EXPLORING THE SOCIO-ECONOMIC ROLE OF CHARCOAL AND THE POTENTIAL FOR SUSTAINABLE PRODUCTION IN THE CHICALE REGULADO, MOZAMBIQUE

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ABSTRACT

Wood fuels play a significant role in the energy requirements of many developing countries. This is especially the case in Sub-Saharan Africa, where dependence is increasing due to growing urban populations, and limited accessibility to alternative fuels. In this region, charcoal is the predominant fuel accounting for over half of the energy requirements (WEC, 2004). However, there are significant social and environmental impacts associated with the consumption of charcoal including: forest degradation, loss of biodiversity and environmental services, as well as health issues. There is growing concern that current levels of resource use will jeopardise the livelihoods of communities dependent upon forests.

A potential leakage effect in the Nhambita Pilot Project due to charcoal production drew attention to this trend, and was the basis for exploring CBNRM as a means to improve welfare in the CR. A variety of methodologies were then used to assess current practices in the area as well the barriers to sustainable production.

The study revealed that charcoal production was an essential component of producer livelihoods, accounting for over 60% of their annual income. It was also found that distribution of charcoal was predominantly taking place in the districts of Mbulawa and Povua within a 2 km wide strip of the EN-1 road, and showed some correlation with LANDSAT imagery on deforestation in these areas. In spite of this trend, the study revealed that at current output levels sustainable production is possible, and outlined the potential of this approach to contribute towards sustainable development in the CR. Recognition of the benefits offered by such a system was welcomed with interest by the producers surveyed, and whose involvement through CBNRM will be a key component in achieving this goal.

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ABBREVIATIONS

AAC	Annual Allowable Cut
CBNRM	Community Based Natural Resource Management
CCL	Chicale Community Lands
DFID	Department For International Development
ECCM	Edinburgh Centre for Carbon Management
FAO	Food and Agriculture Organisation
GIS	Global Information System
GDP	Gross Domestic Product
GNP	Gorongosa National Park
GPS	Global Positioning System
HDI	Human Development Index
ITCZ	Intertropical Convergence Zone
MAI	Mean Annual Increment
MDG	Millennium Development Goal
NTFP	Non Timber Forest Product
NGO	Non Governmental Organisation
PSP	Permanent Sample Plot
PV	Plan Vivo
PRA	Participatory Rural Appraisal
SCP	Sustainable Charcoal Production
SFM	Sustainable Forest Management
SSA	Sub-Saharan Africa
SSI	Semi-Structured Interview
UNCED	United Nations Commission on Environment and Development
UNDP	United Nations Development Programme
UEM	Universidade Eduardo Mondlane
UoE	University of Edinburgh
WEC	World Energy Council
WSSD	World Summit on Sustainable Development

1 INTRODUCTION

Poverty is one of the greatest moral challenges we face today, with a sixth of the world's population living on less than $1 a day (World Bank, 2006). Development initiatives to combat this have been implemented through the Millennium Development Goals (MDG) that aim to reduce poverty in half by 2015 (UNDP, 2005[a]). Over 90 % of the 1.2 billion living in poverty worldwide rely on forests to some extent for subsistence needs (World Bank, 2002). Whilst forest resources provide a wide range of benefits to the rural poor, they also contribute significantly to the economies of developed and developing nations alike (Sengupta & Maginnis, 2005). The extraction of timber for wood fuels accounts for 61 % of total wood removals (FAO, 2005). This highlights the importance of these fuels in the energy mix of many countries

Energy provision is a basic human need and consumption is closely related to the level of a country's development (UN-Energy, 2005). This is observed in the poor Human Development Index (HDI)[1] scores and the low energy consumption of Sub-Saharan Africa (SSA) as well as many other developing countries heavily dependent upon wood fuels for their energy requirements (Arnold & Persson, 2005). The growing demand for charcoal in these countries has resulted in localised deforestation in vulnerable areas, particularly surrounding urban centres in SSA (SEI, 2002). In these locations forest degradation and the associated socio-economic impacts of those dependent on these resources has stimulated development initiatives to address these issues through linking poverty, livelihoods and energy with sustainable resource management.

One of the principal approaches has been the recent trend of decentralisation of natural resources to local communities (Jones & Carswell, 2004). This has resulted in a move towards participatory initiatives, such as Community Based Natural Resource Management (CBNRM), where the secure ownership of resources by traditional communities can promote sustainable management and receive the benefits that accrue from it (White & Martin, 2005).

[1] The HDI is a measure of development based on life expectancy, education and standard of living.

The Nhambita Pilot Project in Sofala Province, Mozambique is an example of a CBNRM initiative where the local community is working in collaboration with the private sector to promote sustainable development. The project is managed by Envirotrade Ltd, the University of Edinburgh (UoE) and the Edinburgh Centre for Carbon Management (ECCM) with the principal aim to devise land use practices that promote sustainable development in the community (Grace et al, 2006).

1.1 Rationale for the study

The Plan Vivo (PV) system adopted by the Nhambita Pilot Project aims to improve livelihoods by offsetting carbon against a variety of agroforestry projects with community smallholders. However, as with any carbon sequestration project one must take into account the "leakage effect" that refers to unexpected carbon emissions of a carbon offset project. In this instance the Grace *et al*., (2006) reported that increased deforestation along the EN-1, identified by LANDSAT imagery may have been triggered by demand for charcoal, and could be a potential leakage effect of the PV offset project.

Several studies on charcoal have shown that the production of wood fuels follows Scherr, (2000) downward spiral of livelihoods, suggesting that deforestation is the result of unsustainable resource use driven by poverty. Although some studies have attempted to address these issues to minimise the socio-economic impacts of deforestation, limited success has been achieved on the ground to date. The rationale for this study is therefore to link these key themes into a sustainable production system within the CBNRM framework of the Nhambita Pilot Project to conserve the area's forest degradation and improve livelihoods.

1.2 Aims, Objectives and Research Questions

The overall aim of this study is to determine whether CBNRM projects for sustainable charcoal production are capable of improving rural livelihoods, and forest conservation. Within this broad aim the specific objectives to:

1. Identify key stakeholders and issues (biophysical, technical, social and institutional) relating to charcoal production;
2. Identify the livelihood strategies of charcoal producers;
3. Determine the extent of charcoal production;
4. Identify barriers to sustainable charcoal production and recommend future actions.

Recognition of charcoal production in the CR as a possible leakage effect raised questions about producers' livelihoods, the technology used, and the potential of CBNRM to address the issue. Additional questions were posed and these were used in place of *a priori* hypotheses. The key questions explored were:

- *Who are the principal actors involved in charcoal production?(Objective 1);*
- *What are the legal regulations surrounding charcoal production and how is this enforced?(Objective 1);*
- *To what extent are these actors dependent upon charcoal production for their livelihoods?(Objective 2);*
- *How are charcoal production activities distributed throughout the study area? (Objective 3);*
- *How efficient are the kilns used in the study area, and what is the level of deforestation is attributed to charcoal production? (Objective 3);*
- *What are the barriers to sustainable charcoal production in the Chicale Regulado? (Objective 4).*

2 FORESTS, LIVELIHOODS AND WOODFUEL

Development strategies have been the subject to change in recent years, reflecting the research and the accepted theories of the time. Currently, poverty reduction is the focus of all development programmes, which are predominantly driven by the MDGs. Addressing environmental degradation is a key component of these goals to ensure the sustainable flow of ecosystem services on which many livelihoods depend. Forests are one such ecosystem that play an important role in the energy sector of many developing nations.

Wood fuels consist of three main commodities: firewood, charcoal and black liquor. Black liquors are the by-products of the pulp and paper industry, whilst firewood and charcoal are derived from tree resources. Discrepancies in assessment of the wood fuel sector over the years have influenced the focus of development initiatives. Currently wood fuel consumption is increasing in the developing world, principally fuelled by urban demand for charcoal. This has driven the unsustainable exploitation of tree resources with significant environmental and socio-economic consequences. Development programmes are now attempting to address these issues of wood fuel consumption and poverty reduction through CBNRM.

2.1 Development Timeline

The focus of development has changed considerably over the last few decades. In the 1970s' development promoted through economic growth was viewed as the most suitable means for many developing countries to rise out of their colonial past (Arnold, 2001). By the 1980's development initiatives became increasingly focused on the environment. In 1987 the United Nations Commission on Environment and Development (UNCED) Brundtland Report offered the first definition for sustainable development as;

> *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs."* (WECD 1987, Pp. 43)

This environmental focus continued throughout the following years, embodied in the "Agenda 21" principles of the UNCED Earth Summit in Rio de Janeiro (1992) to address biological diversity, climate change and forest principles (UNCED, 1997). However, this focus shifted towards poverty reduction in 1996 at the Organisation for Economic Co-operation and Development (OECD) meeting, "Shaping the 21st Century." The outcome was a set of international development targets that later became the MDGs, (Figure 1). These goals were formally adopted by the UN in 2000 and are the drivers for all development initiatives with the aim to reduce world poverty in half by the year 2015.

Figure 1 The Millennium Development Goals. Source: UNDP, (2005[a])

To date, progress towards the MDGs has been varied: South Asia is experiencing a decline in poverty over a selection of the goals, primarily due to the region's economic growth, whereas many Sub-Saharan African (SSA) nations are failing to meet these targets (DFID, 2006).

One of the critical issues preventing poverty reduction in developing countries is the provision of energy. Currently 1.6 billion people lack access to electricity, whilst 2.4 billion are deprived of modern fuels for cooking and heating (UN-Energy, 2005). Lack of energy constrains the delivery of social services, limits opportunities for women and erodes environmental sustainability. The significance of this can be seen in Figure 2 where countries with low rates of energy consumption also have a correspondingly low Human HDI scores. This relationship is particularly evident in SSA and developing Asian countries. The importance of this issue resulted in the World Summit on Sustainable Development (WSSD) in Johannesburg 2002 declaring energy as a basic human need (UN-Energy, 2005). Although energy is not specifically mentioned in any of the MDGs it is implicit in achieving all of them (UNDP, 2005).

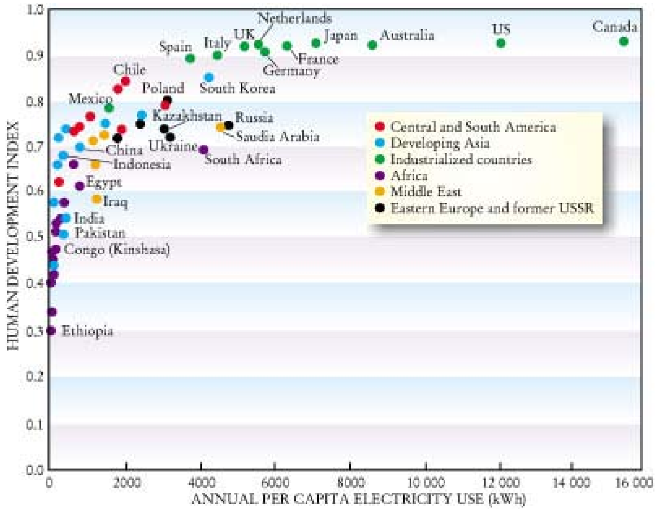

Figure 2 Relationship between the Human Development Index (HDI) and energy consumption. Source: WATT (2007).

One of the goals in which energy is incorporated is MDG 7 that commits nations to "ensure environmental sustainability" (UNDP, 2005[a]). This is particularly important because the degradation of ecosystems and the services they provide are a significant barrier to achieving the MDGs. Many of the regions facing the greatest challenges in achieving the targets also face significant problems of ecosystem degradation, such as deforestation.

2.2 Forests

Forests are an important natural resource that cover approximately one third of the earth's surface, equivalent to 4 billion hectares (FAO, 2005). They comprise a wide variety of ecosystems that range from open savannah woodlands to dense tropical rain forests and are some of the most biological diverse systems on the planet (FAO, 2005). These forest ecosystems not only provide a range of environmental services that include soil and watershed conservation and carbon sequestration, but also extensive economic benefits from timber and recreation (Sengupta & Maginnis, 2005).

However, present day forest cover is approximately half of what existed in pre-agricultural times, the majority of which has been lost in the last three decades (FAO, 2005). This decline has been attributed to various factors that include changing livelihood patterns, such as the transition from hunter-gathering to sedentary agriculture (Sunderlin *et al.,* 2005) and the socio-economic demands of development for timber, wood fuels, fibres and urban expansion (Middleton, 2003). Although deforestation slowed between the years 2000 and 2005, the process is progressing at an alarming rate, with forest loss estimated at 7.3 million hectares per year, predominantly in Africa and South America (FAO, 2005). The consequences of this decline are likely to have significant impacts, not only on the environmental services that forests provide, but also the communities' dependent upon them.

2.3 Forestry and Livelihoods

The formal forestry sector plays an important role in the economies of many developed and developing countries. In 2005 the revenues from production forestry alone was estimated at US$ 64 billion, and employed 10 million people worldwide in forest management and conservation (FAO, 2005; Sengupta & Maginnis, 2005). This is an underestimation of the true figure as it does not account for the lost revenues from illegal logging estimated at US$ 15 billion per year (Brack, 2007) nor the US$ 4.7 billion generated by the sales of Non Timber Forest Products (NTFP), (FAO, 2005).

In relation to the informal sector however, there are approximately 1.2 billion people living in extreme poverty that rely upon forests for their livelihoods (World Bank, 2002). This overlap between forests and poverty is well documented, and is a result of worldwide distribution of forest resources and the ease of access to them (Sunderlin *et al*., 2005; Wunder, 2005). As a result forests have been extensively utilised over the centuries by the rural poor, and continue to be exploited (Middleton, 2003). For many, this dependence is based on a subsistence strategy to supplement inputs, such as fuel, food and medicinal plants, or to help diversify the source of income in times of hardship (Arnold, 2001; Shackleton *et al*., 2006). For others, predominantly the 240 million forest dwellers worldwide, forest resources meet almost all of their daily needs (Sunderlin *et al*., 2005). In general, it is the poorer households that depend on forests for a larger share of their overall livelihood (Arnold, 2001).

The strong links between forests and livelihoods demonstrate that addressing these issues through sustainable development initiatives is a viable means towards reducing poverty worldwide. Development strategies have therefore attempted to link forests livelihoods and energy consumption to poverty reduction through the sustainable management of forest resources. One of the principal approaches adopted by governments has been through decentralisation and CBNRM initiatives (White & Martin, 2005).

2.4 CBNRM

There has been a shift in recent years towards the decentralisation of natural resources to a more participatory management approach. This devolution of power from the state to local communities is commonly referred to as CBNRM and has resulted from a variety of reasons. These include the failure of states to sustainably manage their natural resources due to high transaction costs of policies, and the current emphasis of bottom-up development approaches (Jones & Carswell, 2004).

The rationale behind this drive towards community participation in resource management has been the recognition that without secure tenure rights rural communities lack the long term financial incentives for conserving resources on which many rural livelihoods depend (Sengupta & Maginnis, 2005). Decentralisation of power transfers this control of traditional resources to the communities and therefore the associated benefits of sustainable resource use.

This approach has been widely adopted in wildlife management in Africa, such as CAMPFIRE in Zimbabwe, and joint forest management in India (Jones & Carswell, 2004). The strengthening of networks between the state, community and private enterprises are critical for the success of CBNRM initiatives, and development strategies have embraced this approach as a means to protect and manage forest resources (Carswell, 2004).

Of particular interest in this study is the role of wood fuels in the livelihoods of rural communities, and the potential of SFM under CBNRM initiatives to tackle poverty reduction and the socio-environmental impacts associated with their production.

2.5 Wood fuel Development Timeline

The last thirty years have shown marked differences in the assessment of wood fuels in developing countries. In the 1970s' the growing dependence upon wood fuels by developing nations was recognised, and it was predicted that deforestation would have devastating environmental and social impacts for the rural poor (Arnold, Kohlin & Persson, 2006). It was termed as the "wood fuel crisis" and lead to a variety of development interventions. These included supply-side initiatives to promote fuel wood plantations and improve kiln efficiency, as well as demand-side programmes to enhance cooking stove efficiencies and promote alternative fuels (Arnold, Kohlin & Persson, 2006).

However, by the 1980s' there was little evidence of the wood fuel shortages predicted (Girard, 2002; Arnold, Kohlin & Persson, 2006). Assessments revealed that a significant proportion of wood fuel was coming from land cleared for agriculture, originally overlooked in previous studies (Girard, 2002). Despite this improved outlook, evidence was available of localised shortages in vulnerable forests, especially those surrounding urban centres (SEI, 2002). As a result, governments and development agencies scaled back wood fuel plantation and associated programmes. This approach lasted throughout the 1990s, although data concerning the energy and forestry sectors continued to be collected and assessed for changes in the situation. Recent evaluation of this data revealed variations in the consumption patterns of wood fuels, as well as environmental and socio-economic issues (Arnold & Persson, 2005).

2.6 Wood fuel: World Overview

The harvesting of wood fuels is the single largest use of forests worldwide accounting for 61 % of total wood removals, equivalent to 2,443 million m^3 (FAO, 2005). This is an underestimation of the true value, as only a fraction of woodfuel consumption in rural areas is recorded, making accurate assessments of wood fuel consumption and forest resource use challenging (Arnold & Persson, 2005). However, this data reveals differences in the consumption patterns between regions.

In developed countries wood fuels contribute to 24.7 % of total energy consumption, compared to 83 % for developing nations (WEC, 2004). Within these regions the mix of each type of wood fuel also varies (Table 1). Africa and Asia are by far the largest consumers of firewood, whilst North and Central America account for approximately half of the world's energy consumption from black liquor. In the case of charcoal, Africa consumes over 50 % of the world's total production, of which virtually all is consumed in urban areas (Arnold & Persson, 2005, Chidumayo, 1997). The majority of this charcoal is consumed by households for cooking and heating, whilst a small percentage is consumed by commerce and industry (Brouwer & Falcao, 2004).

Table 1 Estimated world wood fuel consumption by region.
Source: Adapted from WEC (2004).

Region	Charcoal %	Firewood %	Black Liquor %
Africa	50.5	31.3	no data
Asia	16.2	47.6	12.8
Europe	2.5	4.1	18.3
North & Central America	7.1	8.6	49.4
Oceania	0.1	0.4	0.9
South America	23.6	7.9	18.6
Total World	100	100	100

Although these figures show a generalised outlook of the wood fuel situation in the regions around the world, there are considerable differences in wood fuel consumption at the national scale. In Asia, wood fuel consumption as a percentage of total energy consumption varies from 43 % in Malaysia to 98 % in Bangladesh (WEC, 2004), whilst in Africa, wood fuels accounts for 96 % in Uganda, and only 14 % in South Africa (Luoga, Witkowski & Balkwill, 2000; Brouwer & Falcao, 2004).

2.7 The "Energy Ladder"

Analysis of the wood fuel data over the decades has revealed certain trends in the wood fuel consumption. Firewood is the predominant fuel used in the rural areas of developing countries, whereas charcoal is the preferred fuel in urban centres replacing firewood as incomes rise (Arnold, Kohlin & Persson, 2006; Kituyi, 2004). This transition is often referred to as the "fuel ladder" (Figure 3) and describes the situation where firewood and charcoal, which occupy the lower rungs of the ladder, are then substituted by kerosene, gas and commercial electricity as you rise up through the rungs (Brouwer & Falcao, 2004).

The implication of this is that as the economies of developing nations grow, one would expect to see a decline in the wood fuel mix of the country (Girard, 2002). This has indeed been observed in Asia where the consumption of wood fuels is declining in favour of alternative fuels, reflecting the rapid economic growth of the region since the 1980s. However, in Africa, one of the most marginalised regions in the world, economic growth has been slow and wood fuel consumption is increasing (Kituyi, 2004; SEI, 2001). This growth is associated with the rural to urban migration found in many African countries, combined with low incomes and savings, which inhibit the transition to others fuel types. As a result Africa's wood fuel dependence is likely to persist for decades to come, which could have significant consequences for forest resources and the rural livelihoods dependent upon them (Kituyi, 2004; WEC, 2004).

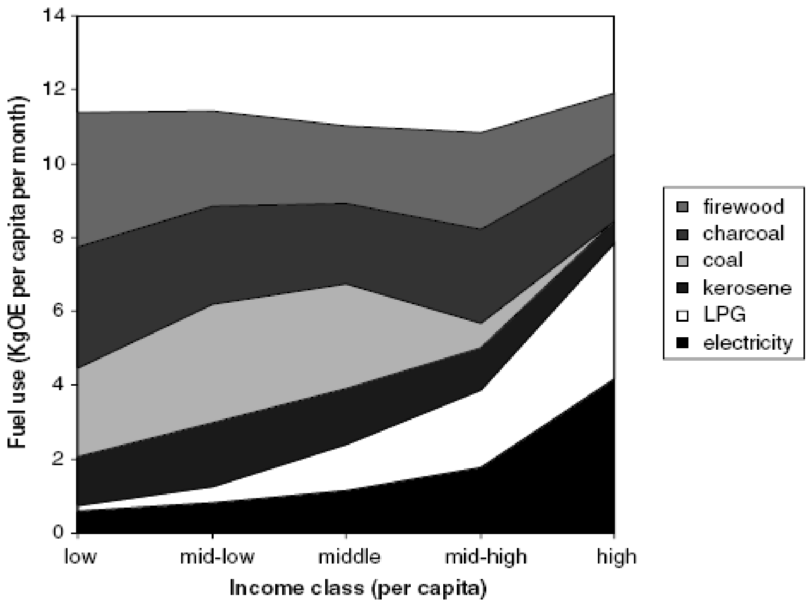

Figure 3 The "energy ladder" relationship between income and fuel type use showing a decline in wood fuel as income increases. Source: Arnold, Kohlin & Persson (2006).

2.8 Environmental and Socio-economic Impacts

Although deforestation on a large scale predicted in the 1970s wood fuel crisis proved unfounded, localised examples in vulnerable forests were recorded (FAO 2005; Kituyi, 2004; Girard, 2002). As the demand for wood fuels increase in these areas the marginal value of tree resources increases, fuelling unsustainable exploitation due to increased profit margins (Luoga, Witkowski & Balkwill, 2000). In this way preferred trees species for wood fuel become increasingly scarce, and alternative species are substituted to meet the growing demand. This process can lead to changes in the species composition of forests and have significant consequences for the environmental services that forests provide (Frost, 1996; IGBP, 1995). One of these services afforded by forests is the regulation of the world's climate through carbon storage and sequestration (IPCC, 2001). Continued deforestation linked to the exploitation of wood fuels is likely to affect this potential, firstly through the reduced storage capacity of forests and their potential to sequester carbon, and secondly because both the production process and the end use consumption of wood fuels are significant sources of GHGs.

In addition to the environmental consequences there are also social and gender implications related to wood fuel consumption (UNDP, 2005). Shortages of wood fuels for subsistence users are becoming more pronounced, particularly for the landless poor due to deforestation, as well as reduced access to forests driven by the privatisation of resources (Arnold & Persson, 2005). These actions reduce the livelihood potential for subsistence users dependent upon forests who must seek alternative means to procure products previously gathered from forests. This is illustrated in firewood collection activities where both deforestation and privatisation of land increases the time spent searching for firewood, preventing women and children from other more productive activities (UNDP, 2005). There are also significant health issues concerning the use of wood fuels where incomplete combustion results in polluted living conditions, significantly reducing the welfare of women. These conditions are directly responsible for the death of more than 1.6 million people annually world wide (400,000 in SSA) due to respiratory diseases (Bailis *et al.,* 2005). This has been predicted to jump to almost 9.8 million deaths by 2030 in line with increased use of wood fuel for energy in developing countries (Bailis *et al.,* 2005).

In spite of the environmental and social impacts of wood fuel production and consumption the trade plays a significant role in the informal markets of developing countries (WEC, 2004). In Kenya alone the charcoal trade is worth US$ 400 million per year, which if extrapolated over the whole of Africa would run into a few billion dollars (Mutimba, 2005). In order to supply this demand a large section of rural households are involved in the activity, facilitated by the low entry barriers. As a result charcoal production is one of the main livelihood components of the rural poor in SSA (SEI, 2002; Kituyi, 2004; Luoga, Witkowski & Balkwill, 2000; Girard, 2002). For many more, the activity acts as a supplemental source of income, "a safety net" in times of hardship (Arnold & Persson, 2005; FAO, 2005). Mutimba (2005) demonstrated this in Kenya where there were over 200,000 charcoal producers, and over half a million people (producers, transporters and vendors) were directly involved in the trade. But, despite being a considerable source of income for millions of people worldwide, charcoal burners receive only a small share of the total revenues compared to the transporters and wholesalers (Ribot, 1997; Mutimba, 2005). Combined with few opportunities in rural areas the low profits associated with the activity is limited in providing sufficient benefits for producers to rise out of poverty.

The unsustainable exploitation of forests for wood fuels not only reduces forest area with the associated environmental impacts but also has significant consequences in the socio-economics of many developing countries. All of these issues introduced are closely related to MDG 2, 3, 4, 5 and 7 and development activities focusing on the link between poverty, livelihoods and wood fuels through CBNRM initiatives are likely to have a significant impact on each of these goals.

3 CHARCOAL PRODUCTION IN MOZAMBIQUE

Mozambique has a wealth of natural assets, of which forests play an important role, not only in the economy of the country, but also the millions of rural livelihoods dependent upon them. The growing demand for charcoal in urban centres has stimulated production in rural areas, and is a key component of livelihoods strategy where few alternatives exist. Although regulations exist for the exploitation of wood fuels, weak state capacity has lead to uncontrolled charcoal production and deforestation on a localised scale. As a result Mozambique has promoted decentralisation and community participation as a means to manage the country's resources in a sustainable fashion.

3.1 Development Indicators

Mozambique in East Africa (Figure 4) is one of the poorest countries in the world, and based on the HDI is ranked 168th out of 177 countries (UNDP, 2005). One of the predominant reasons for these poor statistics are the Liberation War (1964 – 1974) and the Civil War (1979 – 1992). Since the peace agreement in 1992, Mozambique has enjoyed a strong economic recovery with an average growth rate of 8 % per year between 1996 and 2006, which has seen a 15 % reduction in poverty between the years 1997 and 2003, bringing almost 3 million people extreme poverty (World Bank, 2007). Despite this success 54 % of the total population (19.8 million) still remain below the poverty line (World Bank, 2007).

3.2 Mozambique's Forest Resource

Close to 70% of Mozambique (65.3 million ha) is covered by forests and natural vegetation (AIFM, 2007). Total forest area covers 51 % of the country, of which 67 % of this is classified as productive forest (AIFM, 2007). The predominant forest type is miombo woodland dominated by the genera *Brachystegia* and *Julbernardia* and is estimated to account for 70 % of the vegetation cover. Miombo woodlands play an important role in the national and local economy providing timber, NTFPs such as wood fuels, wild fruits, medicinal plants, construction poles and bamboo (Saket, 1999 in Zolho, 2005). Of all of these products, the removal of wood fuels is by far the most important accounting for 92 % of the total 22 million m^3 harvested in 2005 (FAO, 2005).

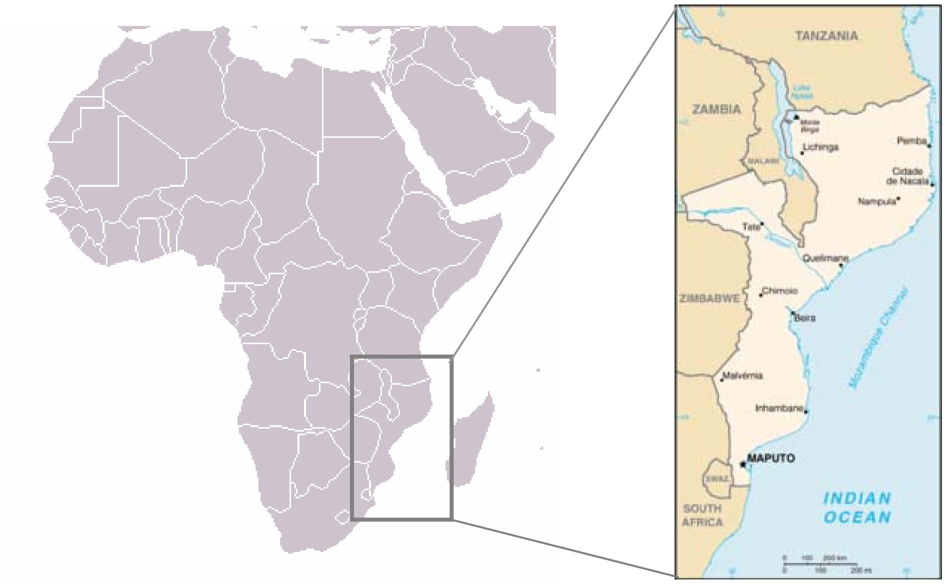

Figure 4 Map of Africa and Mozambique. Source: Wikipedia (2007)

3.3 Wood fuel use in Mozambique

As in other SSA countries biomass from wood is the major household energy source in Mozambique. Wood fuel consumption in rural areas is almost exclusively firewood due to the availability of free wood (FAO, 2000, Chidumayo, 1997). In urban areas, principally the cities of Nampula, Beira, Matola and Maputo this figure is 70 – 80 %, though in this case charcoal is the predominant fuel due to the energy ladder effect described previously (FAO, 2000; SEI, 2002; Chidumayo, Gambiza & Grundy, 1996). Low incomes prohibit the majority of users to move up the "energy ladder," and it is projected that wood fuels will remain the dominant fuel type in Mozambique for the foreseeable future, even in the case of economic development and fuel substitution (Brouwer & Falcao, 2004).

During the wars in the 1970s' and 1980s' population growth in urban centres and along safe corridors soared. This concentrated firewood collection and charcoal production into these areas, and resulted in localised deforestation (FAO, 2000; Falcao *et al.,* 2006). The uncontrolled extraction, partly for wood fuels and partly for agriculture has precipitated in the transition of savannah type woodlands into scrubland in some instances (SEI, 2001). Forests surrounding Maputo are being exploited at ever increasing distances to supply the demand, to the extent that charcoal is now being sourced from as far away as 600 kilometres (FAO, 2000). This process is further fuelled by the increased number of licences required for wood fuel extraction being given where the Maputo Province has seen an average increase of 20 % per year (SEI, 2001).

3.4 Laws governing wood fuel extraction

Under the Forestry and Wildlife Law 10/99 any person making charcoal for commercial purposes must be licensed (SEI, 2001). There are two types of harvesting permits. The first is the simple harvesting license and the second is the concession licence. Whereas at present no forest concession has been given for the production of wood fuels in Mozambique, the lack of capacity to monitor the granting of simple permits means that the majority of charcoal that enters towns is illegal (SEI, 2001).

The implementation of the licensing scheme was designed to collect fees for the Agrarian Development Fund that was created to promote small small-scale rural activities and rural development (SEI, 2001). In spite of wood fuels accounting for 92 % of the total wood removals in 2005 only an average of US$ 11,000 per year was collected by the government between 1993 and 2000 (SEI, 2001). The lack of fees collected due to illegal production not only hinders the efforts of forest guards to enforce these laws due to financial constraints, but also prevents the collection of important data concerning the harvesting and consumption patterns of charcoal (SEI, 2001).

3.5 Rural Livelihoods

The majority of Mozambique's population (63 %) live in rural areas, where subsistence agriculture is the principal livelihood strategy (FAO, 2000). In addition to agriculture the collection of firewood and charcoal production are a major source of income due to ease of access, lack of jobs and insufficient agricultural returns (SEI, 2001, Chidumayo, Gambiza & Grundy, 1996). The degree of involvement in the activity ranges from a seasonal activity in times of hardship to a significant proportion of a households income that can exceed 70% (SEI, 2001). The negative socio-environmental impacts of this activity are further fuelled by the large numbers of demobilised soldiers and urban unemployed that are also involved in charcoal production (Brouwer & Falcao, 2004).

For the majority the activity acts as a "poverty mitigation" strategy preventing producers from falling further into poverty, rather than a "poverty elimination" strategy (Sunderlin *et al*., 2005) due to the small percentage of the profits received at the production phase of the commodity chain (Ribot, 1996). The scale of the wood fuel demand in Mozambique and the dependence upon the commodity by a huge number of rural poor outlines the importance of addressing this issue through sustainable resource management if further progress towards poverty reduction in the country is to be achieved.

3.6 Natural Resource Management

Mozambique, along with many other countries in southern Africa in the last couple of decades has instigated a move away from state driven forest management towards a more decentralised management regime (Falcao *et al.,* 2006). As a result policy changes towards this CBNRM approach were included the National Forestry and Wildlife Law (1999). This new law empowers local communities to own and participate in the management of natural resources through the participatory management of resources in association with government and private business (Falcao *et al*., 2006). The first CBNRM project in Mozambique was established in 1994 in the community of Bawa in the Tete Province, and its success has encouraged the rapid spread of similar project throughout the country (Falcao *et al*., 2006). It was through New Land Law 1997 that the Nhambita Community Pilot Project operating in the Chicale Regulado, Sofala Province claimed its land rights in 2002.

3.7 Charcoal Production Process

There are a variety of kiln designs used to make charcoal in Mozambique. These include traditional earth pit kilns, oil drum kilns (Figure 5a), improved kilns and the traditional earth mound kiln (Figure 5b), which is the predominant type used in the CR. Charcoal output for these kilns ranges from 10 to 60 bags of charcoal (weighing 30-45 kg) per kiln, depending on the size of the kiln (SEI, 2001). Timber to charcoal conversion efficiency is generally low, varying between 14 to 20 %, and depends upon several factors that include tree species, log arrangement and experience (SEI, 2001). The physically demanding nature of charcoal production the activity means that the activity is predominantly undertaken by males, though this is not exclusively the case.

Figure 5 Kiln designs used in Mozambique showing a) an oil drum kiln from the Mucombezi Regulado, Source: UEM (2002) and b) a traditional earth mound kiln from the Chicale Regulado.

Despite the variations in kiln types, the steps for producing charcoal (Table 2) are essentially the same. The main differences arising between regions are the tree species used, the kiln insulation material used and the arrangement (SEI, 2001).

Table 2 Steps involved in the production of charcoal using the traditional earth kiln. Source: Adapted from SEI (2001).

Step	Activity
1. Kiln site identification	1.1. Select site for kiln construction
2. Material Preparation	2.1. Tree felling
	2.2. Cross cutting into short logs
	2.3. Wood drying
3. Kiln construction	3.1. Kiln base structure
	3.2. Stacking logs
	3.3. Kiln insulation with grass & soil
4. Carbonisation	4.1. Ignite kiln
	4.2. Carbonisation control
	4.3. Cooling period
5. Sorting & selling	5.1. Sorting of charcoal
	5.2. Packing into bags
	5.3. Transport to road

Step 1 - Kiln site identification

This involves the identification of a suitable site for charcoal production and is influenced by several factors. These include: stocking density, tree species and size distribution in the area, as well as the degree of slope, availability of insulation material and the proximity to an estaleiro[2].

Step 2 - Material preparation

This step entails the felling of trees, usually by axe, although in the case of very large trees or female producers this is achieved by burning the base of the tree. The trees are then debranched and crosscut into uniform lengths to aid the arrangement of logs in the construction stage. In some instances the logs are left to dry whilst the producer is involved in agricultural activities, whilst others roll their logs directly to the kiln site without drying.

Step 3 – Kiln construction

Kiln construction is one of the most important factors determining the efficiency of the process. The first activity is the construction of the kiln base structure (Figure 6a), which allows the even spread of fire throughout the kiln in the carbonisation stage. The second stage involved the stacking and arrangement of logs for the main body of the kiln (Figure 6b). These can either be arranged in a crosswise manner, as favoured by the CR producers or in a lengthwise fashion, which is preferred by professional migrant charcoal burners that SEI (2001) identified as achieving higher efficiencies and fewer residues. Tight packing is important at this stage to reduce air pockets that lead to reduced conversion efficiencies and partial kiln collapse. This stage is generally performed in a group of the producer's friends and family due to the physical requirements of the task. In return for this service the kiln owner generally provides a meal, as well as returning the favour when others require similar assistance. The third stage involves covering the kiln, initially with grass and then earth though this depends on what material is available where clay, sand and stones have also been used (SEI, 2001).

[2] An estaleiro is a designated selling location for charcoal, usually along on a stretch of road to sell to passing motorists.

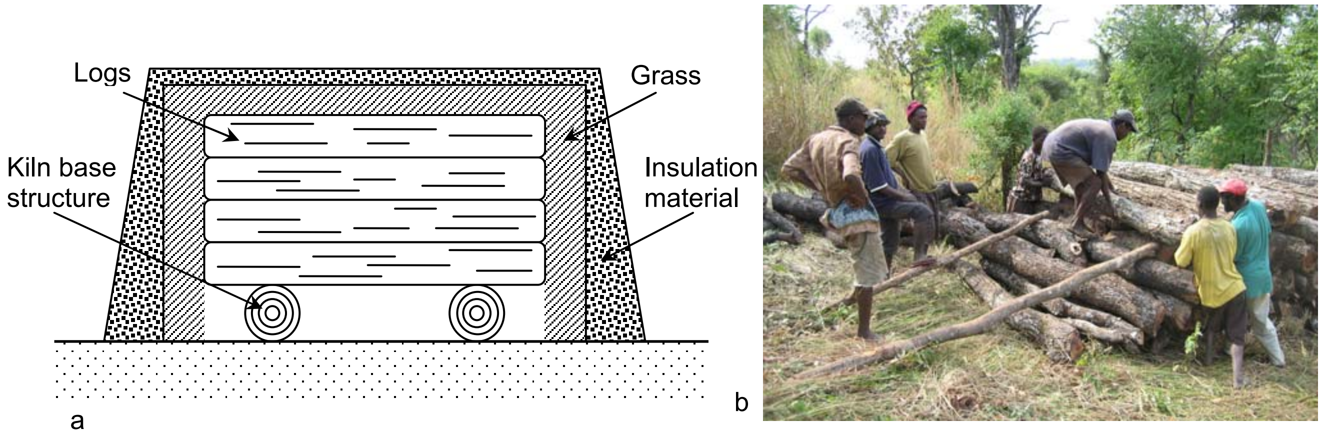

Figure 6 The kiln manufacturing process revealing a) a cross section kiln showing the base structure and layers of insulation material and b) stacking crosscut logs into the main body of the kiln.

Step 4 – Carbonisation

Carbonisation is the process of converting woody biomass into charcoal by burning in the absence of oxygen and also produces a mixture of volatile tars and GHGs. The process is initiated by lighting a fire in the ignition chamber at the base of the kiln. Once the fire has taken hold the opening is sealed to exclude the air, after which constant monitoring is required to ensure an efficient burn by controlling airflow by opening and closing vents. The duration of this process varies between several days to several months depending on the size of the kiln.

Step 5 – Sorting & selling

Once carbonisation is complete the kiln gradually cools and the charcoal is extracted using rakes, hoes and shovels. This stage it particularly time consuming given the friability[3] of charcoal and the need to separate it from the kiln insulating materials (Figure 7a). Once sorted charcoal is then bagged and then carried by hand (Figure 7b) to the estaleiros for sale to passing vehicles.

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[3] Charcoal fines are a significant waste in the traditional earth kilns process as they can not be marketed due to the speed of burn.

Figure 7 The final step of the production process showing a) a completely burnt kiln at the sorting stage and b) charcoal being unloaded at an estaleiro on the EN–1 in the CR.

4 RESEARCH METHODS

The study was undertaken in the community owned lands of the CR in central Mozambique between the 6th May and 11th June 2007. A variety of social science research methodologies were used to explore the study's objectives, and were executed in several stages during the fieldwork period. The data was analysed using descriptive statistics of the livelihood dynamics of charcoal producers and village respondents, as well as kiln distribution and efficiency data.

4.1 Study Area

This study was conducted in the community lands of the CR, Sofala Province in central Mozambique (Figure 8). The boundaries of the CR are limited by the Pungue River to the South, by Gorongosa National Park (GNP) to the East and North and by the Vanduzi River to the West. These community lands extend over an area of approximately 20,000 hectares that are divided into the smaller administration districts of Bue Maria, Mbulawa, Nhanganha, Mtiumbamba, Nhambita, Povua and Pungue (Envirotrade, 2005).

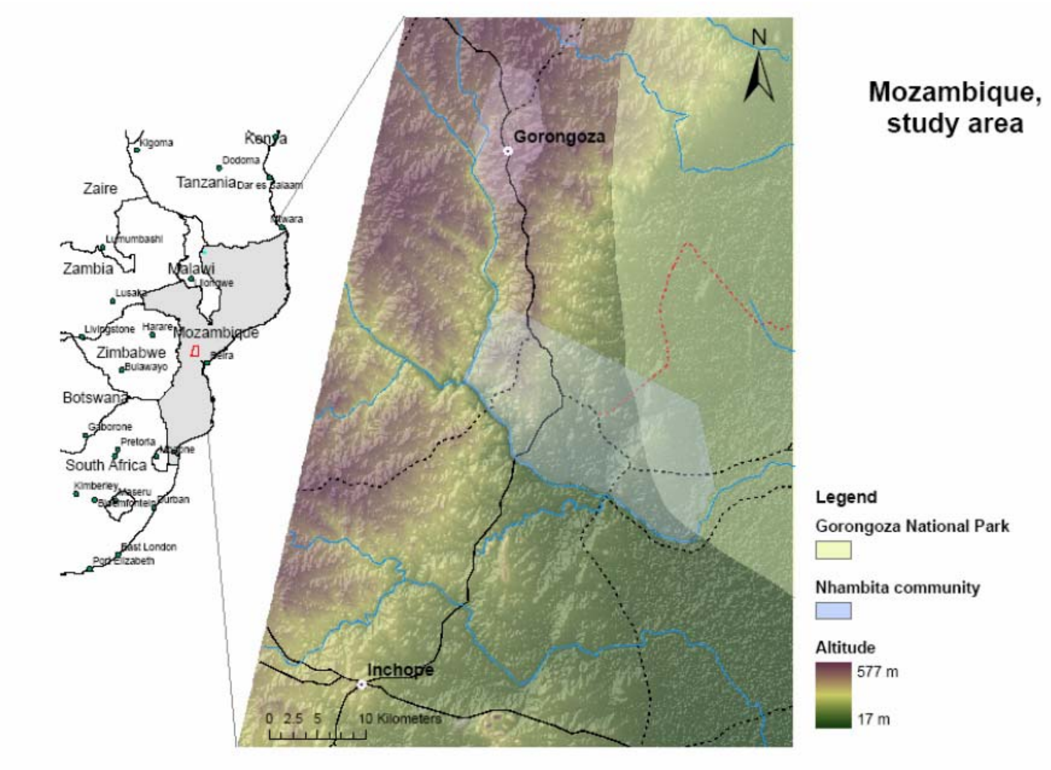

Figure 8 Location map of the Chicale Regulado in Sofala Province, Mozambique. Source: Wallentin (2006)

The CR is bisected by the national road (EN -1) that runs North – South between the towns of Gorongosa and Inchope and connects the sea port of Beira, Mozambique's second largest city to the country's interior. The larger part of the Regulado lies to the East of this road, comprising of the Bue Maria, Nhanganha and Nhambita communities. The rural road (ER–418) runs East - West from the EN–1 road and is the main infrastructure link to the western entrance gate of Gorongosa National Park (GNP), and also provides access to these communities, These three communities lie within the buffer zone of GNP, a strip of land 10 to 20 km wide that surrounds the entire Park, whereas the communities to the west of the EN-1 road (Mbulawa, Povua, and Pungue), lie outside the designated buffer zone.

4.2 Climate and Soils

The climate of the study area is characterised as sub-tropical and is influenced by the Intertropical Convergence Zone (ITCZ), (ARA-CENTRO, 2004). As a result the study area experiences two distinct seasons, the wet season (November to March) is characterised by high rainfall, which can be up to 96 % of total annual rainfall and cooler temperatures 21^{o} C and the dry season characterised by low rainfall and high temperatures that reach 32^{o} C (ARA-CENTRO, 2004).

The altitude within the Regulado ranges from 35 m Above Sea Level (ASL) along the western escarpment of the Rift Valley in the east, and rises to more than 330 m in the western section, which then drops again into the Vanduzi River at the westernmost boundary of the Regulado (Envirotrade, 2005). The soils in the study area are generally poor, highly weathered and freely draining sandy loams on the higher ridges and sandy silt loams along stream and river margins (ARA-CENTRO, 2004).

4.3 Vegetation

The climatic conditions coupled with the nutrient poor soils of the area have lead to dry miombo woodland as the predominant vegetation cover throughout the study area. In the study area the miombo woodlands are dominated by the species *Brachystegia boehmii, Brachystegia spiciformis*, *Julbenardia globiflora, Combretum apiculatum and*

Diplorhynchus condylocarpa (Grace *et al.,* 2006) though other vegetation types such as riverine woodland, bamboo and palm woodland also occur (Muchove, 2003). Forest inventories of the miombo woodlands have been undertaken in the field throughout the CR and 15 Permanent Sample Plots (PSP) of 1 ha have been established. These forest inventories have estimated that miombo woodlands cover 65.8 % of the CR, equivalent to 239 km^2 ha with a basal area of 9.2 m^2 ha^{-1}, stocking density of 157 trees ha^{-1} (Ryan, 2007) and a mean aboveground biomass of 38 t C ha^{-1} (Wallentin, 2006).

4.4 Community Characteristics

The local community is extremely poor and there is widespread deprivation with respect to income, food insecurity, health, and low literacy rates (Jindal, 2003). Most households have no regular source of income, and the majority of livelihoods are dependent upon subsistence agriculture. For a more in depth analysis of socio-economics refer to Jindal, (2003).

4.5 Land use & Management

Population growth within the CR, as in the rest of Mozambique has meant that the miombo woodlands are experiencing ever increasing demands to satisfy local needs (Williams *et al,* 2007). One of the principal causes for miombo woodland degradation is the traditional agricultural method of slash-and-burn practiced in the area (Envirotrade, 2005). This agricultural system clears areas of woodland, usually between 0.5 ha and 3 ha for the cultivation of crops. However, after several years of cultivation soil fertility declines and agricultural yields decrease. Consequently the machambas are abandoned and new areas of forest are cleared, further degrading the miombo resource base. The production of charcoal in the CR is another activity practiced by some of the inhabitants of the community that is putting pressure on the miombo resource. Grace *et al.,* (2006) mid-term report of the Nhambita Pilot Project proposed this was the principal cause for the deforestation along the EN–1 road as observed by LANDSAT imagery between the years 1991 and 2000.

The management of miombo woodlands is therefore a critical issue in the study area, due to the reliance upon the resource by 45 millions rural inhabitants and sustainable land use practices are therefore required within these areas to conserve both the environmental services that these woodlands supply, and the livelihoods reliant upon the resource (Frost, 1996; IGBP, 1995).

Within the boundaries of the CR three main systems of land use management are used. Approximately one quarter of the CR lies within the limits of GNP where, as a protected area it is managed by the State exclusively for the conservation of wildlife in the park. Bordering the GNP boundary westwards until the EN–1 road, and approximately two quarters of the community land, is encapsulated within the buffer zone of GNP. The aim behind the buffer zone is to promote CBNRM initiatives to create alternative livelihood strategies for the communities living within it. By adopting this strategy it is hoped that the communities will reduce their pressure on the wildlife and vegetation resources within the Park itself. To achieve these aims actors such as government institutions, Non-Governmental Organisations (NGO), community associations and the private sector are involved in the management of the zone. The Nhambita Pilot Project is an example of this type of approach.

On the other side of the EN–1 the communities of Mbulawa, Pavoa and Pungue fall outside of the buffer zone of GNP and are managed by the community in accordance with the Land Act N^{o} 19/97. This land is managed as an open access resource for the community where all activities including the production of charcoal is permitted. It was within these three communities that this study took place to evaluate the role of charcoal production within the CR.

4.6 Data Collection Methods

The study adopted variety of methodologies used in the sphere of social science research to explore the objectives and key questions posed. The methods used in the study were:

- Semi-Structured Interviews (SSI);
- Questionnaire survey & kiln measurements;
- Participatory Rural Appraisal (PRA).

To facilitate data collection the methodologies were carried out in several stages during the fieldwork stage that lasted between 6th May and 11th June 2007. The following sections present an introduction to each of the methodologies chosen, and a description of their use in the field.

4.6.1 Semi-Structured Interviews

The SSI interview style was chosen to explore objectives 1 and 4 of the study on the grounds that this technique requires the interviewees to possess knowledge about a subject previously analysed by the interviewer (Merton *et al.* 1953). This technique does not require a rigorous interview guide nor highly structured response categories but instead encourages open ended investigative questions to draw out information about the subject area. The focus of the interviews was therefore to understand both the local and the broader issues regarding charcoal production in the area, and the potential for sustainable production. To this end focused interviews were carried out with a range of stakeholders (Appendix 1) that included Nhambita Pilot Project staff, members of the local community, local government officials, researchers from GNP, UoE and UEM, development agencies and forestry professionals. This phase of the study was particularly useful in extracting relevant information about the subject, and refining the questionnaire survey.

4.6.2 Questionnaire Survey

There are a number of techniques used to collect survey data, though the most widely used is the questionnaire survey (de Vaus, 1991). It is a highly structured data collection technique where each interviewee is asked the same set of questions enabling a relatively large sample of individuals, from which characteristics of the population can then be inferred (Punch, 2005). The questionnaire survey developed for the study consisted of two parts (Appendix 2), each part addressing a specific objective of the study. The first included questions about livelihoods and was undertaken on a population of charcoal producers and a population that was not involved in the activity. The rationale behind this was to allow comparisons between the two groups and determine the importance of charcoal in the community. The second part of the questionnaire was developed solely for the charcoal producers, and was aimed to explore the first and third objective to explore the production process and kilns characteristics utilised in the CR.

The questionnaires were composed of a mixture of open-ended and closed questions based on the key objectives as well information gathered from the SSIs in phase one of the study. Prior to conducting the survey on the two populations the questionnaire was pilot-tested on several producers in the study area. This was done to establish whether the questions were interpreted correctly, and if the range of responses was sufficient. The questionnaire was modified the survey of charcoal producers and villagers conducted in the following manner.

In the case of the charcoal producing population a methodology was developed to locate the kilns and their owners. Firstly, all of the estaleiros along the entire stretch of the EN–1 within the CR's boundary were identified. At every estaleiro the Fumo[4] of each of the three districts (Mbulawa, Povua and Pungue) was informed of the study's objectives and requested to accompany the researcher. The basis for this was the Fumo's familiarity of each district and its inhabitants, and was therefore invaluable in locating kiln sites, as well as assuring the charcoal producers as to the motives of the study. Dois Ranguisse, the son of a Nhambita Sapanda also accompanied the researcher as a local guide, and more importantly was trained to carry out the questionnaires in the local language of Sena for those producers that could not communicate in Portuguese. Starting at the estaleiro tracks used by charcoal producers were followed directed by the Fumo in search of kiln sites and producers. The location of each kiln encountered, regardless of the stage of construction was recorded on a handheld Geographical Positioning System (GPS) (Garmin – Etrex). Where kiln owners were present a background to the study and the motives was offered and the first part of the interview conducted. The second part of the questionnaire (Appendix 2) involved questions and measurements of kiln size, number of trees per kiln, output etc. A total of 62 charcoal producers (Appendix 3), 48 male and 14 female were interviewed in this manner.

In the case of the non-charcoal making population a random sample of people encountered in the Bue Maria, Nhambita and Nhanganha communities were interviewed using the same questionnaire as used for the charcoal producing population. A total of 45 villagers were interviewed of which 27 were male and 18 female.

[4] The Fumo is the third layer of the traditional hierarchy immediately below the Sapanda and the Regulo.

4.6.3 Participatory Rural Appraisal (PRA)

PRA is an array of participatory approaches and methods that seek to emphasise local knowledge and to enable local people to make their own appraisal, analysis and plans (World Bank, 1996; Chambers, 1994; FAO, 1999). This approach has come about in recent years due to the recognition that traditional development strategies with a top-down approach have generally not succeeded in raising the living standards of the rural poor (Binns, Hill and Nel, 1997). PRA has been applied in a wide variety of fields and in the case of this study was used to offer a bottom-up approach for the charcoal producers to analyse their current practices and explore the potential for sustainable charcoal production. Of the variety of PRA techniques available the study employed semi-structured interviews combined with transect walks through the charcoal producing districts, as well as a resource mapping exercise to learn about the community's resource base.

This was the third phase of the study and involved addressing all of the issues uncovered from the SSIs, transect walks and questionnaires at an open meeting with the charcoal producers. Firstly information surrounding the aims of the study and the basis for sustainable charcoal production were given. The discussion was then opened to the participants to offer their opinions and concerns of whether such a system could be achieved. Following this a resource mapping exercise was conducted to explore the extent of forest resources from the producers' perspective, and to propose a location for a concession area for sustainable charcoal production. The mapping exercise was carried out in an open area where all of the participants had access to the map drawing area and the process was initiated by drawing the EN–1 road following which the participants were invited to draw the boundaries of the CR and the resources identified as important to them. Photos of the process and a copy of the resource map was transposed onto paper.

4.7 Data Analysis

The livelihood and charcoal questionnaire data were analysed using descriptive statistics and graphical representations. Arithmetic means, standard deviation and frequency distributions were conducted on the questionnaire data to summarise the patterns in the responses of the two populations. Regression analysis was also used on the relationship between kiln inputs and outputs to determine kiln efficiency and conversion rates, which could then be applied to estimating production rates for calculating sustainable production.

The GPS data from the kiln locations were downloaded and processed using the Geographical Information System (GIS) programme Arc GIS. The distribution of kiln sites was then analysed against deforestation data tracked by LANDSAT between 1991-2000 to determine whether there was any correlation between deforestation and charcoal production.

The PRA and SSI data was compiled and any trends between stakeholder points of interest and opinions were recorded for support of future actions, such as the site proposed by the producers for sustainable production.

The wide range of these techniques enabled us to triangulate the data collected and to make sound inferences from the results.

5 RESULTS

5.1 Descriptive Analysis – Livelihoods

The results presented here are derived from the livelihood survey of the charcoal burners and the village inhabitants to enable comparisons between charcoal and non-charcoal making populations.

5.1.1 Age & Sex

Figure 9 reveals that charcoal production is dominated by males (77 %) compared to females (23 %). There is a large age spread between charcoal respondents that varied between 14 years and 67 years, although the activity appears to be dominated by the 22-35 age bracket. A similar distribution was observed for the age range and mode of village respondents.

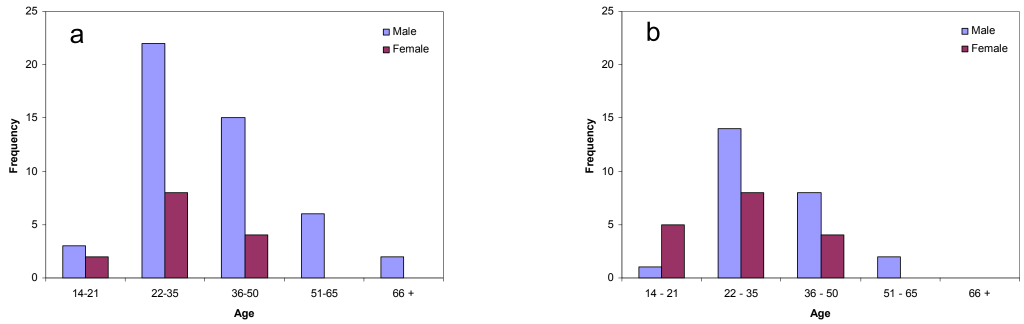

Figure 9 Histograms of age and sex for a) charcoal questionnaire respondents (n = 62) and b) village questionnaire respondents (n = 45).

5.1.2 Family Size

The mean number of children per respondent was 4 for both the charcoal producers and village respondents. However, there was great variability of the number of children in the distribution for both populations shown in Figure 10.

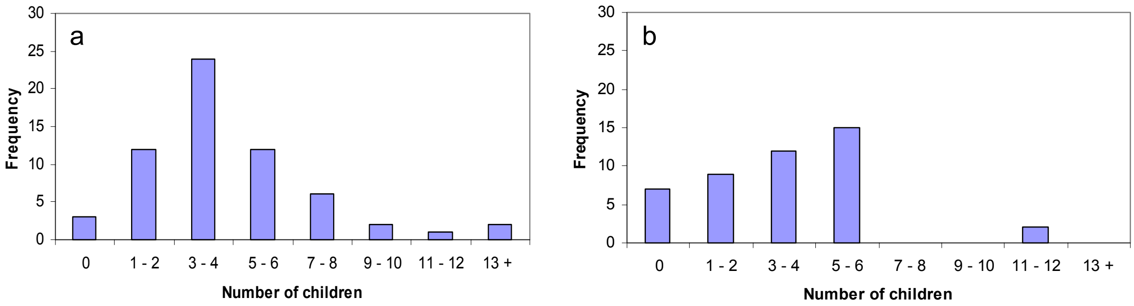

Figure 10 Histograms of number of children per respondent for a) charcoal producers (n = 62) and b) village respondents (n = 45).

5.1.3 Schooling

The differences observed in the schooling between sexes of the two populations are shown in Table 3. Male attendance was higher than women for charcoal producers, whereas attendance was similar for both sexes in the village population. On average males achieved a higher level of education[5] than the women in both populations.

Table 3 School attendance and mean grade achieved charcoal producers (n = 62) and village respondents (n = 45).

Charcoal Respondents	Male %	Female %
Attended School	85 %	29 %
Did not attend school	15 %	71 %
Mean Level Achieved	4°	2°

Village Respondents	Male %	Female %
Attended School	85 %	83 %
Did not attend school	15 %	17 %
Mean Level Achieved	5°	4°

5.1.4 Income

The higher earning capacity of males can be seen in Table 4 revealing that on average males earn double that of the female producers. Profits from charcoal vary between producer (Fig 11b) but contribute a large proportion to annual incomes, though this is greater for males (74 %) than for females (59 %), whilst no village respondents were involved in charcoal production. The incomes of the village population were significantly higher for both men and women employed on the Nhambita Pilot Project, whereas the unemployed had similar incomes to the charcoal producing population.

[5] Level of education. 4° corresponds to the final year of primary school.

Table 4 Income characteristics of the charcoal and village resondents

		Male		Female	
	Income Characteristics	Employed	Unemployed	Employed	Unemployed
Charcoal Respondents	Mean Income $ USD	-	$ 80 - 120	-	$ 40 - 60
	Mean % CC income	-	74%	-	59%
Village Respondents	Mean Income $ USD	$ 400 +	$ 80 - 120	$ 200 - 400	$ 40 - 60
	Mean % CC income	0%	0%	0%	0%

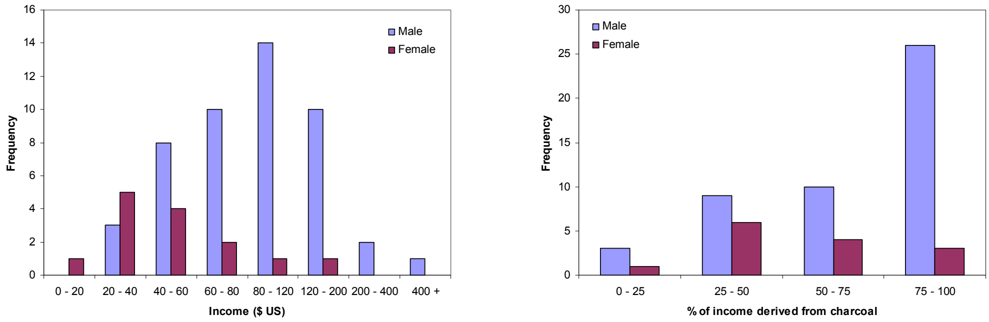

Figure 11 Histograms of a) annual income per by male (n = 48) and female (n = 14) charcoal questionnaire respondents and b) the percentage of income derived from charcoal.

Triangulation of income data from calculations of profits from charcoal production (Figure 12) reveal similar figures to those stated in the survey, with a mean male annual income of US$ 80-120 compared to US$ 40-60 for females.

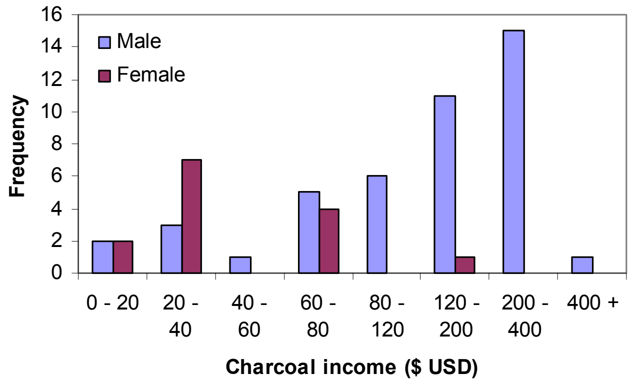

Figure 12 Histogram of income generated from kiln calculations for charcoal production per annum by both male and female questionnaire respondents.

5.1.5 Landholding

Subsistence farming is the central livelihood strategy in the CR, with 100 % and 93 % of the charcoal and village respondents respectively involved in the activity. All cultivated the staples of maize and mapira with a combination of other crops that include sweet potato, sesame, beans, pigeon pea and pumpkin. Machamaba size varied between 0.5 ha and 4 ha and the mean values for this and number of machambas owned can be seen in Table 5.

Table 5 Mean number and size of machambas owned by charcoal producers (n = 62) and village respondents (n = 45).

Charcoal Respondents	Value
Mean no machambas	2
Mean machamba size (ha)	1.6

Village Respondents	Value
Mean no machambas	2
Mean machamba size (ha)	1.3

5.1.6 Plan Vivo

The average PV scheme adoption rate was 60 % and 84 % for charcoal and village respondents respectively. This varied between the charcoal producing districts of Mbulawa (88 %), Povua (27 %) and Pungue (0 %), whereas in the village population adoption for Bue Maria, Nhanganha, and Nhambita with 80 %, 89 % and 81 % respectively. All of the villagers not already part of the PV scheme wanted to become so, compared to 80 % for charcoal producers. The number and type of PV scheme adopted also varies between populations as seen in Table 6 and Figure 13.

Table 6 Degree to which charcoal and village questionnaire respondents are part of the Plan Vivo scheme.

Number of PV systems adopted by respondents	Charcoal Respondents %	Village Respondents %
Not Part of PV	40 %	16 %
1 PV System	90 %	44 %
2 PV System	10 %	64 %
3 PV System	0 %	2 %

All of charcoal burners that are part of the PV scheme stated that their lives were better off due to the income received and wanted to be part of another scheme. The response for the village population was 89 %, the other 11 % indicating that the income derived form the PV scheme was a relatively small amount of money to make any difference.

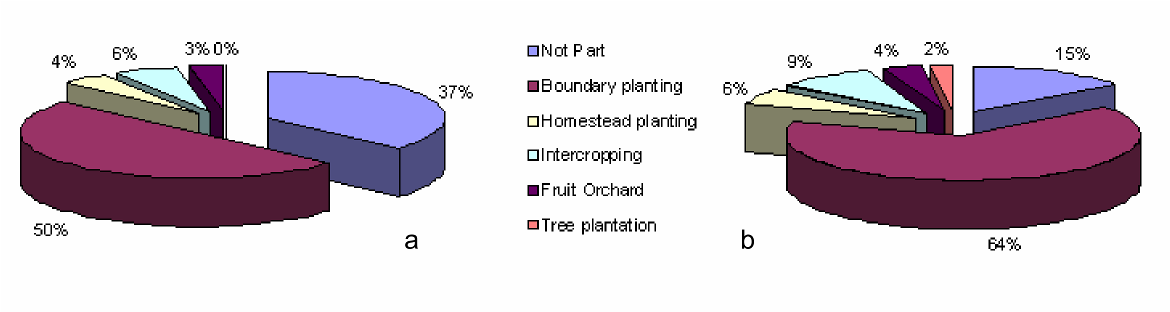

Figure 13 Percentage of respondents signed up to the various PV schemes for a) charcoal respondents (n = 62) and b) village respondents (n = 45).

5.2 Kiln Distribution

The majority of charcoal is being produced in the northern districts of Mbulawa and Povua within a 2 km strip to the west of the EN-1 (Figure 14) and shows some correlation with the LANDSAT deforestation data. The deforestation further west is attributed to shifting agriculture due to the absence of kilns in these areas.

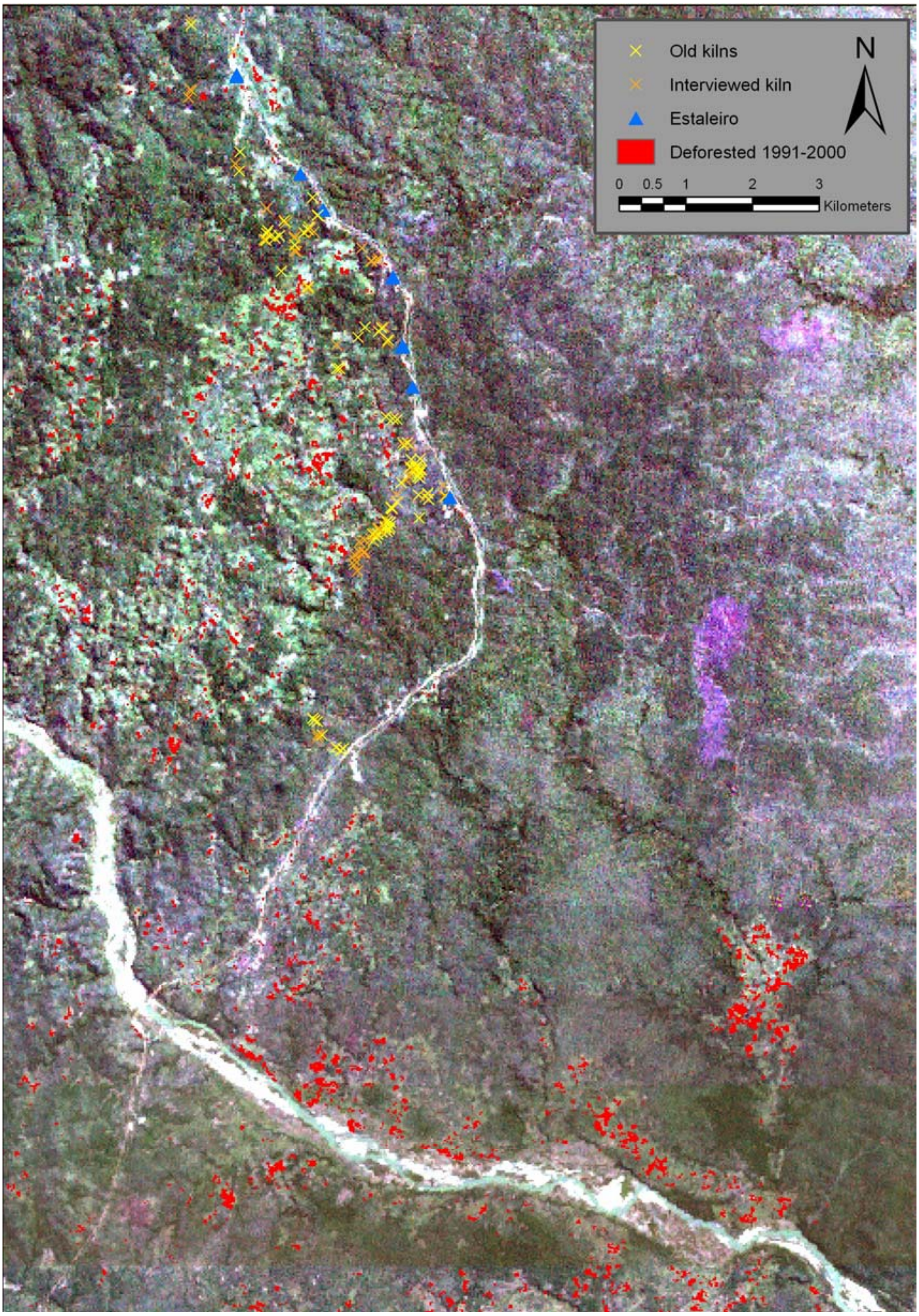

Figure 14 Map of study area indicating the location of kiln sites where interviews were conducted, old kiln sites and areas of deforestation between 1991 – 2000.

5.3 Descriptive Analysis – Charcoal Production

5.3.1 Provenance of charcoal producers

On average 52 % of the charcoal producers were native to the CR. The motives of the other 48 % coming to live in the area can be seen in Table 7. Only 3 % of the respondents indicated that they moved into the area solely to produce charcoal, all of which were active in the Povua District.

Table 7 Percentage of charcoal questionnaire respondents native to each district and the motives of the non-natives for coming to live in each district.

Charcoal Respondents	Native to CR %	Family %	War %	Land %	Charcoal %
Mbulawa (n = 34)	52 %	26 %	6 %	15 %	0 %
Povua (n = 26)	54 %	12 %	12 %	15 %	8 %
Pungue (n = 2)	0 %	0 %	100 %	0 %	0 %
Mean (n = 62)	52 %	19 %	11 %	15 %	3 %

5.3.2 Kiln characteristics

Kiln measurements of the 62 charcoal producers surveyed revealed differences in the mean kiln sizes between males and females shown in Table 8. On average by timber volume[6] male kilns (12.5 m^3) were double the size of female kilns (6.2 m^3).

Table 8 Mean kiln dimensions of all charcoal producers surveyed by sex.

Kiln Dimensions	Males	Females
Mean length (m)	5.4	3.6
Mean width (m)	2.4	1.9
Mean height (m)	1.5	1.4
Mean kiln volume (m^3)	20.8	10.3
Mean timber volume (m^3)	12.5	6.2

Following this initial characterisation, the kilns were ranked in ascending order by volume and categorised into three sizes of kilns. These were;

- Small kilns (0 – 14 m^3);
- Medium kilns (15 – 29 m^3);
- Large kilns (> 30 m^3).

[6] Timber volume was calculated using the 60 % conversion factor to account for air spaces in the kiln identified by O'Kting'ati (1984) in Luoga, Witkowski & Balkwill (2000).

Characterised in this manner the mean dimensions for small medium and large kilns were tabulated (Table 9). On average each of these kiln characteristics doubled as kiln size increases with the exception of kiln width, height and distance to the furthest tree, which are all constrained by physical strength.

Table 9 Kiln characteristics by size of kiln.

Kiln Dimensions	Small	Medium	Large
Mean length (m)	3.2	5.7	9.0
Mean width (m)	2.0	2.4	2.8
Mean height (m)	1.4	1.6	1.7
Mean No of trees $kiln^{-1}$	5	8	13
Mean max dist (m)	22.7	30.9	35.4
Mean Stump wastage $kiln^{-1}$ (m^3)	0.7	1.0	1.7
Mean kiln volume (m^3)	9.4	20.7	41.6
Mean timber volume (m^3)	5.6	12.4	25.0
Mean No of bags (45 kg)	20	51	93
Mean total production time (days)	31	58	82

5.3.3 Charcoal output by kiln size and district

Table 10 reveals the dynamics of kiln output by size and district. Women only produce charcoal in the Mbulawa District, predominantly making small kilns and medium kilns. Males on the other hand are producing in all districts and sizes except for Pungue, where only small kilns are being made. Povua constructs a greater proportion of large kilns than the other two district and also produces the most charcoal with an output of 1514 bags. The total output of all the kilns surveyed in the study was 2633 bags, equivalent to 118 tonnes of charcoal where each bag weighs 45 kg.

Table 10 Number and output of kilns by size and district.

		Number of kilns			Number of bags		
District	**Kiln Size**	**Male**	**Female**	**Total**	**Male**	**Female**	**Total**
Mbulawa	Small	8	12	20	142		142
	Medium	10	2	12	457	72	529
	Large	2	0	2	178	190	368
Mbulawa Total		***20***	***14***	***34***	***777***	***262***	***1039***
Povua	Small	9	0	9	791	0	791
	Medium	9	0	9	550	0	550
	Large	8	0	8	173	0	173
PovuaTotal		***26***	***0***	***26***	***1514***	***0***	***1514***
Pungue	Small	2	0	2	80	0	80
Pungue Total		***2***	***0***	***2***	***80***	***0***	***80***
Total		48	14	62	2371	262	2633

5.3.4 Conversion Rate from Timber to Charcoal

The relationship between timber input and charcoal output can be seen in Figure 15. The equation for this relationship is;

$$y = 3.87\,x - 0.26$$

Equation 1 Charcoal production efficiency.

Using the mean wood density of the five most used species for charcoal production in the area of 788 kg m^{-3} we can calculate that 1 bag of charcoal (45 kg) is equal to 256 kg of wood (0.33 m^3 * 778 kg m^3). Therefore 1 kg of charcoal is produced from 5.7 kg of wood giving a conversion rate of 17.6 %.

In relation to the 2633 bags of charcoal produced from the 62 kilns, equivalent to 118 tonnes (2633 * 45) was produced from 672 tonnes of timber (118 * 5.7).

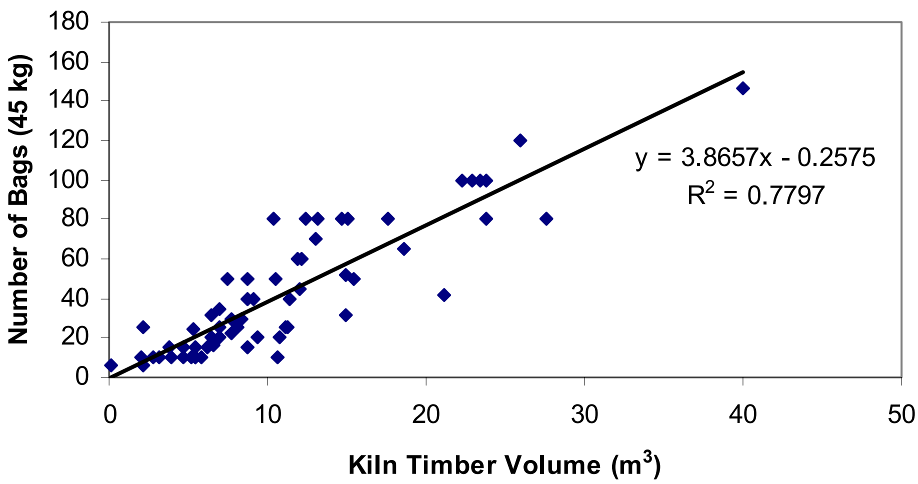

Figure 15 Relationship between timber input in cubic meters and charcoal output in bags (45 kg) from the traditional earthen kilns in the Chicale Regulado.

5.3.5 Wastage

Equation 1 does not take into account any wastage from the felling process, thereby underestimating the impact of charcoal production on the forests in the CR. The largest and smallest diameters of trees felled for charcoal were 95 cm and 13 cm respectively. The mean stump characteristics can be seen in Table 11, which, extrapolated over the 62 kilns equates to 58 m^3 of timber wasted. This is equivalent to 8 tonnes of forgone charcoal.

Table 11 Stump wastage characteristics

Stump measurements	Value
Mean stump diameter (cm)	41.3
Mean stump height (cm)	73.8
Mean stump volume (m3)	0.13

5.3.6 Preferred & used tree species for charcoal production

Given the choice of species for charcoal production the respondents stated that their top five preferred species in order of importance were; *Brachystegia boehmii*, *B. spiciformis*, *Julbernardia globiflora*, *Pterocarpus rotundifolius rotundifolius* and *Burkea africana*. (Figure 16). In reality charcoal burners were using a wider variety of tree species, but the top 4 used were the same as the preferred species, with the exception of *Swartzia madagascariensis.*

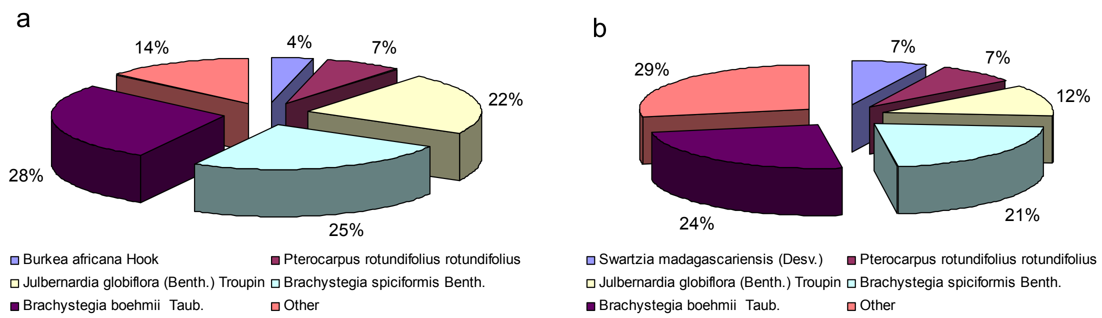

Figure 16 Percentage values of a) the top 5 preferred species for charcoal production and b) the top 5 species used in the kiln over the study period.

5.3.7 Prohibited Species

Certain species are prohibited under law for use as wood fuels due to their valuable nature for timber and furniture. The top 5 prohibited species stated by charcoal producers are *Pterocarpus angolensis*, *Milettia stuhlmannii*, *Afzelia quanzensis*, *Khaya anthoteca* and *Dalbergia melanoxylon* (Figure 17). 97 % of producers surveyed responded that they would not use these trees for making charcoal. However, *Swartzia madagascariensis* a species prohibited for wood fuel was the fifth most utilised species for charcoal production in the study (Figure 16).

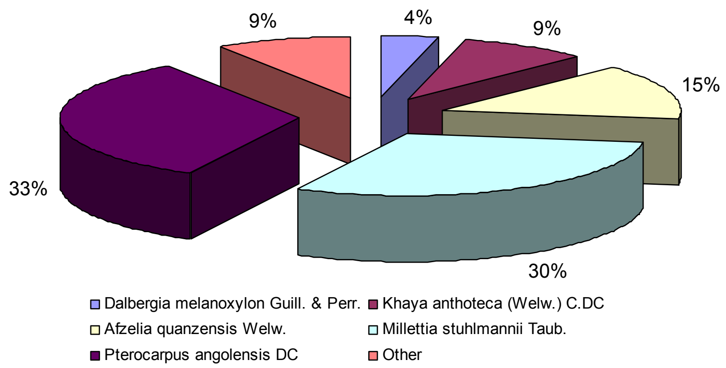

Figure 17 Percentage values of the top 5 prohibited trees for charcoal production cited by the charcoal burners.

5.3.8 Tree Selection Method

Tree distribution is one of the main factors determining the location of kiln sites. The preferred means of trees selection was by size (60 %) followed by tree species (Table 12).

Table 12 Preferred means of tree selection for charcoal production.

Means of tree selection	Percentage %
Any trees	3%
Large trees	60%
Mixed sizes	6%
By species	31%

5.3.9 Tools

The primary tools required for charcoal production in the CR include: axe, hoe, rake and shovel. 92 % of male producers owned one or more tools compared to 71 % for female producers. The axe was the most common tool owned by all the producers owning one tool or more. The distribution of tools (Figure 18) reveals a mean of 2 for both the number of tools owned and rented. Each tool was rented at a price of 50 Mts (US$ 2), but in some cases they were borrowed from family members for free. All of the producers with 4 tools (n = 3) rented out their tools for extra income.

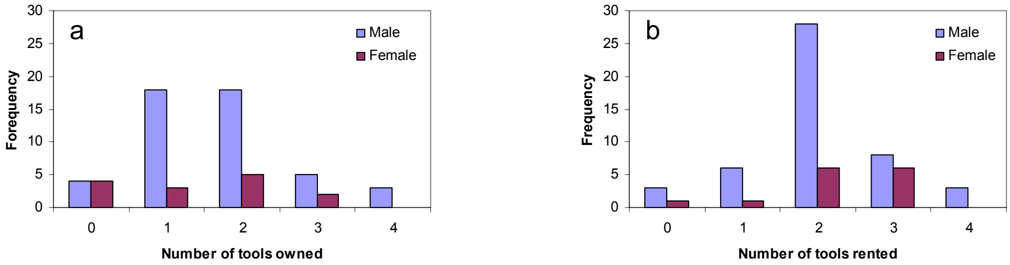

Figure 18 Histograms of a) tool ownership and b) tool rental for charcoal producers.

5.3.10 Charcoal Pricing

There are different pricing structures for the sale of charcoal in the CR (Table 13). Typically male and female producing with a license bag their charcoal at the kiln site, then transport it for sale at the roadside selling stations for 50 Mts (US$ 2) per bag. Widows on the other hand with little disposable income to join a licensed group of producers sell their charcoal unbagged to a licensed producer for 25 Mts (US$ 1). Over the last three years roadside prices have increased on average 10 Mts per year.

Table 13 Price of charcoal for male and female producers at the different selling points.

Selling point	Male	Female
Kiln site	-	25
Roadside (estaleiro)	50	50

5.3.11 Estimated annual charcoal output

Estimated annual output was calculated by multiplying kiln output per producer by the number of kilns made per year (Table 14). Males produce more than ten times as much charcoal as women over the whole year, and medium sized kilns account for 43 % of total annual production. Based on the 62 charcoal burners surveyed an estimated 6078 bags of charcoal are produced over the course of the year, equivalent to 1559 tonnes or 1978 m^3 of timber. By district Povua contributes 57 % of total annual production compared to 47 % and 2 % for Mbulawa and Pungue respectively.

Table 14 Number of bags produced by kiln size and by district.

Kiln size (s/m/l)	Male	Female	Total
Small	1159	389	1548
Medium	2421	144	2565
Large	1965	0	1965
Total	5545	533	6078

District	Male	Female	Total
Mbulawa	1944	533	2477
Povoa	3441	0	3441
Pungue	160	0	160
Total	5545	533	6078

5.4 PRA Feedback Session

The outcome of the PRA feedback session provided the researcher with the insights into the concerns and aspirations of the producers with regards to sustainable charcoal production in the area. These primarily included: the location of the production area, that income from the sustainable system should at least equal that of current production activities, transport, tools, and the suitability of improved kiln technology. In addition to this the participants proposed an area that they deemed suitable for a concession area for sustainable charcoal production (Figure 19).

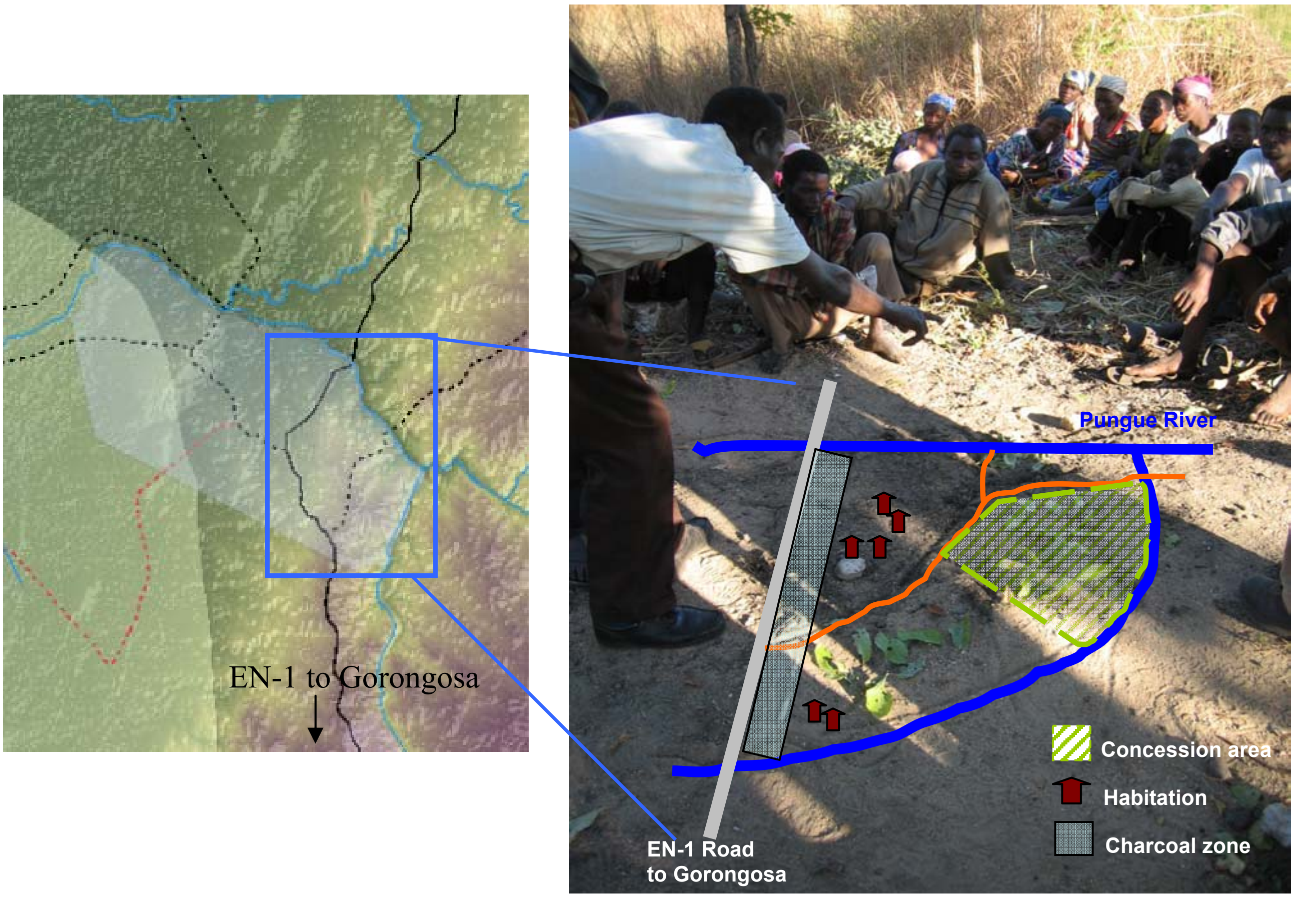

Figure 19 Photo of the PRA resource mapping process and the transposed map identifying the location of the proposed concession area.

6 DISCUSSION

6.1 Key Questions Answered

1. ***Who are the principal actors involved in charcoal production?***

The results suggest that there is an approximate 50 – 50 split of charcoal producers that are native to the CR, and those that have moved into the study area. The motives of those moving into the area varied with only a small percentage (3 %) stating charcoal production as their principal motive for moving to the area. Interestingly, all of these respondents (n = 2) were producing charcoal in the Povua district of PR. Cross tabulating these results with charcoal output it was observed that Povua was the largest producing and could potentially be the reason for their preference of Povua over Mbulawa that had been producing charcoal for a longer period, which the producers might have linked to diminished tree resources.

The results for this question could be biased due to the failure to survey the charcoal burners active in the buffer zone, for reasons previously explained. However, the decision to leave by the majority of these producers, given the choice to stay by the community, implies that they moved to the location solely to produce charcoal. Personal communications with members of the community confirmed this, stating that some had immigrated into the area from the Mucombezi Regulado south of the Pungue. The motive for this move is likely to be because of the declining forest resources in the Mucombezi Regulado as a result of unsustainable exploitation of woodlands resources for charcoal production (pers comm. Serra, 2007). The results therefore indicate that excluding the producers that were evicted, the key actors involved in charcoal production are the permanent residents participating in the activity as a means to diversify incomes.

2. ***To what extent are these actors dependent upon charcoal production for their livelihoods?***

Dependence upon charcoal as a livelihood strategy varies considerably between producers. On average male producers earn US$ 80-120 per annum, of which 74 % is derived from the production of charcoal, which was a similar figure that calculated from the kiln calculation. Women producers on the other hand earn on average half that of the men

(US$ 40-60), of which charcoal constitutes a lower contribution to total annual income at 59 %. The high number of women in the population was not expected (pers comm. Falcao, 2007) due to the physical nature of the activity, but implies that even for women charcoal production is a means to diversify incomes where few other opportunities exist. When based on the World Banks poverty definition of US$ 1 per day it can be seen that more than 95 % of the population fell below this standard. Charcoal production in the CR is therefore a subsistence activity to diversify income streams, an approach that typically lies at the heart of livelihood strategies in rural Africa (Barrett, Reardon & Webb, 2001).

In the SEI (2001) study the annual average household income in Licuati region in Maputo Province was US$ 690. This is considerably higher than the incomes in the CR but the proportion of income derived from charcoal was 65 %, indicating a similar dependence on charcoal between the two areas. Interestingly, the mean incomes of charcoal producers and unemployed villagers were the same, whereas those employed on the Nhambita Pilot Project gained far greater incomes of US$ 400 + and US$ 200-400 for males and females respectively. Where one of the principal sources of income for charcoal producers is through charcoal, for the unemployed villagers this is replaced by selling excess produce and hired labouring.

Although charcoal is the principal income earner for producers, subsistence farming is still a very important activity providing the main staples, and was also found by SEI (2001). This was evident in the data collected revealing the time division between the two activities. A variety of approaches to this division of labour was undertaken by charcoal producers. The most common was either to divide their time between agriculture and charcoal making by half day or every other day throughout the whole year, whereas others devoted all their time to charcoal in the dry season and all their time to their machambas in the wet season. Cross tabulating these results it appears as if those earning a higher percentage of income from charcoal are in the latter group. This indicates dependence on the money earned from the activity to last the whole year, whilst others supplement their income throughout the year with kilns made when money is required. This follows Stack *et al.,* (2003) “hanging on” “stepping up” and “stepping out” observations on livelihood strategies in Africa. Although not readily quantifiable it appears as if charcoal production in the CR is a means to improve livelihoods either as an activity of last resort in some instances, a quick way to make money for essential products (salt and soap) or as a means to diversify income and improve food security.

3. *How are charcoal production activities distributed throughout the study area?*

Charcoal production in the CR as concentrated within a strip 2 km wide along the EN–1 from Inchope to Gorongosa town. The reason for this pattern is the ease of access to the EN–1, which is the selling point for all the charcoal produced in the area. This pattern of exploitation has also been observed in Tanzania along the Morogoro highway, the main supply road for Dar es Salaam (Hofstadt, 1996; Malimbiwi *et al.,* 2005) and the EN-1 into Mapto (SEI, 2001).

Currently charcoal is produced in areas of relatively high forest cover providing the raw inputs for the process. However, as cover declines to a level where distances between trees becomes prohibitive to making kilns due to increasing labour costs relative to charcoal profits, producers move to areas with improved stocking characteristics in search of higher profits (SEI, 2001; FAO, 2000; Chidumayo, 1997). Where this process is carried out in a large area and over a long time period the activity the activity resembles a managed rotation period (pers. comm. Brito, 2007). Where this is not the case due to increasing population pressure, production areas are visited more frequently and/or exploited to a greater extent, thereby reducing the forests capacity to regenerate, and ultimately leading to deforestation. In the case of the rotational system Hofstadt (1996) observed that charcoal production in miombo woodlands in Tanzania was not occurring in areas with stocking densities lower than 20 m^3 ha^{-1}, and assumed that this was the lower limit for production. Unfortunately no data was collected on the stocking density of woodlands at the kiln sites, but an average forest cover the whole CR was estimated at 60 m^3 (Wallentin, 2006). Cross referencing the LANDSAT deforestation data (1991-2000) with kiln distribution reveals some correlation between the two, though more recent images are likely to offer a more complete picture. However, deforestation further west of the 2 km strip indicates that forest clearance for agriculture purposes is the predominant driver for land use change in the area (Flaherty, 2007).

On a smaller scale charcoal production has also been shown to affect species composition of miombo woodlands. This is primarily driven by the exploitation of the preferred species, but where these become increasingly scarce a wider selection of species are used. The extent of this was observed in the south of Mozambique where trees prohibited for wood fuels due to their timber quality were used for charcoal (SEI, 2001) and the use of cashew nut trees (*Anacardium occidentale*), in Tanzania indicate the higher returns of charcoal compared to an export crop (Luoga, Witkowski & Balkwill, 2000). This is also happening to some extent in the CR where the 5th most used species is *Swartzia madagascariensis* a valuable timber tree. This outlines the need for SFM due to current exploitation of preferred trees species, and is highlighted by Williams *et al.,* (2007) study where regenerating machambas did not contain the characteristic miombo tree species of *Brachystegia spiciformis* and *B. boehmii* predominantly used for charcoal production in the CR.

Without a sustainable production system in place the increasing demand for charcoal is likely to fuel deforestation in excess of the 2 km strip that is the current limit of production.

4. ***What are the legal regulations surrounding charcoal production and how is this enforced?***

Due to the low percentage of profits derived from each bag by charcoal producers in the commodity chain they often attempt to increase their returns through operating illegally, for example producing without a license (SEI, 2001; Mutimba, 2005; Ribot, 1997). Illegal activities of this type are rarely identified as the lack of funds to support control and measures and many therefore avoid detection. With limited institutional capacity these unregulated activities can result in the unsustainable exploitation of forest resources. The study identified that 15 % of the producers surveyed were producing charcoal illegally without licenses. However, on closer examination it was clear that even those with licences were operating in a dubious fashion with regards to the licensing law. What made things more complicated was that neither the producers, nor the government official issuing simple licences in the Gorongosa district office were clear of the specifics of the licensing system.

The current regulations state that as the CR falls within close proximity to the GNP only residents of these communities are permitted to hold a licence for producing charcoal for subsistence purposes. This legislation was introduced as a means to attempt to limit forest loss seen in the Mucombezi Community Lands to the south of the Pungue River, thereby reducing pressure on the parks resources. The licenses issued permit the production of 60 sacks of charcoal for three or less people at the cost of US$ 28 and covers production activities over a period of one year and once the 60 sacks have been produced another license is required (pers. comm., Maugente, 2007). At current prices (US$ 2 per sack of charcoal sold at roadside) the total revenue derived from this type of license would be US$ 120 with profits of US$ 92. The poor returns of the activity performed in a legal manner explain the motives for operating in an illegal manner.

This was observed in the field where 15 % of producers ran the risk of producing illegally without a license to achieve greater profits, whilst the majority operated in a group system under a single license. This strategy thereby reduces the capital outlay to operate in a seemingly legal manner. The extent of this strategy can be seen where 25 people were operating under a single license. In order to avoid detection the group's license is left at the estaleiro in the event of an inspection. However, in reality the lack of control and monitoring of the quantity of bags produced under this licence system mean that charcoal output is far in excess of the 60 bag limit stipulated, and has serious implications for SFM.

Evidence from this study has shown that charcoal production is a subsistence activity and that due to limited capital available the licensing system will always be manipulated for greater profits. This therefore validates the need to manage production within a livelihoods approach, such as CBNRM.

5. ***How efficient are the kilns used in the study area and what is the level of deforestation is attributed to charcoal production?***

Calculations of the kilns surveyed in the study estimated that the conversion efficiency from timber to charcoal was 17.6 % and demonstrates the inefficiency of charcoal production in the CR. However, this was higher than the 13.7 % in Pindanganga, Manica Province (Falcao *et al.,* 2006) and between the 14.5 and 19.5 % of the Licuati and Chipango Districts of Maputo Province (SEI, 2001), and the 14.7 – 19.6 % in Tanzania estimated by Hofstadt (1996).

The maximum conversion rate achievable for traditional earthen kilns lies between 25 - 35 % (SEI, 2001) and as mentioned previousley depends upon a variety of factors, one of which is the level of moisture in the wood. High moisture content results in biomass that would have been carbonised is instead burnt to drive off the moisture, and leads to lower charcoal yield and a lower conversion efficiency. The time preference of rural poor in the study area often means that this wood drying stage is bypassed to be able to complete burn and sell the charcoal as fast as possible. However, time taken at this stage as well as tight packing of kilns, in combination with monitoring at the carbonisation stage could result in increased yields and profit margins.

It was estimated that the average productivity per year for males was 116 and 38 bags of for females. Extrapolated over the population surveyed this amounted to 6078 bags per year or 1978 m^3 of timber. Accounting for the 135 m^3 of total annual stump wastage, an estimated volume of 2113 m^3 of timber was felled in the CR per year by the 62 producers. Considering these figures, which are likely to be an underestimation of the number of people producing charcoal in the CR we can estimate that this accounts to harvesting 35 ha ((2113 m^3 / 0.788 t m^{-3}) / 38 t C ha^{-1} *2) of woodland per year.

Based on the 0.7 t C ha^{-1} yr^{-1} growth rate of miombo species estimated by Williams *et al.,* (2007) and the current harvesting rate for charcoal production we can estimate that 1915 ha (2113 m^3 / 0.788 t m^3 / (0.7*2) t ha^{-1} yr^{-1}) is required to support this level of charcoal production indefinitely. This assumes that all woody growth can be used for charcoal, which is unrealistic. Charcoal species probably only account for 30-40% of biomass in the local woodland, so the area would need to be scaled up by this factor for sustainable production.

6. ***What are the barriers to sustainable charcoal production in the Chicale Regulado?***

As alluded to in previous chapters the main development strategies to jointly address poverty and environmental improvement are to increase poor people's access to natural resources, through enhancing the productivity natural resource assets, and involving local communities to resolve their natural resource management concerns (Scherr, 2000). This study has attempted to adopt these principles for sustainable charcoal production in the CR. The initial results indicate that with a suitably large area for charcoal output equalling current levels, and managed on a 30 year rotation period, a sustainable charcoal production system is feasible. There is importantly recognition from the charcoal burners (93 %) that their actions are contributing to deforestation in the area, and the potential for sustainable charcoal production was therefore greeted with some enthusiasm at the feedback meeting. A concession area was proposed by the participants for the activity indicating their ability to plan for such a project, and also acknowledged their lack of capacity at present to manage such a system at present. They were responsive to new technologies for increased outputs, though were adamant that the options and training be offered before any decision is made.

Socio-institutional mechanisms governing access to resources have a crucial role to play (Bene, 2003), and is demonstrated by the licensing system for charcoal production currently in place in the CR. There is need for a more diverse and flexible range of measures, tailored to local priorities and conditions to ensure that poor people can access the social benefits as well as conservation objectives (Smith, Khoa & Lorenzen, 2005). Diversification of livelihood incomes from this CBNRM initiative for sustainable charcoal production will be a key his will be a key issue for its success. Opportunities such as the PV system and others offered by the Nhambita Pilot Project will contribute to this as the project becomes further established in the dynamics of the community and help to offset the additional costs associated with sustainable production.

7 CONSIDERATIONS FOR SFM

The first step towards sustainable charcoal production in the CR has been undertaken through this study. It has evaluated the livelihoods of charcoal producers and the extent of their activities on the forest resource and elicited a positive response for the adoption of sustainable production in the area. There is however a considerable amount of work leading to the implementation of such an initiative. This chapter links the information gathered from the literature review and the results identifying some of the key factors that need to be addressed for sustainable charcoal production.

7.1 Dynamic Inventory

One of the outcomes of the PRA exercise was the proposed site for sustainable charcoal production system. The next step required is to determine the suitability of the concession area. A dynamic inventory of the proposed area must first be conducted to determine species composition, tree density, growth rates etc. over time for the site. This is particularly important as this data forms the basis for SFM through setting the sustained yield of the area (Higman *et al*., 2000).

7.2 Management Plan

Under Mozambican law a management plan must be submitted along with the proposed application for a concession area. The main factors to be considered in the management plan for sustainable production in the proposed area are outlined below.

7.2.1 Annual Allowable Cut

Data collected from the dynamic inventory should be linked with the work of Williams *et al*., (2007) on miombo growth rates to determine the Mean Annual Increment (MAI) for charcoal species in the concession area. This information can then be used to ensure that the quantity of timber removed from the forest does not exceed the rate of replacement, commonly referred to as the Annual Allowable Cut (AAC). This can either be calculated on a volume-based or area based calculations depending upon the site's characteristics (Higman *et al.,* 2000). The AAC can then be used to determine the quantity of charcoal produced on a sustainable basis. Initial calculations have shown that 1915 ha are required for sustainable production at the current harvesting rate. This though is an underestimation of the concession area needed as explained earlier in the discussion, and an area of 2585 ha is more realistic.

7.2.2 Silvicultural system

Both natural and artificial regeneration have a role to play in miombo management for wood fuel, though the degree to which will play in the concession area will depend upon the species characteristics, local environment and socio-economic conditions found in the inventory. Given the propensity of most miombo species to coppice (Chidumayo, Gambiza & Grundy, 1996; Chidumayo, 1997; Frost, 1996) the management of the concession under a coppice with standards rotation silvicultural system has been recommended in the literature by Luoga, Witkowski, & Balkwill, (2004), Matthews, (2001) and Chidumayo (1997).

7.2.3 Harvesting System

Selective harvesting and clear-cutting techniques are both recommended for sustainable management of miombo woodland following a coppice with standards system. Clear cutting, is the best way to encourage regeneration from the stump and seedlings as well as maintaining species diversity, which is not the case with selective harvesting (Chidumayo, 1997). Clear cutting can have negative effects on catchment hydrology (Matthews, 2001) though this can be minimised through leaving shelterbelts/strips between harvested areas (Figure 20) as demonstrated by the Forest Department of Zambia in the management of miombo woodlands for woodfuel (Chidumayo, 1997). Once there is adequate regrowth in the harvested areas (approximately 10 years) the shelterbelts can be felled with the regenerating areas taking over the role of minimising hydrological disturbances.

The rotation period must be fixed to ensure sustainable production. This decision will be influenced to some extent by the type of kiln used as to the size of product required. For medium pole sizes (20 – 38 cm DBH) a 20 to 30 year rotation period has been suggested (pers comm. Falcao, 2007; Chidumayo, 1997).

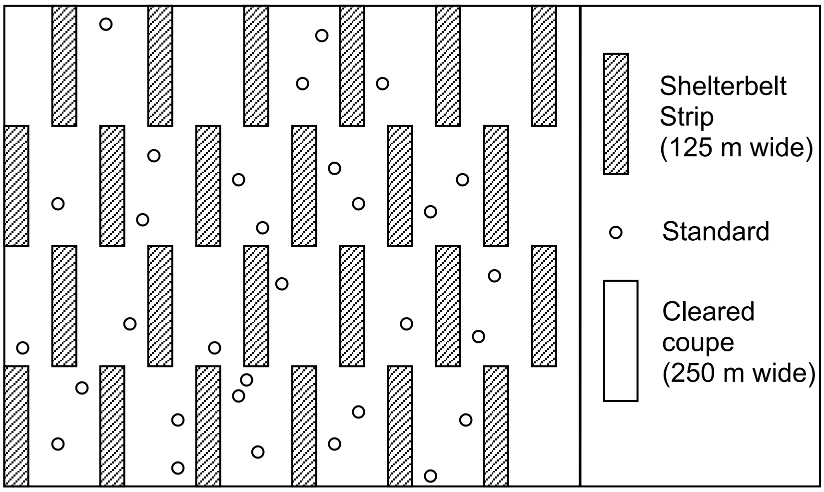

Figure 20 Representational drawing of a coppice with standards silvicultural system with a clear-cutting with shelterbelt harvesting rotation. Source: Adapted from Chidumayo (1997).

7.2.4 Tree Felling Method

Tree cutting method and timing can affect the nature and the rate of regeneration (Chidumayo, Gambiza & Grundy, 1996). Currently in the CR tree cutting is practiced at waist height (Figure 21). This not only creates considerable wastage but also invariably renders the stem defective for coppicing (Chidumayo, Gambiza & Grundy, 1996). Improved felling techniques with a cut 15 - 30 cm from the ground, and at a 45 degree angle will prevent water collection and encourage vigorous regrowth (Chidumayo, Gambiza & Grundy, 1996). Managed in this way with the exclusion of fire, regeneration should produce dense stands of straight poles (Chidumayo, 1997) that could improve kiln efficiency due to improved stacking arrangement.

Figure 21 Examples of tree size and height of cut stumps in the Chicale Regulado by a) a female producer and b) male producer in Mbulawa District.

7.2.5 Fire Management

Fire is one of the most important issues regarding the regeneration of miombo woodlands Chidumayo, 1997; Stromgard, 1986). Coppice shoots and young seedlings are particularly vulnerable to fire events and efficient management is required to ensure sustainable production. Chidumayo, Gambiza & Grundy (1996) have shown that biomass production is more than 30 t ha^{-1} in areas where fire is excluded compared to areas with no fire control after 25 years. The use of early burning and the creation of fire breaks as well as clearing debris away from stumps could help minimise this risk in the concession area.

7.2.6 Kiln Technology

The current kiln efficiency kilns in the CR is 17.6 % with a maximum achievable efficiency of between 25 - 35 % (SEI, 2001). This shortfall in kiln efficiency in the current production process can either be improved through improving felling techniques, combined with the drying of timber and improved stacking techniques, as well as improved insulation of the kilns, or through the introduction of improved kiln technology. Kilns such as the Mark IV, Cusab Kiln and Gayland Batch Charcoal Retort have been tested in the south of the country and have shown higher efficiencies of 25-32% (SEI, 2001). However, observations by Brito (pers. comm.., 2007) have shown that improved kiln technology is not always successful and that it is preferable to work with existing technologies through increasing efficiencies, as explained above, or by fixed kilns. Whatever technology used the introduction of a briquette machine to compress charcoal fines into usable fuel would be increase kiln output significantly. In addition to this by-products (tars and vinegars) collected from the production process could also help to diversify charcoal incomes in the CR.

7.2.7 Charcoal Producers Association

Currently charcoal production in the CR is organised informally. However, for the proposed system to succeed, a participatory approach is required where the charcoal producing communities take ownership of the system through an association. CBNRM in this way would empower the association to manage the resource sustainably by the taking control of regulating and monitoring activities in the area. Achieving a capable association would enable decisions to be made to better serve the objectives of the program and the livelihoods of those involved.

7.2.8 Marketing

The marketing of sustainable charcoal produced in the CR will be a vitally important issue to address. The higher costs associated with sustainable charcoal production means that markets will need to be found to offset these additional production and management costs. Packaging distinguishing sustainably produced charcoal from conventional will be needed to differentiate between the two products. In addition to this cutting out the middleman (transporter) will generate higher profits. This can be seen that the direct sale of charcoal to vendors in Beira is triple that of the price along the EN-1, currently the norm in the CR (pers. comm., Maugente, 2007). A potential niche market is the GNP where the higher price of the sustainable charcoal could be included into the parks fee structure.

7.2.9 Funding from Carbon Credits

Sustainable charcoal production is associated with higher costs than the direct exploitation of forest resources. However, the promotion of the Clean Development Mechanism (CDM) through the Kyoto Protocol for sustainable forestry projects could potentially provide significant additional income through the verification of the process. In fact, preliminary calculations derived from ECCM have shown that the incomes (Appendix 4) based on the carbon credits of one tonne of sustainable charcoal is US$ 48, which is greater than the US$ 44 achieved for the sale of one tonne of charcoal based on the current vending system in the CR (pers. comm., Tipper, 2007).

Summarised in this way it can be seen that there is considerable work to be done before the production of verified sustainable charcoal from the CR. An inventory of the proposed concession is a key activity to ensure a sustainable AAC and that sufficient output is feasible for such a programme to be implemented. Following this the objectives of the management of the area need to be formulated in the management plan outlining the silviculture method, harvesting and rotation periods required. Adopting an association working in conjunction with Envirotrade Ltd, UoE and ECCM will be essential for sustainable management of the resource and verified charcoal.

8 CONCLUSION

In Mozambique, as in the rest of SSA, the consumption of wood fuels is increasing due to growing urban populations' dependency on charcoal. There are significant socio-environmental consequences related to the production of charcoal to meet this demand, which include forest degradation, loss of environmental services and health issues. In spite of these impacts charcoal production is an important livelihood strategy for many rural poor to diversify incomes. It is therefore crucial to link poverty, forest and energy supply with the growing acceptance of CBNRM as a means to improve rural livelihoods and forest conservation.

The study revealed that charcoal production was principally occurring within a strip 2 km wide to the west of the EN–1, and is one of the main land use activities contributing towards land use change in the area. Kiln conversion efficiency is 17.6 % and based on annual production rates an average of 1559 tonnes are produced from an estimated 35 hectares of cleared miombo woodland. For those involved in the activity it is an important livelihood strategy accounting for 74 % and 59 % of annual incomes for males and females respectively. In spite of this, 95 % of the producers fell below the US$ 1 poverty line, indicating that current production strategies are not capable of pulling people out of poverty.

Sustainable charcoal production built upon community participation in the community has therefore been seen as a way to address these issues and the results from this study suggest that it is feasible given growth rates and a concession area of approximately 2585 ha.

As a follow up to this study the suitability of the concession area proposed by the producers should be assessed through an inventory and written into a management plan for sustainable charcoal production. Further research should be carried out into offsetting the higher costs associated with sustainable production against the CDM.

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APPENDIX 1

LIST OF INTERVIEWED STAKEHOLDERS

Mr. Piet van Zyl – Project Manager, Envirotrade, Mozambique;

Mr. Antonio Serra – Operations Manager, Envirotrade, Mozambique;

Dr. Richard Tipper – Director, ECCM, Edinburgh;

Dr. Richard Beilfuss – Director of Scientific Services, GNP, Mozambique

Dr. Rob Morley – Forestry Consultant, TREES, Mozambique;

Dr. Lidia Brito – Forestry Department, UEM, Mozambique;

Dr. Mario Falcao – Forestry Department, UEM, Mozambique;

Community members and charcoal producers - Chicale Regulado, Mozambique;

Mr. Alfredo Maugente – Planning Officer, Sofala Forestry Department, Mozambique;

Mr. Mozinho Antonio – Forest Guard, Gorongosa Agriculture Department, Mozambique;

Dr. Agnelo Osvaldo – Forestry Department, UEM, Mozambique;

Mr, Noel Cooke – Technical Advisor, EU, Maputo, Mozambique

Mr. Marcelo Tisoula – President, Mucombezi Regulado, Mozambique;

Mr. Carlos Bento – Researcher, UEM

Mr. Philip Powell – Projects Manager, Envirotrade Ltd,

APPENDIX 2

CHARCOAL PRODUCERS / VILLAGE QUESTIONNAIRE

Date: ……………………… **GPS Location S**………………………

E………………………

Name:……………………… **Sex:** Male / Female **Age:**…………………..

PART 1 - LIVELIHOOD QUESTIONS

District……………................................ **Where were you born?**

What year did you arrive?.................... **What was your reason for Coming?**

Marital status:

Single		Divorced	
Married		Widowed	

Do you have children? Y/N **If so, how many?**...

Did you go to school? Y/N **If so, up to what level?**..

Are you employed? Y/N **If yes into which income bracket do you fall:**

0 - 500 Mts		1000 - 1500 Mts		2000 - 3000 Mts		5000 - 10,000 Mts	
500 - 1000 Mts		1500 - 2000 Mts		3000 - 5000 Mts		More than 10,000 Mts	

Do you own a machamba? Y/N

If more than one machamba how many hectares is each one?

1		3	
2		4	

How many machambas have you had in your life?...

What crops do cultivate on your machamba?

Maize		Beans		Other	
Sorghum		Sesame		Other	
Pigeon Pea		Pumpkin		Other	

Do you have enough to eat? Y/N **Do you have to buy food?** Y/N

Do you hunt? Y/N **Do you fish?** Y/N

Do you use the forest? Y/N **If so, what are your 3 preferred products?**

Forest Product 1	
Forest Product 2	
Forest Product 3	

What percentage of your income comes from:

Crops	
Charcoal	
Other	

When do you work your machamba? **When do you make charcoal?**

Are you part of the Plan Vivo scheme? Y/N **If yes – what system?**

1) Border Planting		4) Fruit Orchard	
2) House farm		5) Wood farm	
3) Intercropping			

How do you rate your present condition?

1)Well off 2) Self-suff 3) Mod poor 4) V poor

Are you better off than before the scheme? Y/N

Why?...

Do you have any savings? Y/N **In crisis where do you get money/help?**

Friends		Bank	
Family		Charcoal	

PART 2 - CHARCOAL QUESTIONS

Local of kiln?.......................... **Stage of Construction?............................**

Size of kiln?

Length (m)	
Width (m)	
Height (m)	

What are the tree species in your kiln?

Tree species 1	
Tree species 2	
Tree species 3	

What are your preferred tree species for charcoal?

Preferred tree species 1	
Preferred tree species 2	
Preferred tree species 3	

How do you select trees for charcoal?..

Do you fell the trees alone? Y/N

If no, who helps & how do you pay?...

Which trees would you not fell?

Tree species 1	
Tree species 2	
Tree species 3	

Why would you not fell these tree species?...

Would you fell these if there was no choice? Y/N

How long does it take you to fell?..

Size of trees:

Measurements	**Value**
Largest diam (cm)	
Height (cm)	
Smallest diameter (cm)	
Height (cm)	

How many trees per kiln?.................................... **Distance to furthest cut tree?........**

Do you own or rent any tools? Y/N?

If so, which ones?

Tool	What do you own?	What do you rent?
Axe		
Hoe		
Rake		
Other		

How long did it take you to construct the kiln?...

How long does the kiln burn for?

Did your kiln burn well? Y/N **If no, why not?..................**

How long does sorting take?......................... **How many bags per kiln?............**

Do you have to buy empty sacks? Y/N **If yes how much?**

Where do you sell your charcoal?...

Who do you sell your charcoal to?...

How much do you sell each bag of charcoal?...

How many bags do you sell per day?

Number of bags	
1 to 5	
6 to 10	
> 10	

Do you need a licence? Y/N **If yes do you have one?** Y/N

Are you part of a group? Y/N **What is the licence No/Name?**

How much do you pay?

Are you going to make another kiln? Y/N **If yes, where & when?.........................** **How many kilns do you make per year?..........................**

Do you plant after you fell? Y/N **Do you manage the coppice?** Y/N

What is the current condition of miombo woodland?

Good		OK		Bad	

What was the miombo woodland like 10 years ago?

Better		Same		Worse	

Why was it better or worse?..

Would you like to manage in a sustainable manner? Y/N

Would you like to work in a cooperative for sustainable charcoal production? Y/N

How like to work – alone/group? **Why?**

APPENDIX 3

List of Charcoal Producers by District

Name	Sex	Age	District
Alesandra Paulino	Male	50	Mbulawa
Antonio Mateus	Male	38	Mbulawa
Armelia Arlindo	Female	26	Mbulawa
Armerio Randinho	Female	21	Mbulawa
Armindo da Rocha	Male	54	Mbulawa
Arnita Ernesto	Female	22	Mbulawa
Ashnada Geraldo	Female	27	Mbulawa
Belinha Aique	Female	35	Mbulawa
Belinha Jaime	Female	27	Mbulawa
Esteria Augusta	Female	30	Mbulawa
Felipe Fernando	Male	35	Mbulawa
Fernando Manuel	Male	56	Mbulawa
Hjek Manjuta	Male	56	Mbulawa
Ignacio Luis	Male	60	Mbulawa
Ignacio Mateus	Male	30	Mbulawa
Ines Fernando	Female	32	Mbulawa
Jose Armindo	Male	24	Mbulawa
Luca Lorenco	Male	35	Mbulawa
Lucia Mario	Female	28	Mbulawa
Manuel Dias	Male	65	Mbulawa
Manuel Machelenga	Male	26	Mbulawa
Marciano Jose	Male	25	Mbulawa
Maria Antonio	Female	41	Mbulawa
Marta Armind	Female	17	Mbulawa
Paulino Augsto	Male	43	Mbulawa
Pedro Mateus	Male	27	Mbulawa
Rosalia Rocha	Female	50	Mbulawa
Samuel Mateus	Male	32	Mbulawa
Santos Manez Gil	Male	27	Mbulawa
Saringo Luis	Male	38	Mbulawa
Sobrina Maniz	Female	43	Mbulawa
Telezinha Bene	Female	50	Mbulawa
Tome Anonio	Male	31	Mbulawa
Vicente Augusto	Male	32	Mbulawa

Name	Sex	Age	District
Afonso Joaquim	Male	43	Povua
Alberto Mixeli Gil	Male	49	Povua
Antonio Candeado	Male	45	Povua
Antonio Sozinho	Male	36	Povua
Bernado Simbe	Male	47	Povua
Castro Antonio	Male	23	Povua
Eduardo Estevao	Male	46	Povua
Emilio Jose	Male	20	Povua
Fernando Raen	Male	28	Povua
Joao Estacio	Male	34	Povua
Joao Raene	Male	45	Povua
Joaquim Antonio	Male	67	Povua
Luis Seize	Male	55	Povua
Miguel Domingo	Male	29	Povua
Nelson Manuel	Male	31	Povua
Nerito Zeco	Male	22	Povua
Nhagoi Torz	Male	20	Povua
Patrice Sozinho	Male	14	Povua
Pedro Sozinho	Male	33	Povua
Saro Jose Nsingano	Male	26	Povua
Sergio Joaquim	Male	38	Povua
Shelinga Fosse	Male	47	Povua
Sozinho Pedro	Male	67	Povua
Thomas Sabao	Male	43	Povua
Torz Raene	Male	46	Povua
Zacharia Luis Seis	Male	25	Povua

Name	Sex	Age	District
Eusebio Journal	Male	30	Pungue
Rincastro Journal	Male	32	Pungue

APPENDIX 4

Sustainable Charcoal Carbon Offset Calculations

CO_2 Emissions Associated with Inefficient, Non-Sustainable Charcoal Production from Wood		
Wood used in kiln	5.7	kg woody biomass per kg char produced
Additional harvesting losses / damage	2	kg woody biomass per kg char produced
Total wood required per kg charcoal	*7.7*	*kg woody biomass per kg char produced*
Emissions from wood in processing and harvesting	6.4	kg CO_2 /kg
Emissions from combustion of 1kg charcoal	3.3	kg CO_2 /kg
Total	*9.7*	*kg CO_2 /kg char*
Energy content of charcoal	30	MJ /kg
Total CO_2 Emissions per MJ of charcoal	0.32175	kg CO_2 / MJ
Total CO_2 Emissions per MJ coal	0.091	kg CO_2 / MJ
Total CO_2 emissions per MJ natural gas	0.053	kg CO_2 / MJ
1 Tonne unsustainable charcoal =	9.7	tonnes CO_2
Carbon credit	5	$/tonne
1 Tonne sustainable charcoal	**US$ 48**	
1 Tonne unsustainable Charcoal	**US$ 44**	

Source: (pers. comm., Tipper, 2007)