ECOLOGICAL AND SOCIO-ECONOMIC ASSESSMENT OF MOPANE WOODLAND IN THE MAHEL AREA IN MAPUTO PROVINCE, MOZAMBIQUE

By

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Declaration

I the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirely or in part submitted it at any University for a degree.

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Summary

The Mopane woodlands are some of the most economically and ecologically important vegetation types of southern Africa, providing an array of services and products for sustaining livelihood of local communities in dry and low lying areas. Although Mopane woodlands, like other African savannas, have received attention in the last decades, few studies were carried out using an integrated approach that combines socio-economic and environmental considerations. The aim of this study was to document the impact of harvesting woody resources in order to recommend ways of meeting ecological and economic objectives for sustainable use of communal resources in a rural community in the Mahel area, Mozambique. This was achieved by looking at the pattern of species composition, resource availability and dynamics of the woody vegetation and how the woodland is used.

The study found that woodland resources in the area have a promising potential. Local communities who also recognised the crucial importance of these resources for their livelihood corroborated this. Thus, conservation measures are needed because the current unsustainable utilisation of the resources may lead to degradation of the woodland resource base.

The species richness and diversity of the vegetation appeared to be influenced by a number of ecological and anthropogenic factors, but soil characteristics are the most important determinant of distribution and composition of the Mopane and Acacia woodlands in Mahel. The harsh environmental conditions on hard clay soils lead to dominance of over 80% of the Mahel area by *Colophospermum mopane*. There was evidence of high variation of species richness per plot at a distance from the villages. On the other hand species diversity near the villages was higher because of human activities. *Colophospermum mopane* formed mono-specific stands far from the villages. One of the most important aspects of the study is the invaluable contribution of baseline information for long-term studies for biodiversity assessment and monitoring of vegetation changes caused by impact of harvesting in the Mopane woodland.

The availability of woody resources in the Mahel area was higher in Mopane woodland (937 stems ha^{-1}) than in Acacia woodland (271 stems ha^{-1}). The population structure of most tree species was shown to be stable in Mopane woodland. Therefore, sustainable harvesting in the woodland for firewood, construction material and poles, other than charcoal production could be encouraged. The preference across use types and species depended mostly on availability of resources in the woodland. *Colophospermum mopane* was the species with highest multiple use, including for firewood, charcoal, construction material, fencing poles and edible caterpillars.

Local people perceived that crop production was a more important source of benefits for their livelihoods than cattle farming, woodland use and cash income.

Application of strategic management planning is crucial in the Mahel area. This will require a suitable zoning scheme for appropriate use of the woodland resources and conservation of the vegetation as a guarantee for sustainable development of the local communities.

Uittreksel

Mopanie bosveld is een van die mees ekonomies en ekologies belangrike plantegroei tipes en voorsien 'n reeks dienste en produkte wat bydrae tot die lewensonderhoud van plaaslike gemeenskappe in die droeë en laagliggende dele van Suider Afrika.

Alhoewel Mopanie bosveld, soos ook ander savanna tipes in Afrika, in die afgelope dekades aandag geniet het, is daar 'n tekort aan studies wat sosio-ekonomiese, sowel as omgewingsaspekte, integreer en aanspreek. Die doel van die studie was om die impak van oes en benutting van houtagtige hulpbronne te dokumenteer en sodoende aanbevelings te maak aangaande die ekologiese en ekonomiese aspekte van die volhoudbare benutting van gemeenskaplike hulpbronne in die Mahel gebied, Mosambiek. Dit is gedoen deur ondersoek in te stel na die patroon van spesie samestelling, die beskikbaarheid en gebruik van bosveld hulpbronne en die dinamiese prosesse van die houtagtige plantegroei.

In die studie is gevind dat daar belowende potensiaal in die gebruik van die houtagtige hulpbronne in die studiegebied, opgesluit is. Die bevinding is bevestig deur die plaaslike gemeenskappe wat die belangrikheid van die hulpbronne in hul lewensonderhoud herken. In die lig van die huidige onvolhoudbare verbruik van die hulpbron, is maatreëls vir die bewaring hiervan nodig om moontlike oorbenutting van houtagtige hulpbronne te voorkom.

Dit wil voorkom asof die spesierykheid en diversiteit deur 'n aantal antropogeniese faktore beinvloed word, maar grondeienskappe is die belangrikste faktor wat die verspreiding en samestelling van Mopanie en Akasia bosveld in die Mahel, bepaal. Die ongunstige omgewingstoestande op harde, klei grond, lei daartoe dat tot 80 % van die Mahel gedomineer word deur *Colosphospermum mopane*. Daar was verder aanduidings van hoër spesierykheid per plot soos daar van plaaslike nedersettings wegbeweeg word. Daar was egter 'n hoër spesiediversiteit nader aan nedersettings, as gevolg van menslike aktiwiteite. Daar was 'n tendens vir *Colosphospermum mopane* om mono-spesifieke opstande met groter afstand van nedersettings te vorm. Een van die mees belangrike aspekte van die studie is die bydrae wat dit lewer tot grondbeginsels vir langtermyn studies, wat fokus op die impak van menslike gebruik

van Mopanie bosveld op die biodiversiteit en plantegroeisamestelling van die hulpbron. Die beskikbaarheid van houtagtige hulpbronne was hoër in die Mahel Mopanie bosveld (937 stamme ha^{-1}) as in Akasia bosveld (271 stamme ha^{-1}).

Daar is gevind dat die populasiestruktuur, sowel as regenerasie van die populasie, stabiel is in Mopanie bosveld. Derhalwe kan benutting van die bosveld vir vuurmaakhout (uitsluitende charcoal) en boumateriaal aangemoedig word. Die voorkeur van sekere spesies en aanwending vir sekere gebruike het meestal afgehang van die beskikbaarheid van die verkillende hulpbronne in die bosveld. *Colosphospermum mopane* is die spesie wat die meeste aangewend is vir gebruik vir onder andere, vuurmaakhout, charcoal, boumateriaal, heining pale en die voorsiening van eetbare ruspus. Daar is verder bevind dat die plaaslike inwoners gewasproduksie as 'n belangriker ondersteuningsfaktor vir lewensonderhoud sien as lewendehawe produksie, bosveld benutting en kontant inkomste.

Die toepassing van strategiese bestuursbeplanning is van kardinale belang in die Mahel. Dit sluit die ontwikkeling van 'n sonerings skema in, om die toepaslike gebruik van bosveld hulpbronne en die bewaring van die plantegroei te verseker vir die toekomstige volhoudbare gebruik van die hulpbron deur plaaslike gemeenskappe.

Dedication

I would like to dedicate this piece of work to my wife Minellcha and my children Malosa and Marcelino Junior for their patience and punctual support throughout the study.

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CHAPTER 1

Introduction

1.1 Background

Gradual destruction of the environment has been a concern for integrated conservation of renewable resources for rural people in the tropics. In Africa forest loss was estimated at the rate of 4.8% within the period 1980-1990 (FAO, 2000; Contrellas-Hermosilla, 2000). The forest degradation has implications for the local people who depend on the natural resources (Boberg, 2000). It has for example, impact on a decreased availability of essential fruits, fuel wood, fodder and other forest products (Hall & Bawa, 1993; Contrellas-Hermosilla, 2000; Hamilton, 1995). In addition, forest degradation leads to a reduced agricultural productivity, resulting from a loss of soil and water protection, and reduced potential of remnant woodlands (Boberg, 2000) and species diversity (Hall & Bawa, 1993). The outcome has been the reduction of income generation and loss of possibilities of escaping the poverty trap (Hall & Bawa, 1993; Boberg, 2000).

Mozambique with territory of almost 794 770 km^2, including the water bodies, is covered by 618 274 km^2 (78%) of natural vegetation distributed in high forest (0,8 %), low forest (13,7 %), thicket (43,3 %), wooded grassland (19.4 %) and mangroves (Saket, 1994). Forest and woodland resources support the livelihoods of the majority of the population (71%) in the country (FAO, 2000). For instance, Mopane woodlands covering about 15.9 % of the total natural vegetation areas serve as subsistence and a source of income for millions of people, particularly in the provinces of Tete, Gaza, Inhambane and Maputo (Saket, 1994; FAO, 2000). They directly or indirectly provide fruits, medicine, fuel wood, construction material, mushroom, meat, edible caterpillars as well as agriculture and livestock (FAO, 2000).

Mozambique, as other developing countries, continues to be under threat of degradation of forest (FAO, 2000). For instance, over the period 1970-1990, an estimated 4.27% of the vast forest cover of Mozambique was removed (Saket, 1994; DNFFB, 1997). Mostly the deforestation resulted from wood fuel harvesting of the woodlands since the mid 1980s (DNFFB, 1997; Brouwer & Magane, 1999).

In Maputo province for instance, the disappearance of woodland was almost 20% resulted largely from inappropriate farming, extraction of fuel wood and construction material for the urban market mostly associated with high frequency of wild fires (DNFFB, 1997) as depicted in Plate 1.1. This was due in part to the consequence of high concentration of population in the city and its surroundings during the civil war (DNFFB, 1999).

Brouwer & Magane (1999) and Mangue (2000) reported that in the 1980s, the *per capita* energy consumption of fuel wood was about 0.82 m^3/year in Mozambique. Now the consumption ranges between 0.92-1.0 m^3/person/year (Brouwer & Falcao, 2001). This is an increase of 17% compared to data from the 1980s. This current high rate of consumption of wood energy resulting from high pressure of exploitation is associated with the steady devaluation of the local currency (Metical[1]).

Almost three-quarters of the estimated 1 000 000 inhabitants of Mozambique's capital, Maputo, depend on wood energy. The related decrease of real incomes, due to the implementation of the Economic Re-adjustment Programme (PRE) and recent economic changes, contribute to the high rate of fuel wood consumption in the Maputo city (Brouwer & Magane, 1999; Brouwer & Falcao, 2001).

[1] 1$ US American corresponds to 22 000,00 MT

Plate 1-1 Unsustainable charcoal production in southern Mozambique, which is threatening Mopane vegetation and woodland resources in the area, despite the effort to refrain the trend

These strategies resulted in the majority of urban people, particularly in Maputo, Chokwe and Xai-Xai (the major urban areas of the Southern Region) changing from gas and paraffin to fuel wood products, which is a relatively cheaper fuel source (Brower & Magane, 1999). This trend resulted in a transformation from subsistence to market oriented production creating dramatic changes in the socio-economic relations of the resource users in the rural communities areas of Mozambique (Brouwer & Magane 1999).

Since restoration of peace in Mozambique in 1992, signs of accelerated deforestation have become more visible everywhere as a result of the return of refugees to their homelands and high commercial extraction of woodland resources from urban areas (FAO, 2000). The impact of increasing pressure on the use of woodland resources has meant that less attention has been paid to the ecological and socio-economic implications at the local scale (Mussanhane, 2000). This is due to inappropriate legislation and its practical implementation associated with understaffing and lack of operational funds (FAO, 2000).

Furthermore, the exploitation of the forest resources did little to improve the living standard of the local people (Mansur & Cuco, 2002). This situation was aggravated by weak policy of economic decision-making about resource use as was not based on an assessment of the quantitative and qualitative availability of the natural resources. This has resulted in the inefficient use of forest resources in many rural areas.

1.2 Rationale for the study

Sustainable utilisation of natural resources and improving the welfare and socio-economic conditions of the local community continue to be a growing challenge in Mozambique (Nhantumbo, 2000) in the country's effort to conserve biological resources. Although the country is considered to have a considerable stock of forest resources (FAO, 2000), it is still classified as one of the poorest countries in the world with a per capita income of 134 US dollars per year (Mansur & Cuco, 2002). The economy of the country is strongly dependent on the use of natural resources. Natural resources sustain the welfare of the majority of the rural population (71% out of 16.6 million)[2] that still live below the poverty line. Forest resources provide energy about 80 % of the country's population (Saket, 1994). There is no detailed information about the contribution of the forest sector to the national economy. However, the combined agricultural sector for the year 1998, including crop, livestock and forest products accounted directly for 12.7% to the Annual Growth Rate for the Gross Domestic Product (GDP)[3].

Mopane woodland as one of the most important natural vegetation types in the southern part of the Limpopo River, in Mozambique is a source of fuel wood and material for construction for most people, principally, Maputo city. Since the 1980s, there has been gradual destruction of the woodland environment in southern Region of Limpopo resulting

[2] National Institute of Statistics. INA. Publication 1997 census. Maputo. [Internet]. Available from < www.ine.gov.mz>. [accessed on 10 January 2002].

[3] National Institute of Statistics. Indicadores macroeconomicos - INE. Moçambique. Maputo. [Internet]. Available from http://www.ine.gov.mz/sectot1/Macr-economico2/ind_macr.html Accessed. [on 24 February 2001].

from high population pressure on the natural resource base (DNFFB, 1999). The current degradation of woodland is as a result of the unsustainable utilisation of resources through inappropriate commercial extraction of fuel wood and construction material, hunting, and extensive livestock production (DNFFB, 1997; DNFFB, 1999).

This depletion of the resource base calls for an urgent need for conservation and sustainable management of all indigenous woodland. At present the shrinking of the woodland and the increasing demand for resources by urban people suggests that some resources like wood, herbaceous vegetation and wildlife are at great risk of increased illegal and unsustainable harvesting (Anderson & Magane, 2000). Despite the current efforts taking place in rural areas of southern Mozambique to sustainably manage the indigenous woodlands, the following factors continue to be the major threats for conservation:

- ✓ High pressure on resource use associated with unsustainable resource harvesting practices mainly for charcoal, firewood and construction materials.
- ✓ Destruction of natural vegetation for expansion of land for agriculture and illegal hunting mostly associated with uncontrolled bush fires.
- ✓ Poverty in the country leading to inefficient use of the resources.
- ✓ The lack of scientific information about both the natural resource potential and the ecological implications of unsustainable harvesting. This hampers the development of better management options and appropriate conservation measures.

1.3 Objectives

1.3.1 Overall objective

By examining the composition and dynamics of the woody vegetation, this study aimed to document the impact of harvesting by local users of woody resources. A second focus was to recommend ways of meeting ecological and economic objectives in a rural community in order to promote sustainable development.

1.3.2 Specific objectives:

i. To document the relationship between soil types and the vegetation, in terms of composition and abundance of woody species.

ii. To assess the availability of woody resources, as well as the dynamics of the vegetation using size-class distribution and regeneration potential to study the productivity of the area.

iii. To assess the availability of woody resources with increasing distance from human settlements to the woodland.

iv. To document preferences shown by people for local woody species.

v. To assess perceptions of local users about resource value based on benefits received from different productive activities both for subsistence and income generation.

1.4 Research questions

a) How do soil types in the study area influence the vegetation pattern, abundance and distribution?

b) What is the availability of resources of the area, in relation to their use by local people?

c) How do human activities affect the vegetation change in terms of resource availability?

d) What is the potential regeneration of the woody species in the woodland?

e) How do local people value the land and natural resources on which economic activities are based?

1.5 Thesis organisation

This work focuses on *C. mopane* because it is the most dominant species and because of its socio-economic importance. The interaction between various factors determines the intrinsic characteristics of the current state of the vegetation, including environmental characteristics (soils), woody species composition and abundance, vegetation dynamics, resource availability, as well as, how people affect and value the resources they depend on for their livelihood. The thesis comprises five chapters as follows:

The Introduction (chapter 1) presents a background to the species and an overview of its related management problems, rationale and objectives of the study. In chapter 2 the Study Area is described, including ecological aspects and socio economic influences. Methods are outlined in Chapter 3, explaining the procedures and approaches used in data collection. Chapter 4 and Chapter 5 present Results and Discussions presented separately under each section, according to the objective of each section. Finally in Chapter 6 following the same sequence of the sections Conclusions and Recommendations are given under each objective.

CHAPTER 2

Literature review

2.1 Overview of the Mopane vegetation

The Mopane savannas and woodlands are some of the most economically and ecologically important veld types in southern Africa (Smit & Rethman, 1998a; Timberlake, 1999). These vegetation of *Colophospermum mopane* Kirk ex J. Léonard (Kirk ex Benth.) dominated tree species are widely distributed across the African sub-continent at medium to low altitudes and lower rainfall conditions (Timberlake, 1999). Their importance differs from region to region depending on the specific local environment and human activities. These conditions reflect on the conservation and management state of the woodland and the socio-economic situation of a particular local community (Timberlake, 1999).

The ecological and economic importance of *C. mopane* is acknowledged in various sources (e.g. Van Wyk, 1972; Mapaure, 1994; Low & Rebelo, 1996; Van Wyk & Van Wyk, 1997; Smit & Rethman, 1998b; Mashabane *et al.*, 2001). *Colophospermum mopane* is often the dominant species where it occurs (Palgrave, 1977). It has an ecological importance in most areas with low rainfall, acidic, fertile and non-alkaline dominated soils (Mapaure, 1994; Timberlake, 1995). In mono-dominant even-sized stands due to its potential for vegetative propagation, *C. mopane* is a suitable tree species for sustainable management in the rural economies over much of southern Africa (Timberlake, 1999).

2.2 The botany of *Colophospermum mopane*

Colophospermum mopane is also known as Rhodesian ironwood/mahogany, butterfly tree, balsam tree, turpentine tree, mupani/mutanari (Venda), mophane (Tswana), musharo/shanate

(Shona), ipane/ilipani (Ndebele), omutati (Herero), omufiadi (Owambo) and mupani in India (Cunningham, 1996). In Mozambique, the vernacular names of *C. mopane* differ from region to region; namely, gunwe, chanatsi, xanato or xanatsi (Shangana) and chanati (Maputo) in the South. In the Central region it is referred as to mtsanha (Tete), mussano (Sofala), and massamba (Manica and Sofala) (Koning, 1993).

In 1890 John Kirk first gave *Colophospermum* its generic name (Timberlake, 1999). It derives from the Greek, meaning oily seed due to the numerous scattered resin glands, which cover the testa (Venter & Venter, 1996). In some literatures, it is referred to as *Hardwickia mopane* (Timberlake, 1999). Later it was suggested that the name *Colophospermum* be retained over the name *Hardwickia* in the interests of nomenclatural stability and the user community (Smith *et al.*, 1998).

Colophospermum mopane belongs to the family Leguminosae, sub-family Caesalpinoideae. It is one of the ten largest woody plant families and particularly well represented in the miombo woodlands of the south-central region of Africa. *Colophospermum mopane* is a small to medium-sized tree, usually 5 to 14 m in height (Van Wyk, 1972; Palgrave, 1977; Cunningham, 1996; Timberlake, 1999). On alluvial soils, there is a tendency towards woodland development. In this environment *C. mopane* can reach 15 - 18 m tall and the biggest specimen was found 150 cm in stem diameter (Van Wyk, 1972). When the environmental conditions are not favourable *C. mopane* grows into a small and multi-stemmed shrub.

2.3 Distribution and ecology of *Colophospermum mopane*

Colophospermum mopane is the principal tree of the low-lying areas of southern tropical Africa. It reaches its southern most limit just South of the Olifants River in the Kruger National Park (Palgrave, 1977). The distribution of *C. mopane* ranges widely over the subtropical parts of southern Africa, from southern Angola and northern Namibia across northern Botswana and Zimbabwe to southern and central Mozambique and from northern

South Africa to the Luangwa Valley in Zambia and central Malawi (Van Wyk, 1972; White, 1983; Cunningham, 1996; Venter & Venter, 1996; Smit & Rethman, 1998a; Smit & Rethman, 1998b; Timberlake, 1999; Mapaure & Mhlanga, 2000) (Figure 2.1).

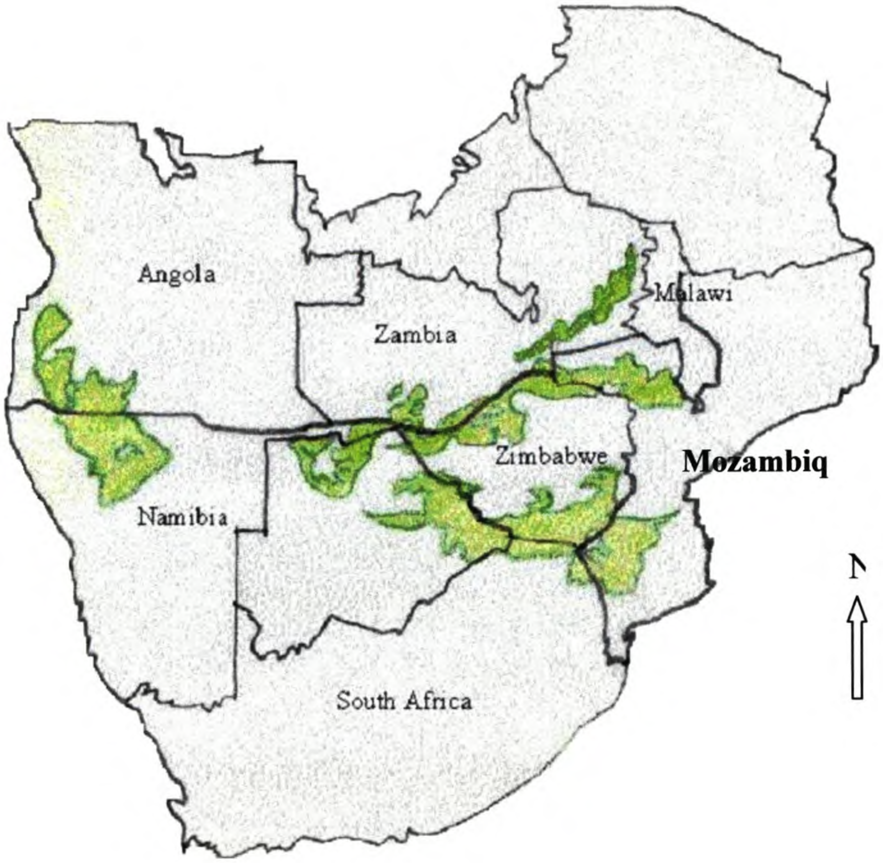


Figure 2.1 Distribution of *Colophospermum mopane* in southern Africa (adapted from Cumming 1999). The green pattern represents Mopane woodland

In total, Mopane vegetation covers an area of 550 500 km^2, in Angola, Namibia, Zambia, Zimbabwe, Botswana, South Africa, Malawi (Mapaure, 1994) and Mozambique (Cumming, 1999; Figure 2.1). In Mozambique, these veld types cover an area of 98 000 km^2 of the Zambezi, Limpopo and Save river valleys (Myre, 1960; Myre, 1964; Mapaure, 1994; Table 2.1).

Table 2.1 The percentage of areas covered by Mopane vegetation in each country in southern Africa (Mapaure, 1994)

Country	Area (km^2)	Area in the country (%)	Area in the region (%)
Angola	11 2500	9	20
Botswana	85 000	15	16
Malawi	10 000	9	2
Mozambique	98 000	16	18
Namibia	77 000	9	14
South Africa	23 000	2	4
Zambia	43 000	6	8
Zimbabwe	101 500	26	18
Total	550 500		

The distribution of the *C. mopane* depends mainly on moisture availability expressed through altitude, annual rainfall and soil texture which dictates plant structure and abundance (Mapaure; 1994). The species can occur as a tree or shrub in closed woodland or in more open savanna situations.

It is a species of the drier savanna zones and is primarily associated with wide, flat valley bottoms of the Limpopo, Zambezi, Okavango, Cunene, Shire and Luangwa Rivers (Cole, 1982). Although *C. mopane* vegetation is normally found in low valleys, in some areas, it can occur up to 1200 metres above sea level (m.a.s.l.), such as in Zimbabwe (White, 1983; Timberlake, 1999). In Mozambique, at the southernmost part of the *C. mopane* range, this species is found at 40 m.a.s.l. near the Chokwe area, less than 100 km from the Indian Ocean.

Colophospermum mopane is generally confined to areas of low to moderate rainfall and is intolerant of severe frosts (Van Wyk, 1972; White, 1983; Timberlake, 1995; Timberlake, 1999). It is capable of growing under a wide range of climatic and edaphic conditions but its actual distribution is severely restricted because of fire and competition from other species (White, 1983). The ability to resprout after fires allows it to persist in its natural range distribution. It is well adapted to survive and even benefit from decay of its heartwood (Smith & Shah-Smith, 1999). This occurs through internal roots produced from the cambium inside the hollow trunk, which the tree utilises to recycle minerals and nutrients for its benefit.

Most of *C. mopane* is situated in the 400-700 mm unimodal annual rainfall zones with a long dry season, although it can be found in some areas with only 100 mm annual rainfall (Viljoen, 1989; Timberlake, 1999). Rainfall seems to be the main influencing factor (Mapaure, 1994). It is a xeric species found in semi-arid sites, often on heavy, calcareous, sometimes sodic soils generally associated with river valleys (Dye & Walker, 1980). Mopane trees growing in sandveld indicate a shallow layer of sand overlaying poorly drained soil (Venter & Venter, 1996). The Save and Limpopo River Valleys are composed of Pleistocene lacustrine calcareous alluviums on which Mopane savanna is found (Mapaure, 1994).

Colophospermum mopane, which often dominates woodland, replaces *Brachystegia* species on poorly drained soils and extends much further South to the Kruger National Park in the East and to northern Damaraland in the West. At its most luxuriant (e.g. in parts of the Hwange National Park and Zambezi Valley), it forms closed woodland of moderate height, although the undergrowth is always sparse. At the opposite extreme, in Namibia, *C. mopane* does not form large trees but only stunted bushes barely topping the grass cover (Winterbottom, 1972). In the North of the Sabi and Limpopo Valleys *Colophospermum mopane* as woodlands often open out into savannas in the South. Further South, the Mopane formations become thicket or savanna-woodlands with not clear distinction (Rattray & Wild, 1961). In the areas of poor soils or where rainfall is less than 500 mm, dry Mopane savannas have more open canopy than Mopane woodlands.

There is little variation of habitat requirement and ecology of *C. mopane* across the subcontinent as compared to many other woody species (Timberlake, 1999). According to Acocks (1975), associated species in Kruger National Park are as follows: *Acacia tortilis, A. nigrescens, Combretum apiculatum, Sclerocarya birrea, Dichrostachys cinerea, Cadaba termitaria, Schotia capitata, Boscia albitrunca, Cassia abbreviata, Commiphora* sp., *Grewia* spp., *Ximenia* sp., *Adansonia digitata* and *Terminalia prunioides.* The grass layer area may comprise the following species - *Anthephora pubescens, Eragrostis superba, Heteropogon contortus, Panicum maximum, Digitaria eriantha, Stipagrostis uniplumis* (Van Wyk, 1972). However, in general *C. mopane* is consistently associated with a number of species across much of its range: for example *Acacia nigrescens, Adansonia digitata, Combretum* spp, *Commiphora* spp, *Terminalia* spp and *Ximenia americana* (Timberlake, 1995). The consistency of association of *C. mopane* species results in lower diversity in Mopane-dominated vegetation as compared to Miombo woodland (Bradley & Dewees, 1993). In transitional zones to other vegetation types, such as Miombo there is more mixed species assemblage in *C. mopane* vegetation. Normally genera are *Acacia, Sclerocarya, Combretum, and Kirkia* (White, 1983; Campbell & Byron 1996).

Dye & Walker (1980) and Mapaure & McCartney (2001) investigated the vegetation and environmental relationship in Zimbabwe. The Mapaure & McCartney study confirmed the key role of the influence of water in species distribution and the small-scale patterning of vegetation within catchments. Dye & Walker (1980) found that a high concentration of exchangeable sodium affects plant growth and cover, resulting in stunted plants, and distinct differences in plant community composition. Plant growth on the sodic soils is hindered by presence (at a relatively shallow depth) of unfavourable physical structure of deflocculated clay from B-horizon (Dye & Walker, 1980; Mapaure & McCartney, 2001). A dense B-horizon with highly-dispersed clay is largely impenetrable to water. The capacity of the soil, as a whole, to absorb and retain moisture is therefore very limited (Dye & Walker, 1980). This feature is reflected in the herbaceous species growing on these soils. Many grasses are xeromorphic and there is a large proportion of annual and succulent plants. Relatively few woody species grow on sodic soils, commonly *C. mopane*, *Acacia gerrardii* and *Acacia mellifera. Colophospermum mopane,* often growing in mono-dominant stands in sodic soil environments, generally forms one community. In larger areas the *C. mopane* may occur in two or three well-defined vegetation-types (Dye & Walker, 1980).

2.4 Dynamics of *Colophospermum mopane*

Despite *C. mopane* being an important economic tree species, little work has been done on the structure and dynamics of the Mopane woodland type compared to other woodland types. For instance, miombo woodland has been studied in more detailed (Chidumayo, 1997). However, among those few studies carried out, Jarman & Thomas (1969) in Kariba, Zimbabwe, found considerable variability in the density of *C. mopane* trees. Also it was observed that elephant browsing promotes coppicing in some specific soil types and disturbance regimes (Lewis, 1986; Lewis, 1991).

Mopane savanna and woodland survive heavy browsing as multi–stemmed shrubs due to the species' ability to coppice strongly (Bond, 1998; Mapaure & Mhlanga, 2000). In Luangwa National Park, Lewis (1986) noted different impacts on tree growth and woodland structure as soil characteristics changed. In sites of high nutrient soils the density *C. mopane* decreased with increase in elephant browsing. In poor soil sites because *C. Mopane* did not coppice, less browsing allowed high survivorship of younger trees. Consequently, a management recommendation was addressed to give more attention to the control of elephant numbers in coppicing areas rather than focus attention on seedling survivorship and sapling rates in non-coppicing woodlands (Lewis, 1991).

Mostly savanna trees, such as *C. mopane* coppice strongly following cutting (Bond, 1998; Smit & Rethmann, 1998a; Shackleton, 2000). This suggests, as a management option for *C. mopane* woodland (Timberlake, 1999) that the correct management of coppicing might be a useful way to promote the sustainable use of this tree species (Smit *et al*., 1996).

Regeneration or establishment of woody species following destruction of woody plants by heavy browsing of herbivores or human activities has been seen as a measure of recovery of the vegetation (Smit *et al.*, 1996). Natural regeneration is a process by which biological populations "renew and/or maintain themselves" (Chidumayo, personal communication, October 2001[1]) by seed or coppicing. According to Jordaan & Wessels (1999) *C. mopane* seedlings were well established after sufficient rainfall. *Colophospermum mopane* trees have a shallow root system with a dense concentration of fine roots in the upper horizons (25 cm) of soils (Palgrave, 1977). The seedlings are initially slow growing but the growth speeds up considerably when the plants reach a height of 200 mm (Venter & Venter, 1996). Many seedlings are burnt by wildfires. Often most of seedlings survive through the root system until the following rain season, when they are able to sprout and grow before the next fires come. This might be the survival strategy that enables *C. mopane* to maintain its seedling regeneration capacity in its natural environment. In well-developed Mopane vegetation, grass is either sparse or absent. As a result fire-damage often is minimal, resulting in high potential regeneration (White, 1983).

2.5 Use of *Colophospermum mopane*

Various authors (Van Wyk, 1972; Palgrave, 1977; Conroy, 1996; Cunningham, 1996; Grundy, 1996; Low & Rebelo, 1996; Van Wyk & Van Wyk, 1997; Madzibane & Potgieter, 1999; Hall, 2000; Mashabane *et al.*, 2001) have documented the direct use value of *C. mopane* woodlands. *Colophospermum mopane* species is a valuable timber tree. Its rich colour makes it attractive for timber. But as it is hard wood, it is not much used in carpentry, except for small articles, such as stools. Also craft materials are made from mopane timber in some areas throughout the southern African Region contributing to the household economy of rural communities where potential market exists. The poles may be utilised for props in mines and fencing-posts.

[1] Chidumayo, personal communication presented at the Universidade Eduardo Mondlane, Maputo during CHAPOSA workshop in October 2001.

Larvae of *Gonimbrasea belina* Westw. *(Lepidoptera),* the Anomolous Emperor Moth. or mopane worm, feeds on mopane leaves. The mopane worms are widely consumed by people as food. In southern Africa mopane worms are becoming an emerging cash source, contributing to local socio-economic uplifting, as well as to some extent the national economy (Styles & Skinner, 1996). For example in Botswana, Zimbabwe and northern South Africa mopane worms "are collected by the bagful dried and sold in major centres. In Botswana the industry was estimated at more than US$ 7 million in 1994" (Timberlake, 1999).

Browsing is probably one of the most valuable uses of *C. mopane* due to the high crude protein content in its leaves, which makes it a highly nutritious food. Mopane veld is generally regarded as valuable browse (Dekker & Smit, 1996; Low & Rebelo, 1996). Its value is more pronounced for ungulates during drought (Styles & Skinner, 2000). Cattle and small stock browse the leaves, either fresh or in the dry state, while, elephant eat green leaves and young branches. The green and fallen leaves are eaten by giraffe, buffalo, eland, kudu, nyala, impala (Venter & Venter, 1996). *Colophospermum mopane* due to its high content of resin in the foliage when green makes savanna habitats susceptible to wildfires. The effect of fire positively alters the palatability of *C. mopane* making it a favourite elephant browse above unburnt vegetal material (Kennedy, 2000).

Colophospermum mopane is one of the most important species in the region for firewood and charcoal (Conroy, 1996; Mashabane *et al.*, 2001). The poles are used for construction and traditional medicine. It plays a relevant role in culture in Namibia for traditional ceremonies during rainy season (Conroy, 1996). As woodland, *C. mopane* vegetation provides a number of other products. Conroy (1996) and Grundy (1996) found that villagers in the Mopane woodlands, additionally extract wild fruits, edible roots, rope, reed for mats, grass, as well as honey. They also, hunt, feed their livestock and produce crops.

CHAPTER 3

Study area description

The study was carried out in the Mahel area in Magude district, Maputo Province (Figure 3.1).

Figure 3.1 Mozambique showing the location of the Mahel study area in Maputo Province

Despite its potential for natural resource use, Mahel is in a remote and under-developed part of Maputo Province. About 2000 inhabitants in the area depend on Mopane woodland as a crucial resource (INPF, 1999) for their subsistence and income generation. The lack of development of the area is caused by a number of factors, for example poor road networks, dry climate and poor soils for crop production.

The National Directorate of Forest and Wildlife (DNFFB), assisted by the Food and Agriculture Organization (FAO), identified Mahel as a potential area to carry out community-based natural management, aiming to uplift the living standards of the local people and promote rural development based on sustainable utilisation of the Mopane woodland resources.

3.1 Biophysical aspects

3.1.1 Location

The Mahel area is located in the upper Incomati Basin at an altitude between 40 and 100 metres above sea level (m.a.s.l) and approximately 100 km from the Indian Ocean (Figure 3.2). It is one of the four administrative areas, locally called “postos”, of the Magude District. It is located approximately 225 km North of Maputo city, 54 km from the town of Magude and 50 km on the way to Mapulanguene, at the border with the Kruger National Park in South Africa. It lies between 24° 25' and 24° 36' South and 32° 22' and 32° 38' East. Mahel is bordered by Mapulanguene on the West, by Panjane on the South-West, by Motaze South-east and on the North-East by the Gaza Province through the Mazimichope River (Figure 3.2).

Mahel covers an area of approximately 2 656 km^2 (INPF, 1999), which is about 36% of the total area of the Magude District. It comprises eight villages: Gombene, Great Mahel village, Matongonane, Manjangue, Ketchene, Chimuine, Chicutso and Daniel. The villages are unevenly distributed in the area, most of them being concentrated along the major rivers, namely as the Uanetsi and Mazimichope (Figure 3.2).

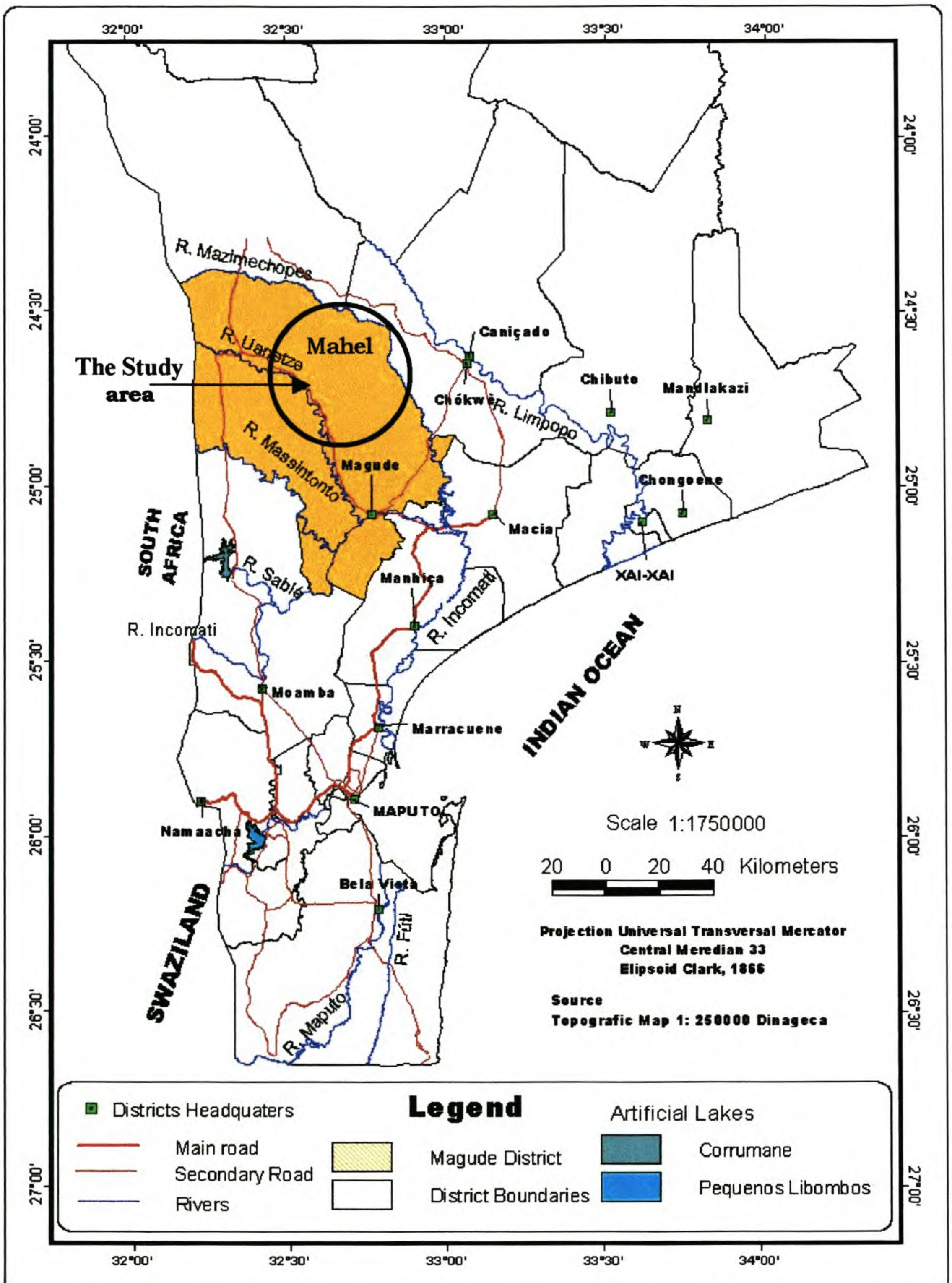


Figure 3.2 Magude district and location of the study area. Source: DINAGECA (1998)

3.1.2 Topography and drainage

The topography of Mozambique is irregular. In the southern region, 90% of the terrain is less than 200 m.a.s.l. and is characterised by flat undulating landscape, except for the western part where the Lebombo Range rises to 801 m.a.s.l (Myre, 1964; INIA, 1993). Along the main river valleys, such as the Incomati, Uanetsi and Mazimichope Rivers, the plain shows the typical characteristics of fluvial erosion (Barca & Santos, 1992).

The main streams, namely the Uanetsi, Mazimichope, Sicani, Bilibiza, Chirrotoane and Simbi, flowing into the Incomati River, form the hydrological system in the Mahel area. Due to the significant influence of the fluctuating seasonal climatic pattern in the region, these watercourses constitute the major source of surface water in the area for only a short period of the year. Also a large number of seasonal pans or marshes are found in the area.

3.1.3 Climate

Mozambique is located in the tropical and inter-tropical zone and therefore has a tropical climate. However, climatic differences are observed throughout the country (Figure 3.3) due to the effects of latitude, topography and the Indian Ocean (Barca & Santos, 1992; INIA, 1993).

In the southern Region like other parts of the country there are two distinct seasons. The hot, rainy season is from November to March, although in the area some rains extend up to 7-9 months per year during winter season. The winter season is from July to September (Figure 3.4).

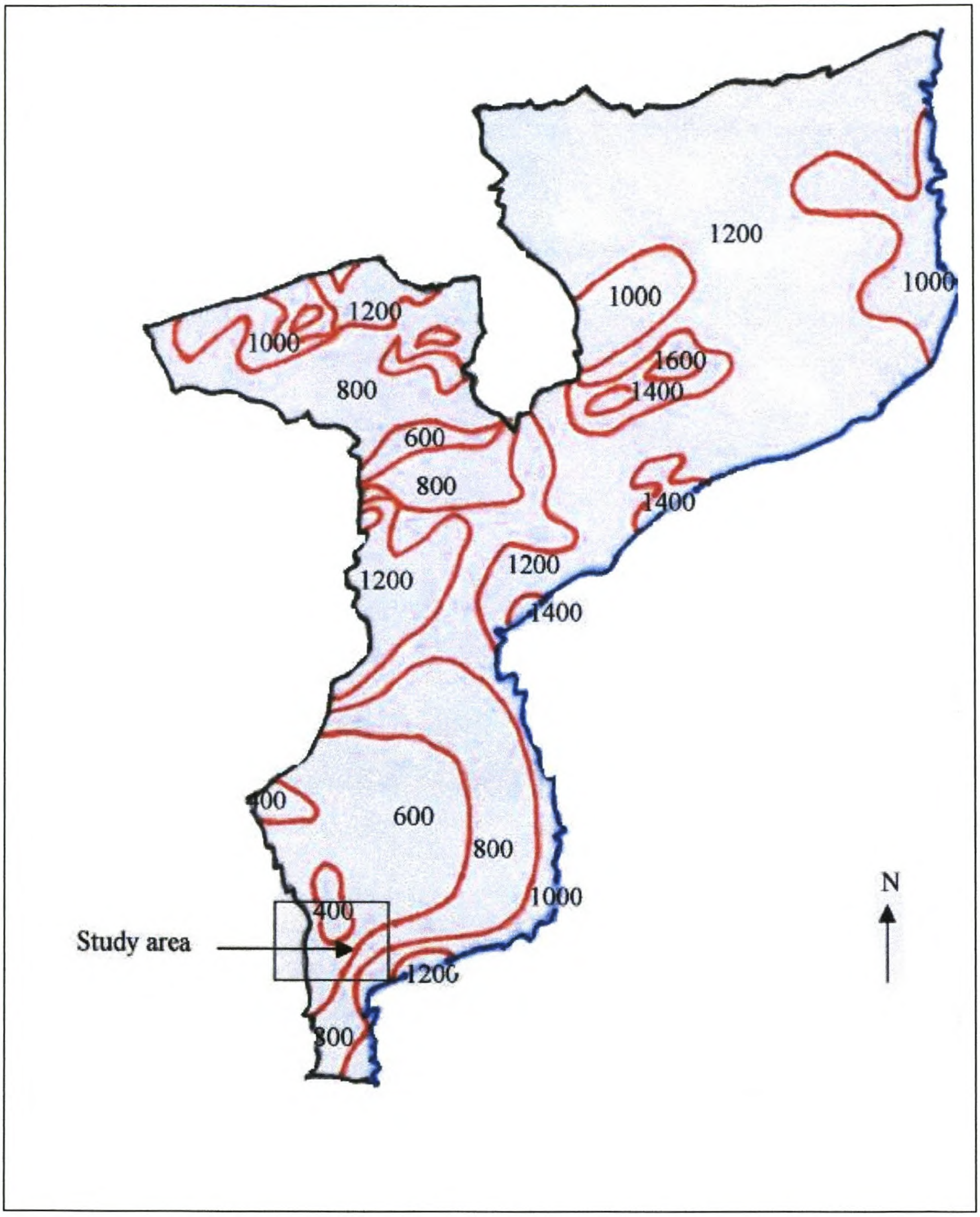


Figure 3.3 Mean annual rainfalls (mm) pattern in Mozambique and the study area. Source: INAM (2001)

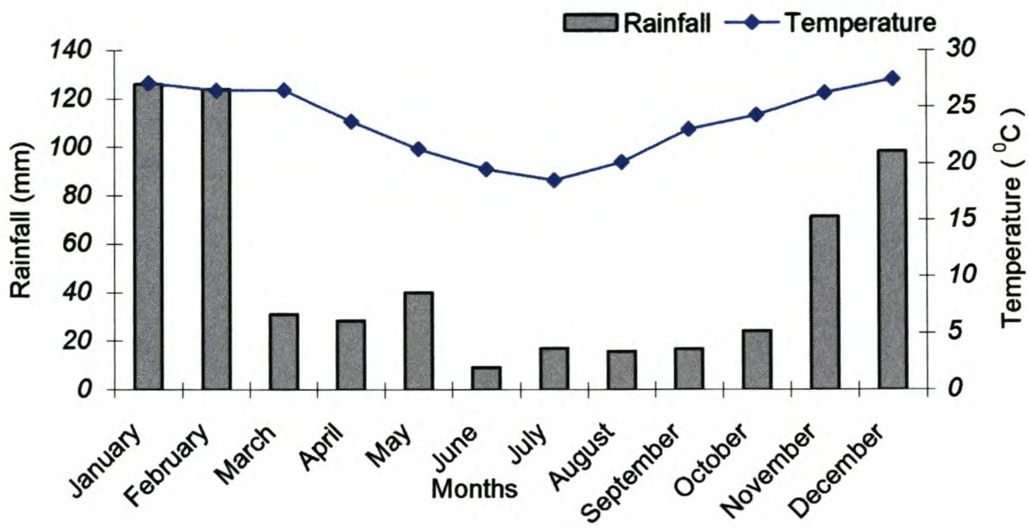


Figure 3.4 Mean annual climate (rainfall and temperature) of Chokwe. Chokwe is the nearest meteorological station to the study area. Source: INAM (2001)

Mean annual rainfall in the study area ranges between 200 - 400 mm (Figure 3.3) and 70% of rainfall is normally distributed between November and February (Figure 3.4). June and July are the coolest months averaging from 18 °C, and January is the warmest month (26 ^{0}C) (Figure 3.4). The potential evapo-transpiration rate is around 1600-1700 mm (Reddy, 1984). The annual average temperature from 1970 to 1996 indicated a range of between 22.5 and 24.5 ^{0}C (Figure 3.5).

3.1.4 Geology and soils

3.1.4.1 Geology

Mozambique is categorised geologically into two distinct regions. Metamorphic rocks with some unconsolidated fluvial, lacustrine, and coastal sediments predominantly cover the North formation.

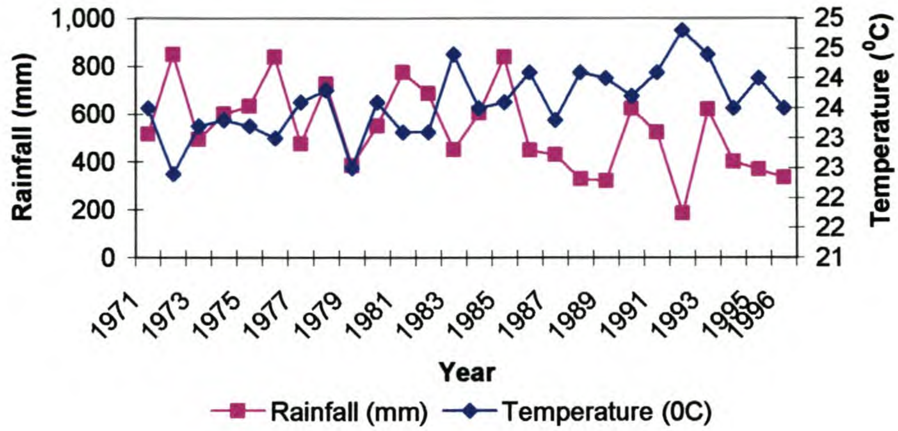


Figure 3.5 Rainfall and temperature values from Chokwe (the nearest station to the study area) reflecting the fluctuation of climate along the years since 1971. Source: INAM (2001)

From the Zambezi River southward, it comprises mainly Tertiary, Pleistocene and fluvial sediments (Barca & Santos 1992; INIA, 1993; Cumming, 1999). Tertiary formation is characteristic of the Magude District (Sousa, 1960; INIA, 1993), including the Mahel area and surrounding regions. The Mahel area broadly contains pediment covered by medium to heavy textured soils of basaltic colluvial origin overlying cretaceous rocks (INIA, 1993). Specifically the geologic formations found in the area are: red sand plateaux remnant in the South -West along Uanetsi River and alluvial plains in the North-East (DNFFB, 1990).

3.1.4.2 Soils

In general the southern region of Mozambique is predominantly characterised by sandy infertile soils except along the major watercourses where the soils are relatively fertile (Sousa, 1960; Reddy, 1984). Two distinct soils found in the area are determined by the underlying geology: these are sandy, mainly red coarse sands (cambic arenosols) in the South-West and medium to heavy-textured soils (Eutric fluvisols) in the North-East (DNFFB, 1990). The major proportion of the study area is covered by heavy-textured soils. Five groups of soils were identified in the area as follows (Table 3.1):

Table 3.1 Soil types in the Mahel area

Category	Geology	Surface and subsoil texture	Depth (cm)	Drainage	Acidity and alkalinity (PH) – surface/ subsoil	Organic matter (%)
MaPe	< 20 cm of hard sodic deposit of Pleistonic.	Sandy-silty-clay	>100	Impeded	(5 – 7 / 5 – 8)	0.5 – 5 low to high
CoSo	Colluvial soils from mananga.	Silty-clay	>100	Moderate to impeded	6.5 – 8.3 / 7.1 –9.1	2 – 4.5 Moderate to high
MPCoAs	Colluvial soils and sodic deposit from mananga.	Silty-clay	>100	Impeded /bad	6 – 7.6 / 6 – 8.5	1.25 – 4.75 Moderate to high
OSRock	Sediment from cretaceous or tertiary.	Clay-clay	<100	Impeded to moderate	6.2 – 7 -/ 6 - 7	0.5 – 2.5 Low to moderate
SPlMPaS	Superior pleistonic eolic sandy.	Sandy-sandy	> 180	Good to excessive	3.9 – 6 / 4 – 6.5	0 – 3 Low to moderate

[a] MaPe: Mananga pediment
MPCoAs: Mananga pediment associated with colluvial soils
CoSo: Colluvial soils
OSRock: Outcrop of sediment rock
SPlMPaS: Sandy plain and mananga pediment association

Mananga pediments: These are sandy soils with varied depth. They are brown yellowish and the subsoil is dominated by a sandy-clay texture. This type is not found along Uanetsi River.

Colluvial soils: They are typically made up of colluvial clay of Mananga pediment with greyish to brown deep clay subsoils. These soils are found mostly in the Manjangue area in the East, dominating larger areas of depressions, for example near the Mazimichope River streams and North of the Simbi River.

Mananga pediment and colluvial soils association: This association of soils is a combination of mananga and colluvial soils found in transitional sites. These are the predominant soils in the area due to the association with mananga soils. This association is not found near to the Uanetsi River.

Outcrops of sediment rock: These are outcrops of Magude sediments. They are shallower soils on non-calcareous rocks (limestone). The subsoil consists of deep moderate brownish clay. A high percentage of clay is found in the surface soil and subsoils. These are relatively acidic soils, which in the study area are only found along the Uanetsi River, from Mahel to Chimuine Villages and in the Gombene area North of the Sicani River.

Sandy plain: These soils are yellowish in colour with a surface and subsoil characterised by brown to yellowish sands respectively. They are non-saline and very localised types. They are found in Mahel village, where they are associated with *Sclerocarya birrea* (marula) tree. In the South-East, near Chimuine village, there is a large portion of these sandy soils.

3.1.5 Vegetation and wildlife

3.1.5.1 Vegetation

The vegetation of Mahel falls within the broad classification of Mopane veld (Myre, 1960; Myre, 1964; Mapaure, 1994). *Colophospermum mopane* is the key species of the study area. It covers the major proportion of the area, forming a mosaic vegetation of open and shrub woodland. Patches of transformed vegetation by human activities in the past are visible in the area from extensive agriculture, cattle grazing and systematic removal of woody material for firewood, mainly before the civil war in 1983. These resulted later in the formation of open secondary woodland (Plate 3-1), mainly along the major watercourses, namely the Uanetsi and Mazimichope Rivers.

However, mixed *Acacia* spp. are common in the south-western area. In the South-Western area the mixed Acacia forms a transition or ecotone between pure Mopane woodland and the river ecosystems along the Uanetsi river valley. In the North-East of the study area it is an extensive pan veld region (DNFFB, 1990), on clay soils mostly dominated by *C. mopane*. In shrub form *C. mopane* is found between pans while on the edges of pans and along the streams *C. mopane* forms a high gregarious vegetation of 4 –7 m, associated with *Acacia* species.

Plate 3.1 Mahel village on the South - West side of the study area and the open vegetation resulted from human influence

Colophospermum mopane woodland in Mahel is in the form of clumps or clones of *C. mopane* trees or shrubs associated with species of *Acacia*. In the ecotones the following species are associated with *C. mopane*: *Dichrostachys cinerea*, *Combretum apiculatum*, *Ziziphus mucronata*, *Acacia nigrescens*, *Acacia nilotica* and the grass *Panicum maximum*. Mussanhane (2000) listed the following woody species (Table 3.2) as the most frequent species in the area.

Table 3.2 Common plant species found in the study area, according to Mussanhane (2000)

Scientific name	Local name
Acacia nigrescens	Khaya
Acacia senegal	Chicaia
Albizia petersiana	Dzanguelanguva
Balanites maughamii	Nulu
Berchemia zeyheri	Chinei
Colophospermum mopane	Gunwe
Combretum imberbe	Mondzo
Combretum molle	Chicucutso
Dalbergia melanoxylon	Shelutsi
Dichrostachys cinerea	Dzenga
Diospyros mespiliformis	Ntoma
Euphorbia sp	Neta matsuni
Guibortia conjugata	Ntsontso
Lonchoncarpaus capassa	Mbanzo
Manilkara discolor	Nwambo
Gymnosporia heterophylla	Xilhangwa
Sclerocarya birrea	Canhu
Spirostachys africana	Xilangamahlu
Ziziphus mucronata	Passamala

The woody resources in Mahel are fairly evenly distributed in the area despite the tendency of *C. mopane* to become increasingly dominant towards the north-eastern direction. Over the whole area 30 000 ha *C. mopane* makes up 86 % of total tree abundance and total density of 169.24 trees/ha (Mussanhane, 2000).

3.1.5.2 Wildlife

The existing vegetation provides an ideal habitat for a diversity of wildlife. However, due to over-hunting activities in the years after 1992, most of the species likely to have occurred there are no longer present (Anderson & Magane, 2000). Table 3.3 lists some species common in the area according to Mapulasse (2000).

Table 3. 3 List of wildlife species found in the Mahel area (Mapulasse, 2000)

Scientific name	Local name
Rodentia	
Paraxerus saxatilis	Esquilo das arvores
Hystrix africaeustralis	Porco espinho
Lagomorphs	
Lepus saxatilis	Ipfundja
Suids	
Potamochoerus porcus	Khumba
Antilope	
Raphicerus campestris	Shipenhe
Sylvicapra grimmia	Mhuti
Tragelaphus angasii	Nyala
Tragelaphus stripsiceros	*Nhongo*
Neotragus moshatus	Chengane
Carnivores	
Canis sp	Nanzana
Crocuta crocuta	Mhisi
Felis serval	Simba
Ictonyx striatus	Xitchewani
Mungus mungo	Nkala
Viverra civeta	Nfungue
Primates	
Cercopithecus pygerythrus	Hahu
Birds	
Colius striatus striatus	Xivovo
Cuculus clamosus	Nfhuku
Numida meleagris	Manguela
Melittophagus pusillus meridionalis	Ngueru
Phaeniculus purpureus	Matengu
Streptopelia capicola tropica	Tuwa-kopa
Tockus erythrorhynchus rufirostris	Nkhotokhoto
Turtur chalcospilos chalcospilos	Tuwa-guguru
Reptiles	
Dendroaspis polylepis	Mamba-chnga
Hemirhagerrhis nototaenia	
Python sebae	Icharu

3.2 Socio-economic aspects of the communities around Mahel

3.2.1 History of settlement and human population

Human settlement in Mahel dates back as far as 1800, before the Portuguese occupied the area and Maghudzo at the time, was a prominent traditional leader of Khussine tribe or Cossa (INPF, 1999). According to INPF (1999), Maghudzo introduced *Sclerocarya birrea* (marula) after his expedition to Tanzania. Since then this species apart from its direct use value has been acknowledged for its spiritual and cultural values for Cossa's tribe and Shangana group in general (INPF, 1999).

Magude District was one of the most affected areas during the civil war in Mozambique, which ended in 1992. Looking for safe areas, most people migrated to the urban areas, such as Maputo, Magude town, Xai-Xai and Chokwe, as well as to South Africa. As a result, Magude District is one of the least populated parts of the country, decreasing from an average of 15 people/km^2 in 1980 to 6 people/km^2 1997. The Mahel area has the lowest density (person/ km^2) in the District.

More recently, the human populations in Mahel have tended to increase gradually, according to the local administration figures of 2001 (Table 3.4). In 2001 the Mahel area supported a total of 2000 people, approximately 25% more than the 1997 national census. This increase in the human population is related to the improvement of livelihood and security in the area. Increasingly people are motivated to return to the area by ongoing socio-economic activities, for example, cattle restocking, natural resource management, and agricultural extension projects. The north-eastern section of the study area is slightly more populated than the southern area (Table 3.4).

Table 3.4 Summary of human population in the Mahel area. Source: Mahel administration 2001

Village	Population	Total population (%)	Households	Section
Mahe-sede	366	18	90	Southwest
Matongomane	436	21	94	Southwest
Chimuine	122	6	21	Southwest
Gumbene	65	3	12	Southwest
Chicutso	217	11	50	Northeast
Manjangue	597	29	196	Northeast
Ketchene	230	11	46	Northeast
Total	2033	100	509	2033

3.2.2 Income generating

3.2.2.1 Crop production

Dry-land agriculture is still the main production system in the area, mainly for subsistence purposes, due to the marginal climate in the region. The major crops cultivated are: maize, groundnuts, cassava, beans, sweet potatoes, sorghum, and pumpkins. These crops constitute the major source of food security in the area and in a good rain season they can also contribute to income generation. However, veld products trade, livestock sales and remittances from the migrant labour force are the guarantee of income for the majority of households (Filimao & Muhai, 2000).

3.2.2.2 Woodland and wildlife activities

The population of Mahel is strongly dependent on natural resources for its livelihood. Woodland resources such as charcoal, firewood, poles and grasses are the most common source of income in the area. The Chicutso and Majangue villagers in the north-eastern section due to its proximity to the Chokwe District are more actively involved in commercial activities based on woodland products. Unlike in Matongomane, Mahel, and Chimuine villages where due to poor road connection to Magude, the commercial extraction of woody resources is not such important activity as in the Chicutso and Manjangue areas. However, game hunting for some families in south-western section constitutes one of the sources incomes, as well as a source of animal protein. The meat is sold, although illegally, at the big markets in Maputo city.

3.2.3 Local development activities

During the colonial era and before the civil war, from the mid 1970s to 1980s, cattle farming in the Magude District formed the basis of the local economy and contributed to a large extent to the national economy. The area was one of the most important livestock areas in the country.

The Government has initiated projects in partnership with the international agencies to promote livestock production in the area, both at household and private levels (Anderson & Magane, 2000; Filimao & Muhai, 2000). This is done with the aim of restocking the area as a strategy for rural development. Other projects of development in the area are game farming and bee keeping. These projects are believed to alleviate the current socio-economic problems of the local people and also contribute to the sustainable use and conservation of the *C. mopane* woodland (Mansur & Cuco, 2002).

CHAPTER 4

Methods

The study comprised two field surveys - ecological and socio-economic. These two surveys were carried out to understand the woodland resource availability and the resulting ecological effects of harvesting in the area. Then, the relationship between resource availability and socio-economic value of the woodland resource was also assessed through the information gathered from the household survey. Data were collected from both primary and secondary sources. Also focus group discussions for trend analysis with key informants were carried out in the area in order to get more insight into perceptions on woodland resources availability over time in the study area (Borrini-Feyerabend, 1997).

4.1 Ecological assessment

4.1.1 Identification of Vegetation unit and plot allocation

The study area, which is 913 km^2, was stratified into two vegetation units (DINAGECA, 1998). These are Mopane woodland or ecozone 1 covering 560 km^2 and mixed Acacia woodland or ecozone 2 of 353 km^2. While the first vegetation unit is strongly dominated by *C. mopane* and covers most of the study area, the other vegetation unit is characterised by an open mixed Acacia woodland mostly located along the drainage lines.

The plots were located using a simple random method. Two hundred random points were located using a GIS computer package on the 1/250 000 vegetation map generated from the DINAGECA (1998) classification. Geographic coordinates of the points were used to locate the points in the field.

4.1.2 Determination of plot size for sampling selection in each vegetation

A preliminary exercise was carried out to determine the plot size for optimum sample size in each vegetation according to Mueller-Dombois & Ellenberg (1974); Van Laar & Akça (1997) and Pereira (2001 and Figure 4.1 a & b. The coefficient of variation (*C.V.*) of number of stems per hectare calculated was based on following formula:

$$CV(\%)=aA^{b}$$

Where *CV* is the coefficient of variation in percentage; *A*, is the plot area in hectares and *a, b* are regression coefficients. The regression coefficients used for the Mahel area were extrapolated from a dry savanna area elsewhere in Mozambique (Pereira, 2001). The plot sizes were selected where the curves indicated stable coefficients of variation (Figure 4.1 a & Figure 4.1 b), i.e. less variation in number of stems per hectare with increased the plot sizes. In ecozone 1 the size of each quadrat defined was 20 m x 20 m that is 1% of the coefficient of variation and in ecozone 2, each quadrat was 50 m x 50 m with 30% of the coefficient of variation.

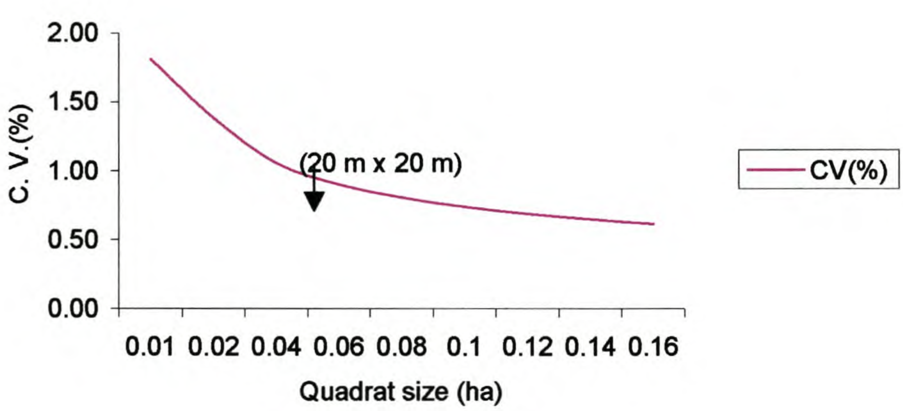


Figure 4.1 a Plot size determination in Mopane woodland for sampling selection. The arrow indicates the optimum quadrat size for sampling in Mopane woodland

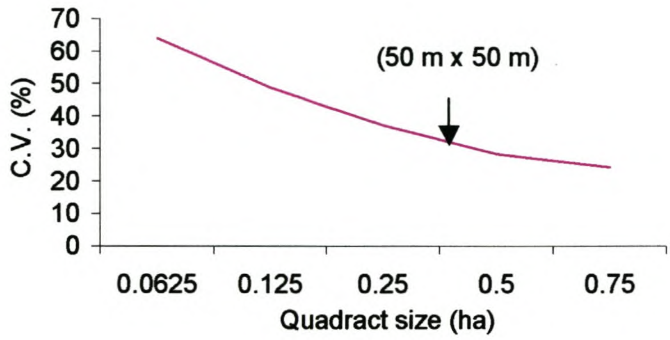


Figure 4.1 b Plot size determination in Acacia woodland for sampling selection. The arrow indicates the optimum quadrat size for sampling in Acacia woodland

The lower coefficient of variation in ecozone1 reflects the characteristic of the Mopane vegetation in the area. Small stem sizes and a density of stems are the major characteristics of the Mopane vegetation in the area. Acacia woodland was characterised by open vegetation and was found to have a high variation of stem sizes and more species per unit area. However, the plot sizes defined were within limits recommended in woodland vegetation analysis (Muller-Dombois & Ellenberg, 1974) and have previously been used in these vegetation types (e.g. Campbell & Du Toit, 1994; Mapaure & Mhlanga, 2000).

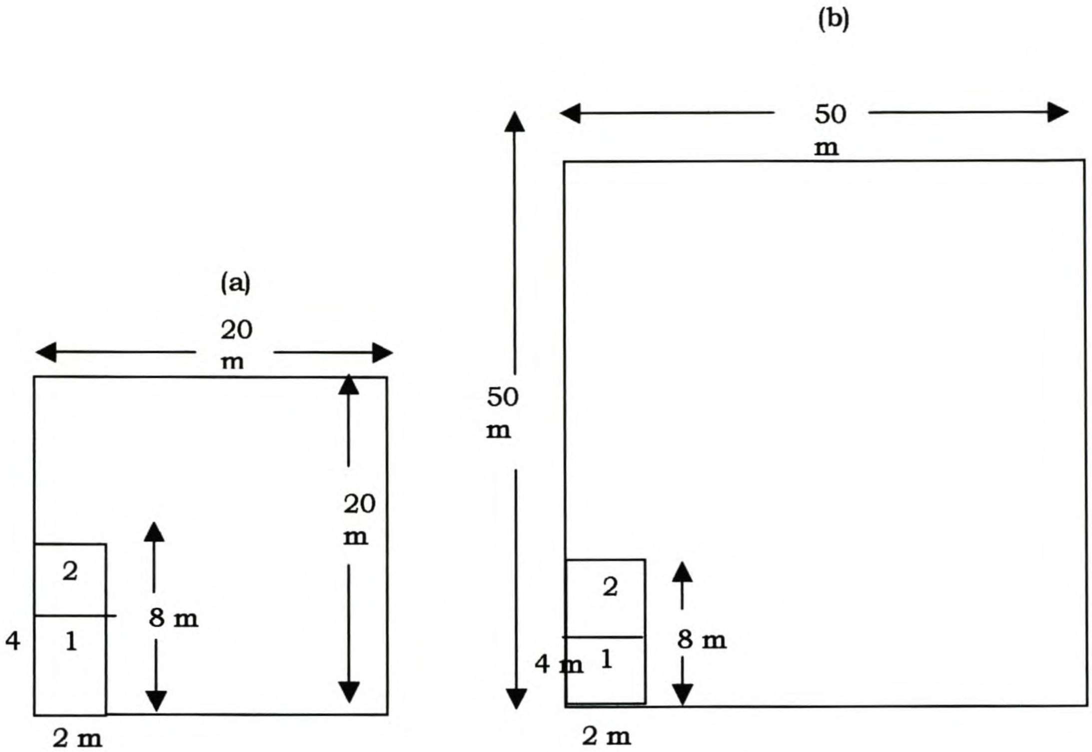


Figure 4.2 Diagrams of the plots and subplots a) Mopane woodland and b) Acacia woodland

4.1.3 Plot location

Geographical position system (GPS II plus)[1] was used to locate the random points in the field. Once the point was located, the plots and respective subplots were marked. Subplot 1 was used for sampling saplings or established regeneration and subplot 2 for seedlings. Selection of sample sites in this way made it possible to sample as much of habitat diversity as possible, including variety of soil types, soil water availability and vegetation types that result from intersection of the drainage system flowing perpendicularly to the Eastern direction.

4.1.4 Distance of plot from settlement

The distance of each plot from the nearest village was recorded to assess the impact of human activities on the woodland. This is based on the assumption that in short and long terms,

[1] GPS II plus 1998. Corporation Kansas

human activities may cause vegetation changes, resulting in scarcity of resources and changes in species composition. Four distance intervals were defined for the purpose of analysis, grouped into four classes, namely, 0 – 5 km, 5.1 - 10 km, 10.1 -15 km and 15.1 km and above. As one aim of the study was to understand patterns of vegetation disturbance from harvesting and other uses, it is also important to understand the vegetation composition and abundance across the area (Mbwambo, 2000).

4.1.5 Determination of soils characteristics

Soil characteristics were taken from soil map of 1:50000 scale (INIA, 1993), using the coordinates of each random point. This information was used to ascertain the possible influence of soil characteristics on the variability of the vegetation pattern, productivity and abundance of woody species. For analysis of relationship between soil types and species richness, diversity and stem density, five categories of soil quality were established in ascending order based on organic matter (Table 3.1).

4.1.6 Measurements

The fieldwork was carried out in an intensive survey within 45 days during the dry season, from July to August 2001. Two teams assisted by local people carried out the work and two botanists from Eduardo Mondlane University (Maputo) identified woody plant species. All individual species not identified in the field were coded, recorded using the local names and taken to the herbarium of Eduardo Mondlane University in Maputo for further identification.

4.1.6.1 Woody resources

In each main plot of 20 m x 20 m and 50 m x 50 m, all species and individual stems with diameter of (dbh) over 4 cm were measured using vernier callipers, and recorded (Appendix

1), to quantify abundance of woody resources and assess population structure in the study area.

4.1.6.2 Saplings

To determine the established regeneration in subplot 1 of 2 m x 2 m individuals of woody species with stems of less than four cm in diameter at diameter at breast height (dbh)) and more than 50 cm tall were registered as saplings, regardless of the nature of regeneration from seedling or sprouting or mature ones.

4.1.6.3 Seedlings

All Individuals of woody species less than 50 cm tall encountered within the 2 m x 4 m subplots from the random point of the main plot were counted and listed to estimate the regeneration potential of the area. These individuals were considered non-established regeneration of growing plants based on the fact that at this growing stage plants are very susceptible to fires in dry the season and therefore may not survive into the next growing season.

4.2 Socio-economic assessment

A structured questionnaire (Appendix 2), informal discussions and personal observations were the major methods used to gather information from primary sources. Also, key informants such as local leaders, local authorities and natural resource management committee members were interviewed to collect additional information.

The questionnaire survey was used to investigate perceptions of the local community towards Mopane woodland. Local people in Mahel depend directly or indirectly on the Mopane woodland for various purposes, such as, collection of woodland products, grazing, agriculture and hunting. Therefore, it was expected that different groups of people and families in the area value the environment differently. This varies according to their reliance on certain socio-economic activities and their extent of involvement in them, whilst considering other relevant sources of income for the families, such as employment opportunities in Maputo or South Africa.

A questionnaire survey to determine opinion and attitudes (Mouton, 2001) was conducted through face-to-face interviews consisting of a structured sequence of objective questions, such as household status, value of household production and woodland resource use (Appendix 2). To strengthen and validate the information gathered at community level from the questionnaire survey, a participatory appraisal was conducted focused on group meetings. This approach was found to be a useful technique in collecting sufficient general information and improves the quality of the questionnaire information (Abbot, 1997).

The participatory approach was used to understand the general perception of resource use trend and availability of natural resources in the last 30 years in the area, including other production activities, such as crop and livestock production. The implications of activities to the environment, in terms of degradation, were also assessed in order to understand the general perceptions about conservation issues.

4.2.1 Sampling frame

Selection of study villages

The study area for the socio-economic survey included all seven villages, namely, Matongomane, Mahel, Chimuine, Gombene, Ketchene, Chicutso and Manjangue. These villages traditionally and administratively belong to the greater Mahel village, each being collected of groups of extended families. In the area both traditional and administrative governance are respected. Therefore, both types of authorities were consulted in the household survey procedures and the natural resource management committees approved the survey prior to its implementation. The head of the village was responsible for informing all the villagers about the research survey and the respective research days of activities for a particular village.

4.2.2 Household questionnaire survey

4.2.2.1 Objectives of the survey

The questionnaire was designed to assess the community's perception of their environment, to identify the present species use and preference in the Mopane woodland based on household level information. People value the resources differently according to the access and degree of benefit they get from a particular source (agriculture, livestock, forest and cash income). The extent to which people are involved in different socio-economic activities can be an indicator of how people perceive and value different resources in the area. Therefore, to understand people's perceptions on resource use value in the Mopane woodland, questions about the degree of benefits they get from different socio-economic activities in the area were asked (Appendix 2).

The stone game method (Turpie *et al.,* 1999) was used to rank the benefits from crop production, livestock, woodland and cash income. Forty stones were used taken as total value attributed and these were allocated to different benefits. A similar method was applied in the Zambezi Delta in assessing overall use value and local perception of natural resources (Turpie *et al.,* 1999). This method was found to provide a relaxed atmosphere and the people felt free to rank the socio-economic activities based on their real life activities.

4.2.2.2 Pilot household survey

Three people were recruited from outside the study area for the household survey to administrate the questionnaire. A pilot survey covering nine households was done initially. The pilot survey served to train the interviewers and the questions were adjusted to the real situation of the area, so as to permit validation of the questionnaire and adequacy of the questions.

4.2.2.3 Sample size and questionnaire coverage

For socio-economic assessment, 19 % of the 509 households were interviewed in the study area. In the four villages (Matongomane, Mahel, Chimuine and Gombene) a total of 43 householders were interviewed, while in other three (Chicutso, Manjangue, Ketchene) 53 householders were sampled (Table 4.1).

Table 4.1 Distribution of households in the study area and households sampled by village

Village	Number of household	Number of house hold sampled	Household sampled per village (%)
Mahel village	184	37	20.1
Chimuine	21	5	23.8
Gumbene	12	1	8.3
Chicutso	292	53	18.2
Total	509	96	17.4

Due to the lack of a list of people and households at the local administration offices, the interview procedure was based on a systematic sample of one household surveyed in every five (20 %) households. The head of the family was the main respondent targeted, being a male or female. In his/her absence then the next responsible adult over 18 years was interviewed. There was no special emphasis on gender during the survey. However, males were the most interviewed during the survey because males in most cases are responsible for welcoming the visitors to households in the area. The questionnaire was translated into the local language (Shangana) in which the questionnaire was conducted.

4.3 Analysis

All field data were entered into MicroSoft Excel 2 (1998) and then exported to Statistica 6 (1998) for analysis and interpretation. Densities, species dominance and frequencies were calculated in MicroSoft Excel 2 (1998) for statistical analysis using Statistica 6 (1998) package. One-way Analysis of Variances (ANOVA) was used to analyse the data. Scheffé post hoc tests (Statistica 6, 1998) were used to determine which variables were significantly different with respect to the environmental factors and vegetation characteristics, including species richness and diversity. Multiple regression analysis was applied to determine the most important factors affecting diversity and availability of woodland resources in terms of stem density per hectare.

Species richness was based on number of species found in each plot. The Shannon - Wiener index (*H'*) was used to assess diversity of woody vegetation since there were a large number of random plots sampled (Jayaraman, 2000). This index is applied in the assumption that a community species is maximally diverse if the species are equally distributed in the area or stand (Lasch *et al.*, 2002). It will be maximum depending on number of species.

1. Diversity of woody vegetation $H' = -\Sigma^{s} p_i \ln p_i$

p_i = the proportion of individuals or the abundance of the *i*th species expressed as a proportion of total cover; *ln = log base10*

2. Stocking density of stems

$D = S/A$

D = number of stems sampled per hectare

S = Number of stems; A = Total area sampled

4. Estimation of use value was based on Martin (1995).

Frequency use value $Vu = (Us/Tu)*100;$ Where: Vu = Frequency use value of woodland products in percentage across villages and species; Us = Total count of uses of a species by village; Tu = Total count of uses of all species in a village.

CHAPTER 5

Results and Discussion: Natural resource assessment

In this chapter the results obtained from the vegetation survey to assess the woody species composition, diversity and physical availability of resources are presented and discussed. Population structure and regeneration potential of the woody vegetation also were assessed.

The ecological survey included 154 plots out of 200 plots initially planned. Forty-six plots were not sampled either due to the presence of land mines in some sections of the study area or because they fell on riverbanks.

5.1 Vegetation composition and resource availability

Factors affecting the species composition, species richness, diversity and density of woody vegetation are analysed based on vegetation types, soil types and disturbance, largely from human impacts. The patterns of the vegetation and soils of the Mahel area are presented in Figure 5.1 and Figure 5.2, respectively.

5.1.1 Results

5.1.1.1 Species composition

Colophospermum mopane achieved over 80 % dominance in Mopane woodland (Table 5.1; Appendix 3). Other common species in this area were *Acacia davyi, Acacia nilotica* and *Euclea natalensis*. In some localised areas, in mixed Acacia woodland along the major watercourses, such as Uanetsi and Mazimichope Rivers, the *Acacia tortilis* occurred in 60 % and 70 % of plots (Table 5.1; Appendix 3). Occasional species in Acacia woodland were *Acacia adenocalyx*, *Acacia nigrescens, Acacia nilotica, Combretum molle, Dichrostachys cinerea, Lannea schweinfurthii and Sclerocarya birrea.*

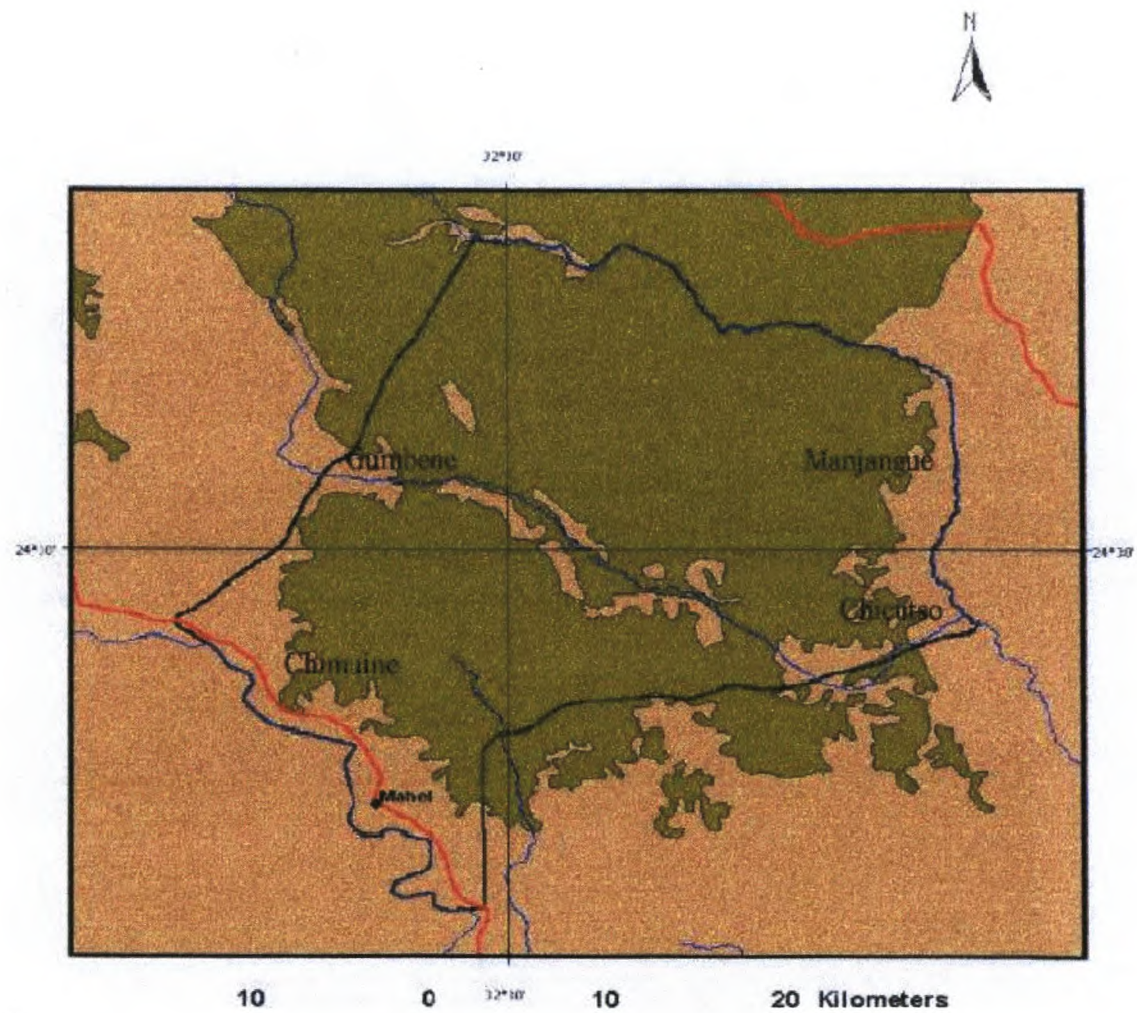


Figure 5.1 Pattern of vegetation in the Mahel area (DINAGECA, 1998). The green pattern is Mopane woodland and the area outlined is mixed Acacia woodland

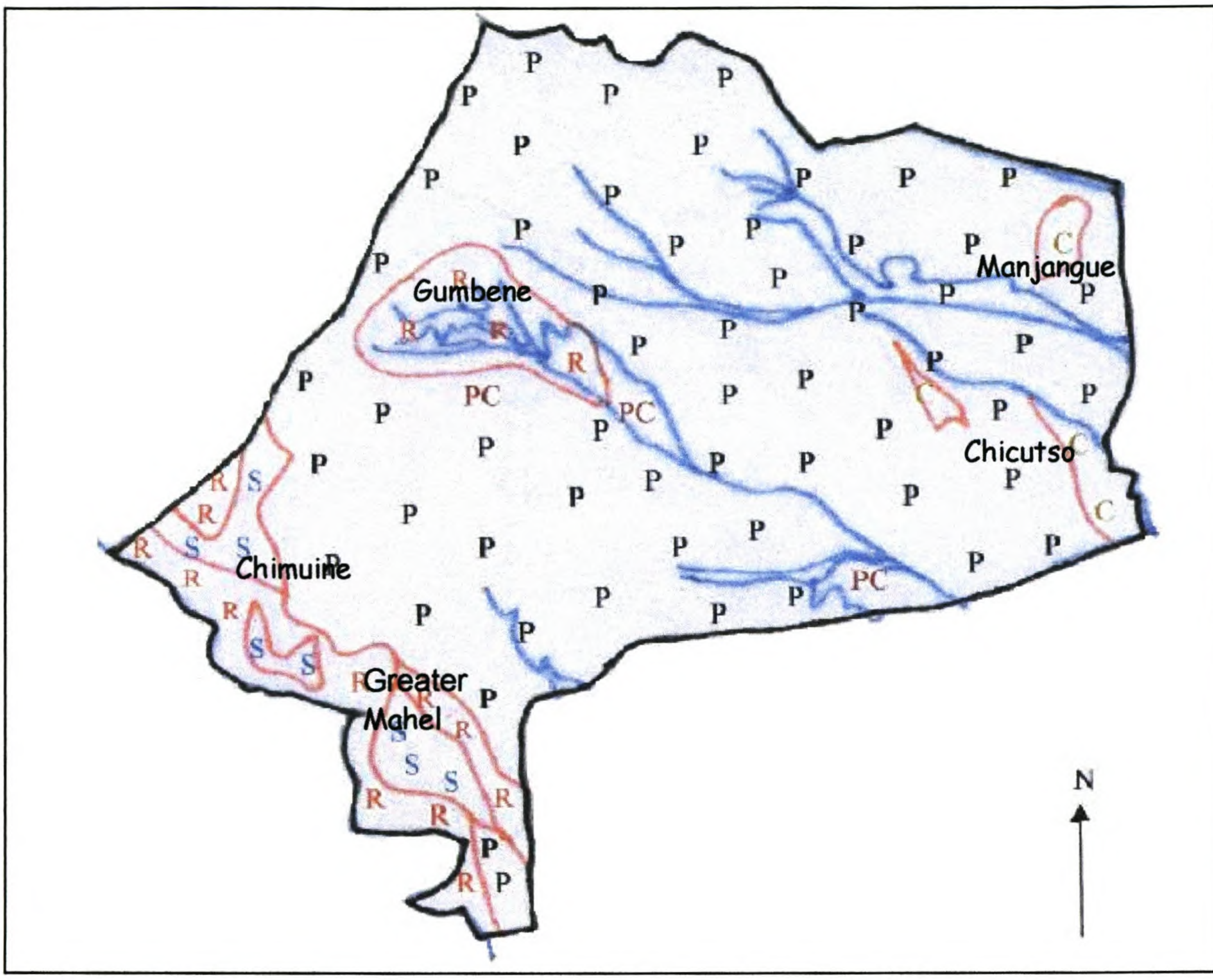


Figure 5.2 Soil map of the Mahel area showing the pattern of the major soil types, where C = Colluvial soils, P = Pediment soils, PC = Pediment and colluvial associated soils, R = Outcrop soil and S = Sandy soils, adapted from INIA (1993)

Table 5.1 Most dominant woody species in the two vegetation types, Mopane woodland and Acacia woodland. The constancy[1] of each species in each ecozone is shown, where: I = 0 - 19%, II =20 – 39%, III = 40 – 59 %, IV = 60 – 79% and = > 80 % occurrence in an ecozone

Species	Mopane woodland	Acacia woodland
Number of plots	128	28
Acacia adenocalyx	I	II
Acacia davyi	II	I
Acacia nigrescens	I	II
Acacia nilotica	II	II
Acacia tortilis	I	IV
Colophospermum mopane	V	I
Combretum molle	I	II
Dichrostachys cinerea	I	II
Euclea natalensis	II	I
Lannea schweinfurthii	I	II
Sclerocarya birrea	I	II

5.1.1.2 Species richness and Diversity

a. Species richness, diversity and vegetation types

A total of 72 woody species occurred within sample plots in the study area. There was a highly significant difference in number of species found per plot between Mopane woodland and Acacia woodland (ANOVA $F = 23.8$, $p < 0.001$, df. = 150). For Shannon-Wiener diversity index (*H*) also indicated highly significantly different between the two vegetation types (ANOVA: $F = 18.46$, $p < 0.001$, df. = 147).

Table 5.2 shows the range of species richness and diversity per plot found in the Mopane and Acacia woodlands. The highest species richness was six species per plot in Acacia woodland and the Shannon-Wiener diversity index (*H*) was 1.18 per plot, SD 0.1 also in Acacia woodland.

[1] Constancy is defined as the number of plots in which each species occurs (Kent & Coker, 1992)

Table 5.2 Woody species richness and diversity per plot in the Mopane woodland and Acacia woodland

Vegetation type	Species richness	Species diversity
Acacia woodland	6, SD 0.48	1.18, SD 0.10
Mopane woodland	3, SD 0.21	0.63, SD 0.05

b. Factors affecting species richness and diversity

The results of this study show that species richness and diversity per plot depend on various factors including soil types, resource use depending on distances from the village to the woodland and vegetation types.

Factors affecting species richness to the woodland

The summary of the multiple regression analysis of species richness per plot as the dependent variable per plot (R^2= 0.23, $p < 0.001$, n = 154) indicated soil types and vegetation types as the stronger variables (t = 3.222, $p < 0.0016$ for soil types and t = 2.639, p = 0.009 for vegetation types). Soil types and vegetation influence significantly species richness in the study area (b = 0.27 for soil type; b = 0.21 for Ecozone) (Table 5.3). Distance from the village to the woodland was not found significant effect on woody species richness per plot (t = 1.398, p = 0.164).

Table 5.3 Summary of multiple regression analysis for species richness per plot of woody vegetation in the Mahel area influenced by soil characteristics, distance from the village and vegetation types

Parameter	Beta (b)	Standard error Beta	B	Standard error of B	T (150)	p-level
Intercept			-252.5650	55.5757	-4.5445	0.0000
Soil type	0.2703	0.0839	1.0250	0.3183	3.2221	0.0016
Distance	-0.1124	0.0804	-0.2690	0.1923	-1.3980	0.1642
Ecozone	0.2172	0.0823	1.5090	0.5718	2.6391	0.0092

Factors affecting species diversity to the woodland

The summary of the multiple regression analysis of species diversity per plot as dependent variable (R^2= 0.18, $p < 0.001$, n = 154) indicated soil types and vegetation types as the stronger variables (t = 2.2, $p < 0.025$ for soil types and t = 2373, p = 0.0189 for vegetation types)(Table 5.4). The two variables, soil and vegetation types affect significantly species diversity in the study area (b = 0.19 for soil type; b = 0.20 for Ecozone type) (Table 5.4). Distance from the village to the woodland was not found significantly affecting woody species diversity (t = 1.82, p = 0.069).

The effect of soil types to woody species richness and diversity

There was a highly significant difference in the number of tree species per plot found on the various soil types (ANOVA, F = 9.6, $p < 0.001$, df. = 147). The total Shannon-Wiener diversity index *(H)* per plot was highly significant different between soil types (ANOVA: F = 5.3, $p < 0.001$, df. = 144). The lowest mean species richness was on sandy soils (*S=2.8*, SD 0.3 woody species) and the highest was (*S*=8, SD 2 woody species) in colluvial soils (Table 5.5). While for index of Shannon-Wiener diversity, the highest was 1.32, SD 0.5 in colluvial soils and the lowest index was 0.5 in sandy soils.

Table 5.4 Summary of multiple regression analysis for species diversity per plot of woody vegetation in the Mahel area influenced by soil characteristics, distance from the village and vegetation types

Parameter	Beta (b)	Standard Error of Beta	B	Standard Error of B	t(150)	p-level
Intercept			-44.8932	12.08974	-3.7133	0.00029
Soil type	0.19518	0.086312	0.1566	0.06923	2.26135	0.02518
Distance	-0.1513	0.082732	-0.0765	0.04183	-1.8288	0.06941
Ecozone	0.2009	0.084669	0.2952	0.12439	2.37275	0.01892

Table 5.5 Mean of species richness *(S)* and diversity (Shannon Wienner index *H*) by soil types. Means followed by the same letters in brackets indicate lack of significant differences whereas those followed by different letters indicate significant differences

Parameter	Colluvial	Pediment	Outcrop	Sandy
Richness	8 (a,b), SD 2	6.81 (b) SD 1	3.88 (a) SD 0	2.8 (a) SD 0.3
Diversity	1.32 (a,b), SD 0.5	1.19 (b) SD 0.1	0.76(a,b) SD 0.1	0.5 (a) SD 0.07

Human activities affecting Species richness and diversity

Table 5.6 presents the range of species richness and diversity with distance from the village to the woodland. There were highly significant differences in number of species with distance from the village to the woodland (ANOVA: F =6.9549, p < 0.001, df. = 148). The lowest species richness was found furthest away at distance of more than 15.1 km (2.65, SD 0.39 woody species) due to probably the presence of woodland dominated by *C. mopane* species (Figure 5.3). The highest was found at intermediate distance, from 5.1 to 10 km (4.8, SD 0.34 woody species per plot).

There were also similar significant differences (ANOVA: F =6.5, p < 0.001, df. = 145) in index of Shannon Wiener diversity with distance from the village (Figure 5.3). The lowest was found after 15.1 km (0.51, SD 0.04) in the Mopane woodland due to the influence of *C. mopane* dominance in Mopane woodland, while the highest were *H*=0.9, SD 0.1 and *H*=0.89 SD 0.07 from 0 - 5 km and 5.1 – 10 km respectively from the villages.

Table 5.6 Means of richness *(S)* and diversity *(H')* with distance from the village. Means followed by the same letters in brackets indicate lack of significant differences whereas those followed by different letters indicate significant differences

Parameter	0 - 5	5.1 - 10	10.1 - 15	15.1 km and above
Richness	4.3 (a,b) ± 0.4	4.8 (b) ± 0.3	3 (a) ± 0.5	2.7 (a) ± 0.4
Diversity	0.9 (b,c) ± 0.1	0.89 (b) ± 0.1	0.53 (a,c) ± 0.1	0.5(a) ± 0.1

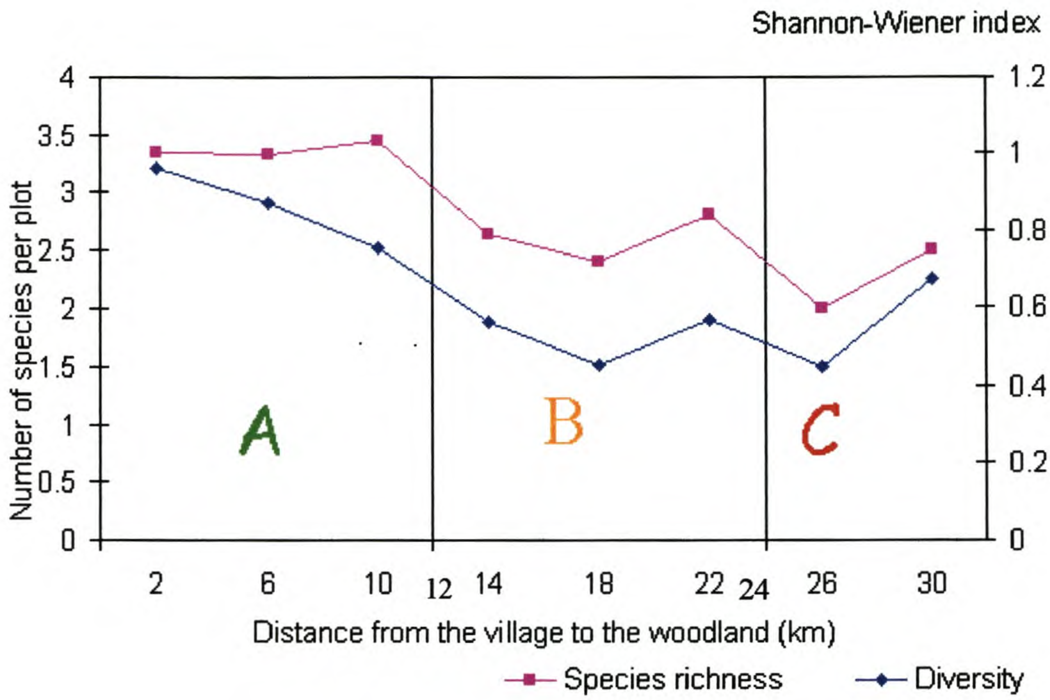


Figure 5.3 Patterns of general mean species richness and mean species diversity with distance from villages to the woodland in the Mahel area. Three scenarios are presented suggesting effects of human impact on species richness and diversity in the Mahel area. "A" (0 to 12 km) section represents near the village strong influenced by local users according to the local community, "B" (12 to 24) is an intermediate level more dominated by *C. mopane* inside the woodland where both local users and people from outside the study area have less impact on the woodland and "C" far from the villages along Uanetsi river but near to the access road there is high commercial extraction of wood resources.

5.1.1.3 Stem density

a. Stem Densities and Vegetation Types

The results of the overall mean stem density to assess resource abundance of *C. mopane* were significantly different between vegetation types (ANOVA: $F = 39.5734$, $p < 0.001$, df. = 152). The highest density was 937 in Mopane woodland, ranging from 981 and 1093 stems per plot (Table

5.7). Also, there was a highly significant difference in stem density for *C. mopane* alone (ANOVA: F= 47.027, p <0.001, df. = 152) which was far greater in Mopane woodland (Table 5.7).

Table 5.7 Total mean densities of stems per hectare for all species and for *Colophospermum mopane* in Mopane woodland and Acacia woodland

Vegetation type	Overall species	*C. mopane*	N
Mopane woodland	937, SD 44	676, SD128	128
Acacia woodland	271, SD 97	5, SD 26	96

b. Factors affecting stem density

Factors affecting the overall density of woody species including *C. mopane*

Similarly, to species diversity, various factors may determine stem densities in the Mahel area. The results from the regression analysis for overall densities as dependent variable of all woody species (R^2= 0.22, p < 0.001, n = 154) indicated soil types and vegetation types as the stronger variables (t = 2.05, p < 0.04 for soil types and t =6.2, p = 0.001 for vegetation types). In general, factors such as, soils and vegetation types affect significantly stem densities in the Mahel area (b = 0.17 for soil type; b = 0.51 for Ecozone type) (Table 5.8). Distances from the village to the woodland were not found significantly effect on woody stem densities (t = 0.72, p = 0.46).

Table 5.8 Summary of multiple regression analysis for stem density per plot of woody vegetation in the Mahel area influenced by soil characteristics, distance from the village and vegetation types

Parameter	Beta (b)	Standard error of Beta	B	Standard Error of B	t(150)	p-level
Intercept			62429.4600	11715.6300	5.3287	0.0000
Soil type	0.1721	0.0838	137.7400	67.0900	2.0530	0.0418
Distance	0.0585	0.0804	29.5100	40.5300	0.7280	0.4677
Ecozone	-0.5105	0.0822	-748.2300	120.5400	-6.2072	0.0000

Factors affecting stem density of *C. mopane* species

The results of the regression analysis for only *C. mopane* densities (R^2= 0.23, p < 0.001, n = 154) as dependent variable indicated distance and vegetation ~~types as the stronger variables~~ (t = 1.36, p < 0.17 for distance from the village and t = 5.78, p = 0.001 for vegetation types). These factors, distance and vegetation types, affect significantly stem densities of *C. mopane* species in the Mahel area (b = 0.11 for soil type; b = 0.47 for Ecozone) (Table 5.9). Soil types do not affect significantly (t = 0.62, p = 0.001) stem densities of *C. mopane* in the Mahel area owing to the mono-specific dominance of this species in hard environmental conditions.

Table 5.9 Summary of multiple regression analysis for density per plot of *Colophospermum mopane* only in the Mahel area influenced by soil characteristics, distance from the village and vegetation types

Parameter	Beta (b)	Standard error Beta	B	Standard error of B	t(150)	p-level
Intercept			62135.6200	10907.7700	5.6965	0.0000
Soil types	0.0518	0.0829	39.0700	62.4700	0.6254	0.5326
Distance	0.10807	0.0795	51.3300	37.7400	1.3602	0.1758
Ecozone	-0.47032	0.0813	-649.18000	112.2300	-5.7843	0.0000

The effect of soil types on stem density

In this study the overall stem density on the different soil types was not significantly different (ANOVA: F = 1.0, p=0.05, df. = 149). However, for *C. mopane* alone there was a significant difference between soil groups (ANOVA: F=2.6, p<0.0356, df = 149). The highest stem density was found in rocky outcrop soils for all species (901, SD 63 stems ha^{-1}) (Figure 5.4 a&b).

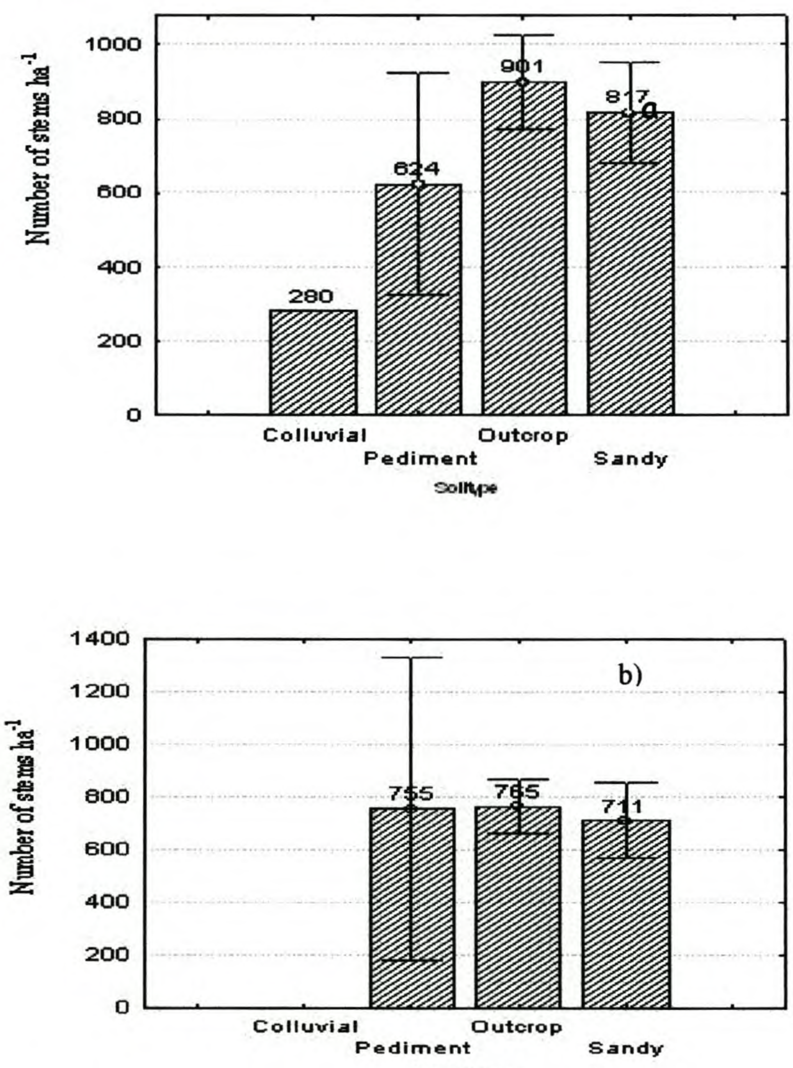


Figure 5.4 a&b Total mean densities of a) all species and b) of *C. mopane* of the five soil types identified in the Mahel area. The vertical bars indicate 95% confidence intervals

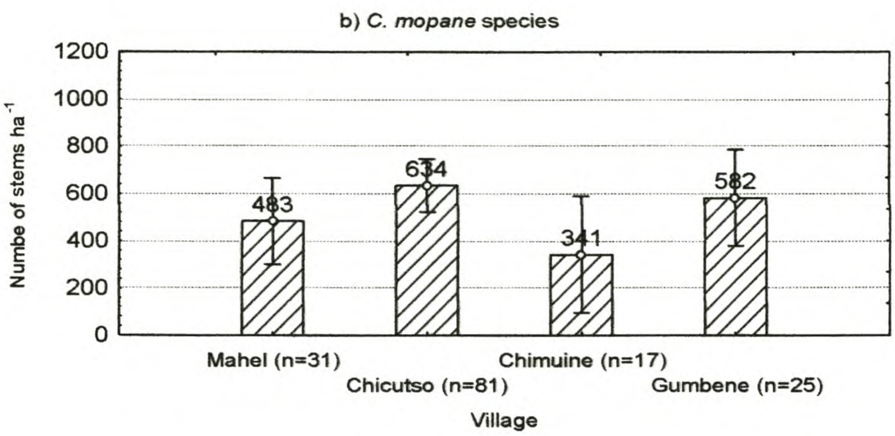
Availability of resources between villages

There were no significant differences between villages in terms of woody resources in the study area, measured as stem densities per hectare, either for overall tree density or for only *C. mopane* alone (ANOVA: $F=0.2658$, $p>0.84996$, df.=150) and (ANOVA: $F=1.8290$, $p>0.14431$, df.=150), respectively. The pattern of stem densities for the woodland surrounding each village is presented in Figure 5.5 a & b, (a) all species and (b) for *C. mopane* alone. However, the stocking density in the woodland is highly variable, the highest being found near Chicutso village both for all species (856, SD 62 stems per ha^{-1}) and for *C. mopane* alone (634, SD 57 stems ha^{-1}), followed closely by Gumbene village for all species and *C. mopane* alone (Figure 5.5 a &b). The woodland surrounding Mahel and Chimuine villages is mostly open Acacia woodland resulting in higher variations in stem densities, for example Chimuine village area 768, SD 134 stems ha^{-1} in overall species and 341, SD 24 stems ha^{-1} for *C. mopane* alone (see Figure 5.1; Figure 5.5 a&b).

Stem density and distance from the village

The stem densities of woody species increase with distance from the villages to the woodland (Figure 5.6 a). There was a highly significant difference in the overall mean tree densities with distance from the villages to the woodland (ANOVA: $F=5.23$, $p<0.01$, df =150). The lowest density was found in between 0 and 5 km (501, SD 93 stems per hectare). The highest was found from 5.1 to 10 km (950, SD 71 number of stems ha^{-1}) and followed by a distance of more than 15.1 km (878, SD 83 stems ha^{-1}).

Similarly, for *C. mopane* alone there was also an increasing stem density from the village to the woodland. There was a significant difference in the number of stems of *C. mopane* per hectare with distance from the village (ANOVA: $F=5.23$, $p<0.01$, df=150). The highest stem density was (712, SD 95 stems ha^{-1}) found between 10.1 and 15 km and the lowest (253, SD 87 stems ha $^{-1}$) was also near the village (Figure 5.6 b).



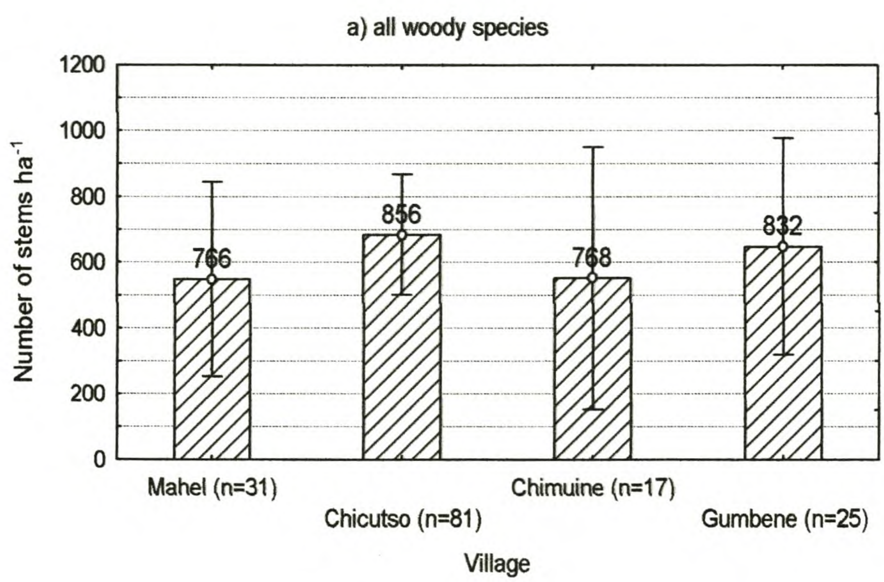


Figure 5.5 a&b Mean densities of a) all species a b) *C. mopane* on its own by village. The bar indicate 95 % of confidence intervals

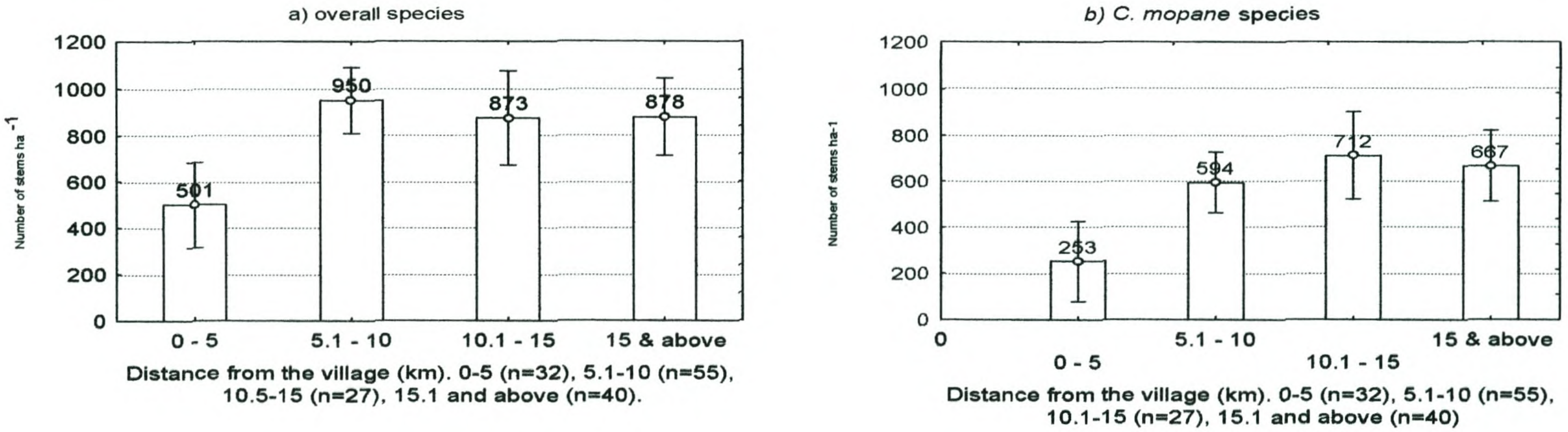


Figure 5.6a & b Total mean stem densities in relation to distance (km) from the villages, a) or all species and b) for only *C. mopane* species. The vertical bars indicate 95% of confidence intervals

5.1.2 Discussion

5.1.2.1 Species composition and species richness

a. Woody species composition

The patterns of vegetation and soils (Figure 5.1 and Figure 5.2) suggest strong relationship between soils and vegetation of the Mahel area. The unfavourable soils for plant growing prevailing in the area may have resulted in formation of the two distinct vegetation types, Mopane and Acacia woodlands dominated by *C. mopane*. The dominance of *C. mopane* varies from one place to another according to the ecological conditions, such as soil characteristics, climate, moisture availability (Mapaure, 1994) and impact of human activities.

Mussanhane (2000) indicated over 89 % dominance of *C. mopane* in 32,785 ha in the Mahel area. In similar Mopane vegetation types of the Limpopo Province of South Africa O'Connor (1992) found that *C. mopane* had a percentage cover of 55% on colluvial soils and 40% on calcrete soils, while *Acacia nigrescens* reached only 13% and 18% respectively on the same soil types. Many factors influence the composition of vegetation, including the water and nutrient supply (Cole, 1982), microclimate, competition (Rieley & Page, 1989) and utilization (Walker, 1979; Vetaas, 1992; Cunningham & Davis, 1997).

The results of this study indicate that distinct soil types determine variation in woody species composition throughout the Mahel area. In the study area, as in other savanna ecosystems, higher clay soils, relatively impenetrable B-horizon, sodic and shallow A-horizon soil characteristics may favour dominance of *C. mopane, a*s do increased pH and soil nutrients, such, P, K and Ca. Increased soil depth does not favour dominant of *C. mopane* species owing to competition with other tree species *C. mopane* (Smit *et al.*, 1996).

Mopane woodland adjacent to Acacia woodland in similar environments is also found elsewhere in the region, for example, in the Northern Province of South Africa (O'Connor, 1999) and in the North and West of Zimbabwe (Timberlake *et al.*, 1993) where Acacias are found in patches of deeper soils and *C. mopane* is excluded (Timberlake, 1995; Smit *et al*, 1996; O'Connor, 1999) due to its shallow root system (O'Connor & Campbell, 1986). Colluvial soils are more favoured by woody species rather than sandy soils because they are deep and found mostly near streams, making more water resources available for plant growth (Smit & Rethman, 2000). The dominance of poorly drained, sodic and heavy-textured clay rich soils towards the north-eastern section of the Mahel area favours dominance of *C. mopane* species, due to the prevalence of shallow soils (O'Connor & Campbell, 1986). Most plants growing in sodic soils have limited root growth due to the impermeable B-horizon in the soils (Dye & Walker, 1980). Only a few tree species, such as *Colophospermum mopane*, *Acacia gerrardii* and *Acacia mellifera* are able to survive such conditions.

Therefore, the distinct separation between *C. mopane* stands and *Acacia* species stands in a sodic environment is governed mostly by differences in permeability of soils (Dye & Walker, 1980). The mixed Acacia woodland in the south-western areas, however, is mostly found on coarse, red, sandy soils characterised by good drainage, which allows the development of many trees including species of *Acacia* and *Combretum* (O'Connor & Campbell, 1986). *Acacia tortilis* occurs in deciduous woodland, wooded grassland and dry scrub (Wards & Rohner, 1997) in a range of soil types from alluvial to alkaline soils (Duke, 1983).

At a wider scale, climate is the major factor determining species composition and structure of the major vegetation types of Southern Africa (Huntley, 1982; Temu, 1993). At regional or local levels the variation in topography and soil characteristics from one site to another, combined with the degree of disturbance, determine the patterns of composition and structure of woody vegetation (O'Connor, 1992; Scholes, 1997). In dry savanna ecosystems uneven distribution of water and nutrients is the most important factors influencing species composition, community diversity and vegetation structure (Werger, 1986; Scholes, 1997; Dahlberg, 2000; MacGregor & O'Connor, 2002). In hot and dry low-lying areas of Mopane woodland throughout Southern Africa, there is a tendency to single-species dominance of *Colophospermum mopane* due to inability of other species to survive in extreme environmental conditions (Dye & Walker, 1980;Vitousek & Hooper, 1993).

b. Species richness and diversity

In Acacia woodland the species diversity was twice as high as than in Mopane woodland, due to mono-specific dominance of *C. mopane* species in the latter. The species richness and diversity were generally low due to mono-specific dominance of *C. mopane* (O'Connor, 1992). The species richness is higher in the Mahel area compared to some areas in the region, however such as in Mua-Tsanya Forest Reserve in Malawi, where only 50 woody species were found in Mopane woodland (Chikuni, 1996).

The pattern of species richness of woody vegetation at regional level is influenced by primary environmental factors, such as site, habitat heterogeneity, rainfall and productivity

(Kruger & Midgley, 2000). In the Mahel area species turnover may have significant role in species richness and diversity in the woodland like other areas in the tropical ecosystems (Philips *et al.*, 1994). Species diversity will decrease with increasing species richness (Godoy & Bawa, 1993). However, the high presence of sprouters of *C. mopane* may reduce species turnover in Mopane woodland in the Mahel area according to Phillips *et al.* (1994).

c. The influence of soils on species richness

Higher diversity in Acacia woodland than in Mopane woodland in the study area may be for various reasons. First the prevailing unfavorable environmental conditions, such as hard clay soils and a water deficit influence formation of mono-dominance of *C. mopane* species in the Mopane woodland (Vitousek & Hooper, 1993) and hence low richness and diversity in Mopane woodland (O'Connor, 1992) as was revealed in this study. In southern African savannas diversity depends primarily on geomorphologic variation of the landscape (Scholes, 1997), which it might be low or high associated with the degree of disturbances.

In Botswana, for instance species richness was strongly correlated with soil types (Dahlberg, 2000). There were more species on red soils while *C. mopane* was markedly associated with white and shallow soils. On the other hand variation of soil characteristics such as water, pH, nutrients and physical properties between soil types determine habitat differences, which in turn influence species diversity (Rieley & Page, 1989; Chaneton & Facelli, 1991). Low species richness and a high cover of *C. mopane* (predominantly shrubs) is associated with colluvial soils. High species richness and moderately tall Mopane associated with sandstone (O'Connor, 1992).

d. The impact of human activities on species richness

Other factors influencing species richness are associated with human activities mostly due to woodland use (e.g. fuel wood collection and construction material), agricultural activities and human settlements. Near the villages suppression of vegetation is reported to promote a dominance of a reduced number of species. Highest species richness and diversity is usually maintained at intermediate level due to disturbance from human activities (Begon *et al.*, 1996). This general pattern is likely to be confounded with the high dominance of *C. mopane* for instance in the Mahel area. Because of that probably no significant effect of disturbance was detected influencing richness and diversity in the Mahel area. There was no detectable increase in species richness with distance from human settlements as found for example by Grundy *et al.* (1993); Shackleton *et al.* (1994) and Mbwambo (2000).

5.1.2.2 Stem Density

Mopane woodland in the Mahel area provides a wide array of products that local people depend on to support their livelihood (Mussanhane, 2000; Macome & Soares, 2000). Management of these resources requires knowledge of targeted species abundance and distribution and their relationship with ecological and human factors.

High variation (937 SD 44 stem ha^{-1}) of stem densities in Mopane woodland may reveal differences in soil conditions and human impacts across the Mahel area. Mussanhane (2000) reported stem density of 169 stems ha^{-1} in the area. Differences in methods used and total area covered between the present study and that of Mussanhane (2000) may be on account for the differences in the results. Usually, the overall density in Mopane woodland ranges from about

200 to 400 stems ha^{-1}, while in Mopane shrub land the stem densities are higher (Timberlake, 1995; Smit *at al.*, 1996).

a. Factors affecting stem densities in the Mahel area

In this study soil characteristics appear to be the overriding factors that determine stem densities in the Mahel area. High stem density found in outcrop rocky soil is likely to be associated with little influence of human activities, such as agriculture (see Figure 5.4 a & b). In the study area towards the north-eastern side dominance of hard clay soils support high density of Mopane woodland, e.g. 918 stems ha^{-1} in Chicutso village. On the south-western side low stem density was found, such as in the Chimuine area where the density was 317 stems $ha\text{-}^{1}$ due to probably settlements, agriculture and grazing in the past. Low density and single stemmed *C. mopane* trees are found frequently on non-calcareous and sandy soils, while dense multi-stemmed shrubs occur on colluvial and hard clay soils (Fraser *et al.*, 1987; O'Connor, 1992; Ben-Shahar & Macdonald, 2002).

High adaptability of *C. mopane* to adverse soil conditions seems to explain the low variation of stem densities across soils mainly in areas dominated by *C. mopane*. The limited number of sample plots in some areas, which randomly fell into colluvial soils for instance, may have masked the expected pattern of variation in stem densities across soil types for all species.

Another growth factor is the stronger coppicing ability of *C. mopane* that may result in suppression of most other species not adapted to extreme environmental conditions (McGregor & O'Connor, 2002). However, soil groups with high organic matter content such as sediment and sandy plain soils, appeared to have higher numbers of stems per hectare.

The physiognomic structure of savannas results from various factors, including low and seasonal moisture availability and low soil fertility (Bourlière & Hadley, 1983; Smith & Goodman, 1986) with influence on stem densities from one site to another. An increasing availability of resources, including nutrients and water, increases spacing between woody plants, size of stems and changes the vegetation structure from closed to open woodland as result of competition (Smith & Goodman, 1986). Biomass of woody vegetation, like species diversity, in savannas is influenced by availability of soil moisture, which in turn depends on quality of soil. Soils affect the productivity and abundance of Mopane woodland (Dye & Walker, 1980; Timberlake, 1995; Dahlberg, 2000). Woody species density in savannas with increasing rainfall is confounded by factors, such as topographic variation, fire, herbivores, soils gradients and anthropogenic disturbances (Bourlière & Hadley, 1983; Smith & Goodman, 1986).

At a small scale, depending on vegetation cover, soil conditions and micro-topography, there is likely to be a localised variation of water and nutrient availability in soils (Rieley & Page, 1989; McCormick, 1995; Mapaure & McCartey, 2001). This may drive the formation of different woody vegetation structure due to differences mainly in microclimate conditions, giving rise to the aggregated Mopane vegetation of the Mahel area (Plate 5 -1).

Stands of tall aggregated *C. mopane* associated with *Acacia davyi* are found on the edges of natural pans over the whole area, suggesting that seasonal water availability has a strong influence on the pattern and structure of the vegetation (Mapaure & McCartey, 2001). The vegetation interspersed between the pans is shorter except along the streams, with stunted *C. mopane* probably influenced in part by sodic soils and water deficit.

Plate 5.1 The common pattern of vegetation in the Mahel area. Aggregated tall *C. mopane* are found around pans, with stunted trees in between. This is a common characteristic towards the North-East of the study area

b. Human impact on stem densities

Apart from harsh ecological conditions of the area, such as soil and climate, disturbances such as harvesting, grazing, agriculture and fires influence on stem density of woody species in the study area(DNFFB, 1990; Mangue, 2000). In the Mahel area local people and outsiders collect products in the woodland for fuel wood, wild fruits, construction material that have impact to the woodland. Charcoal making and collection of construction material activities are likely to have ecological impact in the woodland due to their commercial nature in the region. If the local villagers were the only source of disturbance to Mopane woodlands it would be expected that the availability of resources would increase with increasing distance from the settlements, resulting from a decreased harvesting intensity and clear cutting for agriculture by local users (Grundy *et al,* 1993; Vermeulen, 1996; Luoga e*t al.*, 2002).

In general, high stem density denotes disturbance (Tietema, 1995) and harsh environmental conditions (Timberlake, 1995). Dahlberg (2000) working in a relatively low densely populated area in north-eastern Botswana did not find evidence of people and livestock affecting the vegetation. In contrast, Luoga *et al.* (2002) working in a relatively densely populated area of Tanzania; found that human use caused depletion of the standing crop. Harvesting can reduce the stem size and increase the stem density (Cunningham, 2001) as illustrated in Figure 5.7, as well as reduces species diversity (Obiri *et al.*, 2002).

The ability of *C. mopane* to coppice might be the factor that causes significantly higher stem densities in the Mopane woodland compared to Acacia woodland (Smit *et al.*, 1996). In the study area prevailing hard clay, soils associated with the ability of *C. mopane* to coppice may be the major factors contributing to low stem size and increased stem density found in the north-eastern side. However, the underlying factors associated with coppicing in *C. mopane* are not known (Timberlake, 1995; Timberlake, 1999; Rathoga *at al.*, 2000). A better understanding of coppicing will enhance the current management of Mopane woodland and promote sustainable utilisation of this species. Stem density of *C. mopane* alone, as well overall density for all woody species in the study area, may be categorised as moderately used, falling between tree and shrub Mopane vegetation as compared with other findings in the region (Table 5.10).

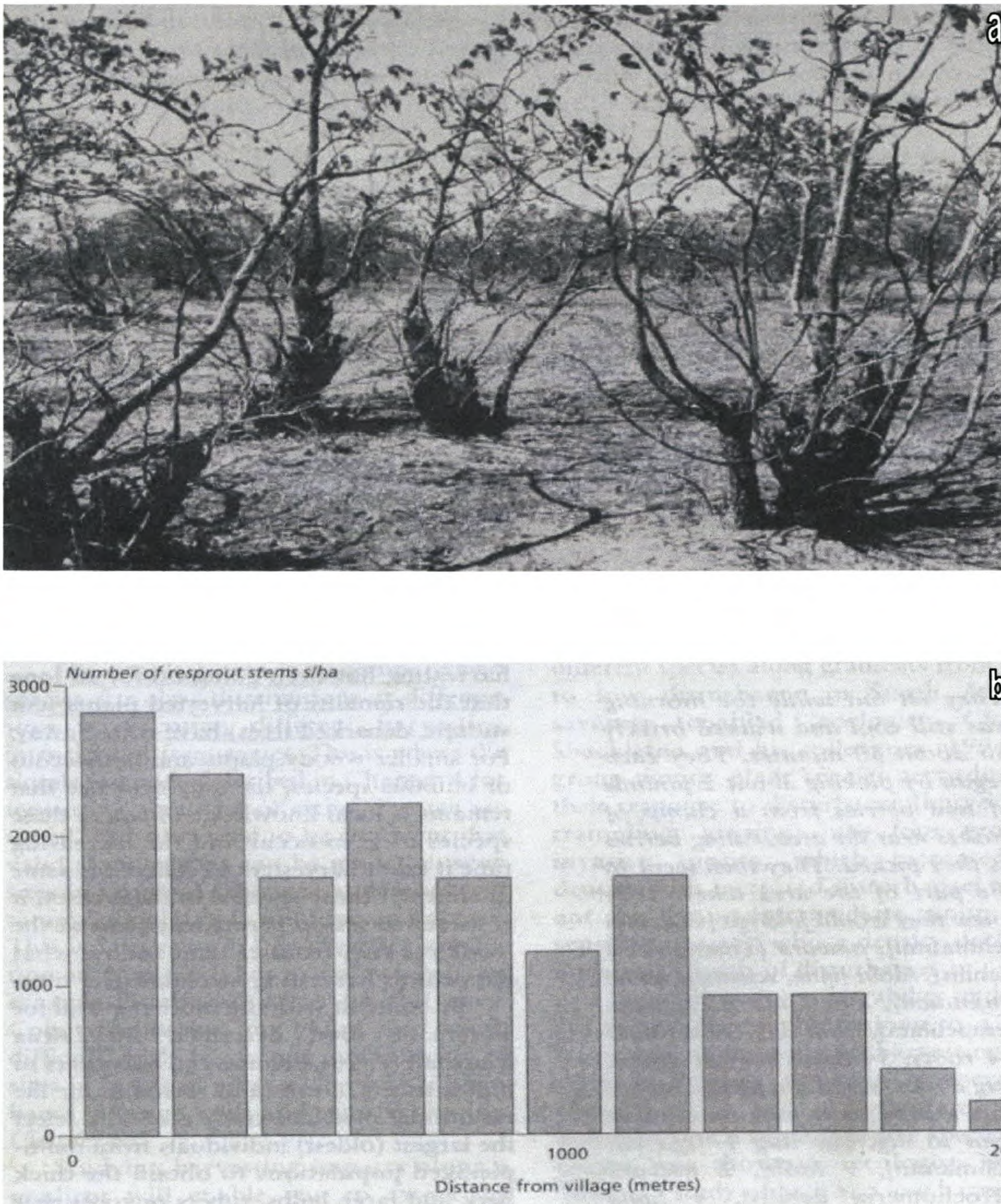


Figure 5.7 Cunningham (2001) illustrating (a) Mopane (Colophospermum mopane) tree outside a village in Botwsana stems resprouting from the stumps of tree felled for building poles and fuel wood, (b) Change in density of mopane coppice (resprout) stems in relation to distance from Morwa village south-eastern of Botswana

Human activities affect species composition and availability of resources in the woodland close to the village (Vermeulen, 1996), but the effect of disturbance depends on various factors, such as rate of regeneration strategy of *C. mopane* and type and frequency of disturbances. Clearing for agriculture and commercial harvesting are likely to have the greatest effect on woody vegetation structure and species composition (Obiri *et al.*, 2000; Luoga, 2002). However, low human population densities in an area are unlikely to have a strong impact on woodland degradation (see Dahlberg, 2000).

Stem densities vary slightly from one village to another. For instance, in the Chicutso and Gumbene areas, there are relatively more woody resources than in others (Figure 5.5 a & b). Low human population associated with clay soils, which support Mopane woodland may explain the high stem density per ha^{-1} of woody resources in Gumbene village area. In Chicutso village, the resource availability does seem not to be in line with the human population density. This village is relatively densely populated as compared to others in the study area and most affected by commercial extraction of woody resources owing to easy access to the markets. Harvesting does not seem to have had a negative impact on the standing stock, however. Predominance of clay soils and coppicing seem to be potential factors for the higher stem density in this section of the study area.

Table 5.10 Summary of mean densities of Mopane vegetation in the region (Timberlake, 1995; Cunningham, 1996)

Stems Ha^{-1}	Status	Areas	Author
	Woodland		
343	Disturbed	N. Botswana/Dukwe	Tietema, 1989
421	Minimal damage	N. Zambia/Luangua	Lewis, 1991
563	Trees	Zimbabwe/Sengwa	Guy,1981a
935	Unharvested	N.Botswana/Dukwe	Tietema, 1989
1 717	Medium utilisation	S.E. Zimbabwe	Kelly & Walker, 1976
3 635	Shrubs	N. Zimbabwe/Segwa	Guy, 1981a
11 700	Unharvested	N. Botswana/Dukwe	Tietema, 1989
	Only *C. mopane*		
119	Shrubs/elephant damage	N. Zambia/Luangwa	Lewis, 1991
214	Trees	N. Zimbabwe/Sengwa	Anderson & Walker, 1974
690	Trees	N. Zimabwe/ Kariba	Frost, 1987
2 940	Shrub	N. Zimbabwe/Kariba	Frost, 1987
8 200	Coppice	C. Botswana/Boteti	Coe, 1991
13 500	Regeneration	South Africa	Scholes 1990

High stem density may also be a response to high selective harvesting for certain large size stems and the predominance of harsh soils in the middle of the woodland, thus increasing stem densities. Commercial extraction of wood products seems to be responsible for stem density decreasing at distance of settlements 15 km from villages due to the proximity to the main access road and Chokwe market (Figure 5.1; Figure 5.8).

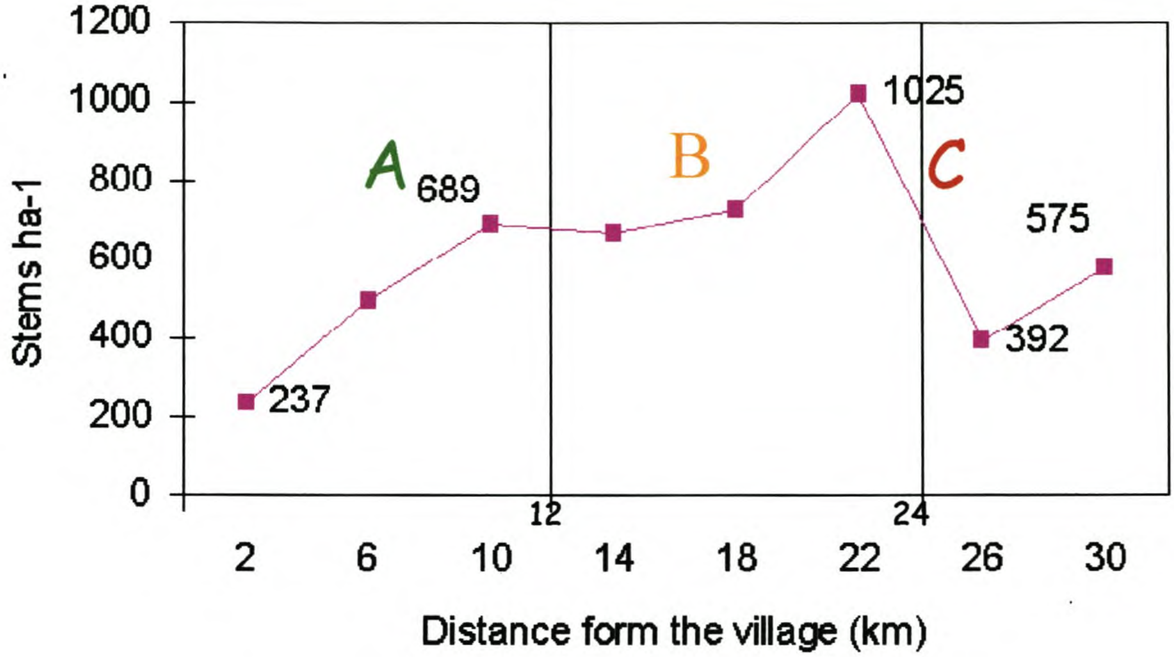


Figure 5.8 An empirical pattern of mean stem number ha^{-1} and distance from the villages to the woodland showing the three scenarios resulting from different users of the woodland as suggested from this study according to the villagers. "A" (0 to 12 km) section represents area of strong influence from local users "B" (12 to 24 km) is an intermediate level inside the woodland where both local users and people from outside the area have less impact on the woodland and "C" far from the villages but near to the access road there is high commercial extraction of wood resources mostly charcoal and construction material

Human disturbances in woodlands differ in type, intensity and frequency from one place to another (Shackleton *et al.*, 2000). Therefore, the pattern of stem densities increasing away from the villages, and then decreasing near access roads cannot be generalised for all villages. The assumption is that the pattern of stem density should be higher in those villages more involved in commercial extraction of woody resources, which will result in stem coppicing. This can be seen in Chicutso and Gumbene villages due to the proximity to the market as compared to the Greater Mahel and Chimuine. Similar patterns were found elsewhere in the region (e.g. Shackleton *et al.*, 2000).

Chicutso and Gumbene villages are both located in woodland dominated by *C. mopane* (see Figure 5.1), resulting in higher stem densities in these areas despite greater woody resource extraction due to proximity to the market and easy road access. Dominance of sodic soils and people from outside encroaching the Mopane woodland on the north-eastern side through the Limpopo corridors in Chokwe district (see Figure 5.1; Figure 5.2; Figure 5.8) are potential reasons for the decreasing pattern stem density far from the village. On the north-eastern side of the study area, illegal activities for commercial extraction of woody resources are reported by local inhabitants to be higher because of lack of control.

The major wood harvesting activities in the Mahel area (charcoal making, harvesting of firewood and construction materials for household use) may have lesser impacts on the woodland because of their subsistence character. But, commercial extraction may have more impact on the degradation of resources along with clear felling for agriculture and human settlements because of economic incentives that drive higher exploitation associated with destructive methods of harvesting (Godoy & Bawa, 1993) as was evidenced in the study area.

Commercial harvesting may override vegetation patterns due to other disturbances because of the wide range of species and size classes harvested (Luoga *et al.*, 2002). Commercialisation of resources depends on access to the market, and a relationship between availability of resources in the woodland and distance to the market would be expected. Distance to market and distance from the village to the woodland were used also as variables to assess the impact of harvesting in the study area.

The weak relationship between stem density and distances to markets also may suggest a relatively low level of commercial extraction of woody products in the study area, with human impact on vegetation being more associated with subsistence use of the woodland, for firewood construction materials, veld foods, agriculture and grazing. Different results were found in the southern African region as a whole concerning human impacts on woodlands in communal lands. These depend on intensity of commercial use of the woody resources, accessibility to the woodland, management policy and land use history. For instance, in a low population density in Botswana Dahlberg (2000) found that although people and livestock have had strong impact on the vegetation, most indicators of degradation were absent, thus the potential productivity was still maintained. In other studies done in more highly populated areas, a strong effect of community activities on the degradation of woodlands was found (e.g. Grundy, 1995; Vermeulen, 1996; Luoga *et al.*, 2002).

The Acacia woodland appears to have been more affected by human activities as this site is more preferred for human settlements and agriculture because of its suitable soil quality and water availability along water courses. Overgrazing is also a factor that determines the pattern and structure of vegetation, as found for example in *Acacia tortilis* thickets in some areas of southern Africa (NFT, 1991). Many factors in the study area may have influenced the status of *Acacia tortilis* in the study area, such as browsing, competition between woody species for water, nutrients at establishment or regeneration and adaptation to fire. However, the history of browsing and ecological adaptation of different *Acacia* sp and other associated species in the area seems to be a more plausible explanation for the different pattern and distribution of woody species in the Acacia woodland in the Mahel area. Nevertheless, further research is needed in order to understand the causes of dominance of *Acacia tortilis* in the Mahel area that may provide a framework in which management of herbivores and fire can be explored.

Stem densities of *C. mopane* vary according to whether the area is a mature woodland or coppice shrubland (Timberlake, 1995) depending on climatic conditions, soil types, fires, browsing, harvesting impact and age (Begon *et al.*, 1996). High variation of size and density is likely to be found in Mopane vegetation across different soil types and micro-environmental conditions (Dahlberg, 2000; Ben-Shahar & Macdonald, 2002). Fire has influence on the stem densities that may increase or decrease according to the intensity and frequency of the fires (Smit *et al.*, 1996).

c. Effect of fire to the woodland

In the study area like other areas in southern Mozambique extensive use of woodland products, agriculture and grazing associated with frequent fires (Plate 1-1) is reported to be the main cause of the transformed wood vegetation structure and species composition (DNFFB, 1990; Mangue, 2000). Fire, although an ecological factor in savanna ecosystems, has become a human induced factor (Eckhardt & Biggs, 2000), which also affects the structure of the woodland in the Mahel area, mostly due to agricultural practices and hunting activities common in the area.

In southern Africa fires are thought to be the second most important cause of disturbance after agriculture, which affects species composition and structure of vegetation (White, 1983, Eckhardt & Biggs, 2000; Mangue, 2000; Trollope, 2000). Fire may increase or reduce woody species diversity and stem density, depending on the level of fire tolerance, frequency and intensity of fire (Lugo, 1997; van Wilgen *et al.*, 2000). Although savanna species are adapted to tolerate different fire intensities and frequencies, their negative impact affects sexual reproduction, vegetative reproduction, seedling establishment, stems, growth and mortality (Hoffmann, 1999). This is likely to be true in the study area since fire is a common phenomenon in Mahel.

It is reported elsewhere in southern Africa, see Smit & Rethman (1998a) for example, that the effect of cattle and game farming and elimination of mega herbivores associated with fires are the underlying causes of increasing tree densities in some areas of the region as a result of suppression of herbaceous plants. Dominance of grass species may also inhibit establishment of woody species regeneration however, resulting in decreasing stem densities of *C. mopane*.

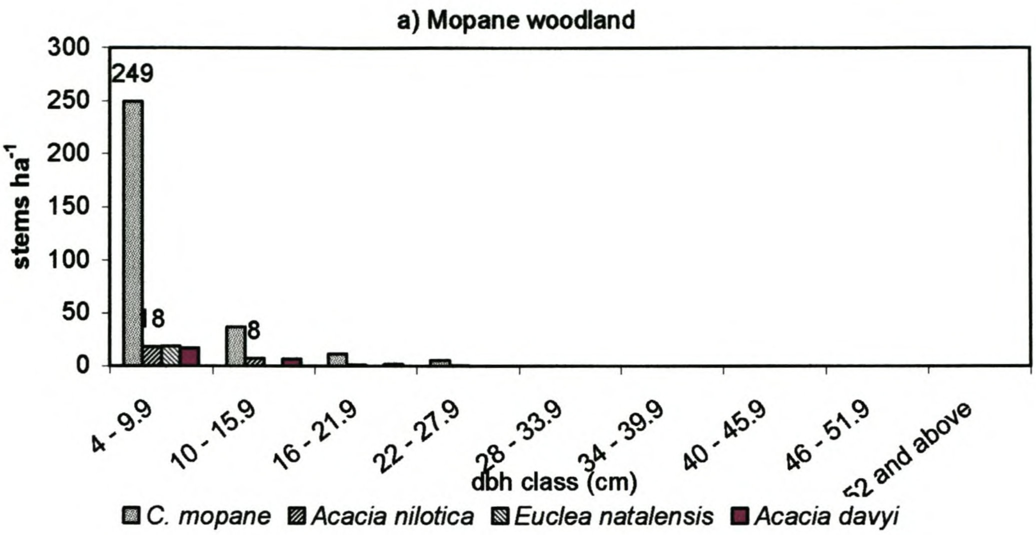
5.2 Dynamics and regeneration potential

5.2.1 Results

5.2.1.1 Population structure

Almost all woody species in the two vegetation types, Mopane woodland and Acacia woodland, indicated an inverse J-shaped pattern (Figure 5.9 a & b). In the Mopane woodland, four species were found concentrated in small size diameters, namely *Colophospermum mopane*, *Acacia nilotica, Euclea natalensis and Acacia davyi*. The most dominant species *C. mopane* in this Mopane woodland was found to be concentrated in the smallest size-class between 4 and 9.9 cm diameter interval with density of 249 stems ha^{-1} (Figure 5.9 a).

In Acacia woodland *Dichrostachys cinerea* was the most dominant woody species in smallest size diameters with 63 stems ha^{-1}, followed by *Acacia tortilis* and *Acacia nilotica* with 34 stems ha^{-1} (Figure 5.9 b). Fewest numbers of individuals were found in the larger size diameters for both vegetation types. In Acacia woodland *Acacia* species tend to be dominant although with low stem densities (Figure 5.9 a & b).



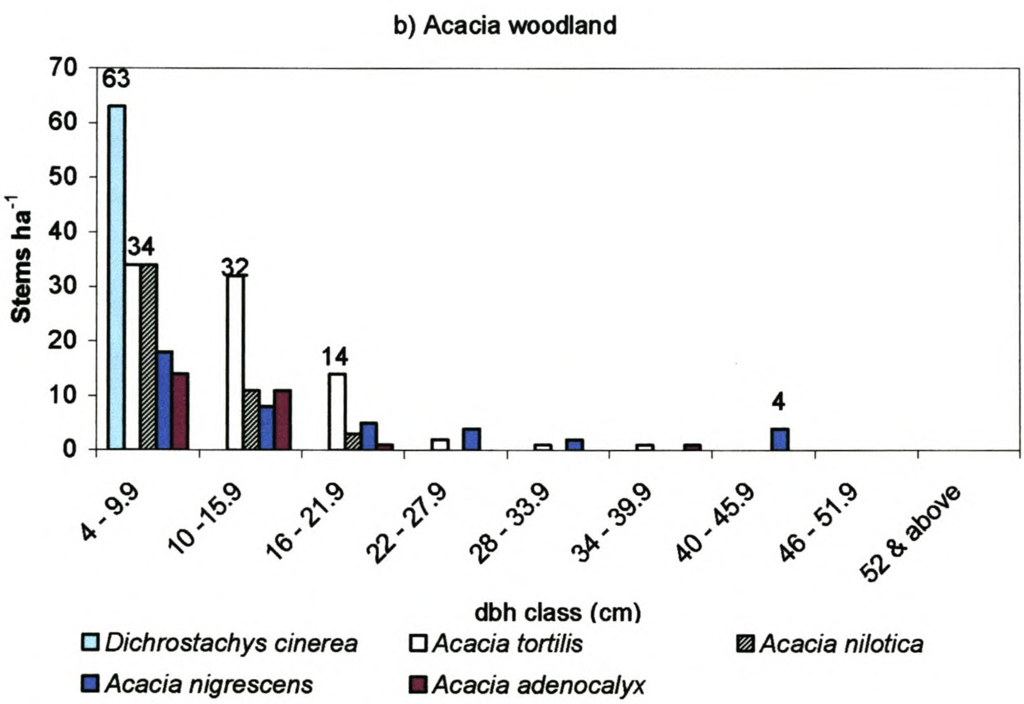
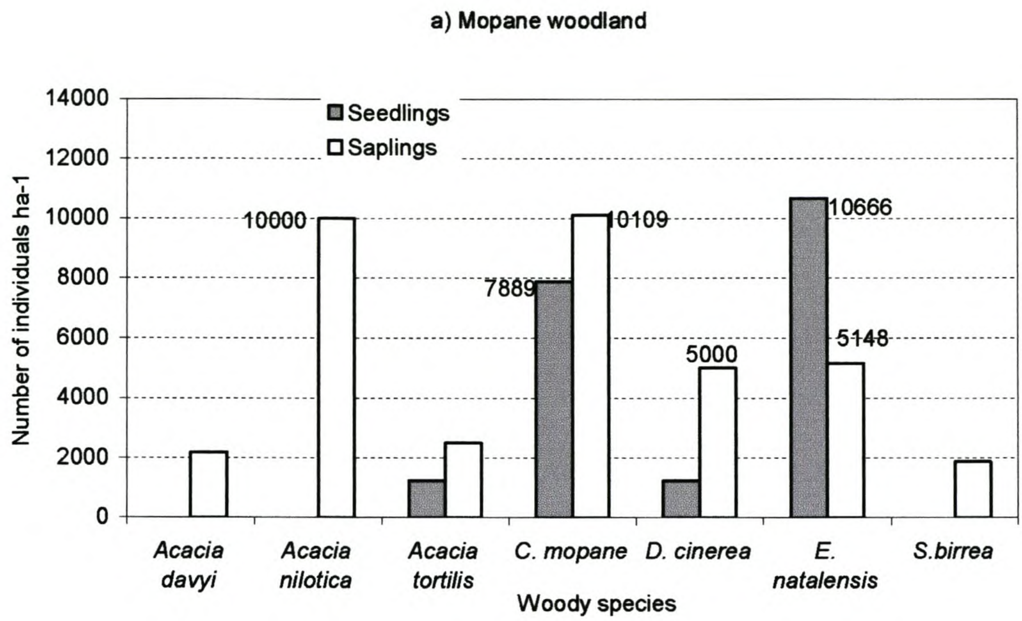


Figure 5.9 Population structure of the abundant and most used woody species in the Mahel area, a) Mopane woodland and b) Acacia woodland

5.2.1.2 Seedlings and saplings

In the Mahel area this study found there was high regeneration of the most used and abundant woody species (Figure 5.10 a & b), the *C. mopane*.

In Mopane woodland seedlings were dominated by *C. mopane* with 7 889 stems $ha^{-1}$and *Euclea natalensis* 10 666 stems ha^{-1}(Figure 5.10 a). Saplings or established regeneration was dominated by *C. mopane* and *A. nilotica* with 10 100 ha^{-1} and 10 000 ha^{-1}, respectively. In Acacia woodland the highest number of seedlings ha^{-1} was observed in *Combretum molle* and *D. cinerea* (Figure 5.10 b). These species also dominated the sapling population. The most sapling species were *Combretum molle* with 8 750 stems $ha^{-1}$and *D. cinerea* 6875 stems ha^{-1} in Acacia woodland (Figure 5.10 b). No seedlings of *Combretum molle* were found.



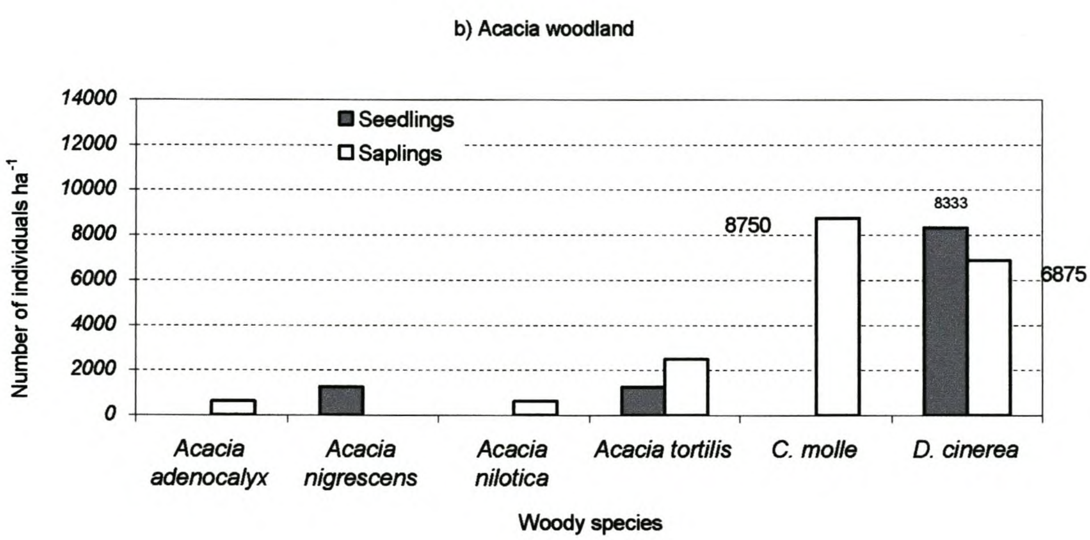


Figure 5.10 a & b Regeneration potential of woody species in a) Mopane woodland, b) Acacia woodland

5.2.2 Discussion

The assessment of dynamics intended to develop an understanding of the pattern of diameter distribution across species over the two vegetation types, Mopane woodland and Acacia woodland. This gives insight about the population structure of woody resources and the recruitment potential of each species (Hall & Bawa, 1993; Geldenhuys, 1996). The success of regeneration of plant development depends on various factors. Generally, harsh environmental conditions, such as low rainfall, extreme temperatures, limited soil nutrients and competition with other plant species from other plant species, browsing (Smith & Goodman, 1986; Motoma, 1998) and fires are major limitations to naturally regenerating of tree growth (Hoffmann, 1999).

5.2.2.1 Population structure

An inverse J-shaped size-distribution curve as Figure 5.9, indicates many more juveniles than adults suggesting a self-replaced population in the study area (Hall & Bawa, 1993; Seydack, 2000) despite the presence of stunted Mopane. Stunted Mopane frequent in the area may be confounded by seedling and sapling population of this species. Thus, *C. mopane* seems to have a stable and active population according to Nascimento & Protor (1997). Various factors allow *C. mopane* species to dominate the population of seedling and sapling in the woodland, among them sprouting strategy from disturbances, for example fires, browsing, resistance of seedlings to fires after germination (Jordaan & Wessels 1999).

Population structure is invaluable information for management plan purpose to predict which type of woody product is likely to be harvested in the woodland at sustainable base. For example, it is not expected the Mopane woodland in Mahel to sustain much charcoal production in the area in short term since *C. mopane* was rare in the larger size diameter. Charcoal making requires adult and larger diameters; therefore the Mopane woodland has potential only to supply poles and other construction materials.

Alternatively, a long-term management plan and conservation measures could be implemented in order to improve stem quality for charcoal making since this is seen as economically viable activity in the area. What it is not clear is whether the high concentration of stem density in smaller sizes is a result of harvesting history or it is a natural factor due to the environmental influences prevailing in the area. Therefore further investigations are necessary in order to understand the major determinant factors of woodland structure in the area.

Class-size is determined by interaction and balanced competition of individuals in a stand, depending on environmental conditions, disturbances, spacing between individual stems and biological characteristics of a particular woody species involved (Midgley, 2002). In Mopane woodland like other woodland types stem-sizes and survival are affected by stocking density and age (Timberlake, 1995). Soil types however seems to be the most natural determinant of dominance of smaller sizes of *C. mopane* apart from the land use history of the Mopane vegetation.

5.2.2.2 Seedlings and saplings

In the Mahel area for instance, fires and herbivores appear to be the determinant factors affecting pattern of regeneration in different ways. Low density of larger herbivores reduces seedling predation, whereas fire intensity and frequency may positively and negatively affect regeneration. Absence of larger herbivores, both wild and domestic that eat seedpods and enhance the germination capacity is considered as the main cause of low regeneration of *Acacia* species in dry environments (Ward & Rohner, 1997). In the Mahel area the reduction of large mammals, including domestic mammals, during the civil war was expected to influence the dynamics of the vegetation, including Mopane and Acacia woodland.

Smit & Rethman (1998b) Limpopo Province of South Africa found that establishment of seedlings was dependent not only on the potential germination but also on other functions, such as tree density, mineral nutrients in soils, fires and competition with other woody and herbaceous plants and tree density has the most important determinant on establishment of seedlings.

Fire is a determinant factor on dynamics of savanna woodlands in different way, including seedling establishment, individual sizes, sexual reproduction and vegetative reproduction (Hoffmann, 1999). Fire may suppress seedlings and reduce the density of seedlings. Meanwhile, suppression of herbaceous plants may reduce competition and stimulate sprouting of seedlings, increasing the density of young individuals (Smith & Goodman, 1986). These arguments are likely to explain the higher regeneration of *C. mopane* owing to the sprouting strategy of this species as compared to other species found in the Mopane woodland as well as in *Acacia* woodland. That is probably the reason for the higher density of seedlings of *C. mopane* in the area. Whereas for *Acacia* spp., low germination rates might be associated with edaphic factors and the reason for the low density, although fires in dry season may have contributed due to the difficulty in identifying some species of seedlings together with a high mortality caused by fires in both Mopane woodland and Acacia woodland.

In mixed Acacia woodland, *D. cinerea* dominated the density of seedlings and saplings. *Dichrostachys cinerea* once it penetrates an area it suppresses the growth and well-being of any other trees around (Ligavha *et al.*, 2000) and is a potential coloniser due to it sprouting capacity as compared to other species after disturbances (Ligavha *et al.*, 2000). Apart from physiological characteristic of *D. cinerea*, edaphic factors may also influence, although there is no documented information regarding influencing factors that may specifically affect patterns of regeneration in the area.

Seedling establishment of many savanna woody species is not a regular annual event and is usually more sporadic and restricted to seasons with a combination of favourable conditions (e.g. wet years). Higher number of saplings than seedlings in some species can obviously explained by the coppicing ability of some species, for example, *C. mopane* (Mushove & Makoni, 1993; Rathogwa *et al.*, 2000) *and D. cinerea* (Ligavha *et al.*, 2000). For some species, seedlings seem to not be present or some did not have leaves because fires at the time of the field survey carried out during the dry season for instance *Combretum mole*. Therefore, it was difficult to identify seedlings of some species. This may be the reason that most of *Acacia* species do not appear to have seedlings. Another explanation might be the lack of success of the seed germination of these species due to biological and environmental factors, as well as leaf fall that makes it difficult to identifying seedlings.

CHAPTER 6

Results and Discussion: Socio-economic Assessment

Results obtained from a household survey assessing pattern of use of woodland resources and perceptions about benefits from socio-economic activities are presented and discussed in this chapter. Also, additional information of the results from informal group meeting and trend analysis of woodland resources in the Mahel area are presented and discussed.

6.1 Results

6.1.1 Use of woodland resources

6.1.1.1 Frequency of use of species and products

Villagers indicated a range of uses of different woody species in the study area according to a particular purpose of use, quality of product and availability of specific species in the area (Appendix 4). The frequency of use of the most abundant and used woody species across various products, were significantly different in the villages including Chicutso (χ^2 = 456, df=6, $p <$ 0.001), Chimuine (χ^2 = 25, df= 5, $p < 0.001$) and Greater Mahel (χ^2 = 127, df= 6, $p >$ .0.05) villages. For Gumbene village there was no significant difference on frequency of use of woody species across products (χ^2 = 5, df=6, $p > 0.05$) probably due to fewer samples associated with low human density in that particular village.

In general, *C. mopane* is the most used tree, ranging from 31.7 % to Chicutso to 71.4 %, in Chicutso and Gumbene villages, respectively (Appendix 4). It is used for building, charcoal, fencing, firewood and also collection of worms. While, *Euclea natalensis* beyond of providing edible fruits, it is also used for firewood and building materials in all the villages.

In terms of products from the woodland in study area, the study revealed firewood and building materials as the most frequently used in the Mahel (Table 6.1). All villagers indicated fruits and caterpillar as the important food products from the woodland depending on species composition of the dominant vegetation type in a particular area around the village.

Table 6.1 Frequency (%) of use of woodland resources in the study area, including Chicutso, Chimuine, Greater Mahel and Gumbene villages

Product	Village				Mean
	Chicutso	Chimuine	Mahel	Gumbene	
Building	18.5	28.3	27.5	14.3	17.72
Firewood	50.7	45.3	38.9	28.6	32.7
Fruits	13.5	18.9	21.1	14.3	13.56
Caterpillar	4.8	7.5	11.3	14.3	7.58
Charcoal	12.2	0	1.1	14.3	5.52
Fencing	0.3	0	0	14.3	2.92

6.1.1.2 Relationship between frequency of use and availability of woodland resources

There was significant variation among villages in the frequency of use of woody species (Figure 6.1 a& b; Figure 6.2 a & b). *Colophospermum mopane* as the most abundant species in the Mahel area, it was identified as the most frequent used in the study area. The only exception was Chimuine village where, although abundant, *C. mopane* less frequently used by local people.

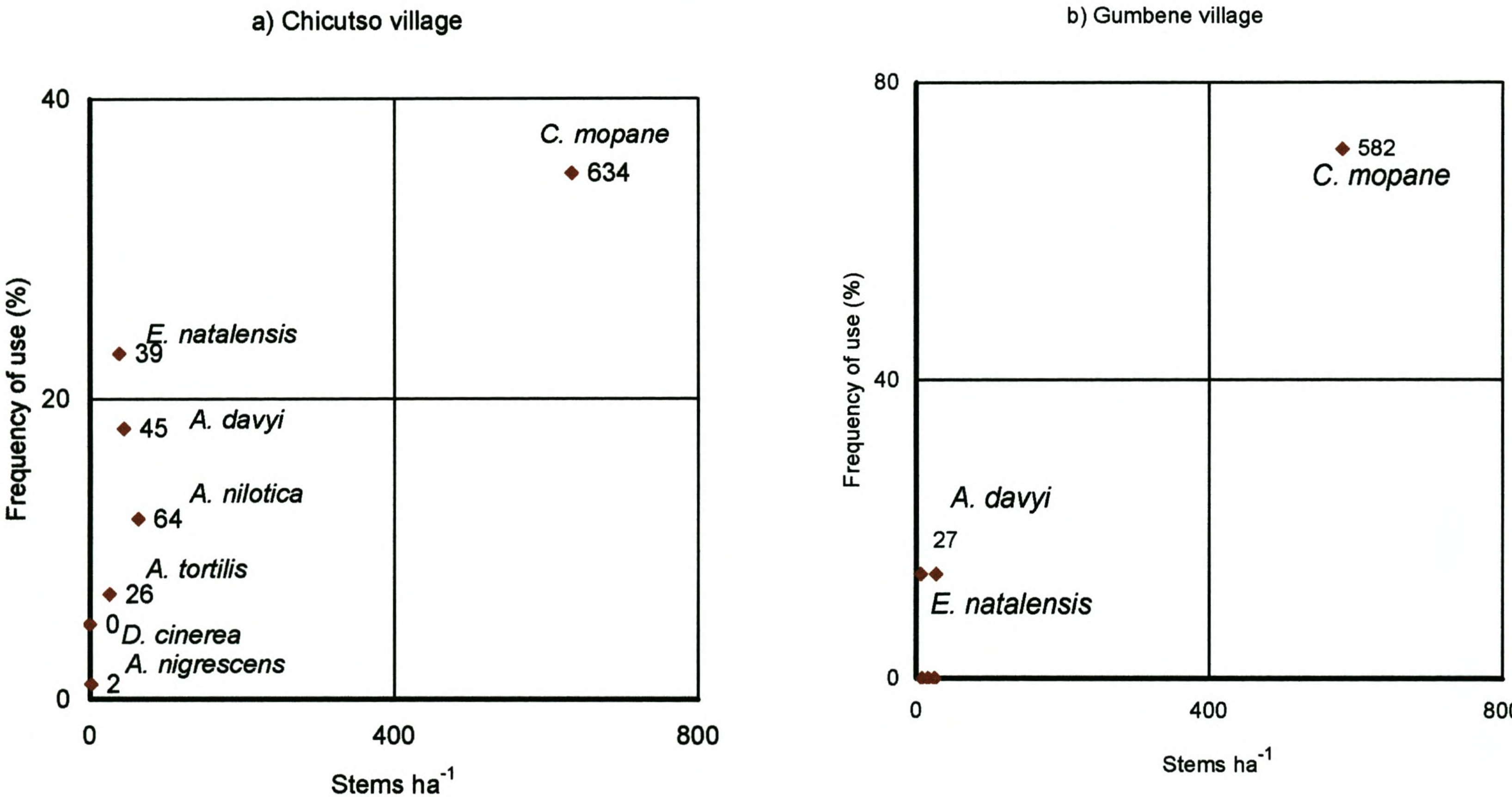


Figure 6.1 a & b Pattern of frequency of use of species versus abundance in stem ha^{-1} in Chicutso and Gumbene villages, both located in Mopane woodland

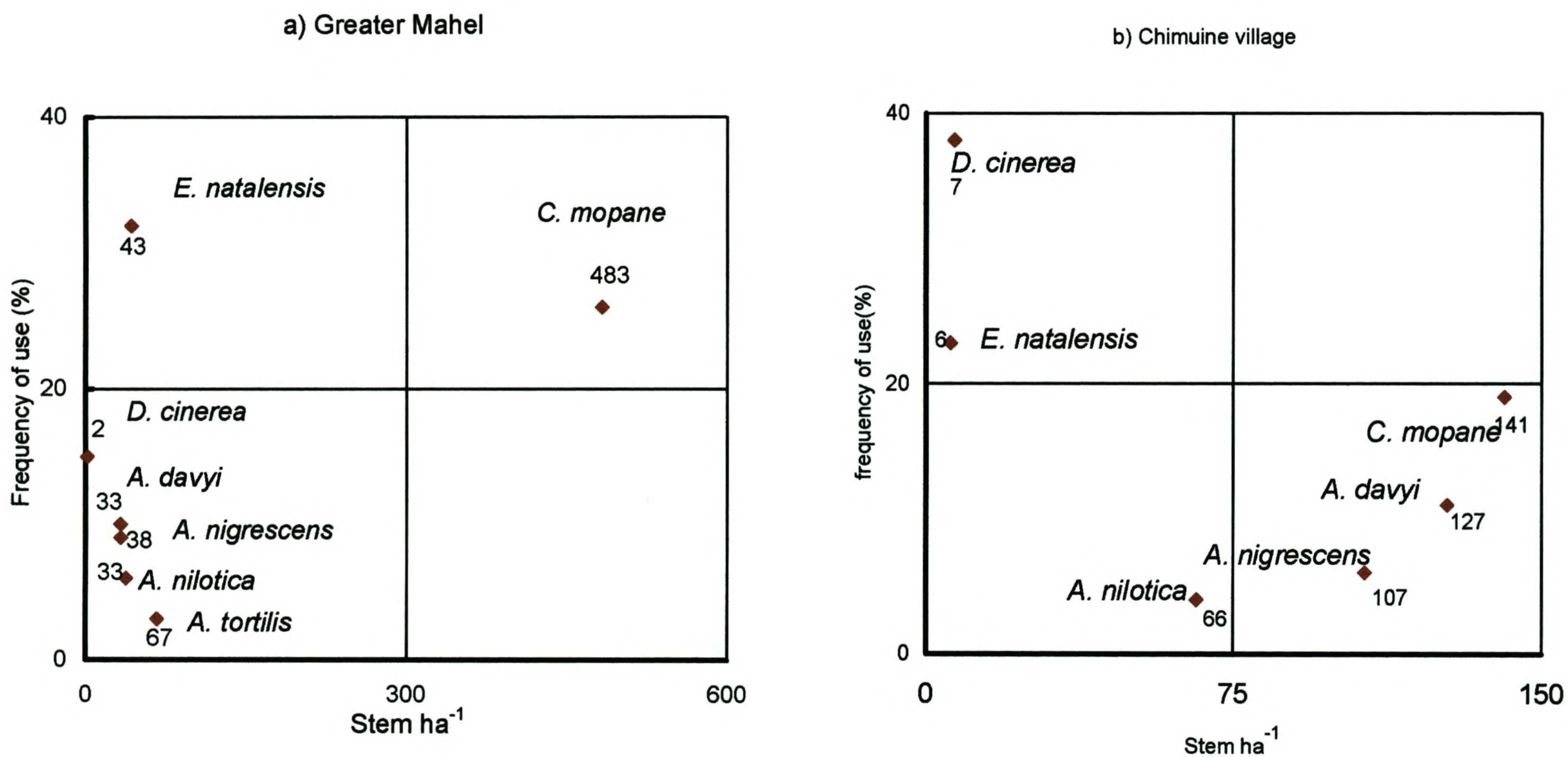


Figure 6.2 a & b Pattern of frequency use of woody species versus abundance in stem ha^{-1} in Greater Mahel and Chimuine villages, both located in Acacia woodland

6.1.2 Perceptions regarding benefits

Apart from Gumbene village, the trends of perceptions about different sources of benefits from socio-economics activities villagers in the Mahel area indicate that they rely mainly on crop production for their livelihood (Figure 6.3). The highest mean value attributed to crop production was found in the Great Mahel village (52% among the most four activities of villagers).

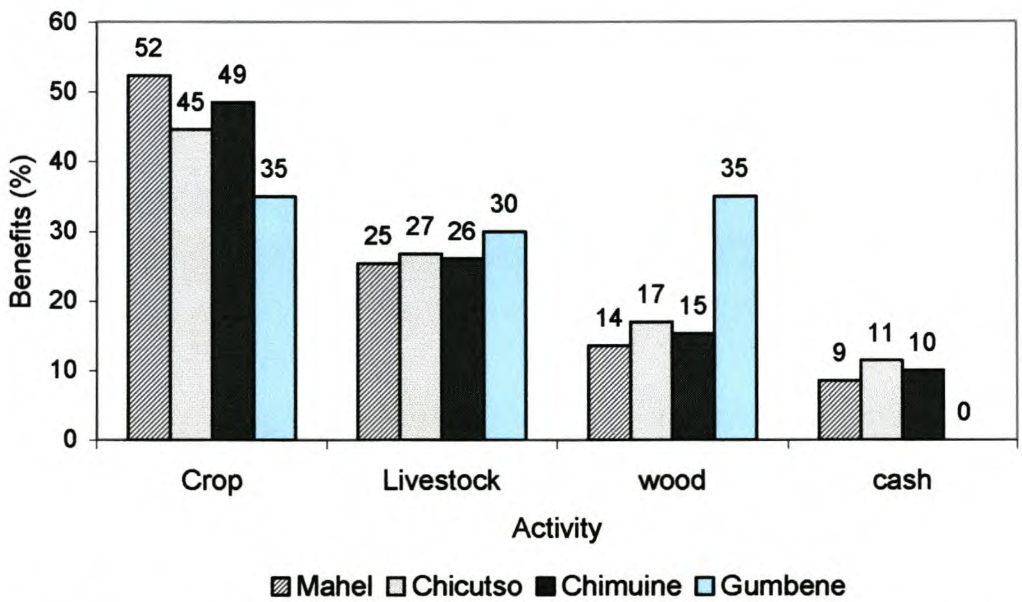


Figure 6.3 Frequency (%) perception to benefits from the major socio-economic activities in Greater Mahel (n= 37), Chicutso (n= 53), Chimuine (n=5) and Gumbene (n=1)

In Gumbene village there was higher score of benefits from woodland products. Income was not even mentioned to be benefits in Gumbene. Also, insufficient sample in Gumbene may have influenced the results from this village. Local people perceive that benefits from woodland resources are not significant for their livelihood although from personal observations it was evident a significant number of people involved in commercial activities of woodland resources, mainly in the Chicutso village.

6.1.3 Focus group discussion and trend analysis

These results are from a participatory exercise, which involved a meeting held in the Great Mahel village and informal discussions. Although the meeting was open to every member of the village, the targeted groups were members of the 'Community-Based Natural Resource Management' committee of the Mahel Community Project, including community leaders, local government officers and local forestry officers. There was almost gender balance among participants at the meeting with five women present out of eleven participants.

From the meeting people indicated four periods to be the most important in characterizing the trend of the woodland resources with human use over time. These were pre-war (1975-1992), during war (1982-1992), post war (1992-1999) and the period after wards (1999-2001) in the Mahel area as showed in Figure 6.4.

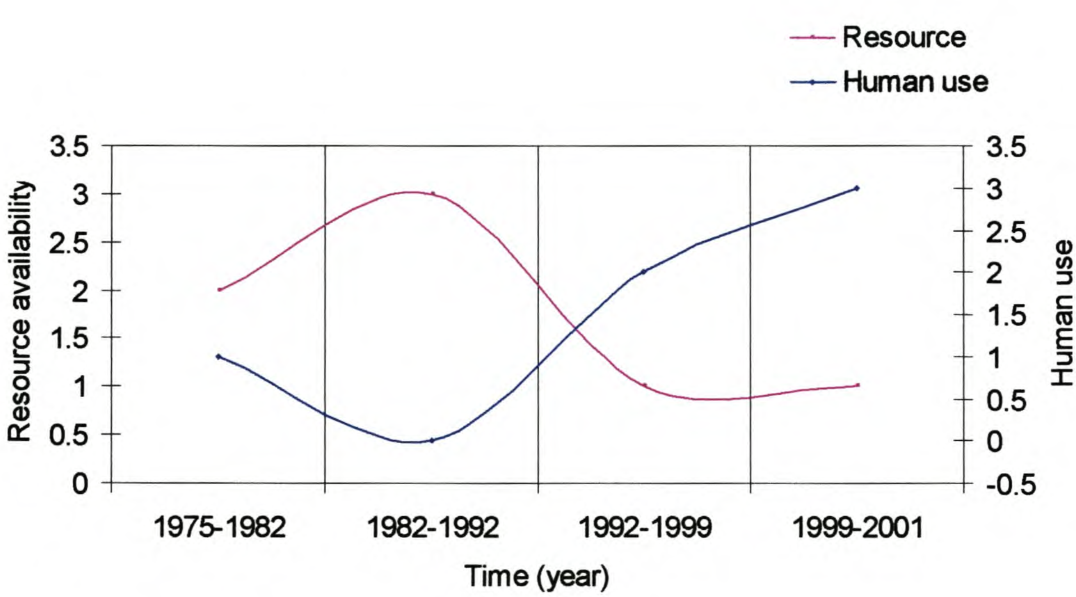


Figure 6.4 Summary of people's perception of change in resource abundance and human use over time in the Mahel area. Resource change and population were categorized based on variable as following: 0 = none, 1 = less, 2 = abundant, 3 = very abundant

Before civil war there were few people living in Mahel area. Some commercial activities were carried out at the time in the area, such as farming; timber and construction material and pole for farming. From 1982 and 1992 during the civil war, people moved away from the area.. Consequently, there was an increased abundance of woodland resources including wildlife. Immediately after the civil war with returning of people into the area there was an extremely necessity of wood resources for reconstructions, resulting in high pressure to the woodland. Local people as well as outsiders imposed by extreme poverty embarked on extraction of woodland resources, mostly charcoal, pole and firewood. From 1999 to October 2001 increasing commercial extraction has been assisted in the area that become a serious concern for the local people because of unprecedented degradation of wood resources in the Mahel area mainly in Chicutso village due to massive commercial extraction of wood fuel and construction material.

Local people said that most of outsiders are mainly from the neighbouring areas, Chokwe District in Gaza Province and Maputo city. Even though, the community members said that there is still high potential of woody resources in areas, such as in the Great Mahel and Ketchene. In Ketchene people said that *Acacia spp.* is the most abundant and most used species for charcoal making and also for building. Chicutso and Manjangue areas were said to be potential areas of *C. mopane*. However, Chicutso and Manjangue villages are the major producers of charcoal in the area.

6.2 Discussion

6.2.1 Use frequency of woodland resources

The high range of use frequency and abundance found suggest a significant role that woodland play across villages of the Mahel area. Most of the uses of woodland resources in the Mahel area are for subsistence of households. But, there is a certain degree of involvement of some villagers with commercial activities for instance in Chucutso, encompassing a group of woodland products varying significantly from one village to another. This was revealed elsewhere in the region for example by Shackleton *et al.* (2000) in South Africa.

In rural areas local people often use small stems rather than big ones for their domestic needs. This includes firewood, roofing and fencing (Macome & Soares, 2000; Rathogwa *et al.*, 2000). For instance, in this study, villagers indicated a range of uses of different woody species in

Mahel as a function of quality of product from and availability of a particular species . For example, *Colophospermum mopane* was the most abundant woody species and covers a range of uses, including source of cash income, as in Chicutso and Gumbene villages. Mussanhane (2000) also encountered similar patterns *C. mopane* use. Hall (2000) in Zinave, Mozambique, apart from firewood and construction material, he found that *C. mopane* also was used for furniture and medicine. Extensive number of uses of *C. mopane* is found also in Conroy (1996) in Namibia.

Some of the uses of woody species were related to collection of edible products such as fruits from *Euclea natalensis* and caterpillar from e.g. *C. mopane*. These products are considered supplementary diet for the villagers in the Mahel area. Therefore, fruits and worms were included as the most frequently used woodland products. Fruits of *Euclea natalensis* are used in the area for beer making by the local communities. This could be the reason why there is high use frequency of this species in the Great Mahel, Chimuine and Chicutso villages where *Euclea natalensis* is apparently not abundant. *Euclea natalensis* was not abundant in terms of stem densities based on size diameter but it is a most abundant shrub species in the Mopane woodland and mostly associated with *C. mopane* in the Mahel area according to field observations.

6.2.2 Relationship between use frequency and availability of woodland resources

There is a relationship between high density, high frequency, large size, and the usefulness of a species (Mutchnick & McCarthy, 1997). Various factors may be influencing the pattern including, type of uses, market value, roads to the market, quality and availability of the resources in the area (Figure 6.5). Hypothetical analysis of four possible scenarios regarding the relationship between frequencies of use of woody species mentioned by local people and physical availability of woodland resources in the woodland are illustrated in Figure 6.5 and described as follows:

High frequency use & low abundance: This situation explains a higher frequency of use of woody species that are not available enough. It includes those species that are highly preferred because of their good quality, and consequently in high demand in the marketplace or have been over exploited, but people still need them to use for various purpose (Figure 6.5). For instance, *Acacia davyi* in Chicutso and Gumbene was found to be frequently used despite its low availability in the area because of its specific quality for certain uses, such as charcoal making and for fire wood collection (Figure 6.1 a & b). Others example are *Euclea natalensis* in Chicutso, Greater Mahel and Chimuine villages and *Dichrostachys cinerea* in Chimuine (Figure 6.2 a & b).

Low frequency use & low abundance: This is a scenario of low available resources and low frequency use of woody species across products as is depicted in Figure 6.1. This may indicate that people do not use those species because simply are not available enough to satisfy their needs (Figure 6.5 and Figure 6.2 a). Alternatively people will frequently use those species more available such as *C. mopane* in Chicutso, Gumbene and Greater Mahel (Figure 6.1 a & b and Figure 6.2 a.).

Low frequency use & high abundance: Other situations of low uses but highly abundant may be related in general to low quality of some species for some villages for example *A. nigrescensis*, *A. davyi* and *C. mopane* in Chimuine village because of less commercial extraction of woodland resources in this particular village (Figure 6.1 a & b).

High frequency use & high abundance: In this situation there is a linear relation of availability of resources and frequency of use of woody species. Thais means that people make most use of certain species that are more available in terms of stem densities since in rural areas in principle local people prefer small stems than big ones for domestic uses, such as firewood, roofing and fencing (Macome & Soares, 2000; Rathogwa *et al.*, 2000).

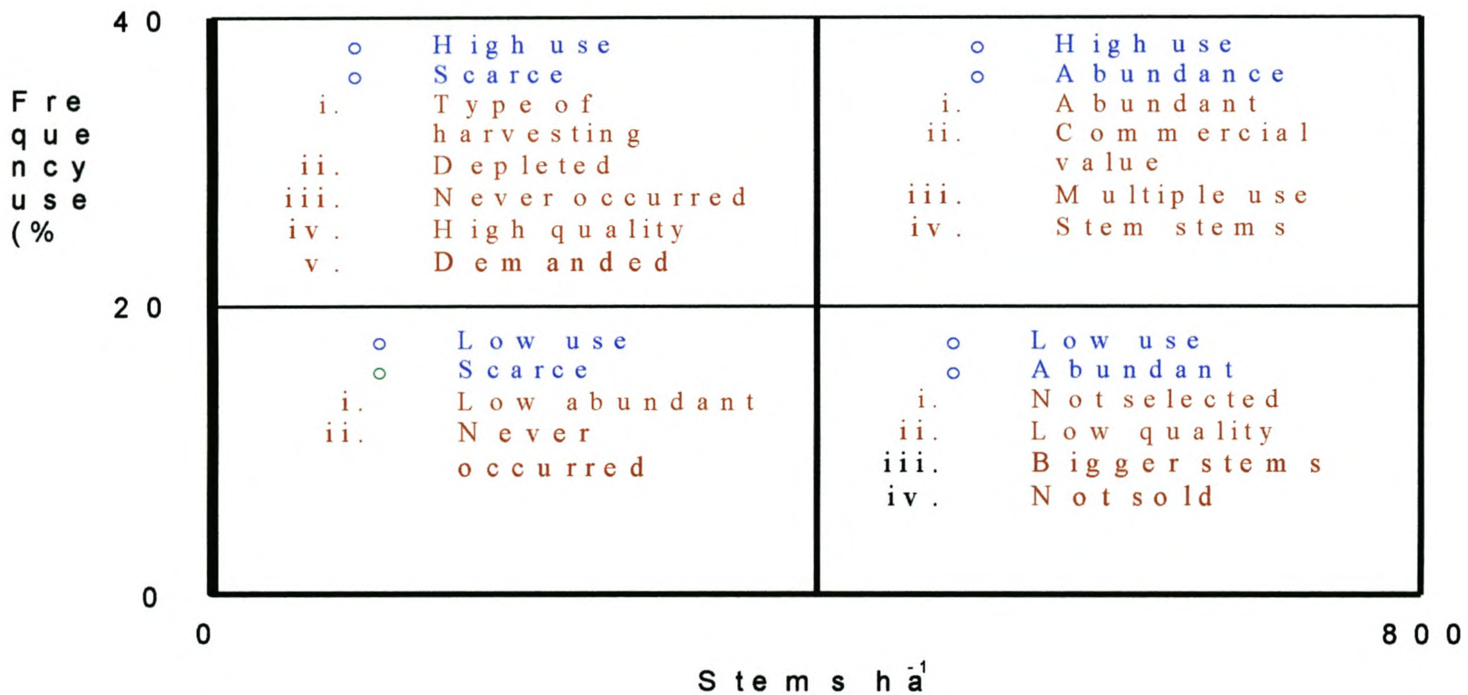


Figure 6.5 Expected patterns of frequency uses of woody species across products in the Mahel area showing relationship between availability and use of tree in the woodland. Red lettering in the Figure shows four possible scenarios from use and availability of resources (stem densities). Blue lettering indicate different factors that may have influence on the four scenarios presented in Figure in red lettering.

When physical abundance of woody resources changes from one site to another, influenced by various factors such as environmental and human factors as well, the degree of demand and use value will also vary. This may also be an indication of a possible sustainable use of resources, such as *C. mopane*, which indicated high regeneration potential and dynamics. This study revealed high demand for some scarce species, for instance *A. davyi* in Chicutso and Gumbene villages, areas of low population of this species.

Therefore, the most common species are expected to be harvested more intensively than the less abundant species (*Murali et al.*, 1996). But *Colophospermum mopane* species according to Timberlake (1995) where it is present, is often dominant, probably that is the reason it is given less value in the area where it occurs for example in the Mahel area (Figure 6.2 b).

6.2.3 Perceptions regarding benefits

Local people in savanna ecosystems across the region tend to assign less value to the woodland resources and favour crop production (Campbell & Luckert ., 2002) despite the extensive use of environmental resources at a household level (Cavendish, 2002). According to Campbell (2002) there is even evidence of this higher value in areas of marginal agricultural productivity as was found in some areas in Zimbabwe. The main assumptions around these trends of local people perceiving less value are attributed to the scarcity of land, subsidies from governments to farmers during crop failure, and land ownership over woodland resources (Campbell, 2002).

Also similar trends were found in the Mahel area where communities perceived more than 50% of benefits to be accrued from agricultural activities, followed by livestock. The main reasons for the local people relying more on crop products might be strongly associated with inefficient commercialisation of woodland products and lack of ownership of the woodland. Similar trends were found in Zambezi Delta (Turpie *et al.*, 1999). However, Hall (2000) found that crop production contribute little to the household economy in Zinave National Park in Inhambane Province.

The harvesting of wild plants, grasses, fruits, bark and wood for domestic use has traditionally been an important subsistence activity that has provided input for household use for many rural people (Campbell & Luckert, 2002; Hamilton, 1995). In rural areas where many people do not have access to productive land and jobs, poverty is prevalent and harvesting of woodland resources can provide the means of barter for necessary items (Veeman, 2002). With increasing commercialisation of many woodland products, the harvesting and sale of these products has become important to the livelihoods of many rural people (Veeman, 2002). "...Achievement of better markets is significant to rural people for whom these markets can be a means of providing or improving household incomes and livelihood" (Veeman, 2002). The marketing of woodland products plays an important role in enabling woodland-dependent households to realise a significant part of their cash income through the sale of woody products (Veeman, 2002).

However, the commercialisation of woodland in the Mahel area by local people is weakened by lack of transportation of the products to the market, as is also mentioned by Macome & Soares (2000). Local people in Mahel perceive the woodland resources as low commercial value as opposite to crop and cattle farming which were attributed high value despite the availability of woody resources and strong dependence of local people to woodland resources in time of drought seasons. This is another factor causing local people to under-value the woodland.

Moreover, Mahel area was one of the areas heavily affected by the recently terminated 16-year civil war, leaving people in subsistence-based economy due in part to difficult road access to the markets. Road infrastructure enables local people to trade their available woodland resources. Therefore, the Mopane woodland resources in Mahel still seem to play more to the subsistence role than as a source of income.

According to Macome & Soares (2000), the Mahel communities mostly use woodland products to supplement and complement their domestic needs, mainly, firewood, edible indigenous fruits, mopane worms and medicine. However, besides agricultural products, charcoal, firewood, poles and wild meat constitute some of the major sources of income for villagers in the area. Crop production, apart from being the major source of food, has multiple use value to the local people in good rainy seasons. The surplus can be sold for cash and also people generate by-products for selling, such as brewing, which is common in the area. Villagers who are actively involved in commercial activities with the woodland resources are expected to highly value benefits from the woodland. This is the case in Chicutso and Gumbene villages as compared to other villages in the area due to mainly difficult access to the markets. The lowest benefits supporting household needs perceived by local people found in cash income in almost all villages mean that direct income from job still is not sufficient for the villagers to support their livelihood.

However, in most cases outsiders extensively extract woody resources illegally with no benefits accruing to the local people. This is again one factor that local people will give less value to the woodland. The Mahel area is classified as multiple land use category under the current forest and wildlife law (DNFFB, 1999). In fact it is an open-access land under the jurisdiction of state control. This implies that no ownership is claimed by the local community despite their recognised role in the management and conservation of the woodland resources associated with high price they pay from degradation of the land. "Land tenure issues and questions of access, use, control and benefit distribution are fundamental to the sustainable utilisation and management of woodland and other natural resources" (Misana *et al.*, 1996).

Ownership and control are crucial factors for effective management and conservation of dry savannas in Southern Africa because of the prevalent property regimes in the region. This affects the efficient use of woodland resources, for instance in miombo woodland (Matose & Wily, 1996). The Mopane woodland in the Mahel area is one of the evidences of inefficient resource use due to the open-access and inefficient commercialisation of woodland products that may lead to degradation of the woodland.

6.2.4 Focus group discussion and trend analysis

Given the trend of resource depletion manifested by local people suggests a need of urgent action to control the use of resources in the area State should assist them to find a way for effective control of the woodland resource utilization in the Mahel area.

A major point from the community is the strong sentiment on the current trend of degradation of the woodland. But, the potential threats of degradation identified by local communities are the people from outside Mahel encroaching illegally into the area mainly through Chicutso area. It was felt that assistance from conservation agencies of Government should assist the community with appropriate resources and incentives to take action for an effective control of the resources. This indicates that there is a great opportunity for implementation of community based program for effective utilisation and management of the Mopane woodland in the Mahel area like other initiatives in the Country (Nhantumbo, 2000; Mansur & Cuco, 2002).

CHAPTER 7

Conclusion and recommendations

The most important conclusion of this study is the existence of a promising potential of Mopane woodland resources in the Mahel area, which was corroborated by local communities who recognise the importance of woodland resources for their livelihood. However, conversion of land for cropping activities for food production will continue if the community in the Mahel area continues to place low value on woodland resources. Also local communities felt that necessary conservation measures should be taken given the current threat of degradation for sustainable utilisation of the woodland resources in the Mahel area in Maputo province. The main conclusions derived from this study are summarised and the respective recommendations are given as follow:

7.1 Species composition and diversity

Knowledge about richness and diversity are necessary to understand the status of resilience and stability of plant communities. In this study the status of woody species richness and diversity appears to be influenced by a number of factors in the Mahel area, including edaphic factors and impact of human activities in the woodland.

The soil characteristics of the study area determine the distribution of the two distinct vegetation types, namely, Mopane woodland and Acacia woodland, in the North-Eastern section and South-Western section, respectively. Harsh environmental conditions due to hard clay soils dominant in the area and water deficit are reflected in the study by the mono-dominance of *C. mopane* in Mopane woodland. Colluvial soils favour high species richness and diversity.

However, it is clear that human induced factors have also influence on species composition and distribution in the Mahel. The, interaction of edaphic and anthropogenic factors determine the current state of the woody vegetation in the Mahel area. Evidence of that is the higher richness found at intermediate level with 4.8 species per plot and the higher diversity of 0.9 per plot near the villages.

Lack of documented information on woodland richness and diversity as reference for the area made it difficult to assess the level of stability of the vegetation. However, the findings are a valuable baseline information for long-term studies on biodiversity assessment and monitoring of vegetation changes from impact of harvesting of the Mopane woodland for appropriate measures for conservation and sustainable use of the biological resources in the area.

7.2 Stem density of woody species

The Mopane woodland had highest stem density than Acacia woodland (937 stems ha^{-1} in Mopane woodland as compared to 271 stems ha^{-1} Acacia woodland) because of interacting factors of ecological and human disturbances.

Specific areas of high densities are found on areas dominated by outcrop soils for overall mean stem densities and on pediment-colluvial soils for *C. mopane* only with average of 889 stems per hectare and 661 stems per hectare, respectively. Chicutso village revealed higher resources available as compared to others, although no significant difference was found between villages. In terms of impact of villagers on availability of resources measured with distance to the woodland, it is concluded that the highest mean stem density is at intermediate distance of 5.1 – 10 km from the village with 950 stems per hectare for all species. While for *C. mopane* only higher mean stem density was found at distance between 10.1 and 15 km with 712 stems per hectare. Commercial harvesting appeared to be reducing stem densities near the roads.

An effective management plan is recommended for all the Mahel area with special attention to Chicutso area in which implementation of an integrated zoning scheme should be a priority for management of woody resources in the area. That, will need identification of potential areas for cropping, potential areas for woodland resources harvesting and grazing based on ecological factors of the environment.

7.3 The population structure and regeneration

Size-class structure, like stem densities, are fundamental information for management of woodland. The conclusion of the study from size-class analysis showed that only construction materials could be harvested in the area, although local people believe on the existence of high potential of woodland resources for long-term for example for charcoal production. This will be possible if the area is left undisturbed for a long time, so as to attain appropriate stem-sizes to produce a good quality of charcoal. It was unclear whether the low density of large diameter stems was the result of ecological factors or harvesting impacts. Therefore, the production of charcoal would not be recommended in short-term.

Long-term studies on dynamics of Mopane vegetation are necessary in order understand what determines demography of the woody vegetation in the area; regeneration and productivity of the Mopane woodland in the Mahel area should be promoted for future management recommendations for sustainable utilisation of woody resources.

However, there is a potential for harvesting of construction material that can be harvested sustainably, as it was revealed in this study by abundant regeneration of *C. mopane* with 10 109 saplings hectare and 7 999 seedlings per hectare in Mopane woodland. Apparently both, *C. mopane* and *D. cinerea* react positively after harvesting by sprouting. Observations suggest that Mopane woodland in the Mahel area characterized by diversity of height structure that may influence the variability of stem densities. Short Mopane woodland may suggest high spouting from disturbances and this factor may be recommended for sustainable management at appropriate time intervals. This implies that there is a need for further investigation to understand growing rate and dynamics for determination of suitable interval of harvesting.

7.4 Frequency of species use

It can be concluded that local people in Mahel give less value woody resources in the area. It was clear that the value attributed to the woodland resources in the Mahel area is mostly for their domestic needs. Firewood was the highest frequently used in all villages followed by construction materials from the woodland. Further investigation should be oriented on answering the question of how to commercialise woodland products that are abundant in the area and have high demands for external markets. One example of such a potential product for marketing is the abundant caterpillar. However, the sustainability and stability of this resource should be investigated before attempting to commercialise. This and other non-timber forest products abundant in Mahel, once well commercialised will increase the value of the woodland by uplifting the living standard of local communities.

Also this study concludes that because of high regeneration of *C. mopane* continued exploitation of this species for construction material will not be a threat in comparison with other species, such as *Acacia davyi* which is high demanded for charcoal but less abundant and lower regeneration. Therefore, it is recommended to discourage commercial utilisation of some of the most preferred species, such as *Acacia davyi* and strategic management plan should be designed to accommodate rational use of woodland resources and sustainable development of the area.

7.5 Perception of benefits in relation to socio-economic activities

It was clear from this study in Mahel that local people perceived cropping to be a far more important source of livlihood benefits from the land than cattle farming, woodland activities and cash income. Low economic value of woodland resources associated with absence of ownership and inefficient commercialisation of the woodland resources is the major factor that should be addressed towards effective utilisation and conservation of biological resources in the area.

7.6 General recommendations

1. Local communities have strong feeling for the need to control the use of natural resources in the Mahel area. The community-based natural resource initiatives are a new experience in the Mozambique, which still need flexible adaptation to the local situation. Therefore, the current effort of the local communities in the Mahel area assisted by the National Directorate of Forestry and Wildlife (DNFFB) and Food and Agriculture Organisation on promotion of community-based project for sustainable use of woodland resources should be encouraged and pursued towards effective implementation of the legal framework and promote incentives at local level for effective participation of the local communities.

2. Investigations should be carried out to understand the ecological impacts of extraction by outsiders and its socio-economic implications to the livelihood of local people and generate recommendations of how to explore more positive value of outsiders to the local economy.

3. Economic valuation of the woodland resources in the Mopane woodland, including other non-wood forest products, such as medicinal plants, beekeeping, and wildlife is an important step for appropriate strategic utilisation and management plan of the woodland that should be carried out. Development of these activities in the communities might someday reduce the negative impacts to the woodland.

4. The possibility of market analysis and development of woodland products should include an improvement of road infrastructure connecting to the market. This will help local people of the Mahel area to effectively commercialise their products from the woodland.

Integrated zoning and strategic management plan must be established taking into consideration ecological and socio-economic aspects for sustainable development of the Mahel area as a priority. These will imply considerations of different soil quality throughout the area. Integrated development is to be also considered since people for their livelihood depend on a diversity of woodland resources, for instance in Mahel cattle production, horticulture, beekeeping, game farming and ecotourism that may boost the economy of the area.

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Appendix 1

Data sheet for ecological survey

Study site name: ……………………………… Plot no:.:……………..

Date: …/…/2001 Plot size: ……………

Nearest village: ……………………… Distance from village (km):

Coordinates: Latitude. Longitude………………………………

1. Saplings		2. Seedlings	
Species	Quantity	Species	Quantity

3. Woody plant

Species	dbh (cm)

Appendix 2

Questionnaire used for social survey

Date of interview: ……………………..

Village: ………………………………..

Name of respondent: ………………….

Household number: …………………..

Name of interviewer: ……………………………………..

A. Value of household production

Over the whole year, in your life, your household may benefit from these things:

Crop production = maize, peanuts, sweet potatoes, cassava for consumption and for selling.

Livestock production = Meat, milk and eggs for household consumption, and for sell.

Natural resources in the forest *(swiloleswikumekaka kwatini): timhandzi, makhala, tihunyi, mirhi, matomane, majengelengendze, swiharhi swakwati*

Cash income (leswimivuyeriwakahiswona): ntirho, kutirhantirho wawena niwunwani thlelweni, npeceni kumbe male leyitakakutapfunakaya yirhumeliwaka hiloyi atirhaka kule nilekaya, etc.

These stones are to show how much your household benefits from each thing. Benefits could be to use, or to sell, or just to enjoy it. If you get a lot of benefit, then we would show this by putting a lot of stones.

Would you say that this is true – that you get the same benefit from each of these sources (X) (Intiyiso swaku ukuma kupfuneka koringana kaswiloleswihinkwaswo?)

Crop production	
Livestock production	
Forest	
Cash income	

B. Woodland resources

We are talking about resources from the woodland, such as charcoal, firewood, poles, timber, worms, fruits and others.

(Like makhala, tihunyi, mitimhandzi, mapulanga)

1. Have you ever-harvested wood or other products from the woodland? (Matirhisa swiloleswike?)

If yes, which species are harvested*? (lokomitirhisa, heyinimisinya leyi miyi tirhisaka?*

Local name	Latin name	Prodcut

3. What do you use the species for?

Appendix 3

Composition of the woody vegetation and constancy by ecozone

The constancy[1] of each species in each ecozone is shown where: I = 0 - 19%, II =20 – 39%, III = 40 – 59 %, IV = 60 – 79% and equal or more than 80 % occurrence in an ecozone

Latin name	Local name	Mopane	Mixed Acacia
MOPANE WOODLAND			
Colophospermum mopane	"Gunwe"	**V**	I
Acaca nilotica	"Changua"	**II**	II
Acacia davyi	"Chaya"	**II**	I
Euclea natalensis	"Lhangua"	**II**	I
MIXED ACACIA			
Acacia tortilis	"Chioo"	I	**IV**
Acacia adenocalyx	"Dzololwane"	I	**II**
Acacia nigrescens	"Chaya""	I	**II**
Combretum molle	"Chicucutso"	I	**II**
Dichrostachys cinerea	"Ndzenga"	I	**II**
Lannea schweinfurthii	"Xicumbanhe"	I	**II**
Sclerocarya birrea	"Canhu"	I	**II**
OCCASIONAL SPECIES			
Acacia exuxivialis	"Bota"	I	I
Acacia burkei		I	I
Acacia karroo	""	I	I
Acacia luederitzii	"Chingai"	I	I

[1] Constancy is defined as the number of plots in which each species occurs (Kent & Coker, 1992)

Acacia seyal	"Chinghai"	I	I	
Acacia sp	"Chaya"	I	I	
Acacia xanthophloea		I	I	
Acalypha sejetalis		I	I	
Albizia anthelmintica	""	I	I	
Albizia petersiana	"Zanguelangua"	I	I	
Aloe marlothi	"Mhanga"	I	I	
Androstachys johnsonii		I	I	
Artabotrys brachypetalas	"Tita"	I	I	
Balanites maughamii	""	I	I	
	"Balatangati"	I	I	
Berchemia discolor	"""Nhiri	I	I	
Boscia albitrunca	"Hlaho"	I	I	
	"Cambanhani"	I	I	
Caparis tomentosa	"Mulhavankwuzi"	I	I	
Cassia abbreviata	"Numanyama"	I	I	
Cassine aethiopica	"Mihlawankawizi"	I	I	
	Chissitana	I	I	
Cissus quadrangularis	"Nyangala"	I	I	
Combretum imberbe	"Mondzo"	I	I	
Commiphora africana	"Xipamapane"	I	I	
Commiphora negrecta	"Ndzeketembe"	I	I	
Dalbergia melanoxylon	"Chipalatsi"	I	I	
Diospyros mespiliformis	"Mtoma"	I	I	
Drypetes arguta		I	I	

Euclea sp	”Changulo”	I	I	
Euphorbia cooperi	””Hlohlo”	I	I	
Euphorbia tirucali	”Neta matsuni”	I	I	
Euphorbiaceae sp		I	I	
Gardenia volkensii		I	I	
Grewia bicolor	”Tsatsamangwena”	I	I	
Grewia hexamita	”Sepane”	I	I	
Guibourtia conjugata	”Tsotso”	I	I	
Hibiscus migeodis		I	I	
Hibiscus virtifolius		I	I	
	”Imbalatangati”	I	I	
	”Inchusso”	I	I	
	”Khauwa”	I	I	
Lonchocarpus capassa	”Mbadzo”	I	I	
Manilcara mochisia	”Nuambo”	I	I	
Manilkara discolor	”Xipamane”	I	I	
Maytenu sp.	”Innai”	I	I	
	”Ncodzomutane”	I	I	
Pappeia capensis		I	I	
Phyllanthus reticulatus		I	I	
	”Ricambanyama”	I	I	
Schotia brachypetala	”””	I	I	
Sideroxylon inerme	”Kuhuma”	I	I	
Spirostachys africana	”Chilangamacho”	I	I	
Sterculia africana	“Sorobobse”	I	I	

Sterculia sp.	"Xissenga"	I	I
Stricnos spinosa	"Massala"	I	I
Strychnos madagascariensis	"Macuacua"	I	I
	"Tdziringuana"	I	I
Terminalia sericea	"Nkonola"	I	I
	"Tsamunga"	I	I
	" Waneho"	I	I
Vangueria infausta	"Itsiwa"	I	I
Ximenia americana	"Ndunduluka"	I	I
Zanthoxylon capensis	" Manongwana	I	I
Ziziphus mucronata	"Passamala"	I	I

Appendix 4

Percentage of woodland resource uses in the Mahel area across villages and woody species

Village	*Species*	*Building*	*Charcoal*	*Fencing*	*Firewood*	*Fruits*	*Worms*	*Grand total*
Chicutso	*Acacia nigrescens*				0.5			0.5
(N = 53)	*Dichrostachys cinerea*				4.6			4.6
	Acacia tortilis		0.3		6.9			7.2
	Acacia nilotica				11.7			11.7
	Acacia davyi	4.8	2.4		10.9	0.3		18.2
	Euclea natalensis	0.3			9.3	13.2		22.8
	Colophospermum mopane	13.5	9.5	0.3	6.9		4.8	35.0
		18.5	12.2	0.3	50.7	13.5	4.8	
Chimuine	*Acacia nilotica*				3.8			3.8
(N = 5)	*Acacia nigrescens*	5.7						5.7
	Acacia davyi	9.4			1.9			11.3
	Colophospermum mopane	9.4			1.9		7.5	18.9
	Euclea natalensis				3.8	18.9		22.6
	Dichrostachys cinerea	3.8			34.0			37.7
		28.3			45.3	18.9	7.5	
Gumbene	*Acacia davyi*				14.3			14.3
(N = 1)	*Euclea natalensis*					14.3		14.3
	Colophospermum mopane	14.3	14.3	14.3	14.3		14.3	71.4
		14.3	14.3	14.3	28.6	14.3	14.3	
Mahel	*Acacia tortilis*				2.6			2.6
(N = 37)	*Acacia nilotica*		0.4		5.3			5.7

Acacia nigrescens	6.0			3.4			9.4
Acacia davyi	4.9			4.9			9.8
Dichrostachys cinerea	3.0			12.1			15.1
Colophospermum mopane	12.1	0.8		2.3		10.6	25.7
Euclea natalensis	1.5			8.3	21.1	0.8	31.7
	27.5	1.1		38.9	21.1	11.3	