THE ROLE OF SHORT ROTATION COPPICE TECHNOLOGY IN FUELWOOD SUPPLY IN RUNGWE DISTRICT, TANZANIA

BY

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ABSTRACT

The current study was carried out during October, 2010 to April 2011 in Rungwe District, Mbeya Region, Tanzania in order to: make an assessment of the role of Short Rotation Coppice (SRC) technology in fuelwood supply, determine the extent of its adoption by the community, identify various sources of household energy, determine the contribution of SRC technology to the total household fuel wood needs, the SRC tree and shrub species used as sources of fuel wood, determined the factors influencing the adoption of SRC technology and the corrective measures required for enhancing its adoption. The methods included reconnaissance, field and social surveys. Data collected was analysed using the Statistical Package for Social Sciences (SPSS). The results showed that the adoption status of SRC technology is almost 97.5% and most of the people gradually adopted the SRC technologies during the 1960s and accelerated in the 1970s. The main agents that spearhead the adoption were WATCO and various government extensionists. The most adopted SRC practices are planting *Eucalyptus* trees in woodlots and field boundary with *Persea americana* and *Leucaena leucocephala* being planted in mixed intercropping with agricultural crops. Moreover, the results showed that a total of 176 tonnes year^{-1} of fuelwood were consumed by respondents of which 128 tonnes year^{-1} (73%) were sourced from SRC technology, 44 tonnes year^{-1} (25%) from non SRC technology and only 4 tonnes year^{-1} (2 %) by buying to supplement the shortage. In addition, it was found that 66 m^3 of fuelwood from *Eucalyptus* plantations were sold monthly. SRC tree species that people prefer most were various *Eucalyptus species*. The study, therefore, recommends that the Government should encourage farmers to plant more SRC trees and shrubs, intercropping with other crops for fertility improvement, those that, contribute to food security, environmental conservation and amelioration.

DECLARATION

I, George Mbyazita Karwani, do hereby declare to the Senate of Sokoine University of Agriculture, that this is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

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The above declaration is confirmed

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DEDICATION

This work is mainly dedicated to my wife Zuhura Msigwa and my son Benson George for the trouble they had to shoulder towards the fulfilment of my education programme. It is also partially dedicated to my beloved parents Ms. Devotha Mbyazita, the late father Mr. Jacob Mbyazita and my brother John Mbyazita who laid the foundation of my education.

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ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of Variance
m^3	cubic metres
CRBD	Complete Randomized Block Design
DALDO	District Agricultural and Livestock Development Officer
FAO	Food Agricultural Organization of the United Nations
FGD	Focus Group Discussion
ha	hectare
i.e.	that is
ICRAF	International Council for Research in Agroforestry
kg	kilogram
LSD	Least Significant Difference
ProBEC	Programme for Basic Energy and Conservation
SADC	Southern African Development Cooperation
SPSS	Statistical Package for Social Sciences
SRC	Short Rotation Coppice
TAFORI	Tanzania Forestry Research Institute
TTSA	Tanzania Tree Seed Agency
URT	United Republic of Tanzania
WATCO	Wakulima Tea Company
WWF	World Wildlife Fund for Nature Conservation
yr	year

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

About 37.7 % (33 428 000 hectares) of the Tanzania's total land area is covered by forests (FAO, 2010). The forest areas are being harvested at a rate faster than the regeneration rate of forests. Deforestation was estimated at 0.97% or 403 350 ha per annum between 1990 and 2010. Therefore, Tanzania lost 19.4% of its forest cover or around 8 067 000 ha during that period (FAO, 2010). The main causes of deforestation are rapid population growth, poverty, clearing for agriculture, wildfires, policy and market failures, persistent reliance on wood fuel for energy, over-exploitation of wood resources and lack of land use plans and non adherence to existing ones. Deforestation is taking place in both reserved and unreserved forests but more in the unreserved forests due to inadequate resources to implement active and sustainable forest management. Besides the woodfuel, the country has considerable biomass resources in the form of forest and agricultural residues. To a varying extent possibilities exist for the economic conversion of these resources to energy for industrial and domestic purposes (URT, 2003).

Currently, 90% of the Tanzanian population depends on traditional biomass. Fossil fuels account for 7% and other sources account for 3% (URT, 2003). Woodfuel (firewood and charcoal) is the main source of energy to both urban and rural areas and will continue to be an important source of energy in the coming decade (Sawe, 2008). The Short Rotation Coppice (SRC) technology is the woody vegetation grown on a repeated coppice cycle of 3- 6 years specifically for the production of biomass. Because wood is the most capable renewable energy source, initiatives have to be undertaken to make biomass production more efficient. East Africa has been identified as a region with one of the greatest potentials for biomass production for energy in the world (Hoogwijk *et al.*, 2005). This is due in part to the region's large amount of marginal land that is not useful for food crop production, but could produce sustainable yields with SRC technology on steep slopes, degraded land or agriculture fallow (Siriri and Raussen, 2003). Coppicing is a traditional method of woodland management, which takes advantage of the fact that many trees reshoot from the stump or roots if cut down. Therefore, the SRC technology has been done to trees or shrubs with high biomass production, which are planted at high densities and harvested at intervals ranging from one to several years. Examples of the SRC trees and shrubs planted in East Africa are *Eucalyptus* spp., *Markhamia lutea, Sesbania sesban, Sapium ellipticum, Leucaena leucocephala* and *Glyricidia sepium* among others (Hoogwijk *et al.*, 2005).

The SRC technology offers options for enhancing the resistance and resilience to environmental change while at the same time satisfying the demand for wood fibres (Heller *et al*., 2003; Volk *et al.*, 2004). The implementation of SRC technology could provide effective alternative source of income and energy for small-scale farmers in rural areas (Volk *et al.*, 2004).

1.2 Problem Statement and Justification

Around 80% of Tanzanian population has very low purchasing power and depends mainly on wood fuel for cooking and heating (URT, 2003). The national forest programme in Tanzania (2001-2010) estimated a deforestation rate of between 130 000 ha and 500 000 ha (FAO, 2010). The main reasons for this deforestation are clearing for agriculture, overgrazing, bush fires, charcoal burning and over exploitation of wood resources. Chidumayo (1993) contends that deforestation caused by charcoal making and fire wood supplies in the miombo woodlands in Central Zambia were reversible when they implemented short rotation coppice technologies. According to Hoogwijk *et al.* (2005), short rotation coppice technologies play a role to the local community for fuel wood production.

1.2.1 Why Rungwe District

In Rungwe District there have been campaigns to emphasise the communities to plant trees every year (URT, 2003). However, cutting trees for household fuel wood consumption needs and pressure for firewood in tea curing factories (Katumba and Mwakaleli Tea Factories) exceed areas afforested. The information on the role of SRC technology in fuel wood supply to the communities in Rungwe is not yet established. A vast number of tea industries in developing world use wood fuel (firewood and charcoal) as the main source of energy. This is because it is usually the only domestic fuel available to the majority of the populations in developing countries (FAO, 2009).

Current consumption of forests in Rungwe District could by no means hinder their future availability. According to WATCO (2010), the company demands over 23 000 m^3 of firewood per annum (over 18 000 m^3 at Katumba and 5 000 m^3 at Mwakaleli Tea Factories respectively). However, these data can be revised. FAO (2009) reported that WATCO takes 1 m^3 or 0.65 tons of dry wood to cure 350 kg of tea. The smallholder farmers contribute much to the supply of fuelwood, which amounts to about 80% of the entire supply. Therefore, consumption of forest products (timber and non timber) should go in pace with sustainable management of natural forests and plantations.

1.2.2 Why SRC technology in Rungwe District

The introduction of exotic trees apart from indigenous trees in East Africa started nearly 100 years ago. Because of the Germans keen interest in the introduction of exotic trees, there is a longer experience with exotics in Tanzania than other East African countries. In Tanzania, *Eucalypts* were introduced in the 1880`s. In Kenya and Uganda introductions date back to around 1910. The main *Eucalyptus* species planted on a commercial scale in East Africa include *E. saligna, E. saligna x grandis, E. camaldulensis, E. tereticornis, E. maidenii* (Madadi *et al*., 2010).

In Rungwe District the tree species mainly planted are *Eucalyptus* due to fast growing rate and coppicing ability. According to the Technical order report (MNRT, 2001), the following species can perform well in the Southern Highlands, *Eucalyptus reginans, E. grandis, E. saligna, E. botryoides, E. citriodora, E. globules, E.maculata, E. maidenii, E. microcorys, E. paniculata.* On the other hand, the TTSA recommends the following tree species in Rungwe District, *Eucalyptus globulus, E. grandis, E. maculata, E. maidenii, E. pellita, E. robusta, E. saligna.* Currently *E. grandis* originated from Australian provenance is the mostly planted in plantations, and the seedlings are readily available to smallholder's farmers. Therefore by providing rapidly growing, local sources of fuel wood, SRC practice will reduce pressure on natural forests most of which are reserved.

1.2.3 Why study the household sector

There are a number of sectors that consume energy. The household sector is used in this study because it consumes the greatest portion of it. In developing countries, the household sector accounts for 30-95 % of total energy use (FAO, 2010). In sub-Saharan Africa (SSA) the household sector is the main consumer of energy: cooking alone takes up to 60-80 % of the total national energy use. In low-income sub-Saharan Africa, the household sector consumes 50-95% of the total energy (Kaale, 2005). In SADC region, households consume 97 % of wood energy for cooking, heating and cottage industries. In Tanzania, the household sector consumes more than 91% of total energy in the country (Kaale, 2005; Simon and Kaale, 2005).

The present study, therefore, was to determine the role of SRC technology as a renewable and sustainable option to the deforestation for high fuelwood demand, identifying and recommending SRC tree and shrub species for energy generation in Rungwe District. The study also quantified the fuelwood consumed from none and SRC technology trees / shrubs in kilograms and compared them to the total fuelwood consumed. The results obtained will provide opportunities, stimulate and develop decision support tools to promote and adopt the SRC technologies to improve peoples' livelihoods, environmental conservation to the study area and other part of Tanzania by growing more SRC tree and shrub species.

1.3 Objectives

1.3.1 Main objective

The main objective of this study was to make an assessment of the role of Short Rotation Coppice technology in fuel wood supply in Rungwe District, Tanzania.

1.3.2 Specific objectives

(i) To determine the extent of adoption of SRC technology in the district.

(ii) To identify various sources of household energy used in the study area.

(iii) To determine the contribution of Short Rotation Coppice technology to the total household fuel wood needs.

(iv) To identify the SRC tree and shrub species used as sources of fuel wood for the households in the study area.

(v) To determine the factors influencing the adoption of SRC technology and corrective measures required for its enhanced application.

1.3.3 Research questions

(i) What is the extent of adoption of the SRC technology in the district?

(ii) What factors are influencing the adoption of SRC technology?

(iii) Which various types of energy sources do households use?

(iv) How much volume (m^3) or weight (kg) do the SRC trees contribute to the total fuelwood of household consumption?

(v) How much volume (m^3) or weight (kg) from other non SRC trees contributes to the total fuelwood needs of household's consumption?

(vi) Which measures should be taken to enhance the use of SRC technology?

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 The Extent of Adoption of SRC Technologies

Adoption refers to integration of new concept, idea or technology. It implies repeated usage of the technology (practice) overtime. It means the ability to make decisions regarding resource uses and technologies. The rate of adoption of SRC technology varies with regard to preferences within the communities and may be influenced by various key factors in decision making such as: social, economic and political factors (Pierre and Sylvain, 2007). Sometimes is very difficult to understand farmer's needs due to local barriers like culture or knowledge and level of understanding or exposure. Extension staff must understand this so as to influence farmers to make useful decisions. According to Ajayi *et al*. (2007a) and Barret *et al.* (2006) it is the realization of farmer's decision to apply the new technology in his/her production process; whereas the final decision is the degree of using the new technology in long run equilibrium of the technology. Therefore, the technological adoption means convention of innovation into farmer's adoption of the new technology; it explains the adoption decision that primarily explains adoption in terms of the decision makers, perception and inherent characters. However, actual decision arrived depends on complex bargaining processes among the householders (Scherr and Muller, 1991). Beyond the household group processes and abilities to harness them can play a crucial role in adoption decision.

Impact assessment on forest ecosystems in Tanzania shows that subtropical thorn woodland currently in existence will be completely replaced (URT, 2003). Subtropical dry forest and subtropical moist forest will decline by 61.4% and 64.3% respectively. There will be an increase in the very dry, dry and moist tropical forests, which are likely to replace the current life zones. The Forest Gap Model predicted that some species are more vulnerable to climate change than others, particularly those; that are drought/heat intolerant with low germination rates, with low survival rate of seedling and with limited seed dispersal/migration capabilities. Since many Tanzanians depend on forests for their subsistence and income, which provide timber, non-timber forest products and fuelwood, the adverse climate change impacts will reduce the ability of the forests in providing timber and non-timber forest products to the communities. According to FAO (2009) the potential for woodland to produce fuelwood mainly hinges on the ability of the woody species to regenerate and grow. Harvested miombo woodlands for woodfuel production would normally regenerate by coppicing and recruitment from stunted saplings. Because of regeneration in areas previously cut and if there is no further disturbance, such areas usually revert to woodland, thus increasing the potential of the area to supply fuelwood over a much longer period.

2.1.1 Concepts of SRC technology

Coppicing is the traditional method of woodland management which takes advantage of the fact that many trees reshoot from the stump or roots if cut down (Chileshe and Kitalyi, 2002). Short rotation coppice refers to a perennial fast growing, high yielding woody crops that is harvested every two to five years and managed under a coppice system (Evans *et al*., 2007). For a coppiced technology, young tree stems are repeatedly cut down to near ground level in subsequent growth years, many new shoots emerge and after a number of years the coppiced tree, or stool, is ready to be harvested and the cycle continues. Coppicing practice depends on the aim and nature of the crop. For example, coppicing practice for fuelwood production refer to Plate 1, likewise grazing pasture trees are cut back to knee height stimulating new shoots production for firewood and animal forage. Coppicing enhances a bush regrowth producing many branches (Chileshe and Kitalyi, 2002) for firewood and timber, among others.

Plate 1: The managed coppices of *Eucalyptus* species from old stumps in Rungwe District, Mbeya, Tanzania

2.1.2 Concepts of bioenergy

Bioenergy is the energy derived from biomass (Upham, 2005). Biomass may be produced by the purpose from grown woody trees or shrubs, forests, sawmills and agriculture. Biomass may be utilized directly for heat energy or converted into gas, electricity or liquid fuels. In addition, (Upham , 2009) contends that there is a vital difference between energy production from fossil fuels and from biomass. Burning fossil fuels releases CO_2 that has been locked up for millions of years. In contrast, burning biomass simply returns to atmosphere the CO_2 that was absorbed as the plants grew and there is no release of CO_2 if the cycle of the growth and harvest is sustainable.

According to FAO (2005), wood fuel is all types of biofuels from trees and shrubs grown in forest and non forest lands, including on farms. The term includes fuelwood and charcoal derived from silvicultural activities such as thinning, pruning, and harvesting such as tops, roots and branches.

2.2 Various Sources of Energy in Rungwe District

Biomass derived energy, petroleum, hydropower; solar energies have been sources of energies in Rungwe District. According to URT (2003) about 99% of the local communities in Rungwe District depend on biomass derived energy as source of their energies. Likewise, the petroleum, hydropower and coal are the major sources of commercial energy in the country. The biomass energy resource, which comprises fuelwood, charcoal and crop residuals, accounts for more than 93% of total energy consumption (Wiskerke *et al.*, 2009). The electricity sub-sector contributes about 0.6% of total energy consumption and is mainly generated from hydropower. Wind, biogas and solar are other sources of energy but very little attempt has been made to utilize them which could be viable alternative sources to reduce the use of wood and oil for heating purposes (Table 1).

Table 1: Overview of annual per capita wood fuel consumption in Tanzania as determined by different authors

Annual /capita wood fuel consumption (tonne/ capita/ year	Source
1.40	(Bradley, 1991)
0.80	(Bradley, 1991)
0.73	(Skutsch, 1983)
1.70	(UN, 1993)
0.85	(MNRT, 1998)
0.87	(EC-FAO, 1999)
1.09	(FAO, 2005)
0.75 – 1.13	(Kaale, 2005)

Source: ProBEC (2006).

2.3 The Contribution of SRC Technology to the Total Household Fuel Wood Needs

Despite other sources of energy to the local communities in Rungwe District, SRC technology has been contributing much to fuel needs. Multipurpose tree and shrub species which can be suitable for fuelwood and charcoal production include: *Casuarina equisetifolia* (fuelwood), *Calliandra calothyrsus* (fuelwood), *Leucaena leucocephala* (fuelwood), *Senna siamea* (fuelwood), *Parkinsonia aculeata* (fuelwood), *Acacia tortilis* (fuelwood) and *Tamarindus indica* (charcoal) (FAO, 2003). Also it underlines that *Acacia mearnsii* and *Eucalyptus* species can be used as fuelwood. According to Munishi *et al.* (2007) out of the 600 species of *Eucalyptus* only few are used in Tanzania including *Eucalyptus saligna, E. grandis, E. camaldulensis, E. globulus, E. viminalis , E. citriodora, E. regnas* and *E. microtheca.*

2.4 SRC Tree and Shrub Species Used for Fuelwood, SRC Practices and Preferences by Households

2.4.1 SRC tree and shrub species used for fuelwood by households

The survey conducted by Buchholz *et al.* (2009) in Uganda, East Africa, used the ability to coppice, biomass productivity, survival capacity, ecosystem integrity, growth shape, high quality fuelwood and local acceptance among other criteria, to identify suitable SRC species for the target region. Among the SRC woody species found in Uganda suitable for fuel wood were *Acacia mearnsii*, *Eucalyptus grands*, *Sesbania sesban* and *Markhamia lutea.* FAO (2003) underlined that productivity of tropical plantation forests grown on short to medium-term rotation lengths varied greatly from 1-2m^3 ha^{-1} yr^{-1} to 25-30m^3 $ha^{-1}yr^{-1}$. Among major tree species adopted for planting by most smallholder forest practitioners in Tanzania is *Eucalyptus* (Munishi *et al.*, 2007).

2.4.2 SRC technologies used

SRC technologies usually denote specific land management units and usually consisting of various trees or shrubs. The various ways in which the SRC components are arranged on the resource management unit constitute SRC practices Buchholz *et al*. (2009).

2.4.2.1 Woodlots

The term "woodlot" is near replica of wood vegetation assortment in smallholding. It is a tract of land of any size and shape that contains naturally occurring or planted trees (Ramadhan *et al.,* 2004 cited by TAFORI, 2004). SRC technologies are increasingly adopted in Rungwe District for the purpose of improving fuelwood supply and combating soil degradation. For each purpose, different tree species are preferred by local smallholders in this way, not only land utilization can be optimized, but labour utilization as well. According to Madadi *et al*. (2010) woodlots can be practised purposely for wood production by considering fast-growing tree species (Plate 2). Rotational woodlot technology involves growing of trees and crops on farms in inter-related phases. Three phases can be distinguished in this technology. The tree establishment and intercropping phase, the tree fallow phase and the cropping phase. During the first phase, trees and crops are planted. After 2-3 years of tree growth, the tree crown cover starts to block sunlight too much and tree roots compete with crop roots, causing lowered crop yields and the whole exercise becoming uneconomical. In this phase the area is left fallow and cattle is allowed to graze. At the start of the last phase, the trees are harvested and crops are planted in between the copping tree stumps. Coppice shoots are pruned so that a single new stem is growing (Nyadzi *et al.,* 2003).

Trees not only have the capacity to provide wood and fodder, they can also, function as a natural fertilizer by fixing nitrogen in the soil, which increases crop yields. Yields can thus be maximized by using smart combinations of trees and crops. Like all organisms, trees are following a logistic growth pattern over their lifetime. In theory, the optimal rotation period that maximizes wood yield is achieved when the annual growth increment is equal to the mean growth increment over the growing period. In this way the mean growth increment can be maximized over successive rotations. According to Ramadhan *et al*. (2002) rotation of woodlots in *Acacia* provided fuel wood within five to ten years of establishment (Plate 2).

Plate 2: The stock of wood behind a woodlot belonging to Katumba Tea Factory in Rungwe District, Mbeya, Tanzania

2.4.2.2 Mixed intercropping

SRC is an energy crop which usually consists of densely planted, high-yielding varieties and the establishment of SRC plantations has much in common with agricultural or horticultural crops as well as forestry (Chileshe and Kitalyi, 2002). Sustainably managed SRC provides a source of renewable energy with virtually no net carbon emissions i.e. no increase in atmospheric carbon (Upham, 2009). Thus stems are usually harvested from SRC plantations every 3–5 years, coppice stools remain productive for up to 30 years before they require replacing and coppice stems are usually cut and chipped Buchholz *et al*. (2009). Planting SRC in place of conventional agricultural crops increases farm diversification and reduces chemical input. Additionally, the plantations form an interesting alternative landscape and habitat type for wildlife.

2.4.2.3 Field boundary

The boundary site by definition implies a special situation with respect to land and tree tenure (Gardner, 2009). This is the practice in which the woody perennials (trees and shrubs) are planted along the farm boundaries to obtain various wood products and for demarcation to avoid conflict with neighbouring farmers (Plate 3). Also trees may be planted on the windward sides as windbreaks to protect crops against strong winds. In semi-arid areas, this practice is adopted most by farmers who have shortage of land.

According to Gardner (2009), boundary planting may be widely or closely spaced, in single or multiple lines. However, the common form of boundary planting consists of a single line of widely spaced trees and shrubs. Depending on the tree species availability, along the boundary, it may be possible to combine with timber or fruit trees for profit maximization.

Plate 3: Field boundary practice in Isumba Village, Rungwe District, Mbeya, Tanzania

2.4.3 Tree and shrub preferences for fuelwood

Practically all tree species could be used as fuel wood. There is normally, a group which is generally more preferred. Such species are usually fast growing, have ability to coppice, burn without excessive smoke and unpleasant odours. The choice of species is nonetheless now very restricted in some localities due to unavailability of some of the preferred species in sufficient quantities. Among the indigenous species, the most widely used species in different SADC countries are *Acacia erioloba*, *A. karroo, A.nilotica, Brachystegia* spp, *Combretum* spp, *Julbernadia* spp, and *Terminalia* spp. The exotic tree species that are being grown for provision of firewood include *Eucalyptus* spp., *Casuarina cunninghamiana* and *Acacia mearnsii* (FAO, 2003).

Woody perennial species are not ubiquitously distributed on the landscape. There is a great variation in distribution amongst woody perennial species found on each habitat. Their natural distribution is controlled mainly by edaphic factors, the amount of precipitation and the means of the dispersal (Munishi *et al.,* 2004). However, there are few species that have got a wider range of environmental conditions and thus they are more widely distributed than other species. Perhaps this is due to a wider range of environmental fluxes while the rest of the species are confined to specific environments and hence, therefore, they are not found in every ecological condition. For example high rainfall, high altitude, alkaline soil and desert (Munishi *et al.*, 2004). In most cases smallholder farmers prefer to plant trees that they are familiar with, multipurpose, fast growing and / or have short term return rather than trees that have long- term maturing periods such as timber trees (Rogers *et al.,* 2005; Wambugu *et al*., 2006). Generally, farmers prefer tree species that are fast growing and produce good quality fuel wood, have ability to do well in poor soils, have ability to sprout or coppice when subjected to cutting or burning, or can be sold as poles and firewood (Oduol *et al.*, 2006).

2.5 Influencing Factors in the Adoption of SRC Technology and Corrective Measures Required for its Enhancement

2.5.1 Influencing factors of the adoption of SRC technology

There are several known factors that have been observed to affect planting SRC trees and shrubs in rural areas (Ssemwanga *et al.*, 2004), including lack of extension service, policy support, land tenure, farmer's education, farmer's income and species preferences and the controversy which have been facing planting of some short rotation coppicing tree species such as *Eucalyptu*s which have been facing controversies and critiques based on technical, ecological and socio economic arguments (Munishi *et al.*, 2007). The main argument being removing too much water from underground reserves and streams, inhibit the growth of other vegetation among others.

2.5.1.1 Lack of extension services / workers

Extension services are critical components in adoption of the technology, across a wide range of issues including natural resource management. In order to ensure successful developments in adoption of technologies, a holistic approach is required. Multifunctional extension programs are useful strategies for accomplishing integrated rural development and can include environmental, economic and agricultural productivity goals. Many extension services providers tend to operate in areas that are easily accessible. It is therefore harder for farmers in remote areas to access technical assistance (Dulal *et al.,* 2011).

Extension workers are responsible with the dissemination of SRC technologies and make sure that they strengthen the human and social capital such that they can continue the adoption of the technology (Reed, 2007). This shows that the extension services, in the process of the dissemination, can have as much impact on the adoption as the nature of the technology itself. It is important to understand different approaches that may be used by different stake-holders, people’s perceptions in the implementation of the practices and the effectiveness in achieving the objectives identified (Franzel *et al.,* 2002). Lack of extension workers and insufficient time for farmers to get used for the new technology may seriously affect the dissemination and adoption of the SRC technology. According to Ssemwanga *et al.* (2004), technology dissemination entails not only training but also making the technology available to the users and that should be played by extension workers. Therefore, extension contact is a key variable in developing a favourable altitude among farmers towards the technology (Ajayi *et al.,* 2007b).

2.5.1.2 Farmers education

Farmer's attainment of education is an important tool for enhancing the technology. According to Scherr (1999) who reported that, resources might be well managed by people if they have education, through education farmers may know the rationale for taking care of their farming practices and other socio- economic factors. On the other hand, Senkondo *et al.* (1999) revealed that the adoption of rain water harvesting technologies in Western Pare Tanzania is not significantly explained by education but rather other factors such as experience in farming and perceived technology characteristics.

2.5.1.3 Shortage of land and land tenure

Rogers (2003) reported that farmer's control of and accesses to land are major factors limiting the uptake of technologies. Certain technologies such as SRC are inherently long-term, requiring security of tenure over land for an extended period of time (Ajayi *et al*., 2007a). Many farmers are resources poor and may lack land security, thus are unable to invest in such technologies. Even where tenure security is given, benefits might only accrue after some years (Franzel and Scherr, 2002).This might be the reason why studies of the privatization lead to increased investment and more sustainable practices (FAO, 2003). In such cases to facilitate the adoption of the SRC technology measures that provide short-term benefits or often incentives are required even if they make some compromises.

2.5.1.4 Perception of the decision makers

The decision of the adoption of the technology depends on complex bargaining processes among the household makers. The process can go beyond the household group (Cramb and Culasero, 2004; Barret *et al*., 2006; Doss, 2006) and ability to harness them can play an important role in adoption decision. The final decision is the degree of using the new technology in a long run. The decision maker's perception and the inherent characters of

SRCs are important aspects in this context (Barret *et al*., 2006). In order to have effective adoption, a farmer must first recognize the existence of the problem (Sood and Mitchel, 2004; Kristjanson *et al*., 2005), which may either be soil erosion or crop failure. These depend on the personal experience perceived by the farmer who decides which methodology to adopt.

2.5.2 Corrective measures required for enhanced dissemination and adoption of SRC technology

The highly successful and widely adopted SRC technologies are achieved by the provision of seeds and seedlings by the Government, active promotion of SRC by extension workers, Government support on land tenure and policy, by laws to prevent fire escape and enhancement of farmer's management skills.

2.5.2.1 Seeds and seedlings provision by the government

Smallholder's tree planting activities are often restricted by limited access to quality planting materials, poor nursery skills and a dearth of appropriate technical information (Aelback, 2001). Tree seeds are key input for promoting SRC technology. Deliberate efforts must be embarked on conducting studies on quality seeds of appropriate species which are important for effective innovation and intervention, particularly for smallholder farming communities (Simons and Leakey, 2004). Efforts must be made to link farmers with the sources of quality tree seeds and expand smallholder access to a wider range of species that are suitable to the biophysical and socio- economic conditions they confront (Michon, 2005). This should include developing farmers' tree propagation and tree nursery management skills.

2.5.2.2 Active promotion of SRC technology by extension workers

Government workers should take a leading role in the provision of SRC extension services. The training of the farmers and helping them to identify appropriate local or improved species sources, is very valuable in motivating their participation. In order for extension services to be effective there should be proactive involvement of farmers in the technology development process and in ensuring the appropriateness of the technology developed (Roshetko *et al*., 2004).

Extension workers have to ensure that they provide a meaningful learning that stimulates the desire to change and therefore seek for new knowledge and technologies. This may largely depend on the competence of the facilitators and their regular contact with farmers. They have to challenge farmers to aspire for improvement in their practices and link them to market chains and supporting agencies (Ssemwanga *et al.,* 2004).

2.5.2.3 Government support on land tenure and policy

SRC technology takes place on various land holdings thus reflecting different characteristics i.e. different tenure and policy systems on the land parcels. Appropriate land tenure and government policy support, are basic in enabling conditions required to facilitate the development of a wide range of SRC technologies on the smallholder land management systems (Roshetko *et al.,* 2006). Developing supportive land tenure and policy conditions often require broad-based negotiations that include participation from the local, regional and national governments as well as the private sector and community based organizations in enhancing SRC technology development (Fay and Michon, 2005; URT, 2005).

2.5.2.4 By- laws to prevent fire escape and enhancement of smallholder management skills

The adverse impact of bush fires on the productive capacity of soils in Africa particularly in the Sahel, Savanna regions and their influence on long term desertification is well established (WWF, 2006). Nevertheless, large areas of forests and shrubs continue to be lost year after year to bush fires all over the continent, undermining the long- term capacity to sustain agricultural and forestry production. According to WWF (2006), usually the bushfires are divided into two categories; those of natural origin and those of human caused origin. Natural fires are fairly rare and almost all the fires are initiated by people. According to URT (2003), a common cause is fire escaping from the control of farmers, charcoal makers and from honey collectors which is common in unreserved land where fires are handled with insufficient care. Fire, also, is used in various ways in traditional ceremonies and rituals, this has to be taken into account when developing a fire management approach by farmers. In addition, WWF (2006) contends that, some villages in Tanzania, however, had rules, regulations and by- laws for fire management although not well known to the communities. These include written permission from village officials to inform at least one member of the village environmental committee and all neighbours about the intention of using fire to clear land for cultivation and to create firebreaks five meters wide around the farm before setting fire. By laws to prevent fire escape are necessary at the village level so as to enhance the growth of trees planted (Lineal and Laituri, 2012). The productivity of most smallholder SRC practices can be improved by enhancing smallholder management skills such as: species selection versus site matching; identifying tree management systems that match farmers' land availability, labour, socio- economic limitations and the existence of accessible market.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials

3.1.1 Geographical location of the study area

Rungwe District lies between latitudes 9^{o} $00^{\prime}$and 9^{o} $30^{\prime}$ E and longitudes 33^{o} and 34^{o} S as shown in Fig. 1. The elevation ranges from 770 m a.s.l to 2 265 m a.s.l, with higher elevation predominating. Shares borders with Kyela District in the South, Ileje District in the West, Makete District (Iringa Region) in the East and Mbeya District in the North (URT, 2003).

3.1.2 Description of the study area

The study was conducted in three wards namely Kandete (Ndala Village), Kinyala (Isumba Village) and Mpuguso (Mibura Village) of Rungwe District in Mbeya Region. Rungwe District covers a total area of 2 221 km^2 of which 1 668.2 km^2 or 75% of the total area is arable land. The selection of the study area was based on the fact that the district is one of the major producers of tea in the country and had been implementing SRC technology to supply fuelwood to the tea curing industries and for household consumption (URT, 2003).

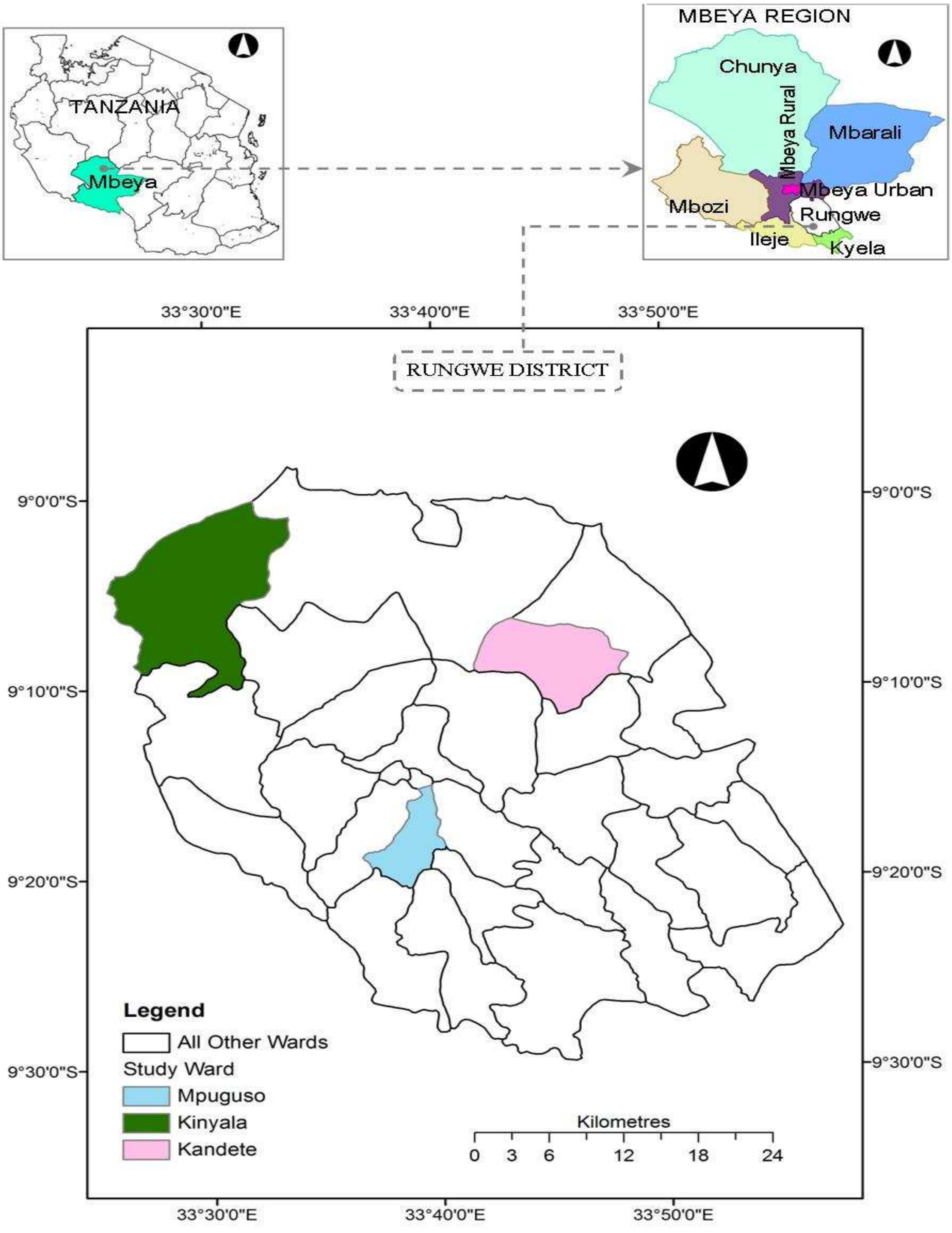

Figure 1: Map showing location of the study wards of Rungwe District

Source: URT (2003)

3.1.2.1 Climate and agro- economic zones

The district is mountainous with Rungwe Mountains and the Livingstone ranges rising from an altitude of 770 m to 2265 m above sea level. These mountains have great influence on the climatic condition of the district, which make it experience cold and rainy seasons. Average rainfall ranges from 900mm in the lowland areas to 2700mm on the highlands. Temperatures are generally modest and range from 18^o-25^oC all the year round. According to URT (2003) basically the District has three distinctive agro-economic zones, the highlands zone covers an area of 222.1 km^2 (10% of the district area). The zone rises to an altitude range of 770 - 2265 m above sea level. Generally, the upland zone is cold throughout the year with high rainfalls averaging between 1500 and 2700mm per annum. The area is suitable for agriculture and the main crops cultivated are potatoes, pyrethrum, maize, beans and vegetables.

The midlands cover an area of 1 666.2 km^2, 75% of the total land in the district, and experiences cold weather and receives average annual rainfall ranging between 800mm and 2200mm. The soils are good for agriculture and livestock development such as cattle, pigs, goats and poultry. The main crops grown are tea, coffee, avocado, cardamom, maize, beans, banana and groundnuts. The lowlands zone lies to the south of the district and covers about 15% of the total land area. It lies at an altitude around 772 m above sea level. The Lowlands zone receives average rainfall of between 900 - 1200 mm. The weather is generally hot and suitable for cultivation of paddy, maize, beans, cocoa and bananas.

3.1.2.2 Population

According to National Bureau of Statistics (2002), the district had 307 270 people with an annual growth rate of 0.9% and population distribution was estimated to be 139 inhabitants per km^2.

3.2 Methods

3.2.1 Sampling procedure and sample size

Multi-stage sampling procedure was used in drawing the samples in which there was selection of group's stage-wise from divisions, wards, villages, and households. The district has four divisions; one division is located in town. All of the three rural divisions were selected and from each division one ward was randomly selected. In each selected ward one village also was selected randomly. Forty households were randomly selected from village register books to constitute the sampling units that make a total of 120 sample households (Table 2). A random sampling technique was preferred in order to avoid biasness and provide equal opportunity for each household to be selected for inclusion in the total area of a sampled population and provide essential information at low cost than complete enumeration.

Table 2: Distribution of respondents in Ndala, Isumba, and Mibura Villages in the Wards studied at Rungwe District

Ward	Village	Households	
		Total	Sampled
Kandete	Ndala	525	40
Kinyala	Isumba	552	40
Mpuguso	Mibura	425	40
Total		**1502**	**120**

3.2.2 Data collection

Both primary and secondary data were collected. Primary data collection was carried out through reconnaissance, field and social surveys

3.2.2.1 Reconnaissance survey

Reconnaissance survey was conducted in order to familiarize with the study area, ascertain sampling process and to help in improvement of the study plans, explain objectives of the study to various administrative levels. More a reconnaissance survey was done to get a general picture of the study area and pre-test the questionnaire. Pre- testing of the questionnaire was done in order to check its validity and reliability. It also helped in identification of relevant partners in villages from whom to acquire various data. Data included extent of adoption of SRC technology, various sources of energy, non and SRC trees and shrubs found in the district and quantification of fuel wood from the SRC technology.

3.2.2.2 Field survey

Through field survey, quantification measurements were carried out using a spring balance and tape measure for determination of weight and volume respectively of fuel wood's head load, piles diameter and height. Transect walk was conducted in order to determine SRC technology and tree species of each household that was ongoing process until the end of field collection of data.

3.2.2.3 Social survey

This was conducted using Focused Group Discussions (FGDs), questionnaire and checklists of probe questions.

(i) Focused Group Discussions

Leading questions relevant to SRC trees and shrubs for fuelwood was used to guide focused group discussions. The FGD was conducted in each village and included local government leaders, influential trees growers, WATCO /factory managers and extension officers (Appendix 2). Participants of focused group discussion was selected based on their time convenience and were briefly interviewed to qualify for group discussion. The discussion with key informants was focused on the role of SRC technology in fuel wood supply. An attempt was also made to revisit unpublished literature and reports in the district's council relevant to subject matter.

(ii) Questionnaire

The sampling frame was village registers and sampling units was head of household, which was randomly selected from the village registers. Semi structured questionnaire with both open and closed-ended questions was used as a tool to interview the household's head (Appendix 1).

3.2.2.4 Secondary data

Secondary data was obtained from Natural resource office of Rungwe District Council, on line databases and Sokoine National Agricultural Library (SNAL).

3.2.3 Data processing and analysis

Primary data collected was recorded, summarized, edited and coded to facilitate data entry, statistical analysis and interpretation into means and percentages. ANOVA was used to determine whether there were significant differences between parameters studied by the aid of Statistical Package for Social Science (SPSS) 16.0 version computer programmes using CRBD analytical model. The F-test was used to determine the existence of differences between the variable means and the Least Significant Difference (LSD) was used for segregating the differing means.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Results

4.1.1 The Extent and Trend of Adoption of SRC Technology in Rungwe District

The results on SRC technology adoption in Rungwe District are presented in Table 3 and associated statistical details are provided in Appendices 4 and 5. It will be noted that, until the time of the study on the average 98% of the population in Rungwe District had adopted the SRC technology and the adoption is more evenly spread throughout the district.

Table 3: Farmers who have adopted the SRC technology in Rungwe District

Information item	Respondents in the study wards (n = 40)			Percentage
	Kandete	Kinyala	Mpuguso	
Adopted	40	40	37	39
Frequency %	**100**	**100**	**93**	**98**

4.1.2 The trend of adoption of SRC technology during the 1960s – 2010 periods

Table 4 presents the adoption trends of SRC technology in Rungwe District over the past 50 years and their associated statistical details are provided in Appendix 6. It will be noted in Fig. 2, that SRC technology in the district started during the 1960’s. The adoption continued gradually during the initial 10 years and drastically accelerated during the 1980’s probably due to the 1970’s oil crisis, climate change and more due to increase in population needs of fuelwood. Also the results show that during the 1990’s and 2000’s there were a constant trend on adoption of SRC technology probably due to the fact that most of the households had already adopted the technology and only few laggards were coming in. Also there was the coming in of the use of agroforestry technologies probably due to shortage and maximum utilization of land.

Table 4: Trend of SRC technology adoption by the Rungwe District communities (during 1960s – 2010)

Information item	Respondents in the study wards (n=40)			Cumm. response	Percentage
	Kandete	Kinyala	Mpuguso		
1960	1	0	5	6	5d
1969 (1970)	1	1	1	9	3d
1979 (1980)	2	15	7	33	20b
1989(1990)	13	18	12	76	36a
1999(2000)	12	3	6	97	17bc
2010(2010)	11	3	9	120	19bc
Total					**100**

The values in the last 6th column that are followed by the same letter do not differ significantly at $p \leq 0.05$.
LSD 0.05 = 8.61

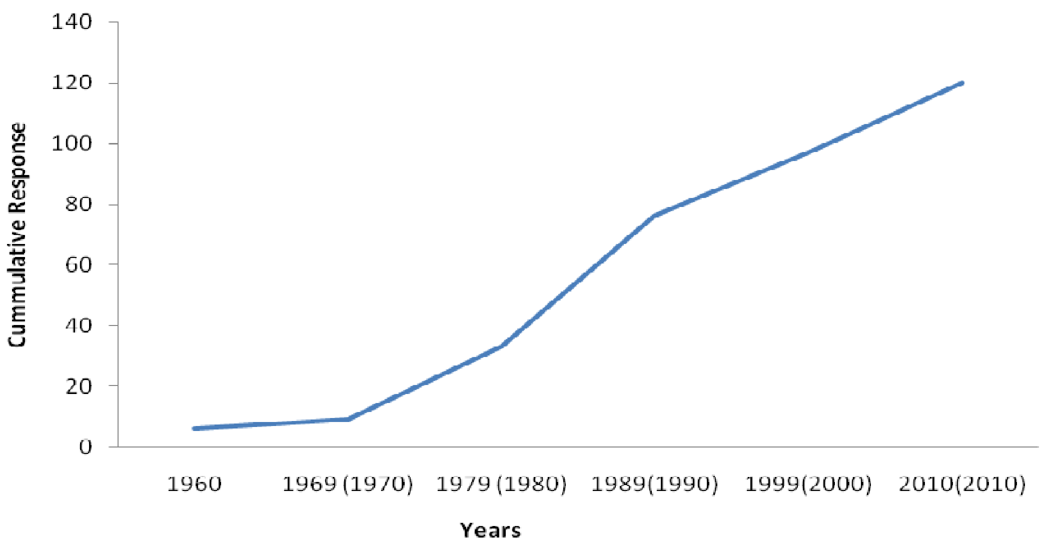

Figure 2: The cumulative trends of adoption of SRC technology in Rungwe District

4.1.3 Various sources of energy in Rungwe District

The results on the various sources of energy in Rungwe District are presented in Table 5 and statistical details are shown in Appendices 7 and 8. It will be noted that the communities in Rungwe District depend widely on fire-wood, followed by kerosene but with different purposes. It is noted that Kerosene is not a substitute of fuelwood and it is the second most widely used source of energy and is mainly for lighting while fuelwood is the most widely used source of energy both for cooking and heating.

Table 5: Various sources of energy in Rungwe District

Energy Sources		**Responses (n=40)**		**Percentage**
	Kandete	**Kinyala**	**Mpuguso**	
Firewood	40	40	40	40.0a
Kerosene	39	40	40	30.3b
Charcoal	6	12	10	9.3c
Biogas	1	0	7	2.67cd
Solar energy	1	0	1	0.67d
Electricity	0	0	1	0.33d
Total				**100**

The values in the same column that are followed by the same letter do not differ significantly at $p \leq 0.05$.
LSD 0.05 = 7.02

4.1.4 Contribution of SRC technology to the household fuel wood consumption needs

The results on the contribution of SRC technology in the district are presented in Table 6 and statistical details in Appendices 9, 10, 11 and 12. It will be noted that the total fuel wood consumed were 176 tonnes year^{-1}of which 128, almost 73%, had been sourced from the SRC technology, while 44 which is 25%, had been consumed from non SRC technology. Only 4 tonnes year^{-1} of fuelwood (2%) were bought by the communities in Rungwe.

Table 6: The overall demand of fuel-wood in tonnes per year by the communities in Rungwe District

	Sum	Minimum	Maximum	Mean	Std Deviation
Total fuel-wood used	176	56	239	122	35
Fuel-wood from SRC technology	128	10	214	89	34
Fuel -wood obtained from non SRC technologies	44	6.4	121	31	21
Fuel-wood bought	4	1	83	3	11

n= 120

4.1.5 SRC Tree and Shrub Species Used as Sources of Fuelwood, SRC Practices and Preferences to the Communities in Rungwe District

The results on SRC tree / shrub species used as sources of fuel-wood by the communities of Rungwe District are presented in Table 7 and statistical details in Appendices 13 and 14. It will be noted that the various species of *Eucalyptus* and *Persea americana* are the most widely used as sources of fuel-wood in the district, together supporting 49 % of all of the district's fuelwood need. The latter also provide fruits and mainly grown in agroforestry practices with the former being produced through woodlots and plantations that are widely spread throughout the whole district.

Table 7: SRC tree/shrub species used as sources of fuelwood by the communities of Rungwe District

Common name	Scientific name	Percentage
Eucalyptus	*Eucalyptus* spp.	26a
Avocado	*Persea americana*	23a
Cedrella	*Cedrella mexicana*	13b
Loquat	*Eriobotrya japonica*	12bc
Ndola	*Ficus natalensis*	9bcd
Bamboo	*Bambusa* spp	4bcd
Plum	*Prunus* spp	4bcd
Grevillea	*Grevillea robusta*	3cd
Guava	*Psidium guajava*	3cd
Lukina	*Leucaena leucocephala*	2cd
Albizia	*Albizia gummifera*	1cd
Total		**100**

The values in the same column that are followed by the same letter do not differ significantly at $p \leq 0.05$.
LSD 0.05 = 9.27

4.1.6 Short rotation coppice practices

The results on SRC practices that were being adopted by the communities in the district are presented in Table 8 and their statistical analysis details are provided in Appendices 15 and 16. It will be noted that over 38% of the fuel-wood used by the communities in Rungwe District is sourced from SRC technologies in the form of woodlots, Agroforestry practices such as mixed intercropping and field boundary planting practices, consist of 62% of the SRC technologies probably reflecting the prevailing land scarcity.

Table 8: The SRC practices adopted by the local Communities in Rungwe District

Practices		Percentage
Woodlot		38a
Mixed intercropping	Agroforestry	62b
Field boundary		
Total		**100**

The values in the same column that are followed by the same letter do not differ significantly at $p \leq 0.05$.
LSD 0.05 = 25.46

4.1.7 SRC tree and shrub species preferred by the communities in Rungwe District

The results on trees and shrubs preferred most by the local communities are presented on Table 9 and statistical analysis details in Appendices 17 and 18. It will be noted that, *Eucalyptus* trees are the most preferred for fuel-wood probably due to their higher productivity and coppicing ability. The next most popular tree species is *Persea americana* which, in addition to providing fuelwood, it is, also a fruit bearing tree species reflecting both higher land use economy and ready market availability.

Table 9: Tree/ shrubs preferred by the communities in Rungwe District

Tree/shrub Species	**Percentage**
Eucalyptus spp	59a
Persea americana (Avocado)	29b
Leucaena leucocephala	8c
Pines	3c
Cedrella	1c
Total	**100**

The values in the same column that are followed by the same letter do not differ significantly at $p \leq 0.05$.
LSD 0.05 = 16.17

4.1.8 Factors Influencing and Corrective Measures for Enhancing the Adoption of SRC Technology by the Communities in Rungwe District

4.1.8.1 Factors influencing the adoption of SRC technology by the communities in Rungwe District

The results in Table 10 and 11 respectively and statistical analysis details in Appendices 19, 20, 21 and 22, show the enhancing and limiting factors for the adoption of SRC technology in Rungwe District. It will be noted that the provision of fuelwood was shown to be the most important of the enhancing factors, probably indicating fuel-wood to be the priority need of the people in the area. The indication that over 85% of the community depend on SRC sourced wood for fuelwood, timber, income generation and building poles, is clear sign of limited alternative sources for meeting the communities households livelihoods.

The indication that wildfire incidences and shortage of land together accounting for over 51% being the main limiting factors for the establishment of SRC technology probably are the reasons for the increased Agroforestry use and the need for extension workers.

Table 10: Factors enhancing the adoption of SRC technology by the communities in Rungwe District

Influencing factors	Percentage
Fuelwood for home consumption	44a
Timber	17b
Income generation	11bc
Control soil erosion	11bc
Food	5cd
Resprouting	3cd
Fast growing	3cd
Poles	2cd
Environmental conservation	2cd
Availability of seedlings	1d
Fence for animals	1d
Total	**100**

The values in the same column that are followed by the same letter do not differ significantly at $p \leq 0.05$.
LSD 0.05 = 9.39

Table 11: Limiting Factors of SRC technology adoption by the communities in Rungwe District

Constraints	Percentage
Wildfire incidences	29a
Lack of Extension workers	23ab
Shortage of land	22ab
Lack of seed and seedling	14bc
Lack of tree planting education	7bc
Drought	5bc
Total	**100**

The values in the same column that are followed by the same letter do not differ significantly at $p \leq 0.05$.
LSD 0.05 = 12.03

4.1.8.2 The corrective measures required for enhancing the adoption of SRC technology

The results on the corrective measures required for improving adoption of SRC technology in Rungwe district are presented on Table 12 and statistical details in appendices 23 and 24. Based on the results, it is indicated that on the average 25% of he people suggest an application of by- laws to prevent wildfires and extension services that include education on the proper selection of SRC trees and shrubs, increased promotion of the SRC technology and provision of the required germplasm, which together accounts for the remaining 75% are the measures that people seek in order to effectively promote the SRC technology. Provision of tree seeds and seedlings by the various stakeholders such as WATCO should be useful incentives.

Table 12: The corrective measures required for enhancing the adoption of SRC technology in Rungwe District

Suggested corrective measures	Percentage
By- laws to prevent wildfires	25a
Education on proper selection of SRC species	24ab
Increase Extension services	23ab
Promotion efforts of SRC technology	18b
Provision of seeds and seedlings	10c
Total	**100**

The values in the same column that are followed by the same letter do not differ significantly at $p \leq 0.05$.
LSD 0.05 = 6.83

4.2 Discussion

4.2.1 The extent and trend of adoption of SRC technology in Rungwe District

The results on the extent and trend of adoption of SRC technology are presented in Tables 3, 4 and in Fig. 2, the statistical analysis details in Appendices 4, 5 and 6. The adoption of SRC technology started during the 1960s and until the year 2010, 97.5% of the population had adopted SRC technology, implying that the extent of adoption is high. The results indicate that initially the trend of adoption of SRC technology in Rungwe District was fluctuating and gradually during 1960s but picked up from 1990s to 2000s probably due to awareness, campaigns by various institutions, extension services, high needs of fuelwood by WATCO factories and the communities in the District. According to Magcale-Macadong *et al*. (2005), in Southern East Asia and Ssemwanga *et al.* (2004) from Uganda, East Africa, the basic information was required for the users to adopt the innovations and increased promotion and support by the government and various institutions was necessary to speed up the adoption of the technologies. In addition, therefore, the combined factors and approaches in promoting SRC technology observed in this study.

4.2.2 Various sources of energy to the communities in Rungwe District

The results in Table 5 and statistical analysis details shown in Appendix 7 and 8 reveal that the communities in Rungwe District depend widely, followed by kerosene as sources of energy. It was noted that Kerosene is not a substitute of fuelwood but a necessary second most widely depended upon source of energy, mainly for lighting while fuelwood being the most widely used source of energy for cooking and heating. According to Kaale (2005). TATEDO (2005) the electricity sub-sector contributes about 0.6 % of the total energy consumption and is mainly generated from hydropower. Tanzania has per capita electricity consumption of 46/KWh per annum, which is growing at the rate of 11 – 13 %. Hence the government is encouraging investments to expand the generating capacity, distribution system and developing indigenous alternative sources of energy. Solar energy is another source of energy but very little attempt has been made to utilize this source of energy that could be a viable alternative source to reduce use of wood from natural reserve forests and kerosene for heating purposes. Also this has been revealed by only 1.7 per cent use of solar energy in Rungwe District.

4.2.3 Contribution of short rotation coppice technology to the total household fuelwood needs

From the results in Table 6, and the associated statistical analysis details in Appendix 9, 10, 11 and 12, shows that SRC technology in Rungwe District has been contributing to the total fuel-wood supplies. The total fuel-wood sourced from non and SRC technology were 176 tonnes year^{-1}, but 128 tonnes year^{-1} of fuel-wood which is almost 73% have been sourced from SRC technology, also 44 tonnes year^{-1} of fuel-wood, which is 25% have been sourced from non SRC technology. Only 4 tonnes year^{-1} of fuelwood (2%) were bought by the communities in Rungwe District. According to Oliver and Ralph (2008), a good estimate for the average annual household fuelwood consumption in South Africa is 4.5 tons which is 30% higher than 3-4 tons per annum reported by Williams *et al*. (1996).

From that point of discussion the study went further and found that the household fuelwood consumption of respondents, 79.8% their family size is 4-6 people who consumes about 61-183 kg per month of fuelwood which is almost 2.2 tonnes consumed annually, the study also found that the only 10.8% live in the family size of about 1-3 people and they consume about 61-175 kg per month and 2.1 tonnes year^{-1} of fuelwood. Further the family size of about 7-10 people which constitute 10% consumes about 84 -214 kg per month of fuelwood that means that they consume about 2.5 tonnes year^{-1} in maximum and about 7kg consumed daily. However the moisture content of the fuelwood which has the close relationship with weight was not measured. It was found that in Tanzania national energy balance is dominated by fuel wood as the main source of energy for cooking where about 96% of the population use wood fuel (URT, 2009). Among rural households, the use of wood fuel for the cooking has increased from 4% in 2000-01 to 7% in 2007 despite declining between 1991-92 and 2000-01 (Malimbwi *et al.*, 2007).

4.2.4 The SRC tree and shrub species used for Fuelwood, SRC practices and preference by the communities in Rungwe District

The results in Table 7 with statistical analysis details in Appendix 13 and 14 shows that the SRC tree / shrub species used as source of fuelwood by the communities of Rungwe District. It will be noted that the tree / shrubs species uses are statistically different. The *Eucalyptus* and *Persea americana* were most used as source of fuel wood in the District (i.e. 64.2% and 50.8% respectively) with the former being used most in the whole district.

The later in addition, it is a fruit bearing tree species both reflecting land economy and market availability. Information on the production rate of different SRC species is very limited but Thomas and Timoth (2007) found that the most reliable SRC tree and shrub species in Uganda were *Acacia mearnsii, Eucalyptus grandis, Sesbania sesban* and *Markhamia lutea*. However, in Rungwe District *Leucaena leucocephala* is an attractive alternate due its high biomass productivity and nitrogen fixing ability. Also the results on the SRC practices in Rungwe District are presented in Table 8 and statistical analysis details in Appendices 15 and 16. The results shows that there are three SRC practices, which are wood lot, mixed intercropping and field boundary these have been implemented in Rungwe District and in average accounts 38.6%, 32.2% and 29.2% respectively. The most adopted is wood lot probably due to the most communities member planted *Eucalyptus* spp. as source of fuelwood which is obvious not intercropped with other food crops. The lower level of field boundary practices which in average accounts 29.2 % in the area, mainly results from the limited tradition in animal husbandly production by the local communities and the livestock normally kept indoor in Rungwe District.

The domination of woodlot practice mainly composed of the exotic wood perennial species such as *Eucalyptus* in all the three villages in Rungwe district. Thus has been reflection of the high dependence of the firewood based supplies for their livelihood. It has been observed by (Rahim *et al.,* 2005) that a general uses of technologies and much of it influenced by what farmers see as incentive or decentive. The biggest incentive is income that obtained from the sale of the products, sustainable increased yields and general improvement of welfare due to raised income (Nyadzi *et al*., 2003; Simon and Leakey, 2004). However, such impact also depends on the circumstances under which SRC technology is adopted. Based on the results there were no significance difference by both villages in the district for all three practices.

Moreover the results show that the tree and shrubs species preferred to be planted by the communities in Rungwe District Tanzania are presented in Table 9 with statistical details in appendices 17 and 18. The higher preferences for *Eucalyptus sp* and *Persea sp* by the Rungwe communities were attributed to fast growth, vigorous growth even in poor soils, capacity to sprout or coppice when subjected to cutting or burning and production of diverse of marketable products firewood, timber, fruits (i.e. *Persea* spp). Mafongoya *et al*. (2005) observed that farmers preferences for specific trees or shrubs were mainly based on the quantities of biomass produced with determine the effectiveness to fulfil their different requirements.

4.2.5 Factors influencing the adoption of SRC technology and corrective measures required for its enhanced application

The results in Table 10 and 11 with statistical analysis details in Appendix 19 and 22 show that the development of SRC technology in Rungwe District was speeded up by fuel-wood needs for home consumption also the income generated from selling fuelwood to Katumba and Mwakareli Tea Factories in Rungwe. According to Katumba Tea Factory Manager (2010), the amount of firewood supplied from farmers were 24 071m^3 in year 2009 and 23 043 m^3 in year 2010. In average 22 000 m^3 per year are required by the Katumba and Mwakareli Tea Factories for tea curing. Also it is estimated that 1m^3 is required to process 250kgs of metric tonne /cbm of green tea. Income generated by selling fuelwood by farmers influences the adoption of SRC technology. That have been mentioned by (Katumba Tea Factory Manager, 2010), that the buying price of 1m^3 of fuelwood is Tsh. 9000. Franzel and Scherr (2002) found that inefficient market and seasonal variations in market prices affected the diffusion and adoption of improved technologies. Therefore the empowerment of smaller holder farmers to organize themselves into producer organizations to enable them to form strong linkages with market actors and raise their bargaining power is a core element to ensuring fair market prices and thus improving their income (Kashuliza *et al.*, 2002).

According to (Thomas and Timoth, 2007), choices and suitability of species depends on many factors such as biophysical limits or available knowledge on and acceptance for a species. Also contend that the factors influencing the species choice may be coppicing ability, biomass yield, drought resistance, pest resistance and impact on soil fertility. Furthermore the lack of seed and seedlings may influence or hinder the adoption of new technology, (Russel, 2004) reported that farmer must be persuaded and provided with the necessary skills to establish and manage their own nurseries and ensure that desirable seeds are accessible to them with emphasis on developing and applying better methods of forecasting seeds needs. Sood and Mitchell (2004) observed that the awareness and knowledge about reliable sources of good seeds and other tree plant seedlings play a big role in enhancing technological adoption.

Shortage of land, perhaps the key issue is that the plot size may be acting as a proxy for assets or wealth (Cramb, 2005a; Barret *et al*., 2006). However smallholder farmers are among those mostly affected by land shortage factor, have limited capacity to cope with their effects. Their ability to mobilize and manage assets in this case, land is fundamental to their resilience in the face of these challenges (Zbinden and Lee, 2004). There is growing urgency to understand and address the threats posed by changes in land use and reinforce the capacity of individuals and communities to withstand or recover from negative effects and to exploit the opportunities that may be available to them (Cramb, 2005b). Improved land access for smallholder farmers can result directly in improved SRC technology, livelihoods and essential tool to poverty reduction, contributing to increased household fire wood and energy security.

Generally economic growths tend to be higher and more broadly shared when the people have equitable and secure access to land (Peterson and Pritchard, 2002). Secure land access and property rights provide important buffers that protect vulnerable groups against deepening poverty, particularly when competition for access to resources and efficiency enhancing land use (Ajayi *et al*., 2007b). Secure tenure is also a key prerequisite for promoting medium and long term investments in land to improve its overall productivity of the small holder farmers in Rungwe district.

By- laws to prevent fire incidences have been mentioned by the communities in Rungwe and thus revealed by (Kaale *et al.*, 2002; Makepe, 2006; Odebode, 2005; Sanginga *et al*., 2006; Rist and Guebas, 2006) who have shown that, for the interventions to be sustainable there must be an active involvement of the people for collective action, implementation of by- laws and linking with local government structures so as increase the ability of the communities to use available opportunities for the collective action. The use of by-laws to protect the planted trees has been reported to be most useful in the adoption of new technologies including SRC technology. (TARP II- SUA, 2005). Therefore sustainable adoption of technologies requires community participation and strategies which ensure effective and sustainable ways of managing resources (Sinha and Suar, 2003; Rist and Guebas, 2006).

Further the results on the corrective measures required for enhancing adoption of SRC technology in Rungwe district are presented in Table 12 and the statistical details in appendices 23 and 24. The measures that have been suggested by farmers in order to improve adoption of SRC technology in Rungwe district included having by-laws to prevent fire escape, education on proper selection of SRC species, increase extension services, promotion efforts of SRC technology, provision of seeds and seedlings.

Education on proper selection SRC species that the use of proper SRC species, and proper arrangement is essential in order to avoid negative effects like competition for resources like, light, water and nutrients such as pruning, pollarding where necessary (Chirwa, 2003).

Increase extension services must be based on and take into account the socio-economic status of the farmers, aspects of the technology and more important on the needs of the farmers in the area where SRC is practiced. Increase of promotion efforts of SRC technology, smallholder farmers must involved in setting SRC technology research agenda and in developing new SRC technologies, farmers involvement will be essential in providing valuable feedback to research, policy makers and development of practitioners (Thangata and Alavalapati, 2003).

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Based on the results, the following conclusions have been drawn;

(i) The SRC technology in Rungwe District started during 1960's and it has been adopted in the whole district. But their adoptions were gradually and picked up during the 2000s period due to increase awareness and the benefits drawn from the adoption of the technology. Till now approximately 97.5% of all the communities in Rungwe District have adopted SRC technology and some of its practices are woodlot, mixed intercropping and field boundary (agroforestry). Therefore it is concluded that the extent of adoption of SRC technology in Rungwe District is high.

(ii) It was observed that average means of 40% of respondents which is approximately 99.2% of the communities in Rungwe District depends on fuelwood that means only 0.8% of the population solely do not relay on fuelwood use as source of energy. There should be NGO's, programmes and various institutions beside the government which can involve directly or indirectly in order to spearheading SRC technology. Moreover; SRC can be integrated in Agroforestry systems (AFs) and being disseminated in the district by proper selection of SRC germplasm in order to overcome the shortage of fuelwood and the impacts on climate change.

(iii) It was been found that SRC technology can contribute more than 73% of the fuelwood consumed hence increase livelihood to the communities in Rungwe District. From that observation and data analysed it is wise to make into consideration of the findings.

(iv) Eucalyptus spp and *Persea americana* were used for fuelwood needs and mostly preferred SRC trees especially in Kandete and Kinyala Wards in the district however Leucaena leucocephala was also preferred by households in Mpuguso Ward.

(v) Wildfire incidences, lack of extension services, shortage of land, inadequate supply of tree quality seed and seedlings and lack of planting trees education were amongst leading factors limiting adoption of SRC technology in Rungwe District.

(vi) It has been revealed that there is weak policy framework on the implications of SRC technology development due to some controversies of SRC pioneer species such as Eucalyptus that it is believed that there is not environmentally friendly which may not be true. Also the conflicting sectorial interests which leads to the competing interest for example energy crops versus food crops.

5.2 Recommendations

Based on the results, discussion and conclusions the following recommendations are put forward as follows:

(i) Despite the fact that SRC technology have been adopted to large extent by the communities in Rungwe district and having impact in their livelihoods. However the most adopted SRC tree species are *Eucalyptus*, therefore more research is required to establish other SRC tree and shrub species in the District.

(ii) Land shortage is amongst the smaller holder farmers can be overcome by developing intensive silviculture or agroforestry system therefore there is need to find out the appropriate SRC species which can increase the fuelwood supply and at the same time saves for availability of food and increase nutrients into soil.

(iii) The Government, Ngo's have greatly impact on SRC technology, therefore it is necessary that they should allow farmers to learn, practice and realize the importance of the technology to other part of the country. Therefore there should be technological development network of policy makers, private sectors and farmers in order to facilitate long term SRC technology and enhance its benefits.

(iv) Rural communities should be assisted to establish their own tree nurseries including provision with desirable seeds and seedlings also they should be given incentives in order to encourage them on the environment managements.

(v) More extension officers should be employed in order to fill the gaps created awareness to the farmers.

(vi) A supportive land tenure and policy conditions must be developed which require broad- based participation from the local, central governments as well as the private sector and community based organizations in enhancing SRC technology development.

(vii) Despite of the present findings on SRC technology there is needs to do more research on other bio energy crops such as *Jatropha curcus*, Palm among others in order to overcome the problems of energy supply in the district.

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APPENDICES

Appendix 1: Questionnaire for the household heads

A: General information

Name of Interviewer...

Name of household respondent...

Gender of Head of household (respondent)..................1. Male.........2. Female

....

Marital status: 1. Married 2. Single 3. Divoced 4. Widow/ widower

Age of respondent............................

Number of people in the household (normally eating there) ....

Village...

Ward..

Division...

Questionnaire Number................................

Date of interview..

B: Specific objectives

(I) Extent of adoption of Short Rotation Coppice of trees and shrubs

1. Do you have trees/ shrubs planted in you field? Yes/No
2. Do you have SRC trees/shrubs in your plot? a)yes=Adopted b)no= Not adopted
3. Who makes decision on tree planting activities in this household? Woman/ Male
4. What practice do you use to grow trees and shrubs in your field?
   a) As woodlot b) intercropping C) in field boundary d) other (s) specify.................

5. How many plots of trees/shrubs do you have?...........................

6. Estimate of its area...................... in acre?

7. When did you start planting SRC trees/ shrubs?

Year	Before 1960s	1960-1969	1970-1979	1980-1989	1990-1999	2000 to date
Start						

8. How many tree species suitable for SRCs you planted in last 5years?

Year	2010	2009	2008	2007	2006
Number of trees					

(II) Various sources of household energy

9. What various source of energy does your household use?

Source of energy	Tick where appropriate	Purposes
1. Firewood		
2. Charcoal		
3. Kerosene		
4. Solar energy		
5. Electricity (hydroelectric)		
6. Bio gas		
7. Others (specify)		

10. For which purposes do you use the energy?

1.Cooking 2. Lighting 3. Heating 4. Others (specify)

(III) Contribution of SRC trees / shrubs to total household fuel wood consumed

11. How much head-loads of fuel wood you need for home consumption per month?

12. What quantity of fuel wood obtained from SRC trees for your household?

Product	Quantity (headload,m^3, kg/ month)
Firewood	

13. Is the own fuel wood production from SRC trees / shrubs sufficient for the households needs?Yes/ No

14. What quantity of fuel wood obtained from Non SRC trees for your household?

Product	**Quantity (headload,m^3, kg/ month)**
Firewood	

15. How much fuel wood do you buy per month?

Product	Quantity (headload,m^3, kg/ month)
Firewood	

16. How much fuel wood do you sell per month?

Product	Quantity (headload,m^3, kg/ month)
Firewood	

17. How long it takes from planting to harvest?

18. How long it takes from coppiced trees/ shrubs to reharvest?

(IV) SRC tree and shrub species used as source of fuel wood

19. Which SRC exotic and indigenous tree and shrub species do you have in your plots?

20. What are the major purposes of planting?

21. Do you plan to extend or decrease planting SRC trees and shrubs? Yes/No

22. If you plan to extend which tree /shrub species? And why?

23. If you don't plan what type of tree/shrub species to decrease?

24. Which new tree/shrub species you plan to plant suitable for SRCs?

Influencing factors of growing short rotation coppice trees/ shrubs

25 What forces behind planting SRC trees/shrubs?

....

26 What are the problems facing planting SRC trees/shrubs?

....

27 What measures should be addressed to solve the problems? If any.

....

Appendix 2: Checklist of probe questions for key informants survey

A: Village leaders/ influential farmers

1. Do you have access to the extension services in your area?
2. How often do they visit you farm per year? (Number of visits)
3. What are main activities? (Content of extension service)
4. Is there any committee in the ward / village government concern with afforestation?
5. Has there been any government involvement in afforestation activities?
6. If yes, what type of involvement?
7. Are there any non-governmental organizations involved in afforestation?
8. Do you get information on possibilities of planting trees/ shrubs?
9. What exotic and indigenous SRC tree species do you have in your plots?
10. Which tree/shrub species do you get fuel wood?
11. When did you start planting SRC tree in your area?
12. Is fuel wood production satisfying your needs in your area? yes/ no
13. If *No* what the reasons?
14. What influencing you growing SRC trees?
15. What are the constraints of planting SRC trees?

B: Fuel wood traders

Name………………………………Occupation…………………..

1. When started that business?
2. Where does trading fuel wood come from?
3. What is the average distance from where it is sold now?
4. What tree species are mostly preferred?
5. What is their abundance in the natural sites?
6. Which month (s) of the year does fuel wood become difficult to get? (Why?)

7. What do your consumers do during that period?
8. What factors contribute to current status of wood fuel consumption?
9. By comparing in last five year, is the fuel wood availability a problem? Yes /No
10. If yes, what is the problem?

C: Tea Factory Manager/Farm Manager

Name of respondent...

Tea factory name..

Location: village/ subvillage ....

1. When did you start processing the tea?
2. During starting had you source of fuel wood? Yes/ No.
3. If *Yes*, how many acre of woodlot?

4. In five years back how much firewood consumed in response to tree planting?

Year	Firewood (Volume in m^3)	No.Tree planted
2010		
2009		
2008		
2007		
2006		

5. If No. Where you get the firewood?
6. Is the supply sufficient for your needs? Yes/No
7. If Yes. How much they supply per year?
8. If No. What other source of the energy which is used as a substitute of firewood?
9. How much firewood in (m^3) required to process 1 tonne of tea.
10. Which tree /shrub species do you like most for fuel wood? (why?)

Rank	Tree species	Reason/ uses
1. 2.		
Total		

Appendix 3: Checklist of the probe questions for District Ward /Village Extension Officers

1. Name……………………………………………………
2. Occupation…………………..
3. District/Ward /Village/ sub village ....
4. Do you have a campaign of planting trees/shrubs in your area?
5. For how long has this campaign have been promoted in this area?
6. How many tree you planted in last five year?
7. What was the source of tree/shrub seedling?
8. Which tree species you planted?
9. To each tree species what its main purpose?
10. What constraint do you face in implementing SRC trees and shrubs?
11. What constraints do farmers face in adopting SRC trees and shrubs in this area?
12. What do you recommend for the success of SRC trees/ shrubs in this area?
13. Why farmers prefer such tree/ shrub species and why they don’t like other tree species?

Appendix 4: The Extent and trends of adoption of SRC technology in Rungwe District

Farmers who have adopted SRC technology in the three wards studied

Wards studied	**Farmers**		
	Adopted %	**Non adopted %**	**Means %**
Kandete	33	0	33a
Kinyala	33	0	33a
Mpuguso	31.5	2.5	34a
Total	**97.5**	**2.5**	**100**

The values in the same column that are followed by the same letter do not differ significantly at $p \leq 0.05$.
LSD 0.05 = 8.61

Appendix 5: ANOVA for adopted SRC technology in Rungwe District

S. of variation	**df**	**SS**	**MS**	**F**	**P-value**
Rows	2	0	0	0	Ins
Columns	1	2166	2166	361	0.0028**
Error	2	12	6		
Total	**5**	**2178**			

Appendix 6: ANOVA for trends of adoption of SRC technology in the wards studied in Rungwe District

S. of variation	**df**	**SS**	**MS**	**F**	**P-value**
Rows	2	1.66537E-30	8.327E-31	4.22E-32	Ins
Columns	5	346.66	69.333333	3.5135135	0.0430*
Error	10	197.33	19.733333		
Total	**17**	**544**			

Appendix 7: Results showing the various sources of energy in Rungwe District

Information item	Respondents in the study wards (n= 40)			Means %
	Kandete	Kinyala	Mpuguso	
Firewood	40	40	40	40.0a
Kerosene	39	40	40	30.3b
Charcoal	6	12	10	9.3c
Biogas	1	0	7	2.67cd
Solar energy	1	0	1	0.67d
Electricity	0	0	1	0.33d
Total				**100**

The values in the same column that are followed by the same letter do not differ significantly at $p \leq 0.05$.
LSD 0.05 = 7.02

Appendix 8: ANOVA for various sources of energy in Rungwe District

S. of variation	df	SS	MS	F	P-value
Rows	2	12.4444	6.2222	0.4179104	0.6694
Columns	5	4372.4444	874.4889	58.734328	0.000***
Error	10	148.8889	14.8889		
Total	**17**	**4533.7777**			

Appendix 9: ANOVA showing total fuelwood in kilograms consumed per month by the communities in Rungwe District

S. of variation	df	SS	MS	F	P-value
Rows	2	8210.117	4105.0582	63.060365	0.0000***
Columns	69	156883.491	2273.6738	34.927324	0.0000***
Error	48	3124.669	65.0973		
Total	**119**	**168218.277**			

*** highly significantly at $p \leq 0.001$.

Appendix 10: ANOVA for the amount of fuel wood in kilograms per month contributed by SRC technology to the total fuelwood consumed by the communities in Rungwe District

S. of variation	df	SS	MS	F	P-value
Rows	2	33.136	16.5681	0.0485161	0.9527
Columns	19	110487.077	5815.1093	17.028314	0.0000***
Error	98	33466.655	341.4965		
Total	**119**	**143986.868**			

Appendix 11: ANOVA for the amount of fuelwood in kilograms per month contributed by the non- SRC technologies to the total fuelwood consumed by the communities in Rungwe District

S. of variation	df	SS	MS	F	P-value
Rows	2	33.13627	16.5681	0.0146774	0.9854
Columns	15	28814.23879	1920.9492	1.7017343	0.0620
Error	102	115139.3931	1128.8186		
Total	**119**	**143986.8689**			

Appendix 12: The role of SRC technology in fuelwood supply and consumption status of the communities in Rungwe District

Statistics		Total Kg of fuelwood used for per month	Kg / Month of fuelwood from SRC	Kg / month of fuelwood from Non SRC	Fuelwood sold / month in m^3
N	Valid	120	120	120	40
	Missing	0	0	0	80
Mean		122.0958	88.5550	30.8450	1.6375
Std. Error of Mean		3.17539	3.43220	1.91182	.14543
Std. Deviation		34.78468	37.59786	20.94294	.91978
Variance		1209.974	1413.599	438.607	.846
Range		183.00	213.60	115.20	3.50
Minimum		56.20	10	6.40	.50
Maximum		239.20	213.60	121.60	4.00
Sum		14651.50	10626.60	3701.40	65.50
Percentiles	25	96.8000	64.5250	12.8000	1.0000
	50	110.3000	89.0000	25.6000	1.0000
	75	146.3000	115.7000	38.4000	2.0000

Appendix 13: SRC tree / shrub species used as sources of fuelwood and preferences of the communities in Rungwe District

Common name	Scientific name	Mean	Means percentage
Eucalyptus	*Eucalyptus* spp	17.33	26a
Avocado	*Persea Americana*	15.67	23a
Cedrella	*Cedrella Mexicana*	9	13b
Loquat	*Eriobotrya japonica*	8	12bc
Ndola	*Ficus natalensins*	6.33	9bcd
Bamboo	*Bambusa* spp	3	4bcd
Plum	*Prunus* spp	2.67	4bcd
Grivellea	*Grivellea robuster*	1.67	3cd
Guava	*Psidium guajava*	1.67	3cd
Lukina	*Leucaena leucocephala*	1.33	2cd
Albizia	*Albizia gummifera*	0.67	1cd
Total		**67.29**	**100**

The values in the same column that are followed by the same letter do not differ significantly at $p \leq 0.05$.
LSD 0.05 = 9.27

Appendix 14: ANOVA for SRC tree / shrub species used as sources of fuelwood by the communities in Rungwe District

Source of variation	df	SS	MS	F	P-value
Rows	2	2.2424	1.1212121	0.0378091	0.9630
Columns	10	1028.1818	102.81818	3.467198	0.0086**
Error	20	593.0909	29.654525		
Total	**32**	**1623.5151**			

Appendix 15: Results showings the SRC practices adopted by the Communities in Rungwe District

Information item	Respondents in the study wards (n= 40)			Means % (response)
	Kandete	Kinyala	Mpuguso	
Woodlot	30	38	23	38a
Mixed intercropping	5	35	36	32a
Field boundary	10	23	36	30a
Total				**100**

The values in the same column that are followed by the same letter do not differ significantly at $p \leq 0.05$.
LSD 0.05 = 25.46

Appendix 16: ANOVA for SRC practices adopted by the communities in Rungwe District

S. of variation	df	SS	MS	F	P-value
Rows	2	566.8889	283.44444	2.2475771	0.2217
Columns	2	84.2222	42.111111	0.3339207	0.7343
Error	4	504.4444	126.11111		
Total	**8**	**1155.5556**			

Appendix 17: Tree / shrub species planting preferred for different uses by the communities in Rungwe District

Limiting factors	Respondents in the study wards (n= 40)			Means %
	Kandete	Kinyala	Mpuguso	
Eucalyptus spp.	27	31	5	59a
Avocado	3	8	20	29b
Leucaena spp.	0	0	8	8c
Pines	3	0	0	3c
Cedrella	0	0	1	1c
Total				**100**

The values in the same column that are followed by the same letter do not differ significantly at p ≤ 0.05.
LSD 0.05 = 16.17

Appendix 18: ANOVA showing the tree / shrub species planting preferences for different uses by the communities in Rungwe District

Source of variation	df	SS	MS	F	P-value
Rows	2	4.1333	2.0667	0.0280289	0.9725
Columns	4	918.9333	229.7333	3.1157324	0.0803
Error	8	589.8667	73.7333		
Total	**14**	**1512.9333**			

Appendix 19: Factors influencing the adoption of SRC technology by the communities in Rungwe District

Enhancing factors	Respondents in the study wards			Means %
	Kandete	Kinyala	Mpuguso	
Lack of fuel wood	31	38	40	44a
Timber needs	17	16	8	17b
Income generation	10	18	0	11bc
Control of soil erosion	1	4	23	11bc
Food	3	1	9	5cd
Fast growing	6	2	0	3cd
Resprouting	4	1	3	3cd
Poles	2	2	2	2cd
Environmental conservation	4	0	0	2cd
Availability of seeds and seedlings	1	1	1	1d
Fences for animals	1	0	0	1d
Total				**100**

The values in the same column that are followed by the same letter do not differ significantly at p ≤ 0.05.
LSD 0.05 = 9.39

Appendix 20: ANOVA for factors influencing the adoption of SRC technology by the communities in Rungwe District

Source of variation	df	SS	MS	F	P-value
Rows	2	1.6364	0.8181818	0.0268978	0.9735
Columns	10	3284.1818	328.41818	10.796772	0.0000***
Error	20	608.3636	30.418182		
Total	**32**	**3894.1818**			

Appendix 21: Limiting factors of the adoption of SRC technology by the communities in Rungwe District

Limiting factors	Respondents in the study wards (n=40)			Means %
	Kandete	**Kinyala**	**Mpuguso**	
Wildfire incidences	17	19	5	29 a
Lack of extension workers	3	14	16	23 ab
Land shortage	1	9	21	22 ab
Lack of seeds and seedlings	3	14	2	14 bc
Lack of trees planting education	3	3	4	7 bc
Drought	4	1	2	5 bc
Total				**100**

The values in the same column that are followed by the same letter do not differ significantly at $p \leq 0.05$.
LSD 0.05 = 12.03

Appendix 22: ANOVA for limiting factors of adoption of SRC technology by the communities in Rungwe District

Source of variation	df	SS	MS	F	P-value
Rows	2	72.3333	36.166667	0.8276125	0.4649
Columns	5	309.1666	61.833333	1.4149504	0.2989
Error	10	437	43.7		
Total	**17**	**818.5**			

Appendix 23: The corrective measures required for enhancing of the SRC technology adoption by the communities in Rungwe District

Limiting factors	Respondents in the study wards			Means %
	Kandete	Kinyala	Mpuguso	
	n=40	n=40	n= 40	
By laws to prevent fire escape	15	12	3	25a
Lack of extension workers	7	6	8	24ab
Land shortage	9	9	11	23ab
Lack of seeds and seedlings	7	8	12	18b
Lack of trees planting education	2	5	6	10c
Total				**100**

The values in the same column that are followed by the same letter do not differ significantly at $p \leq 0.05$.
LSD 0.05 = 6.83

Appendix 24: ANOVA for corrective measures required for enhancing the SRC technology adoption by the communities in Rungwe District

Source of variation	df	SS	MS	F	P-value
Rows	2	0	0	0	1
Columns	4	66.6666	16.6667	1.2658228	0.3587
Error	8	105.3333	13.1667		
Total	**14**	**172**			