Assessment of trade-offs between timber and carbon values of *Pterocarpus angolensis* (Kiaat) in the Kavango Region of Namibia - a comparison of current and potential values

by

MOSES MOSES

Thesis presented in partial fulfilment of the requirements for the degree of Masters of Science in Forestry and Natural Resource Sciences at the Department of Forest and Wood Science in the Faculty of AgriSciences at Stellenbosch University.

Supervisor: Mr. Cori Ham

Co-supervisor: Prof. Thomas Seifert

March 2013

DECLARATION

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Date: March 2013

ABSTRACT

Kiaat trees in Namibia are threatened by unsustainable harvesting practice. This study's aim was to estimate the total value of an average Kiaat tree selected for harvesting with a focus on current timber use value, value of an optimally utilised tree, carbon value, and alternative uses of Kiaat trees. To accomplish this aim, the following specific objectives were set: (1) to estimate the total tree volume and optimum utilisable timber volume of an average Kiaat tree; (2) to estimate the amount and value of carbon stored in the above-ground parts of an average Kiaat tree; (3) to determine timber utilisation levels; and (4) to identify alternative use options to reduce timber losses of Kiaat trees. Previous studies on Kiaat in Namibia and elsewhere focused on growth, development and socio-economical aspects of Kiaat trees.

A combination of a socio-economic survey and tree volumes and biomass determination was used to collect data. The survey entailed Kiaat products assessment and face-to-face personal interviews with known key-informants in and around Rundu. Loggers with permits to harvest Kiaat trees were asked to harvest 40 Kiaat trees and data collected from each tree before and after felling included: lower-stem diameter, diameter at breast height (DBH), upper-stem diameter, stem length, stump height, recovered merchantable logs lengths and lower-and-upper diameters and lengths of branches greater than 10 cm in diameter. All canopy parts smaller than 10 cm in diameter were directly weighed, sampled and oven-dried at 105°C until constant weight. Volume of different tree parts was calculated and in combination with basic wood density used to calculate the biomass.

It was established that a typically harvested Kiaat tree had an above-ground dry volume of 1.63 m^3, of which 1.34 m^3 (82%) was utilisable timber volume but that only 0.37 m^3 (23%) was used and 0.97 m^3 (59%) was left behind in the field. Merchantable logs were mainly cut into planks from which finished products - beds, chairs, doors and tables - were made. An average of 10.7 planks were cut per trunk and the local price of planks was N$45.26 at the time of the study. More income is generated from finished products compared to selling loose planks. Canopy parts were mainly cut into woodcrafts – bowls, music drums, and walking sticks. Current timber use value (N$484.73) surpasses carbon value (N$123.74).

A further result of the study was that a significantly higher income could be earned for local livelihoods from Kiaat trees in the Kavango Region if trees were optimally used. Carbon trading is a noble conservation initiative, particularly when trees unsuitable for timber are considered. Use of timber trees exclusively for carbon trading is, however, not a viable option in respect of supporting local people's livelihoods.

OPSOMMING

Kiaatbome in Namibië word bedreig deur onvolhoubare ontginningspraktyke. Die doelwit van die studie was om die totale waarde van 'n gemiddelde Kiaatboom, wat gekies is vir ontginning, te bepaal met die fokus op huidige houtwaarde, waarde van 'n optimaal gebruikte boom, koolstofwaarde en alternatiewe gebruike vir Kiaatbome. Om hierdie doelwit te bereik is die volgende spesifieke sub-doelwitte gestel: (1) bepaal die totale boomvolume en optimale bruikbare houtvolume van 'n gemiddelde Kiaatboom; (2) bepaal die hoeveelheid koolstof wat in die bogrondse dele van 'n gemiddelde Kiaatboom gestoor word en bereken die monitêrewaarde daarvan; (3) bepaal die houtgebruiksvlakke en houtvermorsing van Kiaatbome; en (4) identifiseer alternatiewe gebruike om die vermorsing van Kiaatbome te verminder. Vorige studies oor Kiaat in Namibië en elders het gefokus op groei, ontwikkeling en sosio-ekonomiese aspekte van Kiaatbome.

'n Kombinasie van 'n sosio-ekonomiese opname en boomvolume en biomassa bepalings is gebruik vir die insameling van data. Die opname het 'n Kiaat produkbepaling en gesig-tot-gesig persoonlike onderhoude met sleutel informante in en om Rundu behels. Boomkappers met permitte om kiaatbome te ontgin is gevra om 40 Kiaatbome te ontgin en data is versamel van elke boom voor en na ontginning. Die data het ingesluit: lae-stam deursnee, deursnee op borshoogte (DBH), bo-stam deursnee, stamlengte, stomphoogte, herwinde bruikbare stomplengte, bo- en onder- deursnee en lengtes van takke wat 10 cm of groter deursnee het. All kroondele 10 cm en kleiner in deursnee is geweeg en 'n steekproef versamel wat oondroog gemaak is by 105 ^{o}C totdat konstante gewig bereik is. Die volume van verskillende boomdele is bereken en in kombinasie met houtdigtheid gebruik om biomassa te bereken.

Dit is bereken dat 'n tipiese geoeste Kiaatboom 'n bogrondse droë volume van 1.63 m^3 het, waarvan 1.34 m^3 (82%) bruikbare houtvolume is. Net 0.37 m^3 (23%) van die bruikbare houtvolume is egter gebruik en 0.97 m^3 (59%) is agtergelaat in die veld. Bruikbare stompe is meestal opgesaag in planke waarvan finale produkte soos beddens, stoele, deure en tafels gemaak is. 'n Gemiddeld van 10.7 planke is verkry per stomp en die plaaslike prys van planke was N$45.26 gedurende die studie tydperk. Meer inkomste is verkry van finale produkte as van die verkoop van los planke. Kroondele is meestal opgesaag in houtkunswerke soos bakke, musiekdromme en kieries. Die huidige houtwaarde van N$484.73 is meer as die koolstof waarde (N$123.74) van die bome.

'n Belangrike resultaat van die studie is dat 'n beduidende groter inkomste gegenereer kan word vir plaaslike lewensbestaan van Kiaatbome in die Kavangostreek as bome optimaal benut word.

Koolstofhandel is ‘n edele bewaringskonsep, veral as bome ongeskik vir houtgebruik is soos in die geval van krom bome en jonger bome. Die eksklusiewe gebruik van houtbome vir koolstofhandel is nie ‘n lewensvatbare opsie om plaaslike mense se lewensbestaan te ondersteun nie.

ACKNOWLEDGEMENTS

I am sincerely thankful to the following persons or institutions:

- The Directorate of Forestry in Namibia for sponsoring my studies.
- My family, relatives, friends, colleagues, and particularly, my wife, Elizabeth N. Moses, for all their invaluable support, motivation, and understanding – without which I would not have been able to pursue and complete this study.
- My supervisor Mr. Cori Ham and co-supervisor Prof. Thomas Seifert of the Department of Forestry and Wood Science for all their invaluable professional advice, guidance, encouragement, and support throughout. Long live!
- All wood processors (respondents) who participated in the survey.
- Mr. J. Ifile and Mr T. Kambata at Rundu Forestry Office for assisting me during fieldwork.

DEDICATION

This thesis is dedicated to my daughter, Anneline Kenongelo Iyaloo; my Father, Venasiu Moses, and to the memory of my late mother, Ndinomukulili Ndeshikema Ndeutapo.

ACRONYMS

CO_2	Carbon Dioxide
CFs	*Gazetted* Community Forests in the Kavango Region
CPB	Dry Biomass of canopy parts equal to or greater than 10 cm in diameter
CWPA	Categories of Wood Processing Activities
DBH	Diameter at breast height
DF	Degree of Freedom
DoF	Directorate of Forestry in Namibia
FAO	Food and Agricultural Organisation of the United Nations
GPS	Geographic Positioning System
IUFRO	International Union of Forestry Research Organisation
MAWF	Ministry of Agriculture, Water and Forestry (Namibia)
MC	Moisture Content in percentage (%)
NTFP	Non-timber Forest products
R	Basic wood density
RFO	Rundu Forestry Office
SAS EG 4	SAS Enterprise Guide 4
TB	Tuberculosis
tCO_2	Tonne of Carbon Dioxide

Table of Contents

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND INFORMATION

Forests cover more than one third of the total land area of the world and provide timber and non-timber products on which communities depend for livelihoods (Lamlom & Savidge, 2003). The distribution, levels of extraction, and utilisation of timber resources, however, differ with countries in time and space (Lindenmayer & Franklin, 2003; Senguta & Maginnis, 2005). Namibia's forests and valuable timber resources in particular, are not only limited in distribution but they are also selectively harvested by local communities to generate income (Mendelsohn & Obeid, 2005).

Namibia's forests consist of approximately four thousand species of plants, of which 10% are woody species. Forests and woodlands together cover 20%, with forests alone covering less than 10% of Namibia's total land area of approximately 823,680 km^2 with timber resources confined and patchily distributed in the Northern regions (Mogaka *et al*., 2001; Mendelsohn & Obeid, 2005). One of the most important timber species in Namibia, particularly in the Kavango Region, is the Kiaat tree (*Pterocarpus angolensis*). This species is not only the most valuable but also the most over-exploited natural forest resource in Namibia (Mendelsohn & Obeid, 2005).

In Namibia all natural resources, including Kiaat trees are the property of the Namibian State (Article 100, The Namibian Constitution of 1990). The Ministry of Agriculture, Water and Forestry (MAWF) through its Directorate of Forestry (DoF), manages forest resources including Kiaat trees in accordance with the National Forest Act 12 of 2001. The Act promotes conservation and protection of forest resources, *inter alia*, through co-operative and participatory management approaches. In particular, sections 23(1) and 24(1) of the Act, respectively, deals with the "*use of forests and forest produce*" and "*control over afforestation and deforestation*" (The Namibian Parliament, 2001). Although the Act has been in force since 2001, over-exploitation of forest resources, particularly Kiaat trees, remains a problem in Namibia (Loot, 2005).

One reason is that Namibia lacks alternative sources of timber. Plantation forestry, which could be an important alternative to natural forests, is not yet developed or practised in Namibia. Other Southern African countries such as South Africa and Zimbabwe mainly source their timber, for local and industry needs, from exotic plantations (Chibisa & Lameck, 2009). The lack of fast-growing alternative sources of timber is a serious concern, which requires that new approaches and strategies were identified to conserving the existing timber resources.

Many urban and rural based people in the Kavango Region rely on Kiaat trees for incomes (Mendelsohn & Obeid, 2005). Wood processors and timber products traders buy a live Kiaat tree at N$200 on stump and a dead one at N$110, irrespective of size or age of the tree, from the Directorate of Forestry (Ministry of Fianance, 2011). The trees are mainly felled to extract the preferred part or parts of the tree, which are processed into wood products such as planks and woodcrafts. Illegal logging of Kiaat trees, however, is also prevalent in the Kavango Region, which further exacerbates the over-exploitation and non-optimal utilisation of timber trees. A concern is that people in the Kavango Region do not optimally utilise trees but rather fell and remove a portion of the main stem i.e. merchantable log from which they cut products and then abandon the canopy (Figure 1.1) as shown by Pröpper *et al* (2010).

Figure 1.1: A Kiaat tree felled and only its trunk removed (Pröpper *et al*., 2010).

Merchantable logs are further non-optimally processed mainly into planks and wood carvings with old-fashioned processing technologies. These products are traded in highly informal markets, which are characterised by under-pricing of products. This state of affairs results in local people earning less income per tree, thereby leading to more demand for timber trees to satisfy more needs than necessary. This is a main concern since felling of timber trees for sawn-wood and wood carvings takes place at non-sustainable levels in the Kavango Region (Mogaka *et al*., 2001).

One possible way of alleviating wastage and non-sustainable harvesting levels is to adopt a whole-tree utilisation approach that optimizes current direct use of the Kiaat trees and explores their alternative uses as atmospheric carbon absorbers and storage i.e. as carbon sinks. The amount of carbon stored in an average standing Kiaat tree could be an important alternative source of income when exchanged for carbon credits. This approach could save Kiaat trees from over-exploitation because it does not involve felling trees. People could instead earn income as compensation for carbon stored in trees by trading it at international carbon trading markets (Marunda & Bouda, 2010).

Adoption of these alternative markets could enhance forest conservation (Marunda & Bouda, 2010). Increased presence of plants such as Kiaat trees could also contribute to the reduction of atmospheric carbon, thereby mitigate the adverse impacts of climate change (Lamlom & Savidge, 2003; Murdiyarso & Skutsch, 2006). Estimating whole-tree timber value, including the carbon value of Kiaat trees is, therefore, an essential step in generating alternative ways of responsible use and allocation of Kiaat trees.

1.2 PROBLEM STATEMENT

Kiaat trees are currently not optimally utilised and products cut from them are traded at highly informal markets and low prices. In this way local people's livelihoods as well as the sustainability of the forest resources (Kiaat trees) from which the livelihood is derived cannot be improved. Harvested Kiaat trees are non-optimally used as people remove and generate income only from the merchantable logs and leave the entire canopy behind unutilised in the forest (Figure 1.1). This practice could be a result of a lack of knowledge with regards to trade-offs between the current direct-use values and potential values or alternative utilisations of Kiaat trees. Allowing this knowledge gap to remain could negatively affect sustainable management and optimal utilisations of Kiaat trees and threaten the sustainability of livelihoods in the Kavango Region of Namibia.

1.4. OBJECTIVES OF THE STUDY

The objective of this study is to estimate the total value of an average standing Kiaat tree, compare the current direct use value to the value of an optimally utilised Kiaat tree, and identify alternative uses of Kiaat trees in the Kavango Region of Namibia. To accomplish this aim, the following sub- objectives were set:

- ❖ Estimate the total tree volume and maximum potential useful fibre of an average Kiaat tree.
- ❖ Estimate the amount of carbon stored in above-ground parts of an average Kiaat tree and determine its monetary value.
- ❖ Determine current timber utilisation levels of Kiaat trees.
- ❖ Identify alternative uses to reduce timber losses of Kiaat trees.

1.5 SPECIFIC QUESTIONS

During the research process, answers to the following questions were sought:

- ❖ What proportion of the total volume of an average Kiaat tree is currently used and what proportion could be optimally used?
- ❖ Which products are cut from felled Kiaat trees and what are their local prices?
- ❖ What other products can be cut from the residual stem and canopy parts of Kiaat trees?
- ❖ How much carbon is stored in the aboveground part of an average Kiaat tree and how much is it worth?

1.6 THESIS STRUCTURE

This thesis consists of six chapters. Chapter 1 presents the introduction in which the problem statement; main aim and objectives; specific questions; and scope are explained. Chapter 2 presents a literature review, while the methodology and methods of the study are presented in Chapter 3. The results are presented in Chapter 4 and discussed in Chapter 5, while the conclusions and recommendations of the study are presented in Chapter 6.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter is structured into three parts: Part one presents a brief information on forest resource uses in Namibia. Part two presents specific details on *Pterocarpus angolensis* (Kiaat). Part three deals with published information on valuation, management and optimum utilisations of timber resources.

2.1.1 Forests in Namibia

Namibia's vegetation types are divided into savannas (64%), desert (16%) and woodlands (20%) as outlined by Mogaka *et al* (2001) and Mendelsohn & Obeid (2005). Trees in the Namibian woodlands are sparsely distributed in patches; small in size, and grow slowly. Forests growth and structure are greatly affected by widespread and frequent bush fires (Mendelsohn & Obeid, 2005). The Namibian forest area inclusive of savannas and woodlands also decreased by 12.6% between 1990 and 2005 (Jim, 2009) as result of urban settlements and woodland clearing to make way for agricultural fields.

Although Mogaka *et al* (2001) concluded that in general the Namibian forests are unsuitable for industrial timber or pulp, existing timber resources support local livelihoods (Mendelsohn & Obeid, 2005). Trees support hundreds of thousands of people in Namibia, especially in the Kavango Region where many people directly sustain livelihoods by extracting Kiaat timber for wood carving, furniture, construction and occasionally fuelwood (Mogaka *et al*., 2001; Mendelsohn & Obeid, 2005; Jim, 2009). In addition, scenic forests based tourism earns Namibia foreign exchange (Mogaka *et al*., 2001), which directly and indirectly supports livelihoods in other sectors of the Namibian economy. Direct timber extraction and utilisation have, however, differently evolved over time in Namibia.

2.1.2 Timber Harvesting in Namibia

Direct legal timber felling in the Caprivi and Kavango Regions began in the late 1920s (Mendelsohn & Obeid, 2005). Although illegal logging was already widespread, the first official logging permit was issued in the Kavango Region in 1933 to fell 1000 trees. Over-exploitation of timber resources resulted in Kiaat trees and other timber species in Namibiabeing proclaimed as protected species in 1952. Sawmills at Katima Mulilo, Rundu, and Tsumkwe, however, remained in operation until 2003. Timber extraction reached a peak of 28,000 m^3 in 1972 and reduced to 8,850 m^3 in 1990. This level of decline in timber availability prompted the Directorate of Forestry (DoF) to close down the three sawmills in 2003 (Mendelsohn & Obeid, 2005). Small scale sawmilling, pit-sawing and illegal felling of Kiaat trees, however, remain prevalent in the Kavango Region (Otsub, M[1], pers.comm, August 2012).

2.1.3 Timber Status

The total standing timber stock for Namibia is estimated at 2 million m^3 (0.8 m^3/tree) (Mendelsohn & Obeid, 2005). Mendelsohn & Obeid (2005) further reported that approximately 2.5 million *Baikiaea plurijuga* and Kiaat trees suitable for quality timber are found in Namibia. Kiaat trees constitute about 0.3 m^3 / ha in the North-eastern regions to which the Kavango Region belongs, but there are many fewer young Kiaat trees than older ones in Namibia. This lack of recruitment of young trees points to a shortage of Kiaat trees to grow to suitable dimensions for timber in the future (Mendelsohn & Obeid, 2005). A similar lack of recruitments of young Kiaat was reported in South Africa due to scarcity of mature Kiaat trees (Shackleton & Shackleton, 2004). This may also be the case in Namibia.

Kiaat trees are over-exploited for their commercial valuable timber and medicinal properties (Palgrave, 1983; Shumba, 2001; Therrel *et al*., 2007). The exact number of people that sustain livelihood from Kiaat trees is, however, unknown, and the economic value of the whole timber industry also has not been assessed in Namibia (Mendelsohn & Obeid, 2005). Rural livelihoods can only be truly reflected through, *inter alia*, collection and analyses of qualitative and quantitative data, and establishment of economic value of commercially-traded goods (timber) derived from natural forest resources (Shackleton & Mander, 2000).

2.2 *PTEROCARPUS ANGOLENSIS* (KIAAT)

2.2.1 Classification and Phenology

Kiaat is a member of the *Fabaceae* family and belongs to the sub-family *Papilionoideae* (Palgrave, 1983; Venter & Venter, 2002; Therrel *et al*., 2007; Mannheimer & Curtis, 2009). Kiaat trees are leguminous and deciduous in winter (June to August in Namibia) as illustrated in Figure 2.1. The trees start flowering after reaching a sapling stage at the age of 20 years with flowers and leaf flush occuring from September to October in Namibia (Stahle *et al*., 1999; Mendelsohn & Obeid, 2005). Flowering lasts 2–3 weeks; fruit development

[1] Otsub, M. is the Chief Forester overall responsible for the Caprivi and Kavango Regions in Namibia

takes 4–5 months, seed pods are produced in summer (January to June) as can be seen in Figure 2.2) and typically flower appears before the leaves (Stahle *et al*., 1999; Venter & Venter, 2002; Takawira-Nyenya, 2008).

Figure 2.1: A Kiaat tree in its natural habitat in the Kavango Region.

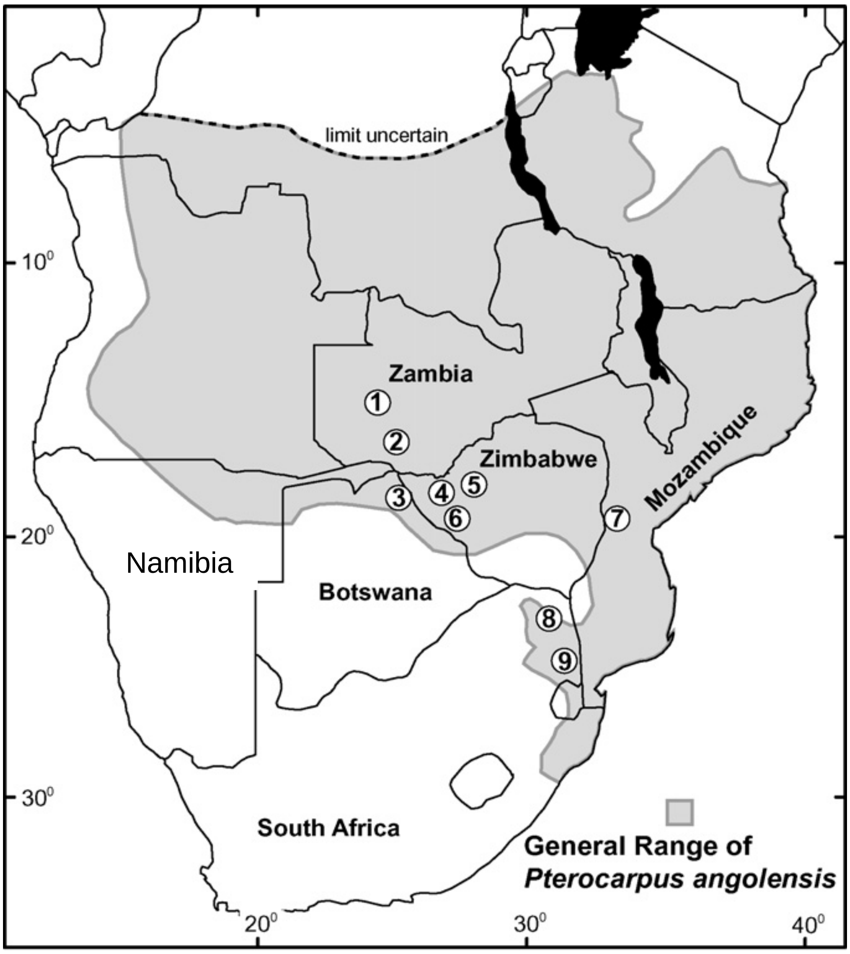
Figure 2.2: Seed pod of Kiaat (Mendelsohn & Obeid, 2005).

2.2.2 Ecology

The nitrogen fixing capacity of Kiaat trees is an important characteristic for soil conservation and dune stabilisation (Takawira-Nyenya, 2008). Pollination and seed dispersal agents of Kiaat trees include insects and wind (Shackleton & Shackleton, 2004; Takawira-Nyenya, 2008). Kiaat trees have thick corky barks able to resist fire heat of up to 450°C (Takawira-Nyenya, 2008; Graz, 2004). The bark is dark to brown-grey and deeply grooved vertically and horizontally forming regular shaped fragments (Palgrave, 1983; Venter & Venter, 2002; Loot, 2005; Mannheimer & Curtis, 2009).

2.2.3 Distribution

Kiaat trees occur throughout Southern and Eastern Africa (Shackleton, 2005). In particular, Kiaat trees are found in Angola, Botswana, Democratic Republic of Congo, Malawi, Mozambique, Namibia, South Africa, Tanzania, Zambia and Zimbabwe (Figure 2.3), and are exotic in Kenya (Caro *et al*., 2005; Therrel *et al*., 2007; Takawira-Nyenya, 2008; Moola *et al*., 2009). Kiaat trees are found from sea level to 1,800 m altitude in areas with annual rainfall of 500 to 1,500 mm, and average temperature of 15°C – 32°C (Mendelsohn & Obeid, 2005). The trees mainly grow in red loams and deep sandy soils with soil acidity values ranging from pH 5.5 to pH 7 (Stahle *et al*., 1999; Therrel *et al*., 2007; Takawira-Nyenya, 2008; Mannheimer & Curtis, 2009). However, Graz (2004) and Mendelsohn & Obeid (2005) point out that in Namibia Kiaat trees are predominantly found in the North-east, in the Caprivi and Kavango Regions.



Site Name

1. Mihozhe	4. Sikumi	7. Mozambique
2. Luampa River	5. Mzola	8. Soutpansberg
3. Pandamatanga	6. Matabeleland	9. Kruger Park

Figure 2.3: General distribution range of Kiaat trees in Africa (Therrel *et al*., 2007).

2.2.4 Germination and Regeneration

Kiaat trees produce up to 10,000 fruits per hectare (Takawira-Nyenya, 2008). There are about 4,000 to 5,000 seeds per kilogram but only 2% of the seeds germinate under natural conditions (Takawira-Nyenya, 2008; Mehl *et al*., 2010). Young Kiaat trees undergo a suffrutex stage in the first 20 years. A suffrutex stage is a successive period of 10 to 25 years of annual die-backs of young Kiaat trees. During this stage, growth is concentrated in roots, and shoots die-back to below ground-level in dry seasons and develop in rainy seasons (Mehl *et al*., 2010; Shackleton, 2005). In the first 10 years after the suffrutex stage, heights increase far faster than the stem diameter, whereas the stem diameter increases much faster than height in the second 10 years (Takawira-Nyenya, 2008).

2.2.5 Growth and Felling

The growth rate, lifespan, and timber age of Kiaat trees differ with countries. In South Africa, an average Kiaat tree takes 80 years to reach a diameter at breast height (DBH) of 27 cm, while the same DBH in Zambia and Tanzania is attained after 40 to 75 years. In Tanzania an annual increase in DBH ranges from 5.5 to 8.5 mm (Takawira-Nyenga, 2008). Kiaat trees could attain an average DBH of 11.8 cm at 40 years, and 55 cm in DBH and 20 m in height at 100 years (Stahle *et al*.,1999; Tasila *et al*., 2006; Takawira-Nyenya, 2008).

Kiaat trees are harvested from natural forests because they are rarely planted in plantations (Caro *et al*. 2005). The DBH at which Kiaat trees are felled also varies between countries. A minimum felling DBH is 27 cm in South Africa, and 25 cm in Zimbabwe (Takawira-Nyenya, 2008).

2.2.6 Commercial Growing

Attempts to grow Kiaat trees in commercial nurseries were unsuccessful in Zimbabwe (Caro *et al*., 2005). Little success with the establishment of Kiaat plantations was however recorded in Kenya, Mozambique and Tanzania (Venter & Venter, 2002; Caro *et al*.,2005). It was discovered in Zambia that special treatment such as adding chicken manure and mycorrhizal inocula to the soil substrate improves Kiaat seedlings growth in nurseries (Moola *et al*., 2009). The long growing period to timber maturity of Kiaat trees could however be a discouraging factor for people to establish Kiaat plantations.

2.2.7 Ownership and Management

According to Article 100 of the Namibian Constitution of 1990, the Namibian state owns all natural resources (The Namibian Parliament, 1990). Kiaat has been proclaimed as a protected species since 1952 (Erkkilä & Siiskonen, 1992; Mendelsohn & Obeid, 2005). Namibia's forest resources are managed and regulated by the Directorate of Forestry (DoF) in accordance with the National Forests Act 12 of 2001 (The Namibian Parliament, 2001).

The DoF manages the resources using co-operative and participatory approaches in consultation with Traditional Authorities who are the custodians of communal lands in Namibia (The Namibian Parliament, 2001). Most of Namibia's forestry resources are found on communal lands on which 95% of the farming population depend for livelihoods (Mogaka *et al.,* 2001). Communal lands make up 37% of Namibia's total land area on which the Traditional Authorities allocate land, control land distribution and ownership, and jointly authorize alienation of forest resources with Forestry Authorities (Mogaka *et al*., 2001; Mendelsohn & Obeid, 2005). Only 119,513 of the 4.6 million hectares (i.e. 2.6% of the Kavango Region) are *gazetted* as community forests (Mendelsohn & Obeid, 2005; Erkkilä & Siiskonen, 1992). Unlike non-*gazetted* communal areas, *gazetted* community forests have management plans (Commonwealth Forests Association, 2010).

The DoF is allowed to directly allocate timber resources on *gazetted* community forests. DoF has to obtain or request a written consent from the Traditional Authority under whose jurisdiction the sought resource belongs to allocate timber resources on non-*gazetted* areas of communal lands. Illegal logging is, however, widespread on both *gazetted* community forests and non-*gazetted* areas of communal lands (Stahle *et al*., 1999; Mendelsohn & Obeid, 2005).

2.2.8 Timber Production and Demand

According to Takawira-Nyenya (2008), approximately 600 m^3 of Kiaat timber can be annually harvested in Namibia per 100 km^2. In 1975 Geldenhuys estimated that the Kavango Region had 370,000 m^3 of Kiaat trees (Erkkilä & Siiskonen, 1992). Namibia's annual demand for rough and sawn wood in general was approximately 27,000 m^3 in 2008 (DECOSA, 2010).

2.2.9 Timber Properties and Uses

Heartwood of Kiaat trees does not have santalins and santrubins, which give other *Pterocarpus* species their commercial insoluble redwoods. Isoflavonoids and prunetin, muningin, tectorigenin 7-methylether, pseudo-baptingenin and angolensin, which give the dye of Kiaat trees its red brownish colour, are however present (Takawira-Nyenga, 2008). According to Venter & Venter (2002), the red gummy sap is composed of tannin (76.7%) and a dark red resin. Other properties and uses of Kiaat trees are presented in Table 2.1 below.

Table 2.1: Properties and uses of Kiaat trees.

Parts	Properties and Uses
Roots	Roots are powdered to make a brownish red dye. The dye is used in cottage industry in Zimbabwe and Namibia. In Namibia, Angola, and Zambia, root dye is mixed with oil to make cosmetic pomade and to dye traditional leather clothes for men and women. Decoctions of roots are used to treat black-water fever, gonorrhoea, diarrhoea, bilharzia, abdominal pains and malaria. Root ash is drunk in water to treat asthma and tuberculosis (TB). Root extracts can, however, be lethal to adults' schistosomes (Schwartz *et al*., 2001; Venter & Venter, 2002; Takawira-Nyenya, 2008).
Stem and Branches	Kiaat timber is durable, light, hard and sizeable. It is thus utilised for furniture; parquet, carpentry; decoration; flooring; veneering; store fitting; general construction, and curio. Being light and strong, the timber is utilised to make - artificial limbs, boats building frames, windows, doors, decking, banks, canoe paddles, fish spears, internal fittings, utensil handles, barracks, coffins, commercial beehives and musical drums. In South Africa and Namibia its wood is also carved into bowls, spoons, trays, and walking sticks (Erkkilä & Siiskonen, 1992; Schwartz *et al*., 2001; Venter & Venter, 2002; Shackleton & Shackleton, 2004; Takawira-Nyenya, 2008).
Barks	Inner barks are used to make dye; bark fibres for baskets, and bark exudate is utilised for traditional medicine as astringent for treating diarrhoea, nose bleeding, headache, stomach disorders, schistosomiasis, body sores, and skin problems. Bark is also utilised as fish poison, stimulant for lactation, and its cold infusion provides for nettle rash and relieves blood in urine, ear-ache and mouth ulcers (Schwartz *et al*., 2001; Takawira-Nyenya, 2008).
Twigs and leaves	Leaves and twigs are utilised as raw materials for the recovery of essential oils, glucosides, glucose, vitalimins – which are basic raw materials for pharmaceutical industries, fodder supplements and fuel. Leafy twigs are used for fodder and flowering trees are an important source of honey (Loot, 2005; Takawira-Nyenya, 2008).

Seeds	The ash of ripe seed is used to treat inflamed areas of skin, bleeding gums, and is applied as dressing on wounds and psoriasis in South Africa (Schwartz *et al*., 2001; Takawira-Nyenya, 2008).
Sap	The sap is utilised to treat nose-bleeding, ringworms, ulcers, eye cataracts, malaria, black-water fever, coughs, stomach-ache, and skin inflammations. Its latex is used for dyes (Palgrave, 1983; Schwartz *et al*., 2001; Mendelsohn & Obeid, 2005).

2.3 TIMBER PRICES

The Namibian government sells a live Kiaat tree on stump at N$200 and a dead one for N$110 (Ministry of Finance, 2011). Proper valuation of timber resources could be an important tool in encouraging or compelling people to use trees optimally. Undervaluation of forest resources causes accelerated deforestation (Kramer *et al*., 1992). Governments under-value timber resources, among others, through ignorance of tax structure based on marketable timber removed rather than potentially marketable timber or absence of taxation at all (Panayotou & Ashton,1992).

Lack of published information on prices or values of products from Kiaat trees could complicate proper valuation. Timber traders, especially unregistered timber agents, hide market-related prices of timber from local people. Timber agents keep fair timber prices secretive in order to maintain low prices at local levels and maximize their profits (Harris, 1996). Timber market in the Kavango Region is characterized by this practice. This practice deprives goverment and local producers of revenues, and encourages people to demand more trees (Harris, 1996). Excessive logging of Kiaat trees has been identified as a key threat to forests in Namibia (Loot, 2005).

2.4 TIMBER OPTIMISATION

Tree optimisation refers to maximised benefits from any given tree harvested. It takes place when producers maximise profits; consumers maximise utility and societies maximise welfare (Mogaka *et al*., 2001). Introduction of optimal utilisation of Kiaat trees could be helpful in addressing tree wastages in the Kavango Region.

A whole-tree utilisation is one possible option to achieve tree use optimisation. According to Röser *et al* (2008), whole-tree refers only to above-ground biomass of a tree, while complete-tree refers to the entire above-and-below ground biomass of a tree. Whole-tree use is also supported because it reduces accummulation of fuel for forest fire, which rather worsens the extent of damage to the ecosystem and properties. Divergent views, however, exist regarding whole-tree use. In particular, Shackleton *et al* (2004) reported that whole-tree use *per se* removes or reduces the availability of deadwoods, which are ecologically important for the ecosystem.

2.5 TIMBER VALUE

Timber value refers to the economic benefits that individuals obtain from current direct use of such resources' woody materials (Pak *et al*., 2010). Timber value can be established either at woodland level or different tree species level or at single species level (Chipeta & Kowero, 2004).

According to Tate (1989), timber value can also be determined at location levels. Divergent views, however, exist regarding valuing a single forest resource in relation to a whole woodland, but a single species approach is widely used because it is more practical, cheaper, less time-consuming, less labour intensive and less skill demanding (Chipeta & Kowero, 2004). There is agreement that the knowledge of Kiaat timber value is particularly important for conservation of such a resource (Adebusola & Sheu, 2007).

The value of trees whose timber products are available at a market is determined using those products' formal or informal market prices (Shackleton & Mander, 2000). The terms timber and timber market price are often wrongly used interchangeably. According to Forbes (1956), "*current market value of a good is the amount of money which a seller, who is willing and able but not forced to sell, will accept for the good from a purchaser who is willing and able but not forced to buy*". In contrast, a market price of a good (timber or carbon) is the amount of money actually paid by a buyer to and accepted by a seller in exchange for a good (FAO, 1983; Pearce, 1990). In cases of under-pricing, the seller sets and accepts money lower than the value of the resource, which leads to high demand for that resources (Kgathi & Sekhwela, 1990; Harris, 1996). In this study, local market prices of Kiaat products will be used to determine timber value of an average Kiaat tree. Conserving Kiaat trees for carbon credits that accrue to local people is, however, one of the possible alternatives by which the trees can be conserved.

2.6. TREE CARBON VALUE

Forests and woodlands sequester carbon from the atmosphere (Marunda & Bouda, 2010). Kiaat trees, as a dominant forest species of Namibia's dry forests and woodlands, can be an important source and storage of CO_2. When harvested, destroyed or decomposed, plants release CO_2 into the atmosphere (Lamlom & Savidge, 2003; Murdiyarso & Skutsch, 2006; Wipe & Gong, 2010).

In contrast, when conserved or preserved, plants absorb and store CO_2 from the atmosphere and thereby reduce green house gases in the atmosphere (Senguta & Maginnis, 2005; Read, 2007). One way to conserve or preserve Kiaat trees without compromising people's income is to retain the trees in the forests in exchange for carbon credits traded at a given price in money per tonne of CO_2 (tCO_2) at local or international carbon markets (Marunda & Bouda, 2010). Marunda & Bouda (2010) reported that markets for carbon sequestration based on dry-forests and woodlands have been adopted in Madagascar, Malawi, Mozambique, Senegal, Tanzania, and Uganda.

2.7 SUMMARY

The review concluded that the current use level of Kiaat trees could be improved. This could be, particularly achieved by optimal use and identification of potential and alternative uses. Some studies such as those by Takawira-Nyenya (2008), also recommends research on determination if more profits can be made from by-products of Kiaat trees. Determination of Kiaat trees' timber and carbon values as well as establish the extent to which trees are optimally utilised are important for the conservation of the species and local source of livelihoods.

CHAPTER 3

METHODOLOGY

3.1 STUDY COUNTRY - NAMIBIA

Namibia is situated in the south-west corner of Africa and shares borders with Angola in the North; Zambia in the East; Botswana in the south-east; South Africa in the South, and the Atlantic Ocean in the West (Figure 3.1). Approximately 2,104,900 people live in Namibia (NPC, 2012), of which 70.6% live in the Northern regions where Kiaat trees are found (Mogaka *et al*., 2001; Mendelsohn & Obeid, 2005; Jim, 2009).

Figure 3.1: Namibia's position in Southern Africa (Google, 2012).

Namibia is divided into western and eastern sections. The eastern section is rocky and hilly, while the western section is flat with shallow sands. Soils are poor in nutrients and moisture retention, which makes it difficult for plant cultivation. The Kavango Region is, however, predominantly covered by the Kalahari sands in which Kiaat trees are commonly known to grow (Mendelsohn & Obeid, 2005).

3.1.1 Study Region – the Kavango Region

The study took place in the Kavango Region, which is one of Namibia's thirteen political regions (see Figure 3.2). It covers a total surface land area of 48,742 km^2 with 4.6 persons per km^2 (NPC, 2012). The region is situated 1,100 m above sea level (Erkkilä & Siiskonen, 1992) and is bordered in the north by the perennial Kavango River, which traverses through the region in the east into Botswana (Mendelsohn, 2009).

The Trans-Caprivi Highway, which links Angola, Zambia and Botswana to the port of Walvis Bay, runs through the middle of the region from west to east. This Highway is an important route for transportation of forest products particularly timber products, and thus influences timber trade (Mendelsohn & Obeid, 2005). Rundu, which has a population size of 61,900 people (28% of Kavango's population, according to NPC, 2012), is the capital of Kavango Region and is pivotal for timber processing and trade.

The Kavango Region has a population size of 222,500 people (Figure 3.2), of which 53% are females and 47% are males. There are on average six persons recorded per household in the Kavango Region, representing the highest household size in Namibia (NPC, 2012). According to the NPC (2007), the region's annual population growth rate was 3.7% in 2011.

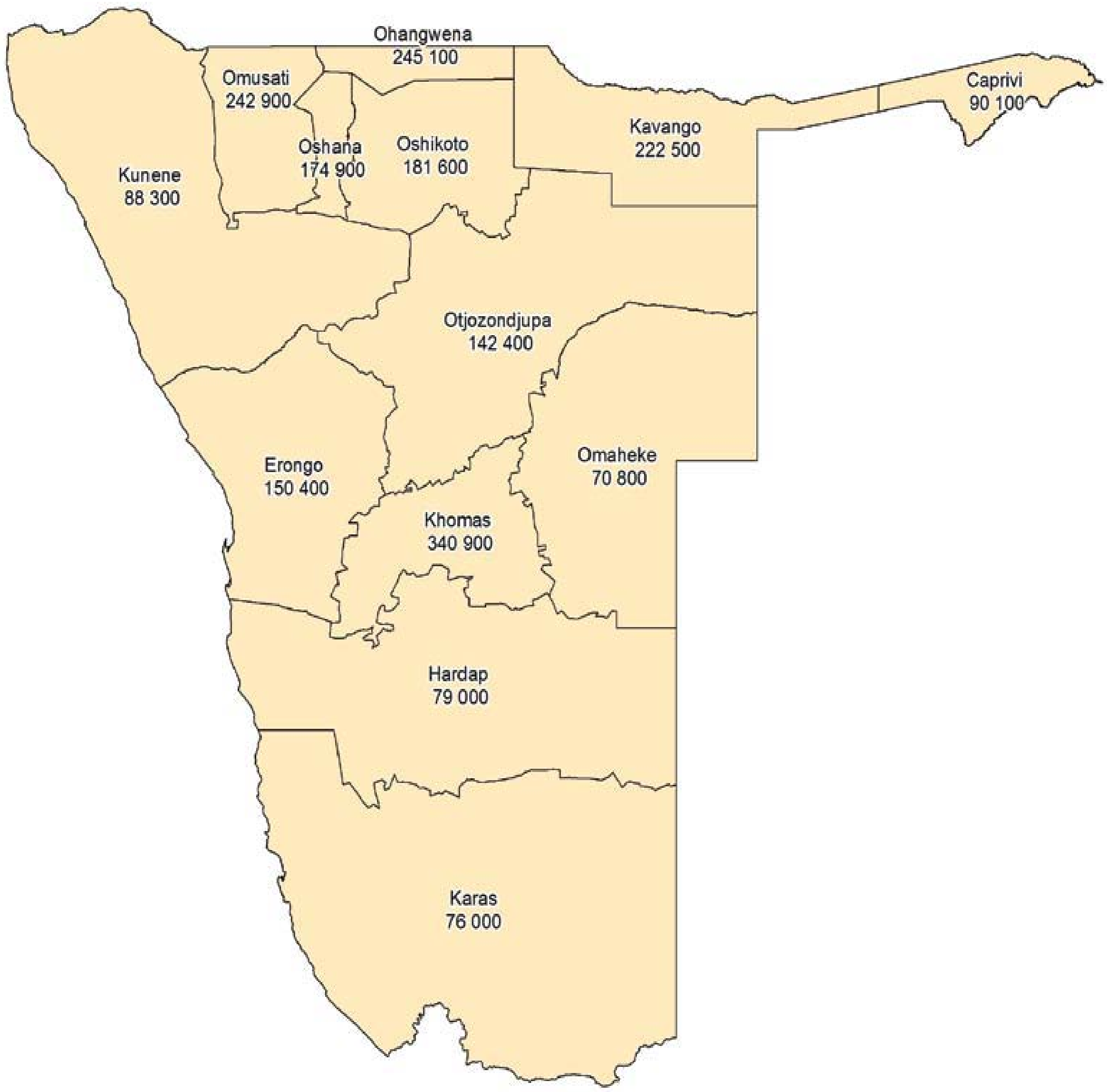


Figure 3.2: Namibia's 13 political regions and their population sizes (NPC, 2012).

Kavango Region receives an annual rainfall of 650 mm to 1,500 mm, 80% of which falls between December and January. Average monthly temperatures vary from 25 to 26°C which contributes to high evaporation rate of surface water in the region.

Tree savannas; woodlands, and riverline woodland are vegetation types of the Kavango Region. Kiaat trees are the third dominant species and are found growing in a variety of soil types that characterise the Kavango Region. Land-use systems in the Kavango Region include protected areas i.e. national parks; *Gazetted* community forests, small-scale agriculture, resettlement farms and urban centres (Erkkilä & Siiskonen, 1992; Mendelsohn & Obeid, 2005; Mendelsohn, 2009).

3.1.2 Study Sites – Rundu and Karukuvisa Area

Identification and assessments of Kiaat products and interviews of key-informants on timber proccessing and trade were conducted in and around Rundu. Fourty Kiaat trees were felled from two adjacent leasehold farms - Farm No. 1428 (19.08.906'S and 019.91.555 E) and Farm No. 1412 (19.16.606'S and 019.91.302 E). The farms are situated about 205 km south of Rundu in the Karukuvisa District of the Kavango Region. The two farms are situated on low-lying areas with flat, deep sandy, non-rocky soils. According to the farm owners, the farms are exposed to annual forest fires. Field observations confirmed the occurrence of forest fires on the two farms as almost every tree wore fire scars (Figure 3.3).

Figure 3.3: A Kiaat tree with fire scar.

3.2 STUDY DESIGN

A combination of interviews with wood processors (key-informants), a survey of Kiaat wood products at local markets and a determination of tree volume and biomass was used to accomplish the objectives of the study. Use of a variety of methods and techniques in one study (triangulation) increases the reliability of the data (Mouton, 1996). Rossillo-Calle *et al.* (2007) reported that such an approach generates mutually supportive empirical data. Phiri (2009) also used a combination of the processes in his study on the evaluation of the performance of joint forest management in Zambia. In this study, the survey part was conducted first and then the determination of tree volumes and biomass. This order was chosen because it was anticipated that the process of products identification and assessments and interviews of key-informants would inform the subsequent process of determining volume and biomass of trees. The survey exercise, in particular, collected data such as market prices of products, raw wood dimensions, potential and alternative use values of products or raw Kiaat woodblocks from canopy parts. Tree volume and biomass had to be determined to verify possible number of specific products that could be cut from an average standing Kiaat tree. These research processes are discussed below.

3.3 DATA COLLECTION – KIAAT TIMBER PRODUCTS VALUE AND TREE USE LEVELS

According to Ulibarri & Wellman (1997), values and utilisation levels of timber products are determined by means a variety of appraisal methods; replacement cost, market-based prices and interviews with people believed to have knowledge about products. In this study, a cross-sectional survey method was used to interview known key-informants (wood processors). This type of survey involves the collection of data from a defined area at one point in time (Babbie,1973). Since timber processing centres or local people with the required expertise are not registered in the Kavango Region, the survey had to rely on referrals by known key-informants. Interviewed key-informants included loggers, supervisors and owners of timber processing outlets, timber agents, woodcarvers, operators of craft centres and marketers of Kiaat wood products.

3.3.1 Market-Based Method

The survey obtained data using a market price approach, which entailed asking for local prices of products and other information from key-informants in interviews using a semi-structured questionnaire (see *Appendix A*). In order to avoid bias and collect reliable data, the questionnaire was designed and administered as described by Venkatachalam (2004) and Becker & Freeman (2009). Stated values, prices or information were used in valuing the resource in question as advised by Chipeta & Kowero (2004).

3.3.2 Questionnaire Design

Questionnaire design refers to drafting relevant questions; deciding whether to use open-ended or dichotomous choice; sequencing of the questionnaire questions; testing the questionnaire, and printing the final questionnaire (Venkatachalam, 2004). The questionnaire questions were predominantly open-ended (see *Appendix A*). This questioning style was chosen over others because it is convenient to answer, does not incur starting point biases, requires a smaller sample size than close-ended formats, and provides more conventional estimate of desired information than other approaches. Open-ended questions are also statistically efficient (Nichols, 1990; Clem *et al*., 2008).

3.3.3 Pre-testing of Questionnaire

The questionnaire was tested in a pre-survey on respondents similar to the ones that were going to be interviewed in the main survey, as advised by Nichols (1990). Two field assistants, who were selected because of their forestry knowledge and are conversant with the local language, were asked to participate (as interviewers) during the pre-survey exercise as parts of their training. According to Mouton (1996), training of research assistants is important because it counteracts researcher effects and it increases the chance of obtaining reliable data. Pre-testing detected and led to rectification of some omissions and complexity in answering of the questionnaire. Additional key-informants were identified during the pre-testing exercise.

3.3.4 Questionnaire Administration

The questionnaires were administered using face-to-face interviews – an approach described in detail by Barbier *et al* (1994), Babbie & Mouton (2001) and Venkatachalam (2004). Timber processors; loggers, woodcarvers, and traders of Kiaat wood products at various wood processing outlets, wood products cooperatives, and open-markets (Figure 3.4) were interviewed in Rundu as well as at wood craft centres and stalls along the 130 km long Mururani-Grootfontein Road. A total of 31 out of 35 known key-informants were interviewed. The remaining four key-informants refused to be interviewed. The personal interview approach was used because it enhances validity of results; has a higher response rate and less delays in obtaining information than in the case of postal surveys (Zhongmin *et al*., 2003; Rosillo-Calle *et al*., 2007; Maguire, 2009).

Figure 3.4: Interview of a woodcarver at Rundu Open Market.

Loggers were interviewed regardless of the species they fell. All respondents were also asked to state attributes they use to select a tree for felling, alternative uses, timber preferences, and timber utilisation levels of Kiaat trees. In addition, the dimensions of all planks that were found on premises of timber outlets, craft centres and Rundu Forestry Office (RFO) i.e. planks confiscated from illegal loggers were measured. A total of 857 planks were recorded. Planks were classified into heartwood-only, and sapwood and heartwood i.e.mixed planks through visual grading.

3.4 DATA COLLECTION – KIAAT TIMBER PRODUCTS ASSESEMENTS

A survey of Kiaat wood products such as wood carvings, plates, music drums, beds, tables, and chairs was conducted at the woodcraft Open Market in Rundu and at the woodcrafts centre at Ncumcra Community Forest near Rundu using pre-designed data sheet (see Appendices: B & C). Wood products traded at stalls along the 130 km long Rundu-Mururani Road were also surveyed. The dimensions of finished woodcrafts were measured, and woodcarvers were asked to state the dimensions of raw wood blocks from which each product could be carved.

A total count approach was used to collate retail prices for Kiaat finished products at markets in Rundu. To avoid possible bias on reporting of product prices on the part of the respondent, the prices that were displayed on price-tags were taken. Since these finished products were made with primary processed products i.e. mainly planks, the number of planks required to make each product was recorded. In case of woodcrafts, a total of 50 units were randomly sampled for each product.

3.5 DATA COLLECTION - DETERMINATION OF TREE BIOMASS

3.5.1 Tree Sampling

The Directorate of Forestry office in Rundu provided a list of loggers permitted to fell Kiaat trees in the Kavango Region. This office was chosen because it is the only one that issues timber felling permits in Kavango Region. Although timber felling was banned during the period of fieldwork (April to July 2012), there were two leasehold farmers who did not fell Kiaat trees allocated to them before the ban. The two farmers agreed to harvest their trees to accommodate the study. Only 40 Kiaat trees were sampled because the two farmers were each permitted to fell only twenty Kiaat trees. Due to the ban, the sample size could not be increased.

The farmers were each asked to select the trees they wanted to fell. The farmers hired a logger, with 13 years of experience, to select, fell and extract merchantable parts for them. All trees were first selected and marked before they were felled using a chain saw (Figures 3.5 & 3.6).

Figure 3.5: Felling of a Kiaat tree at Karukuvisa.

Figure 3.6: Measurements of a felled Kiaat tree.

3.5.2 Tree Measurements

This study focused on above-ground biomass of Kiaat trees, which includes the total organic matter in the above-ground parts of the tree (Brown, 1997). The total above-ground biomass of a conventionally felled tree is subdivided into stump; trunk, and canopy (Phillip, 1994; Van Laar & Akça, 1997). According to Röser *et al* (2008), tree trunks are subdivided into marketable and unmarketable portions. Sub-dividing a tree in these parts is especially important where the least possible utilisable volume is required (FAO, 1980).

3.5.2.1 Measurements Before Felling

The following data was collected (*using data sheet in Appendix D*) for every tree before it was felled:

- ❖ Attributes that the logger used to select each tree for felling were asked for and recorded;
- ❖ Tree height: Standing tree stem and canopy height were measured with a hypsometer (Suunto) before felling (to relate the proportion of each to that of whole tree).
- ❖ Stem height was measured as the distance from ground level to where the first branch starts, while tree height was measured as the the distance along the axis of the stem between the ground and tip of the tree (Husch *et al*., 1982; Husch *et al*., 2003).
- ❖ Tree stem diameter: A diameter tape was used to measure diameter at breast height (DBH) (at 1.3 m above ground level). DBH is one of the dimension used in the estimation of tree volume (Brown, 1997; von Gadow & Hui, 1999). DBHs were measured according to widely used standard procedures as for example described in Hamilton (1975), FAO (1980), Husch *et al* (1982), Husch *et al* (2003) and van Laar & Akça (1997).
- ❖ Canopy widths: Four canopy widths were measured in their projection to the ground for every tree using a tape measure.

3.5.2.2 Measurements After Felling

Brown (1997) recommended dividing a tree into stump, main stem, branches of different size classes and foliage components. Alvarez *et al* (2012) also used this approach in their biomass study. In this study the same approach was adopted, and each of the components was measured before and after felling as follows:

Stump Measurements: Over-bark diameter and under-bark diameter of all stumps were measured using a tape measure. Heights of the stumps were measured from ground level to the point where the trees had been felled, while diameters were measured from a disc cut at the lower-end of the tree.

Trunks and Branch Measurements: Diameter and length of individual branches were measured to estimate the volumes of sections of a tree that could be used for different products such as bowls and planks (West, 2006). Diameters and lengths of the portion of the main stem and branches that were removed, for processing into products, were measured over-bark. Lower and upper over-bark and under-bark diameters for the main stems (trunks) were measured. For all straight portions of branches that were greater than 10 cm in diameter, lower, middle and upper diameters and lengths were also measured over-bark as suggested by Brown (1997). Diameters and lengths of branches were taken in straight portions to determine the type and number of known woodcrafts that can be cut from the canopy parts.

Discs Cutting and Measurements: Volumes of discs cut from different sections of the main stem and branches to estimate the basic wood density of the main stem and branches as it is often not practical to weigh them directly (Brown, 1997). In this study, five discs were cut from each sampled Kiaat tree, providing a total sample of 200 discs. Two discs were cut from the trunk - one at the lower-end where the tree was felled, and the other at the upper-end where the canopy started. The other three discs were cut from the canopy – whereby one disc was cut at the middle of the main part of the trunk that was projected into the canopy, and the remaining two discs were each cut from other branches of the canopy but at the same level as the third disc. Discs were marked to identify the tree and part of the tree each was cut (Figure 3.7). Marked discs were each immediately weighed for fresh mass using a hanging scale (Figure 3.8). The data collected from the discs were recorded in pre-designed form (data sheet), an example of which is attched as *Appendix E*.

Figure 3.7: Example of disc labelling.

Figure 3.8: Example of with-bark discs cut from Kiaat trees.

The following data were collected from every disc:

- with and without bark fresh mass;
- four measurements of with and without bark diameters and heights;
- diameter of the heartwood, and
- with and without bark volume was determined using a displacement method.

The volumes of discs were determined using the displacement method because some discs had holes (Figure 3.9). Disc volumes and their subsequent wood density could, otherwise, be over-estimated if they were estimated as a product of disc's basal area and heights. Displacement method provided accurate estimate of volume of irregular shaped objects such as wood (Brown, 1997; van Laar & Akça, 1997; Husch *et al*., 2003). Oven-dry mass of discs and their volumes were measured for the estimation basic wood density (R) of Kiaat trees as indicated by Brown (1997); Desch & Dinwoodie (1996) and Alvarez *et al* (2012).

Figure 3.9: A Kiaat disc with holes.

De-barking and drying of discs: All de-barked discs and their respective bark were weighed before and after de-barking to determine Kiaat wood density, (Figure 3.10). De-barked discs and barks were oven-dried at 105°C until each reached a constant weight. Oven-drying was conducted to determine moisture content, and oven-dry weight for calculation of with-and-without bark density of Kiaat wood.

Figure 3.10: De-barked discs and bark.

Canopy Biomass: Fresh mass of all canopy parts < 10 cm in diameter was obtained by direct weighing. The parts were cut in pieces, manually piled and their fresh mass directly weighed. Direct weighing of all parts was chosen because it provide more reliable results (Phillip, 1994; Brown, 1997; Van Laar & Akça, 1997; Husch *et al.*, 2003; Alvarez *et al*., 2012).

Canopy parts dry-mass: A sample was randomly drawn from the pile of canopy parts for each tree. Given the fact that Kiaat trees shed their leaves during winter (deciduous species), making leaves temporary part of the trees, it was deemed sensible to exclude them from carbon calculations. During the period of fieldwork (April to July 2012) , in particular, Kiaat tree were found without leaves (see Figure 2.1). However, pods were included.

Selected materials for each of the fourty trees were placed in separate A4 sized paper envelopes of known mass, and weighed immediately in the field. Sample materials in each envelope were cut into smaller pieces to speed up drying and also to avoid case-hardening (Figure 3.11). Case-hardening traps moisture at the core of the wood, which reduces the accuracy of dry mass (Hoadley, 1980; Desch & Dinwoodie, 1996). The bags were then placed in the oven at 105°C (Figure 3.12) and allowed to dry for twenty-four hours until each envelope attained a constant weight. Readings were taken every 72 hours. To be sure that the samples were completely dry, each sample was subjected to oven-drying until it repeated a constant weight three times at intervals of three days. Samples were immediately weighed upon removal from the oven to avoid moisture absorption and re-gaining of weight as advised by Brown (1997).

Figure 3.11: Size of sample of canopy parts per Kiaat tree.

Figure 3.12: Example of some sample envelopes in the oven.

3.6 DATA PROCESSING AND ANALYSES

The data were collected to estimate the total above-ground-ground utilisable timber volume, and total biomass of an average Kiaat tree and subsequently estimate timber and carbon values of the trees. Thus, the data were analysed in five categories: (1) volume estimation, (2) biomass estimation, (3) timber value estimation, (4) carbon content and value estimation, and (5) inferential and descriptive statistical analyses. These categories are described in details below.

3.6.1 Utilisable Tree Volume Estimation

The total above-ground volume of each sampled Kiaat tree was determined as a sum of the volumes of the stump, trunk, branches greater than 10 cm in diameter, and canopy parts smaller than 10 cm in diameter. The over-bark volume of the stump, trunk and branches were estimated using Smalian volume formula (Equation 1.1). Smalian formula consists of four components: 1) over-bark volume in m^3 (V), height in metres (h), over-bark basal area (m^2) at the base (Abo) and over-bark basal area (m^2) at the top of the component whose volume is estimated (Husch *et al*., 2003; Rosillo-Calle *et al*., 2007). Over-bark basal area (m^2) at base and top was calculated using equation 1.2. In case of heartwood volume of the merchantable logs, the same Smalian volume formula (Equation 1.1) was used, but using heartwood basa areas (as determined using heartwood diameters) and lengths of the logs..

$$\boldsymbol{Vo} = \frac{\boldsymbol{h}}{2}(\boldsymbol{Abo} + \boldsymbol{Ato}) \qquad 1.1$$

Where:

Vo = over-bark volume (m3) of the component i.e. stump, trunk or branches greater than 10 cm in diameter.

h = height (m) of the component

Abo = over-bark basal area (m^2) at base of the component as determined using over-bark diameter.

Ato = over-bark basal area (m^2) at top of the component as determined using over-bark diameter.

$$Overbark\ basal\ area\ = \left(\frac{\pi oD^2}{4}\right) \qquad 1.2$$

Where: π = 3.142, oD^2 = average over-bark diameter (cm) of the base or top.

Under-bark Trunk Volume: In order to determine under-bark volume of the tree trunks, which is the volume from which most local timber products are processed, the Smalian volume formula in equation 1.3 was used. The under-bark basal areas (m^2) of the base and top of the component as calcualted using equation 1.4 were, however, used. The trunk bark volume was determined as the difference between the over-bark volume as calculated using equation 1.1 and under-bark volume as calculated using equation 1.3. That is, Under-bark trunk volume equals to over-bark volume of the trunk minus the under-bark volume of the trunk (Husch *et al*., 2003; Rosillo-Calle *et al*., 2007).

$$\mathbf{Vi} = \frac{\mathbf{h}}{\mathbf{2}}(\mathbf{Abi}\ +\ \mathbf{Ati}) \qquad 1.3$$

Where:

Vi = under-bark volume (m^3) of the component i.e. stump, trunk or branches greater than 10 cm in diameter.

h = height (m) of the component

Abi = under-bark basal area (m^2) at base of the component as determined using under-bark diameter.

Ati = under-bark basal area (m^2) at top of the component as determined using under-bark diameter.

$$\boldsymbol{Under-bark\ basal\ area}\ = \left(\frac{\boldsymbol{\pi iD^2}}{\mathbf{4}}\right) \qquad 1.4$$

Where: π = 3.142, iD^2 = average under-bark diameter (cm) at base or at top.

3.6.2 Tree Biomass Estimation

The volumes of stump, trunk and branches that were greater than 10 cm in diameter obtained in sections 3.6.1 above, were converted to dry biomass (weight) using equation 1.5. Average basic wood density of 631 kg/m^3, which was determined for discs cut from tree parts greater than 10 cm in diameter was used to calculate biomass (see equations: 1.5 & 1.6) as described by Desch & Dinwoodie (1996), Husch *et al (*2003) and Rosillo-Calle *et al (*2007).

$$\textbf{Biomass (kg)} = \textbf{volume x basic wood density} \qquad 1.5$$

Where (in equation 1.5): biomass = dry weight of tree parts greater than 10 cm in diamter (stump, trunk and branches), volume = over-bark stump, trunk and branches volume (m^3) of each tree., and basic wood density = 631 kg/m^3.

$$\textbf{Basic wood density} = \frac{\textbf{disc oven\_dry weight}}{\textbf{disc green\_volume}} \qquad 1.6$$

Where: disc green volume = average green volume of the discs in m^3 as obtained using the displacement method, disc oven-dry biomass(kg) = average oven-dry mass (kg) of discs as oven-dried at 105°C until constant mass was reached (Desch & Dinwoodie, 1996; Brown, 1997; Husch *et al.,*2003; Rosillo-Calle *et al.,*2007). The obtained basic wood density then used to computed biomass (see equation 1.5).

Estimation of Biomass of Small Canopy Parts: the moisture content (MC) in percentage (%) of all canopy parts that were smaller than 10 cm in diameter, excluding leaves and pods, for each tree was determined using equation 1.7. The amount of organic matter (dry weight) of canopy parts that were smaller than 10 cm in diameter, for each of the sampled Kiaat trees was calculated using equation 1.8. The total oven-dry mass of all canopy parts smaller than 10 cm in diameter (Canopy Part Biomass - CPB), for each tree, was determined as a product of their total fresh mass (kg) and average percentage of oven-dry mass (kg) (Desch & Dinwoodie, 1996; Curie, 2000; Brown, 1997; Pretzsch, 2009) as described in equation 1.9.

Total Tree Biomass Estimation: The average total above-ground bioamss of the tree (TTB) was calculated as a sum of trunks, branches greater than 10 cm in diameter, and biomass of canopy parts smaller than 10 cm in diameter, using equation 1.10.

$$MC\% = \frac{(\text{Fresh weight of sample} - \text{oven\_dry weight of sample})}{\text{oven\_dry weight of sample}}\ x\ 100 \qquad 1.7$$

$$\boldsymbol{Biomass\ Content}\ \% = \mathbf{100} - \boldsymbol{MC}\% \qquad 1.8$$

$$\boldsymbol{CPB}\ = (\boldsymbol{Total\ Fresh\ Mass\ of\ Canopy\ Parts\ x\ Sample\ Biomass\ Content}\ \%)$$
1.9

$$\boldsymbol{TTB} = \boldsymbol{TSB} + \boldsymbol{TCB} \qquad 1.10$$

Where: *TTB* = total above-ground tree biomass including the stump (kg); *TSB* = total dry mass of the trunk and branches as estimated using volume and wood denssity, and *TCB* = total oven-dry mass of canopy parts as derived using the ratio of directly weighed biomass to oven-dried mass as used by Rosillo-Calle *et al (* 2007) and Alvarez *et al* (2012), and described in Husch *et al* (2003).

3.6.3 Timber Value Estimation

The timber value of each tree was estimated by multiplying the quantity of products that could be cut from it with the average local price of the respective product. The total average current timber value of the trees was determined from the sum of the value of timber products that people cut from the tree. This was then taken as the average value of an average Kiaat tree in respect of timber products identified.

The potential use value of an average standing Kiaat tree was estimated based on the total value of possible products that can be cut from its parts that were not used. The difference between the current and potential monetary values of Kiaat trees were tested for significance using a two-independent sample t-test procedure in *SAS Enterprise Guide 4 (SAS EG 4)*. The same method (procedure) and software were used to test for the significance of the difference between the averages of current timber and carbon values of each tree.

3.6.4 Estimation of Carbon Content and Value

The amount of carbon stored in wood of most species is approximately 50% of that wood's oven-dry weight (Kramer *et al*., 1992; Rosillo-Calle *et al*., 2007; Munishi *et al*., 2010; Subedi *et al.,* 2010). Therefore, the obtained total oven-dry weight of the above-groung parts of the trees (Kiaat trees) was multiplied by 0.5 (or 50%) to obtain the carbon content in an average Kiaat tree as shown in equation 1.11.

$$\boldsymbol{Carbon\ Stored\ (kg) = Total\ Tree\ Biomass\ (kg)\ x\ 0.5} \quad 1.11$$

Carbon is traded in money per tonne of carbon dioxide (tCO_2) (Marunda & Bouda, 2010; Kossoy &.Guigon, 2012). Thus, the amount of carbon obtained from *Equation 1.11* was converted to tCO_2 by multiplying it with 3.67 which is the quotient of 44(molecular mass of CO_2) and 12 (atomic mass of the element carbon) (Alabama Forestry Commission, 2012)

$$\mathbf{tCO2} = \boldsymbol{Carbon\ content\ (in\ tonne)\ x\ 3.67}$$

1.12

Lastly, the monetary value of the Kiaat trees was determined by multiplying the mass of CO_2 obtained using Equation 1.12 by the price per tonnne of CO_2. Since prices vary greatly with international markets (Marunda & Bouda, 2010), this study used €6.20 or N$ 65.47 of April 2012 as reported by Kossoy & Guigon (2012) at Word Bank.

$$\boldsymbol{Carbon\ monetary\ value\ (N\$) = \ Carbon\ stored\ (T)\ x\ price\ of\ carbon\ (\frac{N\$}{tonne})}$$

1.13

3.6.5 Additional Statistical Analyses

The significance of the mean of volumes of the 857 planks that were measured at various timber outlets, open markets, wood carving centres and Forestry Offices in Rundu was tested using a one sample t-test procedure in SAS EG 4. The difference of the mean of the tree prices that respondents would charge if they were the current suppliers of Kiaat trees was also tested using t-test procedure in SAS EG 4. The total dry mass and total carbon content of the fourty Kiaat trees were each regressed on the over-bark DBH of the trees to generate equation that can be used to estimate the two variables (total dry biomass and carbon content) using over-bark DBH. Moreover, the under-bark DBH was also regressed on the over-bark DBH in SAS EG 4 to generate the regression equation that can be used to estimate the under-bark DBH of the trunks and subsequintly the under-bark volume of trunks.

The significant difference between various categorical variable (data) such as categories of wood processing activitites (e.g. joinery, loggers) and tree prices, tree suppliers and wood processors, tree demands and wood procesors, raw materials preference and wood processing activities, timber preference and wood processing activities were tested using Chi-square in contigency tables in SAS EG 4. Chi Square test was used as the variables were predominantly qualitative (categorical data) with levels. For example, wood processing activities as a variable had six levels, namely joinery, loggers, woodcarvers, farmers, joinery-woodcarvers, and joinery-loggers.

Finally, descriptive statistics of DBH classes, comparison of current use timber value, carbon value, potential biomass, and the proportion of trunk that is constituted of bark, sapwood and heartwood were also carried out using both SAS EG 4 and Microsoft Excel Packages.

3.7 SUMMARY

This chapter presented data collection and data analyses methods. A combination of cross-sectional survey of users and products of Kiaat trees and determination of Kiaat trees volume and biomass, was used to collect the data. Tree measurements data were used to estimate volume; biomass; carbon stored; carbon monetary value; current-use value, and potential value of an average Kiaat tree. Qualitative and quantitative data were collected in the two survey exercises, namely products assessments and interviews of key-informants. The data were analysed and the produced results are presented in Chapter 4.

CHAPTER 4

RESULTS

4.1 INTRODUCTION

This chapter presents the results of trade-offs between timber and carbon values of *Pterocarpus angolensis* (Kiaat) in the Kavango Region of Namibia. The current and potential use values of the trees are specifically compared. The chapter is structured into four parts: (1) Wood-users survey; (2) Products assessment survey; (3) Volume and biomass studies, and (4) Tree-use analyses.

4.2 USERS SURVEY

4.2.1 Description of Respondents

The study interviewed 31 (89%) of the 35 known wood processors in and around Rundu in the Kavango Region. The remaining four (11%) processors refused to be interviewed. All respondents, however, were local adult males and were categorised, as per their responses, into six Categories of Wood Processing Activities (CWPA) (Table 4.1). Most (58%) of the respondents were engaged in joinery activities and had an average of 15 years of experience. The other respondents were engaged in logging (19%), wood carving (10%), joinery-and-wood carving (3%), farmers (7%), and loggers-and-joinery (3%). As a group, the respondents' average years of experience was 13 years.

Table 4.1: Categories of wood processing activities (CWPA) with percentage and years of experience of respondents per category.

CWPA	Percentage of respondents	Average years of experience per category
Joinery	58	15
Loggers	19	11
Woodcarvers	10	26
Joinery & Woodcarvers	3	18
Farmers	7	3
Loggers & Joinery	3	5

4.2.2 Tree Selection and Usage

Ninety percent (90%) of the respondents reported that they harvest Kiaat trees for their trunks only, provided the trees are mature and have large DBH with a straight and tall trunk. Only 10% of the respondents said they harvest trees both for their trunks and branches, provided that the trees have large DBH, and have straight and tall trunks and branches. Most (81%) of the respondents indicated that they prefer to obtain Kiaat materials as logs or branches, while the remainder (19%) prefer to obtain Kiaat materials in the form of processed planks. There was, however, no correlation ($p = 0.186$) between the CWPA and raw materials preferences.

4.2.3 Tree Trade Dynamics

4.2.3.1 Tree Prices

Five categories of tree selling prices ranging from N$50 to N$270 were found (Figure 4.1 & Table 4.2). The majority (59%) of the respondents paid between N$200 to N$249 for trees. Sixteen percent (16%) of the respondents pay between N$250 to N$299 for trees, while 3% buy trees at prices ranging from N$100 to N$149 (Figure 4.1). There was also no significant difference ($p = 0.1346$) between categories of tree prices and CWPA indicated in Table 4.1. The majority (84%) of the respondents said that the current Kiaat tree prices were too expensive, while only 16% were satisfied with the tree prices. Fifty-eight percent (58%) of the respondents who indicated that they were unhappy with current tree prices said that they make less profit, while 36% said that they were unhappy with the current tree prices because they do not make profit at all. The remainder (6%) of the respondents were dissatisfied with the current tree price, however, said they were unhappy because their customers do not make profit from what they sell to them (Figure 4.2).

Table 4.2: Summary of Kiaat tree prices in the Kavango Region.

Basic statistics (n=31)	Prices (N$)
Mean	190.32
Median	200.00
Minimum	50.00
Maximum	270.00

Where N$ = Namibian dollars, and N$1.00 = R1.00 (South African Rand).

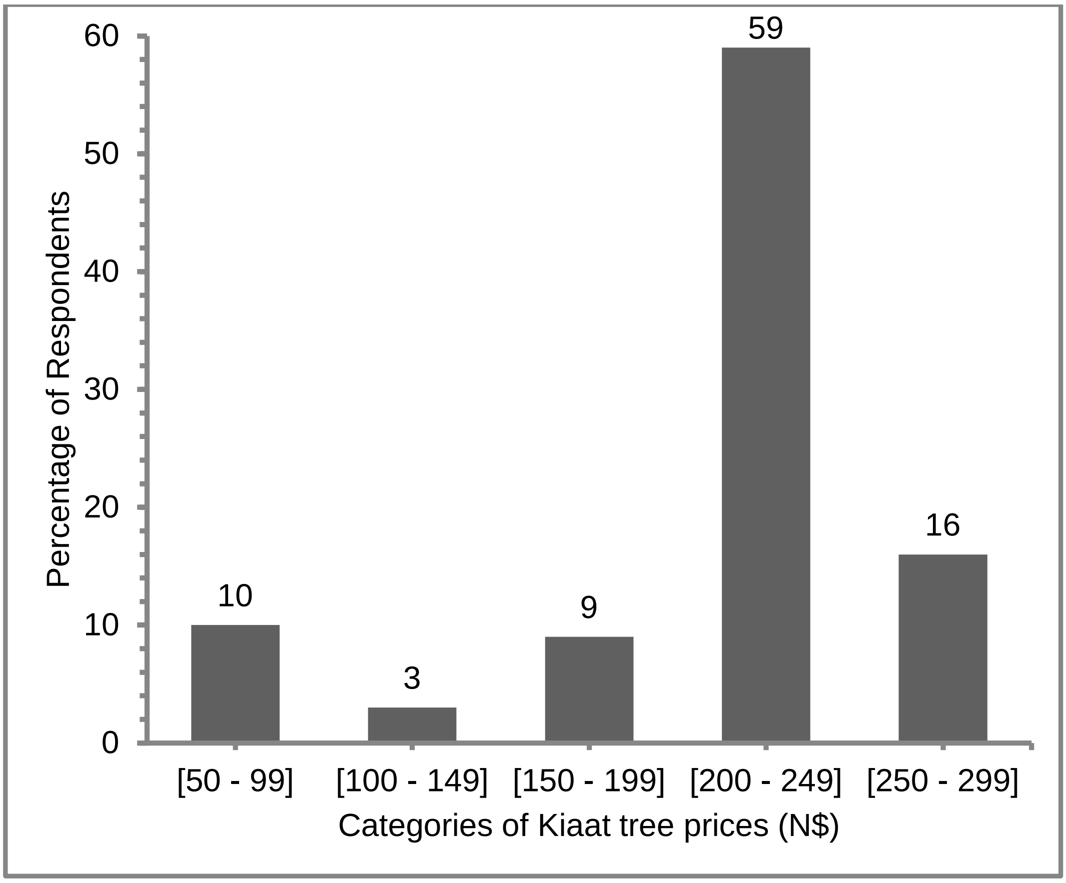


Figure 4.1: Categories of Kiaat tree prices and percentage of respondents (n = 31).

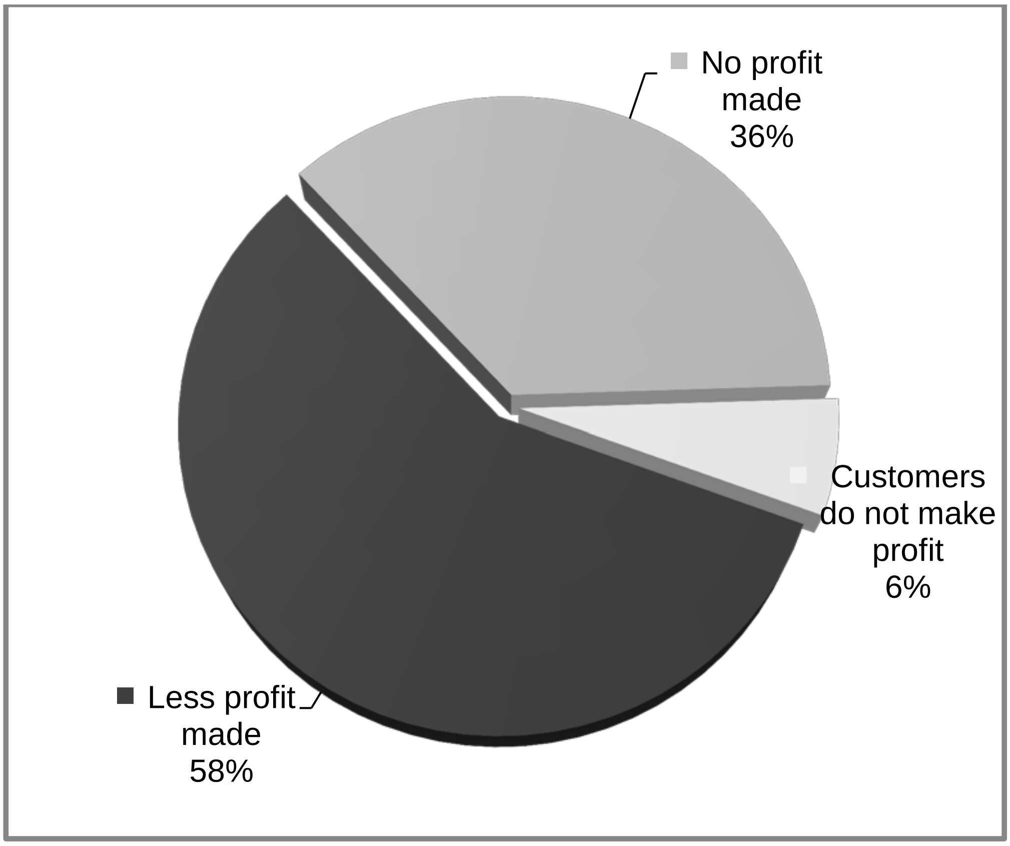


Figure 4.2: Categories and proportions of respondents dissatisfied with current Kiaat tree price (n=26).

4.2.3.2 Tree Pricing and Demand

Table 4.3 presents a summary of respondents' answers on the following survey questions:

i. What price are you willing to pay for a Kiaat tree?
ii. How much would you charge for a Kiaat tree if you were the current supplier?
iii. What is the buying and selling price for one Kiaat plank?
iv. How many planks do you get per stem of an average Kiaat tree?
v. How many Kiaat trees do you need per year to sustain your livelihood or business?

There was a significant difference between the types of products (e.g. planks and woodcraft) cut and CWPA ($p = 0.0295$) and a highly significant difference between the respondents' acceptance of current tree supply prices and the prices that respondents would charge per tree if they were the current suppliers of the trees ($p = 0.0001$). There was, however, no significant difference ($p = 0.4127$) between tree prices that respondents would charge if they were the current suppliers of Kiaat trees and the CWPA.

Table 4.3: Summary of respondents' answers on five survey questions.

Basic Statistics (n=31)	Questionnaire Research Questions				
	(i) Prices respondents willing-to-pay / tree (N$)	(ii) Prices respondents would charge per tree (N$)	(iii) Selling prices of planks (N$)	(iv) Number of planks cut per tree	(v) Number of trees needed / year
Mean	113	246	45	12	120
Median	100	200	45	12	60
Minimum	40.00	30.00	30	5	5
Maximum	300	1000	70	23	100~~1~~0

4.2.3.3 Tree Suppliers and Preferences

With respect to tree suppliers, the respondents were grouped into four categories (Figure 4.3), namely respondents who buy trees from:

i. the Directorate of Forestry (DoF) only (61%);
ii. *Gazetted* Community Forests – CFs (23%);
iii. individual villagers (6%), and
iv. both the Directorate of Forestry and *Gazetted* community forests (10%).

There was no significant differences found between tree suppliers and tree prices (p = 0.1147) as well as between tree suppliers and CWPA (p = 0.1417).

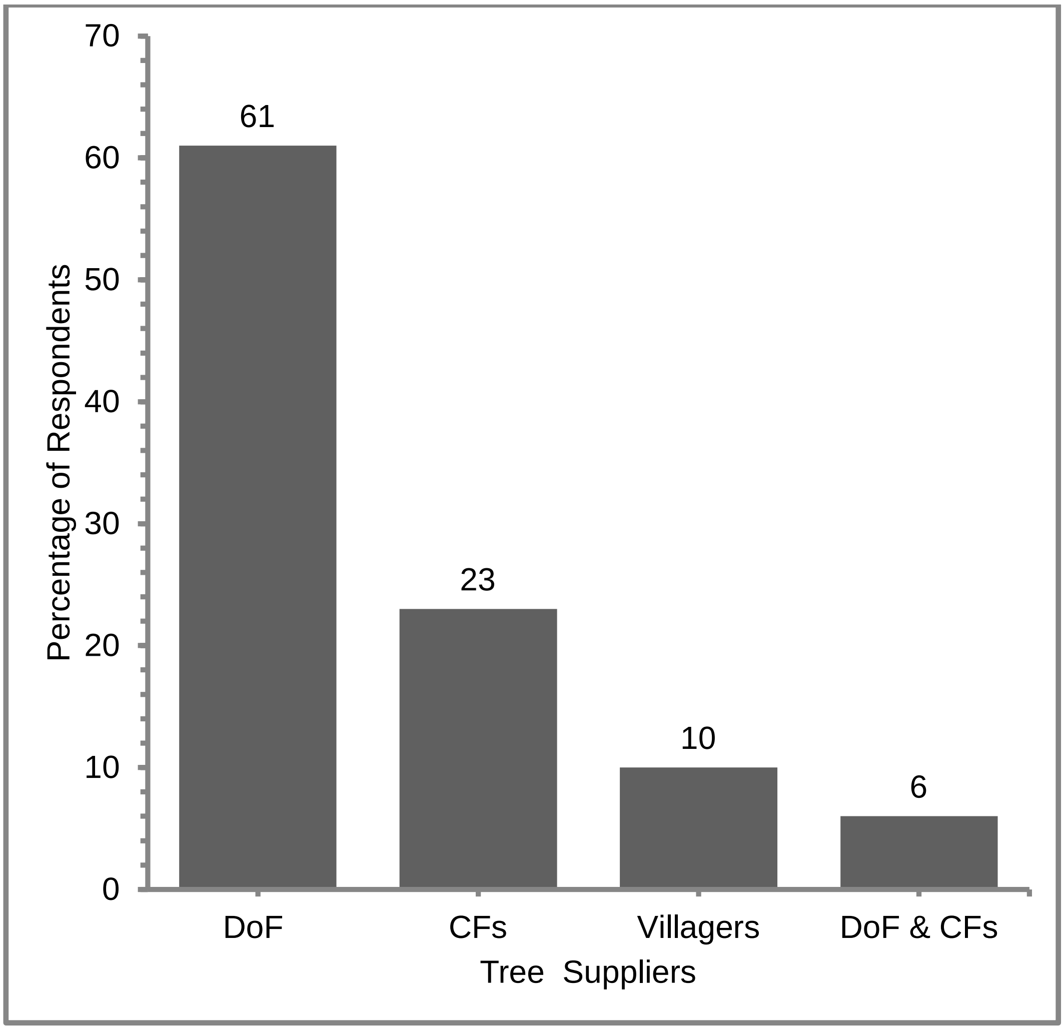


Figure 4.3: Suppliers of Kiaat trees in the Kavango Region (n = 31).

Where: DoF = Directorate of Forestry, CFs = *Gazetted* Community Forests.

Figure 4.4 shows that respondents extract different parts of the trees and have varying timber preferences. Most (61%) of the respondents said they only use trunks of Kiaat trees, 29% use both the trunk and branches, 7% use branches only, and 3% only utilise heartwood portion of the trunks (Figure 4.4).

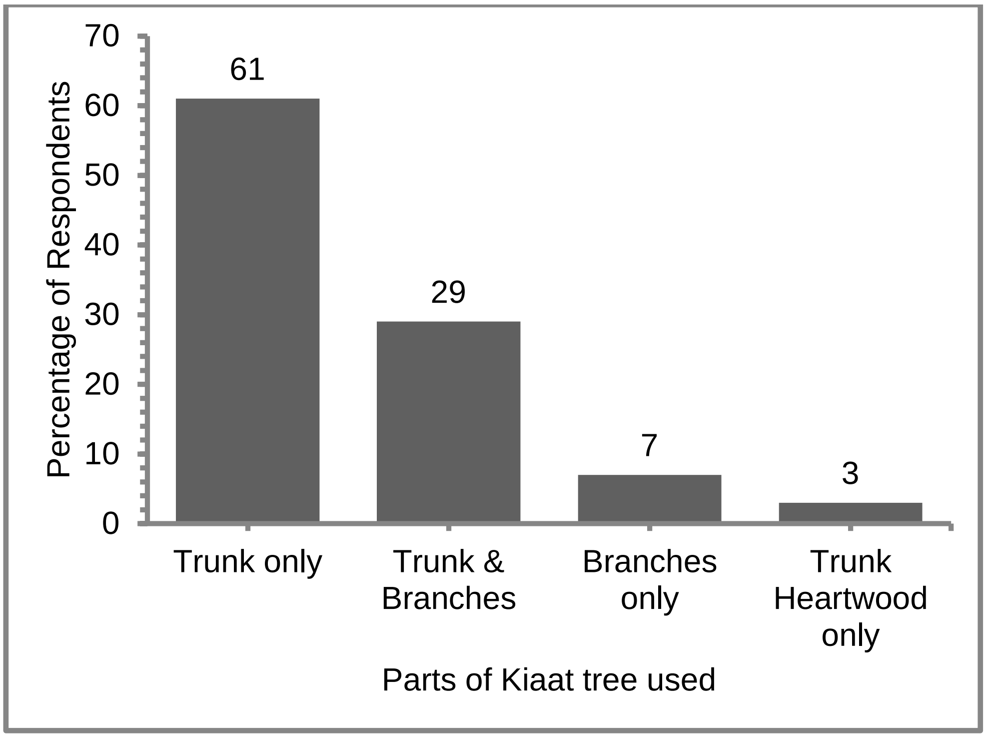


Figure 4.4: Parts of Kiaat tree used by respondents (n = 31).

4.2.3.4 Reasons for Selective Tree Section Use

The majority (68%) of the respondents indicated that they only use the tree trunk because it is the only part of a Kiaat tree that has sufficient heartwood content (Figures 4.6). Sixteen percent (16%) said they only use the trunk because they specialise in cutting planks, while 10% indicated there were barely markets or customers for products cut from canopy parts. Only 6% of the respondents reported that they only use branches because they need small pieces for wood carvings.

There was a significant difference (p = 0.0149) between parts of tree used and CWPA. For instance, 72% of the respondents who were engaged in joinery said they utilise trunks only, 22% of them indicated that they utilise both the trunks and defect-less branches; 50% of loggers said they utilise only trunks (which they process into planks only) and the other 50% of the respondents prefer both the trunks and branches, and 67% of woodcarvers said they prefer canopy wood only, while 33% of them prefer trunks only. All the joinery-woodcarver respondents and logger-joiner respondents only utilise trunks from the Kiaat trees.

Most (68%) of the respondents prefer heartwood-only timber, 7% also take planks consisting of sapwood and heartwood i.e. mixed planks, and 19% require timber cut from branches which are straight and without defect. Six percent (6%), however, said their timber preferences depended on the purpose for which timber is to be used (Figure 4.5).

There was a significant difference (p = 0.001) between timber preferences and CWPA. All loggers (19%) prefer heartwood planks, 58% of the respondents do joinery only, and 78% of them said they prefer heartwood planks, while 17% (i.e. 10% of all respondents) indicated that they also prefer mixed planks. Moreover, virtually all woodcarvers (50%) who constituted the 13% of all respondents said they prefer straight and branches with less defects.

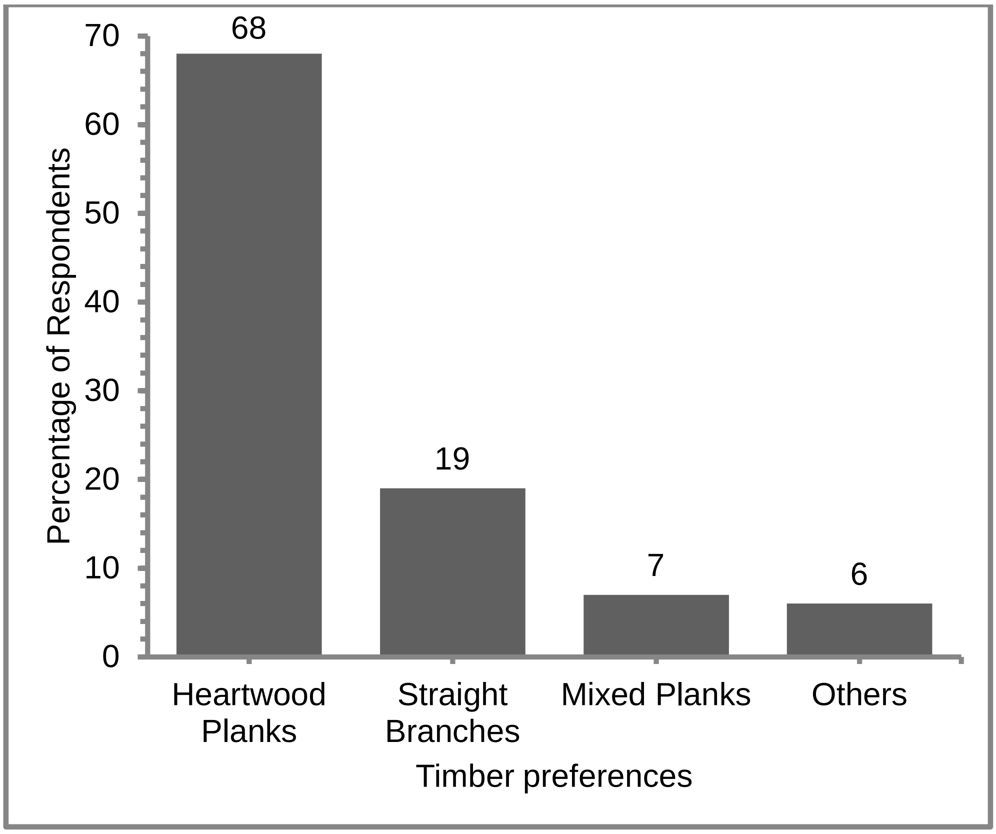


Figure 4.5: Respondents' timber preferences (n = 31).

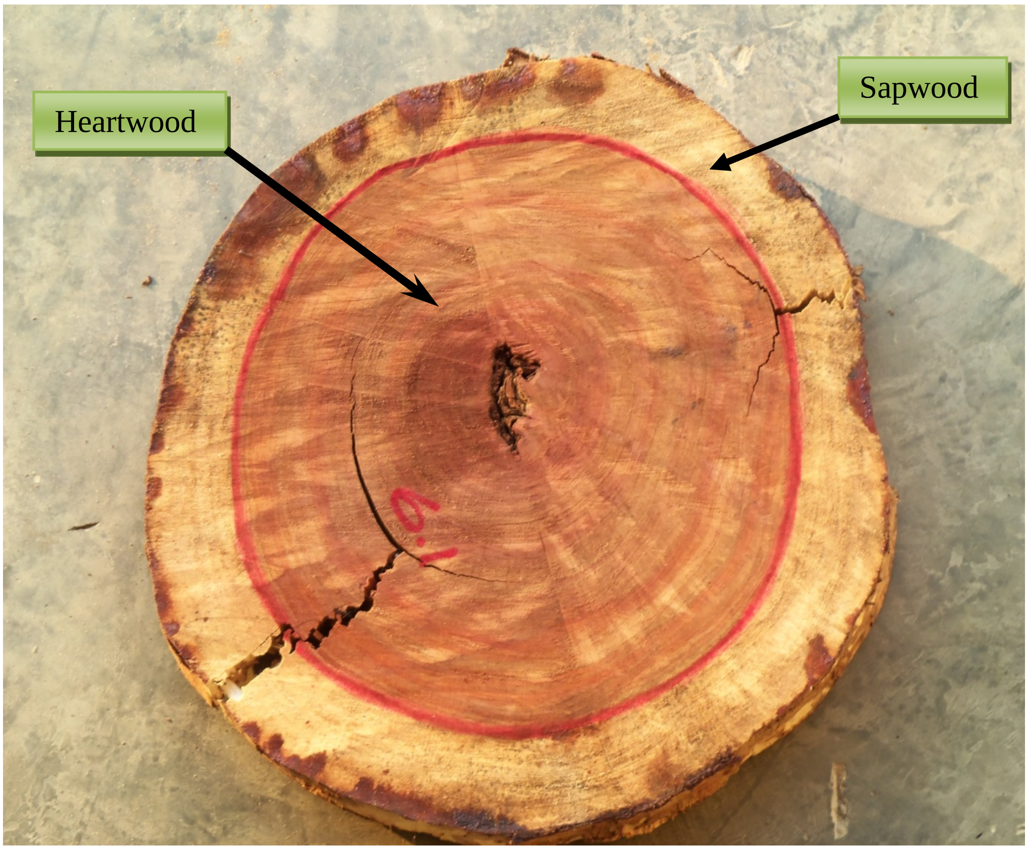


Figure 4.6: Heartwood and sapwood of Kiaat.

4.2.3.5 Products Ranking

The majority (55%) of the respondents said the community of the Kavango Region cannot do without Kiaat planks, while 32% said both planks and woodcarvings are most important to the comunity. Seven percent (7%) of the respondents indicated that woodcarvings are the only important product to the community. Six percent (6%) however said they do not know of Kiaat products that are important to the community.

4.2.3.6 Products Trade and Markets

Respondents sell their products at different markets. Most (61%) of the respondents sell their products in Rundu, 20% sell in Windhoek (712 km away), 3% sell at Oshikango (450 km away) in Namibia, while 16% sell in Cape Town, South Africa (2,112 km away) (Figure 4.7). According to respondents, individual planks were sold at an average price of N$45.26 (see Table 4.3), while 1 m^3 of planks is sold for N$3,500 in Rundu. In Windhoek, on average, individual planks cost N$123.75 while in Cape Town (South Africa) individual planks were sold at an average price of N$125 or at N$4,500/m^3.

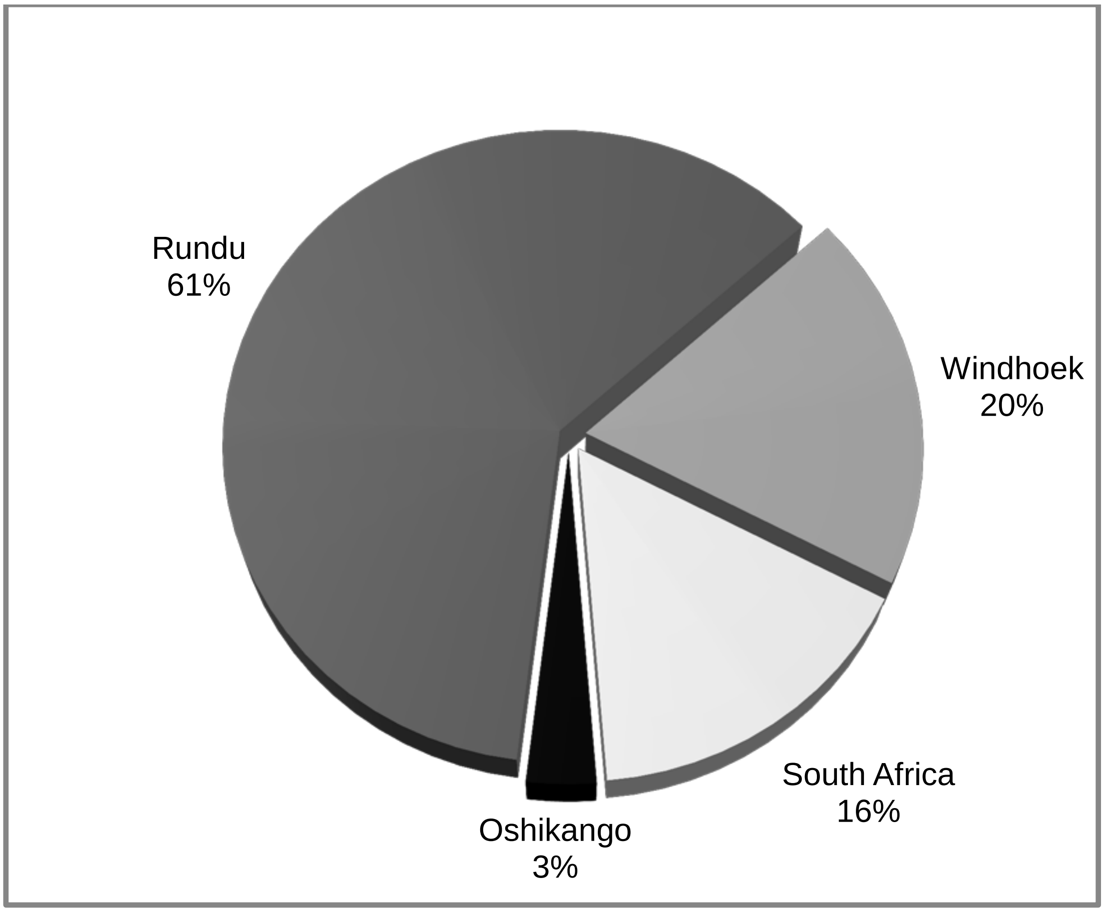


Figure 4.7: Markets of Kiaat products from the Kavango Region (n = 31).

4.2.3.7 Awareness of Canopy Parts Uses

Most (32%) of the respondents said canopy parts can be used as firewood, 29% said the canopy parts can be used for woodcarving only, 10% reported both firewood and woodcarvings as uses of canopy parts, 7% indicated fertilizer as use of canopy, and 3% said the canopy part can be used for bio-energy purpose.. Nineteen percent (19%) of the respondents, however, did not know what canopy parts can be used for (Figures: 4.8 & 4.9). Fifty-two percent (52%) of the respondents said they do not know what bark is or can be used for, while 23% indicated that the bark can be used as a fertilizer. The remainder of the respondents stated decoration (16%), bio-energy (6%) and dye (3%) as possible uses for barks (Figure 4.10). Moreover, 71% of the respondents do not know what Kiaat leaves can be used for, while 19% reported as a fertilizer, 7% health remedy and 3% bio-energy (energy generated using organic matter), as uses for leaves (Figure 4.11).

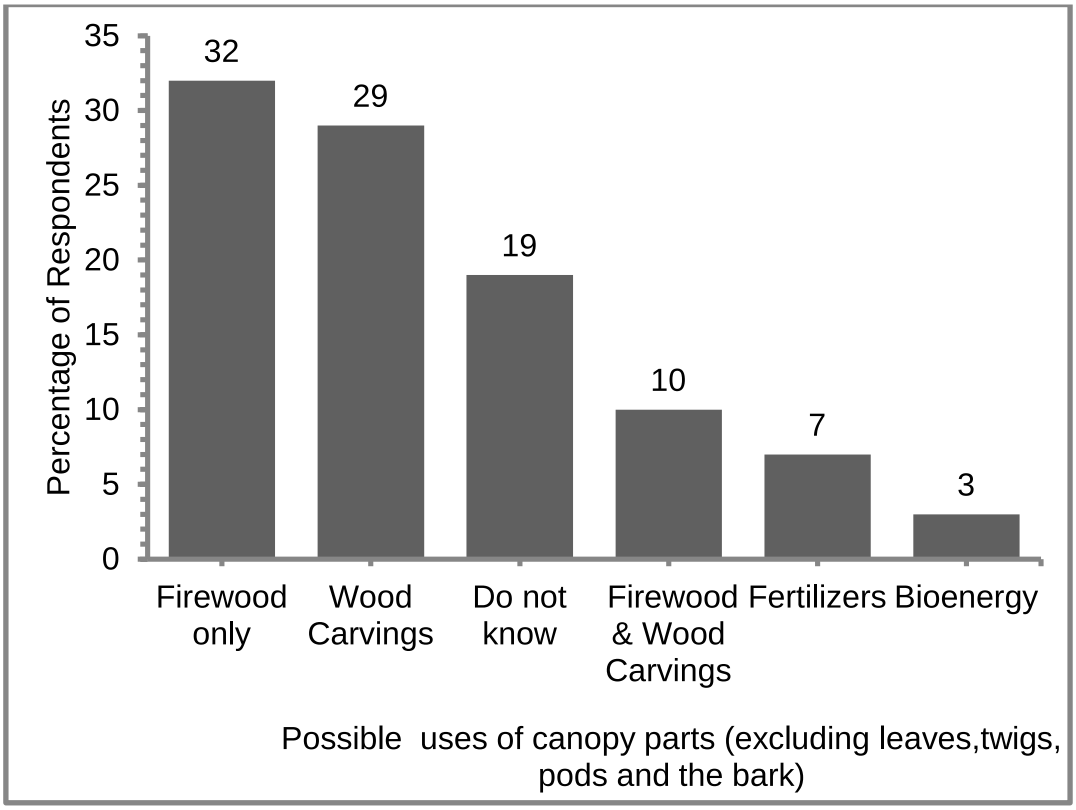


Figure 4.8: Respondents' responses on general uses of canopy parts (excluding leaves, twig, pods and the bark) (n = 31).

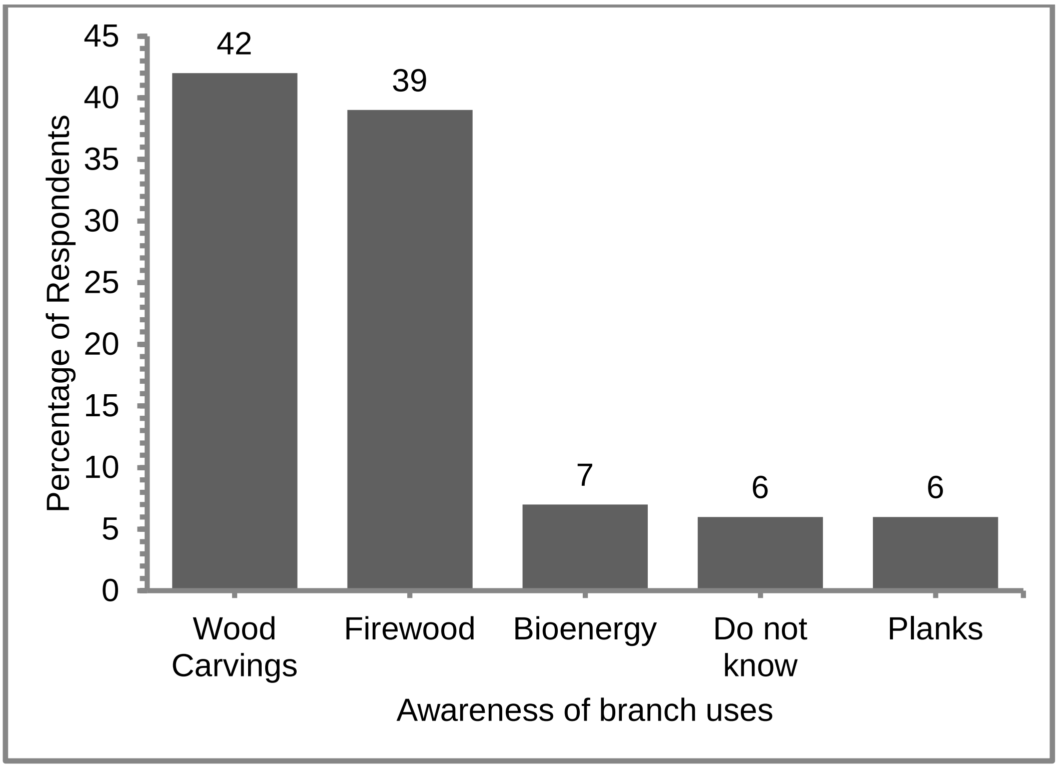


Figure 4.9: Respondents' responses on branch uses (n = 31).

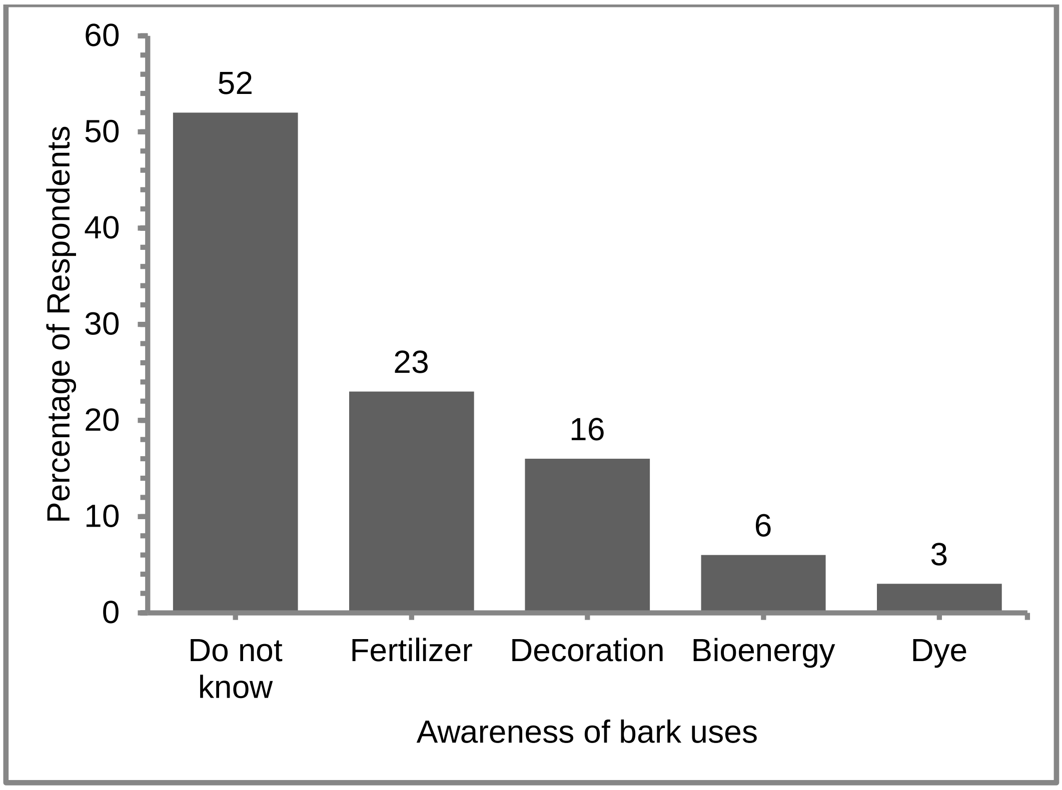


Figure 4.10: Respondents' response on use of bark (n = 31).

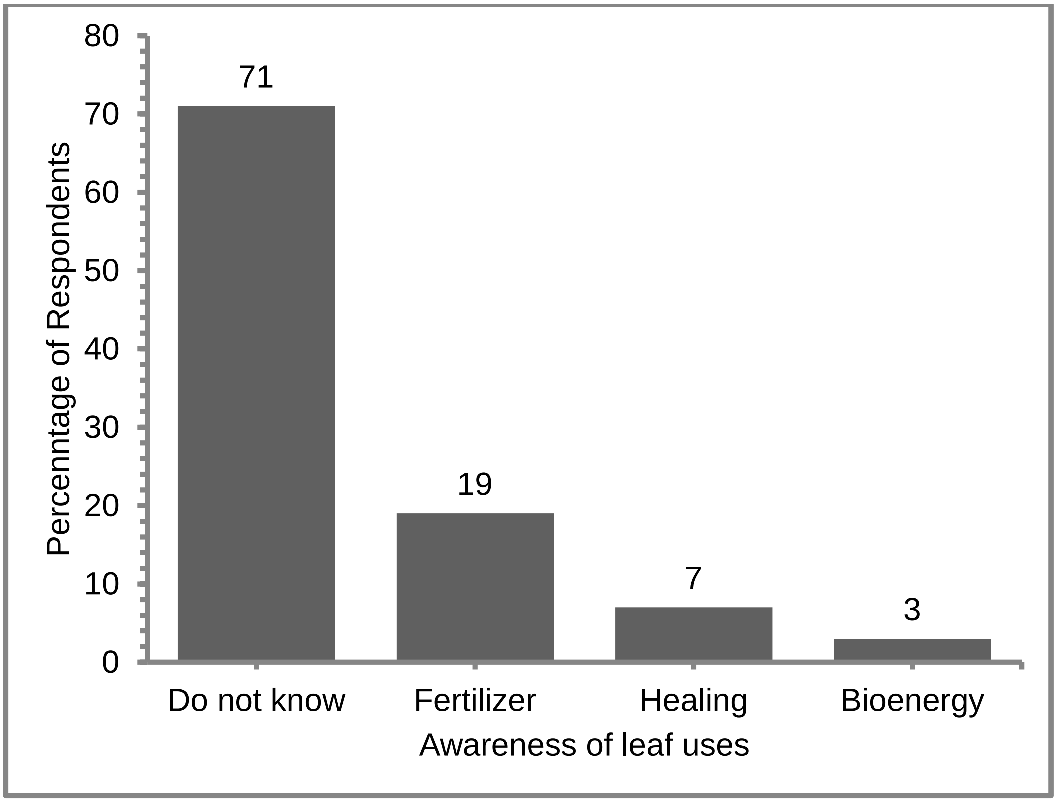


Figure 4.11: Awareness of uses of Kiaat leaves (n = 31).

4.2.3.8 Availability of Alternative Species

Forty-two percent (42%) of the respondents indicated *Baikiaea plurijuga* as alternative timber species to Kiaat trees, 32% indicated both *Baikiaea plurijuga* and *Burkaea africana* as substitutes, and 26% do not know of substitute species for Kiaat trees.

4.3 PRODUCTS ASSESSMENT

Products cut from Kiaat wood were grouped into planks, finished products and woodcrafts. The most common finished products that were found included beds, standard doors, chairs, tables, and woodcrafts were represented by bowls, elephant carvings, musical drums and walking sticks (Tables: 4.4 & 4.5).

4.3.1 Planks

The study found that planks were the most important products cut from Kiaat trees (Figure 4.12). In this study the dimensions of 857 dry planks found at various timber processing outlets, open markets, craft centers, and confiscated planks that were found in the yard of the Directorate of Forestry (DoF) in Rundu were measured. The average plank was found to have an average length of 257.9 cm; width of 23.8 cm, and thickness of 3.7 cm. The average volume of a plank was 0.023 m^3.

4.3.1.1 Planks Classification

The 857 planks were grouped into planks consisting only of heartwood and planks consisting of both sapwood and heartwood i.e. mixed planks (Figure 4.12). Most (90%) of the planks were mixed planks with only 10% heartwood-only planks. Heartwood-only planks were sold at an average local price of N$15.00 more per plank than mixed planks.

Figure 4.12: Heartwood-only and mixed planks *(J.Ifile, 2012*).

4.3.1.2 Finished Products

The four main finished products that people make from planks are ¾ beds, standard doors, chairs and four-seater tables (Table 4.4). An average of nine planks worth N$407.34 are needed to make one ¾ bed (Figure 4.13). The avearge price at which beds were sold is N$975. Six planks worth N$271.56 are needed to make a standard door and sold for N$ 850. A four-seater table is also made with six planks, but sold for N$1,150 (Table 4.4).

Table 4.4: Finished products, number of planks per product and their average local prices.

Finished products	Average units of planks / finished products	Average local price / finished product (N$)
¾ beds	9	975
standard doors	6	850
chairs	3	350
4-seater tables	6	1150

Figure 4.13: Example of a ¾ bed made with Kiaat planks.

4.3.1.3 Woodcrafts

Besides planks, people also use the trunk and branches for wood carvings (Figures 4.14 and 4.15). Table 4.5 shows four varieties of common woodcrafts, the dimensions of raw wood blocks from which they are cut, the volume of the raw wood block, and the average local prices of the woodcrafts. According to the wood processors and traders, these woodcrafts are mainly cut from canopy parts.

Table 4.5: Canopy woodcrafts, dimensions of their raw wood block and their local prices.

Type of woodcrafts	Dimension of raw wood blocks from which final woodcrafts are carved		Minimum to Maximum diameter (cm)	Average Volume (m^3)	Average Selling Price (N$)
	Average Diameter (cm)	Average Length (cm)			
Bowls	32	15	22 to 40	0.01	94
Elephant carvings	35	41	24 to 50	0.04	414
Music drums	17	35	12 to 20	0.008	171
Walking sticks	5	103	4 to 6	0.002	121

Figure 4.14: Variety of Kiaat wooden bowls.

Figure 4.15: Elephant carvings and walking sticks carved from Kiaat wood.

4.4 TREE VOLUME AND BIOMASS DETERMINATION

The study estimated the above-ground volumes and biomass of 40 Kiaat trees to quantify current use values and timber losses based on information obtained from the survey process. Table 4.6 presents tree components and summary statistics of their measurements, according to which the tree volume and biomass were determined as described in sections *3.6.1.and 3.6.2.*

Table 4.6: Summary of tree components and their measurements.

Basic statistics (n=40)	DBH (cm)	Stump Height (cm)	Merchantable Log Length (m)	Defect Log (m)	Stem Height (m)	Tree Heights (m)
Mean	47	23	4.3	0.5	5	8
Median	46	20	4.4	0.4	5	16
Minimum	31	11	2.3	0.0	3	16
Maximum	64	60	7.8	1.9	8	30

4.4.1 Tree Parameters

4.4.1.1 DBH Classes

The trees that were harvested had a DBH range from 30 to 60 cm. Most (43%) of the trees that the logger felled had a DBH ranging from 44 to 50 cm, while 37% of the trees had a DBH between 37 to 43 cm. Only 2% of the trees had a DBH between 30 to 36 cm and 5% had a DBH between 58 cm to 64 cm (Figure 4.16).

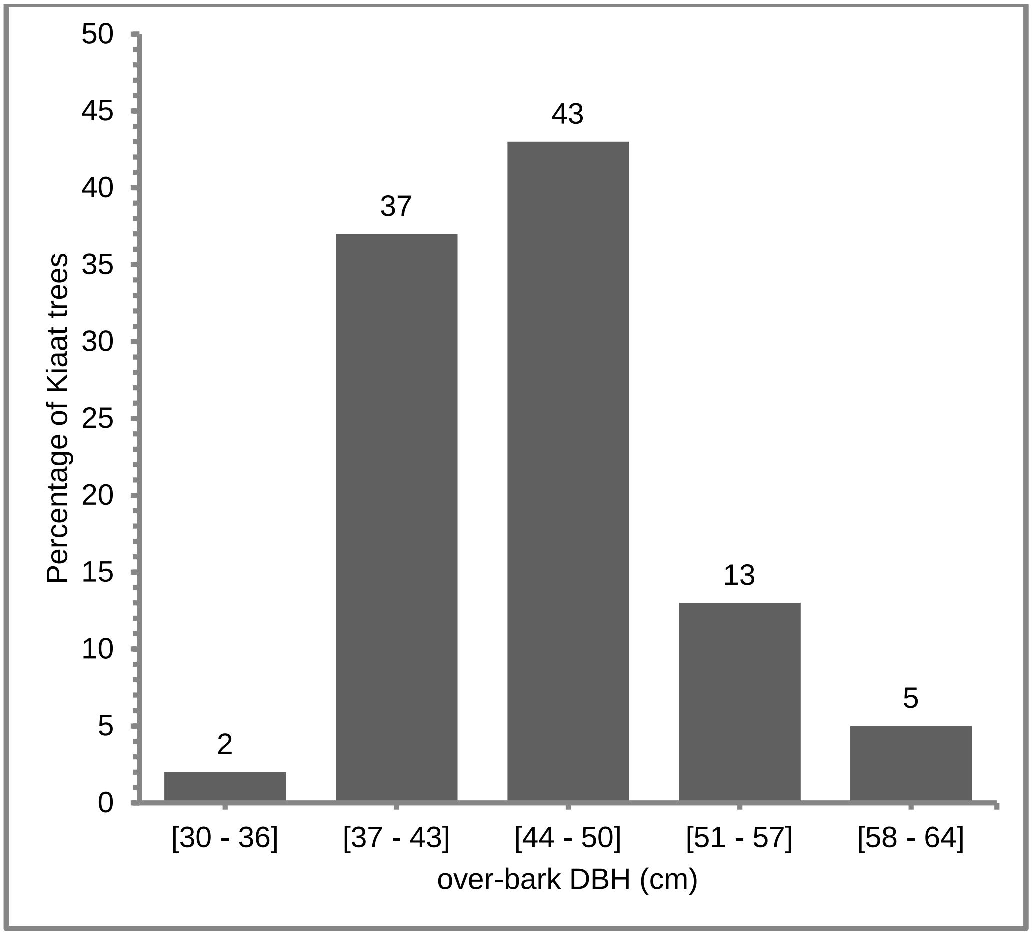


Figure 4.16: Over-bark DBH Classes (n = 40).

4.4.1.2 Stump, Stem and Canopy Heights

The study found that the trees were selectively chosen for harvesting and the harvested trees were selectively used (only a portion of the main stem, i.e. merchantable log, was extracted for processing mainly into planks). Respondents engaged in logging and joinery activities mainly supply other wood processors with raw materials. Lengths of the merchantable logs that were removed from the trees, ranged from 2.2 m to 3 m. It was also found that if a tree stem is not long enough to provide a complete merchantable log or merchantable logs, only one log is cut and the remainder (defect log) is left behind in the field unutilised. The portions of individual tree height which is made up of the stump, stem and canopy are illustrated in Figure 4.17.

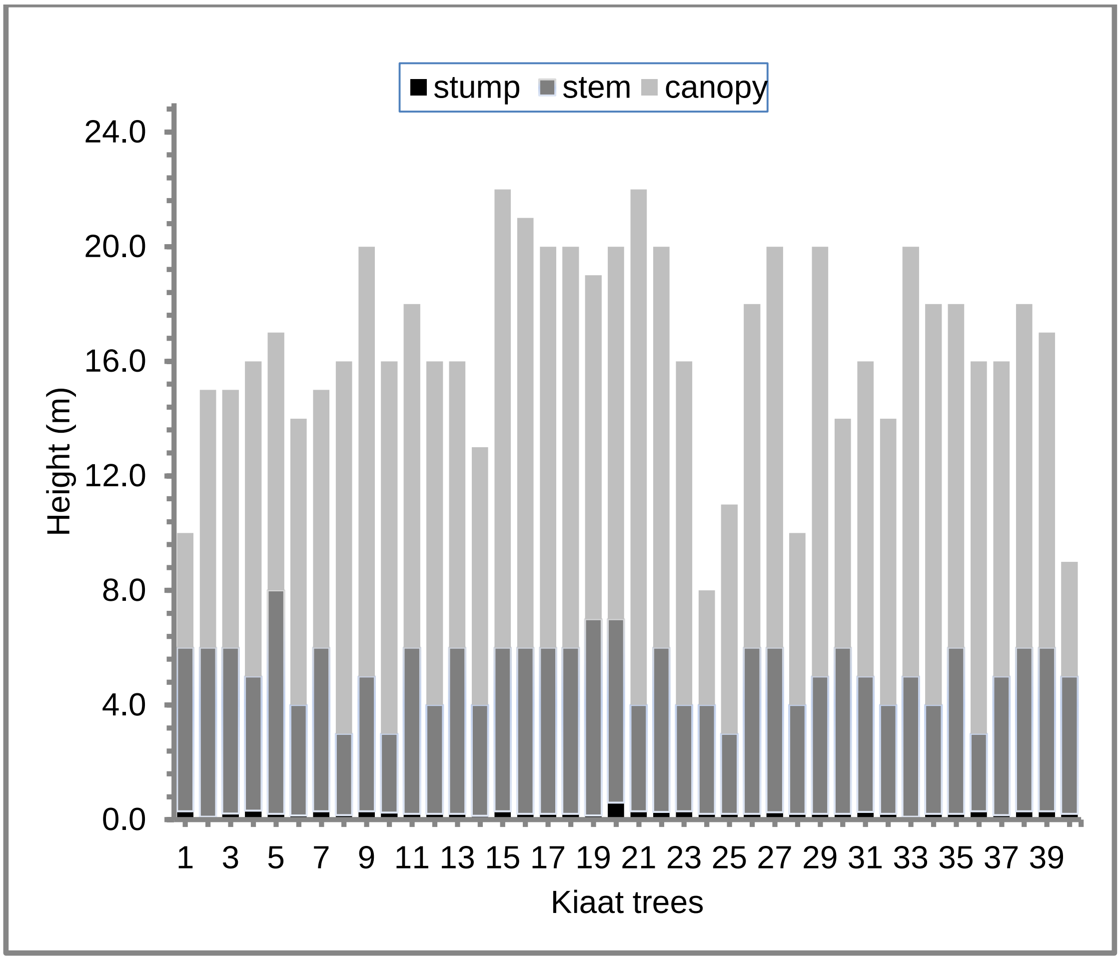


Figure 4.17: Trees and their stump-stem-canopy heights (n = 40).

4.4.2 Determined Volume and Biomass

4.4.2.1 Wood Density and Moisture

The average basic wood density of stems and branches that were greater than 10 cm in diameter was calculated as 631 kg/m^3. No change of basic wood density was detected along the stem. Canopy parts that were smaller than 10 cm in diameter (including pods and twigs, but excluding leaves) had a moisture content of 58%, meaning the oven-dry weight of canopy parts smaller than 10 cm in diameter was 42% of fresh mass.

4.4.2.2 Tree Volume

Table 4.7 shows a summary of the tree components' volume and total volume of the fourty trees (see *Appendix F* for details). Table 4.7 shows that the average volume of the merchantable logs was 0.4 m^3, while the mean of total tree volumes was 1.63 m^3. A minimum defect log volume of zero (0.00) indicates an instance where the whole trunk was extracted as a merchantable log.

Figure 4.18 illustrates the proportion of the total average tree volume that each component constituted. On average, 77% of the potentially merchantable volume of Kiaat trees was not utilised, and only 23% of it was extracted in the form of merchantable logs. It was further found that 15% of an average merchantable log is bark which was also not utilised, meaning only 85% of an average merchantable log (0.4 m^3) was utilised (Figure 4.20).

Table 4.7: Estimated total over-bark volumes of fourty Kiaat trees.

Basic statistics (n=40)	Stumps (m^3)	Merchantable logs (m^3)	Defect logs (m^3)	Branches [>10 cm in diameter] (m^3)	Canopy Parts [<10cm in diameter] (m^3)	Total Tree Volume (m^3)
Mean	0.04	0.4	0.05	0.91	0.26	1.63
Median	0.03	0.4	0.03	0.80	0.24	1.40
Minimum	0.01	0.2	0.00	0.11	0.08	0.64
Maximum	0.11	0.7	0.30	3.30	0.45	4.38

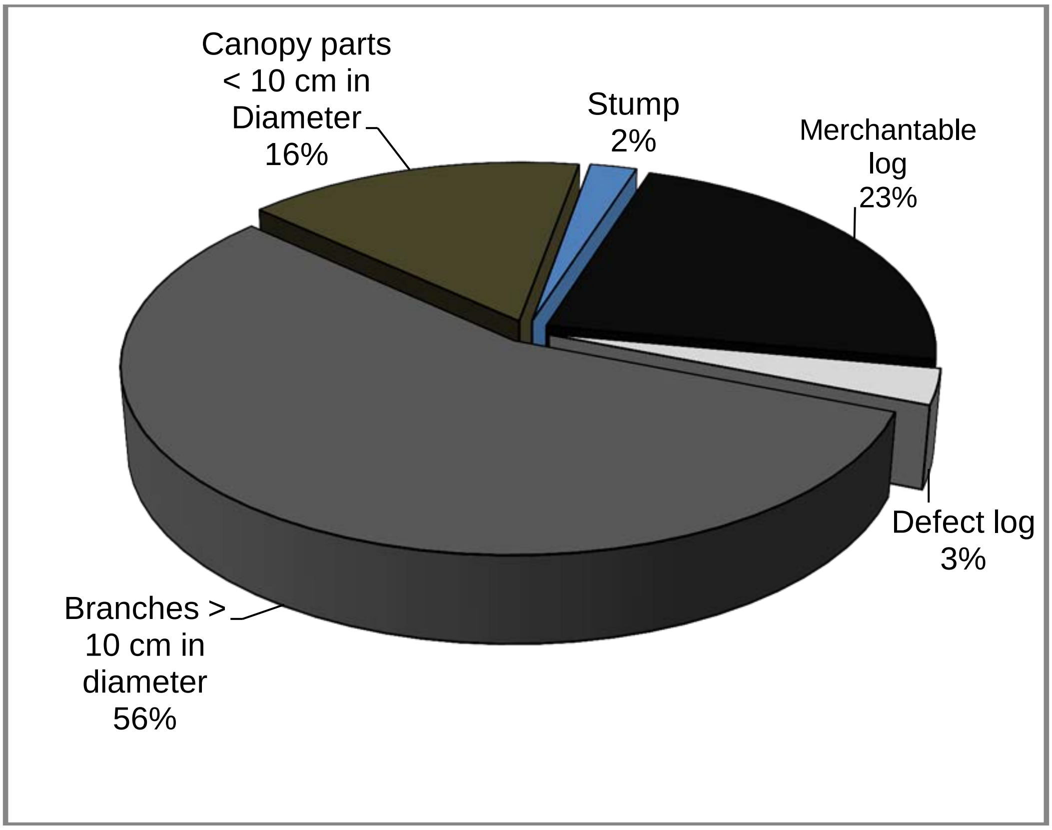


Figure 4.18: Volume percentage of Kiaat tree components (n = 31).

4.4.2.3 Tree Biomass

The total average over-bark biomass (dry-weight) of the fourty Kiaat trees was determined as 1,029 kg, with a maximum of of 2,766 kg (Table 4.8; *Appendix G*). The defect log biomass of zero (0.00) indicates that not all trunks had defect logs. That is, the whole trunk was extracted as a merchantable logs and no part of it was was abandoned.

Table 4.8: Estimated total over-bark biomass of fourty Kiaat trees.

Basic Statistics (n=40)	Stumps Biomass (kg)	merchantable logs Biomass (kg)	Trunk Defect Biomass (kg)	Biomass of Branches > 10 cm in diameter (kg)	Biomass: Canopy Parts < 10 cm in diameter (kg)	Total Tree Biomass (kg)
Mean	23	235	34	573	164	1,029
Median	18	222	20	505	154	885
Minimum	8	124	0.00	69	50	408
Maximum	74	409	1,90	2,082	2,385	2,766

4.4.4 Regression of Variables

4.4.4.1 Under-bark DBH to over-bark DBH

Under-bark DBH (required for the estimation of merchantable log volume without bark) can be estimated with 99% explained variation (R^2 = 0.99) from over-bark DBH using *Equation 1.14* generated from this study's data (Figure 4.19 and Table 4.9).

$$Y = 0.96x - 1.96 \qquad 1.14$$

Where:

Y = under-bark DBH (cm)

0.96 = is the slope or gradient of the equation

1.96 = is the intercept

x = over-bark DBH (cm)

Table 4.9: Parameter estimates of Equation 1.14.

Variable	Degrees of Freedom (DF)	Parameter Estimate	Standard Error	t Value	P-value
Intercept	1	-1.95691	0.16941	-11.55	<.0001
Over-bark diameter(cm)	1	0.95718	0.00543	176.12	<.0001

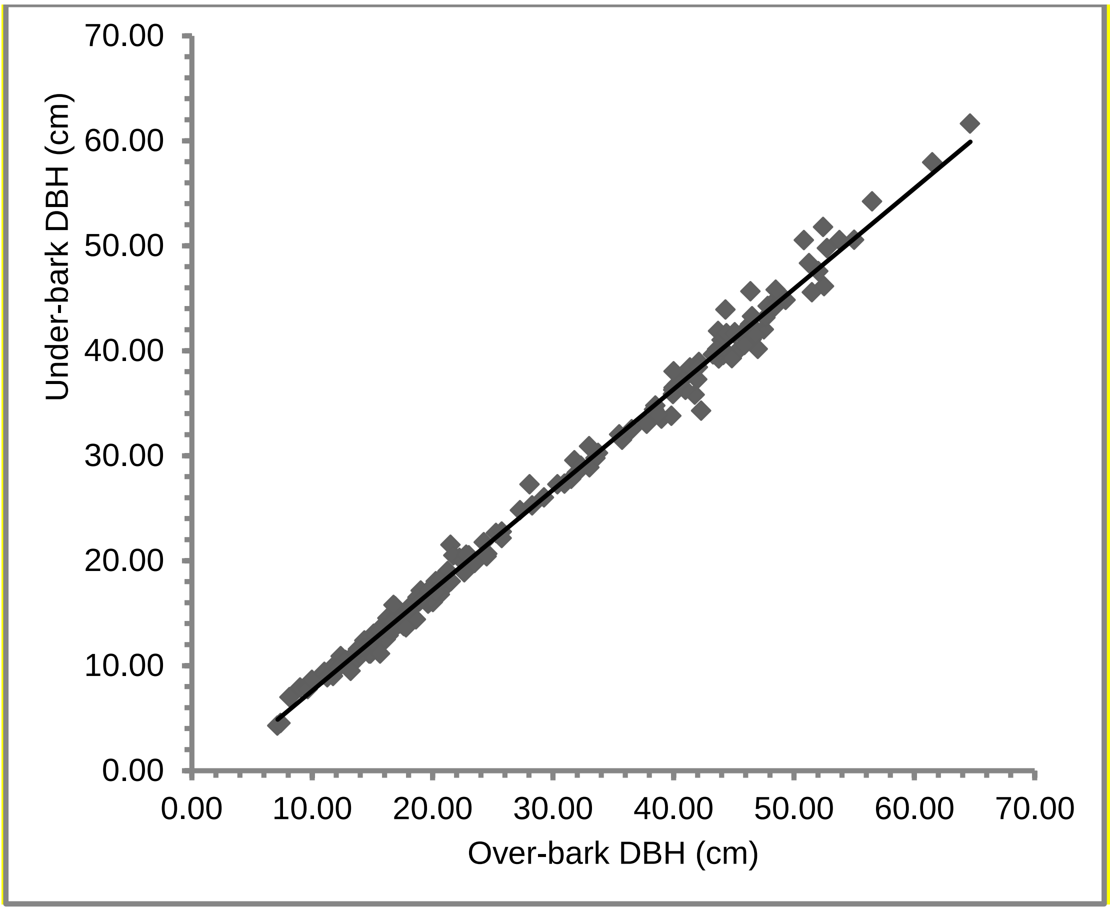


Figure 4.19: Regression of under-bark DBH to over-bark DBH of Kiaat trees.

4.4.4.2 Regression of Total Tree Volume to over-bark *DBH*

The total above-ground volume of an average Kiaat tree can be estimated with 62% explained variation (R^2 = 0.62) from over-bark DBH, using *Equation 1.15* generated from this study's data (Table 4.10, Figure 4.20). The Equation is, however; only valid if x (over-bark DBH) is at least 30 cm.

$$Y = 0.0936x – 2.7522 \qquad 1.15$$

Where:

Y = total above-ground volume of Kiaat trees (m^3)

0.0936 = is the slope or gradient of the equation

2.7522 = is the intercept

x = over-bark DBH

Table 4.10: Parameter estimates of Equation 1.15.

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	95% Confidence Limits	
Intercept	1	-2.752	0.561	-4.91	<.0001	-3.887	-1.617
Over-bark DBH (cm)	1	0.094	0.012	7.85	<.0001	0.069	0.118

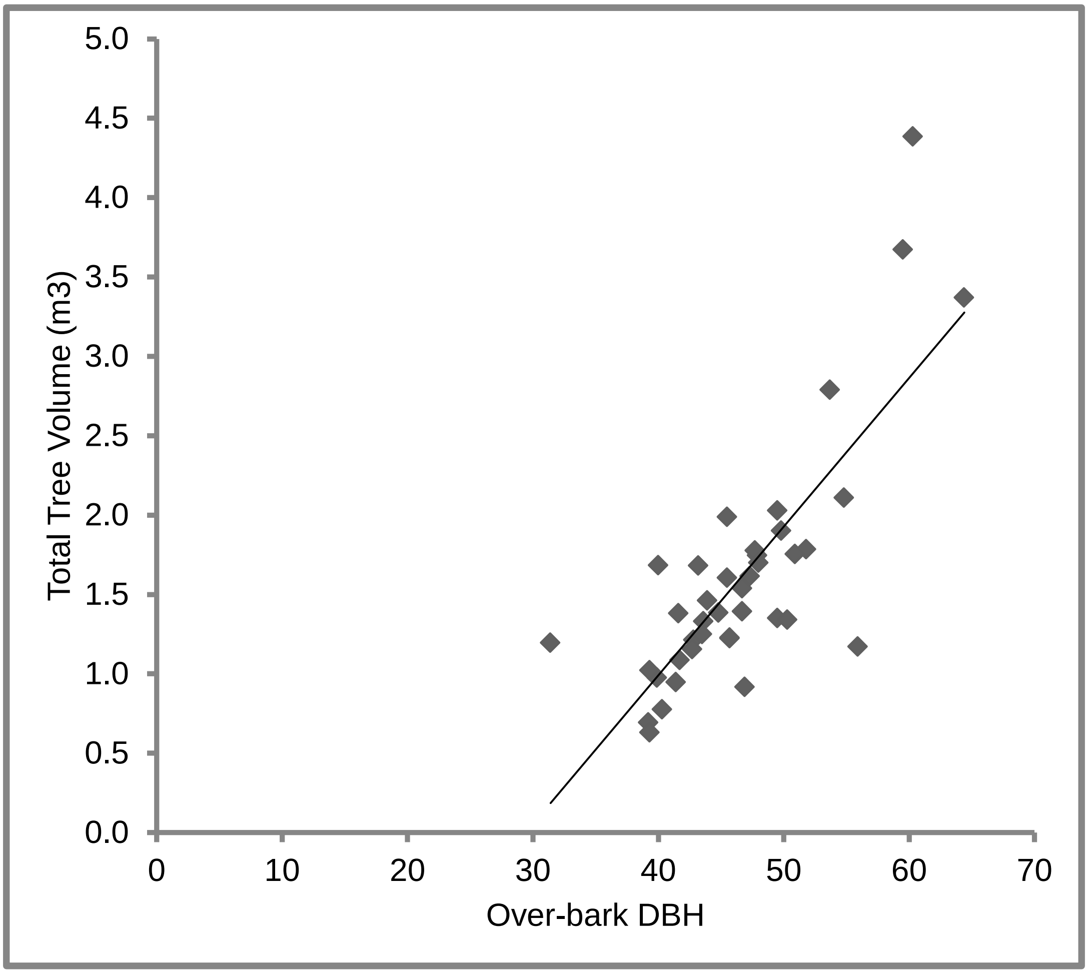


Figure 4.20: Regression of total tree volume on over-bark DBH.

4.4.4.3 Regression of Total Tree Biomass to over-bark *DBH*

Total tree biomass can be estimated with 63% explained variation (R^2 = 0.63) from over-bark DBH, using *Equation 1.16* (Figure 4.21 and Table 4.11). The equation is only defined if x (over-bark DBH) is at least 30 cm).

$$Y = 60.202x - 1774.4 \qquad 1.16$$

Where:

Y = total above-ground dry mass of Kiaat trees (kg)

60.202 = is the slope or gradient of the equation

1774.4 = is the intercept

x = over-bark DBH (cm)

Table 4.11: Parameter estimates of Equation 1.16.

Variable	Degrees of Freedom (DF)	Parameter Estimate	Standard Error	t Value	P-value	95% Confidence Limits	
Intercept	1	-1774.4	354.608	-5.00	<.0001	-2492	-1057
Over-bark DBH (cm)	1	60.201	7.544	7.98	<.0001	45	75

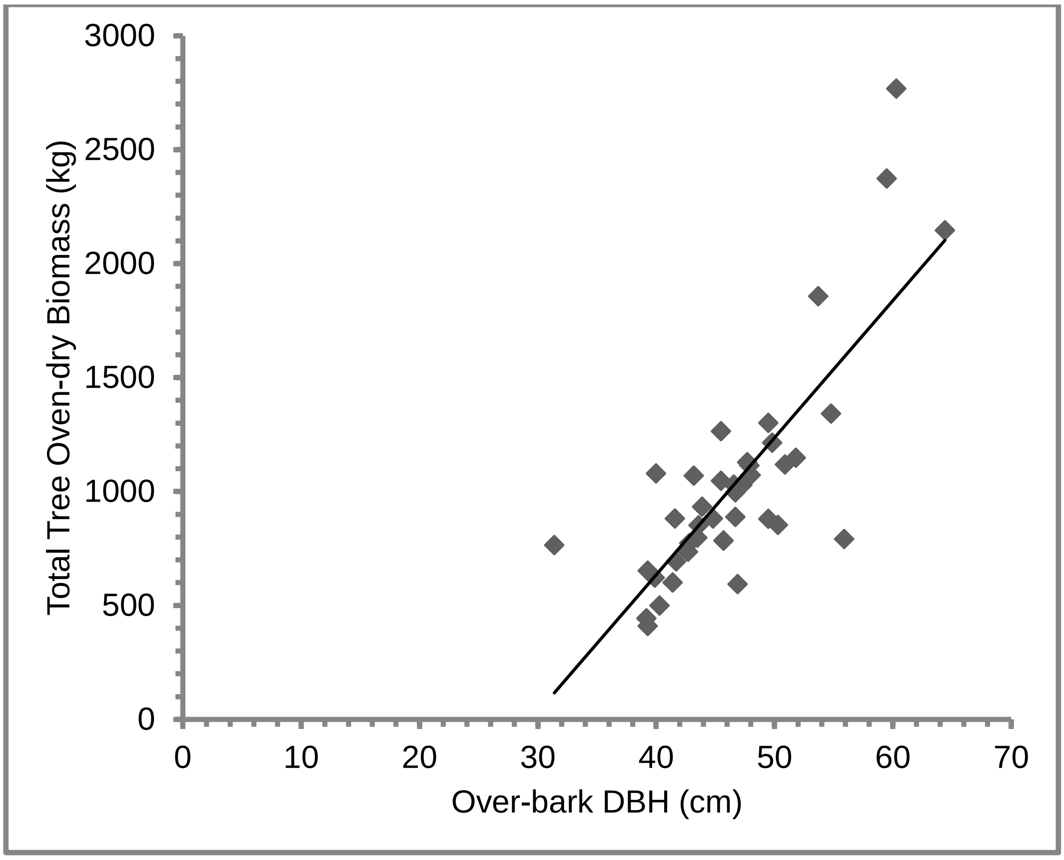


Figure 4.21: Regression of total tree biomass to over-bark DBH.

4.5. TREES USE ANALYSES

This sub-section presents results of further analyses based on surveys and tree analyses findings. In particular, results regarding how much of the merchantable logs is utilised, how much sapwood and heartwood trunks contain, what and how much of each product is cut from both the utilised and unutilised components of the trees, and lastly the amounts and market values of carbon of individual tree are quantified and regressed onto the DBH.

4.5.1 Current Utilisation and Wastage

An average merchantable log consists of the bark (15%), sapwood (30%) and heartwood (55%) (Figures: 4.22, 4.23, 4.24). Sapwood and heartwood (85%) constitute the utilisable portion of the log when it is removed from the forests. The proportions of sawdust and other residues that could be lost from the merchantable log (sapwood and heartwood of 85%) were not specifically quantified.

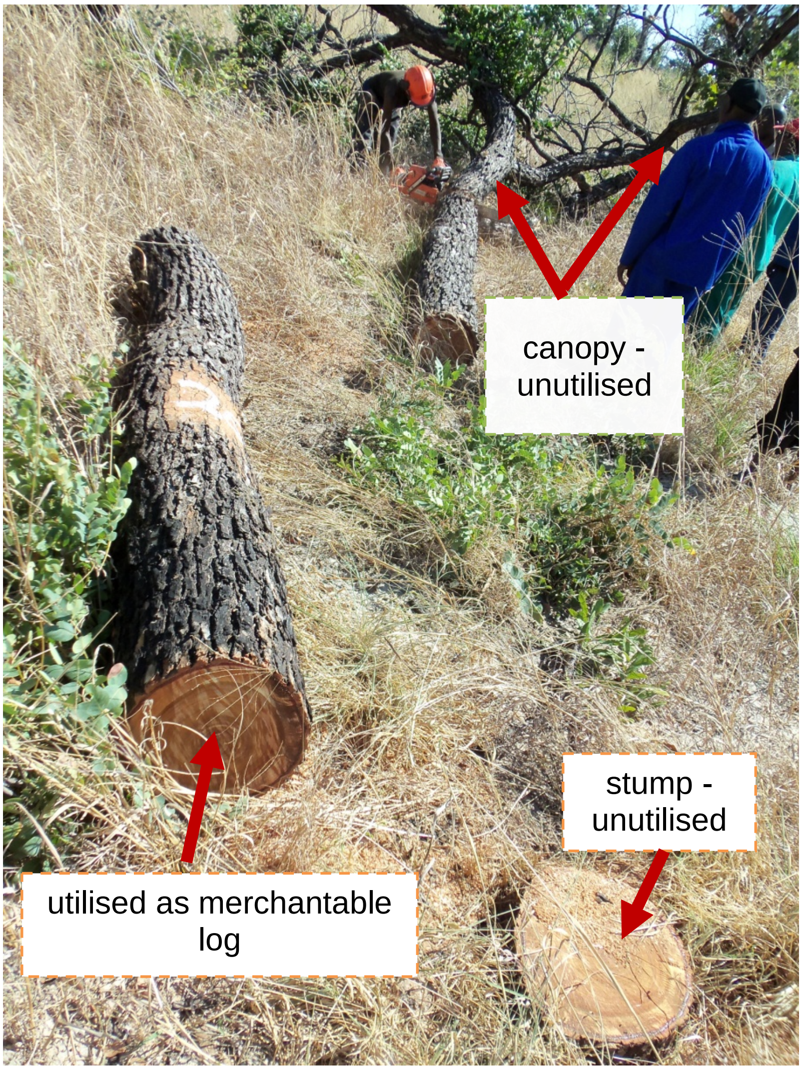


Figure 4.22: Utilised and unutilised components of a Kiaat tree.

Figure 4.23: Example of merchantable logs cut from Kiaat trees to be processed into planks.

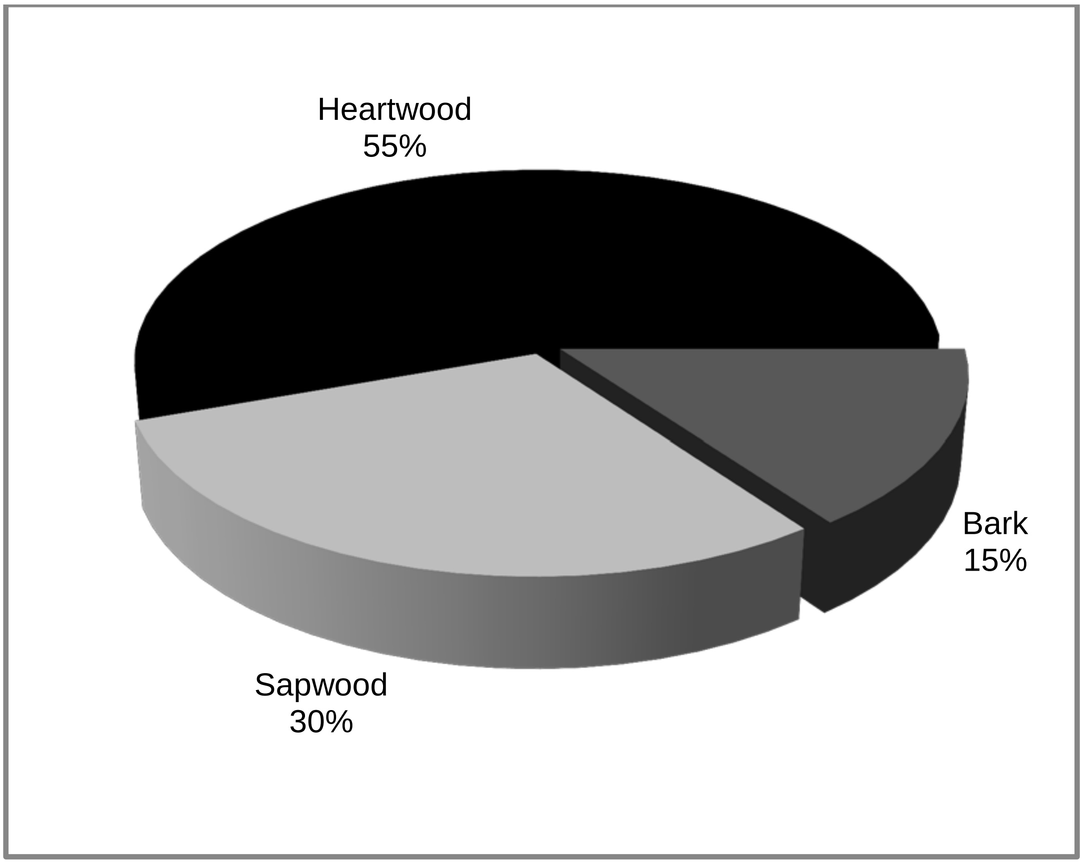


Figure 4.24: Components of merchantable logs and their average percentage (n = 31).

4.5.2 Potential Use Value of Canopy

Bowls, elephant carvings, music drums and walking sticks were identified woodcrafts that were commonly cut from canopy parts of Kiaat trees. Local prices of woodcrafts and dimensions of raw wood blocks from which each could be carved were shown in Table 4.5. Figure 4.25 shows that from an average Kiaat tree, 28 raw wood blocks for bowls; 25 raw wood blocks for music drums; 7 raw wood blocks for elephant carvings, and 3 raw wood blocks for walking sticks can be cut.

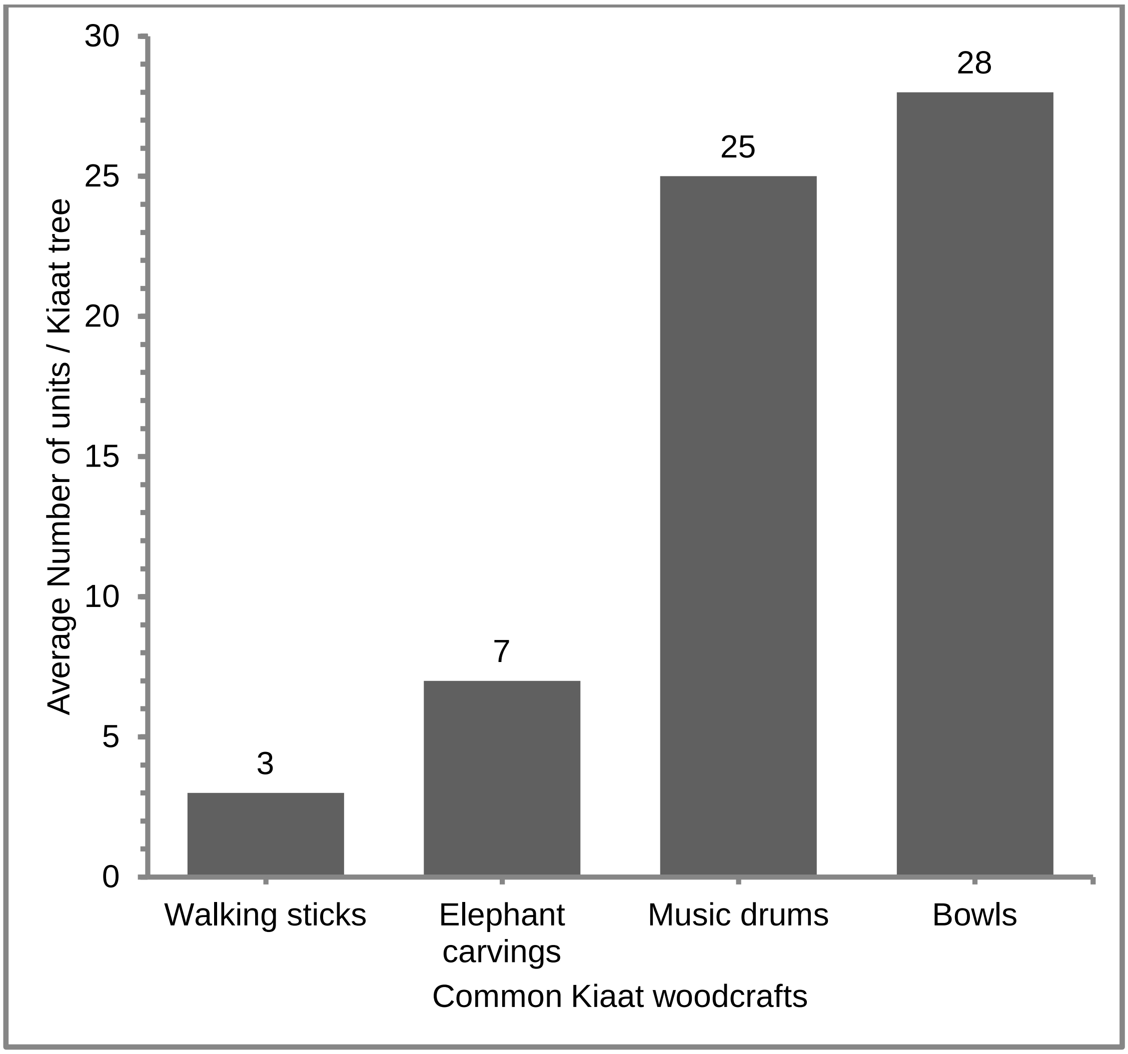


Figure 4.25: Types and average units of raw wood blocks of wood carving products.

4.5.3 Planks Production

It was found that the mean number of possible planks that can be cut from a merchantable log is 11. This value does not vary significantly from 12 planks per log indicated by respondents in the survey (see Table 4.3).

4.5.4 Merchantable Log Monetary Value

The mean estimated monetary value of a merchantable logs is N$484.61 (Table 4.11). This is significantly ($p = 0.0001$) different to the mean of the tree prices that respondents would charge if they were the current tree suppliers (μ = N$245.97) (see Table 4.3). The maximum monetary value of merchantable logs is N$846.36 (Table 4.12), compared to carbon value of N$332.39 (see Table 4.13).

Table 4.12: Monetary Value of Kiaat tree's merchantable Logs

Basic Statistics (n=40)	Merchantable Logs Monetary Value (N$)
Mean	484.61
Median	462.33
Minimum	236.26
Maximum	846.36

4.5.5 Alternative Use as Carbon Store

4.5.5.1 Carbon Content and its Value

Carbon credits are traded in tonnes of CO_2. Biomass of individual trees was converted to tonnes of CO_2 and then into monetary value. One tonne of CO_2 (tCO_2) is 3.67 times more than one tonne of carbon content (www.forestry.state.al.us).

A market price of €6.2/tCO_2 was used in this study (for April 2012). The average amount of carbon stored in the forty Kiaat trees was found to be 0.27 tonnes. That is, 1 tCO_2 = N$65.47. The obtained monetary carbon values of the trees are summarised in Table 4.13 (see *Appendix H* for more details).

Table 4.13: The carbon content of Kiaat trees and their monetary value.

Basic Statistics (n=40)	Total Tree Biomass (T)	Carbon Content (tonnes)	Tonnes of CO_2 (tCO_2) (tonnes)	Above-ground carbon value of Kiaat trees (N$)
Mean	1.03	0.51	1.89	123.61
Median	0.88	0.44	1.62	106.76
Minimum	0.41	0.20	0.75	49.07
Maximum	2.77	1.38	5.08	332.39

** N$65.47/$tCO_2$ as in April 2012*

4.5.5.2 Timber Value versus Carbon Value

At a market price of N$65.47/$tCO_2$ the value of carbon stored in an average Kiaat tree is much lower than the current timber use value of Kiaat trees (Figure 4.26). The average monetary value of carbon stored in average Kiaat tree is N$123.61, while the maximum and median are N$332.39 and N$106.76, respectively (see Table 4.12 above). The mean of timber value is N$484.61, while the maximum is N$8436 (see Table 4.11).

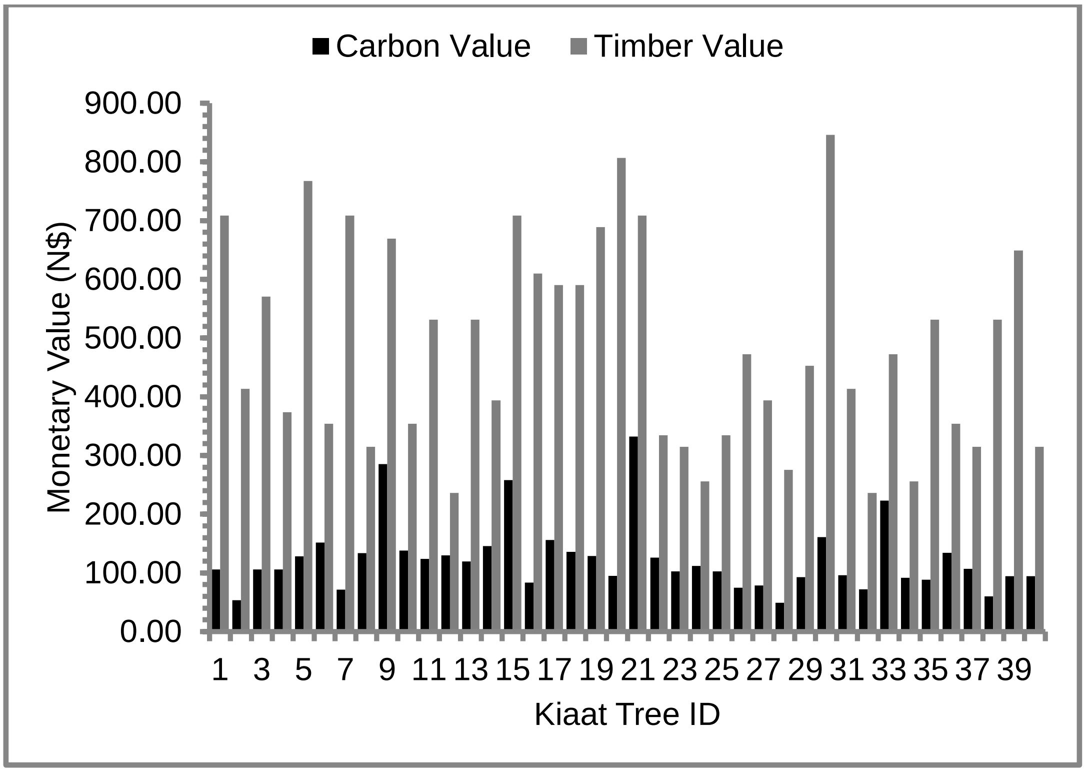


Figure 4.26: Comparisons of trunk timber and carbon values of Kiaat trees (n = 40).

4.5.5.3 Carbon Content Equation

Total tree carbon content (in tonne) can be estimated with 63% explained variation (R^2 = 0.6263) by using over-bark DBH in 1.17 (Table 4.13, Figure 4.27). The equation is only defined if x (over-bark DBH) is at least 30 cm).

Y = 0.0301x - 0.8872 1.17

Where:

Y = total above-ground carbon content of a Kiaat tree (tonnes)

0.0301 = is the slope or gradient of the equation

0.8872 = is the intercept

x = over-bark DBH (cm)

Table 4.12: Parameters estimate for equation 1.17.

Variable	Degrees of Freedom (DF)	Parameter Estimate	Standard Error	t Value	Pr > |t|	95% Confidence Limits	
Intercept	1	-0.8872	0.177	-5.00	<.0001	-1.2461	-0.5283
Over-bark DBH (cm)	1	0.0301	0.004	7.98	<.0001	0.0225	0.0377

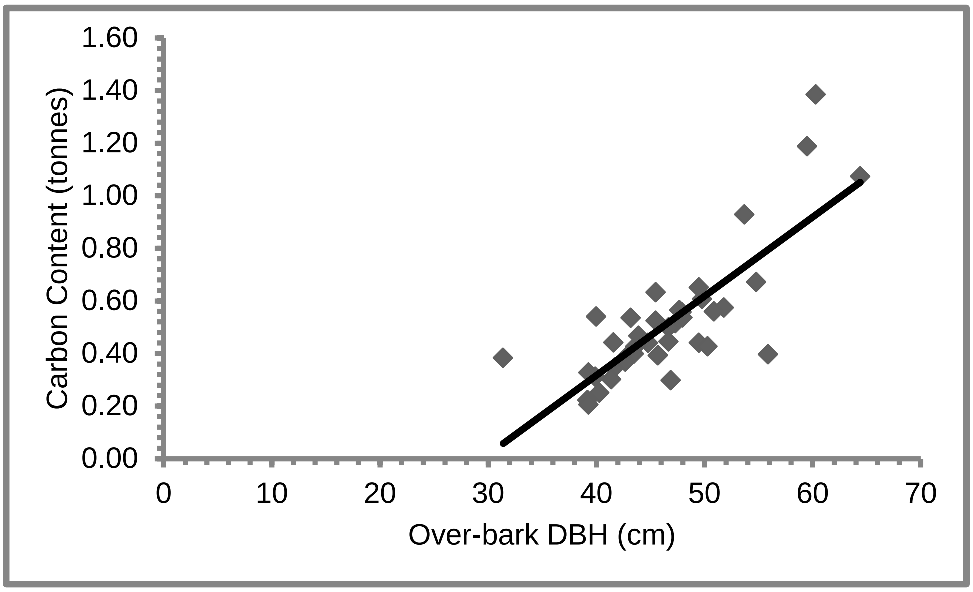


Figure 4.27: Regression of carbon content to over-bark DBH.

4.6 SUMMARY

Kiaat trees are mainly harvested for merchantable logs, which, on average, constitute 23% of the above-ground tree. Planks are the main products cut from trunks i.e. merchantable logs, and are used to make finished products such as beds, chairs, doors and tables. More income is generated when planks are made into finished products. Woodcrafts are mainly cut from canopy parts and represent a significant amount of income, especially when trees are optimally utilised. On average, Kiaat trees' wood density is 631 kg/m^3, total volume is 1.63 m^3, of which 59% is utilisable timber volume but it is not optimally used, while the oven-dry biomass is 1,028.90 kg or 1.89 tonnes of CO_2. At N$65.47/ t$CO_2$ (at the carbon price of April 2012), the average carbon value of Kiaat trees was N$123.61. Optimal tree utilisation coupled with value addition could alleviate over-exploitation of Kiaat trees and improve livelihoods.

CHAPTER 5

DISCUSSION

5.1 INTRODUCTION

This chapter discusses the results presented in chapter four and will focus on the Kiaat tree volume and optimum utilisable timber volume; the amount and monetary value of carbon stored in an average Kiaat tree; the timber utilisation levels and timber losses for an average Kiaat tree, and finally alternative uses of Kiaat trees are discussed within the context of the results of the user survey.

5.2 TOTAL AVERAGE VOLUME AND OPTIMUM UTILISABLE TIMBER VOLUME OF KIAAT TREES

5.2.1 Tree Selection

5.2.1.1 Tree Attributes

The DBH of all 40 sampled trees harvested for this study, ranged from 30 cm to 60 cm. These trees were selected by harvesters based on their size and straightness of trunks in an effort to optimise the volume of quality timber that can be obtained from a tree. The dimensions of the trees and selection process are consistent with observations from other African countries. In Botswana, Zambia and Zimbabwe, the minimum cutting diameter of timber is 30 cm DBH while in the dry-forest and woodlands of Mozambique and Western Africa trees with a diameter of 45 cm were mostly selected for harvesting. According to Sitoe *et al.* (2010), in Mozambique and Western Africa secondary factors such as accessibility and closeness to paths also influenced timber tree selection.

Selective felling of trees and parts extraction thereof does not support the sustainability of the affected resource including the livelihoods it supports. Kiaat trees with a DBH ranging from 50 to 60 cm are approximately 100 years old (Takawira-Nyenya, 2008). Shackleton (2005) also reported that Kiaat trees take on average 90 years to reach harvestable size. Trees within the DBH range of 51 to 60 cm constituted only 2% of all felled trees. The majority of the felled trees were of smaller diameter illustrating the scarcity of mature trees.

This implies that the current seedlings or saplings would take approximately 100 years to reach timber size, a waiting period that outlasts the current local people who depend on Kiaat trees for a living. The current selective logging practices are aimed at optimising income, but have advantages and disadvantages as shown in the next paragraph.

5.2.1.2 Selective Logging Practice

Selective logging could have a positive effect on dense forests such as tropical forests because it reduces competition for water, light and nutrients (Zida *et al*., 2007). It, however, has negative effects on dry-forests and woodlands, such as Namibian forests, which are already open and further opening could cause unfavourable thermal conditions in the under-storey, especially if the current intensity of harvesting is not reduced. Increased solar penetration to the soil increases soil evaporation and evapotranspiration, which negatively affect growth and development of non-timber forest products (NTFPs) such as mushrooms (Zida *et al*., 2007).

Selective logging also eliminates mother trees that produce good quality seeds; micro-habitats of pollinators and seed dispersers such as termite species and other animals (Takamura & Kirton, 2000; Zida *et al.*, 2007). This could cause poor regeneration of timber trees and reduced capacity of forests to produce alternative NTFPs as sources of food and income for local people. Sitoe *et al. (*2010) also reported that selective logging in dry-forests and woodlands reduced canopy cover, which lead to an increase in grass biomass and subsequent forest fire intensity and damage. In the Kavango Region, increased forest fire intensity would destroy pasture resources, properties and above all thatching grasses on which local people and small-scale businesses rely for income and shelter construction. Optimum use of felled trees is, therefore, one way by which the impacts of selective logging could be alleviated.

5.2.1.3 Wood Density

Wood density and quality are some of the factors that influence decisions concerning what parts of the tree to use (Cunningham *et al*., 2005). An average DBH of 47 cm and basic wood density of 631 kg/m^3 for tree parts equal to or greater than 10 cm in diameter were determined for the 40 Kiaat trees. The basic wood density is consistent with Kiaat wood densities found in other studies such as 460 to 500 kg/m^3 by Brown (1997); 650 kg/m^3 when air-dried by Venter & Venter (2002); 625 to 650 kg/m^3 by Obara *et al*. (2005), and 700 kg/m^3 at 12% moisture content by Takawira-Nyenga (2008). Wood density varies with moisture content (Husch *et al*., 2003) as well as with site quality, species, tree age, growth rate, bark percentage, and presence of defects (Phillip, 1994; Obara *et al*., 2005).

5.2.2 Current Use Volume

A total average volume of 1.63 m^3 was found for the above-ground parts of the 40 Kiaat trees, of which only 23% was extracted for commercial use by the two leasehold farmers. The total timber volume is smaller than found by Takawira-Nyenya (2008) who reported that Kiaat trees of 30 cm in DBH have a mean timber volume of 1.9 m^3 in Mozambique. This remains the case when an average DBH of 47 cm applicable to sampled trees is used. The difference could be attributed to climatic differences between Namibia and Mozambique, which influence e.g. height growth, or variations in the enumeration process. According to Timberlake *et al (*2010), humidity and minimum temperatures significantly affect growth and development of Kiaat trees.

The study found that 77% of the total tree volume of 1.63 m^3 is left in the forests unutilised. This level of under-utilisation is much higher than found by Campbell *et al* (2005) who reported that commonly up to 50% of wood is wasted by woodworkers who fell trees, remove the prime sections of the stems, then abandon the rest in the forests. In Tanzania, Kiaat timber recovery rate is 40% (Takawira-Nyenya, 2008); while in Botswana the Kiaat timber recovery rate is 26% (Kgathi & Sekhwela, 1990).

It was found that 59% of the current total average Kiaat tree wastage (77%) is actually utilisable timber volume. This level of non-optimal utilisation of allocated timber trees defies the principles of sustainable forest resources management, which requires, *inter alia*, that resource extractions are balanced socially, economically and ecologically. Timber wastage of such magnitude deprives local people of basic income for socio-economic development (Shackleton & Shackleton, 2004).

The extent of tree wastage in the Kavango Region could be associated with the lack of awareness on the part of wood processors as well as with lack of cooperation or coordination between different user groups (woodcarvers, loggers and farmers) regarding the optimal utilisation of Kiaat trees. Sometimes tree wastage is a result of limited awareness (Shumba *et al*., 2010). Shumba *et al* (2010) advised that it is necessary that perception and orientation of harvesters are looked at and changed as appropriate because they (harvesters) often believe timber resources cannot be depleted. Awareness creation is especially important for the Kavango Region where most of Namibia's forest resources are found (Mendelsohn & Obeid, 2005). Enhanced awareness of users of the timber resources is essential to alleviate over-exploitation of Kiaat trees and rural households' poverty through optimal forest resource utilisation to improve socio-economic conditions.

The extent of timber extraction is also influenced by type and quality of most sought after timber products, preference of certain markets, and customers' advice to woodworkers (Belcher *et al*., 2005; Cunningham *et al*., 2005). Most (68%) of the respondents reported that they prefer heartwood-only timber compared to mixed timber with sapwood. Since tree trunks have a higher percentage of heartwood than sapwood it can be reasoned that harvesters have a limited incentive to use other tree parts considering the current low prices paid for standing trees. Moreover, preference of heartwood-only timber over others could also be associated with the fact that heartwood products are more durable and attractive compared to sapwood timber which spoils faster and is prone to insect attacks (Cameron, 2000).

Supplying trees at give-away prices as low as N$50 per tree encourages tree wastage. Harris (1996) reported that trading of forest products at prices below their fair market prices contributes to depletion of the resources from which such products are cut. Prices at which Kiaat trees were supplied in the Kavango Region ranged from N$50 to N$270 per tree irrespective of size. These whole tree prices are much lower than the profits realised from stem wood. Jenkins & Smith (1999) found that the higher the tree or log prices, the more wood processors try their best to derive more products from the trees they buy. Moreover, Kramer *et al* (1992) found that severe under-pricing of tropical timber led to serious wastage of the timber resources. It was also reported that the rise in log prices forced wood processors to look at less exploited alternatives and indeed compelled them to utilise species once considered weeds (Jenkins & Smith, 1999).

Local prices of timber products are influenced by timber buyers who keep market-related timber prices secret to reduce the price at which they buy from producers (Harris, 1996). Formalising the current timber markets in Rundu, where most (61%) of the respondents sell their products, is therefore important to increase income that people earn from timber products. Even when perfectly formal markets are created, the extent of timber use is highly dynamic. According to Lawes *et al.* (2000), dynamic ecological and economic processes affect and define the extent of timber extraction differently. Shackleton & Shackleton (2004) found that, in Bushbuckridge, South Africa, Kiaat wood products had a subsequent income increase during tourist seasons. Timber wastage also occurs as a result of the specificity and design of sought end-products and tools used to produce the products (Shackleton, 2005).

5.3 AMOUNT AND MONETARY VALUE OF CARBON STORED IN AN AVERAGE KIAAT TREE

5.3.1 Carbon Content and Value

Adoption of markets for carbon sequestered in African dry-forests and woodlands is envisaged to benefit forest development and conservation (Muranda & Bouda, 2010). This means communities or individuals who plant trees or conserve existing tree stands can earn credit based on the amount of carbon sequestered. In this study, the total average carbon content of the 40 Kiaat trees was 0.51 tonnes. Assessed at current market prices of N$65.47/ t$CO_2$ sequestration of the average tree was worth N$123.74. The current gross timber value of an average Kiaat tree's trunk was found to be N$484.73 (10.7 planks @ N$45.26/plank), which at a carbon exchange rate of N$65.47/t$CO_2$, is 392% higher than the carbon value.

According to Chisholm (2010), the price of carbon is very volatile and difficult to predict. Between 2003 and 2004, in particular, the price of carbon credits ranged from US$3.50/t$CO_2$ at the Chicago Climate Exchange to US$15.80/t$CO_2$ in various European markets (Muranda & Bouda, 2010). In August 2009 the carbon price was US$20/t$CO_2$ (Chisholm, 2010) while in 2012 a carbon price of US$4.50/t$CO_2$ was reported at the Nhambita Carbon Project in Mozambique (Jindal *et al*., 2012).

Volatility in carbon price could make it difficult for local people to rely on carbon credits for income, especially if the tree carbon value does not surpass timber use value in the foreseeable future. Even at a 2050 projected carbon credit price of US$200/t$CO_2$ (Jindal *et al*., 2012), the carbon value of an average Kiaat tree (with an estimated 1.89 tonnes of CO_2) will be N$378.00, which is still 22% lower than the current timber value of an average Kiaat tree's trunk.

It is also not easy for local people to set prices or trade in the carbon market, where they have limited power over bargaining and price determination. Access to carbon markets by local people is difficult and in most cases it is achieved through NGOs or organisations that function on behalf of the community or communities participating in carbon trade. Unlike direct trading of forest products the cash received from carbon trading is not available immediately and people who lack alternative sources of income while waiting for cash accrued from carbon. Jindal *et al* (2012) reported that at the Nhambita Project in Mozambique, only 30% of the estimated (US$400-800/ha) carbon stock is paid for immediately, and the remainder (70%) is paid after seven years. However, agro-forestry contract holders are paid US$80.00/annum.

Another limitation is that it is not easy to add value to carbon stock, apart from planting more trees or not cutting existing trees. Namibia has an arid climate with sporadic rainfalls (Mendelsohn & Obeid, 2005) and in particular Kiaat trees grow very slowly (Stahle *et al*., 1999; Shackleton & Shackleton, 2004). Muranda & Bouda (2010) reported that slow growth rates of dry-forests and woodlands, coupled with their high use levels points to reduced carbon credits. In particular, Jindal *et al.* (2012) reported that illegal removal of trees from areas designated for carbon-sinks has also been noted as a serious problem in reducing carbon accumulation and the subsequent income for carbon credit. In contrast, direct use of Kiaat timber and associated value addition increase income along the timber value chain. This includes increasing the number of beneficiaries at various timber value addition stages per extracted raw materials or tree. Moreover, value addition is easily achievable at local level through the manufacture of finished products and woodcrafts. Woodcrafts, in particular, have social value because they are exchanged as gifts and also used for decorations.

Converting Kiaat trees into a carbon sink is also likely to cause local people to forfeit their woodcarving skills. In Bushbuckridge, South Africa, it was found that the ability to convert wood into saleable products formed an important safety net and coping strategy for unemployed or retrenched people (Shackleton & Shackleton, 2004; Shackleton *et al*., 2008). Thus, total conversion from timber use to carbon use of Kiaat trees has the potential to cause people to abandon practising their woodcarving skills, thereby impinge their ability to support their families especially in hard times. Moreover, distribution of cash income earned for carbon credits can be a complex exercise altogether, which could lead to unintended infighting within and between villages.

While preservation of Kiaat trees for carbon credits is a noble idea that has invaluable socio-economic and environmental benefits, the amount of income earned from carbon credits is inadequate to address the immediate needs of rural poor people. Jindal *et al.* (2012) identified this factor at Nhambita in Mozambique as one of the shortcomings of carbon trading. Nonetheless, local people can supplement their income by conserving young trees

(Kiaat trees) until they reach harvestable timber size and trade sequestered carbon. Moreover, people can also increase their carbon credits by not harvesting mature trees that are unsuitable for timber, for example, trees with bent trunks. This option could encourage people to preserve trees. Lastly, converting mature trees to various timber products (furniture) to satisfy socio-economic needs does not necessarily mean all carbon stored in a tree is emitted into the atmosphere. Most of the carbon stock will be tied up in the lumber of the furniture or woodcrafts.

5.4 TIMBER UTILISATION LEVELS AND TIMBER WASTAGE OF AN AVERAGE KIAAT TREES

Planks from tree trunks and woodcrafts from canopy parts were the most important timber products cut from Kiaat trees.

5.4.1 Planks

Most (90%) respondents cut planks from trunks, which they sold at an average local price of N$45.26 per plank. In the Kavango Region planks are mainly sold to locally joinery outlets, carpenters and outsiders. Harvesters pay on average N$190.32 per tree and cut on average 10.7 planks from a tree trunk. Accordingly, one Kiaat tree is worth N$484.73 (for trunk only), which is equivalent to 155% gross profit per tree (in terms of tree trunk only).

The current levels of timber extraction and tree wastage could also be associated with the timber requirements or standards at markets. It was found that 16% of the respondents sold their unfinished products to the South African markets (Cape Town). They also reported that heartwood-only Kiaat planks were sold at an average price of N$4,500/$m^3$ of Kiaat planks compared to N$3,500/$m^3$ in Rundu. According to Shackleton (2005), the scarcity of wood for furniture in South Africa compelled some furniture makers to start importing Kiaat planks from neighbouring countries such as Mozambique and Zambia. The export of unprocessed Kiaat lumber has an adverse impact on the local Kiaat wood industry. Local people are deprived of value addition opportunities and a demand for heartwood-only planks from export markets could encourage wasteful harvesting and processing practices.

The amounts of revenue that respondents earn both per trunk and per cubic metre of timber do not appear to differ from prices that respondent said they were willing to pay for trees as well as from prices they indicated they would charge if they were the current tree suppliers.

In particular, average price that respondents indicated they were willing to pay (N$112.74) is 41% lower than the mean of current tree prices (i.e. N$190.32). Conversely, the mean (N$245.97) of prices that respondents said they would charge for a Kiaat trees is 341% higher than the average amount they were willing to pay. Although Price (1989) reported that the prices consumers are willing to pay for a product suggests their expectation to derive satisfaction from consuming such a product, the amount consumers are willing to pay for a resource (Kiaat tree) also reflects the value they attach to that resource.

Willingness to pay is also determined by the ability to pay and perceived value of what is being purchased (Price, 1989). This means even if respondents earn high revenue per tree or per cubic meter, the magnitude of needs that they have to satisfy with what they earn determines their purchasing power for trees. The results supports Price's (1989) report because the average of prices that respondents would sell trees if they were tree suppliers is relatively higher than in cases where they pay for trees to others, suggesting their expectation to benefit. Nonetheless, Kramer *et al* (1992) reported that the value that people indicate they are willing to pay for resource (Kiaat trees) is the beginning value of that resource specific to that community (to which respondents belong).

The use of planks to make finished products increases the Kiaat lumber value and utility. An average of nine planks (worth N$407.34) is required to make one bed sold at an average local price of N$975.00 (or 139.4% in gross profit) per bed. This supports Denkins (1999) who found that timber value increases at each stage of value addition.

Shackleton & Shackleton (2004) also found that in Bushbuckridge, South Africa, furniture makers earn more annual income than those who sell unfinished products. This is illustrated by the fact that if a Kiaat tree is felled and all planks obtained from it were used to make 3/4 beds only, a total revenue of N$1,160.25 will be earned, which is N$675.52 (72%) more than when all 11 planks are sold individually. Similarly, a standard door made with six planks worth N$271.56 and sold at an average local price of N$850 will generate a 213% profit.

The relationship between raw material and the end-products (finished products) is thus important in the conservation of timber resources. According to Klemperer (1996), the cheaper the end-products, the more demand for the products and subsequently the trees from which such products are cut and *vice versa* when end-products are sold at higher prices. Worth emphasising, however, is the fact that through value addition, the tree value can be raised to maximise incomes and thereby satisfy more local people's needs. Although Chipeta & Kowero (2000) reported that the willingness of people to conserve a resource is proportional to the value they know of that resource (as a tree or its products), it is worth stating that high value products could also result in higher demand and subsequently over-exploitation of the resource.

5.4.2 Woodcrafts

Similar to the findings of Shackleton (2005) in Bushbuckridge, South Africa, bowls, elephant carvings, music drums and walking sticks were among the most common woodcrafts cut from Kiaat canopy parts in the Kavango Region. Nonetheless, cutting woodcrafts from canopy parts does not necessarily mean trees from which such woodcrafts have been cut are optimally utilised. This is because woodcarvers normally cut only the section they think is suitable for their product, and abandon other parts, and *vice versa* for loggers who mainly fell trees for their trunks only.

Optimal tree use is one of the ways by which tree value can be increased (Shackleton & Mander, 2000). The fact that 59% of the underutilised tree volume left in the field after harvesting can still be used, leads to the under-valuation of Kiaat trees by local communities. Although respondents said they mainly cut woodcrafts from canopy parts of the trees, the average dimensions, quality and heartwood content of woodcrafts observed in the markets indicates otherwise for specific products. For instance, elephant carvings are cut from raw wood blocks with an average diameter of 35 cm. Given that the felled trees' DBH ranged from 30 to 60 cm and that there was almost no tree with branches with a diameter of 35 cm, it is safe to say the majority of big woodcrafts are also cut from trunks and not branches.

It is, however, possible to cut small woodcrafts such as bowls, music drums, and walking sticks from canopy parts because the average diameter of raw wood blocks from which they are cut fall within diameters of the branches. As for the extent of extracting raw wood for woodcarvings, the parts of the tree from which to cut such raw materials are influenced by other factors. Belcher *et al* (2005) indicated that woodcarvers' choice of wood is influenced by their customers' preferences, which is not entirely determined locally, particularly where tourists are the frequent buyers.

A combination of carving and furniture making generate the most revenue compared to carvers-only and furniture makers-only (Shackleton & Shackleton, 2004). The study found that from an average Kiaat tree's canopy parts, 28 raw wood blocks from which bowls can be carved, 7 for elephant carvings, 25 for music drums and 3 for walking sticks per single tree (see Figure 5.1 below) can be retrieved. This means if the canopy parts were used for these woodcrafts, the monetary value of the canopy parts is N$2,632 for bowls, N$2,898 for elephant carvings, N$4,275 for music drums, and N$363 for walking sticks, which in total will be N$10,168. Adding the average monetary value of tree trunks of N$484.73 (for planks) to the canopy value, it means an average Kiaat tree is worth N$10,652.73. This means if wood processors could combine products making (carving and furniture making) they could generate more income to improve their socio-economic conditions. Shackleton (2005) showed that carver-furniture makers made R23,084/annum compared to R14,328 for furniture makers, suggesting the importance of value addition (see Figure 5.1 below).

Unlike in Namibia (Kavango Region) where woodcrafts are predominantly sold in their semi-finished or finished form, in South Africa Kiaat wood used for carving is also traded in its raw form at US$1/kg or at US$7/kg after carving (Takawira-Nyenya, 2008). Trading Kiaat raw wood this way can be helpful in alleviating tree wastage because it creates an opportunity for members of the community who lack carving skills or ability to collect and sell parts of Kiaat trees left in the forest by loggers. In this way, more people stand to earn income through reduction of tree wastage, thereby reducing poverty.

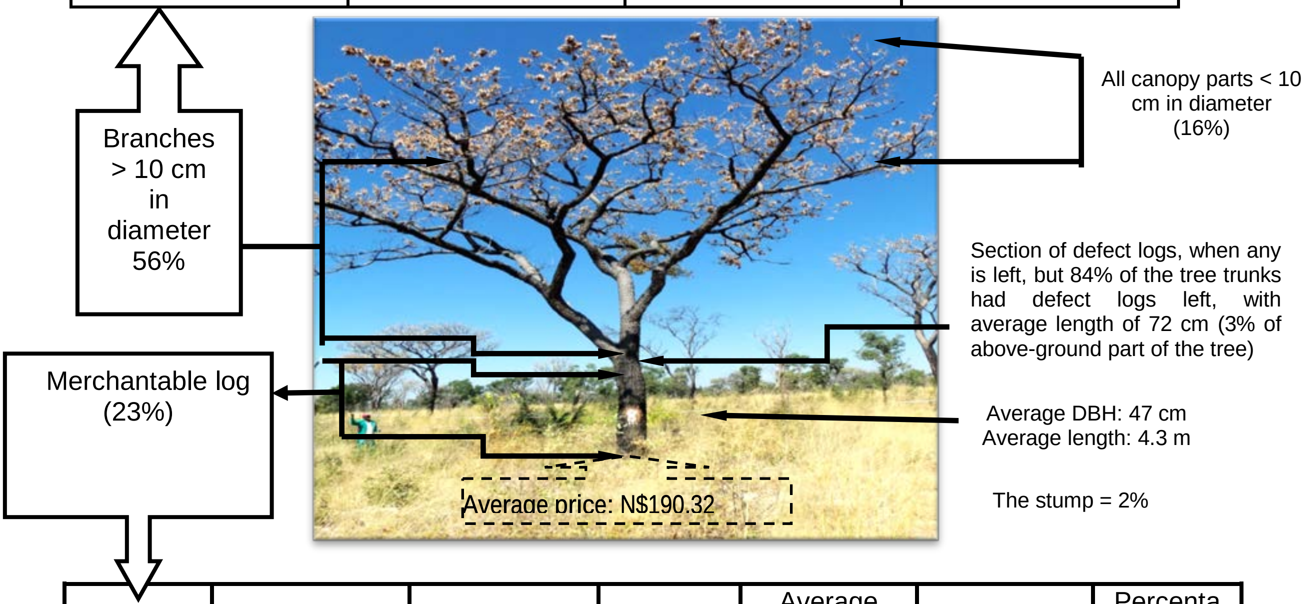
5.5 ALTERNATIVE USE OPTIONS TO REDUCE WASTAGE OF KIAAT TREES

Besides cutting planks and woodcrafts, significant amount of biomass in stem residues and canopy residues is still going to waste. The following alternative uses for canopy parts (except pods), in particular, were identified: branches for firewood; bark for decoration; and foliage for fertilizers, medicine, dye, and bio-energy. Although the majority of respondents (52%) said that canopy parts are also usable as firewood, harvesters in the Kavango Region are unlikely to extract such parts for firewood because there is still plenty of wood species suitable for firewood to choose from. Kiaat wood is seldom used for firewood (Takawira-Nyenya, 2008). It was observed that *Burkaea africana* and *Baikiaea plurijuga* dominated all firewood markets or stalls that were visited in Rundu including stalls along the Rundu-Mururani Road, Kavango Region. Use of Kiaat wood for firewood is however possible in other regions of Namibia such as Omusati and Ohangwena where firewood is scarce (Figure 4.20). In these regions, 96% of households rely on firewood for cooking with an estimated daily consumption of 1.0 kg/ inhabitant (Erkkilä, 2001).

Alternative use of Kiaat by-products as fertilizers (compost) could include government Agricultural Green Schemes such as Sikondo, Vhungu-Vhungu, Ndonga Linena and

Shodikongoro. If Agricultural Schemes such as these combine usage of organic and inorganic fertilisers, it has the potential to not only reduce tree wastage, but also environmental pollution with chemical fertilizers. Takano *et al.* (2000) reported that in Japan bark, sawdust of all timber species are collected and used for fuel, fertilizers, livestock bedding, and culture ground for mushrooms. Moreover, by-products such as canopy parts including twigs and leaves can be used to make basic bio-energy products such as biomass briquettes for local use. Most rural poor households use firewood for heating during winter, and the use of biomass briquettes can be convenient and safer as opposed to making fire in their bed rooms and thereby inhale smoke, which can affect their health. Although canopy parts can also be used for large scale energy generation, which Hillring (2006) reported that its practised in some Nordic and North American countries, absence of a power generating plant in the Kavango Region makes it a less viable option for people to rely on for income. On the other hand, extraction of all canopy parts, especially twigs and leaves, mean removal of organic matter essential in stabilising and improving soil nutrients and non-woody flora such as grasses. Grasses support livestock and other wild animals, which also support the local economy (see Figure 5.1 for a summary of study outcome).

Main woodcraft cut	Average Number of raw wood blocks for woodcrafts / tree	Average local price of each woodcraft carved from each raw wood block (N$)	Estimated total revenue (N$)
Bowls	28	94	2,632
Elephant carving	7	414	2,898
Music drums	25	171	4,275
Walking sticks	3	121	363



Main product cut	Information on planks (in averages)	Finished products made with planks	Number of planks / finished product	Average value of planks used to make each product (N$)	Average price of product (N$)	Percentage of profit mark-up per product (%)
planks	Averages: ❖ 10.7 planks / trunk. ❖ plank prices is $45.26 ❖ revenue / trunk = N$484.73 ❖ gross profit/trunk= 155%	¾ beds	9	407	975	139
		chairs	3	136	350	158
		standard doors	6	272	850	213
		four-seater Tables	6	272	1,150	324

Figure 5.1: Summary of study outcomes.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

This chapter presents conclusions and recommendations of the study with a focus on the study's main aim and specific objectives.

6.2 CONCLUSIONS

The study proved that Kiaat trees are an important source of livelihood income for rural and urban based people in the Kavango Region of Namibia. Local people, especially wood processors buy Kiaat trees from different suppliers at varying but low tree prices ranging from N$50 to N$270, irrespective of tree size or age. From the trees they buy, people cut timber planks mainly from the trunks and woodcrafts mainly from canopy parts equal to or greater than 10 cm in diameter, which they predominantly sell for income at local markets in Rundu and in other markets such as Windhoek (712 km away) and Cape Town, South Africa (2,112 km away) where relatively higher profits are earned.

Revenues that people generate from Kiaat timber products increase with extent of value addition to timber materials extracted from allocated Kiaat trees. The more a Kiaat tree is optimally utilised, the higher the gross income earned per tree. Similarly, the more value is added to final products, the higher the gross income is generated per end-product, and subsequently, the higher the value of an average Kiaat tree. Chipeta & Kowero (2000) concluded that the more valuable a resource is known to be, the more people are willing to conserve it. This means they people would try their best to ensure the resource is not depleted, although sometimes demand for the resource increases with increase in its value.

The total average above-ground volume of an average Kiaat tree in the Karukuvisa District of the Kavango Region is 1.63 m^3, of which a total of 1.34 m^3 (82%) could be optimally used. Nonetheless, only 23% of optimum utilisable timber is currently used and the remainder (59%) is left behind in the forest unutilised. Therefore, on average, there is a high level of Kiaat tree wastage in the Kavango Region of Namibia.

The portion (23%) of the trees that is extracted is mainly cut into planks, which are either sold as such or turned into finished products predominantly sold in local markets. Finished products generate much higher gross income than when planks are sold in their unfinished form.

The prices at which Kiaat trees are sold in the Kavango Region are significantly lower when compared to the profits that people generate from the smaller portion of the tree (23%) that is used. In all local markets where respondents indicated they sell their Kiaat timber products, high profits are generated.

The unutilised timber volume is suitable for a variety of woodcrafts. Woodcrafts are not necessarily always cut from the same canopy of the tree from which planks are cut since timber loggers and carvers buy and utilize their trees separately. Separate allocation of trees, therefore, promote tree wastage but given that gross income generated from canopy parts surpasses the one earned from trunks (be it in planks or finished products form), combined use of both the trunks and canopy parts can reduce tree wastages and has the potential to satisfy more needs both in terms of income and product utility levels.

Identified alternative use options for an average Kiaat tree included using them for firewood, bio-energy, local traditional medicine, dye and as carbon-sinks. No Kiaat firewood was observed during visits to firewood markets in Rundu, meaning Kiaat firewood can rarely be a viable option in Rundu or Kavango Region in foreseeable future. Similarly, usage of Kiaat trees for pharmaceutical products is not yet feasible at local level.

The total average amount of carbon sequestered in the above-ground part of an average Kiaat tree in the Karukuvisa District of Kavango Region is 0.51 tonnes with a monetary value of N$123.74 in carbon credits, compared to the current average trunk timber value of N$484.73. Monetary value of carbon in an average Kiaat tree is 392% smaller than its timber value, even when the portion of carbon of the below ground parts i.e. average of 21% of the above-ground parts of the tree is added. Considering the observed levels of dependency of local people on Kiaat trees for income, substituting local timber use value of Kiaat trees for carbon credits would negatively affect the livelihoods of many poor rural households and in general will deprive consumers of timber products utility. However, in order for local people to sustain their reliance on Kiaat for timber, young and mature trees that are unsuitable for timber could be included in carbon trading schemes. This will help to conserve these trees until a determined harvesting aged is reached.

6.3 RECOMMENDATIONS

Based on the conclusions presented in 6.2, the following recommendations are made:

- The magnitude of tree wastage or non-optimal utilisation of Kiaat trees could be high because wood processors lack information regarding the socio-economic and ecological advantages and disadvantages of wasteful tree usage. It is recommended that awareness campaigns focused on timber status, extraction, utilisation, profit maximization, tree optimisation and disadvantages of tree wastage, is conducted with wood processors to clear the doubt whether wood processors or woodworkers are aware of the impacts or not.

- It is recommended that the Namibian government increase the current give-away tree price of N$50 to N$270 per standing tree to compel wood processors to optimise the use of harvested trees. It is essential that tree prices are set such that harvesting of either old trees or young trees be discouraged. High tree prices are likely to make people extract as much timber from each allocated Kiaat tree as possible to maximise income per tree.

- It was also found and concluded above, that wood processors differ in respects of parts of the tree they cut, in this regard the study recommends that tree part prices are differentiated for a carver who only requires a branch or two branches per tree, from that of a logger who will simply remove the trunk and abandon the canopy to forest fires.

- Alternatively, joint allocation of trees to carvers and loggers is recommended so that carvers take the canopy parts and the loggers take the trunk; or that prices of trees are set as a sum of the trunk and canopy values in which case the price of each part is clearly shown on the cash slip. For example, a cash slip of a Kiaat tree sold at N$450 should clearly indicate: N$200 (trunk) + N$250 thereby compel tree buyers to also use the canopy to recoup the money they paid for it.

- In order to improve their socio-economic conditions, it is recommended that local wood processors are encouraged to optimally use the trees and add as much value as possible to Kiaat raw materials to maximise the value they receive from Kiaat lumber.

- Since higher income is earned from the canopy, it is recommended that wood processors diversify their products by adapting a timber-woodcrafts-residuals converter approach (whole-tree use approach).

- To promote responsible harvesting and optimal use of timber resources in the Kavango Region, it is recommended that the Directorate of Forestry (DoF) as a legal custodian of forests and woodlands in Namibia, identify, register and license all timber processing outlets and individual woodworkers in the Kavango Region.

- The current timber trade markets in the Kavango Region are characterised by wood processors who do not know the fair-market prices of their Kiaat products. Some of the wood processors sell their products to timber agents who set prices and prescribe the quality of products they require. This state of affairs reduces the income to local timber producers and has the potential to increases tree wastage and exploitation of Kiaat trees. It is, therefore, recommended that efforts are made to formalise timber processing activities through, among other things, identifying product markets and publishing of fair-market prices of various timber products in various markets or towns.

- The study recommends that carbon trade is incorporated into the management of Kiaat trees, which could be achieved through restriction, by Government, of selling of Kiaat trees which have not reached timber size (e.g. 30 cm in DBH). Trees with DBH below 30 cm can then be used for carbon trade which they accumulated as they grow, and after trees reached DBH they can be harvested for timber use. In short, there should be timber yield regulation system (harvest prescriptions) in place to achieve sustainable use of Kiaat trees.

- Although carbon use was found to be an unreliable option, there is high potential for local people to supplement their timber use income with income generated through carbon trading. It is, therefore, recommended that carbon markets are also adopted in the Kavango Region, and that local people are encouraged or assisted, especially by the Government and private sector to participate in carbon trade through establishing new plantations, particularly Kiaat plantations.

7. REFERENCES

Adebusola, A.A. & Sheu, A.S. 2007. *Economic Valuation of Non-Timber Forest Products (NTFPs).* [Online] Available at: http://mpra.ub.unimuenchen.de [visited: 16 March 2012].

Alabama Forestry Commission. 2012. Carbon Sequestration: How much carbon have your trees stored? [Online] Available at http://www.forestry.state.al.us [visited: 01 September 2012].

Alvarez, E., Duque, A., Saldarriaga, J., Cabrera, K., Salas, G., Valle, I., Lema, A., Moreno, F., Orrego, S. & Rodríguez, L. 2012. Tree above-ground biomass allometries for carbon stocks estimation in the natural forests of Colombia. *Forest Ecology and Management 267* (pp: 297–308).

Babbie,R.E. 1973. *Survey Research Methods*. Wadsworth Publishing Company, Inc. California, USA.

Babbie, E & Mouton, J. 2001. *The Practice of Social Research*. Oxford University Press: Cape Town.

Barbier, B.E., Burgess, C.J., Bishop, J. & Aylward, B. 1994. *Economics of the Tropical Timber Trade.* Earthscan Publication Ltd. London, UK (pp: 50-60).

Becker, N. & Freeman, S. 2009. The economic value of old growth trees in Israel. *Forest Policy and Economics 11* (pp: 608–615).

Belcher, B., Cunningham, A. & Campbell, B. 2005. Livelihoods, Carvings and Conservation. *Carving Out A Future: Forests, Livelihoods and the International Woodcarving Trade*.Eds: Cunningham, A., Belcher, B. & Campbell, B. Earthscan Ltd. London, UK (pp: 1-9).

Brown, S. 1997. *Estimating Biomass and Biomass Change of Tropical Forests: A Primer*. FAO. Rome, Italy (pp: 4-47).

Cameron, J. M. 2000. Timber Characteristics of Selected Forest and Woodland Tree. South *African Forestry Handbook 2000 Volume 2*. Southern African Institute of Forestry. Pretoria, South Africa (pp: 654).

Campbell, B., Cunningham, A., & Belcher, B. 2005. Carving Out A Future: Planning for Woodcarvings in the 21st Century. *Carving Out A Future: Forests, Livelihoods and the International Woodcarving Trade*. Eds Cunningham, A., Belcher, B. & Campbell, B. Earthscan Publications Ltd. London, UK (pp: 256-262).

Caro, T.M., Sungula, M., Schwartz, M.W. & Bella, E. M. 2005. Recruitment of *Pterocarpus angolensis* in the Wild. *Forest Ecology and Management, 219* (pp: 169-175).

Chibisa, P. & Lameck, R. 2009. Crafts and Rural Livelihoods in Manicaland Semi-arid Areas: Implications for Biodiversity and Environmental Sustainability. *Journal of Sustainable Development in Africa,* Vol. 11, No. 1. Clarion University of Pennsylvania, Pennsylvania, USA.

Chipeta, E. M. & Kowero, G. 2004. Valuation of Indigenous Forests and Woodlands: An International Perspective. *Indigenous Forests and Woodlands in South Africa: Policy, People and Practice. Eds* Lawes, J.M., Eeley, C.A.H., Shackleton, M.C. & Geach, S.G.B. University of KwaZulu-Natal Press. Pietermaritzburg, South Africa (pp: 139- 189).

Chisholm, A.R. 2010. Trade-offs between ecosystem services: Water and carbon in a biodiversity hotspot. *Ecological Economics 69* (pp: 1973–1987).

Clem T.C., Wilson, C. & Nantha, S.H. 2008. Contingent valuation as a dynamic process. *The Journal of Socio-Economics 37* (pp: 1443–1458).

Commonwealth Forestry Association. 2010. *Commonwealth Forests 2010: An Overview of the forests and forestry sectors of the countries of the Commonwealth*. Commonwealth Forestry Association. England (pp: 39, 118-130).

Cunningham, A., Campbell, B., Belcher, B. & Achdiawan, R. 2005. Ecological Footprint: Carving, Sustainability and Scarcity. *Carving Out A Future: Forests, Livelihoods and the International Woodcarving Trade. Eds* Cunningham, A., Belcher, B. & Campbell, B. Earthscan Ltd. London, UK (pp: 199-227).

Curie, D.A. 2000. Timber Preservation in South Africa. *South African Forestry Handbook 2000 Vol. 2*. Southern African Institute of Forestry. Pretoria, South Africa (pp: 447-456).

DECOSA (Development Consultants for Southern Africa - CC). 2010. Timber Study for Pilot Community Forests of the Kavango and Caprivi Regions: Export Markets Phase 2. *Integrated Community-Project Ecosystem Management Project (ICEMA).* Windhoek, Namibia (pp: 1-12).

Denkins, D. 1999. Adding Value to Farm Timber. In: *Farm Woodlands for the Future. Eds* Burgess, J.P.; Brierley, R.D.E.; Morris, J. & Evans, J. Brios Scientific Publishers, Bedfordshire, UK (pp: 123-124).

Desch, E.H. & Dinwoodie, M.J. 1996. *Timber: Structure, Properties, Conversion and Use* 7th Edition. Macmillan Press Ltd. London, UK (pp: 77-85).

Erkkilä, A. & Siiskonen, H. 1992. *Forestry in Namibia 1850-1990*. University of Joensuu, Finland.

Erkkilä, A. 2001. *Living on the land: change in forest cover in north-central Namibia 1943-1996*. University of Joensuu, Faculty of Forestry, Finland (p: 53).

FAO, 1980. *Forest Volume Estimation and Yield Prediction Vol.1*. FAO Centre Technique Forestier Tropical. Rome, Italy.

FAO. 1983. *Forest Revenue Systems in Developing Countries.* Rome (pp: 27 – 50).

Forbes, D. R. 1956. *Forestry Handbook*. The Ronald Press Company, New York, USA.

Google, 2012. Images of Southern Africa. [Online] available at www.google.co.za/Imgres. [visited: 2012, December 04].

Graz, P.F. 2004. *Distribution and Ecology of Pterocarpus angolensis in Namibia*. Polytechnic of Namibia, Windhoek, Namibia (pp: 1-14).

Hamilton, J. G. 1975. *Forest Mensuration Handbook*. Forestry Commission, London (pp: 18 and 143).

Harris, L. K. (Ed.). 1996. *Making Forest Policy Work 1996*: Conference Proceedings of the Oxford Summer Course Programme 1996. University of Oxford, UK.

Hillring, B. 2006. World trade in forest products and wood fuel. *Biomass and Bioenergy 30* (pp: 815–825).

Hoadley, B.R. 1980. *Understanding Wood: A craftman's guide to wood technology*. The Taunton Press. Newtown, USA (p: 92).

Husch, B., Miller, I.C. & Beers, W.T. 1982. *Forest Mensuration 3rd Edition*. John Wiley & Sons. New York, USA.

Husch, B., Beers, W.T. & Kershaw, A.J. 2003. *Forest Mensuration 4th Edition*. John Wiley & Sons, Inc. Hoboken, New Jersey, USA.

Jenkins, B.M. & Smith, T.E. 1999. *The Business of Sustainable Forestry: Strategies for an Industry in Transition*. Island Press, Washngton, USA (p: 99).

Jim, B. 2009. *Commonwealth Forests: An Overview of the Commonwealth's forest resources*. Commonwealth Forestry Association. England.

Jindal, R., Kerr, M.J. & Carter, S. 2012. Reducing Poverty Through Carbon Forestry? Impacts of the Nhambita Community Carbon Project in Mozambique. *World Development Vol. 40*, No. 10, (pp. 2123–2135).

Kgathi, L.D. & Sekhwela, H. 1990. Sustainability of Commercial Agriculture and Forestry in Chobe District, Botswana Hamandawana [Online]. Available at: ttp://www.savannas.net /botswana [visited: 19 July 2012].

Klemperer, W.D. 1996. *Forest Resource Economics and Finance*. McGraw-Hill International, Inc., Singapore (pp: 10 & 101).

Kossoy, A. & Guigon, P. 2012. The State and Trends of the Carbon Markets 2012. [Online]. Available at: www.worldbank.org/intercarbonfinance. (visited: 1 September 2012).

Kramer, R., Healy, R. & Mendelsohn, R. 1992. Forest Valuation. *Managing the World's Forest: Looking for Balance between Conservation and Development.* Ed. Sharma P. N. Kendal/Hunt Publishing Company. Dubuque, Iowa, USA (pp: 237-263).

Lamlom, H.S. & Savidge, A.R. 2003. A reassessment of carbon content in wood: variation within and between 41 North American species. *Biomass and Bioenergy 25* (pp: 381-388).

Lawes, J. M., Mander, M. & Cawe, S. 2000. The Value and Uses of Natural Forests. *South African Forestry Handbook 2000 Vol. 2*. Southern African Institute of Forestry. Pretoria, South Africa (pp: 613-622).

Lindenmayer, B.D. & Franklin, F.J. 2003. *Towards Forest Sustainability*. Island press. London, UK.

Loot, S. 2005. Red Data Book of Namibian Plants. *Southern African Botanical Diversity Network Report No. 38.* SABONET, Pretoria and Windhoek, Namibia (p: 59).

Maguire, B.K. 2009. Does mode matter? A comparison of telephone, mail, and in-person treatments in contingent valuation surveys. *Journal of Environmental Management 90* (pp: 3528–3533).

Mannheiner, C.A. & Curtis, B.A. (Eds). 2009. *Le Roux and Muller's Field Guide to the Trees and Shrubs in Namibia.* Macmillan Education Namibia (Pty) Ltd, Windhoek, Namibia (pp:158-170).

Marunda, C. & Bouda, H. 2010. Environmental Services from the Dry-Forests and Woodlands of Sub-Sahara Africa. *The Dry-Forests and Woodlands of Africa: Managing for Products and Services*.Eds: Chidumaryo, N.E. & Gumbo, J.D. Earthscan Ltd. London, UK (pp: 231-250).

Mehl, W.J.; Geldelhuys, C.J.; Roux, J. & Wingfield, J.M. 2010. The *Die-back of Kiaat (Pterocarpus angolensis) in Southern Africa: A cause for concern.* [Online] Available at: https://www.up.ac.za/dspace [visited: 03 April 2012].

Mendelsohn, J. & Obeid, S. 2005. *Forests and Woodlands of Namibia*. Sing Cheong Printing, Hong Kong.

Mendelsohn, J. 2009. *Socioeconomic Series: Land use in Kavango: past, present and future***.** RAISON (Research and Information Services of Namibia and OKACOM, Mauni, Botswana (p: 6).

Ministry of Finance, 2011 (unpublished). Approved Forest Products Prices for the Directorate of Forestry[2].

Mogaka, H., Simons, G., Turpe, J., Emerton, L. & Karanja, F. 2001. *Economic Aspects of Community Involvement in Sustainable Forest Management in Eastern and Southern Africa*. The World Conservation Union (IUCN). Nairobi, Kenya.

Moola S. W., Muimba-Kankolongo A. & Kangwa J.M. 2009. Growth performance of *Pterocarpus angolensis* seedlings in mycorrhizae colonized and uncolonized soils from high rainfall area of Zambia. *Journal of Applied Biosciences 19 (*pp: 1054-1064).

Mouton, J. 1996. *Understanding Social Reserch 1st Edition*. Van Schaik Publishers, Pretoria, South Africa (pp: 156 -159).

Munishi, T.K.P.; Mringi, S.; Shirima, D.D. & Linda, K.S. 2010. The role of the Miombo Woodlands of the Southern Highlands of Tanzania as carbon sinks. *Journal of Ecology and the Natural Environment Vol. 2*(12) (pp. 261-269).

Murdiyarso, D. & Skutsch, M. 2006. Promoting Carbon Benefits from Community Forest Management. *Community Forest Management as a Carbon Mitigation Option: Case Studies*. Eds: Murdiyarso, D. & Skutsch, M. CIFOR. Bogor, Indonesia (pp: 1-6).

National Planning Commission (NPC). 2007. *National Population Census 2001 Report*, Namibia.

National Planning Commission (NPC). 2012. *National Population Census 2011 Report*, Namibia.

Nichols, P. 1990. Social Survey Methods: A field guide for Development Workers. *Development Guidelines, No. 6.* Ed: Pratt, B. Oxfam GB, London, UK (p: 13).

Obara, O.A., Martina, G.H., & Hoft, R. 2005. Neem (*Azadira indica*, A. Juss*., meliaceae*) and its Potential for Woodcarving in Kenya: A case Study for Malindi. *Carving Out A Future:*

[2] Forest Products Prices List refers to the official prices of forest products as approved by Treasury Division of the Ministry of Finance in Namibia. This is used in the whole of Namibia.

Forests, Livelihoods and the International Woodcarving Trade. Eds: Cunningham, A., Belcher, B. & Campbell, B. Earthscan Ltd. London, UK (pp: 221-223).

Pak, .M., Türker, F.M. & Öztürk, A. 2010. Total economic value of forest resources in Turkey. *African Journal of Agricultural Research Vol. 5* (15) (pp. 1908-1916).

Palgrave, C.K. 1983 *Trees of Southern Africa.* Struik Publishers. Cape Town, South Africa (pp: 321-322).

Panayotou, T. & Ashton, S.P. 1992. *Not By Timber Alone: Economics and Ecology for Sustainable Tropical Forests*. Island Press. Washington D.C., USA (pp: 5 & 61).

Pearce, H.P. 1990. *Introduction to Forest Economics*. University of British Colombia Press, Canada.

Phillip, S.M. 1994. *Measuring Trees and Forests 2nd Edition*. CAB International, Wellingford, UK.

Phiri, M. 2009. *Evaluation of the Performance of Joint Forest Management (JFM) Programme: Case of Dambwa Forest Reserve in Livingstone District, Zambia. Thesis presented for the degree of Master of Forestry (Developmental Forestry)*. University of Stellenbosch, Stellenbosch, South Africa.

Pretzsch, H. 2009. *Forest Dynamics, Growth and Yield*. Springer-Verlag Berlin. Germany.

Price, C. 1989. *The Theory and Application of Forest Economics*. Basil Blackwell Ltd Oxford, UK (pp: 259-261).

Pröpper, M., Gröngröft, A., Falk, T., Eschenbach, A., & Fox, T. (Eds). 2010. *Biodiversity in southern Africa.Volume 3: Implications for landuse and management*. Klaus Hess Publishers. Windhoek, Namibia (pp. 1–31).

Read, P. 2007. The Role of Biomass in Carbon Storage and Climate Change. *The Biomass Assessment Handbook: Bioenergy for Sustainable Environment.* Eds: Rosillo-Calle, F.; De Groot, P.; Hemstock, L. S. & Woods, J. Earthscan Ltd. London, UK (pp: 225-231).

Röser, D.; Asikainen, A.; Stupak, I.; & Pasanen, K. 2008. Forest Energy Resources and Potentials. *Managing Forest Ecosystems – Sustainable use of Forest Biomass for Energy: A Synthesis with focus on the Baltic and Nordic Region Volume 12.* Eds: Roser, D.; Asikainer, A.; Raulund-Rassmussen, K.& Stupak, I. Springer. Dordrecht, The Netherlands (pp: 9 – 25).

Rosillo-Calle, F., De Groot, P. & Hemstock, L.S. 2007. General Introduction to the Basis of Biomass Assessment Methodology. *The Biomass Assessment HandBook*.Eds Rosillo-Calle, F., De Groot P., Hemstock, L.S. & Woods, J. Earthscan Ltd. London, UK (pp:27-41).

Schwartz, M. W. Garob, M. T. & T. Banda-Sakala, T. 2001. Assessing the sustainability of harvest of *Pterocarpus angolensis* in Rukwa Region. Tanzania. *Forest Ecology and Management 170* (pp: 259–269).

Senguta, S. & Maginnis, S. 2005. Forests and Development: Where Do We Stand? *The Earthscan Reader in Forestry and Development*.Ed: Sayer, J. USA (pp: 11-126).

Shackleton, C.M. & Mander, M. 2000. Value and Uses of Woodlands. *South African Forestry Handbook 2000 Vol. 2*. Southern African Institute of Forestry. Pretoria, South Africa (pp: 635-638).

Shackleton, C.M., Grundy, M. I. & Williams, A. 2004. Use of South Africa's Woodlands for Energy and Construction. *Indigenous Forests and Woodlands in South Africa: Policy, People and Practice. Eds*: Lawes, J.M., Eeley, C.A.H., Shackleton, M.C. & Geach, S.G.B. University of KwaZulu-Natal Press, Pietermaritzburg, South Africa (pp: 339-360).

Shackleton, E. S. & Shackleton, C.M. 2004. The *Pterocarpus angolensis* DC based woodcraft industry in the Bushbuckridge district, South Africa. *Forest Products, Livelihoods and Conservation: Case Studies of Non-Timber Forest Product Systems Volume 2 – Africa. Eds* Sunderland, T. & Ndoye, O. Center for International Forestry Research, Jakarta, Indonesia (pp: 203-226).

Shackleton, E.S, Shackleton C.C. & Cousins, B. 2004. The Economic Value of Land and Natural Resources to Rural Livelihoods: Case Studies from South Africa*. At the Crossroads: Land and Agrarian Reform in South Africa in the 21st Century. Ed*: Cousins, B. University of the Western Cape, Bellville, South Africa (pp: 35-50).

Shackleton, E.S. 2005. Bowls, Spoons and other Useful Items: The Kiaat Woodcrafts of Bushbuckridge, South Africa. *Carving Out A Future: Forests, Livelihoods and the International Woodcarving Trade.* Eds: Cunningham, A., Belcher, B. & Campbell, B. Earthscan Ltd. London, UK (pp: 81-102).

Shackleton, E.S., Campell, R., Lotz-sisitka, H. & Shackleton, C. 2008. Links between the Local Trade in Natural Products, Livelihoods and Poverty Alleviation in a Semi-arid Region of South Africa. *World Development Volume 36, No. 3* (pp: 505–526).

Shumba, E., Chidumayo, E., Gumbo, D. Kambole, C., & Chishaleshale, M. 2010. Biodiversity of Plants. *Carving Out A Future: Forests, Livelihoods and the International Woodcarving Trade. Eds*: Cunningham, A., Belcher, B. & Campbell, B. Earthscan Ltd. London, UK (pp: 47-54).

Shumba, M. E. 2001. *Biodiversity and Planning Support Programme*: Zimbabwe Case Study: Paper Prepared for the International Workshop, held in CIFORD Headquarters, Borgor, Indonesia.

Sitoe, E., Chidumayo, E. & Albert, M. 2010. Timber and wood products. *The Dry-forests and woodlands of Africa: Managing for Products and Services. Eds*: Chidumayo, N.E. & Gumbo, J.D. Earthscan Ltd, London, UK (p: 131).

Stahle, W.D., Mushove, T.P., Cleaveland, K.M., Roig, F. & Haynes, A.G. 1999. Management Implication of Annual Growth Rings in *Pterocarpus angolensis* from Zimbabwe. *Forest Ecology and Management 124* (pp: 217-229).

Subedi P.B., Pandey, S.S., Pandey, A., Rana, B.E., Bhattarai, A., Banskota, R.T. Charmakar, S. & Tamrakar, R. 2010. *Forest Carbon Stock Measurement Guidelines for measuring carbon stocks in community-managed forests. Publishers:* Asia Network for Sustainable Agriculture and Bioresources (ANSAB); Federation of Community Forest Users, Nepal (FECOFUN) and International Centre for Integrated Mountain Development (ICIMOD).

Takamura, K. & Kirton, G.L. 2000. Effects of disturbance by selective logging on occurrence of termites species. *Forests and Society: The Role of Research: Poster Abstracts Volume 3. Eds*: Jandl, R., Deval, M., Khorchidi, M., Schimpf, E., Wolfrum, G. & Krishnapillay, B. IUFRO Vienna (p.482).

Takano, T., Murata, K. & Nishimura, K. 2000. Utilisation of residues at sawmills, and pre-cut factories in Japan. *Forests and Society: The Role of Research: Poster Abstracts Volume 11. Eds*: Jandl, R., Deval, M., Khorchidi, M., Schimpf, E., Wolfrum, G. & Krishnapillay, B. IUFRO Vienna (p: 168).

Takawira-Nyenya, R. 2008. *Pterocarpus angolensis* DC. Plant Resources of Tropical Africa 7(1). Timber 1. PROTA Foundation. Eds Louppe, D., Oteng-Amoako, A. A. & Brink, M. ackhuys Publishers, Leiden, Netherlands / CTA, Wangengen, Netherlands (pp: 473-478).

Tasila, B., Mark, W.S. & Caro, T.M. 2006. Effects of Fires on Germinations of *Pterocarpus angolensis*. *Forest Ecology and Management* 233 (pp: 116-120).

Tate, R. 1989. ISA Tree Valuation Guide: A Critical Examination. *Journal of Arboriculture 15*(6) (p: 145).

The Namibian Parliament. 1990. *Sovereign Ownership of Natural Resources (Article 100). The Constitution of Namibia. Konrad Adenauer Stiftung. Windhoek, Namibia (p: 52).*

The Namibian Parliament. 2001*. National Forest Act 12 of 2001 as amended by the Forest Amendment Act no. 13 of 2005.* [Online] Available at: http://www.mawf.gov.na/documents [visited: 9 March 2012].

Therrel, D.W, Stahle, W.D., Mukelabai, M.M. & Shugart, H.H. 2007. Age and Radial Growth Dynamics of *Pterocarpus Angolensis* in Southern Africa. *Forest Ecology and Management,* 244 (pp: 24-34).

Timberlake, J. Chidumayo, E. & Sawadogo, L. 2010. Distribution and Characteristics of African Dry forests and woodlands. *The Dry-forests and woodlands of Africa: Managing for Products and Services. Eds*: Chidumayo, N.E. & Gumbo, J.D. Earthscan Ltd, London, UK (pp: 18-35).

Ulibarri, A.C. & Wellman, F.K. 1997. *Natural Resource Valuation: A Primer on Concepts and Techniques*. [Online] Available at www.hss.energy.gov [visited: 03 December 2012].

Van Laar, A. & Akça, A. 1997. *Forest Mensuration*. Cuvillier Verlag. Göttingen, Germany.

Venkatachalam, L. 2004. The contingent valuation method: a review. *Environmental Impact Assessment Review 24* (pp: 89–124).

Venter, F. & Venter, J. 2002. *Making the Most of Indigenous Trees*. Briza Publications. Pretoria, South Africa (p: 248).

Von Gadow, K. & Hui, G. 1999. *Modelling Forest Development*. Kluwer Academic Publishers. London, UK.

West, W.P. 2006. *Growing Plantation Forests*. Springer-Verl Berlin Heidelberg. Berlin, Germany (pp: 1-34).

Wipe, S. & Gong, P. 2010. Can forests save the world? *Journal of Forest Economics 16* (pp: 177–178).

Zhongmin, X., Guodong, C., Zhiqiang, Z., Zhiyong, S. & Loomis, J. 2003. Applying contingent valuation in China to measure the total economic value of restoring ecosystem services in Ejina region. *Ecological Economics 44* (pp: 345-358).

Zida, D., Sawadogo, L., Tigabu, M., Tiveau, D.& Ode´n, C.P. 2007. Dynamics of sapling population in savanna woodlands of Burkina Faso subjected to grazing, early fire and selective tree cutting for a decade. *Forest Ecology and Management 243* (pp: 102–115).

8. APPENDICES

8.1 Appendix A: Survey Questionnaire

1. What category of wood work do you do?
2. How long have you been working in this category - or years of experience?
3. What attributes do you (or you think loggers) use to select a Kiaat tree for felling?
4. At what price (N$) do you or your suppliers buy Kiaat trees?
5. From which institution (s) or supplier (s) do you buy your raw materials?
6. In what form do you buy / prefer your raw materials?

7 Are you satisfied with the price you pay for a Kiaat tree or Kiaat raw materials?

   a) If yes, why?
   b) If No, why?

8. How much are you willing to pay for a Kiaat tree - which is to be felled on communal land?
9. How much would you sell Kiaat trees if you were the current tree supplier?
10. What requirements should any timber meet before you buy or extract it from a tree?
11. What part or parts of Kiaat tree do you use or prefer to use?
    a) Why do you use only that part (s)?
    b) What products do you cut from the part (s) you used?
    c) Why you do not use the other parts you leave in the field?
12. How many planks do you or could be cut from one Kiaat tree?
13. At what price do you sell or buy a plank?
14. Besides local markets, where else do you or your customers sell their products?
15. What could the parts / canopy parts of the trees that are left in the field be used for?
16. If you are forced to use the whole Kiaat tree allocated to you, what would you use the:
    a) Bark
    b) Branches
    c) Foliages (twigs & leaves)
17. How many Kiaat trees do you need per year to sustain your livelihood or business?
18. What do you think should be done to make people reduce wastage of Kiaat trees?
19. Which Kiaat products do you think this community cannot do without?
20. If felling of Kiaat trees is banned, what alternatives or substitutes tree species will you fell / use?
21. For what else can Kiaat trees' canopy parts be used?
22. Do you have any comment or other information about Kiaat use and conservation you think is omitted in previous questions - which you would like to share?

THANK YOU!

8.2 Appendix B: Product Assessment Data Sheet

Plank No	core/ mix	Plank Dimensions (cm)				Plank No	core /mix	Plank Dimensions		
		Width	Heigh	Length				Width	Heigh	Lengt
1										
2										
3										
...										

8.3 Appendix C: Woodcraft Assessment Data Sheet

Woodcraft ID:			
Product	units	price	Part of tree it is cut from

8.4 Appendix D: Tree Measurements Data Sheet

Data Collector: ....; Date: ....; Place: ....; Species: *Pterocarpus angolensis* (Kiaat)

	1. GPS:...........................; Logging attributes:											3. Canopy Biomass			
	TH	SH	LSD	DB	US	StH	TDL	CW							
	2. Branches + their diameter & length ranges in straight units (in cm)														
	No											Freshmas		sam	sa
Tre	1														
	2														
e	3														
	4														
1	5														
	6														
	7														

4. Products cut from trunks				
Products	*No of Products*	*Volume /*	*Others*	*Remarks*
e.g. planks				
....				

Keys: GPS = GPS coordinates of sampled tree; TH = tree height; SH = stem height; LSD = lower stem diameter; DBH = diameter at breast height; USD = upper stem diameter; StH = stump height; TDL = trunk defect length; CW = canopy width; FB = fresh biomass, and DW = dry-weight.

8.5 Appendix E: Disc Measurements – for estimation of wood density.

Tree	Discs	Readings					Discs Density Variables & Distribution						Mean	other
							VariableNa	Trunk		Canopy Discs				
1	sides							1	2	3	4	5	...	...
	Diameter						WithBarks							
	Bark						No Barks							
	Height						Total							
2	Diameter						WithBark							
	Bark						No Barks							
	Height						Total							
...	Diameter						WithBark							
	Bark						No Barks							
	Height						Total							

8.6 Appendix F: Estimated total over-bark volumes of forty Kiaat trees.

Tree No.	Over-bark DBH (cm)	Stump (m^3)	Merchan-table Log (m^3)	Defect Log (m^3)	Branches >10 cm in diameter] (m^3)	Canopy parts < 10cm in diameter] (m^3)	Total Tree volume (m^3)
1	50	0.05	0.55	0.08	0.50	0.21	1.39
2	39	0.01	0.32	0.08	0.20	0.10	0.70
3	45	0.03	0.48	0.00	0.70	0.19	1.40
4	42	0.03	0.30	0.03	0.80	0.23	1.39
5	43	0.03	0.59	0.00	0.80	0.27	1.70
6	46	0.02	0.30	0.05	1.20	0.43	2.00
7	47	0.05	0.48	0.00	0.30	0.12	0.94
8	48	0.03	0.26	0.06	1.00	0.42	1.77
9	60	0.09	0.47	0.27	2.50	0.43	3.76
10	52	0.05	0.25	0.05	1.10	0.37	1.82
11	47	0.03	0.42	0.09	0.80	0.30	1.63
12	40	0.02	0.20	0.08	1.00	0.41	1.71
13	47	0.03	0.42	0.10	0.70	0.34	1.58
14	50	0.02	0.29	0.04	1.20	0.37	1.92
15	64	0.07	0.49	0.21	2.20	0.43	3.40
16	42	0.03	0.46	0.00	0.50	0.11	1.10
17	50	0.03	0.47	0.10	1.10	0.36	2.06
18	48	0.03	0.48	0.00	1.00	0.28	1.79
19	48	0.02	0.54	0.03	0.80	0.31	1.69
20	56	0.12	0.58	0.10	0.11	0.35	1.26

Tree No.	Over-bark DBH (cm)	Stump (m^3)	Merchan table Log (m^3)	Defect Log (m^3)	Branches >10 cm in diameter] (m^3)	Canopy parts < 10cm in diameter] (m^3)	Total Tree volume (m^3)
21	60	0.08	0.52	0.03	3.30	0.45	4.39
22	46	0.04	0.28	0.20	0.90	0.25	1.66
23	44	0.04	0.23	0.00	0.80	0.28	1.35
24	44	0.02	0.20	0.04	0.90	0.30	1.47
25	50	0.03	0.27	0.00	0.90	0.16	1.35
26	40	0.02	0.38	0.00	0.50	0.09	0.98
27	39	0.03	0.31	0.02	0.50	0.18	1.04
28	39	0.02	0.21	0.03	0.30	0.08	0.64
29	43	0.03	0.35	0.00	0.70	0.15	1.23
30	55	0.04	0.65	0.00	1.20	0.24	2.13
31	44	0.03	0.35	0.00	0.70	0.18	1.26
32	41	0.02	0.21	0.03	0.50	0.20	0.95
33	54	0.02	0.31	0.30	2.00	0.31	2.94
34	31	0.03	0.20	0.05	0.70	0.23	1.22
35	43	0.03	0.44	0.00	0.50	0.20	1.17
36	51	0.05	0.29	0.00	1.10	0.33	1.77
37	47	0.02	0.26	0.09	0.80	0.24	1.41
38	40	0.03	0.37	0.00	0.30	0.09	0.79
39	46	0.04	0.48	0.00	0.50	0.21	1.24
40	46	0.02	0.25	0.03	0.70	0.24	1.24
Average	47	0.04	0.37	0.05	0.91	0.26	1.63

8.7 Appendix G: Estimated total over-bark biomass of fourty Kiaat trees.

Tree No	Over-bark DBH (cm)	Stumps biomass (kg)	Merchantable Logs Biomass (kg)	Trunk Defect Biomass (kg)	Biomass of major Branches > 10 cm in diameter (kg)	Biomass of Canopy parts 10 cm in diameter (kg)	Total Tree Biomass (kg)
1	50	34	346	49	316	134	879
2	39	8	200	47	126	61	442
3	45	18	303	0	442	118	880
4	42	22	190	17	505	147	881
5	43	17	375	0	505	172	1068
6	46	13	188	32	757	273	1263
7	47	31	300	0	189	74	593
8	48	17	161	40	631	265	1113
9	60	54	296	171	1578	274	2373
10	52	29	161	29	694	235	1148
11	47	18	262	54	505	189	1028
12	40	15	124	48	631	260	1079
13	47	17	263	60	442	213	996
14	50	14	185	26	757	231	1213
15	64	43	312	131	1388	271	2145
16	42	17	293	0	316	67	692
17	50	20	295	66	694	224	1300
18	48	18	301	0	631	179	1128
19	48	14	340	16	505	196	1071
20	56	74	367	61	69	221	791
21	60	50	329	21	2082	285	2767
22	46	23	174	124	568	158	1046
23	44	26	146	0	505	174	851
24	44	16	129	28	568	192	932
25	50	18	168	0	568	99	853
26	40	13	237	0	316	55	621
27	39	17	198	10	316	111	653
28	39	15	134	20	189	50	408
29	43	17	222	0	442	92	773
30	55	25	409	0	757	149	1341
31	44	21	222	1	442	111	797
32	41	12	132	17	316	124	601
33	54	15	197	190	1262	193	1856
34	31	16	128	31	442	147	764

Tree No	Over-bark DBH (cm)	Stumps biomass (kg)	Merchantable Logs Biomass (kg)	Trunk Defect Biomass (kg)	Biomass of major Branches > 10 cm in diameter (kg)	Biomass of Canopy parts < 10 cm in diameter (kg)	Total Tree Biomass (kg)
35	43	17	276	0	316	126	735
36	51	31	185	0	694	208	1118
37	47	13	165	57	505	149	888
38	40	21	234	0	189	54	499
39	46	28	306	0	316	134	784
40	46	13	159	20	442	150	784
Average	47	22	235	34	573	164	1029

8.8 Appendix H: Estimated total over-bark biomass and carbon content of forty Kiaat trees.

Tree No.	Over-bark DBH (cm)	Total Tree Biomass (T)	Carbon Stored (T)	Tonnes of CO_2 (tCO_2) (T)	Carbon Value (N$)
1	50	0.88	0.44	1.61	105.59
2	39	0.44	0.22	0.81	53.13
3	45	0.88	0.44	1.62	105.74
4	42	0.88	0.44	1.62	105.83
5	43	1.07	0.53	1.96	128.32
6	46	1.26	0.63	2.32	151.75
7	47	0.59	0.30	1.09	71.29
8	48	1.11	0.56	2.04	133.75
9	60	2.37	1.19	4.35	285.09
10	52	1.15	0.57	2.11	137.89
11	47	1.03	0.51	1.89	123.54
12	40	1.08	0.54	1.98	129.58
13	47	1.00	0.50	1.83	119.66
14	50	1.21	0.61	2.23	145.77
15	64	2.15	1.07	3.94	257.74
16	42	0.69	0.35	1.27	83.18
17	50	1.30	0.65	2.39	156.15

Tree No.	Over-bark DBH (cm)	Total Tree Biomass (T)	Carbon Stored (T)	Tonnes of CO_2 (tCO_2) (T)	Carbon Value (N$)
18	48	1.13	0.56	2.07	135.52
19	48	1.07	0.54	1.97	128.69
20	56	0.79	0.40	1.45	95.03
21	60	2.77	1.38	5.08	332.39
22	46	1.05	0.52	1.92	125.70
23	44	0.85	0.43	1.56	102.22
24	44	0.93	0.47	1.71	111.99
25	50	0.85	0.43	1.57	102.50
26	40	0.62	0.31	1.14	74.59
27	39	0.65	0.33	1.20	78.39
28	39	0.41	0.20	0.75	49.07
29	43	0.77	0.39	1.42	92.84
30	55	1.34	0.67	2.46	161.08
31	44	0.80	0.40	1.46	95.69
32	41	0.60	0.30	1.10	72.16
33	54	1.86	0.93	3.41	222.95
34	31	0.76	0.38	1.40	91.79
35	43	0.73	0.37	1.35	88.25
36	51	1.12	0.56	2.05	134.30
37	47	0.89	0.44	1.63	106.72
38	40	0.50	0.25	0.92	60.00
39	46	0.78	0.39	1.44	94.14
40	46	0.78	0.39	1.44	94.25
Average	47	1.03	0.51	1.89	123.61