"*Charcoal production and use in Mozambique, Malawi, Tanzania, and Zambia: historical overview, present situation and outlook*".

Falcão, M. P.[1]

[1] Lecturer at Forestry Engineering Department, Faculty of Agronomy and Forestry Engineering, Eduardo Mondlane University. E-mail: mfalcao@uem.mz or mariopaulofalcao@hotmail.com

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SUMMARY

International Network for Bamboo and Rattan (INBAR) has organized a conference that was held in June 2008 in Maputo on charcoal production/use and sustainability of forests resources. This paper was presented on the conference and is a overview of charcoal production and use in selected countries in SADC region (Mozambique, Malawi, Tanzania, and Zambia).

The objective of this overview paper is to highlight the major trends, charcoal production technologies, charcoal markets and lessons from success and failures regarding the management systems, technologies and, community enterprises in selected countries in SADC. The limited budget and literature on charcoal and the purpose of the study (production of a overview paper) mean that this study is very much a descriptive one.

The main vegetation cover used by the households to produce charcoal in the study countries is obtained from miombo woodlands, which are dry tropical woodlands. Most of the charcoal in Mozambique, Malawi, Tanzania and Zambia is produced by the traditional earth kiln method, is labour intensive and, mainly carried out by men.

Charcoal production efficiency in the study countries varies between 10% to 25%. 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. More technologically advanced kilns such as the Mark IV, Cusab Kiln, and Gayland Batch Charcoal Retort give higher efficiency rates of 25–32%, but these kilns 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.

Woodfuel (charcoal and firewood) consumption in the study countries is closer to 1 m^3 *per annum per capita*. The key factors influencing woodfuel trends are economic growth, population growth, policies and institutions.

Although woodfuel is the most important forest product for Mozambique, Tanzania, Malawi and Zambia, 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.

It is recommended that each study country establish its own Wood Energy Unit and this Unit should prepare a Dendroenergy Strategy. using participatory methods and involving all stakeholders.

1. INTRODUCTION

1.1. Overview

International Network for Bamboo and Rattan (INBAR) is organizing a conference that will be held in June 2008 in Maputo on charcoal production/use and sustainability of forests resources. Several background papers will be developed for presentation at this conference. One of these is a overview of charcoal production and use in selected countries in SADC region.

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 resources, including solar and wind energy.

1.2. Objectives

The objective of this overview paper is to highlight the major trends, charcoal production technologies, charcoal markets and lessons from success and failures regarding the management systems, technologies and, community enterprises in selected countries in SADC. The limited budget and literature on charcoal and the purpose of the study (production of a overview paper) mean that this study is very much a descriptive one.

This paper was motivated by the fact that woodfuels in the SADC region is an important source of income to the families and its importance in the agenda for donor support has diminished.

1.3. Scope of the study

Four countries in the SADC region were selected, namely Mozambique, Malawi, Tanzania and Zambia. They are included in this overview paper due to the availability of charcoal literature and their similarities.

For the purpose of this study **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. CHARCOAL

The main vegetation cover used by the households to produce charcoal in the study countries 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, Malawi, Tanzania and Zambia 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).

Charcoal production efficiency in the study countries 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.

Charcoal is a fuelwood by-product obtained by the process of carbonisation. Wood destilation is another method of making charcoal. The equipment needed for wood destilation is more complicated than that for conventional charcoal production, but the process is also more energy-efficient. Making *Rhizophora* charcoal in a retort and condensing the effluent gases can substantially increase the amount of energy recovered. Countries making charcoal in this way have much to gain simply from the extra energy obtained. Additionally, they can use the by-products in simple but effective ways. For instance, in Ghana and Costa Rica the gases produced are used to dry fuelwood used in heating systems and their liquids employed as an effective wood preserver.

According to Frisk (1984), a kiln of 6.7 m diameter and 7 m in height is estimated to require 9 tonnes of clay, 9 tonnes of fine sand and 15 000 - 17 000 pieces of bricks (6 cm * 11 cm * 23 cm) to build. Using 1984 prices, this type of kiln will cost about US $7 000 including the roof shelter.

According to producers in the study countries, 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; Luoga *et al.*, 2000a, BTG, 1990; Adamo *et al.* 1997; Vilanculos 1998; Muchanga *et al.* 1997; Howell, and Convery, 1997; Mangue and Wate, 1998).

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, 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).

For the study sites 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; Luoga et al., 2000a and many others). Table 2.2 shows woodfuel consumption levels in several countries (Agarwal, 1986; Brouwer and Falcão, 2004; and many other authors).

Table 1. 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).

3.1. Key factors limiting woodfuel trends

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).

3.2. 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.

3.3. 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 19^{th} and 20^{th} 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.

3.4. 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).

4. WOODFUEL SURVEYS

Although woodfuel is the most important forest product for Mozambique, Tanzania, Malawi and Zambia, 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 developing countries like Mozambique, Malawi, Tanzania and Zambia. 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).

5. WOODFUEL MARKETS

Woodfuel supports lucrative local trade. Trade in charcoal is a major source of income for many households in the study countries. For example, in Zambia, the charcoal industry generated about US$30 million in 1998 alone, and in the same year about 60 000 Zambians directly depended on charcoal production for the bulk of their income (Kalumiana 2000).

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.

According with Kalumiana (2003), Zambia had in 2003 about 50000 charcoal producers, 3500 transporters and 10000 distributions and retailers. 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).

6. WHERE DO WE GO FROM HERE?

In Tanzania, Zambia, Mozambique and Malawi the areas neighboring the main urban centers are badly deforested. In general in areas that are cleared for charcoal production subsistence farming (shifting cultivation) is practiced in the more fertile (arable) patches, where the land is cultivated for about 3 to 6 years before it is left fallow for about 3 to 4 years (Frost, 1996; Luoga *et al.*, 2000a; Falcão, 2005). This fallow period is too short for the woodland trees to regain their original stem diameters, thus subsistence farming is another cause of land cover change. The negative impacts of land cover changes on biodiversity and ecosystem function in miombo woodlands have not been well studied.

Commercial plantations for fuelwood and construction timber are big business in South Africa, Zimbabwe, Malawi, Tanzania and Zambia. Mozambique is benefiting in the last 3 years from investment in forest plantations mainly from South Africa and Sweden investors, but none of these investments is for fuelwood.

There is an urgent need to develop environmentally sound methods of sustainable fuel-wood production and exploitation. In Mozambique, Tanzania, Malawi and Zambia considerable effort has been expended to alleviate fuel-wood shortage through the introduction of fast growing exotic trees, agroforestry, and use of energy saving stoves. In Kenya, in the past Conventional agroforestry approaches have met with little success because of inappropriate species, long cropping intervals and inadequate husbandry techniques used by the harvesters, mostly the rural poor (Young and Francombe, 1991).

In these four countries, most of the interventions in wood energy sector to face wood energy shortages and demand can be grouped into two broad categories namely, (a) those aimed to enhance the supplies and (b) those that attempted to reduce consumption either through enhancing energy efficiency or through encouraging substitution. According with Nair and Tieguhong (2004), a general indication of these interventions is given below:

- There have been substantial efforts to establish woodfuel plantations primarily through public sector investments, often supported by bilateral and multilateral agencies. While some of these plantations have become important sources of woodfuel, there are also instances of failure (for example in Mozambique) on account of economic, policy and institutional factors. Getting all the necessary and sufficient conditions for success right has been extremely difficult. Consequently the share of woodfuel produced by plantations remains low, although no precise estimates are available. In general, most woodfuel is produced from natural woodlands with very limited investments in their management. Also a significant share of woodfuel comes from trees and other growth outside the forests. A key issue as regards woodfuel production is the absence of investments in management of the woodlands as a result of poorly developed markets.

- Demand reduction strategies have primarily focused on enhancing energy efficiency through the use of improved cook-stoves and encouraging substitution. Here again the performance of the different approaches have been patchy. Energy efficient stoves have found wider use in urban areas where woodfuel has to be purchased, whereas in rural areas with better access to woodfuel and other biomass, their impact have been rather marginal. There are also several other cultural and social aspects that impact the use of improved stoves. Substitution has focused on providing alternative fuels, especially kerosene, coal, electricity and liquefied petroleum gas (LPG). The effectiveness of such options is largely related to economic viability and more particularly ready availability of the alternatives. Mozambique for example has substantial fossil fuel resources, the access to these resources by rural poor people is often very limited. The main factors that determine substitution are relative prices of different fuels and the income of the households.

Exploring the possibility of using indigenous trees and shrubs for sustained yield harvesting can be very attractive and potentially viable economic and ecological alternative. This is especially so in arid and semi-arid areas, which have numerous and often extensive stands of tree and shrub species.

7. CONCLUDING REMARKS AND RECOMMENDATIONS

Wood energy systems are complex and very site specific. Firewood and Charcoal are fuels and source of income of the poorest of the poor in these countries. Woodfuel are part and parcel of the problem of poverty and sound wood energy systems are tied to the development process.

Although commercialisation of wood resources provides tangible monetary benefits to rural communities, it also contributes to environmental degradation (massive depletion of woody vegetation) that will ultimately threaten the long-term survival of these communities. The weak enforcing control mechanisms to check overuse of resources, needs to be strengthened in theses countries.

From the current literature review for the study countries it was found the following:

- Data bases on charcoal aspects are extremely week;
- Institutional arrangements exist but need to be enhanced;
- Some actions are undertaken but should be articulated, planned & organized;
- Joint actions with public and private partners needed;
- The CBNRM has played great role but insufficient to ensure Sound Wood Energy Systems.

It is recommended that each study country establish the following:

- A Wood Energy Unit and this Unit should prepare a Dendroenergy Strategy;
- Wood Energy data base and planning tools are vital and they should be included in the strategy
- The Community Based Natural Resource Management (CBNRM) can support field action;
- Kyoto and Johannesburg (WSSD) help for implementing Dendroenergy Strategy.

Dendroenergy strategy should be built using participatory methods and involving all stakeholders (private sector, donors, agencies, governments, civil society, etc.). The layout of the proposed strategy is indicated Appendix 1.

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Appendix 1. Dendroenergy strategy – lay out.

	Strategy Preparation					
	Nr	**Outputs**	**Nr**	**Main Outputs**	**Nr**	**Activities**
Phase 1	**1.1**	**National WEIS (Wood Energy Information System) [Note: Joint work with forestry and energy statisitics units]**	**1.1.1**	**Collection of existing data**	**1.1.1.1**	
			1.1.2	**Verification of data**	**1.1.2.1**	**Preliminar National WEIS - Desk DB**
			1.1.3	**Field verification and fill data gaps**	**1.1.3.1**	**Selection of pilot areas**
					1.1.3.2	**Information System -**
					1.1.3.3	**Training of surveyors**
					1.1.3.4	**Field work**
					1.1.3.5	**Data collation**
			1.1.4	**National Wood Energy Information System WEIS**	**1.1.4.1**	**First draft**
					1.1.4.2	**National workshop**
					1.1.4.3	**National WEIS publication**
	1.2	**National WISDOM (Woodfuel Information Supply Demand Overview Mapping = Wood Energy Maps). [Note: Joint work with GIS experts and forestry inventory units]**	**1.2.1**	**Preparation data set**		
			1.2.2	**Initiation National WISDOM**	**1.2.2.1**	**National training of the WISDOM users**
					1.2.2.2	**First draft of national WISDOM**
			1.2.3	**Analysis and interpreation of data**	**1.2.3.1**	
			1.2.4	**Preliminar WISDOM**	**1.2.4.1**	**National workshop**
			1.2.5	**Finalization of National WISDOM**	**1.2.5.1**	**National WISDOM publication**

	1.3	Strategy formulation	1.3.1	Technical studies	1.3.1.1	Kiln efficiency
					1.3.1.2	New production techniques
					1.3.1.3	Identification new techical solutions for industrial wood energy uses
					1.3.1.4	Identification of new wood fuel supply areas
			1.3.2	Economic studies	1.3.2.1	Cost & prices of woodfuels
					1.3.2.2	Market arrangements
					1.3.2.3	Economic analysis of new opportunities
					1.3.2.4	Income distribution within the marketing chain
			1.3.3	Environmental studies	1.3.3.1	Analysis of local impacts
					1.3.3.2	Carbon inventories
					1.3.3.3	Deforestation rates from diferent activities
					1.3.3.4	
			1.3.4	Socio-economic studies	1.3.4.1	HHD Revenue from agriculture vs charcoal making
					1.3.4.2	Effect of HIV on dendroenergy
					1.3.4.3	
			1.3.5	Institutional & legal studies		
			1.3.6	Strategy preparation	1.3.6.1	First draft of national strategy

					1.3.6.2	National workshop
			1.3.7	Strategy finalisation	1.3.7.1	National woodfuel strategy
	1.4	Project formulation for external internal support	1.4.1	Project formulations	1.4.1.1	Project formulation to suppport WE Strategy Developemnt
					1.4.1.2	Submission to donors
					1.4.1.3	Project implementation
					1.4.1.4	Other projects
			1.4.2		1.4.1.5	Submission to donors