsky 1999). The electricity status can only have one of two alternatives: positive when the households have electricity or negative when the households do not have electricity. For tests that required additional analysis before using either the Wilcoxon Scores Method or the Pearson Correlation Coefficient the additional details appear given below.

Household income and wood collected

Since the questions on the volume of wood collected were not directly included in the questionnaire, the values of wood used and wood purchased were used as the basis for the calculations of collected wood. It was necessary to convert the monthly wood purchase to mass units since these data were in a monetary form. This was done by multiplying the expenditure in Rand by the mass of a unit in which the wood is purchased and dividing this value by the monetary value of a purchasing unit.

The values for the mass of the purchased quantity of wood were used as the basis for determining the cost of wood in each case. The questionnaire contained a question on the price of wood per bundle. When the questionnaires were returned, it was clear that the wood purchases were not done on a per bundle basis, but rather either as a light truck load of wood or alternatively as a wheelbarrow load of wood. To get an estimated mass of both of these quantities of wood, 10 wheelbarrows and 2 light truck loads of wood were weighed to obtain a mean mass for both of these quantities respectively.

Electricity and the use of fuel

In order to get a more representative idea of the quantity of each source of fuel that was used per month, including wood, it was necessary to convert the expenditure per household on electricity, gas, paraffin, candles and fuel wood, into a common unit of energy. For this purpose, the monthly household use of each fuel source was converted into Mega Joules (MJ) as a standard unit of energy. The expenditure on each type of fuel was then converted to quantities first and then into energy units by using the following conversions (Griffin *et al*. 1993; Smal, pers. comm[3]):

Gas :	49.8 MJ per kg
Paraffin:	37 MJ per litre
Candles:	3.45 MJ per candle
Wood:	17 MJ per kg
Reticulated electricity:	3.6 MJ per kWh

The numbers of candles that were used per household was an absolute value as obtained from the questionnaire. This was multiplied by the energy value of a candle (3.45 MJ per candle) to calculate the total amount of energy that was used in the form of candles on a monthly basis. The wood used was already in a mass unit and could therefore be converted directly into the energy units for that quantity of wood by using the above wood energy value. The monthly energy consumption of paraffin per household was determined by multiplying the monthly paraffin expenditure with the above energy value of paraffin, and then dividing it by the price per litre of paraffin at the

[3] Smal, N.J., Senior Systems Engineer, ABB Reyrolle, P.O. Box 8080, Elandsfontein 1460. Date: 4 March 2002.

time of the study (R2.50). The energy consumption of gas purchased in each case was determined by multiplying the monthly gas expenditure with the above energy value of gas and dividing it by the price per kg of gas at the time of the study (R5.92).

The calorific conversions for electricity were complicated as there were a number of different ways in which households could pay for electricity. Some of the households paid on a monthly basis after receiving an account from the Electricity Supply Commission (ESCOM) based on their monthly electricity consumption. The families who were using >300 kW of electricity per month were charged at a lower rate than those who were using ≤300 kW per month. Although the lower energy users were charged a higher monthly rate, they were not charged the basic administration fee of R44.10 that was paid by the high user group.

The alternative method of payment for electricity was based on a pre-paid service. This involves an advance estimate of the household's electricity expenditure and then doing a pre-purchase of this electricity in the form of a meter card. The household can then utilize this pre-paid electricity until the allocated quota was used up. The household would then have to purchase another card in order to get further access to electricity. This method ensured that families spent only a realistic amount that was related to what they could afford on electricity and did not end up with a large and possibly unpayable bill at the end of the month. It also allowed families to budget for their electricity more accurately and avoided accusations and miscalculations when it came to the paying of bills at the end of each month. The cost for this electricity was the same as for high-energy users. This payment option was the cheapest alternative since no administration fee was involved.

The question relating to electricity expenditure made no allowance to distinguish which method of payment was used by each household. The majority of the people living in the village made use of the pre-paid system, as it was the most economically viable method (Sihlangu, pers. comm.[4]). However, there were several households who paid by means of receiving an account for their monthly electricity consumption. For the scope of this study, it was decided to use a unit price that was based on the most popular pre-paid method at a rate of R0.2398 per kW hour. The kW hours were converted to Mega Joules by using the conversion factor of 3.6 kW = 1 MJ.

RESULTS AND DISCUSSION

Household size

The most common household contained three members (20%), followed by four members (17%) and five members (15%). The other size groups all occurred at a frequency of ≤10%, with the lowest frequency (1%) for households of 13 and 15 members (mean: 5.80; range: 1 to 15; SD: 2.77 people per household) (Table 4.1). In a study by Griffin *et al*. (1993) an average household size for each of six rural settlements around Gazankulu, a former homeland in Mpumalanga, South Africa were found to vary from 7.2 to 8.4 people per household. In another study done in the same area as the previous study, mean household sizes ranged from 7.24 to 8.39 people (Banks *et al.* 1996).

[4] Sihlangu, V. Resident of Makoko, P.O. Box 904, Kabokweni, 1245.
Date: 4 March 2002.

Table 4.1: Frequency distribution (n = 100) for the number of people living in a household in Makoko village, Mpumalanga province, South Africa based on a questionnaire survey from February to March 2001

People in the household	Number of households	People in the household	Number of households
1	1	9	4
2	2	10	5
3	20	11	3
4	17	12	2
5	15	13	1
6	11	14	0
7	8	15	1
8	10	-	-

To get a measure of the age class distribution of the people living in the sampled households, the ages of the household members were grouped into appropriate age class intervals (Table 4.2). These age class intervals were initially based on class intervals of ten years each. It was later decided to subdivide two of these groups further into two classes where exclusive data were required for additional calculations related to other aspects that will be dealt with later. The mean age of people living in the village was 24.3 years (range: 1 to 88 years; SD: 17.45 years).

Of the sampled population 58.7% have no monthly income and 91.7% earn a monthly income of <R1000.00 (Table 4.3). The mean monthly income per person is R272.79 (range: R1.00 - R3300.00; SD: R525.82). The per capita income was calculated by using all members of each household, and hence it reflects a mean income per capita for the entire sampled population. Although these data are accurate, they do not represent the mean monthly income of the working force because the children who are still of school-going age (0 to 19 years) and the pensioners (≥65 years old for males and ≥60 years old for females) have also been included. This creates a reduction in the mean monthly income. Moreover, the government subsidies were also included as a monthly income because they do contribute to the household income. However, they do not relate to the employment status of the people that were surveyed. For these reasons, a second calculation was done by excluding all the people ≤19 years old and the pensioners. It was assumed that the elderly people were no longer part of the age group that could reasonably be expected to be in formal employment. Any person who was older than 58 years and with a monthly income of R570.00 was also excluded because this was obviously a pension income. In such cases, it was assumed that the age of the person had not been correctly recorded or given on the questionnaire.

Table 4.2: Percentage age class frequency distribution of the people living in the sampled households (n = 100) of Makoko village, Mpumalanga province, South Africa based on a questionnaire survey from February to March 2001

Age class in years	Frequency	
	Number of people	Percentage of population
0 - 5	65	11.2
6 - 9	59	10.2
10 - 19	150	25.8
20 - 29	121	20.8
30 - 39	76	13.1
40 - 49	55	9.5
50 - 59	26	4.5
60 - 64	13	2.2
65 - 69	7	1.2
70 +	9	1.6
Total	581	100.0

Table 4.3: Mean monthly income (Rands) per capita for the people living in 100 households sampled in Makoko village, Mpumalanga, South Africa, based on a questionnaire survey in February and March 2001

Mean monthly income	Number of respondents	Percentage of population
No income	341	58.7
1 - 499	102	17.7
500 - 999	90	15.5
1000 - 1499	17	2.9
1500 - 1999	15	2.6
2000 - 2499	10	1.7
2500 - 2999	4	0.7
3000 - 3499	2	0.3
Total	581	100

Members of the community who were ≥60 years old and who were still earning a salary were included as workers in the analysis. The assumption was made that any person who qualified for old age pension, but who was still earning a salary, did not receive a government pension. This may not be entirely true but there was no way with which to identify such cases. The mean monthly income under these restrictions was R483.09 (range: R1.00 to R3300.00; SD: R668.30). It is accepted that this is a crude method of classifying the working force but these results do give a more representative mean monthly income per capita for those people who are likely to be able to earn an income. Griffin *et al.* (1992) found a mean per capita income for employed persons of R313.00 per month in Athol, a rural settlement in Gazankulu, Mpumalanga, South Africa. The village in the above study with the lowest mean monthly income for employed persons was a refugee settlement at R161.00 per capita per month. Inflation may account for some of these differences.

Since the fuel wood use was determined on a household basis in the present study the total household income is a more useful value to compare with other studies (mean: R1585.00; range: R1.00 to R7660.00; SD: R1370) than the per capita income. Griffin *et al.* (1993) reported that a refugee settlement in Gazankulu, Mpumalanga, South Africa had a household income of R253.00 per month. However, Griffin *et al.* (1992) reported one of R724.00 per month in Rolle, a rural village in Mpumalanga, South Africa. The above study found that the household income differed significantly between settlements. They attributed these differences mainly to income from pensioners because the refugee households were not receiving pensions.

Fuel use per household

Only 18% of the 100 households that were interviewed in the present study did not have access to reticulated electricity. The mean monthly electricity expenditure for the 82 households that did have access to electricity was R108.82 (range: R1.00 to R290.00; SD: R71.40). The mean monthly electricity expenditure for all the sampled households, including those that have no access to electricity, was R89.23 (range: R1.00 to R300.00; SD: R77.05) (Table 4.4). Makoko village used electricity at 453.79 KWh per month. Griffin *et al.* (1993) found that two settlements in Gazankulu, Mpumalanga, South Africa used electricity at a rate of 216.5 KWh and 416.4 KWh on a monthly basis respectively. There is an eight year difference between the studies and fuel consumption may have increased during this time.

Only 19 households in the present study reported using gas as a source of energy (Table 4.4). The mean monthly expenditure on gas for those households that used gas was R74.79 (range: R1.00 to R115.00; SD: R27.26). The mean monthly gas expenditure for all of the 100 sampled households was R14.21 (range: R1.00 to R160.00; SD: R31.70). In total, 12.63 litres of gas were used per household per month. This is within the range of 11.3 to 16.0 litres for the mean gas use reported by Griffin *et al*. (1993) working in Gazankulu, Mpumalanga, South Africa.

Of the 100 households sampled 87 used paraffin (Table 4.4). However, the paraffin was used as both a source of energy and an ingredient in making floor polish. This secondary use of paraffin compounded the quantification of paraffin as a fuel source.

Table 4.4: The mean monthly energy expenditure on and use levels of five energy sources per household in 100 households in Makoko village, Mpumalanga, South Africa based on a questionnaire survey in February and March 2001

Energy source	Households that use this energy source	Mean ± SD of energy expenditure for households that use this resource only	Mean ± SD of energy expenditure for all households	Energy quantity consumption by households that use this resource only	Energy units (MJ) used by households that use this resource only
Electricity	82	R 108.82 ± 71.40	R 89.23 ± 77.05	453.8 KWh	1633.64
Gas	19	R 74.79 ± 27.26	R 14.21 ± 31.70	12.6 litres	628.97
Paraffin	87	R 50.52 ± 60.74	R 43.95 ± 59.13	20.2 litres	747.80
Candles	94	R 11.68 ± 2.03	R 10.98 ± 9.10	21.3 candles	73.42
Wood	72	228.0 ± 2.7 kg	164.1 kg ± 124.1	228.0 kg	3875.70

It only became apparent after the questionnaires had been completed and no distinction was made between the quantities of paraffin that were used for floor polish and fuel. The mean monthly expenditure of those households that used paraffin was R50.52 (range: R1.00 to R446.00; SD: R60.74). When considering the paraffin use for the entire sampled population, the mean expenditure on paraffin was R43.95 (range: R1.00 to R450.00; SD: R59.13). The mean monthly paraffin use was 20.21 litres. Two similar settlements in Mpumalanga, South Africa, had a mean use range of 4.6 to 17.3 litres per month (Griffin *et al*. 1993). This difference in paraffin use between the previous study and the present study may be the result of the additional use of paraffin for making floor polish in Makoko village.

Of the 100 households that were included in the present study, 94 used candles for lighting in their homes (Table 4.4). These households used a mean of 2.66 packets of candles (range: 1 to 16 packets of candles; SD: 2.03 packets of candles) per month, or 16 individual candles per household per month. At the time of the present study, the candles sold at a mean price of R4.39 per packet, converting into a mean monthly cost of R11.68 per household for those who were using candles. The mean monthly expenditure on candles for the entire sample of 100 households was R10.98 (range: R1.00 to R76.63; SD = R9.10). Other studies showed similar results in terms of candle use ranging from 10.7 to 37.5 candles per household per month (Griffin *et al.* 1993). Of the six settlements included in the above study, the two with the highest candle consumption per household, and were also the only two settlements with access to reticulated electricity. This suggests that although households do have access to electricity, candles may still be a more cost-effective way of providing them with lighting.

Of the 100 households that were surveyed in the present study, 72 used wood on a daily basis for fuel. The mean daily mass of wood used by these households for energy was 7.49 kg (range: 1.0 kg to 9.0 kg; SD: 2.70 kg) (Table 4.4). For practical reasons, the respondents were asked to estimate their wood use on a daily basis. However, it was necessary to convert the daily wood use to a monthly basis, to compare it with the rest of the data. The households that used wood as an energy source had a mean monthly consumption rate of 228.0 kg of wood. Griffin *et al*. (1993) found that the mean monthly wood consumption in six rural settlements in Gazankulu, Mpumlanga, South Africa varied from 250.9 to 399.9 kg. In the above study, the two villages with the lowest fuel wood use of 250.9 kg and 305.2 kg were also the only two that had access to reticulated electricity. None of the other households studied had access to electricity and used wood at rates in excess of 309.3 kg per month. For the present study, the mean monthly mass of wood used per household for the entire sample of 100 households was 164.1 kg (range: 1 to 365.25 kg; SD: 124.10 kg). This converts to 338.9 kg of wood per person per year. Griffin *et al*. (1992) reported an annual wood use range of 505.2 to 560.4 kg per person per year. Banks *et al.* (1996) reported that two settlements in Mpumalanga, South Africa, used wood as their primary energy source at a rate of in >500 kg per person per year. However, neither of the two villages in the previous study had access to reticulated electricity at the time of their study.

Household income and energy use patterns

A significant but weak positive correlation was found between the household income and the number of rooms in each household (Table 4.5). Working in Mpumalanga, South Africa, Griffin *et al*. (1993) used aerial photographs to estimate the number of rooms in a household, and then used the number of rooms as a measure of household income. The

Table 4.5: Pearson Correlation Coefficients (r) to test for linear correlations between various energy sources and household information based on a questionnaire survey done in February and March 2001 in Makoko village, Mpumalanga, South Africa

Comparison made	Test values		Number of households
	r	P	
Income and number of rooms	0.48	<0.01	100
Income and fuel wood use	0.02	>0.05	72
Income and wood purchases	0.09	>0.05	29
Income and wood collected	-0.47	<0.01	61
Income and paraffin expenditure	0.26	≤0.05	87
Income and gas expenditure	0.61	<0.01	19
Income and electricity expenditure	0.39	<0.01	82
Income and candle expenditure	0.12	>0.05	94
Income and energy expenditure	0.55	<0.01	100
Electricity expenditure and wood use	-0.04	>0.05	54
Electricity expenditure and wood use	-0.16	>0.05	100
Electricity expenditure and other energy source expenditure	0.25	≤0.05	100
Electricity expenditure and other energy source expenditure	0.26	≤0.05	82
Electricity use and other energy source use	0.0678	>0.05	82

correlation in the present study does not support this method. More investigation into the use of number of rooms as an indication of household income is needed before it can be seen as a viable and more cost- and time-effective alternative. The mean household income of R1760.00 (range: R0.00 to R7760.00; SD: R1443.17) for those households that have electricity was significantly higher than the mean of R787.20 (range: R0.00 to R1600.00; SD: R425.48) for those households without electricity ($Z = -2.98$; $P<0.01$). Only 46% of the respondents indicated that cooking was their main use of electricity, while 25% and 11% used it mainly for lighting and other electrical appliances respectively (Table 4.6). Griffin *et al*. (1993) who also worked in Mpumalanga, South Africa found that electricity was only available to some respondents and was perceived to be expensive and was not widely used. They also found that reticulated electricity, even when available, was always used for lighting and only in selected cases, for cooking and for powering other household items.

Household income and fuel wood use

There was a significant negative correlation between household income and the mass of wood collected per household (Table 4.5). However, there was no correlation between household income and the monthly quantity of wood that was used or the quantity of wood that was purchased per household. This suggests that households in the higher income bracket will be less likely to collect wood than those in the lower income bracket but that wood use levels are related to factors other than household income. This argument is supported by the lack of a significant correlation between electricity expenditure and wood use. Beyers (1996) reported on the role of fire as an important cultural tradition within the households, but in the present study only 16 of the 100 households reported that they used wood for cultural reasons. Households in Makoko

Table 4.6: The use distribution of each type of energy source in 100 households sampled in Makoko village, Mpumalanga, South Africa based on a questionnaire survey in February and March 2001

Main use	Percentage of households			
	Electricity	Gas	Paraffin	Wood
Lighting	25	3	21	0
Cooking	46	16	57	55
Heating	0	0	2	3
Domestic appliances	11	0	*	*
Specific households only	18	81	13	26

Notes

* : Not applicable

village that have incomes above the mean of R1585.00 (range: R1.00 to R7660.00; SD: R1370.00) will not necessarily be earning sufficiently more than the majority of households, that these extra earnings would be reflected in their use of energy sources. There was a significant difference in household income depending on the main use of wood within the household ($r = 0.35$; $P<0.01$). Households that indicated that their main use of wood was for cooking purposes had a mean monthly income of R1160.91 (range: R1.00 to R4800.00; SD: R921.26), whereas those using wood mainly for cultural purposes had a mean monthly income of R1970.63 (range: R1.00 to R4110.00; SD: R1298.48). It was expected that this relationship would be negative because of the more affluent families making more use of reticulated electricity as an energy source than the poorer ones.

The method that was used to determine the mass of wood collected is crude and depends on a number of unreliable factors. The conversion ratio that is used to convert the daily to a monthly wood use will compound any original errors. The daily wood use per household is based on an estimate by the respondents. Due to the nature of the equation that was used here, an overestimation of the mass of wood used will also result in an overestimate of the wood mass that was collected because these values are directly proportional. However, an overestimation of the mass of wood purchased will result in an underestimation of the mass of wood collected for that household because these two values are inversely proportional to one another. Of the 63 households that purchased wood, the data from five households showed that the monthly mass of wood purchased exceeded the estimates of the mass of monthly wood use.

Household income and expenditure on other fuel sources

The total fuel expenditure by each household reflects the combined expenditure for electricity, gas, paraffin, candles and wood. This total fuel expenditure per household was positively correlated with the household income (Table 4.5). However, it is important to remember that fuel expenditure per household does not necessarily equate to fuel use per household because the wood expenditure estimate that was used here refers to wood purchases and not to wood use. Some families purchase and collect wood, while others only collect or only purchase wood. There was a significant positive correlation between monthly household income and the monthly expenditure on paraffin and gas but not candle use (Table 4.5). This was contrary to what was initially expected when it was predicted that as household income increased, the likelihood of households using other fuel sources would decrease because they would then be able to afford electricity. The strongest of these correlations is the use of gas indicating that as monthly income increases, the more likely the households are to spend money on gas. Gas was still perceived to be a more cost-effective fuel source than electricity. The above results suggest that those households with a high mean monthly income will not necessarily use more electricity as energy, but will continue to use the more cost-effective and traditional energy sources such as wood, paraffin and gas. This argument is supported by the weak correlation between monthly household income and electricity expenditure but not by the weak correlation between electricity expenditure and expenditure on other fuels or by the lack of a significant correlation between electricity use and the use of other fuels.

Community and Kruger National Park issues

All 100 respondents had heard of the Kruger National Park before, even if they had not officially visited the park yet. There were 76 respondents who had actually visited the Kruger National Park previously.

Disadvantages of living adjacent to the Kruger National Park

The most often selected disadvantage of living adjacent to the Kruger National Park related to livestock losses to predators that had escaped from the Kruger National Park (56%) (Table 4.7). The constant threat of predators attacking livestock has influenced the construction design of overnight livestock pens. The pens are constructed by using a large number of heavy pieces of wood that are collected from the communal lands around the village. There is a preference to build livestock pens from woody plant species with thorns or spines. This could result in a species-selective harvesting of construction wood. It also seems these fences require more wood to be made predator proof than the fences that are built for holding livestock overnight in villages that are further away from the park border. The next three most frequent disadvantages, each with a frequency of 11%, related to livestock losses due to the railway line and trains, land shortages for dwellings and land shortages for growing crops. A Land shortage for grazing their livestock was the fifth most frequently selected option (6%). Crop raiding by animals escaping from the Kruger National Park was reported with a low frequency (5%), while the disadvantages of limited access to wood and no water for irrigation were never indicated as priorities.

Table 4.7: The disadvantages of living adjacent to the Kruger National Park as reported by 100 households of Makoko village, Mpumalanga, South Africa based on a questionnaire survey in February and March 2001

Disadvantage	Number of households
Livestock loss to predators from the Kruger National Park	56
Livestock loss due to railway lines and trains	11
Land shortage for dwellings	11
Land shortage for growing crops	11
Land shortage for grazing animals	6
Crop raiding by animals from the Kruger National Park	5
Limited access to wood	0
No water for irrigation	0

Advantages of living adjacent to the Kruger National Park

In this question, the respondents could indicate as many advantages as they liked that seemed relevant to their particular household. It is for this reason, that the 140 options that were selected exceed the sample size of 100 (Table 4.8). Aesthetic considerations, including the beauty and tranquillity of the surroundings, were chosen with the highest frequency (60.7%). This is a measure of the value that the people living in Makoko village attach to living in the proximity of the Kruger National Park. The advantage that was expressed with the second highest frequency (14.3%) was safety. People feel that by living in the village close to the park they are safer from human dangers, than living elsewhere. Their village is reasonably remote, and has limited access for undesirable people because the park borders one side of their communal land. Of the 100 respondents, 7.1% indicated that being allowed to hunt wildlife that escape from the park was an advantage of living in the area. Almost 6% of the respondents indicated that they collected wood illegally in the park and that because of this living adjacent to the park was an advantage. Only one respondent chose the advantage of free animal viewing through the fences of the park (0.7%). This indicates that an appreciation for aesthetics does not extend to wild animals, but mainly concerns landscapes.

Reasons for the existence of the Kruger National Park

The option that was chosen by most respondents (81%) was that the park was a destination for wealthy tourists (Table 4.9). The second most frequent reason given was that the park was a grazing source for the livestock of the residents living within the park (73%).

Table 4.8: The advantages of living adjacent to the Kruger National Park as identified by 100 households of Makoko village, Mpumalanga, South Africa based on a questionnaire survey in February and March 2001

Advantage	Number of households	Percentage
Aesthetics	85	60.7
Safety	20	14.3
Hunting escaped animals	10	7.1
Wood collection	8	5.7
Tourists purchasing vegetables	4	2.9
Tourists purchasing crafts	3	2.1
Compensation	3	2.1
Educational visits	3	2.1
Playing soccer	3	2.1
Free animal viewing	1	0.7

Table 4.9: The percentage frequency of the possible and main reasons for the existence of the Kruger National Park as identified by 100 respondents from Makoko village, Mpumalanga, South Africa based on a questionnaire survey in February and March 2001

Item	Main reason	Other possible reasons
Wealthy tourist destination	29	81
Grazing for livestock of Kruger National Park residents	25	73
Animal conservation	17	68
Animal and land conservation	7	17
Plant conservation	7	2
Meat source for Kruger National Park residents	6	29
Animal and plant conservation	5	15
Animal, plant and land conservation	3	11
Plant and land conservation	1	6
Land conservation	0	14
Total	100	316

The third most common choice was the Kruger National Park was a place for the conservation of animals (68%). Only two (2%) of the respondents indicated that the conservation of plants was a reason for the existence of the Kruger National Park. When the respondents were asked to indicate the main reason why they gave a specific answer in the previous section, the most frequent response (29%) once again was that the Kruger National Park was a destination for wealthy tourists. Grazing for livestock of the Kruger National Park residents was indicated as a main reason by 25% of the respondents. The latter option, however, could have been a misleading one because it was based on a misconception of what members of the park staff are allowed to do. The concept that the Kruger National Park was a place for the conservation of animals was the only other frequent response (17%).

Developments between the Kruger National Park and the community

The question of what future developments between the Park and the community would be preferable was asked in the form of an open question, but there was only space for five suggestions per respondent. The problem with this type of question is that the results are usually variable and diverse, with many options. Although the question was carefully explained to the enumerators before conducting the survey, in hindsight, it seems that the question was not fully understood by the enumerators, the respondents themselves, or by both. Many of the answers related to things that the community would like the Kruger National Park to make available to them or donate to them. They were not really developments as was understood by the researcher (Table 4.10). Consequently the results have a different than intended relevance. In all 40 different answers were given to this question. Many of these answers occurred with a frequency of 3% or less. However, they were included in Table 4.10 to show what the perceptions

Table 4.10: Development needs between the community and the Kruger National Park as suggested by 100 respondents from Makoko village, Mpumalanga, South Africa and based on a questionnaire survey in February and March 2001

Need	Percentage of respondents
Improved job creation	29
Improved relationships	29
Safety from dangerous animals	28
Workshop and training locations	23
Removal of fence for wood, grazing and water access	16
Recreational area or stadium	11
Banks, crèches and shopping centres	8
Small project development workshops	8
Sponsoring of schools	7
Buildings for businesses	7
Free visits for schools to the Kruger National Park	6
Hospital and ambulance services	6
Street lighting	6
Job provision equality	5
Wood supply or collection	4
Free meat	3
Taxi rank	3
Houses for the poor	3
Free visits for community members to the Kruger National Park	2
University	2
Bursaries for school and university students	2
Clinics	2
Water	2
School for handicapped people	1

Table 4.10 continued

Need	Percentage of respondents
Roads	1
Better crime security	1
Casino	1
Post office	1
Public phones	1
Petrol station	1
School uniforms	1
School furniture	1
Robots	1
Hotel	1
Police station	1
Churches	1
Museum	1
Less unnecessary burning of land	1
Building of dams	1
Share in Kruger National Park business	1

of the community are towards their own development needs. Four of the 40 suggestions occurred with a frequency of >20%. The community mentioned employment opportunities in the form of job creation as one of their major requests, with an improved relationship between themselves and the Kruger National Park rating highly as well. There was a definite need for workshops and training locations within the community. These can be linked to developing the necessary skills to run rural development projects on a sustainable basis. The community members also expressed their concern about dangerous animals that escape from the park, and improved safety in this regard was an important issue.

Socio-ecological issues

The mean monthly household income of those respondents who had visited the Kruger National Park was significantly more (mean: R1673.03; range: R1.00 to R7660.00; SD: R1466.18) than those who had not (mean: R 1305.83; range: R1.00 to R3600.00; SD: 979.39) ($F = 2.24$; $P \leq 0.05$). The perceptions of those respondents that have visited the Kruger National Park were compared with those that have not done so because it influenced their response to some parts of the questionnaire (Table 4.11). Those respondents who had visited the Kruger National Park thought that the main reason for the existence of the park was to act as a destination for wealthy tourists, but those respondents who had not visited the park at the time of the interview thought that the major reason was the conservation of animals. This means that by visiting the park, the perception that the park is a destination for wealthy tourists was strengthened. A trained environmental education officer who can explain the mission, vision and major activities of the park should accompany the visiting community members.

Table 4.11: Comparisons between the perceived reasons given for the existence of the Kruger National Park by 100 respondents from Makoko village, Mpumalanga, South Africa who have and have not visited the park, based on a questionnaire survey in February and March 2001

Reason given	Have visited		Have not visited	
	Respondents	Percentage	Respondents	Percentage
Animal conservation	46	18.7	22	31.4
Plant conservation	2	0.8	0	0
Land conservation	10	4.1	4	5.7
Animal and plant conservation	12	4.9	3	4.3
Animal and land conservation	16	6.5	1	1.4
Plant and land conservation	4	1.6	2	2.9
Animal, plant and land conservation	9	3.7	2	2.9
Wealthy tourist destination	63	25.6	18	25.7
Meat source for Kruger National Park residents	25	10.2	4	5.7
Grazing for livestock of Kruger National Park residents	59	24.0	14	20
Total	246	100.0	70	100.0

CONCLUSIONS

There were no significant relationships between income and volume of wood used or volume of wood purchased apart from a negative correlation between monthly household income and mass of wood collected. These results do not support the concept that economic development and the drive towards electrification will be the immediate solution to the wood harvesting imbalance. Higher monthly incomes are related to a greater expenditure on other fuel sources combined, but wood use is apparently determined by factors other than household income or electricity usage. Therefore demand for fuel wood is likely to remain a concern for conservation areas close to rural communities. Residents of the Makoko community did not indicate that the boundary of the Kruger National Park is a disadvantage in terms of meeting their fuel wood needs. This may indicate that they do not yet need to enter the park to meet their requirements or that they already do enter the park to fetch wood illegally and hence are not hindered by boundary fences. Finally, the mission of the Kruger National Park was not well known in the Makoko community, as most people were still under the impression that the park existed primarily as a wealthy tourist destination. It is fundamental that the neighbouring communities be made aware of the conservation benefits of the park, both to themselves and to the wider community, in order to encourage and successfully develop worthwhile long-term sustainable partnerships between themselves and the park.

CHAPTER 5

BALANCING FUEL WOOD SUPPLY AND DEMAND

INTRODUCTION

South Africa produces and consumes the largest portion of all the energy in sub-Saharan Africa but the distribution of this energy within South Africa itself is markedly unequal between the affluent and the poor and between urban and rural areas. These disparities have contributed to an environmental decline around the mainly poor, rural communities. Strategies for reducing these disparities include extensive electrification, establishing woodlots and social forestry. Social forestry is the planting of trees within the home environment of rural communities, thereby eliminating the problems of access and ownership experienced by woodlots (Shackleton 1994a).

Although 74% of South African households have potential access to electricity, with more than 80% of them active customers, the Department of Minerals and Energy have an eight-year plan to achieve 100% electrification (Ensor 2004). In the above report, it is predicted that in order to achieve this goal, alternatives to reticulated electricity such as solar energy and mini-hydro systems would have to be investigated. Temporary solutions are being sought to diminish the negative environmental impacts of unsustainable harvesting of fuel wood. In order to find such solutions, it is important to understand and quantify the problem.

The impact of the unsustainable harvesting of woody plants within the Makoko village communal area is clear when the woody species diversity, density, structure and biomass between the communal and conservation areas are compared (Chapter 3). Although this impact was quantified, it still remains essential to establish the causal factors behind this vegetation degradation scientifically. This negative effect on the vegetation is reflected in other studies where the woody plant dynamics were compared between communal and conservation areas (Shackleton *et al.* 1994; Lykke 1998; Higgins *et al*. 1999; Shackleton 2000) although few studies have combined ecological and social aspects to provide valuable comparisons between the supply and demand of fuel wood for a specific area (Griffin *et al*. 1992; Shackleton 1994a; Banks *et al.* 1996).

If there is to be any future for a management plan that strives towards the sustainable harvesting of the fuel wood resource of Makoko village, the current status of the availability of this resource to the community members must be determined in addition to understanding the nature of the demand for fuel wood within the village. The purpose of the present chapter is to examine the difference between the supply of and the demand for fuel wood and to provide suggestions for balancing the expected disparity between the two values.

The determination of the sustainable harvesting rate for fuel wood from African savannas requires an estimate of the total surface area that is available for harvesting and the annual production of the usable fractions of wood within the area (Shackleton 1994a). In South Africa, there is little information available on the annual growth rate of indigenous trees. Without such information, researchers must either seek predictive relationships based on the few existing data and other variables for which there is a better national coverage, such as rainfall or biomass, or they can set up the required number of monitoring sites and obtain the required empirical data. The latter approach allows the validation and refinement of any previously derived relationships under the first option. Fuel wood production is a function of the surface area of land under a specific management system, the standing crop of the woody plant biomass and the annual production of wood as a proportion of the woody plant biomass (Shackleton 1994a).

Rutherford (1978) calculated that the mean annual wood biomass production in the savannas in South Africa was 4 to 5% of the standing wood biomass. After refining this estimate for inaccessible wood, wood that is too small for fuel and undesirable species, an approximate annual production rate of 3% of the standing wood biomass was expected (Shackleton 1994a). Guy (1981) found a logarithmic relationship between woody plant productivity and woody plant mass in the Sengwe area of southern Zimbabwe, with production rate of 9% for a woody plant biomass of 10 metric tonnes per ha and 7% for 20 metric tonnes per ha. Shackleton (1994a) studied the productivity of the woody vegetation of the savanna biome and calculated a mean woody plant biomass production rate of 1.4% in terms of stem basal area for several climatically different sites in both the Mpumalanga and Limpopo provinces of South Africa. Due to the generally strong positive linear relationship between the basal area per woody plant and the total biomass per woody plant in Southern African savannas, these values were interpreted as the annual woody plant productivity (Shackleton 1994a).

Fuel wood demand is directly related to the number of people within an area that make use of wood as an energy source. Consumption of fuel wood depends on socio-economic status, fuel wood supply, accessibility and the cost of other fuels (Shackleton 1994a).

MATERIALS AND METHODS

The Supply of fuel wood

For the purposes of the present study, the woody plant biomass values in Chapter 3 as based on the methods of Rutherford (1979) were used to determine the wood biomass in the Makoko village communal area. This wood biomass was combined with an estimate of 3% annual woody productivity (Shackleton 1994a) to determine the quantity of fuel wood that will be available for harvesting in a sustainable manner from the Makoko village communal area.

The demand for fuel wood

For the present study, the daily fuel wood use per household (Chapter 4) was used to calculate the demand for fuel wood within the Makoko village as a whole based on a population size of 5600 people (Makoko Needs Assessment 1996).

Balancing fuel wood supply and demand

In the present study, the volume of fuel wood that could be harvested sustainably from the Makoko village communal area annually was calculated. This was compared with the annual demand for fuel wood by the Makoko village. The difference between the supply and demand was used as a basis for the assessment of the sustainability of current harvesting practices of Makoko village. In addition, these comparisons were used to support the recommendations that were made towards achieving a sustainable harvesting strategy in the future.

RESULTS AND DISCUSSION

The supply of fuel wood

The wood biomass for the communal area up- and lowlands were 4622.50 kg per ha and 3382.90 kg per ha respectively (Table 3.6). Based on a surface area of 1621.90 ha for the uplands and 798.70 ha for the lowlands (Chapter 2), the total wood biomass for the communal area up- and lowlands are 7496.70 metric tonnes and 2701.90 metric tonnes respectively. Assuming an annual productivity of 3%, this amounts to a harvestable wood biomass of 224.90 metric tonnes and 81.06 metric tonnes of fuel wood for the up- and lowlands respectively. This is the mass of fuel wood that can be harvested annually on a sustainable basis. Similar-sized areas within the Kruger National Park conservation area can provide 1402.30 metric tonnes and 109.60 metric tonnes of fuel wood annually for the up- and lowlands respectively. By combining up- and lowland fuel wood availability, a total harvestable wood biomass of 306.00 metric tonnes is available in the communal area annually as opposed to 1511.90 metric tonnes in the conservation area. When divided between the population of 5600 people, the communal area can provide 54.60 kg of fuel wood per person annually. Alternatively, the conservation area could provide 270.00 kg of fuel wood per person annually.

It is important to note that this sustainable supply would not allow for any vegetation recovery from past harvesting practices. If recovery of the woody vegetation were to be taken into account, a harvesting ratio of less than 3% of the standing wood biomass would have to be considered.

Shackleton (1994a) estimated the mean woody plant standing biomass for various land-use types in Mpumalanga province, South Africa to be 20.40 metric tonnes per hectare for conservation areas, 17.50 metric tonnes per hectare for commercial cattle ranching areas and 4.80 metric tonnes per hectare for communal areas. The results of the present study support these values, with a standing wood biomass of 4.20 metric tonnes per hectare for the communal area of the Makoko village and 20.80 metric tonnes per hectare for the conservation area within the Kruger National Park.

The demand for fuel wood

The mean monthly household use of fuel wood in Makoko village was 164.10 kg per month (Chapter 4). This converts to 1 968.70 kg of fuel wood per household per year. At the time of the present study, there were 5.80 people per household in the village. Consequently the mean annual wood use per person is 338.90 kg.

This demand is similar to the per capita fuel wood consumption that was obtained by Shackleton (1994a) in his study in the Mhala district of Mpumalanga, South Africa. In his study, the per capita fuel wood consumption ranged from 391.00 to 552.00 kg per person per year between four villages studied. In a summary of several recent studies, the mean annual per capita consumption of fuel wood was 687.00 kg for South Africa as a whole, but for the purposes of the above study, per capita consumption levels of fuel wood of 350.00, 550.00 and 750.00 kg per person per year were used.

Balancing fuel wood supply and demand

The annual per capita demand for fuel wood for the Makoko village was 338.90 kg. The annual per capita supply of fuel wood from the Makoko village communal area, if harvested sustainably, was 54.60 kg. Under these harvesting rates, the vegetation would remain stable in its current state with little recovery to the desired state as is found in the conservation area. The conservation area was able to provide 270.00 kg of fuel wood annually per person if it were harvested sustainably. Therefore, had the communal area been managed in a way similar to conservation area, it would still not be able to supply the required amount of fuel wood on a sustainable basis to the people of Makoko village. The human population of Makoko village has grown to a point where it is no longer possible for the natural resources upon which so many of the people depend to be harvested sustainably in the long-term. Realistic alternatives to fuel wood harvesting therefore have to be developed.

Banks *et al.* (1996) did a study to determine the supply and demand of fuel wood in two rural settlements in the Mpumalanga province of South Africa. They explored scenarios of wood supply in relation to changing demand as a result of increasing consumption patterns and human population growth. He found that Athol village had a per capita demand for fuel wood of 505.20 kg per person per year, and a supply of 629.60 kg of fuel wood per person per year. The second village, Welverdiend, had an annual per capita demand of 506.40 kg and an available sustainable supply of 261.94 kg of fuel wood. From the above study, it was clear that Athol village was able to harvest fuel wood on a sustainable basis, since the supply of fuel wood exceeded the demand. This was not the case with Welverdiend where the demand for fuel wood greatly exceeded the supply.

Shackleton (1994a) examined the possibility of growing more trees for fuel wood in the Northern province of South Africa or the redistribution of fuel wood after sustainable harvesting. The above study used a crude calculation of demand and supply plotted on a logarithmic scale under different scenarios to determine where fuel wood supply may be considered to be above consumption levels (points below the isocline) or undersupplied (points above the isocline). The various scenarios were straddled over the isocline, with the demand of certain areas outweighing the supply, and the opposite for other areas.

CONCLUSIONS

The woody vegetation around the communal area of Makoko village is being exploited far beyond its production capacity. Even if the vegetation were in a pristine condition as it is in the conservation area, the production of fuel wood would still be insufficient to be harvested sustainably and would gradually be depleted. This means that communities living at these densities can no longer be completely dependent upon natural resources if a sustainable energy supply in the long term is the aim. Alternative energy and fuel sources have to be developed and used to assist in creating a balance between energy supply and demand, particularly in terms of fuel wood. A possible solution may be a combination of harvesting wood from both the communal and conservation areas. However, if the aim is to restore the communal area to a more natural condition over time, then the harvesting of fuel wood within these areas will have to cease almost completely. This would place increased pressure upon the resources within the conservation area to meet the needs of the community, which in turn will affect the long-term integrity and sustainability of the Kruger National Park.

CHAPTER 6

THE MANAGEMENT OF SUSTAINABLE USE: PRINCIPLES AND PRACTICE

INTRODUCTION

Makoko village is one of the many rural villages that lie on the border of the Kruger National Park. From a purely ecological point of view, buffer zones or boundaries that are under the same type of land-use management are more successful than an abrupt boundary between different types of land-use. The greater the dissimilarity between the land-use types, the greater is the edge-effect. An edge-effect is defined as a change in the conditions or species composition within an otherwise uniform habitat as one approaches a boundary with a different habitat. Edge-effects at the boundary between natural lands and human-occupied lands (urban edge-effects) arise due to human related intrusions such as lighting, noise, invasive species, exotic predators (dogs and cats), hunting, trapping, off-road activities, dumping and other forms of recreation and disturbance (Taussig 2003). Studies have been done around the world to document edge-effects and to learn how these affect biodiversity in conservation areas and human occupied areas. Some show an increase in biodiversity (Berry 2001) and others a decrease within the edge-effect zone (Revilla *et al.* 2001; Galetti *et al*. 2003; Batary and Baldi 2004; Tomimatsu and Ohara 2004). Although some species are unaffected by edges or show preferences for edges, human-induced edge-effects are generally unfavourable to native plant species and encourage the invasion of exotic plant species (Taussig 2003).

Depending on their spatial arrangement, communal areas such as the Makoko village could act as wildlife movement corridors and possibly habitat linkages between core habitat areas if managed correctly. Movement corridors facilitate the efficient movement of animal species by providing adequate cover and a lack of physical obstacles to movement, but do not provide live-in habitats for them. In addition, habitat linkages provide permanent resident live-in habitats and movement habitats and are capable of sustaining a full range of community and ecosystem processes, including seed dispersal and animal movement over a period of generations (Taussig 2003).

Connectedness through landscape linkages and movement corridors can contribute towards preventing the extinction of local populations of plants and animals through habitat fragmentation and isolation. These are the most serious threats to biological diversity. The probability of extinction becomes greater as species movements (immigration and emigration) are impeded by the conversion of natural habitat as found within the Kruger National Park, to inhospitable land covers, as seen in the Makoko village communal area. Habitat linkages prevent habitat fragmentation and isolation by permitting the travel, migration and meeting of mates for wide-ranging animals, plant propagation, the interchange of genetic material, the movement of populations in response to environmental changes and disasters and the colonisation of available habitat by individuals (Taussig 2003).

In terms of the people, a sustainable livelihood is desirable. If a sustainable fuel wood harvesting policy could be successfully implemented in Makoko village, this would play a major role in developing a sustainable livelihood structure for the Makoko village community. Tangible improvements in lifestyle contribute towards an appropriate increase in the quality of life that eventually leads towards sustainable development. Traditional tribal authorities that were lead by chieftainships are currently under the pressure of being replaced by commercial law in modern society. Encouraging small-scale community-based natural resource management will serve to re-empower these traditional authorities.

The more the Makoko village community needs are met in terms of natural resources, the less likely will there be conflict between the Kruger National Park and themselves. Presently the park is not associated with material benefits by the community members (Chapter 4). If the park were to get more involved in assisting the Makoko community to strive towards sustainable management of their land, this would be a tangible benefit to the community. Positive relations between the park and the neighbouring communities will strengthen the link between the two stakeholders, not only to the benefit of the community but also to the park by creating a sense of ownership of the park through local participation by the people (Cunningham 2001). As the human population living adjacent to the Kruger National Park continues to increase, so does the pressure on the environment to sustain them. The less the communal lands are able to meet the demands of the people, the more the people will be looking towards the Kruger National Park to supplement their basic natural resource needs.

SUSTAINABLE HARVESTING OF NATURAL RESOURCES WITHIN A CONSERVATION AREA

The practice of sustainable utilization of the natural resources within a national park, nature reserve or world heritage site is allowed and discussed in detail in the new National Environmental Management Biodiversity Act of 2004 (Act No 10 of the Republic of South Africa).

It would therefore be wise for all national parks, nature reserves or world heritage sites to have detailed policies and management programmes in place regarding the sustainable use of all their natural resources. To date any pressure to allow the harvesting of resources such as fuel wood has been successfully avoided by the Kruger National Park. This is mainly because the impact of this practice is not known yet. Consequently it cannot be guaranteed that such harvesting will not affect the integrity of the Kruger National Park ecosystem negatively. Should negative impacts occur from harvesting, it would be contrary to the mission statement of the Kruger National Park, as well contravene the National Environmental Management Biodiversity Act of 2004 (Act No 10 of the Republic of South Africa). However, the time may come when the implementation of wood and other harvesting practices within national parks, such as the Kruger National Park, will become part of the official policy of the park. When, or if, this happens proper policies must already be in place to avoid a negative impact on the environment. However, there is a great deal more research required on the long-term sustainability of such projects before realistic sustainable implementation policies can be formulated. The outcome of such policies should include harvesting quotas allocated to both internal users (Kruger National Park staff) and external users (local neighbouring communities such as the Makoko village community) and should cover all the natural resources to be used within or removed from the Kruger National Park, This would include wood, gravel, stones, reeds, thatch, meat, land and water. It is essential that the principles and practices of sustainable harvesting of each of these resources be thoroughly investigated and a detailed and factual policy be documented and implemented to ensure the long-term sustainability of harvesting these valuable resources.

Promoting controlled harvesting of natural resources within the Kruger National Park that are in limited supply in communal areas could allow for better relations between the park and the community and will strengthen the current delicate park management and neighbour link. This in turn will promote better cooperation and enhance positive border relationships between the major stakeholders.

Creating sustainable harvesting opportunities for neighbouring communities also places the park in a favourable position with government in terms of justifying the expenses allocated to national parks annually at a time when more than 18 million South Africans (about 40% of the population) are living in poverty (Liebenberg 2004). It is essential that the government recognises the value of parks such as the Kruger National Park as an asset of great biological importance, not only in terms of wilderness and biodiversity, but also as a potential sustainable supply of natural resources for the people who are living adjacent to the park.

The use of fuel wood within the Kruger National Park

According to the latest wood use policy of the Kruger National Park (Foxcroft 2004), no harvesting of indigenous wood within the park is allowed. All wood that is used within the

Kruger National Park by tourists and staff must be originally purchased from outside the Park.

Fuel wood use by wilderness trails camps

Wood used by the wilderness trails camps of the park is made up of mainly large pieces of wood that are purchased from Jabula Fire Wood in Hoedspruit, Limpopo province, South Africa. According to du Plessis (pers.comm[5].) the trails camps purchase a mean of 10 metric tonnes of fire wood per camp once every four months. The camps are occupied for approximately 27 nights per month. This amounts to 93 kg of fire wood being used per night per trail camp. However, according to Morumo (pers.comm.[6]) the Napi trails camp in the Pretoriuskop area has only purchased a mean of 5.6 metric tonnes of fuel wood in four months. This amounts to 52 kg of fire wood per night. Using the latter more conservative fuel wood use data, it means that 1527 kg of wood is used per person per year per trails camp. This usage is three fold greater than that being used by the people of Makoko village, who survive currently on 339 kg per person per year (Chapter 5).

Fuel wood use by tourist camps

The tourist camps in the Kruger National Park sell wood in lots of 8 kg per bag. All the tourist camps and staff shops within the Kruger National Park purchase this wood from Gravelotte Charcoal, near Phalaborwa, Limpopo province, South Africa. For example,

[5] Du Plessis, P.: Manager and owner, Jabula Fire Wood. Hoedspruit. Personal communication, 15 June 2004.
[6] Morumo, B.: Procurement Officer, Kruger National Park. P.O. x402, Skukuza, Kruger National Park, 1350. Personal communication, 15 June 2004.

the tourist purchases of wood at Biyamiti bush camp amount to 355 kg of wood per bed per year. The above calculation is based on the purchases of wood from the Biyamiti shop itself, and does not include any wood that was purchased elsewhere and brought into the camp by the tourists.

Integrity of fuel wood supply companies

Although the Kruger National Park Policy states that the purchase of indigenous hardwoods that have been illegally and unsustainably collected from areas outside National Parks is not condoned, there is no guarantee at this stage that the current suppliers of fuel wood to the park, are complying with this policy. When asked where his company collected wood, the owner of the Jabulani Fire wood company did not respond. He was also not prepared to give the researcher accurate details on his wood sales to the Kruger National Park. Although he is not harvesting wood within the park, the Kruger National Park has to be sure of where the wood comes from that is being purchased for use within the Park. An on-site friendly investigation of the suppliers is recommended so that management can ascertain the source of the fuel wood supply.

If the Kruger National Park is unknowingly supporting the unsustainable harvesting of fuel wood in areas surrounding the Park, it will only increase the unsustainability of natural resource use within these areas. In so doing, it increases the negative impact on the environment surrounding the park. The Kruger National Park is in an ideal situation to embark on a mission to reach a state of sustainable development. However, the ecological, social and economic consequences of the above actions will not be in line with the basic requirements for sustainable development.

FUEL WOOD HARVESTING

Shackleton (1996) reported that the total yield of utilisable wood in the central Mpumalanga province is 287863 metric tonnes. At the time of his study an exchange rate of US$ 1.00 = R3.50 existed and he estimated this wood to have a value of US$ 6.5 million.

Shackleton (1994a) reported on how the ranchers in the Hoedspruit district of the Limpopo province of South Africa sold fuel wood that was cleared from encroached lands to local entrepreneurs at R40.00 per load. An outside contractor used machinery and chain saws to clear the wood from the land. The fee charged did not cover the costs. At a mean mass of 651 kg of fuel wood per load the farmers received R 0.06 per kg of wood. The fuel wood was resold at R 0.13 per kg in an adjacent village to yield a gross profit of R 0.07 per kg of fuel wood for the wood vendors.

To avoid contractual costs, Shackleton (1994a) suggested that the farmers put out a franchise for both the sustainable collection of dead wood from their farms and for the clearing of encroached lands. It was suggested that these farmers charge R 0.02 per kg of wood, which will be almost a nett profit because there would only be minor supervision costs involved. The local wood vendors could then employ their own labour, possibly family members, to collect the wood at a remuneration of R 0.05 cents per kg of wood. Each labourer can collect 400 to 500 kg of dead wood per day, which would translate into a daily income of R18.00 to R22.50 per collector. The yield per day would be less when clearing encroached areas because the wood there has to be cut down and trimmed as opposed to collecting dead wood from the ground. A yield of 300 to 500 kg of wood per day is realistic, depending on the density of the encroachment. While such an income cannot be accepted as an adequate normal wage, it would be significantly higher than the mean daily income per capita for the area. The above study also suggested that there would be an incentive when the harvesters are paid per kg for woof rather than per day. The daily per capita income from wood can be as high as R25.00 to R30.00 when cutting dead wood, but it will be less when cutting wood from bush-encroached lands.

The development of a suitable transport infrastructure to transport the collected wood and support facilities for processing the wood, would require central planning, even though small-scale entrepreneurs already operate in and around the former homeland areas. Given appropriate planning and funding the above programme could be implemented. The set-up would require credit finance for setting up central distribution points and buying vehicles for transporting the wood. Criteria for transport subsidies may have to be investigated where there are long distances between a supply point and the markets. Such subsidies may be a more appropriate form of funding than tree-planting programmes that are aimed primarily at alleviating the fuel wood crisis, since the transport industry has many secondary support services that would also benefit from it (Shackleton 1994a).

The establishment of marketing systems for wood that is harvested from conservation areas and private properties could be a stimulus for greater cooperation on the harvesting of other secondary indigenous products such as thatch grass, fruits, medicines, wood for carving, reeds, edible herbs and weaving materials. With minimal management, all such products can be harvested on a sustainable basis while creating jobs and stimulating the local rural economy. The basis for such an extended programme would be an integrated management strategy for land that is under extensive production or conservation, with managers and landowners acknowledging the need to engage their neighbouring communities for mutual benefit and to promote multi-purpose land-use (Shackleton 1994a).

Dead wood harvesting

Although there has been some research on the ecological role and value of dead wood as part of the biological system in forests around the world (Hull 1999) there is a lack of data pertaining to semi-arid savannas in southern Africa, other than generalised statements regarding the role of dead wood in nutrient cycles and provision of nesting sites for hole-nesting bird species (Shackleton 1998). A study by Simelane *et al.* (2000) reported that dead wood played a vital role in the conservation of some invertebrates and other organisms by providing food, shelter and the opportunity to reproduce. However the ecological effects of woody removal from the system by sustainable harvesting would be negligible. Collectors cannot remove all the dead wood, as some occurs too high up in trees, are too difficult to remove by hand, are too small, are too big (unless cut by saws) or are already well decomposed. This leaves some remaining dead wood that will continue to provide microhabitats for invertebrates, nesting logs for birds and germination sites for seedlings. However, unsustainable harvesting that is characterised by a steady decline in the woody biomass per unit surface area, may be ecologically detrimental (Shackleton 1994b).

Dead wood is generally favoured over live wood for energy purposes by rural communities. However, all too frequently, the highly localised demand for dead wood in the immediate vicinity of a settlement cannot be met and rural communities then resort to the harvesting of live wood to satisfy their energy needs. There is still little understanding of the rate at which useful dead wood is produced naturally in African savannas. Its potential commercial value in unexploited areas is also not yet fully appreciated. The dead wood yield from previously unutilized areas has been approximated at 750 kg per ha (range: 107 to 1708 kg per ha). Consequently a unit of private or conservation land of 1 000 ha would yield approximately R15000 every 3 to 5 years from harvesting dead wood alone at the prices that were valid in 1994 (Shackleton 1994b; 1998).

Shackleton (1998) studied the annual production of harvestable dead wood in Mpumalanga, South Africa. He concluded that the mean annual production of harvestable dead wood across a rainfall gradient from 500 to 850 mm per year ranged from 211.7 ± 27.6 kg to 590.1 ± 176.2 kg of wood per ha. A dead wood production of 1.7% of the standing wood biomass is below the rate of production of standing wood biomass and should lead to a nett accumulation of this biomass. The harvesting method that was used by Shackleton (1998) excluded a portion of the annual production of dead wood from being collected by excluding pieces of wood that were too high up to reach, to strong to break off, too big to carry or too small to be useful for fuel wood purposes. This meant that the dead wood production exceeded that which was measured during the above study. In addition, a proportion of the dead wood was lost through breaking up and decomposition between the sampling periods, although wood decays relatively slowly in these environments. It was assumed that wood biomass losses from large pieces of dead wood due to decay would be in the order of 2.0 to 5.0% of the total dead wood biomass per year.

Shackleton (1998) also reported a wood fall rate of branches >20 mm in diameter of 682 kg per ha per year in a Nigerian savanna, one of 874 kg per ha for a miombo region in Zaire and one of 1500 kg per ha in a lowland tropical forest in Mexico. When dead wood production was calculated as whole tree mortality on 51 permanent plots throughout the South African Savanna Biome, it was estimated at 1.2 ± 0.32% of the standing woody plant biomass in 1992/1993, at 2.2 ± 0.6% in 1993/1994 and at 2.3 ± 0.5% in 1994/1995. Extrapolation of the mortality data from the Amazonian tropical forests indicated a whole tree mortality rate of 1.9% of the standing woody plant biomass per hectare. All these estimates included pieces of wood that would have been regarded as too big to remove, hence an annual rate of dead wood production of 1.5 to 2.0% of the standing woody plant biomass was accepted as being realistic for the above study.

The ecological consequences of dead wood harvesting are unknown. However, practical limitations on the methods involving harvesting wood by hand would help to ensure that some dead wood remains to serve its broader ecological functions, such as nesting sites for certain bird species, micro-habitats for small vertebrates and invertebrates, nutrient recycling and micro-sites for seed germination. Comparison of areas that are subject to unsustainable harvesting of wood through the extraction of live and dead wood at rates greater than their annual productivity rate with protected areas have detected a declining above-ground woody plant biomass and significant changes in the woody stand structure. It has also been documented that there may be a decline in hole-nesting bird density in areas that are subjected to intense wood harvesting, which include the removal of live wood, although there is an increase in avifauna richness in logged forests relative to unlogged ones in Sabaha, Malaysia (Shackleton 1998).

In most savannas, 50 to 80% of the woody plant biomass occurs below the ground. Moreover, of the above-ground biomass, <10% is dead wood, and <23% of this dead wood is harvestable by hand. Therefore the expected impact of harvesting wood by hand on the ecosystem dynamics will probably be small, but it requires further study (Shackleton 1998).

Live wood harvesting

There is an abundance of literature on bush encroachment by various woody plant species, including *Dichrostachys cinerea* and *Colophospermum mopane* but there is no certainty on the nature if the natural density and distribution of these species. Cunningham (1996) reported that *Colophospermum mopane* is a good source of fire wood and charcoal, and that it has become so dense that it dominates most of the vegetation where it occurs in the Venetia Limpopo Nature Reserve, in the Limpopo province of South Africa. This makes it an ideal candidate for utilization. In the same study, Cunningham developed a sustainable harvesting model for *Colophospermum mopane* where dense *Colophospermum mopane* stands have formed as a result of mismanagement of the area. The objective of the above model was to reduce the bush density and to utilize *Colophospermum mopane* on a sustainable basis, simultaneously achieving economic viability and improving the visibility for wildlife viewing in the reserve. In the above study, it was predicted that a harvesting rate of 27% of the woody plant biomass every five years will achieve optimal harvestable yields for up to 60 years. Over 60 years the initial number of 1141 harvestable stems would gradually be reduced to 444 stems after which it would remain stable. The initial total harvestable woody plant biomass yield was 8000 kg of wood per hectare, which would decline to 1500 kg per hectare after 60 years. He suggested harvesting the wood on a five-year rotation basis by harvesting every fourth tree with a stem circumference at breast height of >130 mm once every five years on a given area of land.

Resprouting

A key attribute of the resilience and productivity of savannas is the ability of damaged trees to sprout from a stump (Shackleton 2000b). This has been well studied following fires (Bond and Midgley 2001) but less so after chopping. Survival of the cut stem and growth rate of the resultant coppice shoots are influenced by woody plant species, tree size, height of cutting and the root to shoot ratio after felling (Shackleton 2000b). Some of these aspects can be manipulated by a manager or harvester to maximize or suppress regrowth rates. If managers wish to optimize browse production in the harvested area, a high cutting height is recommended as this will result in increased coppicing. However, for the purposes of the present study, the objective is to minimize the rotation time between wood harvests. It is therefore recommended that, where possible, the Makoko village community harvests fuel wood at a low cutting height. This will produce fewer shoots and an earlier establishment of apical dominance, which will be preferable for fuel wood harvesting (Shackleton 2000b).

The size of the cut stem does not influence the number of coppice shoots. However, an increase in initial stump sizes significantly increases the diameter of the coppice regrowth, which will affect the time between the harvests. Harvesting large stumps will allow frequent harvesting in Makoko communal area and will hence increase productivity (Rathogwa *et al.* 2000).

Season of harvest

Rathogwa (2000) found that cutting *Colophospermum mopane* stems in December resulted in the production of many coppice shoots. This was regarded as undesirable because most of the shoots will ultimately die from intershoot competition. He therefore recommended that a harvesting season that will only produce a limited number of shoots be used as a management tool to avoid the expensive and often impractical exercise of pruning shoots. In addition, harvesting should be avoided during the spring when the palatable new leaf flush provides an important source of food for browsers (Cunningham 1996).

Where to harvest

Post-harvesting recovery is influenced by the soil type, with woody plants growing on clay soils having slower growing and fewer coppicing shoots than those growing on more sandy soils (Ligavha *et al.* 2000). In the above study, harvested stems on clay soils required more time to recover, remaining dormant up to two months after being harvested, than those on sandy soils that were flourishing at the same time.

In the Makoko village communal area, the uplands are located on sandy soil whereas the lowlands are characterized by clayey soil. Therefore, for maximum recovery after harvesting, it is recommended that only the uplands were harvested. Harvesting on the lowlands is not recommended because it will result in long periods of dormancy without re-growth and hence low wood production by the harvested plants.

This principle also applies to any future harvesting of fuel wood that may take place within the conservation area of the Kruger National Park. In addition to the above restriction based on topographical position, it is recommended that for any harvesting of natural resources within the park, the Recreational Opportunity Zonations plan (ROZ) is taken into account (MacFadyen 2003). This is a management tool through which the Kruger National Park has been divided into areas of utilization from allowing high human impact, with limited motorized impact for example in the area around Skukuza camp, to allowing almost no human impact such as in the pristine hiking wilderness areas of the park. If allowed within the park, limited and controlled harvesting by neighboring communities should be restricted to within these high human impact zones. The impact of this harvesting should be closely monitored to allow for immediate adaptive management strategies if the impact is severe.

PRINCIPLES FOR COMMUNITY- BASED NATURAL RESOURCE MANAGEMENT

Conservation and resource management through decentralised control to local communities have been widely advocated in the past decade. The merits of the local management of communal natural resources have also been rightly questioned, as the capacity of local institutions for resource management has been reduced by economic, political and religious change. Before decentralisation is advocated, it is important to have a predictive understanding of where community-based conservation is likely to succeed or fail. A successful community-based natural resource management programme must have clearly defined and accepted boundaries around the resources. These boundaries must be of an appropriate scale that can be controlled and managed (Cunningham 2001).

Whether the land or the resources themselves are privately or communally owned, long-term tenure is a major incentive for successful natural resource management and conservation. There should be legal confidence in the long-term access to these resources, as agreed upon by the individuals or group(s) that have legal tenure to the land. For national parks and communities this will require formal co-management agreements. However, formal tenure is often less important than having confidence that all the agreements will be honoured by all the parties concerned (Cunningham 2001).

The greater the resource predictability in space or time, the greater the incentive for establishing property rights or managed use. This is displayed by the strong rights that are attached to long-lived perennial resources that provide a predictable resource in unpredictable environments. Examples include tree fruits and bee-hives. With mobile resources such as wildlife, private or common property rights apply to traps and trapping sites rather than to the resource itself (Cunningham 2001).

Effective management of natural resources is best achieved by giving the resource a focused value in order to determine whether the benefit from managing the resource exceeds the cost. In addition, the relationship between resource scarcity and vulnerability to human impact has to be recognised by the resource users. If the resource user's belief system does not link human impact, such as over hunting, with resource depletion, then this poses a problem that may even exacerbate overexploitation. Control measures must allow for the rapid breakdown of customary controls with a shift from subsistence use to commercial harvesting, particularly when commercialisation is accompanied by an influx of outsiders (Cunningham 2001).

Community-based natural resource management is favoured by smaller groups of people where natural resources have few uses. The more uses and users there are of a particular landscape or resource, the more complex and potentially conflicting its management becomes. Moreover, the more clearly defined the user group, the greater the chance of a successful community-based natural resource management project. Greater success is achieved when resource users live near the resource, or amongst mobile or semi-nomadic communities, so as to be able to frequent the resource area regularly. This simplifies the monitoring of who is using the resource or resource area and helps to restrict access to it by outsiders (Cunningham 2001).

Although no community is completely homogeneous, many communities are divided in terms of socio-economic status and diverse interests. Social control over resource use is more likely to occur in homogeneous than in heterogeneous communities because homogeneity breaks down with the influx of outsiders into an area. Religious or ritual belief systems are widely accepted by communities. Consequently, these systems maintain group pressure for actions that encourage short-term individual sacrifice in favour of long-term group benefit (Cunningham 2001).

Any rules that are developed for natural resource use should be simple, practical, enforceable and appropriate. Users' knowledge is best built on existing local knowledge of sustainable yields and resource status. Mutual agreements reached on the use of natural resources have to be kept to diligently and penalties must be set for individuals who exploit these resources at the expense of the whole group. Any individuals or groups who try to abuse the system must be easy to detect. This largely depends upon having small, clearly defined geographic boundaries around the resource and a small and identifiable group of resource users who live near the resource. Consensus has to be reached on punitive measures for those who break the rules that were agreed upon. There should be a sliding scale of punishments, but punishments for serious offences must match the severity of the transgression (Cunningham 2001).

Well-developed mechanisms for conflict resolution should be established. Mediation may be brokered by outside institutions such as non-governmental organisations, or there may be internal mechanisms, such as when conflicts are expressed through witchcraft accusations and are resolved by cleansing rituals and therapy. The state should support and encourage decentralised control and it must be careful not to undermine it. Where resource groups are effective in preventing an open-access situation and are managing resource use on a sustainable basis, state control should be minimised. However, the state can play a crucial role when local institutions require support, whether in law enforcement or through technical input.

There is no single or magic formula for success, particularly when dealing with the additional complexity of common property resource management because there are too many ecological, social, political and economic variables. It can be useful, however, to highlight events or programmes with a greater likelihood of success or failure.

FUTURE MANAGEMENT AND RESEARCH PERSPECTIVES

Before any form of sustainable harvesting policy can be written and implemented, there is a need for detailed research into quantifying the upper and lower thresholds of sustainability. Quantifying sustainable harvesting quotas for renewable natural resources is a difficult task with major implications if not done correctly. Sustainable use is currently a popular research topic and the principles of sustainable use and community based natural resource use are well documented. However, the practical aspects of these are not as well covered in the literature.

There is a clear missing link between the principles and the practice of sustainable use. This could be attributed to the lack of clear objectives in terms of defining and implementing sustainable use principles and practice. The first step towards linking the theory and practice of sustainable use would be to identify a clear set of objectives pertaining to sustainable natural resource use within and around the Kruger National Park. These objectives should cover both research and management priorities, with the research themes being based directly upon the management requirements. The objectives should pertain to the Kruger National Park as part of a matrix within the adjacent areas, rather than as an isolated island, and should address the pertinent issues of the adjacent areas in addition to those within the park's boundaries. The following list of questions could serve a framework for future research and management in and around the Kruger National Park:

- Quantification of wood use by Kruger National Park residents and staff
- Incorporation of a more detailed sustainable use section into the Kruger National Park Objectives hierarchy
- Quantification of sustainable use of natural resources
- Construction and implementation of an effective wood use policy
- Investigation into the ethics of the harvesting strategies of the current wood supply companies
- Quantification of the sustainable supply of all natural resources being used within and removed from the Kruger National Park

- Zonation of Kruger National Park into possible areas where future sustainable harvesting of natural resources could take place
- Collaborative investigation by Kruger National park and adjacent communities on possible alternative fuel sources
- Collaborative discussions between the Kruger National Park authorities and adjacent communities on assistance to the decision-making process aimed at implementing a Community-based Natural Resource Management programme with the sustainable use of the renewable natural resources within the Makoko village communal area as a major objective

CONCLUSIONS

The current harvest of fuel wood within Makoko village is unsustainable. From the present study, it is evident that a more detailed study is required to investigate realistic options for supplementing the deficit in the supply of fuel wood to the community (Chapter 5). The option of planting woodlots to supply such villages with a sustainable fuel wood supply is a possibility that has to be thoroughly investigated. Although the present study has shown that Makoko village seems to be more efficient in the mass of fuel wood used when compared to some regions of the Kruger National Park, the community will still have to be dedicated to investigating the possibilities of using more efficient fuels in the future in order to minimise the impact of fuel wood harvesting on their environment. The possibility of collecting waste form sawmills and plantations have not been investigated thoroughly yet, and these resources are presently being underutilized. However, in using those resources there are transport difficulties because many of the sawmills and plantations are located some distance away from the villages. Although the people could walk to these sites, it would be difficult to transport enough wood back to the villages to make it a sustainable option. These difficulties could possibly be solved with more thorough planning. The recommended fuel wood harvesting principles that can be applied within the communal areas to attempt to produce a larger harvestable yield include aspects such as understanding the science of resprouting, taking the season of the harvest into account and only harvesting in specified areas.

There is an urgent need for including a detailed natural resource use harvesting policy in the Kruger National Park management plan. In terms of the use of fuel wood within the Kruger National Park, a further investigation into the current fuel wood supply companies should be done. Once the park management has clarity on the use of fuel wood within the park, this should be conveyed clearly to tourists before they arrive at the park. There currently are large quantities of indigenous hardwood fuel wood that are being sold on all the major roads leading to the Kruger National Park. Tourists are not sure if purchasing the wood would support the local industry, and would contribute towards the development of the neighbouring community. Neither do they know if doing so would promote the unsustainable harvesting of indigenous hardwoods. The Kruger National Park authorities have to take a stand on the matter and make their views clear to visitors in advance.

An ecological assessment of the sustainable utilization of the woody vegetation in the Lowveld Bushveld, Mpumalanga Province

by

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SUMMARY

This study was done in the communal area surrounding Makoko village and in the adjacent conservation area within the Kruger National Park, Mpumalanga, South Africa. The woody plants within the two areas were compared in terms of species diversity, density, size structure class and biomass to determine the impact that the harvesting of fuel wood within the communal area has had upon the woody plants.

There was no difference in woody plant species richness between the conservation and communal areas. The conservation area has 46 and 45 woody plant species on

the uplands and lowlands respectively, and the communal area has 47 and 49 woody plant species there respectively. Overall, the conservation area has 11 unique species, while the communal area has 16. The Shannon-Wiener Index, indicates that both the communal uplands and lowlands are more diverse (H' = 2.907; H' = 2.995) than the conservation ones (H' = 1.762; H' = 2.165). However, the significant difference in the H'-value between the uplands and lowlands of the conservation area was not observed in the communal area. Within in the communal area, there was an increase in species diversity with a decrease in disturbance gradient.

The uplands of the conservation area had a mean density of 5748 woody plants per hectare, while the lowlands had one of 2983 woody plants per hectare. The communal area had an upland density of 4477 woody plants per hectare and a lowland one of 3435 woody plants per hectare. When woody plant density was plotted against a disturbance gradient in the communal area, there was a significant linear correlation for both the uplands and lowlands. *Terminalia sericea* showed a significant linear increase in cumulative stem diameter with a decrease in disturbance level. *Dichrostachys cinerea* showed no significant response to an increase in harvesting.

There was no difference in sapling counts between the conservation and the communal areas. There were significantly more dwarf shrubs in the communal upland than in the conservation one. However, there were significantly more shrubs, multi-stemmed tall shrubs, single-stemmed medium trees and tall trees in the conservation uplands than in those of the communal area. There were significantly more saplings, dwarf shrubs, shrubs, multi-stemmed tall shrubs and single-stemmed medium trees in the communal lowlands, compared to the conservation lowlands but in the conservation lowlands there were significantly more tall trees than the communal lowlands.

For the uplands, the woody plant total biomass on the conservation area was the greatest at 31160 $kg.ha^{-1}$, with that in the communal area significantly less at 5354 $kg.ha^{-1}$. The lowlands had a lower total woody plant total biomass than the uplands in both land-use systems at 5031 $kg.ha^{-1}$ for the conservation area and 3925 $kg.ha^{-1}$ for the communal area. There was a significant increase in woody plant wood biomass with distance away from the village in the uplands of the communal area but not in the lowlands. The harvestable woody plant wood biomass in the conservation area was 1402.3 metric tonnes per year. However, the communal area in it's current condition had 224.9 metric tonnes of harvestable wood annually.

The socio-economic status of Makoko village was determined by interviewing 100 households within the village. The use of fuels including wood, paraffin, candles and electricity was determined. The use of fuel within each household was compared with the household income. There was a significant positive linear correlation between household income and number of rooms and expenditure on paraffin, gas and electricity. There was a significant negative linear correlation between household income and the mass of wood that was collected. Community and Kruger National Park issues such as advantages and disadvantages of living adjacent to the Kruger National Park were also noted.

The demand for fuel wood within Makoko village was 338.9 kg per person per year. The supply of fuel wood in the communal area is 54.6 kg per person per year, if harvested sustainably. An identical area of conservation land could provide 270.0 kg of fuel wood per person annually on a sustainable basis. Even if this happened, the current demand exceeded the supply.

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APPENDIX A

A copy of the questionnaire completed by 100 households in Makoko village, Mpumalanga in February and March 2001