Camelthorn (*Acacia erioloba*) firewood industry in Western Cape, South Africa

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 entirety or in part submitted it at any university for a degree.

Abstract

The reliance of firewood demand on indigenous trees such as *Acacia erioloba* is a continuing phenomena despite the concern that over-exploitation of these resources will degrade the environment. This study tested the hypothesis that the cutting of *A. erioloba* in the Northern Cape is driven by (a) market demand in the Western Cape, (b) ignorance of the long-term ecological consequences and/or (c) ignorance of legislation along the chain of custody of this product. The assumption is that whoever is involved in the *A. erioloba* firewood industry (resource owner, trader or user) is neither aware of the protected status of the resource nor the negative consequences associated with the over-exploitation of the resource or they are driven by short term monetary gains. Therefore, there is a need to understand the needs of every participant in the chain and to further find out if there may be substitutes for *A. erioloba* firewood. The results of this study show that there is a market for firewood in the study area and that this demand is driven mainly by the availability rather than the quality of firewood. It will also be shown that *Acacia mearnsii* which is available in the study area is a better product than *A. erioloba* and therefore it can be a suitable replacement but consumers were found to burn almost everything that would give them embers. The most preferred firewood in the study area is *A. cyclops*. The concept of indigenous trees is not clearly understood by retailers and consumers. The major role players in the supply chain were found to be the retailers and the transport owners who may be targeted when firewood trade is to be stopped in the short-term. The results further highlighted the fact that the majority of consumers were aware that indigenous trees were protected in South Africa but the majority of retailers were not aware. The study recommends that firewood trade should be stopped completely by strict enforcement of the law or by the involvement of every role-player and/or that the trade should be regulated.

Opsomming

Die fenomeen dat die aanvraag vir vuurmaakhout staatmaak op inheemse bome soos *Acacia erioloba* duur steeds voort ten spyte van die kommer dat oorbenutting van hierdie hulpbronne, ter versadiging van die behoeftes van 'n steeds toenemende populasie, die omgewing sal degradeer.

Hierdie studie het die hipotese getoets dat die afsny van *A. erioloba* in die Noord-Kaap aangedryf word deur (a) die mark aanvraag in die Wes-Kaap, (b) onkunde oor die langtermyn ekologiese gevolge en/of (c) onkunde oor die wetgewing van hierdie produk by die skakels in die verskaffersketting. Die aanname is dat wie ook al betrokke is by die *A. erioloba* vuurmaakhout-industrie (hulpbron eienaar, handelaar of gebruiker) is beide onbewus van die beskermde status van die hulpbron asook van die negatiewe gevolge geassosieer met die oorbenutting van die hulpbron of hulle is aangedryf deur korttermyn monetêre gewin. Daarom is dit nodig om die behoefte van elke deelnemer in die ketting te verstaan en om verder uit te vind of daar plaasvervangers vir *A. erioloba* vuurmaakhout is.

Die resultate van hierdie studie toon dat daar 'n aanvraag is vir vuurmaakhout in die studie-area en dat hierdie aanvraag hoofsaaklik gedryf word deur die beskikbaarheid, eerder as die kwaliteit van die hout. Daar sal ook aangetoon word dat *Acacia mearnsii,* wat in die studie-area beskikbaar is, 'n beter produk is as *A. erioloba* en dus 'n geskikte plaasvervanger kan wees, maar dit wil voorkom of die verbruikers omtrent enigiets sal brand wat kole sal verskaf. *A. cyclops* is die vuurmaakhout van voorkeur in die studie-area. Handelaars en verbruikers verstaan nie die konsep van inheemse bome duidelik nie. Die vernaamste rolspelers in die verskaffersketting is die handelaars en die eienaars van die vervoer en hulle kan die teikengroep wees as die handel in vuurmaakhout in die korttermyn stopgesit word. Die resultate het verder na vore gebring dat die meerderheid verbruikers daarvan bewus is dat inheemse bome beskermd is in Suid-Afrika, maar die meerderheid handelaars is nie hiervan bewus nie.

Hierdie studie maak die aanbeveling dat handel in vuurmaakhout totaal gestaak moet word deur strenger wette of deur die betrokkenheid van elke rolspeler en/of dat handel gereguleer moet word.

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CHAPTER 1

Introduction and Objectives

Firewood is the most commonly used energy source especially in developing countries. Due to the scarcity of the resource among other things, firewood has become a tradable commodity (FAO 1985; Eberhard 1990) and unfortunately the distance from the source to the user is increasing on a daily basis. The higher demand is exacerbated by higher population densities in metropolitan areas. Sometimes the firewood resource comes from harsh environments such as the arid ecosystems of southern Africa. According to Kanel (2000), the demand for fuelwood also increases with the increase in income levels of the people. This research focuses on the sales of *Acacia erioloba* E. Mey, in the Western Cape Province of South Africa. This was done because it was observed that some retail outlets in the Western Cape Province were found to sell *Acacia erioloba* which is an indigenous hardwood growing in the Kalahari area. Indigenous trees are protected by law in South Africa. Although it is likely that the wood is also sold in other South African cities, the Winelands area of the Western Cape was selected as a case study.

The harvesting of a resource cannot be sustainable if the replacement rate is exceeded by the consumption rate. It has been reported that *Acacia erioloba* is slow growing and long-lived (Barnes *et al.* 1997; Leger 2000) and it seems unlikely that any harvesting of this resource can be sustainable especially if live trees are harvested to meet the demands of a firewood market. *A. erioloba* trees are believed to play an important role in the maintenance of biodiversity in arid systems of southern Africa. Unfortunately these trees are being removed from many places in the Northern Cape and North West Provinces of South Africa to satisfy the firewood market in big cities (Anderson and Anderson 2001; Liversidge 2001).

Wherever it occurs, A. *erioloba* is known as the best firewood. There is evidence that between Sishen and Olifantshoek in South Africa, large specimens of this tree have become rare (Barnes and Fagg 1995; Barnes *et al.* 1997; Leger 2000; Anderson and Anderson 2001). This has been attributed to the fact that these trees have been used as a source of energy before coal was available for the diamond mine industry in the

Kimberley area (Barnes *et al.* 1997). The wide scale use of these trees has also been noted in Namibia where they are used for charcoal making (Barnes *et al.* 1997).

Hardwoods are reputed to produce firewood of high quality and further, the formation of good coals may depend on hemi-cellulose content and its concentration is found to be higher in hardwoods (Eberhard 1990). According to Abbot *et al.* (1997) and Bhatt and Tomar (2002), a suitable species for firewood should possess the following qualities; high calorific value, high density, low ash content and a low moisture content. Most of the hardwood species possess these qualities. Hardwoods are slow growing by nature and the growth rate becomes slower when they grow in arid systems due to harsh environmental conditions.

Commercial use of natural resources is reputed to cause serious environmental problems as it is selective, foreign (required by outsiders who may not be affected by resulting problems), and driven by economic realities that cause resource overuse (Leach and Mearns 1988; Briers and Powell 1996). Over-exploitation of a resource that lives for about 300 years (Barnes *et al.* 1997) can have devastating effects on the environment. *A. erioloba* is considered to be a keystone species, that is a species upon which many other species depend for their continued existence. Some authors have noted that the removal of keystone species can result in the collapse of the whole ecosystem in arid areas (Weltzin and Coughenour 1990; Dean *et al.* 1999; Munzbergova and Ward 2002).

The current level of *A. erioloba* trade clearly shows that the legislation and legislative measures in place are not effective in protecting the exploitation of protected indigenous tree resources. When one reads through the National Forest Act No. 84 of 1998 and the National Forest and Fire Laws Amendment Act No. 12 of 2001, the impression is that both Laws are good. One therefore, wonders if the proper implementation of these Laws at the ground level is the main area of concern. If this is the case, then what can be done to strengthen the laws or to make sure that everybody buys-in into this noble idea of protecting the scarce and unique resources.

The problems associated with over-exploitation of this resource can be avoided in two possible ways. The first approach may be to stop the trade completely, but the argument may be that the exploitable resources are available. Then the question arises; do we have all the information and mechanisms related to proper control for the resource use. The second approach should obviously be the promotion of sustainable resource use based on sound information and proper mechanisms to implement management tactics.

The understanding of the supply chain and roles played by different stakeholders/role-players can enable us to know how, when and what to do when circumstances require interventions. Another study focused on the supply side (Milton 2001 unpublished) and this study looks at the remaining part of the supply chain until the end-user level. The study also deals with the consumer perceptions and consumer behaviour in the Western Cape Province of South Africa.

The main hypothesis for this study is to show that the cutting of *A. erioloba* in the Northern Cape is driven by (a) market demand in the Western Cape, (b) ignorance of the long-term ecological consequences and/or (c) ignorance of legislation along the chain of custody of this product. The assumption is that whoever is involved in the *A. erioloba* firewood industry (resource owner, trader or user) is neither aware of the protected status of the resource nor the negative consequences associated with the over-exploitation of the resource or that they are driven by short term monetary gains. Therefore, there is a need to understand the needs of every participant in the chain and to further find out if there may be substitutes for *A. erioloba* firewood. The study has the following specific objectives:

A. To investigate the forces that drives the industry, specifically:

1. Why do retailers stock *A. erioloba* firewood?
2. What is the demand for this firewood?
3. What is the cost of this firewood relative to the firewood types sold in the study area?
4. For what purpose is the firewood used in the study area?
5. Are there any substitutes for this product and how does it compare with substitutes?

B. To investigate if retailers and consumers are aware that Camelthorn is a protected tree.

C. To find the links in the supply chain and to develop guidelines to reduce sales from supplier to consumer by answering the following questions:

1. Who are the important role players in the supply chain?
2. What appropriate strategies should be designed to motivate and/or to force each role player to contribute to sustainable harvesting of the resource?

Chapter 1 deals with the introduction, hypothesis and the specific objectives of this study. Chapter 2 covers the literature review on the main topics that fall within the domain of this study. Chapter 3 looks at the study area and the socio-economic status of the people living in the Western Cape, as this will enable us to understand the economic position of the end-users. Chapter 4 covers the social survey which will help us to understand the needs of different role-players in the firewood industry. Chapter 5 compares the quality of *A. erioloba* with other firewood types sold in the study area. Chapter 6 is a general discussion of the results and provides recommendation on ways in which the firewood industry could be controlled or made more sustainable. Full references to all cited literature are given in Chapter 7. Raw data, detailed analyses and copies of questionnaires used in the study are presented as appendices.

CHAPTER 2

Literature Review

2.1 Introduction

Sustainable utilisation of natural resources is important for our benefit and that of the future generations but then the question is what is required in order to use resources in a sustainable way. A better understanding of the basic properties of the resource, distribution, utilisation, functions and threats facing the resource will enable decision makers to develop informed policies. The knowledge of how the ecosystem functions is important as the impact of resource utilisation on other members of the ecosystem needs to be understood. It is again important to know if users have alternatives to the resource and whether substitution may be considered as an option. The control measures are also reviewed as they will help us in choosing the most appropriate policy options for protection of this resource and its ecosystem.

2.2 *Acacia erioloba*

2.2.1 Distribution and establishment

Acacia erioloba typifies the tree component of the arid zones of southern Africa (Barnes *et al*. 1997). It is endemic to the Kalahari sand formations (Figure 2.1) that are derived from erosion of southern Africa, from the mountains of Lesotho, down through the Orange River catchment area (Barnes and Fagg 1995; Barnes *et al*. 1997). The annual rainfall varies widely (<50 mm to 900 mm) across the range of *A. erioloba* (Barnes and Fagg 1995; Barnes *et al*. 1997). In areas where the rainfall is below 250 mm per year, *A. erioloba* indicates the presence of underground water which may either be fresh or brackish (Barnes *et al*. 1997). A large part of the Kalahari area is arid and harsh for plant recruitment, establishment and survival (Barnes *et al*. 1997).

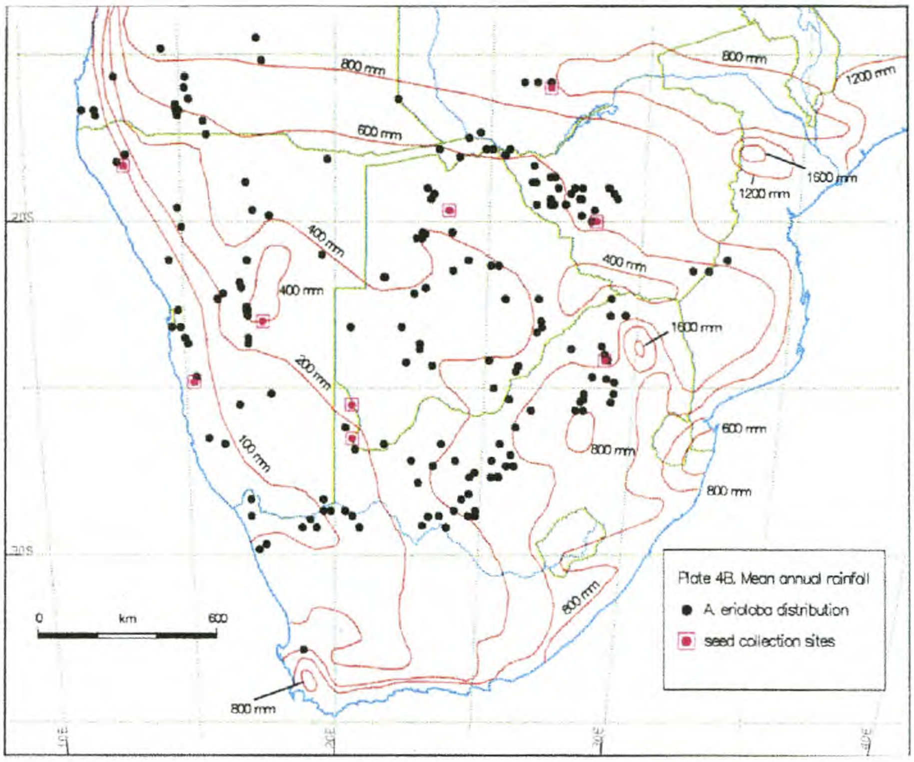

Figure 2.1: ***Acacia erioloba*** **distribution and mean annual rainfall isohyets (Source: Barnes** ***et al.*** **1997).**

In the driest parts of its range *A. erioloba* is the only tree in the landscape (Barnes *et al.* 1997). The trees are slow-growing, taking 15-20 years to reach reproductive maturity, and live for one to two centuries. Seedling recruitment is sporadic, and apparently facilitated by ideal weather conditions following fire or grazing (Barnes and Fagg 1995; Barnes *et al.* 1997; Barnes 2001). Seedlings germinate and survive more abundantly in high than in low rainfall years, and together with saplings, they suffer a high mortality rate in the dry years due to desiccation (Barnes and Fagg 1995; Barnes *et al.* 1997; Barnes 2001). Survival of seedlings is influenced by grass competition and population levels of predatory insects and rodents (Barnes *et al.* 1997; Barnes 2001), as well as by rainfall quantity and seasonality. Wilson and Witkowski (1998), as quoted by Barnes (2001), found that frequent rainfall during the first seven weeks was essential for seedling establishment and survival. Young trees out-compete each other (self-thinning) until there remains a woodland of well-spaced trees (Barnes *et al.* 1997).

Some Kalahari farmers consider that *A. erioloba* populations are increasing in density and reducing the grazing value of their land. This perceived problem is used to justify increasing in density and reducing the grazing value of their land. This perceived problem is used to justify the felling of this protected tree species. Although it is listed among 1652 other woody species that may become weedy in southern Africa (Wells *et al.* 1986 in Barnes *et al.* 1997), the tree is seldom considered to be invasive, because of its infrequent recruitment and slow growth. It is likely that the temporary thickening of *A. erioloba* populations in disturbed areas may facilitate the recovery of grazing grasses where these have been over-exploited (Barnes and Fagg 1995).

2.2.2 Uses of *A. erioloba*

In addition to being the source of firewood *A. erioloba* serves a variety of other functions.

2.2.2.1 Direct uses

The bark, pods, young shoots, flowers, and leaves of the *A. erioloba* tree are valuable browse for livestock and wild animals especially during the dry winter season (Barnes and Fagg 1995; Barnes *et al.* 1997; Anderson and Anderson 2001). Pod pulp and gum are used as food supplements and gum is reported to be rich in protein and carbohydrates (Barnes *et al.* 1997). Bark, gum and roots are also of medicinal importance as they can be used to cure diarrhoea, coughs, tooth aches and colds (Barnes *et al.* 1997; Leger 2000). Powder from roots is used for treating nose bleeding (Barnes *et al.* 1997). Seeds can be used as substitute for coffee (Barnes *et al.* 1997). The *A. erioloba* tree is believed to have an aesthetic value as it is unique to this arid system (Anderson and Anderson 2001). It has cultural significance in Botswana where in some areas locals claim that important events took place beneath the branches of a Camelthorn tree (Anderson and Anderson 2001). This tree is important to the surrounding communities, especially the poor who can have these life-saving benefits when other options such as medical services are not available.

2.2.2.2 Ecological functions

The site beneath the canopy of the *A. erioloba* trees is nutrient rich and shaded, and this leads to many fleshy-fruited shrubs, trees and climbers growing under the canopy (Jeltsch *et al.* 1996; Barnes *et al.* 1997; Dean *et al.* 1999; Anderson and Anderson 2001; Barnes 2001). This is similar to the contribution of trees in other arid savanna communities (Weltzin and Coughenour 1990; Munzbergova and Ward 2002). The seeds of these plants are dispersed by birds, jackals, and foxes which use these trees as perches and shade when it is hot (Jeltsch *et al.* 1996; Barnes *et al.* 1997).

Animals that rest in the shade of these trees also concentrate nutrients and disturb the soil; and the overall result is the development of distinctive plant communities (Jeltsch *et al.* 1996; Barnes *et al.* 1997; Dean *et al.* 1999; Anderson and Anderson 2001). Shade reduces soil temperature and evaporation levels, as a result soil moisture level remains high below the canopy (Dean *et al.* 1999; Anderson and Anderson 2001). Soils beneath living trees have been recorded to have higher organic carbon, nitrogen, and phosphorus concentrations (Barnes *et al.* 1997; Dean *et al.* 1999). The *A. erioloba* tree thus improves the conditions for establishment and growth of other plant communities thereby increasing species richness and diversity.

In wetter areas the grass cover becomes more pronounced and the species composition changes to more palatable and nutritious perennials and forage grasses beneath the canopy (Barnes *et al.* 1997). In arid areas the life cycles of many animals, birds, and insects are closely linked to *A. erioloba* trees as these provide the main source of food, perches, breeding sites and shelter (Barnes and Fagg 1995; Barnes *et al.* 1997; Dean *et al.* 1999; Anderson and Anderson 2001; Barnes 2001). *A. erioloba* trees do not form nodules, but it is reported that they use nitrogen from the underground water and this makes these trees as important as the nodulating species because this deep nitrogen is not available for use to shallow-rooted plants (Barnes and Fagg 1995; Barnes *et al.* 1997; Leger 2000).

Barnes and Fagg (1995) believe that the productivity of degraded arid zones can be improved by using indigenous pioneers such as 'acacias' which are capable of cycling water and nutrients from greater depths, fixing nitrogen, ameliorating the microclimate, providing useful products to man and animals, and a suitable environment for later successional species to re-establish ("natural repair-kit").

2.2.3 Threats to *A. erioloba* and associated species

Trees are being felled in many areas in the Northern Cape Province to support the firewood industry in large cities. In some areas *A. erioloba* trees are being killed by herbicides which are meant to kill invasive *Acacia mellifera* to improve pastures (Anderson and Anderson 2001). The major perceived threats to *A. erioloba* and its associated species are land transformation (including surface mining and the conversion to woodland and to cropland), tree clearing for pasture, and large-scale felling of live and dead trees for firewood (Anderson and Anderson 2001, Liversidge 2001). Fire can also kill *A. erioloba* trees and the intensity of fire can be increased by increased fuel load (Barnes *et al.* 1997). It is reported that if fire is not intense trees are able to coppice (Barnes *et al.* 1997). Large trees are resistant to drought and very low temperatures (as low as -15ºC to -20ºC) but seedling and sapling mortality can be significantly increased by these conditions (Barnes *et al.* 1997).

Dean *et al.* (1999) pointed out that after tree death; there is a rapid change in the radiation intensity and soil temperature which is followed by leaching of salts such as calcium, magnesium, potassium, and sodium during the rainy season. There is also a possibility of losing large birds, frugivores, and habitat-specific plants if the large trees are replaced by uniform grassland or thicket (Dean *et al.* 1999). Removal of deadwood results in the loss of habitat of many animals such as ants, spiders, lizards and rodents (Shackleton 1998; Anderson and Anderson 2001; Liversidge 2001) and some animals such as snakes that hibernate beneath the bark are killed in the process (Powell 2001).

2.3 Semi-arid and Arid Savannas of Southern Africa

2.3.1 Description and comparison

The savannas include all ecosystems in which C_4 grasses potentially dominate the herbaceous layer while the woody plants vary in density from widely spread individuals to closed woodland with patches of grasslands (Huntley 1982; Rutherford and Westfall 1986; Grossman and Gandar 1989; Simioni *et al.* 2000). Southern African savannas vary from tall moist woodlands receiving up to 1800 mm of rainfall per annum to sparse grasslands with scattered thorn-bushes where the rainfall can be 50 mm per annum or lower during dry years (Huntley 1982).

The savanna vegetation can be classified as "moist" and "arid" biomes (Huntley 1982; Grossman and Gandar 1989). These biomes are different in terms of flora and fauna, climatic and soil conditions, and physiognomy and dynamics (Huntley 1982). A large portion of these savannas is found to the north of the Tropic of Capricorn in southern Africa, and a fairly large proportion of arid savannas occur on Kalahari sands to 29º S (Huntley 1982). Camelthorn (*A. erioloba*) woodlands are found in this region. The altitude ranges from sea level to approximately 2000 m (Huntley 1982). The focus of this section will be biased towards the arid savannas but the differences between the two types are occasionally noted.

Arid savanna comprises trees and shrubs (*Acacia, Commiphora, Colophospermum, Rhigozum),* with an under-storey of grasses *(Stipagrotis, Panicum, Enneapogon,* and *Aristida)* (Huntley 1982). Arid savannas are found in areas receiving less than 650 mm of rainfall per year with frequent severe mid-summer drought, whereas moist savannas receive more than 650 mm of rain per year except for southern-most outliers on sandy latosols in areas subject to frequent dry years with less than 600 mm (Huntley 1982).

Aridity limits plant production and also influences competitive interactions between grasses and trees. Grasses tend to predominate in the most arid savannas and the tree component increases along a gradient of increasing water availability. Heavy and persistent grazing reduces grass cover, giving woody plant more access to water

(Walker *et al.* 1981; Knoop and Walker 1985; Weltzin and Coughenour 1990). This can lead to tree population increases (bush thickening) even under arid conditions (Jeltsch et al. 1997), and may explain why *A. erioloba* is considered to be a "problem" on some livestock ranches.

2.3.2 Over-utilization of savannas

Arid savannas of southern Africa have supported pastoral communities for a very long time (Huntley 1982). A change has been realized in the savannas since the late 1800s when human occupation of these areas increased; this has been attributed to the introduction of domestic cattle and sheep which replaced indigenous large mammalian herbivores and their predators (Walker *et al.* 1981; Grossman and Gandar 1989; Palmer and van Rooyen 1998).

The problem was further exacerbated by fixed settlements, and intense and persistent grazing by cattle (Walker *et al.* 1981; Grossman and Gandar 1989). Overstocking resulted in the change in vegetation structure in the form of species composition change, decline in perennial grass cover and an increase in the biomass of annual grasses and woody vegetation (Walker *et al.* 1981; Grossman and Gandar 1989). The results are unproductive savannas with high proportions of unpalatable grasses (Walker *et al.* 1981; Grossman and Gandar 1989).

Exotic grazers in these systems are not effective in maintaining the balance between the trees and the herbaceous layer as they consume a negligible amount of the woody vegetation (Walker *et al.* 1981). If the herbaceous layer is maintained at low densities for a long time due to grazing, the soil surface will change which will lead to a decrease in the infiltration rate (Walker *et al.* 1981). Ultimately this water will be accessible to woody plants; as a result their biomass will increase (Walker *et al.* 1981). In short the savanna system will be transformed.

2.3.2 Causes of over-utilization in South Africa

Grossman and Gandar (1989) attribute the degradation of South African arid savannas to increasing costs of production and high land prices, population increase in communal farms, firewood collection, rural-urban fluxes, population resettlement, replacement of diverse indigenous herbivores by grazers, misconception about some grazing strategies, changes in fire regimes, perverse incentives and the subdivision of farms into sub-economic units. These problems force farmers to overstock, woody biomass is over-exploited, the soil is impoverished, the 'veld' is overgrazed, the balance between trees and the herbaceous layer is disturbed and the soils are eroded (Grossman and Gandar 1989). Banks *et al.* (1996) warns that initiatives aimed at addressing deforestation will fail if the socio-economic situation of the people does not improve.

2.4 Energy Use in Southern Africa

Southern Africa has a wide variety of energy resources (traditional and modern) but the availability of these resources varies greatly from country to country (Eleri 1996). Biomass (fuelwood, charcoal, and crop residues) is the dominant energy in the region and accounts for eighty percent aggregate energy demand, but coal and deposits of crude oil are also found within the region (Eleri 1996). There is a huge potential for hydropower exploitation in southern Africa (Eleri 1996). Woodfuel is used mainly for cooking, lighting, and heating (space warming) with a substantial amount of wood used in agro-industries and brick firing (Eleri 1996). The contribution of woodfuel to the total energy consumed ranges from fourteen percent in South Africa to ninety-three percent in Malawi and Mozambique (Eleri 1996).

Woodfuel is widely used in southern Africa as a main source of energy, but it also has a luxury or recreational market. Unlike commercial use which may require high quality firewood, domestic use of firewood is less selective and a variety of species are used (Briers and Powell 1996). Woodfuel consumption has been noted as a major contributor to the total wood removal in the world and it accounts for ninety-two percent (92%) of the total African wood consumption (FAO-WETT unpublished). The exploitation of firewood can be regulated by integrated policies and management plans (Eleri 1996).

2.5 Incentives and Disincentives for Conservation

2.5.1 Convention on biological diversity

According to the Convention on Biological Diversity (UNEP-CBD 2002), Article 11, all contracting parties should adopt economically and socially acceptable incentives for conservation and sustainable use of components of biological diversity. States are further bound by the UN Charter and principles of international law to use their resources in such a way that the environment of neighbouring states is not compromised (UNEP-CBD 2002: Article 3). As a result of these basic principles, states are looking at acceptable ways within their borders to protect biodiversity.

These ways are classified into incentives, perverse incentives and disincentives. Incentives are tools or measures that are used to encourage appropriate management practices and protect priority areas (NBI-SA 2001; Botha and Njobe unpublished; Barnes *et al* unpublished). Introduction of incentives is done because of the realization that conservation objectives cannot be achieved in public reserves alone and that a variety of approaches are required to successfully address all pressures on biodiversity (NBI-SA 2001). Disincentives discourage bad practices whereas perverse incentives promote unsustainable use of resources indirectly (NBI-SA 2001).

The most commonly used forms of incentives are motivational incentives, voluntary schemes, property or rights-based incentives, fiscal and economic incentives and regulatory incentives (NBI-SA 2001). Motivational incentives involve extension service provision; rights-based incentives entail allocating use rights in exchange to conserve; fiscal and economic incentives include tax rebates, cash grants, and subsidies; and regulatory incentives comprise rules and laws guiding conservation behaviour (NBI-SA 2001). It is argued that a reasonable access to wood resources can be given to the local communities in a sustainable way especially in areas that were previously not accessible (Shackleton 1993), and that this will reduce the pressure on existing resources.

2.5.2 Legislative power

Governments or relevant authorities make the laws and regulations to protect the environment and in some quarters this method is referred to as "command and control". The authorities can introduce a permit system or taxes and fines and this should be affordable (not too high or too low) so that transgressors are not forced to resort to illegal means while ensuring that the law is still respected (Goodstein 1999). In some quarters of economics, legislation is regarded as inefficient because it applies uniform standards and is not cost-effective (Goodstein 1999). The main criticism against uniform standards is that benefits and costs vary from place to place (Goodstein 1999).

If the punishment and the likelihood of being caught are high enough to discourage illegal trade, compliance may benefit potential offenders in the form of avoided punishment costs (fines and penalties, a damaged reputation, and the fear of jail terms). The compliance costs comprise additional outlays and resources to complete paperwork (Goodstein 1999). The marginal benefits of compliance can be increased by increasing the severity of the punishment and the monitoring of compliance (Goodstein 1999). Enforcement of the law depends on motivation, training and experience of the enforcement staff (Goodstein 1999).

In some instances government enforcement may be inadequate and this problem can be solved by drafting the law in such a way that private citizens are empowered to take violators to court (Goodstein 1999). In short, environmental degradation should be made an expensive activity through the introduction of taxes and marketable permit systems (Goodstein 1999). It should however be noted that there is no tool that is universal and without flaws.

2.5.3 Standardization and certification

Developments in forest management lately have focused on progressing towards sustainable forest management based on the "Forest principles" agreed at the United Nations Conference on Environment and Development (UNCED) that was held in Rio in 1992 (FAO 2001). The sustainable management concept balances environmental, socio-cultural, and economic objectives of management (FAO 2001) and this is done by indicator and criteria setting. It should however be noted that the setting of criteria and indicators does not automatically translate into good management practices, the implementation of these at the ground level is very important in assuring that resources are used in a sustainable way. It is argued that in the past, traditional tribal laws limited the harvesting of live wood and these laws were respected (Shackleton 1993) but unfortunately that may not be the case now as traditional authorities have limited powers in most cases yet there is still a need for citizens to respect the law.

Forest certification is a tool that can be used to ensure sustainable use of the world's forest resources. It is used to confirm the achievement of certain predefined minimum standards of forest management in a given forest area at a given point in time (FAO 2001). In 2000, the forest area that had been certified was estimated at 80 million hectares which is about 2% of the total forest area of the world (FAO 2001). The most common standards are the International Organisation for Standardization (ISO) 14000 standards and the Forest Stewardship Council (FSC) standards. The FSC certification follows a set of predetermined principles and criteria in assessing the performance of forestry operations (FSC 1996). The ISO 14000 provides a framework for managing and auditing forest resources (ISO 2002).

The *A. erioloba* tree is an important tree in arid systems of southern Africa but if the harvesting rate is not controlled there is a risk of resource degradation. The savanna systems need to be managed better and the improvement of management strategies may enable these systems to remain productive for a longer time. It is widely accepted that conservation needs to be encouraged by provision of incentives and when incentives do not work there should be better regulation as existing measures do not seem to halt over-exploitation of the resources.

In conclusion, *Acacia erioloba* is a slow growing tree with sporadic recruitment. It is a key resource and habitat feature for animals and plants in Kalahari arid-savanna. The presence of large old trees lends aesthetic value to the landscape and maintains land-use options such as tourism and game farming. However, landowners consider that bush thickening by this and other woody plants reduce the grazing value of the rangeland. Despite its protected status, *A. erioloba* is being cleared or selectively harvested for sale as firewood. Possible drivers of this activity are a ready market for the wood, and an economic climate where meat prices and profit margins are falling. This thesis will explore the market incentives in order to recommend interventions that can prevent large-scale over-exploitation of this tree species and loss of associated plant and animal diversity.

CHAPTER 3

Study Area

3.1 Description

The study was conducted in the towns of Paarl, Stellenbosch and Somerset West in the Winelands area of the Western Cape Province (Figure 3.1). The Western Cape is found on the southern tip of Africa and is bordered by the cold Atlantic Ocean in the west and the warmer Indian Ocean in the south (GCIS 1998). The province has three climatic regions, a winter-rainfall area around the Peninsula and the Boland areas, the all year-round rainfall area along the south coast towards George and the summer rainfall area in the Great Karoo area (GCIS 1998). The rainfall in the Fynbos biome ranges from 210 mm in the inland valleys to 400 mm on coastal forelands with the mountainous areas receiving between 800-3000 mm (Cowling *et al.* 1997).

The Western Cape Province has the following vegetation types or biomes: Forest, Fynbos, Grassland, Nama Karoo, Succulent Karoo and Thicket (Western Cape Government 2002). The Fynbos, mainly restricted to the winter-rainfall region, is one of the six floral kingdoms of the world. It is a treeless vegetation dominated by shrubs and is highly diverse in terms of species composition (GCIS 1998). It occupies an area of 129 386 km^2 which is just above ten percent of the country's total land area (Central Statistical Services (CSS) 1995; GCIS 1998; Department of Health and Social Services 2000).

The indigenous forests in South Africa cover less than 0,5 percent of the country's land area (Collins 2001; WWF South Africa 2002)), and in the Western Cape these occur in the year round rainfall area on the south coast, and in protected mountain valleys that receive 1000 mm or more rainfall annually. Indigenous forests are noted to be sensitive to harvesting and slow growing and suitable areas for tree growth are limited in South Africa (Collins 2001). According to Owen and van der Zel (2000), South Africa has 360 000 ha of closed canopy natural forest, about 18 million hectares of natural woodlands and about 1.5 million hectares of forest plantations.

Forest plantations occupy 72 727 ha in the Western Cape (FSA 2002) and natural forests occupy about 60 000 ha (DWAF 1995).

Figure 3.1: Study area. The red marking shows the sites that were sampled.

3.2 Demographics and socio-economic status of inhabitants

According to the 1996 census the province has 4 108 860 people which makes about ten percent of the South African population with the majority of inhabitants speaking Afrikaans (59%) followed by English (20%) and isiXhosa (19%) (GCIS 1998; Department of Health and Social Services-Western Cape 2000). Eighty-seven percent (87%) of the entire provincial population stays in towns whereas the national average is fifty-four percent (Department of Health and Social Services 2000). The province has the highest Human Development Index (0.76) in South Africa compared to the national average of 0.69 (Department of Health and Social Services 2000). About seven percent of people aged 20 years or more have not undergone any schooling, 17.9 percent (national average 33.9%) are unemployed, Eighteen percent of the employed earn less than R500 (national average 26%), and both the infant and maternal mortality rates being very low compared to the national average (CSS 1995; Department of Health and Social Services 2000).

The average number of people that have access to electricity for cooking and heating in the Western Cape is comparable to the national average. Access to electricity is not equally distributed across population groups but the majority of households have access to electricity for cooking and heating purposes (Figure 3.2).

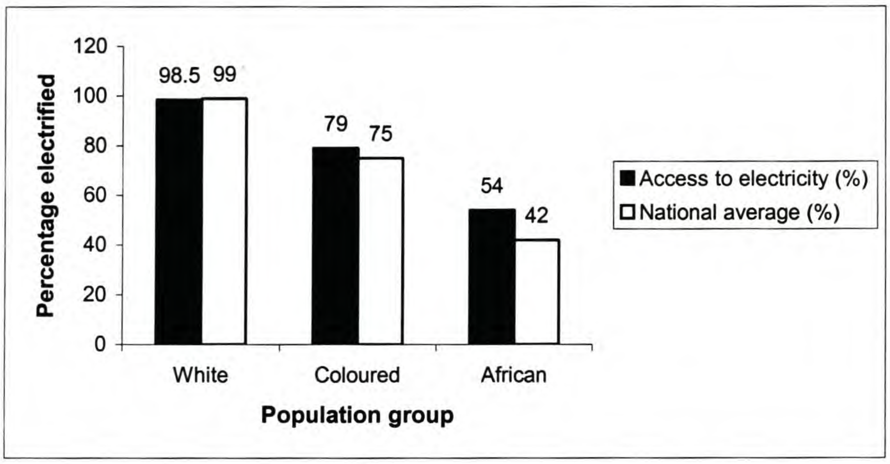

Figure 3.2: Access to electricity for heating and cooking in the Western Cape by population (Source: October household survey, 1995).

Nine percent of African households in urban areas of the Western Cape use wood for heating and four percent use wood as fuel for cooking compared to five percent that uses wood for heating and four percent for cooking nationally (CSS 1995). In the Western Cape, ten percent of the Coloured households use wood for heating and six percent for cooking which compares well with the national figures of nine percent and six percent for heating and cooking respectively (CSS 1995).

The majority of households, African (39%) and Coloured (45%) get their firewood from the 'veld' while 19 percent and 32 percent of African and Coloured households respectively get wood from merchants (Figure 3.3). If it can be assumed that the firewood from woodlots, forests, veld and homeyards is not paid for, then 67 percent of the African and 68 percent of the Coloured households do not pay for firewood that they use. Nationally, 19 percent of African and 33 percent of the Coloured households pay for firewood that is used (CSS 1995) and this compares well with the provincial figures. No information on firewood used for recreational activities could be found. It was also not possible to access information on how many white owned households use firewood for heating purposes.

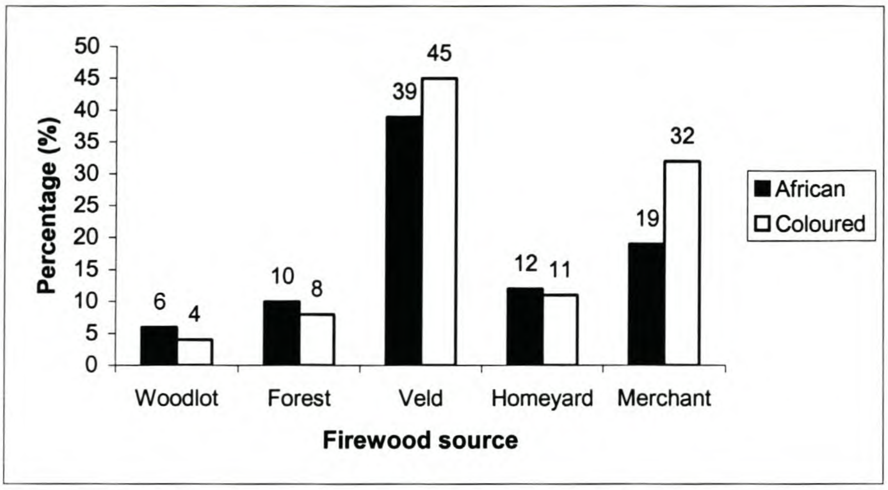

Figure 3.3: The proportion of households that get wood from recorded sources for domestic use in the Western Cape by population group (Source: October household survey, 1995).

The Stellenbosch Municipality has a population of slightly more than 100 000 inhabitants with the majority concentrated in Stellenbosch (Zietsman 2001). Fifty-nine percent of inhabitants are 19-60 years of age, nine percent are between 14 and 18 years, 24 percent are below 14 years of age, six percent are above 60 years and about two percent were unspecified (Zeitsman 2001). Seven percent of the potentially economic active group is unemployed (Zeitsman 2001) and 89 percent of the entire population has access to electricity. The Drakenstein Municipality (where Paarl is situated) has a population of 186 188 of which about 10 percent is illiterate, 17 percent unemployed and 83 percent has access to electricity (CSS 1996). Thirty percent of the people found in the Drakenstein Municipality are classified as children, 38 percent as youth, 27 percent as middle aged and four percent as elderly (CSS 1996). It was not possible to get the demographic information of the Somerset West area as it is now part of the bigger City of Cape Town Municipality and the information is aggregated.

CHAPTER 4
Social Survey

4.1 Introduction

The firewood supply chain involves different role-players with different needs and the understanding of how each role-player is affected or benefits will enable the study to understand the chain better. The aims of this chapter are to review the literature on firewood sales and the supply chain, to determine the role that is played by consumers, retailers and the transport sector in the *A. erioloba* firewood industry, to determine the level of understanding about the protected status of indigenous trees by retailers and consumers and to further establish the motivations for firewood use and sales in the study area. Finally, the identification of the important role-players in the firewood supply chain.

4.1.1 Firewood Sales

4.1.1.1 Overview of firewood industry around the world

The purchase of firewood is influenced by timely supply, reliability of the quantity and quality of firewood, consistency, convenience, absence of contamination, income, preferences of end-users, and the price (Leach and Mearns 1988; Hoadley 2000; Kanel 2000; ANU Forestry 2001). The price of firewood is influenced by the price of the automotive fuels which can increase the cost of harvesting and transporting firewood, the distance from the source of firewood, and the introduction of taxes (FAO 1985; Leach and Mearns 1988; ANU Forestry 2001). Fuelwood marketing includes the following steps: wood production on-farm or off-farm, harvesting and conversion of trees, transportation, and the transaction of fuelwood between end-users and retailers or wholesalers (Leach and Mearns 1988; Kanel 2000).

In most cases the fuelwood value does not include production costs, opportunity costs to other industries, environmental costs, welfares costs, and perverse incentives (Doyle 2000). It is obvious that if these costs can be included the revenue can be reduced significantly or the price will be increased. Kanel (2000) stated that, "the market price of bundles of fuelwood is equal to the value of labour devoted to the collection and transportation of fuelwood". The supply can be influenced by the property right regimes of the land and forests, the technology of production, and input costs (Leach and Mearns 1988; Kanel 2000). Banks *et al.* (1996) highlighted the fact that an understanding of wood supply and demand alone will not be enough to guide which form of action is to be taken. There is a need to understand how wood is used locally and the social, economic, and ecological determinants are important in identifying the priority areas for intervention and sustainable consumption rates (Leach and Mearns; Banks *et al.* 1996).

Doyle (2000) showed that in some parts of Australia, woodlands and forests are being depleted due to over-harvesting and in some parts firewood is supplied from woodlands which are about 500 km away and the supply for the study area comes from areas that are more than 1000 km away. The firewood industry depends on outdated measures such as the total reliance on native woodlands and forests to supply its products (Doyle 2000). Therefore, there is a need to establish a large, profitable, plantation-based firewood industry (Tűrker and Kaygusuz 1995; Doyle 2000) but Kanel (2000), indicated that forest or tree management devoted to firewood production cannot be profitable. Sound policies are important in regulating the firewood industry as they (policies) can affect the cost of production, transportation, conversion, and the ultimate use of firewood or substitutes (Leach and Mearns 1988; Kanel 2000).

The density of energy in firewood is low compared to the volume and together with the increasing distances from the source implies that the cost of transportation is a major determinant of the total value of purchased firewood (Leach and Mearns 1988; Kanel 2000). Kanel (2000) highlighted the fact that people whose opportunity cost was lower than the market price of firewood were the ones who collect and sell firewood but in this case firewood was sold by farmers even though the work was done by poor labourers. It is possible that farmers were experiencing difficult times or that their opportunity cost was low (i.e. there is not much else that they could sell). Unemployment drives people to sell firewood as a livelihood means and if they can be provided with more productive jobs, their opportunity cost of labour would increase

(Leach and Mearns 1988; Kanel 2000). The property rights of forest owners should be clearly defined, and the rules and regulations should be enforceable (Leach and Mearns 1988; Kanel 2000).

4.1.1.2 The supply chain and its contribution to the firewood price

The economics of wood supply are strongly influenced by the concentration of the resource (the growing stock per hectare) which is in turn influenced by climatic and site conditions and silvicultural practices of managers (FAO 2001). Leach and Mearns (1988) divided the firewood supply chain into three broad categories namely; resource price, roadside price and transport costs. A permit system can be used to allocate harvesting rights to harvesters and/or transporters may be charged along the way for the amount of wood they are transporting (Leach and Mearns 1988). The weakness of this strategy has been identified by Leach and Mearns (1988) as the avoidance of paying fees especially if they are too high. The problem can be avoided by empowering the local authorities to implement the laws (Leach and Mearns 1988).

The roadside prices include tree felling and chopping, transportation to the roadside and stacking, capital investment in the form of axes, saws, barrows and carts, rural wage rates, labour efficiency and supervision (Leach and Mearns 1988). Haulage distance, truck size and payload, road conditions, loading time, and fuel and maintenance costs are the major determinants of the transport costs (Leach and Mearns 1988). Modes of transport such as return transport (wood specific), back haulers (wood transporting as a side-business) and integrated transporting (big volume trucks owned by wholesalers) can also have a significant effect on the final firewood price (Leach and Mearns 1988).

In addition to the above-mentioned costs, wholesalers and retailers may incur additional costs in the form of bagging and bundling, storage and security, and stall license fees (Leach and Mearns 1988). The costs can be reduced by shortening the supply chain which will reduce the mark-up costs and improve the efficiency and finally, the selling of firewood of better quality (Leach and Mearns 1988). It should however be noted that the retail price should be affordable to the consumers, otherwise they will be forced to switch to cheaper options (Leach and Mearns 1988).

4.2 Methods

A structured questionnaire was developed for retailers, transport owners and consumers (a separate questionnaire for each sector). A mixture of open-ended and closed questions was used of which the majority of questions were open-ended. A face-to-face interview method was used when both retailers and consumers were interviewed. A census of all the retail outlets that sell firewood in Stellenbosch, Somerset West and Paarl town centres (n = 37) was carried-out in 2002. Firewood consumers were visited at different recreational barbecue or 'braai' sites around the Cape Town area and this was done because the initial strategy of waiting for consumers at the retail outlets was not successful.

The areas visited are Paarl Mountain Nature Reserve (near Paarl), Wiesenhof, Assegaibos Nature Reserve, the Eiland (all near Stellenbosch), Kogelbay and Blaauwberg (Big Bay) and a hundred (100) people were interviewed in total (see Fig. 3.1). The data were processed using the Statistical Package for Social Scientists (SPSS) programme. A telephone interview method was used for obtaining information from transport owners. In this case transport owners who have telephone numbers listed with the telephone utility were telephoned (13 listed) with the assumption that they should represent all the transport owners. Only two transport owners were able to respond positively with one disclosing all the information and the other feeling that some information was his business secret. The preference index was used to determine the preferred firewood type and it was given by the following formula:

$$\Pr eferenceIndex = \frac{AmountTaken}{AmountAvailable}$$

$$AmountTaken = \frac{BundlesofA.eriolobaBought}{AllBundlesofFirewoodBought}$$

$$AmountAvailable = \frac{BundlesofA.eriolobainShop}{AllBundlesofFirewoodinShop}$$

4.3 Results

4.3.1 Types of firewood sold

Five kinds of firewood were offered for sale at one or more of the retail outlets surveyed in the Winelands area during this study. Wood originated as a by product of fruit-farming, from alien vegetation clearing programmes, or from natural savanna beyond the borders of the Western Cape. The wood types encountered in the study area were "wingerdstompe" or commercial Grape Vines (*Vitis vinifera* L), off-cuts from commercial plantation trees such as *Eucalyptus sp.* and *Pinus sp.*, invasive alien woody weeds including Black Wattle (*Acacia mearnsii*), Rooikrantz (*Acacia cyclops*), and indigenous Camelthorn (*A. erioloba*) wood imported from the Northern Cape Province and Namibia.

4.3.2 Firewood ranking by retailers and consumers

Of the 30 retailers (81% of the retailers) who ranked *A. cyclops* according to how it sells, 83 percent said it sells best, the remaining seventeen percent ranked it second (Figure 4.1). Nine percent of the 11 retailers (30%) that ranked *A. mearnsii* said it was best selling, 64 percent ranked it second and 27 percent ranked it third (Figure 4.1). Forty-four percent of the 18 retailers (49%) that ranked *A. erioloba* said it was the best selling firewood type, 50 percent ranked it second and the remaining six percent ranked it third (Figure 4.1). Twenty-two percent of the 9 retailers (24%) that ranked *V. vinifera* said it was best selling, 33 percent ranked it second while 44 percent rated it as the third best firewood type (Figure 4.1).

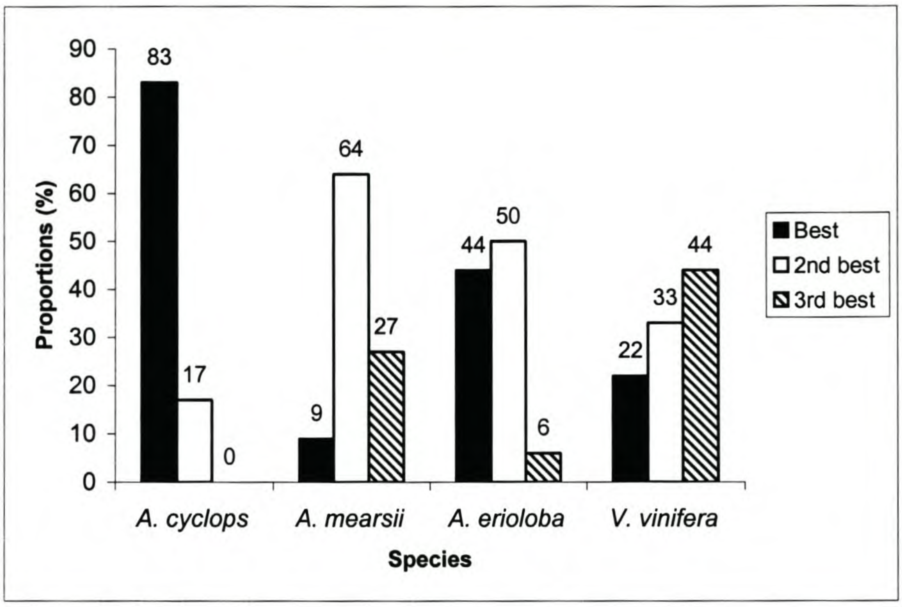

Figure 4.1: The proportion of retailers that ranked the firewood types according to how they sell (*A. cyclops* (n = 30), *A. mearnsii* (n = 11), *A. erioloba* (n = 18) and *V. vinifera* (n = 9))

Eighty-one percent of the retail outlets in the Winelands area sold *A. cyclops*, 49 percent *A. erioloba*, 30 percent *A. mearnsii* and 24 percent *V.vinifera* (Table 4.1). *Acacia cyclops* is the common species sold in the study area. Eighty-five percent of the consumers in the study area use *A. cyclops* as the main type of firewood, twenty-one percent *A. mearnsii*, fifteen percent *V. vinifera*, eleven percent *A. erioloba* and the remaining use wild olive (*Olea africana*), *A. saligna* and pine (*Pinus sp.*) (1% for each species) (Table 4.1). Most consumers use *A. cyclops* in the study area.

Table 4.1: The availability and use of various firewood types in the study area

Wood type	Availability (% of shops)	Use (% of consumers)
A cyclops	81	85
A mearnsii	30	21
Vitis vinifera (Vine-stems)	24	15
A erioloba	49	11
Olea africana (wild olive)	0	1
A saligna	0	1
Pinus sp (Pine)	0	1

4.3.3 Prices of firewood

A kilogram of *V. vinifera* was found to be the most expensive at R1.59, followed by *A. erioloba* at R1.49, *A. mearnsii* (R1.21) and the cheapest was found to be *A. cyclops* at R1.11 (Table 4.2). One (1) South African Rand was able to buy 16.81 megajoules (MJ) of *A. cyclops* , 15.96 MJ of *A. mearnsii*, 13.62 MJ of *A. erioloba* and 12.37 MJ of *V. vinifera* (Table 4.2).

Table 4.2: The cost of firewood per unit (Dry mass and heat value) of the four firewood types sold in the Winelands Area.

Species	Price (R)	Mass (Kg)	MC (%)	Dry mass (Kg)	HV (MJ/Kg)	P/M (R/Kg)	Heat/Bag (MJ)	HV/P (MJ/R)
A.m.	7.72	8.87	27.9	6.39	19.27	1.21	123.18	15.96
A.c.	8.01	10.21	29.6	7.19	18.74	1.11	134.72	16.81
A.e.	8.15	6.09	10.4	5.45	20.35	1.49	110.98	13.62
V.v.	7.55	6.88	30.8	4.76	19.62	1.59	93.36	12.37

KEY

R = Rand	P = price	*A.c.* = *A. cyclops*
MC = moisture content	M = mass	*A.e.* = *A. erioloba*
HV = heat value	*A.m.* = *A. mearnsii*	*V.v.* = *V. vinifera*

4.3.4 Seasonal trends in firewood sales

All the firewood types sold best in summer, with the sales for *A. mearnsii* and *V. vinifera* being the same for the winter season and all year round (Figure 4.2). *A. erioloba* sales were never mentioned to peak in winter. The peak demand (summer) for *A. cyclops*, *A. erioloba* and *V. vinifera* were longer than that of *A. mearnsii* (more than 70%) (Figure 4.2). Even though the majority of retailers showed that *A. mearnsii* sales peaked in summer, Twenty-seven percent of the retailers indicated that the sales were either constant or peaked in winter (Figure 4.2).

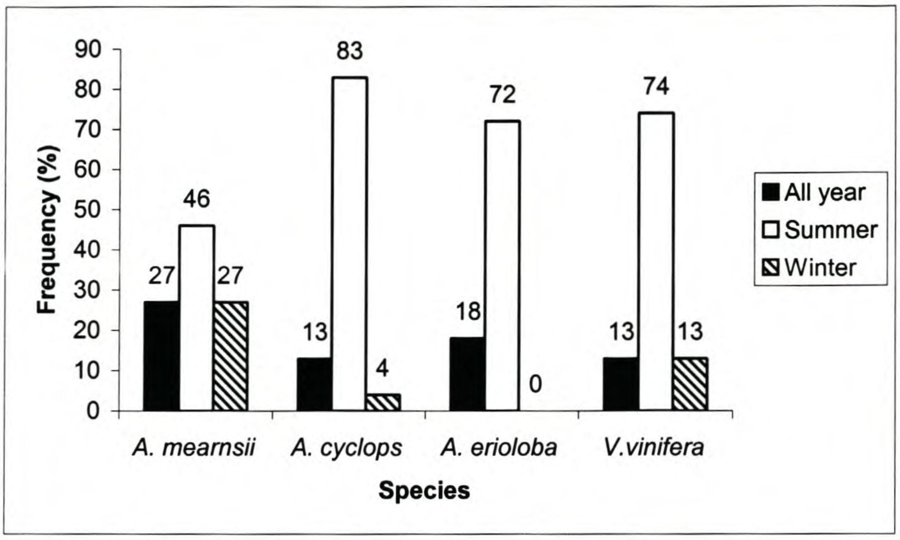

Figure 4.2: The proportion of retailers that responded on when their sales peaked (season during which more firewood is bought).

Fifty-eight percent of the 36 retailers that responded to how the peak period affected their stock, said their stock was never affected and 42 percent showed that their stock was affected. Sixty-one percent of the 15 retailers that indicated that their stock was affected by the peak period showed that they ordered more when the demand increased. Twenty-three percent showed that they had to wait for the supply to come and eight percent got their supply from the 'sister' companies (Figure 4.3). The remaining eight percent showed that they ordered less when the season was not good for firewood sales (Figure 4.3).

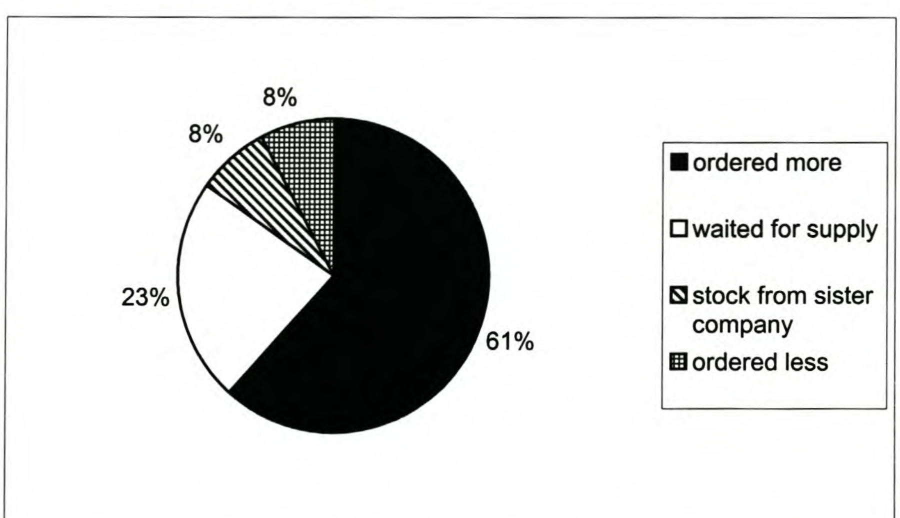

Figure 4.3: Retailers' response on what they did when the demand for firewood increased. Proportions based on 15 retailers who said their stock was affected by the peak season.

4.3.5 Consumer Awareness

Fifty-five percent of a hundred (100) consumers interviewed were aware that indigenous trees are protected by Law in South Africa. A large proportion (41%) had no knowledge about protected trees while three percent guessed that alien invasive trees are protected and one percent said trees of Cape origin are protected. The majority of respondents made the choice for firewood based on whether it can provide good embers (coals) or not and all the firewood types that were used in the study area were reported to have good coals as shown by the long bars at A (Figure 4.4).

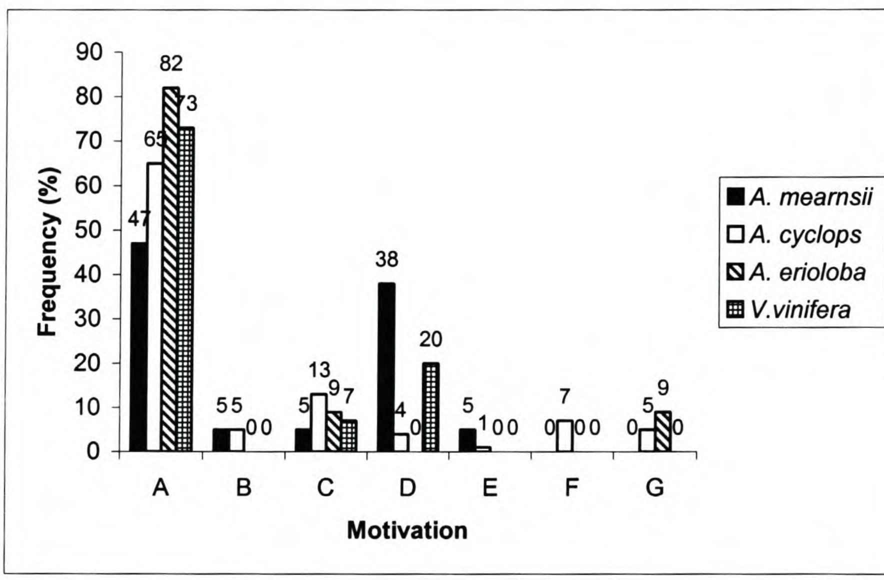

Figure 4.4: Motivation for using four common firewood types in the Winelands area

KEY

A = Good coals B = Clean & flavour C = Dry, quick & good coals	D = Lasts longer and cheap E = Multi-purpose F = Easily accessible	G = Good coals and flavour

4.3.6 *A. erioloba* use by consumers

Eleven (11) consumers out of a hundred (100) interviewed said they normally use *A. erioloba*, ten respondents (91%) use it for 'braaing' purposes only and one respondent (9%) use it for the fireplace.

4.3.7 Firewood types tried

Twenty-one more respondents said they sometimes use *A. erioloba* and if this number is added to the 11 that normally use *A. erioloba* the proportion increases to 32 percent (Table 4.3). This takes into consideration the number of respondents that used *A. erioloba* and those that used it in combination with other species.

Table 4.3: The proportion of consumers in response to what other firewood types they have tried other than the one that they use regularly.

Common name	Scientific name	Frequency
Port Jackson	*Acacia saligna*	24
Camelthorn	*Acacia erioloba*	21
Vine-stems	*Vitis vinifera*	18
Black wattle	*Acacia mearnsii*	16
Bluegum	*Eucalyptus sp.*	16
Rooikrans	*Acacia cyclops*	10
Pine	*Pinus sp.*	8
Firewood not used		8
Anything that burns		5
Ironwood	*Olea capensis*	5
Sweet thorn/soetdoring	*Acacia karroo*	2
Ebony	*Euclea sp.*	2
Poplar	*Populus sp.*	1
Orange tree	*Citrus sp.*	1
Yellowwood	*Podocarpus sp.*	1
Peach tree	*Prunus persica*	1
Pear tree	*Pyrus sp.*	1
Oak	*Quercus sp.*	1
Apple-tree (common apple)	*Malus sylvestris*	1

4.3.8 Obstacles for wider use of *A. erioloba*

Twenty-one respondents indicated that they sometimes use *A. erioloba* but they were not using it as often as the preferred firewood type. When responding to why that was the case, forty-eight percent showed that it was not available, thirty-eight percent said it was expensive, ten percent believed that it was not as good as the firewood type they preferred and four (4) percent believed that it was wet (Figure 4.5).

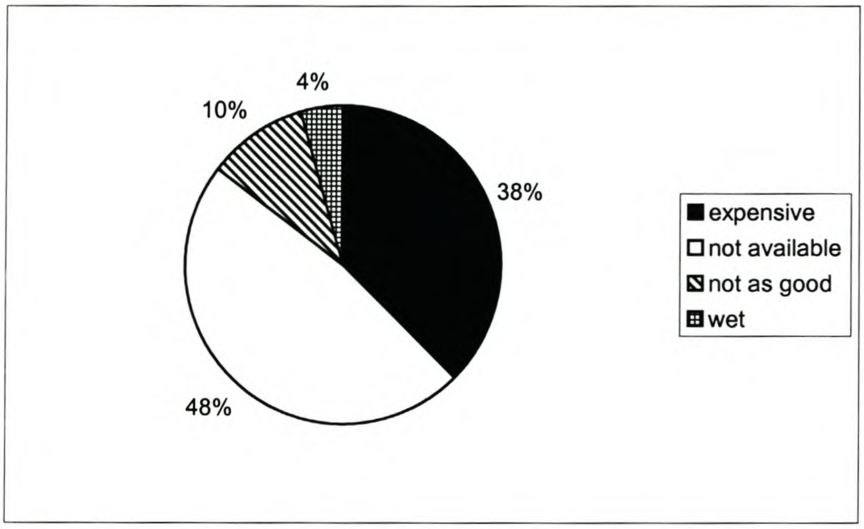

Figure 4.5: Proportion of consumers responding to why *A. erioloba* is not used as often as the preferred firewood based on 21 respondents

4.3.9 Preference index

A. cyclops is the most preferred firewood with a preference index value of 1.15 followed by *A. erioloba* (0.91), *A. mearnsii* (0.72) and the least preferred firewood is *V. vinifera* (0.70) (Table 4.4). This indicates that supplies closely matched demand for *A. cyclops* and *A. erioloba*, but that *A. mearnsii* and *V. vinifera* were oversupplied.

Table 4.4: The preference index table for the different firewood types sold in the Winelands area. Values for amount taken and amount available are based on the proportion of each firewood over the total either sold or bought.

Species	Amount sold (Kg)	Amount bought (Kg)	Amount taken	Amount available	Preference index
A. erioloba	21101.01	40777.42	0.18	0.20	0.91
A. cyclops	75528.99	116003.71	0.65	0.57	1.15
A. mearnsii	13869.55	34230.48	0.12	0.17	0.72
V. vinifera	5293.75	13406.25	0.05	0.07	0.70
Total	115793.30	204417.87			

4.3.10 Price difference along the supply chain

The bulk of the revenue goes to the transporter (36%) and the retailer (31%), the farm owner received twenty-three percent and the labourer got the least (10%) (Figure 4.6).

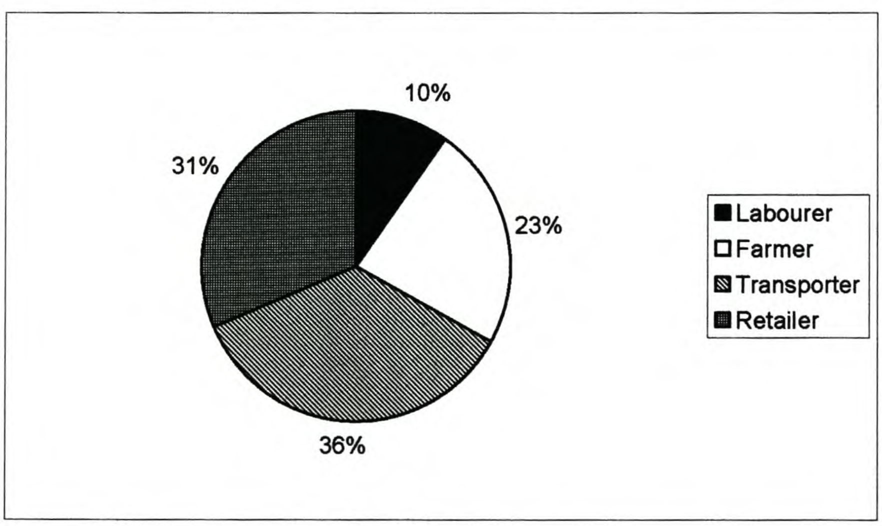

Figure 4.6: Revenue sharing by sector. Values (labourer, farmer and transporter) based on information from Milton (2001) (unpublished) and the final mean retail price (R8.15) in the study area.

4.3.11 Who is using or selling firewood

About 89 percent of the retailers were between 21 and 50 years of age with the majority (about 46%) being between 21 and 30 years of age (Figure 4.7). Three percent of the retailers were above 60 years of age and none of them were below 21 years of age (Figure 4.7).

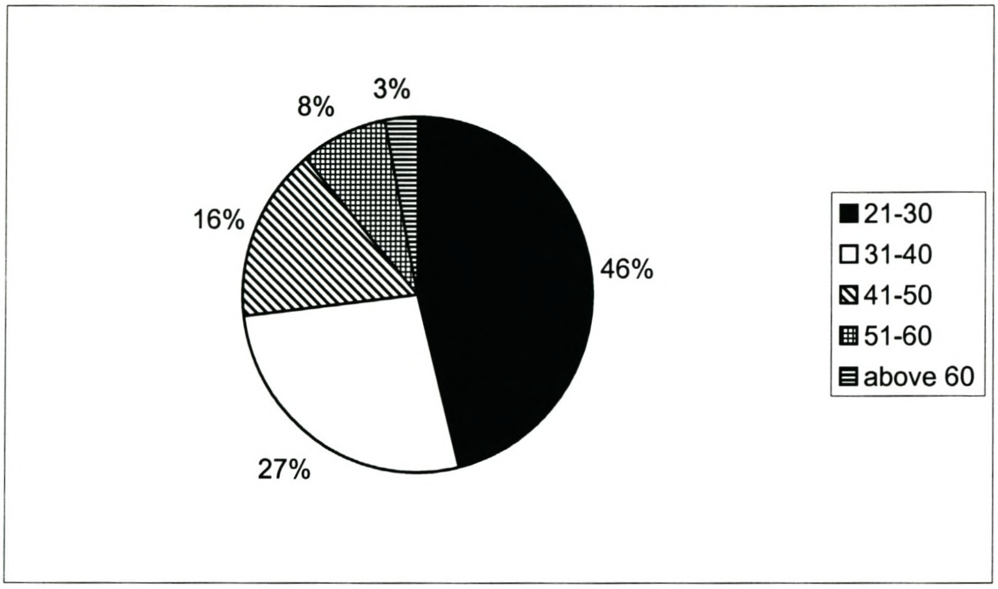

Figure 4.7: Retailers by age groups

Most of the consumers (87%) were aged between 21 and 50 years with a larger percentage (35%) being between 31 and 40 years of age (Figure 4.8). Three percent were below 21 years of age and none was found to be above 60 years of age (Figure 4.8).

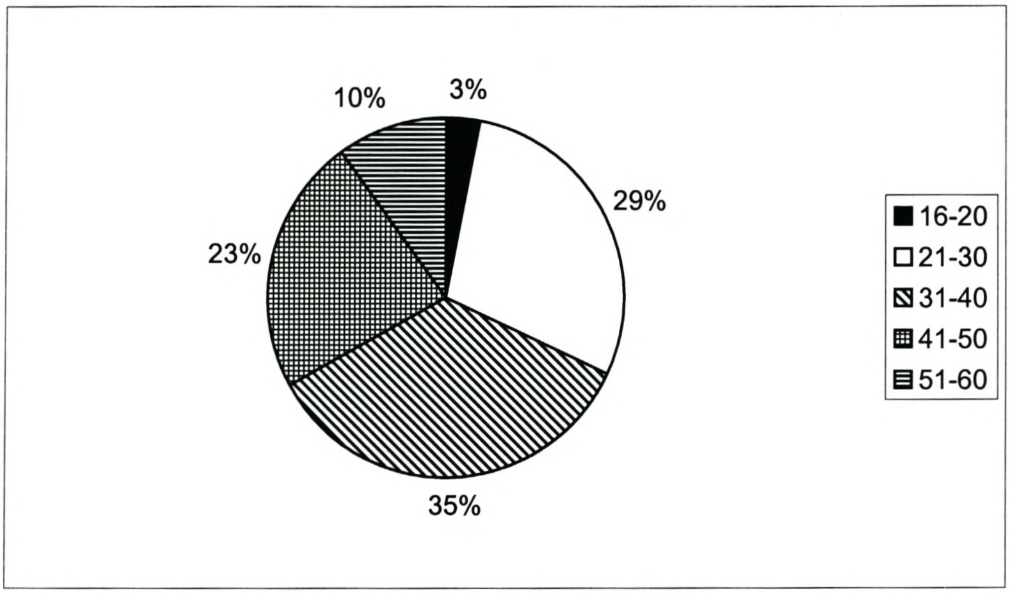

Figure 4.8: consumers by age groups.

4.4 Discussion

Vitis vinifera was found to be more expensive when one looked at the cost per kilogram and this was slightly different from the expectation as one believed that *A. erioloba* would be more expensive as it is transported over longer distances. There are two possible explanations to this deviation from the expectation. Firstly, *V. vinifera* was found to be lighter in weight and bulky as a result a bag full of these pieces will weigh less than other firewood types. This was supported by the density results which clearly showed that *V. vinifera* was the least dense firewood compared to other firewood types sold in the Winelands area. The bulkiness can therefore deceive consumers who may think that there is more firewood in the bag. Secondly, *V. vinifera* came from the surrounding vine farms and as a result this firewood was sold at a higher price compared to the firewood that came from the Working for Water area where some costs were paid for by the development project (*A. cyclops* and *A. mearnsii*). In short, it would more expensive to cut, package and bundle the firewood at the farm as the farm owner has to pay for all these activities.

A bundle of *A. erioloba* looked very small but it followed *V. vinifera* in terms of cost per kilogram at R1.49. This was expected as this firewood type came from the Northern Cape Province and Namibia and had to be transported over long distances. The transport and handling costs were expected to add to the final retail price. This agrees with what Leach and Mearns (1988) found when they were looking at what could increase the price of firewood. The distances of over 1000 kilometers are too long yet the cost of a bundle of *A. erioloba* was not very different from other firewood types.

The mean retail price of all the firewood types ranged from R1.11 per kilogram for the cheapest (*A. cyclops*) to R1.59 per kilogram for the most expensive firewood in the Winelands area (*V. vinifera*) yet the firewood came from different locations which are far apart. *A. erioloba* came from the Kalahari region which was over a 1000 km from the study area, *A. mearnsii* and *A. cyclops* came from the Working for Water Project area in the Western Cape Province and the harvesting of these firewood types was subsidized by the development project while *V. vinifera* came from the surrounding Vineyard farms. It is either that the firewood that came from the Working for Water Project area (*A. cyclops* and *A. mearnsii*) was over-priced or *A. erioloba* was under-priced. There may be several explanations for this similarity in prices as it was expected that the transport costs would increase the price of a bundle of *A. erioloba* significantly. If *A. erioloba* was under-priced, the trade will not be sustainable because the rate of removal will deplete the resource. One of the possible reasons for low prices may be the transport subsidies, as will be explained in more detail in the following paragraph.

Leach and Mearns (1988) divided the transport sector into return transport, back hauling and integrated transporting. Both the back hauling and integrated transporting were reported to reduce the costs involved in transporting firewood. Therefore, if the firewood is not under-priced then these modes of transporting firewood may be playing an important role in the *A. erioloba* trade and lowered the retail prices. If the firewood that comes from the Working for Water Project area is over-priced that will be a clear indication of an increasing demand (Stern 1999). This may be a good sign to business but a serious concern to policy makers, environmentalists and conservationists as this demand should be satisfied all the time or otherwise natural populations will have to meet the demand. In most cases population growth had been noted to increase consumption of firewood to levels higher than woodland production (Banks *et al.* 1996). Alternatively the implication is that the firewood was affordable to the people in the study area which may be an indication of their higher buying power.

Clearly, if the demand surpasses the supply, there will be more pressure on the resources especially naturally occurring populations to satisfy the demand. In the Western Cape managers should start measuring the available firewood stock and calculating how long the available resource would last so that they could plan accordingly or otherwise indigenous trees will become victims of the trade. Abbot *et al.* (1997) and Abbot and Lowore (1999) highlighted the fact that indigenous trees are the preferred firewood because of their quality. Jain and Singh (1999) supported this by showing that the gap between demand and supply can be eased by increasing the supply of better quality firewood.

The bigger share of the money that is made in the firewood trade goes to both the transport owners (36%) and the retailers (31%) and this agrees with previous studies (Leach and Mearns 1988). It should however be noted that the share that goes to retailers is purely hypothetical as the telephone interview with transport owners was not successful. Only two transport owners were willing to disclose some information and in one case the respondent was willing to tell how much is charged per bundle, so the information from this sector cannot yield any statistically meaningful results. But surely, if sixty-seven (67) percent of the share goes to the two sectors then it is obvious that they are the main beneficiaries in the trade.

When it comes to the heat that is produced for every R1.00 spent, *A. cyclops* was found to yield more returns followed by *A. mearnsii* and then *A. erioloba*. One would have expected *A. erioloba* to yield more returns as it has a high calorific value, higher density and lower moisture content but that was not the case. The lower moisture content is a common phenomenon in hardwoods and higher moisture contents are reputed to decrease the available heat of combustion (Jain and Singh 1999; Bhatt and Tomar 2002). This can be as a result of the greater mass and the relatively lower prices for both *A. cyclops* and *A. mearnsii*. This is also supported by the data from the retailers that showed more retail outlets (81%) selling *A. cyclops* and 83 percent of the retailers ranking it as the best selling firewood. It had been reported that a higher ash content in firewood especially silica reduces the calorific (heat) value (Abbot *et al.* 1997; Jain and Singh 1999; Bhatt and Tomar 2002) and this was the case with *A. erioloba*.

A. erioloba is ranked second by retailers and it is the second most common firewood sold in the Winelands area despite the fact that the heat produced per Rand placed it third in the ranking list. This can be accounted for by the fact that *A. mearnsii* is mainly seasonal and from the personal communication with the consumers it was discovered that it was used mainly for the fireplace. Normally, more firewood is used for the fireplace and this was bought in large quantities from local suppliers and roadside vendors in the study area. The implication is that it makes economic sense to buy firewood types that give you more returns for the money spent and unfortunately that may not be the case if one buys *A. erioloba*.

The majority of consumers (85%) said the firewood type that they used frequently was *A. cyclops* and *A. erioloba* came fourth in the list. If firewood quality was the main criterion used by the consumers for firewood selection then the expectation would be that *A. erioloba* and *A. mearnsii* should rank higher than *A. cyclops* in the list. There is a strong possibility that consumers were influenced by the availability of *A. cyclops* in this case and this was supported by the fact that *A. cyclops* was the most common species sold in the study area.

The other possibility is that consumers may be aware that they were getting their money worth especially in terms of the energy that is given for every Rand spend as *A. cyclops* topped the list in this respect. It was also discovered (from the communication with consumers) that the consumers that did not know much about firewood were advised by retailers or suppliers to use *A. cyclops* for 'braai' purposes and *A. mearnsii* for the fireplace. It was therefore deduced that suppliers were aware that *A. mearnsii* had longer lasting coals than *A. cyclops* and because 'braaing' does not take long it was wise to use the firewood that had coals that would last long enough for the activity.

All the firewood types were reported to sell best in summer and this could be associated with the fact that the main activity was 'braaing' (barbecue) and the study area experienced winter rainfall. Fifty-eight percent of the retailers showed that the peak period does not affect their firewood stock and this could be attributed to good stock control. In retail outlets that were affected by the increasing demand, the majority (69%) showed that they ordered more firewood when the demand was higher. When the information from the retailers who showed that their sales peaked in summer and the consumers who specified that most of the firewood was used for 'braaing' was combined, there is a strong possibility that the firewood sold in the Western Cape retail outlets was targeting mainly the 'braai' market.

The majority of consumers interviewed (55%) were aware that indigenous trees were protected by law in South Africa but a large proportion (45%) did not know or were not sure if there were any protected trees. It was also noted that some consumers did not know what indigenous trees were as some of them believed that exotics such as *A. cyclops* and *V. vinifera* were indigenous. There is therefore a need to disseminate information to raise consumer awareness if their help may be required. Simple non-scientific phrases should be used. The exotic may not be easily understood by a non-scientist. In some cases consumers were even saying *A. erioloba* was exotic as it did not come from the Western Cape.

Eleven percent of the consumers preferred *A. erioloba* which ranked it fourth after *A. cyclops*, *A. mearnsii* and *V. vinifera* and an additional twenty-one (21) respondents indicated that they sometimes use *A. erioloba,* this added up to thirty-two percent. When asked why they did not use *A. erioloba* as often as the preferred firewood, eighty-six percent of the 21 respondents claimed that *A. erioloba* was not always available or it was more expensive compared to other firewood types. This showed that there is demand for *A. erioloba* and this was also supported by the fact that it was the second common species sold in the study area. The preference index values also placed *A. erioloba* second after *A. cyclops*. Is *A. erioloba* preferred because of its quality or because it was readily available in the Western Cape? It is doubtful that it was selected because of its good coals (embers) as consumers believed that every firewood type that they use was of high quality or had better embers except for *A. saligna* which everyone was complaining that it did not produce embers. Only experienced firewood users were able to tell how different species differed in terms of their quality.

In conclusion, there is clearly a demand for firewood in the study area and retail prices of firewood were comparable. The price of *A. erioloba* was found to be relatively lower which may be an indication for the involvement of backhauling and integrated transporting which implied that the industry was well coordinated. The level of consumer awareness was higher than that of retailers which was understandable as most retailers were not specializing in firewood sales but were selling it because it was demanded by their customers. Firewood consumers were mainly influenced by the availability of firewood and adequacy of embers to make a choice for firewood. This study gives a better understanding of the *A. erioloba* firewood supply chain and retailers and transport owners were found to be important role players.

CHAPTER 5
Wood Quality

5.1 Introduction

Among other things firewood preference was found to be influenced by the quality and quantity of firewood (Leach and Mearns 1988; Kanel 2000). The basic properties of wood such as density, moisture content, ash content and calorific value differ from species to species. Most of these properties are not totally independent, for instance, moisture content and ash content have a direct influence on the density which may in turn influence other properties of wood. Density, moisture content, ash content and heat values are then used to calculate Fuelwood Value Index (FVI) which is an index of firewood quality that is the firewood with the highest FVI is regarded as the best firewood (Abbot *et al.* 1997; Jain and Singh 1999; Bhatt and Tomar 2002). The purpose of this chapter is to review the literature on wood quality and methods used for its quantification, and then to compare the quality of all the firewood types sold by different sampled retail outlets using the Fuelwood Value Index and to establish if there is a suitable substitute for *A. erioloba* in the study area.

5.1.1 Wood structure

Wood can be classified into two main categories, softwood which is the wood that comes mainly from Gymnosperms, and hardwood which comes mostly from Angiosperms (Tsoumis 1991; Kollmann and Côté 1968). Gymnosperms are fine-leaved cone bearing trees whereas angiosperms are broad-leaved and the seeds are not protected in the cone. Hardwoods can be divided into two groups; ring-porous hardwoods in which earlywood pores are larger than latewood pores, they (pores) are also arranged in a ring around the pith, and diffuse-porous hardwoods, in this case pores are more or less uniform in size and are scattered (Tsoumis 1991). The arrangement and type of vessels that constitute softwoods, ring-porous hardwoods and diffuse-porous hardwoods is different and therefore the classification is based on how the vessels are arranged in the wood material.

The way vessels are arranged affects the important properties of wood such as density which in turn has a direct influence on other basic wood properties (Tsoumis 1991). When the cells are closely packed and composed of vessels with higher density, the implication is that there is more wood material per unit volume (there is more to burn). Wood is mostly made up of dead cells which are mainly in the form of cell walls, wood tissue, cementing material, and cell cavities (cell lumina) (Tsoumis 1991).

The principal chemical elements of wood are carbon (C), hydrogen (H), oxygen (O) and small amounts of nitrogen (N) (Eberhard 1990; Tsoumis 1991). The proportions of these materials differ between hardwoods and softwoods. The main organic components of wood are cellulose, hemi-cellulose, lignin, mineral water, and small amounts of pectic substances (Eberhard 1990; Tsoumis 1991). It is mainly these organic materials that are burned during combustion. Extractives which are mainly organic in nature and minerals are normally stored in wood vessels. Extractives include gums, fats, resins, sugars, oils, starches, alkaloids, and tannins and can be extracted from wood using cold or hot water or neutral organic solvents such as alcohol, benzene, acetone, or ether (Tsoumis 1991).

5.1.2 Density of wood

Density is defined as the dry mass contained in a unit volume of wood, which is an index of quantitative production (Koehler 1924; Tsoumis 1991; Haygreen and Bowyer 1996). Density is described as a good index of wood quality as it affects hygroscopicity, shrinkage and swelling, mechanical, thermal, acoustical, electrical, and other basic wood properties (Tsoumis 1991; Hoadley 2000). It (density) can be affected by the cellular composition (structure), proportion of void volume, cell types, moisture content, chemical composition, and extractive content of the wood (Tsoumis 1991; Haygreen and Bowyer 1996). This can lead to a situation in which wood types with the same density exhibiting differences in wood properties.

The proportion of latewood to earlywood influences density, due to the fact that latewood have thicker walls and smaller cavities (Tsoumis 1991; Haygreen and

Bowyer 1996). Latewood is therefore denser than earlywood. The amount of extractives deposited within cell walls and in the cavities have a direct influence on density (Tsoumis 1991; Haygreen and Bowyer 1996). The higher the amount of extractives contained in wood the higher the density.

There can also be a variation in density within a tree, between trees of the same species, and between species (Tsoumis 1991; Haygreen and Bowyer 1996). Within a tree there can either be a vertical or a horizontal variation. The variation between trees of the same species is influenced by soil type, water, climate, slope, aspect, latitude, stand composition, and tree spacing (Tsoumis 1991; Haygreen and Bowyer 1996). The variation between species is caused by the difference in the anatomical structure (Tsoumis 1991). All the above mentioned factors affect the size and wall thickness of the cell and thus the density (Haygreen and Bowyer 1996).

Wood being a hygroscopic material can either experience an increase in density or a decrease depending on the absorption or loss of moisture respectively. Density can be classified as oven-dry density, basic density, and air-dry density (Tsoumis 1991). The amount of cell wall material and cell cavities affects the density of wood. The cell wall material can be influenced by the anatomical structure of wood which may also differ depending on the position in the tree or due to the growth conditions (Tsoumis 1991).

5.1.3 Moisture content

The moisture content is defined as the weight of the water expressed as a percentage of the moisture free or oven-dry weight of wood (Koehler 1924; Kollmann and Côté 1968; Tsoumis 1991; Haygreen and Bowyer 1996). It can also be expressed as a percentage of wet weight in other applications. The weight of water in the green wood is commonly greater than or equal to the weight of dry wood substance. This water is located within the cell wall and in the cell lumen (Haygreen and Bowyer, 1996).

When all the water in the cell lumen has been removed and the cell walls are still saturated, the wood is referred to as to have reached the fibre saturation point

(Koehler 1924; Kollmann and Côté 1968; Tsoumis 1991; Haygreen and Bowyer 1996). The fibre saturation point is affected by extractive content, the proportion of earlywood and heartwood, compression and tension wood, density, and temperature (Kollmann and Côté 1968; Tsoumis 1991) and most wood properties change below the fibre saturation point (Koehler 1924).

Moisture content may be affected by species, position of wood in the tree (source), tree age, extractive content, thickness, density, temperature, season of the year, site quality, and relative humidity (Tsoumis 1991; Haygreen and Bowyer, 1996). The maximum moisture content that wood may contain depends on the space available in its mass (Tsoumis 1991). The amount of moisture in wood is important because it affects its weight, strength, shrinkage or swelling, durability, finishing, conductivity, inflammability, and permeability (Koehler 1924; Kollmann and Côté 1968; Tsoumis 1991).

5.1.4 Ash content

The inorganic part of wood is analyzed as ash by burning the wood material at temperatures around 600 °C. Wood ashes consist mainly of potassium, calcium, magnesium, silicon, and phosphoric acid in combination (Koehler 1924). The ash content of wood ranges from about 0.1 percent to seven (7) percent (Koehler 1924). The ash content has a direct effect on heat value and combustibility of wood as it is non-combustible.

5.1.5 Heat value (Calorific value)

The heat value is defined as the quantity of heat produced from a mass of 1 gram or 1 kilogram of wood when it is completely burned (Koehler 1924; Eberhard 1990). The molecules forming wood's major constituents were made by using the energy from the sun and it is this energy that is released during combustion (Hoadley 2000). The burning process takes place under the action of high temperatures and leads to the chemical decomposition of wood and the production of flammable gases (Koehler 1924).

The combustion process begins with the evaporation of moisture, followed by the evaporation of volatile substances; the superficial carbonisation and exit of flammable gases; and the ignition and formation of glowing charcoal (Koehler 1924). If different fuels are to be accurately compared, it is crucial that energy release is measured in the same way (Eberhard 1990), and the bomb calorimeter offers these conditions. The flammability of wood is affected by factors such as species, moisture content, temperature, dimensions, and wood structure while the heating value is influenced by moisture content, extractives, and the chemical composition of wood (Koehler 1924).

Moisture reduces the heating value whereas extractives especially oleoresin together with lignin increase the heating value as they have a higher heating value compared to cellulose (Koehler 1924). The presence of resin in softwoods is the main reason that causes the difference in heating values between hardwoods and softwoods (higher heating values for softwoods than in hardwoods). Species with long, open passages in their mass are more flammable (the case of hardwoods) than species with short and closed vessels (tracheids) (the case of softwoods) (Koehler 1924). Small pieces of wood and constructions that favour free movement of air facilitate the ignition and combustion of wood (Koehler 1924). Eberhard (1990) observed that the spread of calorific values is between 15 to 25 MJ/kg with most values lying between 18 and 21 MJ/kg.

5.2 Methods

Wood quality analyses were carried out on the four types of wood most commonly offered for sale in local retail outlets (*A. erioloba, A. mearnsii, A. cyclops* and *V. vinifera*). Wood samples used in quality determination tests were obtained from a minimum of three suppliers so as to get representative samples.

5.2.1 Density

Density was determined using the liquid immersion method (Steinmann and Vermaas 1978). The wood samples were about 20 mm thick. The method involved the impregnation of wood samples with water under vacuum (-90 kPa) for five (5) hours and soaking under pressure (600 kPa) for about twelve (12) hours (over-night) in the pressure vessel. The wood samples were then left in water for an additional two (2) hours after the pressure had been released. The mass of the saturated sample was then determined. The wood samples were then oven-dried for 48 hours (until a constant mass was reached) at 103 ± 2°C. The densities of the four firewood types were compared using ANOVA and Scheffe's Test (STATISTICA 6.0.)

$$Density = \frac{OvendryMass}{SaturatedVolume}$$

$$SaturatedVolume = \frac{Mass\langle SaturatedSampleInAir\rangle - Mass\langle SaturatedSample\,\mathrm{Im}\,mersed\rangle}{DensityofLiquid}$$

5.2.2 Moisture content

The as-received moisture content was determined (Tsoumis 1991) because wood is a hygroscopic material and the firewood that was bought had different levels of moisture content. In this case, firewood was bought from surrounding retail outlets. Three different retail outlets were chosen for each firewood type. This was done to ensure that the samples chosen were representative and it should be noted that there was no retail outlet that was selling all the four firewood types. A total of eight (8) retail outlets was chosen. The firewood was then cut into discs of about 20 mm thickness. These discs were weighed and then oven-dried for approximately fifteen (15) hours (until a constant mass was reached). The as-received moisture content was determined. The moisture contents of the four firewood types were compared using ANOVA and Scheffe's Test (STATISTICA 6.0.)

5.2.3 Ash content

To determine the ash content, wood had to be prepared for chemical analysis using the TAPPI standard method (T 264 om-88) (TAPPI 1992). In this case wood samples were oven dried at 103 ± 2°C, to constant weight. Firewood samples were chipped, ground and milled through a 40 mm wire-mesh. Extractives were then removed using the non-polar solvents (alcohol, benzene and distilled water). The ash content was then determined using TAPPI standard method T 211 om-85 (TAPPI 1992). The dry samples were then burned in a muffle furnace at 575 ± 25° for 4 hours to ensure complete combustion. The remaining ash was then weighed and the percentage ash content determined. The firewood samples from the eight different retail outlets were used. The ash contents of the four firewood types were compared using ANOVA and Scheffe's Test (STATISTICA 6.0.).

5.2.4 Heat value (calorific value)

The calorific value of wood was determined using the (Digital Data Systems) CP 500 Automatic Calorific Processor. Twenty-one (21) samples were taken from each species and the average calorific value was calculated. The standard experimental procedure was followed based on the instructions given by the manufacture. The main components for determining the heat value are the calorimeter (including the firing chamber), interface, balance, solid state cooler, the filling station (with gauges), oxygen cylinder, the bomb (and other accessories), running water tap, and the pellet-maker. ANOVA and Scheffe's Test were used to compare results.

5.2.5 Fuelwood Value Index (FVI)

The fuelwood value index was calculated using density, ash-free calorific value (heat value), moisture content and ash content values as described by Abbot *et al.* (1997); Jain and Singh (1999); and Bhatt and Tomar (2002). The firewood with the highest fuelwood value index is regarded as the best (Abbot *et al.* 1997; Jain and Singh 1999; Bhatt and Tomar 2002). The formula is as follows:

$$FVI = \frac{Density \times AshfreeHeatValue}{MoistureContent \times AshContent}$$

5.2.6 Temperature change over time

The four different firewood types were burned in a self-made 25 litre tin stove that had four small holes towards the top end to allow smoke to escape and one bigger hole at the bottom to allow air to flow into the stove so as to facilitate burning. The firewood was placed on a wire-mesh that was in turn placed on a tri-pot stand. The firewood that was used was oven-dried for at least 96 hours at 103 ± 2°C. Most of the firewood pieces used weighed 100-200 grams (g). Each time approximately 1 kilogram of each firewood type was burned in the stove and in most cases about 7-8 pieces were used. Blitz firelighters which were supported beneath the firewood were used to start the fire.

An oil-bath containing 770 ml of cooking oil was prepared and a thermometer was inserted into the oil to record temperature changes. The temperature was measured every five minutes and recorded. The ambient air temperature was also measured. This method was repeated at least seven (7) times for each firewood type. The average values for each point were calculated and the curve of temperature against time was constructed. The four different curves were compared focusing mainly on the peak temperature, the length at which each firewood type sustained temperature above 100°C and the time taken to reach the peak temperature.

5.3 Results

5.3.1 Density

A. erioloba had the highest density (0.756 ± 0.014 (S.E.)), followed by *A. cyclops* (0.662 ± 0.019 (S.E.)), *A. mearnsii* (0.576 ± 0.013 (S.E.)) and *V. vinifera* had the least density (0.513 ± 0.009 (S.E.)) (Table 5.1). The sample size (n) for all the species was twenty (20) except for *V. vinifera* which had twenty-one (21) samples (Table 5.1). The results were significantly different that is all the density values were different from one another (Table 5.1). This means that *A. erioloba* was found to be denser than all the four firewood types.

Table 5.1: Mean species density of four firewood types sold in the Winelands area ($F(3, 77) = 55.022$, $p < 0.05$). If species (firewood types) share a letter, the implication is that they are not significantly different when a Scheffe's Test is performed.

Firewood Type (species)	Mean Density (g/cm^3)	Standard Error	Range (-95% - +95% confidence interval)	Sample Size (n)	Scheffe's Test
A. erioloba	0.756	0.014	0.727 – 0.785	20	d
A. cyclops	0.662	0.019	0.622 – 0.702	20	c
A. mearnsii	0.576	0.013	0.548 – 0.604	20	b
V. vinifera	0.513	0.009	0.493 – 0.533	21	a

5.3.2 Moisture content

A. erioloba had the lowest moisture content (10.44 ± 2.08 (S.E.) %) and *V. vinifera* had the highest at 30.08 ± 2.13 (S.E.) % while the moisture contents of *A. cyclops* and *A mearnsii* were similar to that of *V. vinifera* which were 29.59 ± 2.08 (S.E.) % and 27.91 ± 2.13 (S.E.) % respectively (Table 5.2). The post-hoc test (Scheffe's Test) (Table 5.2) showed that the results were significantly different, that is all the other moisture contents were different from that of *A. erioloba* but they were not different from one another (*A. cyclops, A. mearnsii* and *V. vinifera*). *A. erioloba* was found to be the driest of all the four firewood types sold in the study area.

Table 5.2: As-received mean moisture content of the four firewood types sold in the Winelands area ($F(3, 88) = 21.188$, $p < 0.05$)

Firewood Type (species)	Moisture Content (%)	Standard Error	Range (-95% - +95% confidence interval)	Sample Size (n)	Scheffe's Test
A. erioloba	10.44	2.08	6.30 – 14.57	22	a
A. cyclops	29.59	2.08	25.45 – 33.73	22	b
A. mearnsii	27.91	1.88	24.18 – 31.65	27	b
V. vinifera	30.80	2.13	26.57 – 35.04	21	b

5.3.3 Ash content

A. erioloba had more ash (1.42 ± 0.16 (S.E.) %) than all the other species (Table 5.3). It was followed by *V. vinifera* (0.92 ± 0.03 (S.E.) %), *A. cyclops* (0.52 ± 0.11 (S.E.) %) and *A. mearnsii* had the least (0.22 ± 0.01 (S.E.) %) (Table 5.3). The post-hoc test (Scheffe's Test) revealed that the ash contents of *A. erioloba*, *V. vinifera* and *A. mearnsii* were significantly different ($p<0.05$) from one another (Table 5.3). There was no significant difference between the mean values of *A. mearnsii, A. cyclops* and *V. vinifera* (Table 5.3) that is the means of both *A. mearnsii* and *V. vinifera* were closer to that of *A. cyclops*. But it should be noted that the ash contents of *A. mearnsii* and *V. vinifera* were significantly different from one another (Table 5.3). Therefore, *A. erioloba* contained more mineral salts than the other species.

Table 5.3: The average ash content of the four firewood types sold in the Winelands area ($F(3,94) = 26.869$, $p < 0.05$)

Firewood Type (species)	Ash Content (%)	Standard Error	Range (-95% - +95% confidence interval)	Sample Size (n)	Scheffe's Test
A. erioloba	1.42	0.16	1.10 – 1.74	26	c
A. cyclops	0.52	0.11	0.29 – 0.75	26	ab
A. mearnsii	0.22	0.01	0.20 – 0.25	26	a
V. vinifera	0.92	0.03	0.86 – 0.98	20	b

5.3.4 Heat value (Calorific value)

A. erioloba had the highest calorific value (20.36 ± 0.04 (S.E.) MJ/kg) and *A. cyclops* had the lowest calorific value (18.74 ± 0.04 (S.E.) MJ/kg) (Table 5.4). The calorific values of *A. mearnsii* and *V. vinifera* were lower than that of *A. erioloba* but greater than that of *A. cyclops* at 19.27 ± 0. 04 (S.E.) MJ/kg and 19.62 ± 0.06 (S.E.) MJ/kg respectively (Table 5.4). The post-hoc test (Scheffe's Test) revealed that all the calorific values were significantly different ($p<0.05$) from one another (Table 5.4). The firewood type that had the highest heat output was *A. erioloba*.

Table 5.4: The average calorific values (heat values) of the four firewood types sold in the Winelands area ($F(3, 80) = 221.25$, $p< 0.05$)

Firewood Type (species)	Calorific Value (MJ/Kg)	Standard Error	Range (-95% - +95% confidence interval)	Sample Size (n)	Scheffe's Test
A. erioloba	20.36	0.04	20.28 – 20.43	21	d
A. mearnsii	19.27	0.04	19.19 – 19.35	21	b
A. cyclops	18.74	0.04	18.67 – 18.82	21	a
V. vinifera	19.62	0.06	19.49 – 19.76	21	c

5.3.5 Fuelwood Value Index

A. mearnsii had the highest Fuelwood Value Index (18242), followed by *A. erioloba* (10588), *A. cyclops* (8080) and finally *V. vinifera* at 3564 (Table 5.5). *A. mearnsii* was found to be the best firewood.

Table 5.5: Fuelwood Value Index table

Species	HV (MJ/Kg)	Ash –free HV(MJ/KG)	Density (g/cm^3)	MC (%)	Ash Cont. (%)	FVI
A. erioloba	20.36	20.65	0.76	10.44	1.42	10588
A. mearnsii	19.27	19.31	0.58	27.91	0.22	18242
A. cyclops	18.74	18.84	0.66	29.59	0.52	8080
V. vinifera	19.62	19.80	0.51	30.80	0.92	3564

5.3.6 Temperature change

A. erioloba peaked at 160.3°C ± 5.4°C (S.E.) and the peak temperature was reached after 35 minutes. The oil-bath temperature was maintained above 100°C for 100 minutes (Appendix 1). The average peak temperature for *A. mearnsii* was found to be 147.1°C ± 5.9°C (S.E.) which was also reached after 35 minutes. *A. mearnsii* was able to maintain the oil-bath temperature above 100°C for 90 minutes (Appendix 1). *A. cyclops* peaked at 143.9°C ± 5.9°C (S.E.) after 35 minutes and was able to maintain oil-bath temperature above 100°C for 80 minutes (Appendix 1). Finally, vine-stems were found to peak at 139.7°C ± 6.3°C (S.E.) after 35 minutes and maintained the oil-bath temperature above 100°C for 80 minutes (Appendix 1). The results clearly showed the difference in peak temperature but very little difference in the length of time that the species maintained temperature above a 100°C especially if one looks at *A. erioloba* and *A. mearnsii*. When analysis of covariance (ANCOVA) was performed on a log transformed data the results were not significantly different ($p>0.05$) (Figure 5.1).

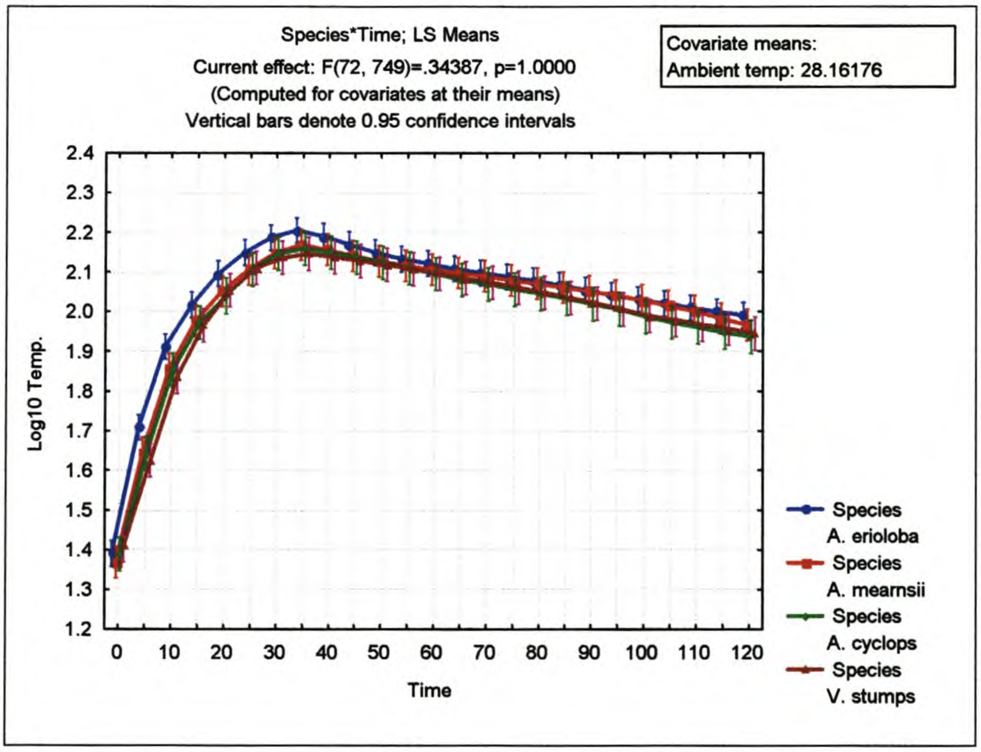

Figure 5.1: A log-transformed mean temperature over time data. The results were analyzed using ANCOVA (STATISTICA 6.0) with temperature as the independent variable, species and time as categorical variables and the ambient air temperature as the continuous variable.

5.4 Discussion

The Fuelwood Value Index (FVI) was used to determine the difference in quality for the four firewood types (*A. erioloba*, *A. mearnsii*, *A. cyclops* and *V. vinifera*). *A. mearnsii* was found to have the highest FVI (18242) followed by *A. erioloba* (10588), *A. cyclops* (8080) and lowest value went to *V. vinifera* (3564). The difference between *A. mearnsii* and *A. erioloba* could be as a result of *A. mearnsii* having a lower ash content, higher ash contents were found to reduce the heat value because minerals that form ash are non-combustible (Jain and Singh 1999).

Bhatt and Tomar (2002) showed that tropical species had higher ash as compared to temperate species. Jain and Singh (1999) further pointed out that higher proportions of carbon in wood can also result in the variation in combustibility of firewood. The difference in the proportions of structural compounds such as hemi-cellulose is also reported to contribute to long lasting coals (Eberhard 1990). One can therefore deduce that even though *A. erioloba* looked superior to *A. mearnsii* in most qualities that were measured, it is possible that some structural elements and lower ash content gave *A. mearnsii* a higher FVI value.

The FVI values in our case were higher than some values found in the literature (Jain and Singh 1999; Bhatt and Tomar 2002) but this difference could be attributed to the fact that moisture and ash content values used in the literature were higher than the ones used in this study. The values in this study were still within the range that some literature specified especially for ash content (Koehler 1924). The calorific values were comparable to those observed in the literature (Eberhard 1990; Jain and Singh 1999). The heat yield of *A. erioloba* compared well with that of *A. nilotica* (20.674 MJ/Kg) (Barnes and Fagg 1995).

The oil-bath experiment did not yield statistically significant results ($p>0.05$) which may give the impression that all the firewood types sold in the study area were similar in the heat output and the time taken to maintain the temperature above 100ºC. The possible explanations to this similarity include the condition under which the experiments were carried out; these were variable as the experiments were conducted outside. When the weather was good, there were clear differences with *A. erioloba* raising the oil-bath temperature the highest, followed by *A. mearnsii*, *A. cyclops* and *V. vinifera*. It should be noted that compounds responsible for raising the temperature are mainly extractives (oleoresin) and lignin and these do not necessarily help in keeping embers (coals) longer.

There was little variation between *A. erioloba* and *A. mearnsii*. Even when it came to maintaining the temperature above 100°C the variation was still too small. These results are still useful as they do not vary a lot from what the laboratory results yielded even though they are the other way round that is in this case *A. erioloba* looks better than *A. mearnsii*. All the firewood types in the study area reached the peak temperature after 35 minutes and this shows that starting with similar levels of moisture and having the same size of pieces/cuts it took almost the same time for wood to burn. The differences in FVI could only be attributed to structural composition of firewood. According to the FVI values, *A. mearnsii* looked to be a superior firewood but *A. erioloba* is also good as it ranked second yet the two species were not as common as *A. cyclops* in retail outlets in the study area.

In conclusion, *A. mearnsii* could be a suitable substitute for *A. erioloba* in the study area as it had a higher FVI value than *A. erioloba* and was comparable to *A. erioloba*, in terms of keeping embers longer and the length of time it took to maintain the oil-bath temperature above 100°C. *Acacia cyclops* is the most commonly used firewood type in the study area.

CHAPTER 6
Conclusions

In the introduction it was assumed that a better understanding of the different role-players along the firewood supply chain would enable us to understand the *A. erioloba* firewood industry which will in turn make it possible to establish links in the chain and determine if there are substitutes for *A. erioloba* firewood. The literature review has shown that the resource plays an important role in arid zones of southern Africa and there is a possibility that it may be a keystone species. It should be noted that it might be dangerous to recommend any form of trade on hardwoods growing in arid systems based on incomplete information and natural mortality of trees especially if the trade has to satisfy the needs of the ever-growing metropolitan areas but this option is explored in scenario three.

Highly demanded species can be protected by use of alternatives or limited commercial exploitation and this can be facilitated by policy (Luoga *et al.* 2000). Therefore, this section focuses on possible interventions on how the industry can be regulated and further highlighting how each sector can be approached. A three scenario approach will be adopted in this case. Scenario one involves stopping the trade completely by enforcing the law and scenario two discusses the involvement of all role-players in protecting the resource, while scenario three looks at a regulated firewood industry.

Scenario One

Degradation of arid savannas has been acknowledged by different authors (Walker *et al.* 1981; Grossman and Gandar 1989; Palmer and van Rooyen 1998; Luoga *et al.* 2000) and therefore this can be used as a starting point. The information on arid savannas of southern Africa is patchy; as a result it cannot allow one to recommend that any form of trade can be controlled. The recruitment rate of *A. erioloba* is not known, and even if it was known, the environmental conditions suitable for the establishment and recruitment of trees in arid systems are variable, unpredictable and harsh.

The amount of the harvestable stock is not known currently but even if the stock was known, harvesting of the resource based on natural mortality of trees for satisfying the needs of markets in metropolitan areas may not be sustainable (Grossman and Gandar 1989). Luoga *et al.* (2000) have noted that subsistence use and low population densities can be sustainable as the resource can have enough time to recover but this may not be possible if the resource is harvested to meet the needs of metropolitan areas. The current laws also prohibit damaging of trees without proper authorisation from the Minister of Water Affairs and Forestry and this authorization goes with the baseline assessment of the available stock, therefore the department can just make it difficult or impossible to get such permits. The assumption is that the law will be enforced successfully, efficiently and cost-effectively which may be difficult as governments are sometimes understaffed and officials cannot be everywhere all the time. This recommendation is based purely on scientific information without looking at other realities and therefore there is a need to look at other options.

Scenario Two

This section focuses on the supply chain by trying to look at how each role-player is affected and how the role-player can be approached starting at the resource level to the end-user level. Luoga *et al.* (2000) stated that "nobody consciously tries to degrade land, but it is an inevitable consequence of use". The results of this study have shown that the protected firewood is transported over distances of more than 1000 km and it is still sold profitably which is different from findings of earlier studies which found that firewood could not be sold profitably when it is transported for more than 100 km (FAO 1985). There may be several explanations to this. The farmers may not be aware of the consequences of the trade, legal or environmental and/or their opportunity cost is so low that they do not care about tomorrow. If this is the case, then there is a need to establish the factors that have lowered their opportunity and how they can be addressed. The economic valuation of the resource should be undertaken to establish the true economic value of the resource and this information should be compared to what farmers are currently making from the sales of firewood.

Wood suppliers

The results also showed that the least share of the final price went to the labourers. Lower opportunity costs had been noted to influence consumption of resources (Kanel 2000). The author (Kanel) recommended that if people were provided with better jobs their opportunity cost would increase. The increase in the opportunity cost of labourers will increase local salaries which will in turn increase the price of the firewood unless other means of lowering the price can be devised. Technological development and discovery of new sources have been noted to decrease the price of a resource or commodity (Jaeger 1995; Goodstein 1999).

The cost of contravening the law is so low that it is not a deterrent. This has been attributed to the fact that authorities may be understaffed or law enforcement staff is demoralised by different factors (Goodstein 1999). Ineffective enforcement of the law has been noted to discourage people from abiding by the law because they may not realise the benefits of adhering to the law (Goodstein 1999). If some powers could be devolved to the local authorities or the law recognises the important role that civilian suits can play in law enforcement then the cost of harvesting the resource can be increased as the probability of being caught when you are engaged in an illegal activity will be increased. As the harvesting cost increases, the price of firewood will also increase and it will become more expensive compared to other options and this will force consumers to find substitutes.

If the harvesting of *A. erioloba* is not driven purely by economic realities, that is farmers and workers may not be aware of the negative effects resource removal could have on their future. Awareness campaigns on how keystone species removal can affect their lives, that of their livestock and the whole environment can be intensified. The process of bush thickening and bush encroachment should be clearly defined to the farmers with few conflicting statements on what causes are and which species are more invasive. Introduction of incentives such as free advice and some tax rebates where possible can also encourage farmers to buy-in into the concept of protecting indigenous trees (Grossman and Gandar 1989; NBI-SA 2001; Botha and Njobe unpublished; Barnes *et al.* unpublished).

Wood transporters

The literature review has shown that backhauling and integrated transporting can reduce the cost of transporting firewood. There is a likelihood that the effect of these modes of transporting firewood cannot be significant if harvesting of the resource is an expensive activity. Transporting firewood from protected resources should become an expensive activity that is, punishments should be high enough to discourage the transport sector from delivering this resource to the wholesalers and retailers. Transport owners as responsible citizens should also be given information on how their activities are affecting the environment. The awareness campaigns can be in the form of radio and television programmes, posters, information leaflets distributed in popular newspapers and discussion with the sector when members are known.

Wholesalers and retailers

Wholesalers' involvement has been noted in the literature review to be capable of reducing the handling and mark-up costs and thus reducing the retail price of firewood. Fortunately, the majority of wholesalers have a reputation which they might not want to dent by selling illegal commodities. The reputable wholesalers need to be given the right information and be encouraged to help in curbing the illegal trade by allowing responsible authorities to put posters that discourage the trade in protected resources at their places. In exchange they may get free publicity in radio and television slots that have been secured for disseminating the information about the dangers of the illegal firewood trade. Those that are not reputable and are not willing to stop selling the resource should be discouraged by tougher laws, constant monitoring and an improved enforcement of the law. Goodstein (1999) noted that stringent application of the laws can restrict illegal activities.

If the firewood supplies from the protected resources (natural woodlands) may not reach the retail outlets it may not be possible for retailers to provide these resources but it is important that they (retailers) should be targeted for information dissemination. Together with an informed public, they can refuse to buy and sell the protected resource provided they have the right information. Local authorities and civilians should be empowered to take action if the law is contravened. This study has shown that retailers tend to sell the firewood that is commonly used (*A. cyclops*) which makes it safe to conclude that they are driven by the demand. This is supported by the response that retailers gave when asked if their supplies were affected by the high demand period where the majority showed that they were never affected. Those that were affected showed that they ordered more which indicated that the supply was not a problem. If consumers do not demand the resource (*A. erioloba*) and the laws are tough then the probability of retailers selling a protected resource will be relatively low.

Wood consumers

The literature review showed that the population in the Western Cape has a high human development index that is, the literacy rate is high, the unemployment rate is low and the number of people found in the lower salary brackets is lower compared to the national averages (CSS 1995). 'Braaing' is a common outdoor entertainment in the study area and therefore there is a market for firewood. This study has also shown that the demand is most probably driven by availability of firewood rather than by the quality, but the concept of quality should not be overlooked completely. Consumers prefer the firewood that can provide embers (coals) and is affordable and available. The results of this study have shown that the firewood sold at the retail outlets is used mainly for 'braaing'. The preference index values showed that *A. cyclops* was the most preferred firewood and the fuelwood value index figures indicated that *A. mearnsii* is a better option despite a popular belief that *A. erioloba* is superior. All this information shows that substitutes for *A. erioloba* are available in the Western Cape and luckily they are all alien and classified as invasive.

The question will then be, are the consumers aware of the negative effects the trade in *A. erioloba* can have on the environment or are they equipped to help in fighting the illegal trade or do they really care. Citizens have contributed positively to the successful implementation of the law in the USA (Goodstein 1999). The results of this study showed that the majority of consumers were aware that the indigenous trees are protected by the law in South Africa which showed that the community is well informed. The implication is that, as responsible citizens, they may be willing to help provided they have the correct information and during the survey some consumers were showing that they can be the first to volunteer if exotics were to be cleared. The only problem that was recognised in this sector is that some respondents were not sure about which trees were indigenous and which ones were alien. This gives the impression that the use of pure scientific expressions should be minimized so that the majority of consumers can get the full meaning of what is communicated to them. The high literacy rate also gives hope that consumers can be able to access the information that is disseminated.

The results of the study have also shown that the majority of retailers and consumers are aged between twenty-one (21) and fifty (50). This is the economically active group and it can be used as a starting point for information dissemination in the short-term. In the long-term, school-going children can be taught about their environment and how they can look after it as they will grow-up with this information and hopefully become caring adults. Awareness campaigns should take into consideration the important role that local languages can play in order for the message to reach a wider audience. The whole exercise can be implemented as a joint-venture between government, environmental organisation, the civil society and the corporate world.

In conclusion, the protection of the resource can be improved by an aggressive campaign to involve all role-players in implementing the law and by the introduction of incentives when the need arises as responsible authorities may not be successful when working alone.

Scenario Three

There is a possibility that the economic position of the farmers or resource owners is so bad that it forces them to sell *A. erioloba* or the resource is plentiful and can be harvested without damaging the environment for a certain period of time as highlighted in the Kimberley workshop but the only weakness is the lack of information. The other possibility may be that, harvesting of the resource may help in thinning the trees where stands have thickened as suggested by some delegates that attended a workshop on protected trees in Kimberley on 29 October 2002. Then, the question will be, how can this situation be addressed. It is obvious that authorities cannot afford to ignore the plea of resource owners because there is lack of information as this might force them into illegal trade which may be difficult to regulate.

A study that assesses how much resource is available and ready for harvesting should be undertaken as the first step and some delegates in the workshop implied that they have an adequate number of dead trees that may be harvestable. The study can be done as a joint venture between resource owners and the responsible authorities (Department of Water Affairs and Forestry) or any organisation that may be willing to fund the initiative. The study should be carried out by a credible person, institution or body. The study should also be able to give recommendation on how much can be harvested for a certain period of time. Once the authorities have satisfied themselves that harvesting can be sustained for a given period of time permits can be issued for harvesting. These permits should clearly outline the conditions that must be satisfied and the punishments. Monitoring and research on how harvesting is progressing and affecting the systems should be part of the deal. Self-monitoring and self-reporting with clear guidelines on what information should be included in the report should be encouraged. The same kind of reporting has been noted to be successful in the USA (Goodstein 1999). If trade is authorised then whoever is transporting firewood should be in possession of valid permits.

It has been shown that firewood trade that relies on natural mortality of trees cannot be sustainable in the long run, therefore, establishment of plantations (*A. erioloba*) on badly degraded sites should be considered as an option for long-term trade in *A. erioloba* as this will reduce pressure on the natural populations in the long run. How will the trade be regulated once it is established? It has been shown that sometimes the law may not be efficient or cost-effective in stopping the trade. After the Rio Convention forest certification has gained popularity as a way of ensuring that forest operations are done in an environmentally friendly way. Bass *et al.* (2001) have noted considerable improvements in forest management and market practices since the introduction of forest certification.

Therefore, farmers may be encouraged to form groups that can be attached to a certifying body. This can be one of the conditions attached to the issuing of the permits. In the beginning resource owners may be given a fixed period of time that they may trade without being certified. This time should not be longer than the prescribed period for sustainable harvesting of firewood. But those that will join later should not be accepted until they are members of a group that has already been certified. The permits can be tradable but conditions should not change unless there is an established need for changes.

If the laws and conditions that go with permits are not followed, the responsible authorities should not hesitate to take appropriate actions. The role that can be played by citizen law suits should be recognised by the law and citizens should be sensitised about the dangers of the illegal trade and how they can notice products from an illegal source. A combination of forest certification and incentive-based regulation measures have a high likelihood of succeeding where purely 'command-and-control' measures are likely to fail.

General conclusions

- There is clearly a demand for firewood in the study area but this demand is not necessarily quality specific rather the demand was found to be influenced more by the availability of the resource.
- *Vitis vinifera* was found to be more expensive than *A. erioloba* even though *A. erioloba* had to be transported over longer distances. This gives the impression

that *A. erioloba* is either under-priced or it is transported cheaper from the source.

- The firewood that is sold by retail outlets in the study area is used mainly for recreational barbecue which is known as 'braaing' locally. It was discovered that firewood for the fireplace is normally bought in large quantities not in small bundles as it can be expensive and this was supplied by local dealers.
- *Acacia mearnsii* was found to be the best firewood in the study area as it had the highest Fuelwood Value Index and it can be a suitable replacement for *A. erioloba* hence there may be no need to bring firewood from outside if the supply can be improved in the study area.
- The majority of consumers were aware that indigenous trees are protected in South Africa, unfortunately that is not the case with retailers.
- The transport owners and retailers were found to be the main beneficiaries along the supply chain and they are the main people that can be targeted if the trade has to be stopped. This can be strengthened by the informed public that may refuse to buy products from illegal sources and/or alert authorities of illegal activities.
- The firewood trade can be stopped by enforcing the law or through the participation and cooperation of different role players. It has been realised that the law has not been very effective in stopping the trade but it is believed that the participation of all role-players can have a positive spin-off on law adherence.
- Finally, if allowed, firewood trade should be regulated and regulation can be enhanced through the introduction of incentives and forest certification as a way of self-regulation.

CHAPTER 7

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Appendices

Appendix A

Table: Mean temperature values for different firewood type recorded every fifth minute with ambient air temperature as a covariate (ANCOVA results)

Species*Time; Weighted Means
Current effect: F(72, 749), p = 1.0000
Effective hypothesis decomposition

Species	Time	Temp Mean	Temp Std.Err.	Temp -95.00%	Temp +95.00%	N
A. erioloba	0	23.7500	1.038100	21.4652	26.0348	12
A. erioloba	5	51.0000	2.956759	44.4922	57.5078	12
A. erioloba	10	81.4167	3.666925	73.3458	89.4875	12
A. erioloba	15	103.8333	4.244128	94.4921	113.1746	12
A. erioloba	20	124.4167	4.466132	114.5868	134.2466	12
A. erioloba	25	141.0000	5.112374	129.7477	152.2523	12
A. erioloba	30	153.7500	5.463550	141.7248	165.7752	12
A. erioloba	35	160.3333	5.375778	148.5013	172.1653	12
A. erioloba	40	154.9167	5.107123	143.6760	166.1574	12
A. erioloba	45	147.9167	5.259131	136.3414	159.4919	12
A. erioloba	50	141.0833	5.129325	129.7938	152.3729	12
A. erioloba	55	135.9167	5.000694	124.9102	146.9231	12
A. erioloba	60	132.4167	5.105639	121.1792	143.6541	12
A. erioloba	65	128.4167	5.087802	117.2185	139.6148	12
A. erioloba	70	125.5000	5.023430	114.4435	136.5565	12
A. erioloba	75	122.5833	5.032408	111.5071	133.6596	12
A. erioloba	80	119.8333	4.744747	109.3902	130.2765	12
A. erioloba	85	116.7500	4.597636	106.6307	126.8693	12
A. erioloba	90	113.4167	4.420096	103.6881	123.1452	12
A. erioloba	95	109.9167	4.203999	100.6637	119.1696	12
A. erioloba	100	107.1667	3.997790	98.3676	115.9657	12
A. erioloba	105	104.5000	3.794933	96.1474	112.8526	12
A. erioloba	110	102.0000	3.582364	94.1153	109.8847	12
A. erioloba	115	99.5833	3.436564	92.0195	107.1472	12
A. erioloba	120	97.5000	3.269464	90.3040	104.6960	12
A. mearnsii	0	22.3750	0.419928	21.3820	23.3680	8
A. mearnsii	5	43.8750	3.440502	35.7395	52.0105	8
A. mearnsii	10	71.2500	3.853338	62.1383	80.3617	8
A. mearnsii	15	94.3750	4.030852	84.8435	103.9065	8
A. mearnsii	20	112.2500	4.439072	101.7533	122.7467	8
A. mearnsii	25	127.2500	5.027602	115.3616	139.1384	8
A. mearnsii	30	140.1250	5.692845	126.6636	153.5864	8
A. mearnsii	35	147.1250	5.871960	133.2400	161.0100	8
A. mearnsii	40	142.7500	4.678026	131.6882	153.8118	8
A. mearnsii	45	137.8750	4.808614	126.5044	149.2456	8
A. mearnsii	50	133.7500	5.041790	121.8281	145.6719	8
A. mearnsii	55	130.2500	5.277141	117.7715	142.7285	8
A. mearnsii	60	127.5000	5.861497	113.6398	141.3602	8
A. mearnsii	65	125.1250	5.914382	111.1397	139.1103	8

A. mearnsii	70	123.0000	6.065123	108.6583	137.3417	8
A. mearnsii	75	119.8750	6.095776	105.4608	134.2892	8
A. mearnsii	80	117.5000	5.750776	103.9016	131.0984	8
A. mearnsii	85	115.0000	5.606119	101.7436	128.2564	8
A. mearnsii	90	112.2500	5.146948	100.0794	124.4206	8
A. mearnsii	95	109.5000	4.492056	98.8780	120.1220	8
A. mearnsii	100	106.3750	4.131488	96.6056	116.1444	8
A. mearnsii	105	103.0000	4.358899	92.6928	113.3072	8
A. mearnsii	110	99.8750	4.257084	89.8086	109.9414	8
A. mearnsii	115	95.7500	4.130678	85.9825	105.5175	8
A. mearnsii	120	92.1250	3.997488	82.6724	101.5776	8
A. cyclops	0	23.5714	1.109636	20.8562	26.2866	7
A. cyclops	5	43.2857	2.678968	36.7305	49.8409	7
A. cyclops	10	70.7143	3.278460	62.6922	78.7364	7
A. cyclops	15	93.0000	3.236694	85.0801	100.9199	7
A. cyclops	20	110.8571	3.334014	102.6991	119.0152	7
A. cyclops	25	127.0000	4.898979	115.0126	138.9874	7
A. cyclops	30	139.7143	5.780568	125.5697	153.8588	7
A. cyclops	35	143.8571	5.909752	129.3965	158.3178	7
A. cyclops	40	140.5714	6.097842	125.6505	155.4923	7
A. cyclops	45	136.7143	5.967030	122.1135	151.3151	7
A. cyclops	50	132.5714	6.221534	117.3479	147.7950	7
A. cyclops	55	128.5714	6.439673	112.8141	144.3287	7
A. cyclops	60	124.2857	6.026585	109.5392	139.0322	7
A. cyclops	65	119.8571	5.382638	106.6863	133.0280	7
A. cyclops	70	116.8571	5.422302	103.5892	130.1250	7
A. cyclops	75	113.4286	4.922529	101.3836	125.4736	7
A. cyclops	80	110.4286	4.597396	99.1791	121.6780	7
A. cyclops	85	107.2857	4.302349	96.7582	117.8132	7
A. cyclops	90	103.8571	4.131347	93.7481	113.9662	7
A. cyclops	95	100.8571	4.061601	90.9188	110.7955	7
A. cyclops	100	96.5714	4.173939	86.3582	106.7847	7
A. cyclops	105	93.2857	3.720690	84.1815	102.3899	7
A. cyclops	110	90.5714	3.456238	82.1143	99.0285	7
A. cyclops	115	87.8571	3.232488	79.9475	95.7668	7
A. cyclops	120	85.5714	2.801846	78.7156	92.4273	7
V. stumps	0	24.8571	1.163504	22.0102	27.7041	7
V. stumps	5	41.5714	2.534121	35.3707	47.7722	7
V. stumps	10	68.2857	4.627631	56.9623	79.6091	7
V. stumps	15	92.2857	5.780568	78.1412	106.4303	7
V. stumps	20	113.4286	7.060477	96.1522	130.7049	7
V. stumps	25	129.4286	8.482074	108.6737	150.1835	7
V. stumps	30	137.0000	7.761320	118.0087	155.9913	7
V. stumps	35	139.7143	6.285714	124.3337	155.0949	7
V. stumps	40	137.0000	6.313251	121.5520	152.4480	7
V. stumps	45	134.1429	6.378642	118.5349	149.7508	7
V. stumps	50	131.1429	6.200724	115.9702	146.3155	7
V. stumps	55	127.5714	5.714881	113.5876	141.5552	7
V. stumps	60	124.4286	5.764659	110.3230	138.5342	7
V. stumps	65	121.1429	5.679657	107.2452	135.0405	7
V. stumps	70	118.0000	5.429198	104.7152	131.2848	7

V. stumps	75	114.7143	5.254088	101.8580	127.5706	7
V. stumps	80	111.4286	5.286358	98.4933	124.3638	7
V. stumps	85	108.1429	5.417909	94.8857	121.4000	7
V. stumps	90	104.8571	5.893615	90.4360	119.2783	7
V. stumps	95	101.2857	6.014721	86.5682	116.0032	7
V. stumps	100	97.5714	5.789387	83.4053	111.7375	7
V. stumps	105	95.1429	5.492109	81.7041	108.5816	7
V. stumps	110	92.5714	5.222922	79.7914	105.3515	7
V. stumps	115	90.4286	5.089004	77.9762	102.8809	7
V. stumps	120	87.8571	5.077629	75.4326	100.2817	7

Appendix B

QUESTIONNAIRE (RETAILERS)

The researcher is interested in the firewood sales in the Western Cape Province (Winelands/Boland Region). Some of the important questions that will assist him in the research include, why firewood is bought; where does it come from and what is it used for. The study will enable the researcher to understand the role that firewood plays in the livelihood of the locals.

1. General Information

Name of the business: --

Town: ---

Sex of the Interviewee: Female ☐ Male ☐

First Language: Afrikaans ☐ English ☐ Other (Specify) ☐

AGE (years as of the birth date)	
Below 16	
16 – 20	
21 – 30	
31 – 40	
41 – 50	
51 – 60	
61 and above	

2.

a)

i. Which types of firewood do you sell?

Black wattle	
Rooikrans	
Kameeldoring	
Wine stumps/roots	
Other (Specify)	

ii. What is the retail price of a bundle or packet of each type?

Black wattle	
Rooikrans	
Kameeldoring	
Wine stumps/roots	
Other (Specify)	

iii. How many bundles of each type do you sell per week/month?

Black wattle	
Rooikrans	
Kameeldoring	
Wine stumps/roots	
Other (Specify)	

iv. Which firewood types sells best? Please rank them according to how they sell, starting with the best selling. **1 = Best, 2 = Second best, 3 = Third best**

Black wattle	
Rooikrans	
Kameeldoring	
Wine stumps/roots	
Other (Specify)	

v. Why do your customers like these firewood types? **(the three best selling)**

Firewood type	**Reason(s)**
1	
2	
3	

b)

i. During which season/time of the year do you sell the most bundles of wood?

Firewood type	**Time/season**
Black wattle	
Rooikrans	
Kameeldoring	
Wine stumps/roots	
Other (Specify)	

ii. How many bundles of each firewood type do you sell during this time?

Firewood type	**Number of bundles**
Black wattle	
Rooikrans	
Kameeldoring	
Wine stumps/roots	
Other (Specify)	

iii. Does this time or season affect your stocks of firewood?

Stock not affected	
Stock affected	

iv. **Please, explain**

----

v. If firewood stocks were affected, how did you solve the problem?

----

vi. How many times per week/month do your supplies come?

----

vii. How many bundles/packets of each firewood type do you buy each time?

Black wattle	
Rooikrans	
Kameeldoring	
Wine stumps/roots	
Other (Specify)	

viii. Who is your firewood supplier? Please provide details

----

c)

i. Do you know where your supplier(s) get the firewood from?

Yes	
No	

ii. If yes, please specify (Name of the place/area)

----

iii. Which of the firewood types that you sell are indigenous?

Black wattle	
Rooikrans	
Kameeldoring/camelthorn	
Wine stumps/roots	
Other (Specify)	

iv. Which of the following trees are protected in South Africa?

Tree groups	
Alien Invasive trees (foreign)	
Trees of Cape origin	
Indigenous trees (local)	

Appendix C

QUESTIONNAIRE (CONSUMERS)

The researcher is interested in the firewood sales in the Western Cape Province (Winelands/Boland Region). Some of the important questions that will assist him in the research include, why firewood is bought; where does it come from and what is it used for. The study will enable the researcher to understand the role that firewood plays in the livelihood of the locals.

1. General Information

Date: --

Town: --

Sex of the Interviewee: Female ☐ Male ☐

First Language: Afrikaans ☐ English ☐ Other (Specify) ☐

AGE (years as of the birth date)	
Below 16	
16 – 20	
21 – 30	
31 – 40	
41 – 50	
51 – 60	
61 and above	

2.

a)

i. Which firewood types do you use?

Black wattle	
Rooikrans	
Kameeldoring	
Wine stumps/roots	
Other (Specify)	

ii. What do you use these/this firewood type(s) for?

Firewood type	**Use**
Black wattle	
Rooikrans	
Kameeldoring	
Wine stumps/roots	
Other (Specify)	

iii. How many bundles of each firewood type do you use on average per month?

Black wattle	
Rooikrans	
Kameeldoring	
Wine stumps/roots	
Other (Specify)	

iv. According to your own opinion, which of these firewood types do you think are the best? Use the following scale to rank them: **1 = Best, 2 = Second best, 3 = Third best**

Black wattle	
Rooikrans	
Kameeldoring	
Wine stumps/roots	
Other (Specify)	

v. Why do you think these firewood types are the best?

Firewood type	**Reason(s)**
1	
2	
3	

vi. How long have you been using these/this firewood type(s)?

Firewood type	
1	
2	
3	

vii. Which other types of firewood have you used in the past?

Firewood type
1
2
3
4
5

viii. Why did you stop using these firewood types?

Firewood type	**Reason(s)**
1	
2	
3	
4	
5	

b)

i. During which season/time of the year do you use the most bundles of firewood?

Firewood type	**Time/season**
Black wattle	
Rooikrans	
Kameeldoring	
Wine stumps/roots	
Other (Specify)	

ii. How many bundles of each firewood type do you use during this time?

Firewood type	**Number of bundles**
Black wattle	
Rooikrans	
Kameeldoring	
Wine stumps/roots	
Other (Specify)	

iii. Do you always find it available at the shops?

Yes	
No	

iv. If not, what do you do when it is not available?

----

v. Do you sometimes buy wood in large quantities? (e.g. truck load)

Yes	
No	

vi. If yes, where do you buy these large quantities? (Supplier details or place)

----

c)

v. Which of the firewood types that you use are indigenous? **(Please tick from the list provided)**

Black wattle	
Rooikrans	
Kameeldoring/camelthorn	
Wine stumps/roots	
Other (Specify)	

vi. Which of the following trees are protected in South Africa?

Trees	
Alien Invasive trees (foreign)	
Trees of Cape origin	
Indigenous trees (local)	

Appendix D

QUESTIONNAIRE (TRANSPORT OWNERS)

The researcher is interested in the firewood sales in the Western Cape Province (Winelands/Boland Region). Some of the important questions that will assist him in the research include, why firewood is bought, where does it come from and what is it used for. The study will enable the researcher to understand the role that firewood plays in the livelihood of the locals.

1. General Information

Name of the business: --

Town --

Sex of the Interviewee: Female ☐ Male ☐

First Language: Afrikaans ☐ English ☐ Other (Specify) ☐

AGE (years as of the birth date)	
Below 16	
16 – 20	
21 – 30	
31 – 40	
41 – 50	
51 – 60	
61 and above	

2.

vi. Which types of firewood do you transport?

Black wattle	
Rooikrans	
Kameeldoring	
Wine stumps/roots	
Other (Specify)	

ii. Where do you get these firewood types from? (Name of the place) (Closest town)

----

iii. Who is the owner of the woodland or source of firewood?

Own	
Private farmer	
Company	
Municipality	
Other (Specify)	

iv. What kind of businesses do you supply with firewood?

Supermarkets	
Garages	
Corner shops	
Other (Specify)	

v. How many times do you make deliveries per week/month?

----

vi. How much firewood do you transport per load?

----

vii. Are you involved in another business?

Yes	
No	

viii. If yes, please specify
