REPORT ON CHARCOAL AND FIREWOOD SUPPLY TO MAPUTO AND MATOLA CITIES

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SUMMARY

To accomplish this work, the data were collected from primary and secondary sources. Three methods were used, namely monitoring the firewood and charcoal at a specific check points, interviewing charcoal transporters about the tree species and literature review. Woodfuel (charcoal and firewood) data for all year (2011) was collected from the reports from Maputo Provincial Forest Services. Four different official check points to Maputo and Matola cities were identified in close collaboration with government institutions (Maputo Provincial Forest Services and National Directorate of Forestry and Wildlife). These check points are Matola-Rio, Moamba, Marracuene and Gare de Mercadorias. At these points and during 10 days, a structured questionnaire was applied for at least seven transporters of charcoal/firewood per day (for where were possible) and the charcoal/firewood bags were counted.

The results of the current study shows the following:

- Fuelwood and charcoal are main energy sources and forest products causing depletion of forests and vegetation around Maputo and Matola cities;
- Production areas are located away from the Maputo and Matola cities (main urban markets) where the charcoal is sold. Although there is charcoal coming from 6 districts surrounding Maputo city (Moamba, Matutuine, Namaacha, Goba, Boane, Manhiça), the majority of charcoal that feeds Maputo urban markets is currently coming from further locations (>300km) such as Magude disctrict in Maputo, but mainly from Gaza Province, namely the districts of Mabalane, Massingir, Mapai, Chicualacuala and Guijá;
- The weight of the charcoal bags has been changing over time and in the year 2012 varies from 40 kg to 100 kg;
- The main species used for energy purposes in Maputo and Matola cities are the 4th class according to the Forest Law and Forest regulation. However, the producers and market sellers also acknowledge the use of forbidden species;
- The total of solid volume supplied to Maputo and Matola cities for woodfuel in the year 2011 is equal 280 546.50 m^3. This amount represents approximately 20,000.00 ha of devastated forests;

Sustainable Forest Management in Mozambique cannot be done without Sustainable Wood energy systems. Actions on wood energy require at least two partners DNTF, DNE and others. Firewood use in rural areas is hard to intervene, however actions needed for production, trade and use of woodfuel in urban areas.

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FIELD WORKING TEAM

This work was done by the technical team indicated on the following Table.

Table 1. Members of the technical team.

Name	**Observation**
Mário P. Falcão	Coordinator of the Team
Agnelo Fernandes	Biomass Survey Specialist
Virgulino Paunde	Field Surveyor
João Roberto Tambisse	Head of Surveillance at SPFFB

LIST OF SYMBOLS AND ABREVIATIONS

CBNRM	Community Based Natural Resource Managment
DBH	Diameter Breast height
DNE	National Directorate of Energy
DNTF	National Directorate of Land and Forestry
Ha	Hectare
FAO	Food and Agriculture Organization of United Nations
Kg	Kilogram
m^3	Cubic meter
RLFFB	Forest and Wildlife Law and Regulation
SPFFB	Provincial Forest and Wildlife Service
%	Percentage
US$	American Dollar

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1. INTRODUCTION

1.1. Context

Fuelwood and charcoal accounted for about 91% of Africa's roundwood production in 2000. In southern Africa region, more than 90 per cent of rural households depend on woodfuel, including fuelwood and charcoal, for their energy requirements. The sustainability of this high dependence is questionable and, increasingly, African countries are looking at the energy opportunities offered by other alternative sources, including solar and wind energy.

The demand for woodfuel is rising due to the relatively high cost of electricity and petroleum-based fuels (e.g. paraffin) as well as the rapid human population growth, particularly in urban areas in Mozambique, Malawi, Tanzania and Zambia. Demand for woodfuel in the urban areas of developing countries is usually higher than in rural areas. One of the main reasons for this is inability of the households to have access to other fuels such as gas and fossil fuels in the energy mix of the urban areas. There is a kind of ladder of energy sources in the urban areas: from fuelwood at the bottom, through charcoal, kerosene and gas, to electricity at the top. People generally climb this ladder as their income increases. Therefore charcoal, which is hardly used in the rural areas because of availability of free wood, is quite popular in urban areas because of higher income and other factors such as its lightness and non-smoking nature (FAO, 1993; Brouwer and Falcão, 2004; Luoga *et al*., 2000a).

The present domestic biomass energy for domestic purposes demand for Maputo and Matola cities is leading to forest depletion with a trend of increasing the rate of deforestation. This survey of charcoal and firewood entry in different official check point was conducted in order to quantify, analyse and to comprehend better this situation.

1.2. Objectives

The objective of this report is to give an estimation of the amount of biomass (charcoal and Firewood) entering Maputo and Matola cities. The analysis shall encompass all entry routs via all transport modes (road, rail, sea/river).

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- Estimate the average charcoal bag size;

- Identify the current woodfuel supply regions;
- Identify the harvest species for woodfuel purposes;
- Estimate the annual quantity of woodfuel supplied;

1.3. Scope of the study

Two cities in southern region of Mozambique were selected, namely Maputo and Matola. They are included in this report due to the high consumptions levels which are directly related with population size.

For the purpose of this report **woodfuel** includes firewood and charcoal. Fuelwood is synonymous to firewood. Included in this study are other materials obtained from other parts than stems of trees and shrubs to be used as fuel for cooking, heating or generating energy through direct burning, not only in households but also in rural industries like curing and smoking.

Woodfuel needs refer to the least possible amount of woodfuel necessary regarding the lowest energy estimated to be indispensable for household consumption, artisanal purposes and rural industries, in line with local conditions and the share of woodfuel in their energy supplies.

2. LITERATURE REVIEW

2.1. Relevant Legislation for the woodfuel sub-Sector in Mozambique

At a national level, the following laws, policies and decisions have importance to the woodfuel sub-sector in Mozambique:

1. Resolution 10/97 of 7th April (Forestry and Wildlife Policy) [Boletim da República No. 14 – Supp., Series I – 7th April 1997]
   The National Forestry and Wildlife Policy empower local communities to own and participate in the management of natural resources through community-based natural resources management (CBNRM) initiatives (Brouwer and Falcão, 2001).

2. Law 10/99 of 7th July (Forestry and Wildlife Law) [Boletim da República No. 27 – 4th Supp., Series I – 12th July 1999]
   Forestry and Wildlife Law was approved in 1999, and regulates the basic actions for the protection, conservation and sustainable use of forest resources.

3. Decree No. 11/03 of 25th March 2003 (amending Decree No. 12/2002 on Forestry and Wildlife Law) [Boletim da República No. 13 – Series I – 26th March, 2003, pp. 78 and 79.
   This Decree provides a new version of articles 20, 21, and 29 of Decree No. 12/2002 on the Forestry and Wild Fauna Act. In particular, it amends those provisions dealing with licensing procedures and forestry exploitation concessions.

4. Decree 12/2002 of 6th June 2002 (Regulations of the Forestry and Wildlife Law) [Boletim da República No. 22 – Series I – 6th June, 2002, pp.194(3)-194(27)]. This Decree consists of 119 articles, acknowledges the existence and the role of local communities on the management of natural resources and allows them to enter into partnership with the private sector in its exploration of natural resources (forestry and wild life).

5. Ministerial Diploma No. 52-C/2003 of 20th May, 2003 (on forest species used for producing timber) [Boletim da República No. 20 – Series I – 20th May 2003, pp.

160(54) and 160 (55)]. This Decree deals with commercial trees classification and does not mention any 'inclusive forestry' activities.

2.2. Charcoal

The main vegetation cover used by the households to produce charcoal in Mozambique is obtained from miombo woodlands, which are dry tropical woodlands. The harvesting of miombo woodlands and other forest vegetation types is essential for the livelihood of the rural dwellers (employment, income, consumption goods and services). The harvesting is stimulated by the purchasing power of urban dwellers. This can be seen in the growth in fuel wood and charcoal consumption substituting electricity and gas as alternative sources of energy, and the increased use of wood based products for building houses (Karekezi *et al*., 2003; Falcão, 2005; Luoga *et al*., 2000a).

Most of the charcoal in Mozambique is produced by the traditional earth kiln method. The method consists of the following steps: (i) locating suitable trees; (ii) choosing the right place to build the kiln i.e. flat and sandy soils and closer to the trees; (ii) cutting the trees and transporting them to the kiln site; (iv) gathering material necessary for kiln construction (grass, clay/sand, and stones when available); (v) constructing the kiln; (vi) operating the kiln; (vii) unloading the kiln; (viii) putting the charcoal into bags. The process of charcoal production is labour intensive, mainly carried out by men and bears some similarities to that in Kenya, and Uganda (Luoga *et al*., 2000a and 2000b, Falcão, 2005).

Charcoal production efficiency in Mozambique, Malawi, Tanzania and Zambia varies between 10% to 25% (Lew and Kammen, 1997; Okello *et al.*, 2001; Stassen, 2002, Pereira and Joaquim, 2001; Falcão, 2005). Efficiency varied between kilns, which though similar in design, are usually different because the size, species and composition of wood used as well as the time taken for carbonisation, are different. Pereira and Joaquim (2001) found for Licuati and Chipango, Maputo Province (southern Mozambique) an average charcoal yield of 14.1% and 19.5% respectively, ranging between 6.1% and 35.5%. The efficiency of conversion of *Acacia drepanolobium* wood to charcoal in Laikipia, Kenya, ranged from 10.2% to 18.2%, with an average of 14.2%

(Okello *et al.,* 2001). More technologically advanced kilns such as the Mark IV, Cusab Kiln, and Gayland Batch Charcoal Retort give higher efficiency rates of 25–32% (Cunningham, 1996; Lew and Kammen, 1997; Okello *et al*., 2001). These kilns could significantly improve charcoal production in the rural areas. However, some of these kilns have been tested in the South of Mozambique and the results showed that they are usually out of the financial reach of most charcoal burners and they use much more labour than the system applied now. This means they are unlikely to be implemented by the charcoal burners.

According to charcoal producers in Mozambique, good properties for charcoal production are long burning, little smoke, sparks or ash, and generation of high temperatures. In accordance with several studies, the most common trees species for charcoal are: *Brachystegia spiciformis*, *Brachystegia bhoemii*, *Julbernardia globiflora*, *Millettia stuhlmannii*, *Pterocarpus angolensis*, *Afzelia quanzensis*, *Burkea africana*, *Khaya nyasica*, *Parinari curatellifolia*, *Afrormazia angolensis*, *Sclerocarya birrea*, *Erythrophleum suaveolens*, *Ozora obovata*, *Dalbergia melanoxylon*, *Crossopteryx febrifuga*, *Lannea* sp., *Combretum* sp., *Dombeya shupangae*, *Dichrostachys cinerea*, *Combretum apiculatum*, *Markhamia obtusifolia*, *Acacia sieberiana*, *Pterocarpus rotundifolius*, *Schrebera trichoclada*, *Cussonia arborea*, *Combretum fragrans*, *Acacia* sp., *Senna senguiana*, and *Boscia salicifolia.* This list includes species such as *Afzelia quanzensis*, *Dalbergia melanoxylon*, *Erythrophleum surveolens*, *Millettia stuhlmannii*, and *Pterocarpus angolensis* that are valuable commercial timber species and they are forbidden by Forest Laws to be used for charcoal making in the study countries (Brouwer and Falcão, 2004; Adamo *et al.* 1997; Vilanculos 1998; Mangue and Wate, 1998).

2.3. Woodfuel consumption

The demand for woodfuel is rising due to the relatively high cost of electricity and petroleum-based fuels (e.g. paraffin) as well as the rapid human population growth, particularly in urban areas in Mozambique. Demand for woodfuel in the urban areas of developing countries is usually higher than in rural areas. One of the main reasons for this is inability of the households to have access to other fuels such as gas and fossil fuels in the energy mix of the urban areas. There is a kind of ladder of energy sources in the urban areas: from fuelwood at the bottom, through charcoal, kerosene and gas, to electricity at the top. People generally climb this ladder as their income increases. Therefore charcoal, which is hardly used in the rural areas because of availability of free wood, is quite popular in urban areas because of higher income and other factors such as its lightness and non-smoking nature (FAO, 1993; Brouwer and Falcão, 2004).

For Mozambique, it is estimated that 75% urban households use charcoal and all poor households use it for cooking, about 50% use charcoal for heating water for bathing and water for drinking, and 70% use charcoal for heating in cold season (Brouwer and Falcão, 2004). The following Table shows woodfuel consumption levels in several countries (Agarwal, 1986; Brouwer and Falcão, 2004; and many other authors).

Table 2. Woodfuel consumption in some African countries

Country	**Consumption *per capita* (m^3/*annum*)**
Angola	0.96
Kenya	1.48
Madagascar	0.59
Malawi	0.90
Malaysia	0.50
Mali	0.58
Mozambique	0.96
Niger	0.58
Nigeria	0.84
Senegal	0.55
Sudan	1.75
Uganda	1.77
Zaire	0.91
Zimbabwe	0.96

Source: Agarwal (1986), Brouwer and Falcão (2004).

The key factors that affect the outlook of demand and supply include the current state of forest resources and their use, population, income, technology, institutions and policies, prices of forests products, substitute products and wood raw material. Each of these factors affects both demand and supply of wood. The state and potential of existing forests is a factor in the development of the future supply of products and services while past and current levels of consumption are factors in determining the future demand for products and services (Brooks *et al*., 1996; Conteh, 1997).

The demand for and supply of wood change in response to changes in population, economic growth, technology, policy and institutional aspects and the price of forest products and substitute products. It should be recognized that these factors differ in their effects on demand for fuelwood and demand for roundwood although factors such as population growth and economic growth are important for both. The demand for industrial roundwood is derived from the demand for forest products. Therefore, an understanding of the dynamics of the supply and demand process of these markets can be brought to operation in understanding future developments for this component of wood demand and supply. This situation is contrary to fuelwood demand structure and the process of supply are quite different from those for industrial products. Three billion people depend on wood to meet basic energy needs and much of the production of fuelwood is based on gathering from forests and scattered trees by individual households and through exchange in informal markets. Where alternative (fossil energy) fuels are available and affordable, they are often preferred; however, where fuelwood is scarce and in demand, there are often few alternatives (Brooks *et al*., 1996).

a) Population growth

Population growth has historically been a major factor influencing wood consumption and it is not likely that the close relationship between population growth and growth in consumption will change significantly in the foreseeable future. World population increased from 2.4 billion people in 1950 to 5.5 billion people in the mid-1990s. World population grow at a rate of 2.0% per year in the early 1970s and is currently increasing at a rate of 1.7% per year.

On a *per capita* basis, world consumption of timber, both fuelwood and industrial round-wood, declined slightly over the past four decades to 0.6 m^3 *per* person from 0.7 m^3 per person (Brooks *et al.,* 1996). There has been changes in patterns of consumption (among developing and developed countries) and in the composition between fuelwood and industrial roundwood, and among industrial products), but the net result has been little change in global *per capita* consumption. To this end, growth in population can provide a crude, but an effective indicator of trends in aggregate consumption. The basic dynamics of population change create social, economic and technological change that effect health, fertility and longevity.

b) Economic growth

Economic growth will have a particular impact on the demand for fuelwood, because the marginal propensity to increase consumption of commercial energy in developing countries is very high and highest among the poorest countries with currently high dependence on wood and biomass. The strong preference for convenience, efficiency and cleanliness in cooking and heating fuel may be expected to lead to substitution of commercial fuels as income rises. Energy is of particular importance in the context of wood demand as it constitutes both a basic need of human civilization and an essential component in economic activity and development. World energy consumption tripled in the first fifty years of this century and then increased four fold in the forty years to 1990. In their global energy perspective the World Energy Council and IIASA present a range of scenarios projecting world consumption of primary energy at least doubling and possibly more than tripling over the period 1990-2050 (IIASA, 1995).

Throughout human history wood has been an important source of fuel. Up to the industrial revolution it was the main fuel for both domestic and industrial needs. The discovery of fossil fuels and the technology to use them, to transport them and to distribute electrical energy widely lead to the virtually complete replacement of wood as fuel, so that over the span 150 years of the 19th and 20th century the contribution of fuel consumed in today's developed economies has changed from virtually 100% fuelwood and charcoal to the situation where fuelwood contributes only 1-2%. In developing countries wood remains an important source of energy averaging 15% with some of the poorest countries still in the position of depending on wood or other biomass for 70% or 80% of their energy supply (IIASA, 1995).

Income growth permits, in the first place, purchase of improved stoves which reduce the quantity of fuelwood and then the substitution of more convenient commercial fuel. This movement will tend to be lead by urban communities where the supply price of woodfuel is higher due to transport cost and the availability of discretionary income allows the choice. Rural population may experience lower rates of growth of *per capita* income and thereby lower rates of growth in demand for forest products. Both the lower levels of disposable income and distance from markets may slow the trend towards the substitution of commercial energy for fuelwood. Fuelwood may be expected to remain the principal fuel of poor rural communities with low income and better access to wood supplies. Thus the demand for fuelwood may continue to grow in those areas. Several factors may favour some future increase in the use of wood biomass as a source of industrial energy. Increase in cost of commercial energy or improved efficiency in the recovery of wood residues such as off-cuts, sawdust and bark and spent pulping-liquors and improved efficiency in use to generate heat and energy, would favour their use for energy supply within the process for sale. In view of the importance of wood and paper in urban waste, a contribution to reducing the volume of waste maybe made by utilization of the portion of wood and paper waste not suitable for recycling in industrial production, for heat or energy generation. This would constitute and increasing supply trend. Growing wood absorbs carbon dioxide, in this way the use of wood for energy, with replacement on a continuing basis may be seen as neutral in relation to the release of greenhouse gases. Growing additional woody biomass for energy would increase supply (IIASA, 1995).

Global energy perspectives (IIASA, 1995), suggests the gradual replacement of traditional renewable fuels such as fuelwood and biomass by high quality commercial fuels. End use conversion of biomass would be improved significantly. This would be seen to be consistent with the expectation of substitution by commercial fuels with increased income and urbanization. It is also consistent with an expectation of increased demand for industrial wood products with increased population and income. The increased contribution of biomass is projected to over 8 billion TOE by 2100. However, the enormous commitment of land this would involve should be recognized. A feature of fuelwood use is the widely varying level of *per capita* domestic consumption both between countries and within countries. Consumption levels vary greatly even between countries where wood constitutes the main source of energy. In many countries, *per capita* consumption is around one cubic metre *per annum*. This figure is incidentally similar to that for the consumption of industrial wood in many developed countries. Considerably higher levels characterize some African countries such as Sudan and

Uganda, while much lower rates are typical of many Asian countries. Generally, *per capita* consumption levels correlate with the extent of forest and woodland and with the availability of the resource. In parts of the developing world where fuelwood is plentiful, 2 000 kg or more may be used per person per year, while in areas of scarcity only one-quarter of that amount may be used (Eckholm *et al*., 1984).

Economic factors are also, of course, a major influence on levels of consumption. They tended to reach a maximum in developing countries in the middle range income (Laarman, 1987). As income rises, more fuelwood is initially consumed, but beyond a certain level its use decreases as other fuels such as oil are substituted. According to Foley (1985), price influences the amount of fuel that is consumed, but does not have a great influence on choice between fuels. This conclusion has not answered the question of what determines the transition from wood to other fuels as a country becomes richer. Real income and an index of commercial energy prices are significant factors in relation to demand, but adjustment in consumption in response to these factors tends to be very slow and slight (Laarman and Wohlgement, 1984). These authors also found that a contracting forest area was a significant variable in terms of supply, but that it had a stronger braking effect on fuelwood consumption in middle-income than in low-income developing countries. Since levels of consumption appear to depend on the availability of the resource and on income, it is not surprising that consumption levels also vary greatly within countries. In Tanzania, for instance, household consumption in villages near wooded areas is three times higher than in villages with little or no woodland (Agarwal, 1986). Similarly in Nepal, people moving to the well-wooded plains, where firewood is relatively abundant, consume twice as much as those remaining in the forest-depleted hills. In essence, people use more wood when it is readily available than when it is scarce. Reasons for variation in consumption levels are confusing between local people and visiting consultants or researchers, and mistaking of actual levels of consumption as a result of suspicion or apprehension of tax collection or forest regulations. Levels of use of fuelwood also, of course, depend on the availability and price of alternative fuels, and therefore vary through time. Much uncertainty therefore exists over the concept of fuelwood needs, and this uncertainty is matched in some areas by that surrounding the availability of fuelwood.

Of the 3 400 million m^3 of roundwood felled for human purposes in 1991, 5% had been used as a source of energy in the form of fuelwood and charcoal, 89% of it in developing countries. The total fuelwood and charcoal consumption in developing countries was 1 600 million m^3 in 1991 and is growing more or less parallel to population growth (Steinlin, 1994).

Wood energy serves not only domestic purposes but also local small industries. The overcutting of forests for fuel needs is exacerbated in drier and densely populated areas, leading to serious forest depletion in many regions.

The main sources of domestic energy in Mozambique, Malawi, Tanzania and Zambia are electricity, liquid petroleum gas, kerosene, charcoal and firewood. The first three are available only in urban centres, and to the wealthy members of the community. Kerosene is usually used by the low income groups for lighting. Charcoal and firewood are the main sources of heat to the majority of rural people and town dwellers.

c) Policies and institutions

Energy policy relates to forestry and forest products in several ways (Solberg, 1996). Measures that lead to increased price of fuelwood stimulates the production of wood for fuel, encourages forest industry to economize in energy and to increase the utilization of wood residue from its manufacturing process to generate energy for own use or sale. Policies that support the marketing of energy from biomass and the other renewable resources, facilitate the latter. Increased energy cost also means increased cost of transportation which has an impact on supply. The response to the oil crisis in the mid 1970s demonstrated this in many regions, as did the more recent movement to market pricing of energy in the former USSR. Russian experience also shows the effect of increasing energy price reducing supply through increased transport cost for timber from Liberia. It has also resulted in increased demand for fuelwood in many regions of the former USSR and some Eastern European countries.

Subsidization of commercial energy has the effect of reducing the demand for fuelwood and is a measure that has been used to reduce the pressure of fragile protection forests in some arid countries. Subsidizing smokeless fuels or restricting the use of smoky fuels and fire places, to reduce air pollution in urban areas has a similar impact on diminishing the demand for woodfuels (Brooks *et al.*, 1996).

In urban areas the problem of waste disposal has grown into a major problem. Approaches to reduce the volume to be disposed of, have included consideration of reducing consumption, requiring the recycling of used material and utilising waste in energy generation.

The forestry sector with its association with natural forests and less developed areas, has through history had a lower priority in societies choices for institutional development. In most countries forestry education and training are recent additions, the earlier cases mainly dating from the late 1800s and early 1900s. Similarly most government forestry organisations are recently established. Some countries do not have these organisations yet, or have them only in very preliminary forms. Many government agencies responsible for the implementation of forest policy lack the resources to establish or implement the measures to carry it out. There are many cases too, where the legal framework for the implementation of forest policy is weak or lacking (Solberg, 1996).

With increasing demand for the products and services of forests driven by the population increase and increase in wealth, the demand for the institutional framework and infrastructure to regulate the use of that scarce resource increases. A supply response, improving the strength of the institutional framework, will be increasingly necessary to reduce uncertainty and to ensure an approach to the optimum investment in institutional infrastructure. This will lead to increased aggregate supply of forest products and services, although the supply of wood may decline, all other factors being equal. Forest cover plays a significant role in sustaining global environment systems. Forests also have a direct role in sustaining humanity by providing food, fuel, services and income. Striking an enduring balance among the various uses of forests presents the formidable task of choosing between use and preservation. Countries are faced with the complex decisions on the allocation of resources to alternative uses some of which are in competition (Solberg *et al*., 1996).

2.4. Woodfuel surveys

Although woodfuel is the most important forest product for Mozambique, reliable statistics on its production, trade and consumption are not readily available. The dominance of the informal sector makes it difficult to obtain reliable information on production and trade of woodfuel.

Estimates of firewood and charcoal production and consumption depend on the results of ad hoc surveys. These include some national surveys which are more frequently limited to urban households, rural households for specific regions and surveys of woodfuel consumption by specific industries. Many of these surveys are undertaken in conjunction with multilateral and bilateral agencies and include expatriate staff and external financial support. There are wide variations between estimates. These result from different surveys because of the differing populations and diverse objectives. Estimating present woodfuel demand is generally a difficult task because systematic data on past consumption by type of forest product are not always available. Oral inquiries and rough sampling may be a satisfactory approach to this problem (FAO, 1983).

Fuelwood and charcoal are important items of wood consumption in Mozambique. They may comprise some 90 percent of total wood consumption. The consumption of woodfuel could be sampled in connection with population sampling. It would then be possible to establish a relationship between the family size and the fuel consumption. The effect on fuel consumption of the income level could possibly be desirable to detect the trend, if any, in the consumption per head (or per family or household). If it is not possible, then one could assume that the unit consumption will remain constant over a given period.

FAO (1983) mentions that, woodfuel surveys can be, and have been, undertaken for a variety of purposes. The most important purpose for carrying out a survey is to prepare for action; that is, to collect information needed to improve the rural energy situation, so as to facilitate the development process. Within such a framework surveys may need to be undertaken for a spectrum of purposes, ranging from the estimation of the magnitude of fuel use, and/or the spatial variation in this use, to the planning of a specific project (or projects). Different surveys are likely to be needed to serve the planning process at the macro, sector or project level, and they can differ widely.

The planner at the national level, concerned primarily with the share of fuelwood in the country's forest product balance, or of woodfuel in its energy balance, needs only broad aggregate estimates. To establish energy balances, more details would be needed to differentiate use by household, commercial, industrial and transport sectors. Still more detail is needed if the aim is to differentiate among different types of fuel (FAO, 1983).

Estimates of traditional fuel use, even those requiring information on end use, sector, fuel, and spatial variation, can be used on surveys of demand characteristics. Traditional fuels in this context are those which are part of the broad class of energy supplies based on renewable resources. Project evaluation of energy investments that depend on fuelwood requires a kind of survey that differs from consumption surveys. In many cases investment planning requires understanding of supply resources, the existing and potential demands, and the nature of the systems in which these supplies and demands are balanced. Woodfuel surveys will not be effective in providing the information that will allow the identification and planning of successful interventions in fuelwood shortage situations, unless they reflect the relevant inter-relationships within the surrounding systems, and are correctly designed to show the appropriate level of detail. These points are to be emphasized because most past work on fuelwood has not fully met these criteria (FAO, 1983).

To assess the likely magnitude of local fuelwood needs, the starting point will be the measurement or estimation of the quantities used at present. It should also take into consideration how usage might change, or could be changed, in the future. If the fuelwood used is purchased, it may be necessary to assess the quantities involved somewhere along the distribution chain; that is by recording how much is sold by the fuelwood merchants, or how many lorry loads or donkey loads are brought in for sale over a particular period, and how much wood there is in such loads. In the more usual situation, where fuelwood is gathered rather than bought, it is unlikely that useful estimates can be obtained except by direct measurement at the household level, by means of a sample survey. If the population to be surveyed encompasses areas or groups which are likely to exhibit markedly different usage patterns (hill and valley locations, groups with different income levels), then a stratified sample survey should be designed which will allow these differences to be identified, and then taken into account (FAO, 1978).

Weighing is likely to be the most accurate form of measurement of fuelwood, but care must be taken to record the type of wood, and whether it is green or dry, in order to be able to translate this weight information into equivalent volumes of standing wood. In most areas fuelwood use varies markedly with the season. In mountains more is needed in the cold season than the hot season, in the tropics less tends to be used in the wet season than the dry. The measurement of fuelwood use must therefore be repeated at sufficient intervals to establish the nature and magnitude of this seasonal fluctuation, in order to arrive at a realistic estimate for the year as a whole. The survey should also incorporate measurements or estimates of such other information as will be needed in assessing future change and alternative solutions to the fuel requirement (FAO, 1978).

2.5. Woodfuel markets

Woodfuel supports lucrative local trade. Trade in charcoal is a major source of income for many households in Mozambique.

As charcoal becomes an important tradable commodity, there is an opportunity for governments to recognize and regularize charcoal production by putting in place long-term plans for sustainable production, while at the same time creating a supportive legal and economic framework for micro- and small and medium enterprises (SMEs) development. Increasing efficiency and ensuring that the development of this sector does not accelerate deforestation requires appropriate policy interventions. There is ongoing research to develop more efficient charcoal production methods using improved kilns in a number of countries in Eastern and Southern Africa. There is also research on charcoal briquettes production using wastes such as farm refuse, sawdust and woodchips (Kalumiana 2000). These initiatives can be supported through active private sector involvement.

In Mozambique about 150000 families are employed on charcoal production and on average the annual income generated e about 250-300 US$ per family (Falcão, 2004).

3. METHODOLOGY

3.1. Data collection

To accomplish the survey objectives three methods were used, namely monitoring the firewood and charcoal at a specific check points, interviewing charcoal transporters about the tree species and literature review. Woodfuel (charcoal and firewood) data for all year (2011) was collected from the reports from Maputo Provincial Forest Services.

Four different official check points to Maputo and Matola cities were identified in close collaboration with government institutions (Maputo Provincial Forest Services and National Directorate of Forestry and Wildlife). These check points are Matola-Rio, Moamba, Marracuene and Gare de Mercadorias. At these points and during 10 days, a structured questionnaire (see Annex 1) was applied for at least seven transporters of charcoal/firewood per day (for where were possible) and the charcoal/firewood bags were counted (See Annex 2).

In order to estimate the average charcoal bags size, several charcoal bags were selected randomly from different trucks at all check points. The selection was dependent on availability of the truck driver.

3.2. Data analysis

The amount of biomass that entered Maputo and Matola cities was estimated base on amount of charcoal bags and amount of firewood registered at checkpoints. The data on charcoal was then converted into biomass, assuming the charcoal kiln efficiency of 13%. For the firewood, the amount of biomass was estimated based on the assumption that 1 ester is equal 0.7 m^3 of biomass. The following two formulas were used.

The efficiency of kiln charcoal production (E):

$$E = \frac{P_{ch}}{V \times \delta} * 100 \qquad (1)$$

Where,

P_{ch} = Total weight of charcoal produced (kg);

δ = Density of miombo wood in Mozambique (858 kg/m^3);

The volume of the timber in the kiln (V):

$$V = \frac{3.14 \times (D)^2}{4} * L * N \qquad (2)$$

where,

D = Average diameter of logs in the kiln (m);

L = Average length of logs in the kiln (m);

N = Number of logs inside the kiln.

4. RESULTS

4.1. The charcoal supply chain

The main stakeholders involved in the charcoal supply chain to Maputo and Matola cities are: Government authorities (mainly forest officers), producers (rural households), middlemen, transporters, wholesalers, retailers and consumers (Figure 1).

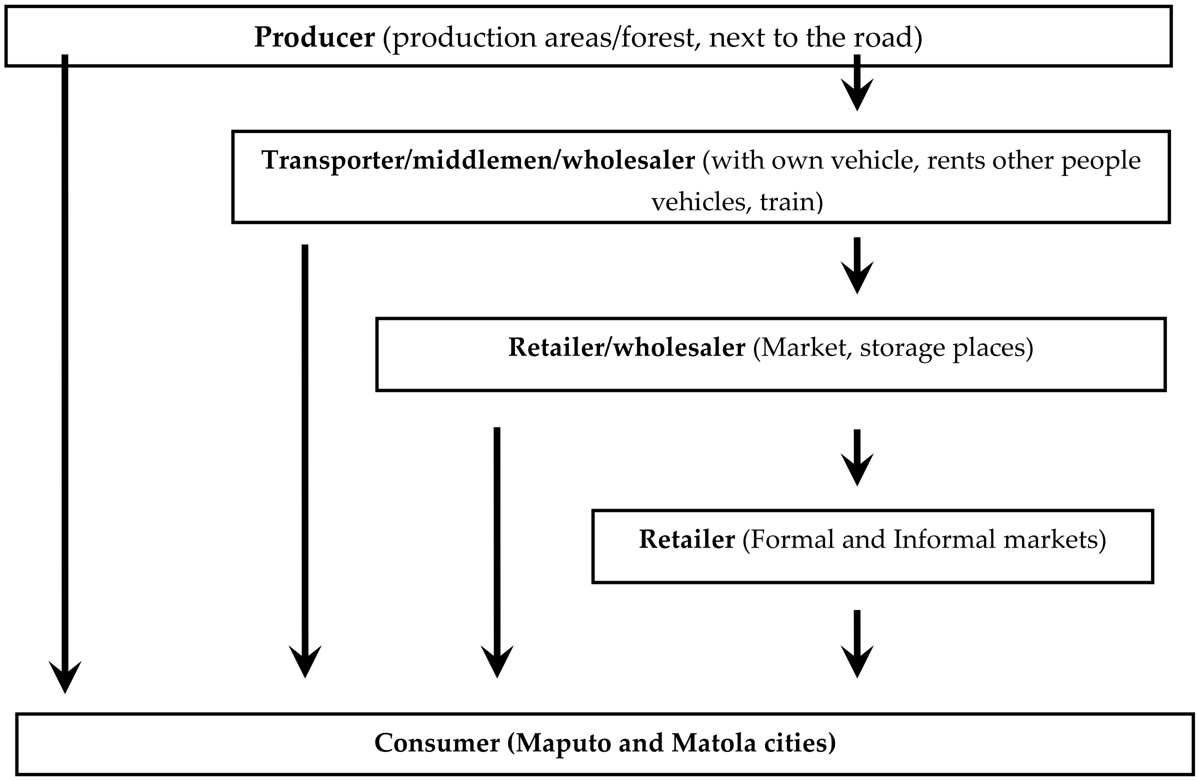

Figure 1. Maputo and Matola cities woodfuel supply chain in 2012.

4.1.1. Producers

Producers are households or individuals that burn the firewood to produce charcoal. Most of them live in rural areas, in temporary camping sites with precarious living conditions, close to the resources because there is little wood left around Maputo and Matola cities. In some cases they are locals from the production areas but there is a growing trend for producers to migrate from one area to another seeking for the resources availability. Also there is an increased trend of getting "outsiders" working as full time producers, being paid by third persons who hold the charcoal production license for the volume produced. Two different scenarios can be observed, i) those who receive a monthly payment and ii) those who receive a payment according to their productivity. The second kind of arrangement incentivizes the increased production and may pose a threat to the environment as there is little attachment from these producers to the resources.

Most of the producers learned the activity through friends or seeing others doing it and have never benefited from any training which can be seen as a limitation because they have some problems with the kilns' failures (due to unburned wood or conversion of wood into ashes).

A few producers have benefited from trainings in the usage of improved kilns however, there has never been a follow up on what was previously done and most of the trained producers are not using this knowledge allegedly because the introduced technology (Casamance) is time consuming. In this scenario, the introduction of improved charcoal production technologies that are cost effective in terms of time or the promotion of kilns that allow for the usage of forest exploitation or agricultural residues for charcoal production would be an asset. For instance the promotion of the use of drum kilns could be a good option. This would promote reduction of wastes as well as promote the resources sustainability by reducing the amount of trees that are currently being cut.

Only a few women (less than one quarter) are involved in the production process because the activity is considered labour-intensive. Women are involved mainly to help their husbands to cover the kilns. There are, however, a few cases of women producers and this occurs often when the woman is the head of the household because the husband is absent or when they have become widows.

Production areas are normally located away from the main urban markets where the charcoal is sold. Although there is charcoal coming from 6 districts surrounding Maputo city (Moamba, Matutuine, Namaacha, Goba, Boane, Manhiça), the majority of charcoal that feeds Maputo urban markets is currently coming from further locations (>300km) such as Magude disctrict in Maputo, but mainly from Gaza Province, namely the districts of Mabalane, Massingir, Mapai, Chicualacuala and Guijá.

The licensing process

Only a few producers are currently licensed. Mainly the transporters or the wholesalers who normally buy from the local people hold licenses. Although the forest law and its respective regulations state that the producers should be the licensed ones, the licensing process is a clear attempt at having some control over the charcoal production which is difficult due to the limited capacity the Government has to control the vast forest areas. Producers are mainly licensed where there is a community/producers association organized in the area (e.g. Mabalane area, Mahel, Massingir) or in the case where the individual, mostly from outside, is involved in all the supply chain stages from production to selling to the final consumer in the city markets. As most producers are not licensed, this gives them less leverage to negotiate the charcoal prices.

There is uniformity in the charcoal prices in the production areas mainly where there are producers' associations, because the charcoal price is decided jointly by all producers. However, a limitation is the lack of clear procedures for the price definition. Also, although there is uniformity in the prices of charcoal within the same area, there is still lack of uniformity on the sizes used for the charcoal packaging which are decided by the transporters who decide on the quantities that are fed into the bags.

Production process

The production process normally involves 4 stages namely: the preparation of material, kiln preparation, carbonization and packaging and sales.

Charcoal producers use mainly the traditional methods of charcoal production, with earth mounded kilns covered with soil being the most common. These kilns are made using different species and sizes of firewood having therefore, varied but normally low production efficiencies (around 10 to 15%), which implies more wood is cleared to produce charcoal and therefore causing more deforestation. There is no standard shape, however the majority of kilns are shaped in a rectangular format.

Producers normally use the whole tree and the species used are dependent on the availability in the area.

There is an increasing tendency of using more motorized equipment such as the chainsaws for cutting the trees which increase the productivity of the operations allowing the operators to cut more trees in less time and therefore contributing to accelerated deforestation.

Another problem noticed was the disregard of the height recommended as the best for species regeneration, i.e., 30cm from the floor (Figure 2).

Figura 2. Trees cut above the recommended height - 30cm in Matutuine District.

There are no specific management techniques being applied to the charcoal production process. Also, though the legislation allows it, there are still no charcoal concessions in the country and charcoal production takes place under the simple license exploitation regime.

Additionally, there are no replacements of the trees cut for charcoal. Moreover, despite all producers stating they use big trees and use the entire tree for the production process, it was possible to see there is little observance of the sizes in the trees being cut which, according to the RLFFB, should be trees with a DBH equal or above 30cm for most of the species in the 4^{th} class. All these can also be problematic and threaten the sustainability of the species.

One option to tackle this problem would be the definition of areas suitable for charcoal production alone and manage them as charcoal concessions. People that are currently operating as enterprises for profit making and operating under the simple license regime should be compelled to get a concession because this would oblige them to present a management plan for the area and manage it sustainably.

Due to the continuous demand, charcoal production occurs all around the year particularly when it is a paid work. If done as alternative activity, the production is seasonal as during the rainy season producers normally abandon the charcoal production in favour of agriculture which is regarded as the most important activity.

On average, producers may be able to burn one kiln producing 20 to 30 bags of charcoal per month. The average price of charcoal is 120Mt/bag, therefore, producers' income can be between 2.400 and 3,600Mt/month (~ 100 and 150 USD/month) per person which is almost two times above the minimum wage[4] in the country. Even in those cases where producers consider agriculture as the major activity, it was possible to see that the contribution of charcoal for these communities' livelihoods is of crucial importance with regard to buying food and clothes, getting medical aid and paying school fees for the family. Hence, sustainable charcoal production is required to ensure these producers have a long lasting source of income.

Most of the producers are not making any savings or investing in other income generating activities which would help improving their livelihoods. Also, there are no banks in these areas. Except for the producers involved in the whole supply chain, most of the producers have little information about markets.

Dimension of activity

Based on calculations, using the registers from the SPFFBs, is estimated that 149.760 trees are currently being cut officially every year to supply charcoal to urban markets in Maputo. Taking the average value of 93.7 trees/ha[5], officially 1,598.29 ha are being cut

[4] Minimum wage in 2011 for Mozambique is 1800.00 Mt for the Agrarian Sector

[5] Marzoli *et al.* (2007)

yearly to supply charcoal for Maputo markets. This is only a small part of the volume involved in the supply chain as Pereira (2001) reported that only 1% of the charcoal that entered Maputo City was licensed and the remaining 99% entered through illegal ways. Considering this, a close estimation of the real situation would come to a number of 159,829 ha being cut every year to supply Maputo markets.

There is no definite information on the contribution of charcoal production to deforestation, however, a study done in 2005 by FAO consultants has estimated an annual area of 100.000 ha being cut for the whole country for fuelwood production which corresponds to a volume of 10million m^3 of trees. For charcoal alone the study estimated that around 5 million m^3 of wood are being cut every year and this accounts for a business volume of about 180 million USD (FAO, 2005).

4.1.2. Transporters

Transporters normally function as middlemen and wholesalers. This category includes individuals that carry the charcoal from the production areas to the district headquarters using donkeys, tractors, trucks and pushing trolleys or that transport charcoal from the district headquarters to the main markets in Maputo city. Transporters can be divided into different groups:

1. People who own one or more vehicles and transport their own products - normally licensed and having their own employees or buying from producers to resell in Maputo.
2. People who own one or more vehicles and transport third person products mostly from women that dedicate to the buying and reselling business. Not all of these vehicle owners have a license being in these cases the responsibility of having all documents with the owners of the products.
3. People who dedicate themselves to buying the charcoal in the rural areas and reselling it in the city of Maputo. They don’t have their own transport and can use either rented trucks or train carriages for the charcoal transportation. Individuals that transport the charcoal from the inner production areas to the collection areas (e.g. for the train station), using trucks, tractor or animals.
4. People who transport the charcoal from the wholesalers to the retail outlets/ places.

Both sexes are involved differently in the activity but men are the main vehicle owners. Only 18% of the transporters are females and most of them fall under the category 3. Majority of transporters are “outsiders” from the production areas being most of them living in Maputo, Chòckwé and some exceptions from Xai-xai.

Main reasons engaging in the transportation are: subsistence (32%), unemployment (21%) and the profitability of the business (21%). Consequently, if the problems associated with charcoal production are to be tackled by reducing the amount of charcoal that is currently produced, then alternative means of subsistence and employment opportunities should be given to the individuals involved in the transportation activity as well.

There are different transportation means being used for the charcoal. Except for Chicualacuala, Mabalane and Magude, where there are train stations, majority of Charcoal that is brought to Maputo city is being brought by either small or big trucks. Animals and pushing cars are only used for transporting charcoal within small distances such as from production areas to the main road or from the market in the city to the retailing place.

The amount of charcoal currently being brought by train is twice that of 2007. This increase can be attributed to the increases in petrol prices that led to a shift from the usage of trucks to trains. Trains are cheaper costing 20.5 Mt/bag and 44.5Mt/bag for the cargo and passenger trains respectively while the truck costs may reach up to 260Mt/bag depending on the area and the truck capacity. Train allows for bigger quantities of charcoal (around 350 bags/carriage) to be brought to Maputo at one time but has the inconvenience of only being available twice a month or in small loads using the passenger train.

Most transporters prefer species such as Chanato (*Colophospermum mopane*) and Xivondzuana (*Combretum molle*). Other species also transported with less frequency are: Micaias (*Acacia sp*) and Mondzo (*Combretum imberbe*). The main reason for the species preference is the quality of charcoal produced in terms of calorific content. Other reasons are the long lasting characteristic of the charcoal produced and consumers’ preference.

Charcoal is being transported all over the year but the rainy season (December-March) is the period with little quantities being transported due to the unavailability of charcoal and difficulty of trucks to access the production areas leading to increased prices in the city markets.

Benefits from the charcoal transport may be stated as the incomes that transporters get. Some transporters may get monthly net incomes between 150.000 and 220.000Mt[6] per vehicle. Hence, charcoal transportation is more profitable for the transporters who are earning over 20 times more than what producers get. Some of the transporters may have more than one vehicle (some had 2 or 3 vehicles). If nothing is done to revert the situation the Government aspirations of reducing the rural poverty through sustainable use of natural resources may be difficult to achieve in the case of the charcoal production areas as we will keep enriching the urban people who do not re-invest in the rural areas. Consequently, these rural areas that are still “rich” in resources are likely to remain with the current high poverty levels.

Most of the charcoal is transported during the night period (8pm to 5am) and this seemed to be purposefully so because the law enforcement agents are more vulnerable to corruption and also are in many cases tired of the work shifts. It is possible to see that some trucks do pass the check posts without any documents or declaring a smaller quantity than the reality. To avoid the problem of underestimation of charcoal quantities in loaded trucks, law enforcement trainings should include modules in this regard and more supervision of agents should be in place. Additionally an incentive system should be put in place so that they feel motivated to accurately register the information. Part of these incentives could be provided by the 50% benefit sharing mechanism that ought to be approved by responsible entities. Additional measures include the reduction of night transportation to avoid corruption problems.

Truck owners are generally outsiders who do not belong to the production areas and are mainly driven by the incomes generated by these activities. So, when there are little

[6] This still includes the costs related to payment of salaries (5000Mt/mont) and vehicle maintenance costs

revenues generated through this activity they are likely to switch to other profitable activities.

Quantities of charcoal that enter using the passenger train are small compared to the loading train. The majority of charcoal is coming from Mpunzi followed by Combomune and Chicualacuala. Mabalane has a community association which helps to control what is coming from there but it is impossible to ascertain about the charcoal that is coming from other places.

Due to the informal characteristic of the business there are no statistics that relate the number of transporters involved in this supply chain. Assuming that except for the cases of community associations the majority of licenses are issued for transporters, then we can come to a figure of around 96 transporters for Maputo province and around 216 for Gaza. This is only the number of transporters that are currently registered and there is still a large portion of charcoal that is being brought unregistered/illegally.

Gaza is requiring 11 times more charcoal than Maputo and most of this charcoal is being produced to supply Maputo markets. Also, the number of licensed individuals from Gaza is twice the number of transporters from Maputo. Currently in Maputo there are 2 main supply areas namely the Matutuine (42%) and Magude (41%) districts, while in Gaza majority of licenses are being issued to Massingir (45%) and Mabalane (35%) districts.

Based on producers' production capacity a total of 5,098,553m^3 or equivalent to 4,078,842tons of wood are currently being exploited to supply the urban demand of Maputo city. This figure does not differ greatly from the one estimated using the transportation data which estimates an equivalent volume of 4,395,293tons or 5,494,116m^3 of firewood used for charcoal production. The exploited area is slightly higher in this case estimating around 172,229 ha currently being cut every year to supply Maputo markets.

The recent forest inventory estimated, for Maputo and Gaza provinces, an annual change of forest cover of around 17,000 and 13,000ha, respectively, between 1990 and 2002 (Marzoli, 20007). It is known that the charcoal production is amongst the main reasons for the changes in the forest cover. As this data seems to be outdated it is important to assess how these figures of forest cover changes have altered between 2002 and 2008.

In 2005, an FAO study estimated that around 211,994 tons of charcoal was consumed per year in Maputo City representing 29% of the total consumption in the country. A more recent study carried out by Sitoe (2007), estimated a total consumption of 5 million tons of charcoal for the whole country which compared to the estimated value of 659,294tons means that Maputo city alone is currently consuming almost 13% of the charcoal consumed in the country.

Comparing the current estimations, which can only be used as rough indicators, given the little rigor used in their estimation, with that of FAO (2005), one wonders about the reasons that led to the increase of around 210% in the quantities of charcoal being consumed in Maputo city. Current quantities of charcoal that enter Maputo city have tripled in four years while the population size did not increase greatly[7]. One explanation is the continuous increase in fossil fuels' prices which may have motivated some to switch from the usage of these fuels to charcoal which is considered cheaper than gas.

4.1.3 Wholesalers

Wholesalers normally receive the charcoal from transporters with whom they have already made arrangements to sell the charcoal and pay them afterwards. Some of the wholesaling places belong to the transporters or the producers that are involved in the whole supply chain.

Mainly women are engaged in wholesaling business, mostly in the age range of 40-60years.

Wholesaling places are widespread along Maputo city markets but the main are: Xiquelene (Mucoriane), Malanga, Adelino, Inhagoi, Janet. Other markets may have

[7] According to INE, 2008, Maputo city population growth was 11.3% (from 987,943 to 1,099,102 inhabitants) between 1997 and 2007

wholesaling places but the quantities of charcoal currently being traded appear to be lower than in the above-mentioned markets.

Main reasons for engaging in the activity are subsistence and poor employment opportunities. As long as consumers demand charcoal and producers still produce it, this activity is likely to continue. It is important to note that wholesalers would have little alternatives if the charcoal business was to be closed because of their age, educational level and lack of preparedness for formal jobs except informal sales.

Market trends normally follow the production trends; during the summer/rainy season, charcoal becomes scarce thus, the charcoal prices tend to rise. Also, charcoal prices vary, among others, depending on the area where the charcoal is being sold, and the origin of the charcoal as well as the species used.

Main costs involved in the wholesaling are the market fee the charcoal purchase prices that are being paid to the transporters (350Mt/bag). On average, wholesalers may get monthly net incomes between 3,650 and 12,200Mt which is still over the minimum wages in the country and more than the producers' net income.

4.1.4. Retailers/resellers

Retailers buy the charcoal in bags from the transporters or wholesalers and resell it in small cans or piles. They can be found in all markets and along the roads in the city.

Due to the informality of the activity, it is difficult to estimate the numbers of people that are involved in it. But one may assume there are large numbers of individuals involved in this activity.

As with other stakeholders in the supply chain, the main reasons for entering in this business are subsistence mean and unemployment.

Retailers sell the charcoal all year as there is always demand for this source of energy. One bag may be divided into 4 (four) cans of 25L plus other small cans and piles. Retail prices vary between 100 and 130 Mt for the 25L can, 10 to 15 Mt per can of 1800gr, 8 to 10Mt of 900gr cans and 5 to 7Mt for the small piles. Retailers may sell 4 to 9 bags of charcoal per month. They buy the charcoal at 350Mt/bag and sell it at 470 to 500Mt/bag therefore getting an income that varies between 480 and 1350 Mt (~19 to 54USD/month).

4.1.5. Consumers

Charcoal consumers are normally located in the urban and peri-urban areas and may be divided into two different groups (Sitoe, 2007): i) Domestic - those who use it for cooking and heating the houses and ii) large/industrial consumers - those who use charcoal to cook or generate heat for industrial processes such as collective kitchens (e.g. hospitals, schools, prisons, army base, restaurants and fast food outlets).

It is estimated that around 70-80% of the urban population consume charcoal in their houses (Sitoé, 2007) mainly because it is considered accessible and cheaper than other sources of energy. The National census estimated the urban population at 1.099.102 inhabitants for Maputo city. Therefore one may assume that almost 880,000 inhabitants currently using charcoal.

Main reasons for the usage of charcoal are the accessibility and the absence of affordable alternative sources of energy. Mozambique has a huge potential in terms of energy. However, only a small portion of this potential is currently being explored (DNERN, 2006).

When compared to the use of gas or electric energy, the use of charcoal is more expensive to the user. However, low income levels make charcoal a good alternative for a great part of the population as the user can buy it in small quantities for daily consumption. Also, charcoal doesn't have initial costs associated with its usage except for the stoves which are simple but less efficient and normally cost less than 150 Mt each (~6 USD) (Figure 9).

The costs of using alternative energies such as the gas or electricity are prohibitive to the majority of the population. Initial investments needed to acquire the stove are at least 500Mt (~25 USD) and the other necessary equipment is estimated at an amount of 2,700Mt (equivalent to (~107USD), which is two times above the minimum wage in Mozambique.

Another important issue is related to the cultural aspects, such as the belief that the food prepared using charcoal tastes better than the one done using electric or gas stoves, may also hinder the replacement of charcoal by other sources of energy.

The increase in urban population is leading to increased consumption of charcoal which increases the rate of deforestation. Hence, to alter this situation, the Government should put some effort in providing alternative and affordable sources of energy to urban populations.

4.1.6. Estimates of market size

There are no exact figures related to the number of people and the quantity of charcoal being consumed in Maputo. In 2005, FAO estimated that 150,000 are employed in the fuelwood sector in Mozambique, the value of charcoal in the market amounted at 180 millions USD and approximately 10 millions m^3 of wood are being removed from the forests in the country every year to supply energy for urban populations.

Sitoe (2007) estimated a *per capita* consumption of 0.9 ton/year. Current demand is around 14.8 million tons/year and the current production capacity is 22 million ton/year. This means that the total balance for the country is still positive (Sitoé, 2007). However, it is important to note that the consumption and demand are not equally distributed in the country and therefore some provinces currently have a negative balance (Drigo *et al*, 2008).

Maputo is no longer a viable source of charcoal as there is little biomass left but there are still some areas with low forest potential that should be managed for sustainable charcoal production in the southern part of the country (Figure 3).

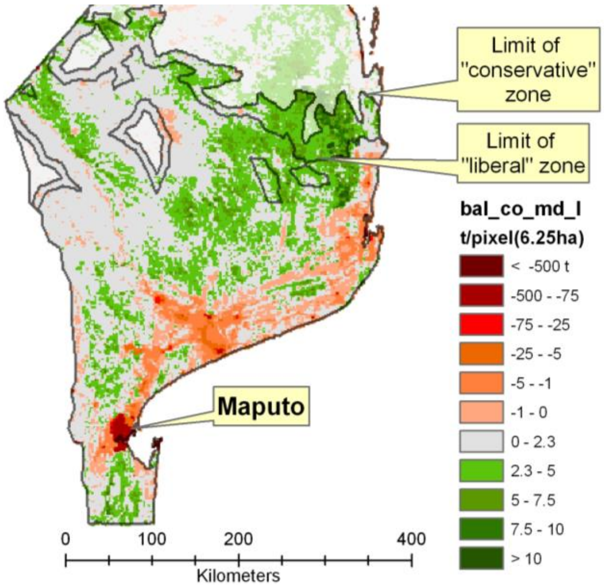

Figura 3. Map of WISDOM analysis for Southern Mozambique (Adapted from Drigo *et al*, 2008).

Around the costal areas where the main urban and peri-urban areas are located, the woodfuels balance is negative. Areas that still hold a positive balance in the southern region of Mozambique are mainly located in the hinterlands of Inhambane and Gaza provinces (Drigo *et al*, 2008). Gaza still has a positive balance and the same is the case in Inhambane but it is crucial to introduce management programmes for areas that are currently suffering from the pressure of Maputo market demand and may in a short while lose the vegetation cover as has happened in Maputo.

Most of the people interviewed were not aware of the linkages between the charcoal production and the global environment. Besides reducing the carbon stored in the forests and releasing emissions during the burning process, charcoal production and consumption also causes reduction of the forest cover, biodiversity and environmental services threatening the resources' sustainability as well as causing health problems. Looking at current consumption patterns, it is important that the different stakeholders take actions to solve the problem and avoid future environmental problems. Options to tackle this problem include: i) dissemination of improved production technologies such as the drum kilns, ii) introduction of stoves with improved efficiency, iii) provision of affordable alternative energy sources and iv) the introduction of fast growing species and agricultural wastes for charcoal production. Further, awareness raising campaigns for all stakeholders involved in the supply chain are needed.

4.2. Estimation of average charcoal bag weight

Several charcoal bags were selected randomly and weighted at four different check points depending on the accessibility of the transporters. The weight of these charcoal bags varies from 40 kg to 100 kg (Table 3).

Table 3. Charcoal bags weight at different checkpoints around Maputo and Matola cities.

Charcoal bag identification number	Weight (kg/bag)			
	Matola Rio check point	Gare de Mercadorias Check Point	Moamba Check Point	Marracuene Check Point
1	55,0	66,0	45,0	60,0
2	45,0	90,0	47,0	75,0
3	59,0	70,0	54,0	53,0
4	65,0	90,0	50,0	64,0
5	50,0	90,0	40,0	55,0
6	60,0	55,0	65,0	50,0
7	62,0	50,0	55,0	80,0
8	70,0	65,0	50,0	75,0
9	55,0	80,0	49,0	50,0
10	40,0	65,0	50,0	50,0
11		90,0		
12		55,0		
13		51,0		
14		90,0		
15		54,0		
16		80,0		
17		100,0		
18		95,0		
19		89,0		
20		90,0		
Average	**56,1**	**75,8**	**50,5**	**61,2**
Minimum	**40,0**	**50,0**	**40,0**	**50,0**
Maximum	**70,0**	**100,0**	**65,0**	**80,0**

Between the year 2004 and 2002, the average size of each charcoal bag coming into the Maputo market was equal to 33 Kg (Brouwer and Falcão, 2002). The Mozambican Forest law states that the license fee should be paid per charcoal bag, being the main reason for the variation of the charcoal bag sizes at different checks points and along the years.

4.3. Amount of woodfuel by checkpoint

4.3.1. Matola Rio checkpoint

According with Maputo SPFFB (2012), during the year 2011, about 15.522 charcoal bags and 68 esters[8] were supplied to Maputo and Matola cities through the Matola Rio Check point (Table 4).

Table 4. Number of charcoal bags and firewood entered in 2011 at Matola Rio check point.

Months	**Amount of charcoal (in bags)**	**Amount of firewood**		**Total amount of woodfuel harvested (kg)[a]**	**Total amount of woodfuel harvested (m^3)**
		Esters	**m^3**		
January	550	20	14	183 333,33	258,4444
February	1759	6	4,2	586 333,33	785,9778
March	2119	0	0	706 333,33	941,7778
April	1790	0	0	596 666,67	795,5556
May	2324	13	9,1	774 666,67	1041,989
June	1225	0	0	408 333,33	544,4444
July	886	11	7,7	295 333,33	401,4778
August	1574	18	12,6	524 666,67	712,1556
September	732	0	0	244 000,00	325,3333
October	751	0	0	250 333,33	333,7778
November	836	0	0	278 666,67	371,5556
December	976	0	0	325 333,33	433,7778
Total					**6946,267**

[8] According with Falcão (2005) 1 ester is equal to 0.7 m^3

[a] This amount was estimated based on the average charcoal bag size

4.3.2. Gare de Mercadoria Check Point

During the year 2011, about 511 and 286 wagons carrying charcoal bags and firewood, respectively went through the Gare de Mercadoria Checkpoint to Maputo and Matola cities. The amount distributed over the months is indicated on the following Table 4. Each wagon takes 30 tons.

The transportation to Gare de Mercadorias through railway is done once a week. This is due to high price of wagon renting and the scarcity of charcoal/firewood in the area. The owners have to fill completely the wagons in order to compensate the cost, since the renting price is per wagon. The main points of wagon loading are Combumune and Mabalane stations in Gaza Province.

Since the renting is per wagon, the owners of the charcoal fill the bags to the maximum of its capacity.

The total recorded firewood that passed through Gare de Mercadorias (included charcoal converted to firewood) is 175992,5 m3.

4.3.3. Moamba and Marracuene Check Points

The Moamba and Marracuene check points are road points that controls the charcoal/firewood from north of Maputo and Matola cities. At Moamba Check Point there is no data available for months of September and October. The officials at SPFFB reported as missing files.

The charcoal/firewood coming through this point is mainly from Magude and Moamba Districts. The total recorded firewood that passed through Moamba (included charcoal converted to firewood) is 13935,1 m^3.

Marracuene check point is located at Estrada Nacional Nro 1 at north of Maputo city and controls all charcoal/firewood coming from the north of the city. This point is strategically located in orde to avoid illegal entrance of charcoal/firewood through other dirty roads to Maputo city.

The charcoal passing trough Marracuene is coming from Magude and Manhiça districts from Maputo province and Massingir, Chicualacuala, Mabalane and Gijá districts from Gaza Province.

At Marracuene Check Point there is no data available for months of February, March, April, May, June and July. The officials at SPFFB reported as missing files. Therefore the months of May to August are considered as peak months. A reliable analysis cannot be done for this important check point.

The total recorded firewood that passed through Marracuene (included charcoal converted to firewood) is 83673,16 m^3.

Table 5. Amount of wagons carrying firewood and charcoal from September 2010 to December 2011 in Gare de Mercadorias

Months	**Charcoal (wagon)**	**Firewood (wagon)**	**Firewood (kg)**	**Firewood (m3)**	**Charcoal (wagon)**	**Charcoal (kg)**	**Conversion of charcoal to firewood (kg)**	**Charcoal (vagão)**	**Charcoal (kg)**	**Conversion of charcoal to firewood (Kg)**	**firewood (m3)**	**Firewood (m3)**	**Total Firewood (m3)**
Sept.2010	21	15	450000	600	21	630000	3743316	21	630000	3743315,5	4991,1	600	5591,1
Oct.2010	53	44	1320000	1760	53	1590000	9447415	53	1590000	9447415,3	12596,6	1760	14356,6
Nov.2010	35	27	810000	1080	35	1050000	6238859	35	1050000	6238859,2	8318,5	1080	9398,5
Dec.2010	53	29	870000	1160	53	1590000	9447415	53	1590000	9447415,3	12596,6	1160	13756,6
Jan.2011	23	27	810000	1080	23	690000	4099822	23	690000	4099821,7	5466,4	1080	6546,4
Feb.2011	24	6	180000	240	24	720000	4278075	24	720000	4278074,9	5704,1	240	5944,1
Mar.2011	39	24	720000	960	39	1170000	6951872	39	1170000	6951871,7	9269,2	960	10229,2
Apr.2011	40	24	720000	960	40	1200000	7130125	40	1200000	7130124,8	9506,8	960	10466,8
May.2011	46	24	720000	960	46	1380000	8199643	46	1380000	8199643,5	10932,9	960	11892,9
Jun.2011	49	22	660000	880	49	1470000	8734403	49	1470000	8734402,9	11645,9	880	12525,9
Jul.2011	46	22	660000	880	46	1380000	8199643	46	1380000	8199643,5	10932,9	880	11812,9
Aug.2011	45	12	360000	480	45	1350000	8021390	45	1350000	8021390,4	10695,2	480	11175,2
Sept.2011	46	24	720000	960	46	1380000	8199643	46	1380000	8199643,5	10932,9	960	11892,9
Oct.2011	61	29	870000	1160	61	1830000	10873440	61	1830000	10873440	14497,9	1160	15657,9
Nov.2011	40	24	720000	960	40	1200000	7130125	40	1200000	7130124,8	9506,8	960	10466,8
Dec.2011	52	48	1440000	1920	52	1560000	9269162	52	1560000	9269162,2	12358,9	1920	14278,9
								673	20190000	119964349	159952,5	16040	175992,5

Source: Mozambique Railway Company **(2012).**

Table 5 - Number of charcoal bags and firewood entered in 2011 at Moamba check point.

Months	Charcoal (bags)	Firewood (esteres)	Firewood (m3)	Charcoal (Bags)	Charcoal (kg)	Conversion from Charcoal to firewood (Kg)	Charcoal (Bags)	Charcoal (kg)	Conversion from Charcoal to firewood (Kg)	Firewood (m3)	firewood (m3)	Total firewood (m3)
January	435	251	175,7	435	21967,5	130525,8467	435	21967,5	130525,8	174,0	175,7	349,7
February	750	3733	2613,1	750	37875	225044,5633	750	37875	225044,6	300,1	2613,1	2913,2
March	958	3133	2193,1	958	48379	287456,9222	958	48379	287456,9	383,3	2193,1	2576,4
April	985	2837	1985,9	985	49742,5	295558,5264	985	49742,5	295558,5	394,1	1985,9	2380,0
May	746	2376	1663,2	746	37673	223844,3256	746	37673	223844,3	298,5	1663,2	1961,7
June	868	1746	1222,2	868	43834	260451,5746	868	43834	260451,6	347,3	1222,2	1569,5
July	108	197	137,9	108	5454	32406,41711	108	5454	32406,4	43,2	137,9	181,1
August	410	1790	1253	410	20705	123024,3613	410	20705	123024,4	164,0	1253	1417,0
November	257	240	168	257	12978,5	77115,27035	257	12978,5	77115,3	102,8	168	270,8
December	196	339	237,3	196	9898	58811,64587	196	9898	58811,6	78,4	237,3	315,7
							5713	288506,5	1714239,5	2285,7	11649,4	13935,1

Table 6. Number of charcoal bags and firewood entered in 2011 at Marracuene check point.

Months	Ch (bags)	Firewood (est)	Firewood (m3)	Charcoal (bags)	Charcoal (Kg)	Firewood (Kg)	Charcoal (bags)	Charcoal (Kg)	Firewood (Kg)	Firewood (m3)	Firewood (m3)	Firewood total
January	1275	50	35	1275	78030	463636,3636	1275	78030	463636,3636	618,18	35	653,18
August	17455	217	151,9	17455	1068246	6347272,727	17455	1068246	6347272,727	8463,03	151,9	8614,93
September	31082	215	150,5	31082	1902218	11302545,45	31082	1902218	11302545,45	15070,06	150,5	15220,56
October	31039	511,5	358,05	31039	1899587	11286909,09	31039	1899587	11286909,09	15049,21	358,05	15407,26
November	51386	1310	917	51386	3144823	18685818,18	51386	3144823	18685818,18	24914,42	917	25831,42
December	35648	945,604	661,9228	35648	2181658	12962909,09	35648	2181658	12962909,09	17283,88	661,9228	17945,80
							167885	10274562	61049090,91	81398,79	2274,3728	83673,16

Table 7. Summary of the quantities of wood biomass per check point

Check Points in Maputo city	**Amount of firewood ($m^{3)}$**
Matola Rio	6947.0
Moamba	13936.0
GARE	175993.0
Maracuene	83674.0
Total	**280550.0**

The Table 7 summarizes the total recorded amount of firewood (included charcoal converted to firewood) that entered to Maputo and Matola cities. As can be seen also at this table, that Marracuene and Gare de Mercadorias are the important check points., even though 6 recorded months are missing for Marracuene check point.

4.4. Tree species harvested

According to producers, the main species used in Maputo and Matola cities are chanato *(Colophospermum mopane),* Xivondzuane (*Combretum sp)* and micaias *(Acacia sp.)* because they are readily available. In these two places more species used due to absence of the preferred species.

Most of these species used for charcoal making belong to the 4th class according to the Forest Law and Forest regulation but there are some species that are not part of the 4th class and currently being used for charcoal production namely: *Lonchocarpus capassa, Ornithogalum sp. Androstachys johnsonii, Terminalia sericea, Combretum imberbe, Ziziphus mucronata, Guibourtia conjugata and Combretum molle.*

1st, 3rd class species and even precious woods are currently being used illegally for charcoal production but after the charcoal is produced and packed only a few people are capable of identifying the species that have been used to produce it. This reflects the lack of capacity for the law enforcement that the Forest and wildlife sector is currently facing as well as the low levels of awareness of local communities regarding what can be used for charcoal production or the little option producers have in Maputo due to the scarcity of charcoal producing species.

The major reasons for the use of such species are the quality of charcoal produced and the abundance of the species in the area. Other reasons, cited less frequently, were the clients' preference and the long lasting characteristics of the charcoal produced using the species. In Maputo, the abundance of the species is the second major reason, while in Gaza there are still more options. Therefore, producers can select the species that produce good quality charcoal.

4.5. Comparison between woodfuel supply and demand

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5. CONCLUDING REMARKS AND RECOMMENDATIONS

In Mozambique, wood energy aspects have been studied by different organizations and activities. However, most of them are isolated actions focused on too specific topics.
Wood energy systems are complex and very site specific; fuelwood and charcoal are fuels & incomes of the poorest of the poor. Woodfuel are part and parcel of the problem of poverty. Data bases on wood energy aspects are extremely week, Institutional arrangements exist but need to be enhanced, Energy Steering Committee should be enhanced and some actions are undertaken but should be articulated, planned & organized. Joint actions with public and private partners needed and the CBNRM has played great role but insufficient to ensure Sustainable wood energy systems.

Fuelwood and charcoal are main energy sources and forest products causing depletion of forests and vegetation around Maputo and Matola cities.

Production areas are located away from the Maputo and Matola cities (main urban markets) where the charcoal is sold. Although there is charcoal coming from 6 districts surrounding Maputo city (Moamba, Matutuine, Namaacha, Goba, Boane, Manhiça), the majority of charcoal that feeds Maputo urban markets is currently coming from further locations (>300km) such as Magude disctrict in Maputo, but mainly from Gaza Province, namely the districts of Mabalane, Massingir, Mapai, Chicualacuala and Guijá.

The weight of the charcoal bags has been changing over time. Between the year 2004 and 2002, the average size of each charcoal bag coming into the Maputo market was equal to 33 Kg and in the year 2012 varies from 40 kg to 100 kg. This weight variation can be explained by the fact that the Mozambican Forest law states that the license fee should be paid per charcoal bag.

The main species used for energy purposes in Maputo and Matola cities are the 4th class according to the Forest Law and Forest regulation. According to the producers chanato *(Colophospermum mopane)*, Xivondzuane (*Combretum sp)* and micaias *(Acacia sp.*) are most common used species and readily available. However, they also acknowledge some species are not part of the 4th class and currently being used for charcoal production namely: *Lonchocarpus capassa, Ornithogalum sp. Androstachys johnsonii, Terminalia sericea, Combretum imberbe, Ziziphus mucronata, Guibourtia conjugata and Combretum molle.*

The total of solid volume supplied to Maputo and Matola cities for woodfuel in the year 2011 is equal 280 546.50 m^3. This amount represents approximately 20,000.00 ha of devastated forests. Thus was estimated based on the assumption that 1 ha of Miombo forest has an average of 14 m^3 of wood (Marzoli, 2007).

According to Marzoli (2007), the IMA (annual mean increment) for forests in Gaza Province is 0.414 m^3/ha/year. This means that only 8,280 m^3 of firewood can be used in 20,000 ha to have a sustainable charcoal/firewood production.

Sustainable Forest Management cannot be done without Sustainable Wood energy systems. Actions on wood energy require at least two partners DNTF, DNE and others. Firewood use in rural areas is hard to intervene, however actions needed for production, trade and use of woodfuel in urban areas.

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