JATROPHA PRODUCTION IN TANZANIA: OPPORTUNITIES AND CONSTRAINTS TO SMALL SCALE FARMERS IN ARUSHA AND RUKWA REGIONS

BY

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ABSTRACT

A study was carried out to assess biofuel production and its influence on improving livelihoods of Jatropha small-scale farmers in Arusha and Rukwa regions in Tanzania. General objective of the study was to assess the Jatropha production as well as the prospective opportunities and constraints to small-scale farmers in Tanzania. Specifically, the study aimed at examines and compare profitability of Jatropha production; assessing factors, opportunities and constraints which influence production; and then analysed seeds oil contents. The data were collected from 186 households in all of the three districts of the study areas. The study results revealed significant differences in income between different cropping systems of Jatropha at $p<0.01$ level of significance. Independent Samples T-test and the total factor productivity test results revealed that living fence has higher performance than in other production systems. There was also a significant difference ($p < 0.01$) in the gross margins between mono-cropping, intercropping and living fence systems. Maize and beans, which were intercropped with Jatropha, showed higher gross margins than that of Jatropha. The results of regression analysis indicated that extension services, household size, production systems, and the age of Jatropha plants have positive impact on agricultural productivity. Seeds oil contents ranged from 25.54% to 30.17% and living fence system showed higher percent of oil contents than the rest. The costs of production were relatively higher in mono-cropping and intercropping than in living fence. Farmers faced challenges as having a limited good agronomic practices, processing equipments and skills for processing Jatropha seeds. Access to credit and working capital were other challenges that farmers face in the study area. Multiple use of Jatropha such as provision of energy sources, charcoal, fertilizer, soap making, money by selling seeds are opportunities found. It is therefore recommended that further research on Jatropha value chain be conducted before extensive cultivation of the crop is embarked upon to avoid the conflicts of interest.

DECLARATION

I, Frank Godlight Lyimo, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and that it has neither been submitted nor being concurrently submitted in any other institution.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

ACRONYMS AND ABBREVIATIONS

DALDO	District Agriculture and Livestock Development Officer
EWURA	Energy and Water Utility Regulatory Authority
FAO	Food and Agriculture Organisation of the United Nations
GEXSI	Global Exchange for Social Investment
ha	Hectare
KAKUTE	*Kampuni ya Kusambaza Teknolojia*
NBS	National Bureau of Statistics
NGO	Non Governmental Organization
PAC	Practical Action Consulting
SNAL	Sokoine University of Agriculture National Library
SPSS	Statistical Package for Social Sciences
SUA	Sokoine University of Agriculture
TR	Total Revenue
TVC	Total Variable Costs
TMA	Tanzania Meteorological Agency
Tsh	Tanzania Shillings
URT	United Republic of Tanzania
XP	The aggregate output of seeds and prices
US$	United State Dollar

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Tanzania is among the countries, which depend entirely on imports for her petroleum products requirement. However, the prices of these products have been rising sharply. This trend together with the increasing concerns about global climate change has led to the rapid growth of biofuels industry. Biofuels are fuels produced from crops, plant residues or wastes biomass for a wide range of applications (Kgathi *et al.*, 2009; FAO 2008; Philip, 2007). Biofuels can be in solid (fuel wood), liquid (bio ethanol) or gaseous (biogas) form. Biofuels from Jatropha oil is one of the most viable candidates for biodiesel feedstock's especially due to its adaptability to semi-arid lands. *Jatropha curcas L.* is a large shrub or small tree reaching the height of up to 5 meters, and usually is growing in marginal lands (Heller, 1996; Jongschaap *et al*., 2007; Philip, 2007; Tomomatsu *et al*., 2007). Having been introduced to Africa some centuries ago, the plant is now widely grown in semi-arid lands throughout the drier area of the continent (Tomomatsu *et al.*, 2007).

The production of Jatropha has been promoted for its perceived economic and ecological advantages. From the private investors' perspective, a newly available energy crop is expected to be less expensive to produce than other energy crops such as rapeseed and soybeans. The argument based on the availability of low-cost labour and land in Africa (Tomomatsu *et al.*, 2007). Jatropha production is expected to contribute to the improvement of rural livelihood because the main production location for the crop is in semi-arid lands where income poverty level is high and land productivity is low (Tomomatsu *et al.,* 2007). Small-scale farmers are expected to engage in the feedstock production at the first stage of biofuel value chain, that is Jatropha seeds (Wiskerke, 2008; Tomomatsu *et al.*, 2007). Small-scale Jatropha farmers are those who have pieces of land up to 0.5 ha dedicated to the cultivation of Jatropha. The farmers include those who work in nurseries, the gatherers and collectors (Messemaker, 2008). Smallholder farmers comprise the bulk of Tanzania's population and are the principal residents of most of the areas with the great potential of biofuel investments (Sulle *et al.,* 2009).

1.2 Problem Statement and Justification

According to Kgathi *et al.* (2009), rapid growth of the production of biofuel crops such as Jatropha is one of the factors, which affect food security. The risk factors of Jatropha production to food insecurity are context specific, depending on country characteristics such as availability of land, climate change, labour force, and bio energy demand. As the implications of Jatropha development for developing countries are scrutinized more closely, one emerging concern is the negative impact of high food prices which is partly a result of increased competition from biofuels for agricultural output and resources on income poverty and food security (FAO, 2008). Availability of local energy and farm power is fundamental to intensifying agriculture, whilst on the other hand, agricultural development is essential to poverty alleviation (Brittaine *et al.,* 2010).

While Jatropha grows faster in the first years, it only occupies space but does not produce seeds yet. The bigger the Jatropha plants become, the more soil they cover and the less space is left between the rows for intercrops. Therefore, over time, the trend leads to the decrement of the intercropping yields, which is not necessarily equal to the increment of the Jatropha yield. Although there are inadequate facts on the actual performance of Jatropha cultivation, thousands of small-scale farmers are currently establishing Jatropha plantations all over East Africa (Wahl *et al.,* 2008**).** This new source of demand for agricultural commodities creates not only opportunities but also risks for the food and agriculture sectors (FAO, 2008; Tomomatsu *et al.*, 2007).

In spite of the controversies regarding the promotion of Jatropha production, very limited data are available on the profitability of the crop. Furthermore, inadequate information is available on the efficient production systems of the crop. Meanwhile, more investments are coming to Africa and thousands of hectares are expected to be converted to Jatropha production (GEXSI, 2008; Brittaine *et al.,* 2010). It is therefore not well known what will be the effect of these investments, although there have been increasing investments and policy decisions concerning the use of Jatropha as an oil crop, these investments and policy decisions have been based on inadequate information about advantages and disadvantages of the same. Lack of knowledge of successful methods of establishing and preserving Jatropha could be a barrier to its successful cultivation (Zeller *et al.*, 2011).

Based on the above information, biofuel production particularly *Jatropha curcas* has a lot of unknown benefits and risks to the Jatropha small-scale farmers. An increase in the demand for land for Jatropha cultivation, energy fuel, volatile prices of fossil fuel, high prices of food commodity and climate changes contributed by green house effect bring opportunities as well constraints to small scale farmers. Based on that information there is need to conduct research on production systems and the impact of Jatropha production on the livelihood of people living in the rural areas in Tanzania so as to bridge knowledge gap on this aspect.

1.3 Objectives

1.3.1 Overall objective

The overall objective of the study was to assess the Jatropha production as well as the prospective opportunities and constraints to small-scale farmers in Tanzania.

1.3.2 Specific objectives

(i) To examine the profitability of Jatropha production as a biofuel feedstock produce in the study areas among Jatropha small-scale farmers.

(ii) To compare profitability of Jatropha production between different production systems.

(iii) To assess the factors which influence productivity in Jatropha production for different production systems.

(iv) To analyse the Jatropha seeds oil contents from different districts.

(v) To assess the opportunities and constraints to Jatropha production in the study areas

1.4 Hypotheses

(i) Profits from the Jatropha intercropping are higher than that of both mono-cropping and living fence

(ii) Jatropha production is the most profitable crop enterprise in the study areas

(iii) Age of Jatropha tree, age of the household head and the type of production systems constitute the major factors which influence productivity in Jatropha production.

(iv) Oil content from the Jatropha seeds from Monduli is higher than from other districts.

1.5 Significance of the Study

The assessment of the production systems available in the study areas and investigation in which small scale Jatropha farmers benefit from farming, were made to give a clear understanding of the situation on the ground. As majority of farmers' lives depend on agriculture, the benefits accrued from agricultural production can contribute significantly to poverty alleviation. All agricultural activities were assessed in the view of coming up with proportionality contribution of crops to household income. Three production systems (i.e. mono-cropping, intercropping and living fence) were covered in the current study. It is also worth noting that other agricultural activities, the cost of production and revenues from the produce were also assessed.

Oil contents from the Jatropha seeds, which are the essential part of this oil crop, were analysed to predict the potential of Jatropha in alleviating energy poverty, which pose a challenge for development of most farmers in the rural areas.

It is envisaged that the findings from this study would provide information that would enable policy makers to formulate and modify policies related to the improvement of Jatropha production and make the crop have the desirable quality for fetching high prices in the local and world market. Farmers in the study areas and all over the country were considered to benefit through a range of inputs, outputs, and management options that would be technically and practically feasible. In the long run, the findings would contribute in ensuring economic, social and ecological sustainable livelihoods through benefits which are assossiated with Jatropha as a biofuel crop.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Definition of Concepts

2.1.1 Biofuels

The concept of biofuels refers to fuels derived from biological sources; it can also be defined as transportation fuels derived from biological (e.g. agricultural) source (Von Lampe, 2006). According to Milder *et al.* (2008), biofuel refers to energy derived from recently living plants, animals or their by-products. Being a subtype among many types of biomass, biofuels are in various forms; these include liquid such as fuel ethanol or biodiesel, or gaseous such as biogas or hydrogen (Philip, 2007). Furthermore, the most common feedstock's for producing biodiesel are generally vegetable oils, which are derived from oilseed crops such as oil palm, Jatropha, sunflower, and rapeseed.

2.1.2 Profitability

Profit can be defined as revenue minus cost, that is, the price of output times the quantity sold (revenue) minus the cost of producing that quantity of output and can be either accounting or economic profit. Profitability is the primary goal of all business ventures. Without making profit the business will not be sustainable, hence not viable. Profit measured from income and expenses (Hofstrand, 2009). An income is money generated from the activities of the business while expenses are the costs of resources used up or consumed by the activities of the business.

2.1.3 Accounting and economic profits

Accounting p**rofit** can be defined as the sales of the farm less the costs of production such as labour costs and fertilizers. In addition to deducting business expenses, opportunity costs are also deducted when computing "economic profit". The opportunity cost is the investment returns given up by not having money invested elsewhere and wages given up by not working elsewhere (Hofstrand, 2009). Opportunity costs relate to capital (net worth), labour, or management ability that could be used or employed off the enterprise in question. These are deduced, along with ordinary business expenses, in calculating economic profit.

The economic profit is calculated because it provides a long-term perspective of farm enterprises. Similarly, the farmer can consistently generate a higher level of personal income by using his/her money and labour elsewhere, after examing the viability of farming.

2.1.4 Productivity

The term productivity is defined as an output per unit of an input, where an input can be land, labour and/or capital, and an output can be agricultural produce. If an output is Y and an input is X, productivity, which is p would be Y/X. Normally, production involves more than one input. If X includes only one of those inputs, then the productivity computed is a partial measure of productivity. In case X is an aggregate of all inputs and Y is an aggregate of all outputs, then the productivity computed is a total measure of productivity [Total Factor Productivity (TFP)] (Philip, 2007).

2.2 Small Cash Crop Production

The rural economy of many African countries is based on cash crop production. The crops are grown primarily for marketing with only a small proportion of the produce being kept back for home use (Rweyemamu, 2001). This definition encompasses a wide range of crops. However, most of the cash crops growers share some common characteristics (i.e age, education level, lack of support from the government, accesss to market information, household size, and compositions).

Tanzania is predominantly an agricultural country with a crop production sector playing an important role in the socio-economic development of its people. In the country's economic development, agriculture has been given a top priority, and it is the sector that is predominantly based on the small-scale peasant agriculture (Philip, 2001).

Agriculture is practised mainly by small scale farmers. Jatropha as a biofuel crop is grown by smallholder farmers and promoted by local NGOs for non-transport applications such as fuel for cooking and feedstock for soap making. In this light, as Foerster *et al.* (2008) argues, the crop is expected to contribute to household income. . It is estimated that smallholder's production under labour intensive farms with low production technology account for more than 75 percent of the total agricultural production in the country (Mushi, 1993; Philip, 2001). Furthermore, Tanzania's 3.5 million farm families work on smallholdings with areas cultivated averaging 0.9 hectares with some 93 percent of all farmers cultivating less than 2.0 hectares (Peter, 2006). It is also reported that smallholder farmers on privately owned pieces of land carry out about 85 percent of agricultural production. This accounts for about 90 percent of the marketed agricultural output that depend mainly on rain fed agriculture (Peter, 2006). Agricuultural production is still carried out by small scale farmers whose lives depend heavily on agricultrure and use different production sytems depending on the land availabilty and the types and number of economic activities on the location. About 80 percent of the produce comes from mostly inter cropping production system which counts for less than 2 hectares per household (Peter, 2006).

2.3 An Overview of the Status of Biofuels Production

The Jatropha experts from different countries around the world found different Jatropha yields from different countries. In Cambodia, five tonnes of seeds can be collected from one hectare with 1 300 plants per year which represents a yield of 3.8 kg per plant per year (Henning, 2007). Jatropha is being promoted as an ideal plant for semi arid areas where it is said to benefit the rural poor as a cash crop. The crop is aimed at supporting women in particular who use the oil extracted from the seeds for soap making. Generally, literature cites an amount of 550 to 600 mm of annual rainfall as a minimum requirement for *Jatropha curcas L.* to grow. *Jatropha curcas* seed yields usually range between 4 and 8 tons per hectare per year (for mature plants of 4 to 6 years). Some sources report the yields of being as high as 12.5 tonnes (El Gamassy, 2008), and a few sources indicate yields of less than 1 tonne per hectare (Kempf, 2007). The yield of Jatropha seeds varies, in accordance with the manner in which the crop is cultivated (Zeller *et al.,* 2011).

Jatropha biofuel production could be especially beneficial to poor producers who have little opportunity for alternative farming strategies particularly because of being in semi-arid and remote areas (Brittaine *et al.,* 2010).

Bio energy systems are unlikely to yield net benefits when feedstocks are produced on land that is highly suitable for conservation or food production (Milder *et al*., 2008). Biofuel crops such as palm, coconut, and Jatropha can provide important opportunities for improving returns from agriculture, especially in on relatively unproductive or infertile lands (Sulle *et al.,* 2009).

Many experts and producers promote biofuels as cheap and environmentally friendly energy source due to their chemical properties. Experience with Jatropha production in Sub-Saharan Africa which is traditional and South Asia has revealed that yields have along been marginal, as the best reported yields have been between 1 and 1.6 tonnes per ha (Brittaine *et al.,* 2010). In Africa, there is growing interest from foreign private investors in establishing biofuel projects. Being part of the global village, Tanzania is not left behind in promoting biofuels as an alternative source of energy. Currently, the country plans to convert millions of hectares of arable land into biofuels production centres (Mcharo, 2009; Sulle *et al.,* 2009). The justification for the promotion of large-scale biofuels has been the argument that the country's demand and prices for petroleum products have been growing rapidly and at a rate of more than 30% per year (Mcharo, 2009). For Tanzania, biofuel production has the potential of providing a substitute for the current costly oil imports, which is US$ 1.3-1.6 billion per year, accounting for approximately 25% of the total foreign exchange earnings (Sulle *et al.,* 2009).

Moreover, Jatropha is promoted based on its suitability for marginal lands and its multiple uses, hence reducing competition with food crops and offering income alternatives to farmers (Ariza-Montobbio *et al.*, 2010). Jatropha is an underutilized, oil-bearing crop, which produces seeds that can be processed into non-polluting biodiesel. Evidence suggests that if well exploited, the crop can provide opportunities for good returns and contribute to rural development (Brittaine *et al.*, 2010). Jatropha seeds contain non-edible oil with properties that are well suited for the production of biodiesel.

Biofuel feed stocks are produced on small farms and processed in on-site or nearby small-scale facilities to generate electricity, biogas for cooking or liquid biofuels for running machinery or vehicles (Milder *et al.*, 2008).

In Tanzania, the government has set guidelines on the production of biofuels in relation to food crops. The major problem is that the market is deregulated and the buyers dictate the prices thereby taking advantage of the farmers' ignorance or lack of alternative (Osogo, 2010). Jatropha oil seeds earn lower prices than other cash and food crops, whilst price is the major factor that farmers take into consideration when prioritising field crops (Sulle *et al.*, 2009).

2.4 Potential of Jatropha Production for the Improvement of Rural Livelihood

Jatropha (*Jatropha curcas)* being one of the sources of biofuel feedstock's and an environmental friendly source of energy, can grow on marginal land in many countries. It is worth noting that the marginal land, which is usually occupied by poor people, could as well be used profitability for Jatropha crop production (Muok, 2008).

In Tanzania, the area under Jatropha production is about 15 km (of Jatropha hedges) with a possible harvest of 12 000 kg of seeds (i.e. 0.8 kg of seeds per m of Jatropha hedge) and the monetary cash which is earned by the village people, is more than 3 000 US$ per year (Wiskerke, 2008; Muok, 2008; Mtui, 2007). As Parawira (2010) reports, the yields of approximately 4 tonnes of seed per hectare can be achieved in unkept hedges. It is assumed that there is enough labour needed for Jatropha production, because small-scale peasant farmers constitute more than 80 percent of the total population in the region (Philip, 2007).

Jatropha production as biofuel feedstock can contribute to improvement of livelihood of the people in rural areas (Tomomatsu *et al.*, 2007). It is also expected that biofuels have the potential of providing a new source of agricultural income and economic growth in rural areas, and a source of improvements in local infrastructure and in broader development (Sulle *et al.,* 2009). Experiences based on the oilseed study in Kenya among hundreds of farmers growing Jatropha show that the crop experiences extremely low yields and there are generally uneconomical costs of production being incurred (Osogo, 2010). As such, there is need for assessment of the agronomic and economic viability of Jatropha through research and development (Osogo, 2010).

2.5 Potential of Biofuel Production in Tanzania

Jatropha is among the crops, which can be used as feedstock in Tanzania for producing biodiesel. According to Philip (2007), oil palm and Jatropha are crops that have high oil contents. Unlike other oil crops, Jatropha is not a food crop and its use for biodiesel production is not likely to compete with food. Among the crops identified, Jatropha has relatively high potential for biodiesel production. The crop has good return, requires relatively low inputs, and can be grown in the marginal land areas and which other crops cannot be produced. In addition, not only that Jatropha has high potential of biodiesel production per hectare but also it has higher returns from its alternative uses (i.e. soap making, charcoal, medicinal uses). The possibility of using the crop for biodiesel is higher than other oil crops. These qualities make the use of the crop as energy source for fuel production very attractive as well as having little possibility to compete with fossil fuel (Philip, 2007). It may not be true that Jatropha oil production requires minimum amounts of labour because labour is required to prepare the land, set-up nurseries, plant, irrigate, fertilise, prune, harvest and process the seeds ready for the market, particularly in the early years (Parawira, 2010).

Willingness of the farmers in the rural areas to grow biofuel crops like Jatropha, an increase in the opportunities for the spread and growth of the crop in large areas and volatility in prices of the conventional fuel make e biofuel the best alternative source of energy to many people (Sulle *et al.,* 2009).

The potential impact of biofuel production on the price of food crops in Tanzania is already a major concern (Sulle *et al.,* 2009; Mshandete *et al.,* 2009). Interest in

Jatropha curcas as a source of oil for producing biodiesel has arisen because of the crop's perceived ability to grow in semi-arid regions with low nutrient requirements and little care (Brittaine *et al.,* 2010). Additionally, biofuel development in Tanzania needs to be viewed within the context of the overall Tanzanian economy and policy debates surrounding the production of the crop (Sulle *et al.*, 2009).

Tanzanians, especially the rural people, depend wholly and exclusively on agriculture and crop production for food and business purposes. Allowing biofuel production means scrambling for land resources between biofuel producers and agriculturists (Kamanga, 2008).

2.6 Jatropha Production Systems

Intercropping, mono-cropping and living fence are different production systems used in Jatropha production areas. These systems involve incurring costs of production at varying degrees. During the first five years of a Jatropha plantation, the Jatropha crops are small enough to allow intercropping of understory crops, like beans, onions and groundnuts, since these crops do not compete with Jatropha for light and water (Wiskerke, 2008). Jatropha can also be intercropped with vanilla (*Vanilla planifolia*) to serve as a pole for vanilla vines and to provide shade for vanilla leaves (Loos, 2009). The benefits of intercropping are expressed by the fact that the opportunity cost of agricultural land is zero when the land is intercropped (Wiskerke, 2008). The advantages of intercropping include helping to boost cash flow, weed control, provision of shade, and availing nutrients as Jatropha's root system is deep (Osogo**,** 2010).

Farmers also grow Jatropha as a live fence (hedges) around the fields to prevent cattle and other animals from destroying the crops. Such fences also help farmers in preventing soil erosion and land degradation (Wiskerke, 2008). Small-scale farmers in some rural areas have extensively planted Jatropha as hedge and boundary marker. Some farmers with limited landholdings have decided to experiment with growing Jatropha as a farm hedge, on contours and degraded land (Sulle *et al.,* 2009; Tomomatsu *et al.*, 2007).

Jatropha is now a cash crop monoculture (Loos, 2009). Large monocultures have been the favoured mode of biofuel feedstock production precisely because they generate high yields. However, the long-term sustainability of these yields is doubtful in many instances when biofuel feedstock production depletes topsoil, soil nutrients or groundwater supplies, which may not be renewable within meaningful timeframes (Milder *et al.,* 2008). On a monoculture plantation, the spacing is denser so that more seeds are produced per hectare and thus more labour is needed (Wiskerke, 2008). Avoiding monoculture is a sustainable, less expensive solution (Osogo, 2010).

Whether the approaches remain sustainable will depend on the economic viability of the biofuel crops in what may not be prime conditions; and as such further and detailed economic and agricultural analysis as well as follow-up studies on such initiatives will be important in monitoring the situation (PAC, 2009). Internationally, there is an ongoing substantial work on sustainability criteria for Large-Scale biofuels production for developed country markets as a liquid transport fuel.

However, there has not been corresponding work undertaken for Small-Scale Bioenergy Initiatives (PAC, 2009).

2.7 Processing of Jatropha Seeds and Oil Content Levels

Biofuel development in Tanzania centres mainly on the cultivation and processing of Jatropha plant seeds, which are very rich in oil (Mshandete, 2011). Smallholder farming is the dominant mode of production in the current Jatropha growing areas. The plant oil is supposed to be used as straight vegetable oil only (Loos, 2009). The seed typically contains 35% oil, which has properties highly suited to making biodiesel, though the oil contents are highly variable depending on many factors (Gohil *et al.,* 2008). As stated earlier, unlike other major biofuel crops, Jatropha is not a food crop since the oil is non-edible and is, in fact, poisonous (Brittaine *et al.,* 2010). Jatropha has a high yield potential of more than 2 tons of oil per hectare per year (GEXSI, 2008). Jatropha oil which lies in the range of 25–40 percent, is highly suitable for producing biofuel and it can also be used directly in generating power to suitably adapted diesel engines and provide light and heat for cooking (Brittaine *et al.,* 2010). However, as Sulle *et al.* (2009) and Parawira (2010) report, Jatropha's oil yields are lower than other oil crops and each Jatropha seed can yield 30-40% of its mass in oil (Sulle *et al.,* 2009). According to Tomomatsu *et al.* (2007), 3.5 kilograms of Jatropha seeds with 32% oil content would be required to produce 1 litre of Jatropha oil and the commercial price of Jatropha oil is thus expected to be less than that of crude palm oil. Indeed Jatropha can grow in the semi-arid lands but may be without any commercial yield being achieved (Parawira, 2010). Also, a total of 299 man-days are needed per year and per hectare to run the mono-cropping plantation under maximal production; this is in contrast to 70 man-days per hectare required for maize cultivation, looking for opportunities of trading Jatropha seeds, oil or utilizing the oil for cooking stove, electrification or soap production. Jatropha production in Tanzania is estimated to be 18 000-58 000 tonne per year (Wiskerke, 2008; Foerster *et al.*, 2008; Philip, 2007; Tomomatsu *et al.*, 2007).

The production of the crop typically requires 200 people per hectare to harvest and, as demand grows, even more work force would be required to manage the crop during growing stages. In some parts of the world, for example in various African nations, these necessary increases in labour are regarded as a positive social impact to local communities as they create jobs and increase income generating activities (Philip, 2007; FAO, 2008). A significant yield gain from Jatropha production on land productivity is likely to move to high quality arable land and replace food production. Yield is a good indicator of crop productivity, which allows experts to evaluate both the biological and the economic sustainability of a cropping system (Zinck *et al.,* 2002).

As Osogo, (2010) argues, Jatropha production would contribute to poverty reduction by diversification of income sources and creation of employment opportunities. The assumption that the market price biofuel is equal to that of diesel or kerosene is likely to be too optimistic, since Jatropha oil cannot be directly used in conventional equipment (Wiskerke, 2008). Unless farmer groups are able to operate small-scale oil extraction operations (preferably with transesterification), the rural economic benefits are likely to be absorbed by the bigger entities in the industry (Tomomatsu *et al.*, 2007).

There is little data on the possible economic impacts of large plantations of Jatropha, although the maximum wages for employees would be determined by the international price of Jatropha oil, but it is not particularly attractive at present (Tomomatsu *et al.*, 2007). Although according to Philip (2007), there is a high potential of producing biodiesel by using Jatropha as a feedstock, yield and oil content are the two primary factors responsible for motivates farmers to produce Jatropha seeds. Special emphasis is being put on improved production and productivity of the planting material (Salé *et al.,* 2009). Jatropha oil is only economically viable when its price is competitive with the prices of the available alternative oils at the markets and gas stations. In Tanzania, the prices of fossil fuels change every month and are announced by (Energy and Water Utility Regulatory Authority) EWURA. Therefore, there is no actual price, which can be considered as competitive with the price of Jatropha oil, and which was not yet in the market at the time of this study.

2.8 Potential of Biofuel and Income Generation from Production

According to FAO (2008), biofuels may offer an opportunity for developing countries like Tanzania where 75 percent of the world's poor depend on agriculture for their livelihoods to harness agricultural growth for broader rural development and poverty reduction. Traditionally, rural women that comprise majority of rural population use *Jatropha curcas* for medicine and for soap production. The women can easily sell Jatropha soaps in the local markets and in the nearby towns, and increase their opportunities of earning an income using local resources (Henning, 1996).

In Tanzania, Biofuel production is increasing in terms of the area cultivated and the volume produced. According to Philip (2007), Jatropha crop which has a high potential for biodiesel production, has good returns and requires very low inputs. Tanzania is one of the countries that have abundant arable land and cheap labour. It is expected that each hectare of plantation would yield seeds sufficient to produce 2.5 tonnes of bio-diesel annually (Awasthi *et al.*, 2006). Biofuels may also provide a new source of agricultural income in rural areas, becomes a source of improvements in local infrastructure, and brings broader development (Sulle *et al.,* 2009). It is expected that biofuels would provide an opportunity for Africa to develop their economies because of increasing global demand for energy (Osogo, 2010).

Jatropha is a crop that uses less water, fertilizers, and labour, making it a favourable crop for cultivation among poor small-scale farmers, (Ariza-Montobbio *et al.,* 2010). Thus, the crop is expected to be cultivated with minimum costs. This is of special importance to Africa where the majority of poor small-scale farmers practice mixed crop-livestock agriculture and few specialise in either crop production or livestock keeping only (Nhemachena *et al.,* 2010). It appears that there is no possibility for small-scale farmers to raise their incomes if they switch from food crop production to Jatropha production (Zeller *et al.,* 2011). Since Jatropha is much less profitable than many food crops even on marginal land, its production does not seem profitable at all for farmers.

Introducing alien species at a large scale in any environment, even when such an initiative can potentially contribute to rural employment and poverty alleviation, needs serious consideration. The claimed tolerance of *Jatropha curcas* against pests and diseases on a few dispersed trees might not apply in general to all the trees in all plantations (Parawira, 2010). Therefore, even in intercropping systems, the benefits farmers accrue from Jatropha cultivation are questionable since intercropping of food crops can provide more income and greater stability of food supply than Jatropha (Zeller *et al.,* 2011). Jatropha plantation should not be taken as highly profitable cash crop without considering the value of by-products and other advantages (Barua, 2011). This can only be realised if negative impacts on food availability and access are avoided, which means only small-scale biomass production can be considered, and this may mean growing the crop as fences and hedges, alongside roads or in intercropping systems (Zeller *et al.,* 2011).

In all the Jatropha cases, a non-food crop is being used to produce the biofuel and all initiatives are promoting one or all of a series of measures to decouple this activity from food production including intercropping with food (PAC, 2009). Information on cultivation, establishment, management and productivity of Jatropha under various climatic conditions is lacking (Parawira, 2010). This study was aimed at exploring the information of Jatropha production from different production systems and the benefits, which small-scale farmers obtain from growing the crop.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Conceptual Framework

The conceptual framework of this study (Fig. 1) draws on production systems and factors, including the mono-cropping, intercropping and living fence/hedges systems, agronomic factors, insitutional factors and environmental facors.

The analysis of economic impact considers the Jatropha yields, uses of Jatropha seeds and the way farmers benefit from these uses (i.e. protection of farm out of animals, nurseries establishment, demarcation, control from soil erosion) which considered as an opportunities. Moreover, the processing of Jatropha seeds to get percentage oil contents that becomes a sources of employment, as people get engage in the oil extraction and soap making industries. The by-products of the crop are used for making charcoal and fertilizers; and this process, in one way or another, generates income to farmers. The analysis of economic impact relates to the production activities that are the among the factors of Jatropha production (i.e. land preparation, planting, weeding and harvesting). The analysis would also focus on the profitability from production systems practiced which include mono-cropping, intercropping and living fence/hedge, all of which which contibute to income generation, management of production factors (i.e.land, labour), protection of farms from animals and contol of erosion. On the other hand, commodity marketing aspects include access to commodity markets and inputs and outputs prices and lastly by-products uses (husks and briquette) which include fertilizers and charcoal.

At the household level the aspects analysed include the characteristics of the heads of households, which include the age, marital status, level of education and sex. As for insituttional factors which were under considerarion included extension services, agricultural inputs, processing, marketing and acessibility to credits. The agronomic factors like production systems, cultivated areas, Jatropha plant age and rainfall were also investigated; furthermore, environmental factors were also used as indicators for household economic impact.

Accessibility to energy was evaluated using indicators such as the type of energy used, efficiency, availability and affordability. Credits accessibility was also evaluated especially because of its contibution in meeting the costs of production. The analysis of Jatropha oil contents was also done to assess its contribution to household income through respective production system. Furthermore, the uses of seeds and by-products were considered too as highlighted above.

The analytical framework in this study also considered the contribution of different stakeholders in Jatropha production in influencing access to benefits like land, money and processing equipments. The underlining assumption was that access to all of these would influence agricultural productivity and profit making at all levels. The income from Jatropha yields in the production systems and from the yields of crops intercropped with Jatropha were evaluated using different indicators, including the value and benefits generated from cultivation of Jatropha, the uses of Jatropha oil and its by-products, farmers' involvement in the production from the beginning to the final stage, improved Jatropha production and well being and capabilities, and the opportunity of reducing income and energy poverty as well as constraints that farmers face in Jatropha subsector.

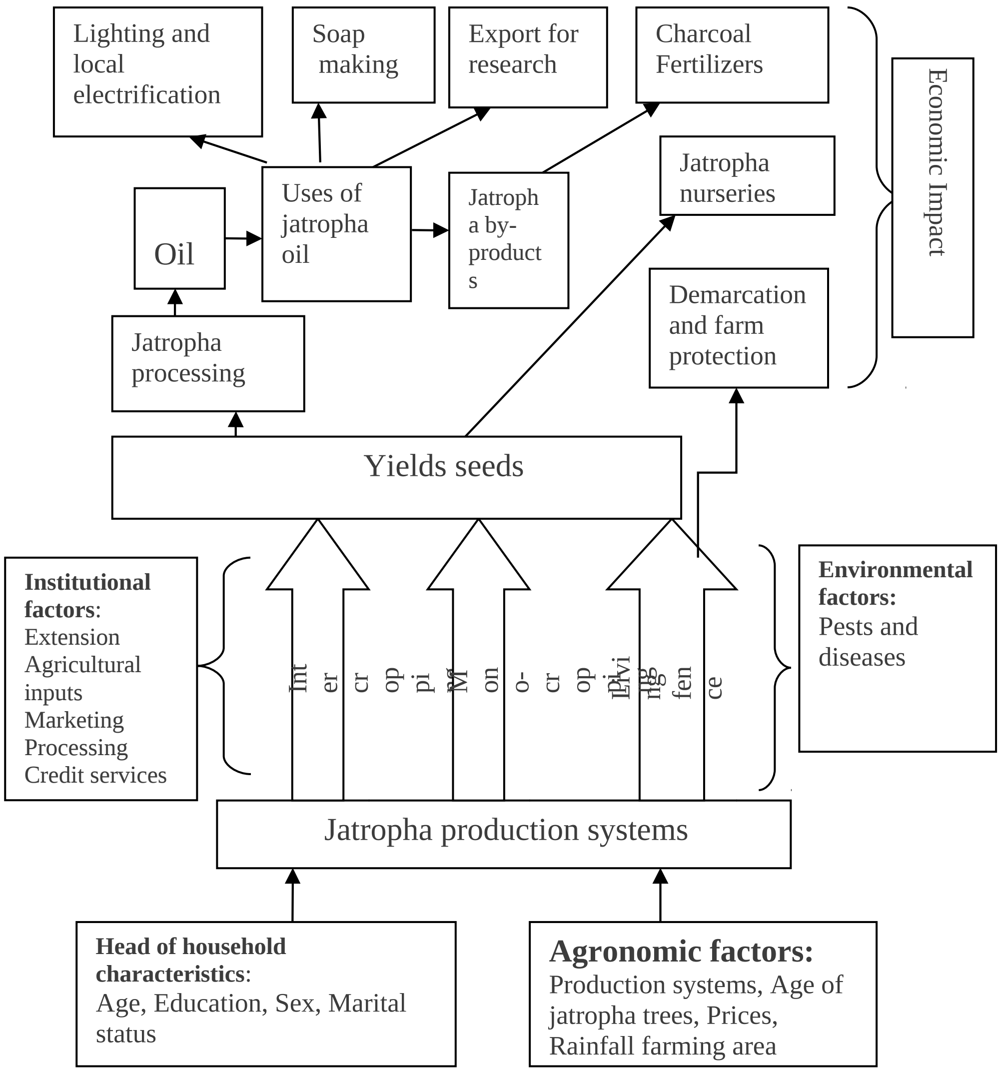

Figure 1: Conceptual framework for the study

3.2 The Study Areas

The areas of study were Arumeru and Monduli districts in Arusha region and Mpanda district in Rukwa region (Fig. 2). The first two districts have semi-arid characteristics and the third district has characteristics of lakeshore weather.

Arumeru and Monduli districts have farmers growing Jatropha as living fence/hedge surrounding their farms. In Mpanda district, farmers grow Jatropha by either intercropping with food crops or as a single crop. In all the three districts, there are companies and NGOs, which deal with Jatropha production.

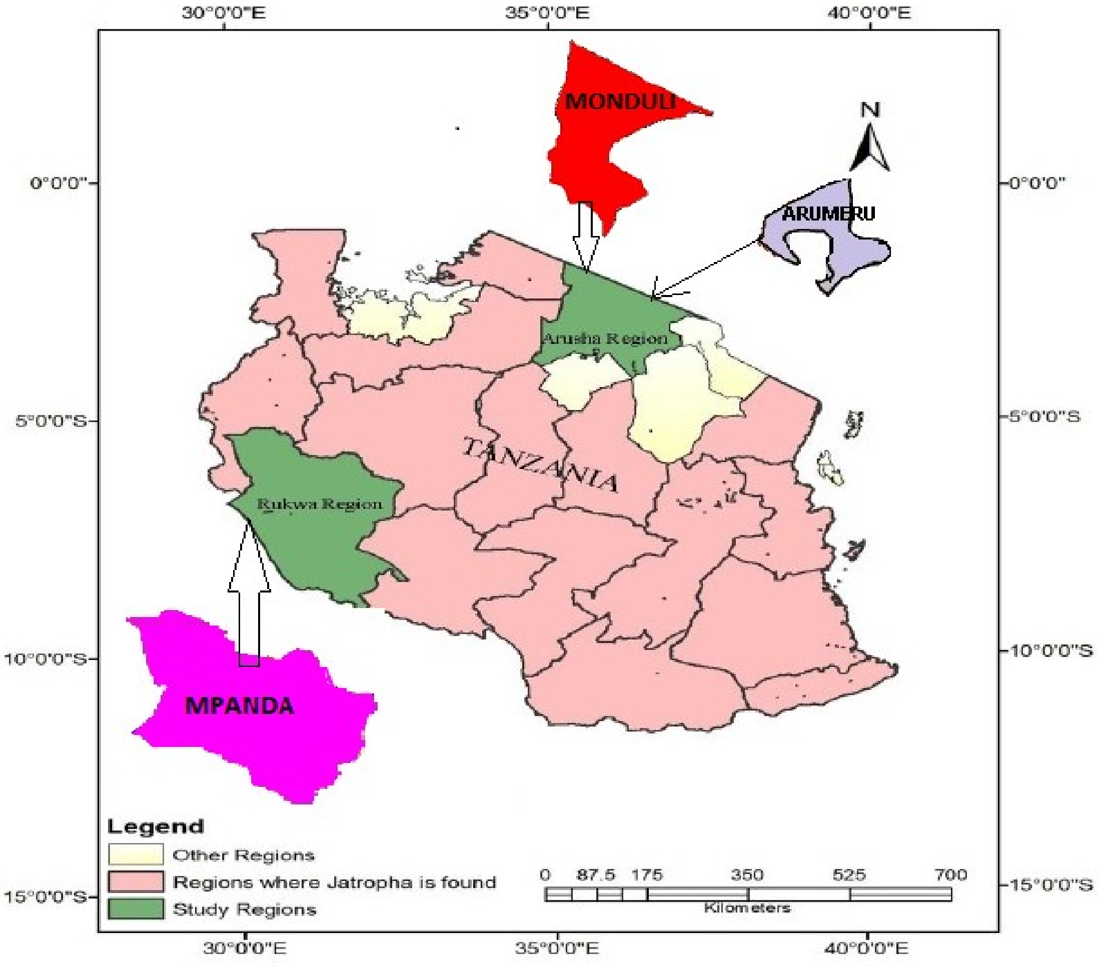

Figure 2: Location of study areas

3.2.1 Arumeru

Arumeru district is located in Arusha Region in the northern part of Tanzania. It is one of the five districts in the Arusha Region of Tanzania. Other districts include, Ngorongoro, Karatu, Monduli, and Arusha. Arumeru is bordering Monduli District to the north and west, Kilimanjaro Region, to the east, and Arusha and Monduli Districts to the south. The district is located on the coordinates 3° 8′ 0″ S, 36° 52′ 0″ E where there is marginal land dedicated to *Jatropha curcas* cultivation.

Almost a half of the Arumeru land is under agricultural cultivated while the rest comprises bush and open grasslands. Arumeru has 2 896 000 ha of area, out of which 156 700 ha is arable land. The district utilized 65.6 % (104 733 ha) of its arable land for crop production. Rainfall is between 1 000 mm and 1 200 mm and the altitude is between 1 000 meter and 2 500 meter above the sea level. According to the 2002 Tanzania National Census, the population of the Arumeru District was 516 814.

The main economic activity for the people in Arumeru district is agriculture and the dominant agricultural practice is mixed farming. This is because a significantly large area of land has been under smallholder cultivation since the colonial era. The major crops grown in the district are coffee, bananas, maize and beans; and minor ones include wheat, barley, finger millet, pigeon peas, sunflower, and paddy. Horticultural crops such as tomatoes, onions, cabbage and Irish potatoes are also grown. Most of the farmers in Arumeru district keep cattle on the mountain slopes. The animals along the slopes are stall-fed and in the lowlands are open-grazed (URT, 2009).

3.2.2 Monduli

Monduli is one of the five districts of Arusha Region in Tanzania. Other districts include, Ngorongoro, Karatu, Arumeru, and Arusha. The district is located in the northeastern part of the country on the latitude of 3° 19' 60 South and a longitude of

36° 15' 0 East. It borders Kenya to the north , Kilimanjaro Region and Arumeru District to the east, Manyara Region to the south and Ngorongoro and Karatu Districts to the west .

Monduli District is divided into 3 divisions namely, Manyara, Makuyuni and Kisongo. The district has 11 Wards and 39 villages, with an area of 6 419 km^2. According to the 2002 Census, the District had 185 237 people. More than 90% of the population in Monduli District is engaged in agriculture and livestock keeping. The District is estimated to have 105 547.5 hectares of potential arable land but only 87 632.5 hectares are under cultivation. Rainfall is low (400 - 500 mm/year). Although large-scale farming is practiced in the Southern part of the District (Lolkisale), subsistence farming is the main form of farming. Major food and cash crops grown in the district include maize, beans and paddy, which are the leading staple food crops. Coffee and sunflowers are also grown but at a small scale. The district is also inhabited by pastoral communities, which traditionally keep a variety of domestic animals such as cattle, goats, chicken, pigs, rabbits and pigeons.

3.2.3 Mpanda

Mpanda district is one of the three districts of Rukwa Region. The district lies between latitudes 5^0 15’ to 7^0 03’ south of Equator and longitude 30^0 to 33^0 31’ East of Greenwich. It is bordered by Urambo district to the North Sikonge district to the East, Chunya district to the East, Nkansi district to the South, Sumbawanga district to the South – East and the Democratic Republic of Congo (DRC) to the West. Kigoma district is found in the Northwest of Mpanda.

The district has a total area of 47 527 km (4 752 700) of which 932 136 ha is ideal for crop production. A total of 2 801 163.7 ha is under Forest reserve, 860 000 ha under Game Reserve, 168 400 ha containing water bodies, and about 1 684, which are used for other activities. Mpanda rainfall ranges from 900 mm to 1300 mm and has been reliable for many years.

According to the 2002 Tanzania National Census, the population of Mpanda District was 412 683. Agriculture is the main activity of the Mpanda's economy employing about 90% of the population. Crops such as maize, paddy, beans, cassava, groundnuts, coffee, sunflower, and Jatropha are the major grown in the district. Based on the available data in the district, maize is the most important food crop. Small holders in most of the villages in the district grow the crop. It is noted that Mpanda district produces between 25% - 30% of the regional maize production in Rukwa region. Paddy, which is used as food and cash crop, is mainly grown in Mpimbwe and Kakese plains. These plains comprise small-scale farms. It has been observed that the quantity of paddy produced in the district ranges between 30% and 40% of the regional total production. Beans are among the types of food and cash crop grown by farmers in the district, mainly grown in Nsimbo, Karema and Kabungu divisions. There are five irrigation schemes found in Mpanda district. These include Uruwira Irrigation schemes, Karema, Mwamapuli, Ugalla, and Kakese Irrigation schemes.

3.3 Research Design

A cross sectional research design was used. The design allows data to be collected once at a single point in time that may be used in descriptive analysis and for determination of relationships between variables (Bailey, 1998).

The study population included Jatropha small-scale growers and living fence. The sample households included both farmers producing Jatropha in the living fence, intercropping as well as in the mono-cropping. A household was considered to be the unit of analysis in the study. In addition, four companies i.e. Kampuni ya Kusambaza Tekinologia (KAKUTE), Diligent Tanzania limited, Prokon Renewable Energy, DISAT and farmers were involved in the interview.

3.4 Sampling Technique

In order to obtain a representative sample, purposive, multistage and random sampling techniques were employed. The first stage involved purposive selection of two regions based on the availability of households involved in Jatropha farming and the difference in production systems. The second stage involved purposive selection of three districts with farmers involved in Jatropha production and had a link with companies dealing with Jatropha. The third stage involved simple random selection of 19 villages from three districts. The fouth stage involved simple random sampling of 100 households from Mpanda with farmers who are supplied seeds by the company, 70 from Monduli with famers who were selling Jatropha seeds to collectors, and 16 from Arumeru where there were farmers who were selling Jatropha seeds to company agents dealing with Jatropha. The Prokon Jatropha farmers' register and village register available at the village government offices were used during this stage. Therefore, a total of 186 households from three districts were interviewed in the study.

3.5 Data Collection

Primary data collection was done using a structured questionnaire that comprised both open and closed ended questions (Appendix 1). This was administered to the contracted small scale farmers (those given seeds by the company), non contracted farmers and living fence owners and farmers cultivating *Jatropha curcas L.* A checklist was used to collect information from focused group discussions and from key informants who were interviewed. The checklist was also used to stakeholders including consultants, NGOs and private companies (JPTL, KAKUTE, Diligent, Prokon and DISAT) who are engaged in *Jatropha curcas* production in Arumeru, Monduli and Mpanda districts. Other stakeholders involved in the study include policy makers at relevant government levels, research and academic institutions and local farmers and extension officers.

Secondary data were obtained from the DALDO's offices, SNAL, internet, stakeholders' offices and from previous studies. The pre-testing of questionnaire was done in January, 2010 in Monduli where there were groups of Jatropha farmers who had direct contacts with companies dealing with Jatropha crop. The pre-testing exercise involved data collection tools to determine whether the items could yield the intended information. The pre-test of the tools facilitated the refining of the tools before they were finally used in the actual data collection practices.

3.6 Data Analysis

The quantitative and qualitative techniques used to analyse the data. For more precise analysis, computer based statistical programmes (Microsoft EXCEL, LIMDEP version 8.0 and SPSS version 12) were used. Descriptive statistics charts and tables used to present the results. Different analytical tools were used to estimate the profitability from different production systems. The key quantitative analytical techniques that were used in this study are total factor productivity, regression techniques and gross margin analysis.

3.6.1 The total factor productivity

The total factor productivity technique was used to test the hypothesis that factors such as age of Jatropha tree, age of the household head and production systems which include extension services provided, land size, education level, have a significant impact on the profitability of Jatropha production. The technique was also used to determine the profitability of production systems (mono-cropping, intercropping and living fence) of Jatropha in terms of returns per hectare. A multiple regression analysis and gross margin analysis were also used in this study as explained in the next subsection. Labour used per hectare (manday/ha), convertion of the area under the living fence/hedges into hectare as well as Ccmputation of human labour in mandays used by the Jatropha small scale farmers in the production systems were as shown below:

Mandays used=[(NL)x(WHR)x(WD)]x(1/8) ….………………………………… (1)

Where NL=Number of labourers (Hired and family labourers)

WHR=Number of working hours per day

WD=Number of working days in a season for Jatropha beans, paddy rice and maize production.

Total Factor Productivity (TFP) is the ratio of aggregate output to the aggregate inputs. The TFP was modelled as:

$$TFP_i = \frac{Y_i}{X_i} \quad \text{……………………………………………………………………} (2)$$

Where Y_i is the aggregated output per farm in terms of value (yield in quantity times price/kg) and X_i is the aggregated input per farm in terms of value (activity times cost per unit).

Conversion of hedge distance increase was done as follow,

First, the width of the hedges and the total area covered by the hedges were measured (Plate 1). The width was measured by doubling the distance from the stem to a fictitious spot below the branch to the farthest reach out by branch. The hedge width was increased by 50 percent, to compensate for the root (which cannot be easily measured) and canopy system competing for light and resources in an additional area outside the hedge.

Width=150%*FBP*2………………………………………………………………… (3)

Where: FBP is the farthest branch point from the stem (Plate 1)

2 is the factor for the estimation distance for both sides of the stem perpendicular to the length direction

Length=HD+2*(150%*FBP)……………………………………………….…. (4)

Where: HD is the hedge distance

[2*(150%*FBP)] is the area at the head and tail of the hedge

Area (m^2) = Width x length …………………………………………………..... (5)

Then the area in hectare: 1 ha=10000 m^2

Plate 1: Farmers measuring the hedge width in Engaruka village (Monduli district)

3.6.2 Linear regression analysis

A good and reliable business decision is always found on a clear knowledge on how a change in one variable can affect all the other variables that are in one way or another associated to it. The dependent and independent variables should be quantifiable. The most common parameters of interest on regression analysis are F ratio, coefficient of determination, and beta coefficients. The aim of using regression analysis was to determine how the predicted variable reacts to the variations of the predictor variables. The coefficients of the variable indicate the responsiveness of producer profitability as a results of a unit change in an explanatory variables used, *ceteris puribus.*

A similar model was used by Parikh and Shah (1994) in their study on the relationship between size, structure and efficiency in agricultural enterprises where they found a positive relationship between the size and efficiency of the studied enterprises. Otieno (1995) used a similar model in her study on institutional credit and the efficiency of resources use among small scale farmers in Kenya. In the study, the researcher found out that there existed a positive relationship between access to credit and the amount of inputs used and farm productivity. Additionally Mutakubwa (2007), used regression analysis to study factors that influence production and marketing of cassava, and the findings revealed that the revenue of cassava business for traders was mostly explained by selling price. However, the researcher did not examine the factors influencing farmers profitability. The current study thus intended to bridge such knowledge gaps for agricultural production particularly, the Jatropha crop. Below is the regression model which was used in this study:

$$TFP_i = \alpha + \beta_1\chi_1 + \beta_2\chi_2 + \beta_3\chi_3 + \beta_4\chi_4 + \beta_5\chi_5 + \beta_6\chi_6 + \beta_7\chi_7 + \mu$$

……….(6)

Table 1: Expected signs of the variables in the multi-regression model

S/N	Variable	Code	Units	Nature	Expected sign
1	Total factor productivity	(Y)	index	Dependent	Positive
2	Age of household head	(χ_1)	Years	Independent	Negative/ Positive
3	Age of plants	(χ_2)	Years	Independent	Positive/Negative
4	Production systems	(χ_3)	Rank	Independent	Positive/Negative
5	Area(ha)	(χ_4)	ha	Independent	Positive/Negative
6	Households size	(χ_5)	Number	Independent	Positive/Negative
7	Extension services	(χ_6)	Frequency	Independent	Positive/Negative
8	Education level	(χ_7)	Years	Independent	Positive/Negative

α constant

μ -error term

3.6.3 Gross margin analysis (GMA)

In order to evaluate the profitability of Jatropha in different production systems (Intercropping system, mono-cropping system and living fence/hedge system on marginal lands), the contribution margin and net operating income are calculated. In the current study, gross margin analysis was used to determine the difference between gross income earned from Jatropha seeds and variable costs incurred for Jatropha and other crops that were intercropped with Jatropha.

The variable costs consisted of labour (hired and family) used in fruits and seeds processing, farm preparation, sowing, weeding and harvesting activities in the study areas. The gross revenue were estimated at real prices. The gross margins were modelled using the following expression:

$$GM = \Sigma TR - \Sigma TVC \quad \ldots\ldots (7)$$

Where:

GM = Average gross margin (Tsh/ha)

TR = Average total revenue (Tsh/ha)

TVC = Average total variable costs (Tsh/ha)

The costs involved include input costs as those in planting materials, seeds, labour (hired and family), fruits and seeds processing, farm preparation, sowing, weeding and harvesting. These costs were calculated for each household on the hectare basis. Other costs include the costs of materials such as hand hoes, packing bags, fertilizers, seeds and seedlings, and transportation.

A comparison of incomes between production systems was made using an Independent Samples T-test to test the hypothesis that profit from the intercropping system was higher than that from living and mono-cropping Jatropha production systems per hectare. The comparisons of gross margins for mean was done using Independent Samples T–test to check for any statistical difference in the variables between production systems.

3.6.4 Oil extraction and analysis

Extraction of seed oil was carried out using the method in which the seeds from 15 samples in triplication for each sample were air dried and weighed. Then, kernels were powdered. The oil was extracted from the samples with known weight in chemical extraction using hexane (50°C - 80°C) for 6 hours without interruption by gently heating the sample. The hexane was evaporated on a water bath until only oil remained in it. The oil yield was expressed in terms of percentage of the powdered sample (Gohil *et al.,* 2008).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Socio-economic Characteristics of Heads of Households

4.1.1 Sex of heads of households

About 80% of the heads of households were males and only 20% were females. In Arumeru district, males and females were approximately equally represented during the interviews. This implies that, in Arumeru district, the local community members were more aware of the importance of gender balance in owning resources. Furthermore, the results show that in Mpanda district, males headed 92% of the households and females headed only 8% of the households. In the case of Monduli district, male and female heads were 65.7% and 34.3% respectively (Table 2). The results suggest that culture and economic activities undertaken by farmers in the study area determine who is likely going to head the household between a male and a female. Almost all household heads in Monduli district were from the semi pastoralists' community, while the rest were entirely from among the crop growers.

Table 2: Distribution of heads of household by sex in percentage

	District name			
Sex	**Monduli n=70**	**Arumeru n=16**	**Mpanda n=100**	**Total n=186**
Male	46 (65.7)	9 (56.2)	92 (92.0)	147 (79.0)
Female	24 (34.3)	7 (43.8)	8 (8.0)	39 (21.0)
Total	70 (100)	16 (100)	100 (100)	186 (100.0)

Note: Number in parenthesis indicate percentage

4.1.2 Marital status of the heads of households

Majority (89%) of the household heads were married, and only 5% were single. It was also noted that 3% of the household heads were divorced, 2% widowed and 1% were separated (Table 3). Marital status influences decision making at the household level, including the use of produce and management of resources and environmental services. Understanding the distribution of marital status of the household heads was pertinent for assessing management and utilization of land for agriculture and improvement of livelihood of household members. The fact that majority of the household heads were married in the study area implies that land ownership and management was mainly based on the marital status due to cultural attributes. The study results reveal that, in all the districts majority of the heads of households were from married households; and that these are the ones with the right to landownership matters in most of the families.

Table 3: Distribution of head of household by marital status in percentage

Marital status	Monduli n=70	Arumeru n=16	Mpanda n=100	Total n=186
Single	5 (7.2)	0 (0.0)	5 (5.0)	10 (5.4)
Married	63 (91.4)	15 (93.80	87 (87.0)	165 (89.2)
Divorced	0 (0.0)	0 (0.0)	6 (6.0)	6 (3.3)
Widowed	2 (1.4)	1 (6.2)	1 (1.0)	4 (1.6)
Separated	0 (0.0)	0 (0.0)	1 (1.0)	1 (0.5)
Total	70 (100)	16 (100)	100 (100)	(100)

Note: Number in parenthesis indicate percentage

4.1.3 Education level of heads of households

The farmers in the study area like other farmers in the rest of Tanzania have completed primary education level. Generally, about 67% of the household heads in the study area had attained primary education, followed by 27% of farmers who had no formal education. In Arumeru district, about 94% of heads of households had attained primary education level, while in Mpanda district those with primary education were 77%. In the case of Monduli, less than 50% of the household heads had attained primary education (Table 4).

It is beyond reasonable doubt that education level determines the level of knowledge individuals have on the efficient use of available resources in alleviating poverty. According to Sumbi (2004), educated people are more knowledgeable on the benefits of the ecosystem services and management approaches. In this study, the results reveal that farmers from Mpanda and Arumeru districts could adopt technologies better than could farmers from Monduli because of the differences in the levels of education that determine the level of knowledge and skills possessed by these two groups of people.

Table 4: Education levels of household heads in percentage

Education level	District name			
	Monduli n=70	**Arumeru n=16**	**Mpanda n=100**	**Total n=186**
None formal school	36 (51.4)	1 (6.2)	14 (14.0)	51 (27.4)
Primary education	33 (47.2)	15 (93.8)	77 (77.0)	125 (67.2)
Secondary education	1 (1.4)	0 (0.0)	8 (8.0)	9 (4.8)
Post-secondary education	0 (0.0)	0 (0.0)	1 (1.0)	1 (0.5)
Total	70 (100)	16 (100)	100 (100)	186 (100.0)

Note: Number in parenthesis indicate percentage

4.1.4 Household size and age of heads of households

The sizes of households in the study area were relatively large. This is because people believe that having many children would distribute death risks. The results indicate that on average, every family had more than six members. The mean of household size was 6.0 and the average age of the head of household in the study area was 48 years with the standard deviation of 4.0 and 14.0 respectively.

Table 5: Distribution of head of household size and age

District	Variables	Min	Max	Mean	Standard Deviation
Arumeru	Household size	2	10	7.25	2.08
	Age of head of households	26.00	63.00	43.94	8.93
Monduli	Household size	1	22	7.44	4.32
	Age of head of households	19.00	80.00	40.03	12.57
Mpanda	Household size	1	15	5.38	2.69
	Age of head of households	29.00	88.00	54.71	12.67
Overall mean	Household size	1	22	6.32	3.50
	Age of head of households	19	88	48.0	14.17

Generally, the average household size was relatively high. This has an implication on the demand for food and energy for life, which would also increase with the increase of household size. The average age of heads of households in Arumeru, Monduli and Mpanda districts were 44, 40 and 55 years respectively which range between 19 and 88 years. The results reveal that farmers in the study area had manpower for production based on the mean household size presented and on the mean range of 5 and 7 of the size of the household (Table 5). Moreover, the results reveal of there being a possibility for the farmers from the rural areas to increase agricultural productivity by using available work force and hence improve their livelihood through agricultural production. The older people are more open-minded and often, express the need to have the alternative sources of income and energy.

According to Kessy (1998) as cited by Sumbi (2004), development pressures over resources are caused by, among others, an increase in human population. This might also be magnified by an uneven distribution of economic and social benefits, which act as disincentives for effective use of land for growing a certain crop and hence leading to ineffective adoption of technologies. In this regard, rural communities are supposed to have a high real social rate of time preference, that is, they prioritize short-term development projects like growing annual crops more than conservation of the same resources (growing perennial crops like Jatropha).

4.2 Jatropha Production

4.2.1 Production system by gender of heads of households

In all the three production systems, the living fence/hedge had the highest percent of females (77%), followed by 23% of intercropping system. Furthermore, the results show that the intercropping system was leading by having 51% of males, followed by living fence/hedge by having 37% of males and finally mono-cropping system by having 12.2% of males (Fig. 3).

Living fence/hedge was the production system that was mainly found in Monduli and partly in Arumeru due to the nature of economic activities in these two districts.

Majority of farmers were semi pastoralists, however, they planted Jatropha plants for land demarcation, and for keeping livestock at bay. Jatropha plants were also used for contorting erosion and for some cultural purposes.

Out growers and contracted Jatropha, farmers in intercropping and mono-cropping production were found in Mpanda district, where males due to cultural attribute (inheritance) of the people living in the area owned most of the farms. On average, females were leading in living fence because women and young men were mainly involved in the collection of Jatropha fruits. Therefore, the records of yields from the living fence were found from the females rather than males (Fig. 3).

Also, females were found to be engaged in homestead management in most of the households in the rural areas. Therefore, these are the ones who suffer the most from energy poverty. This implies that if females are supported in Jatropha production, there is a possibility for rural dwellers to be relieved of energy problems and income poverty.

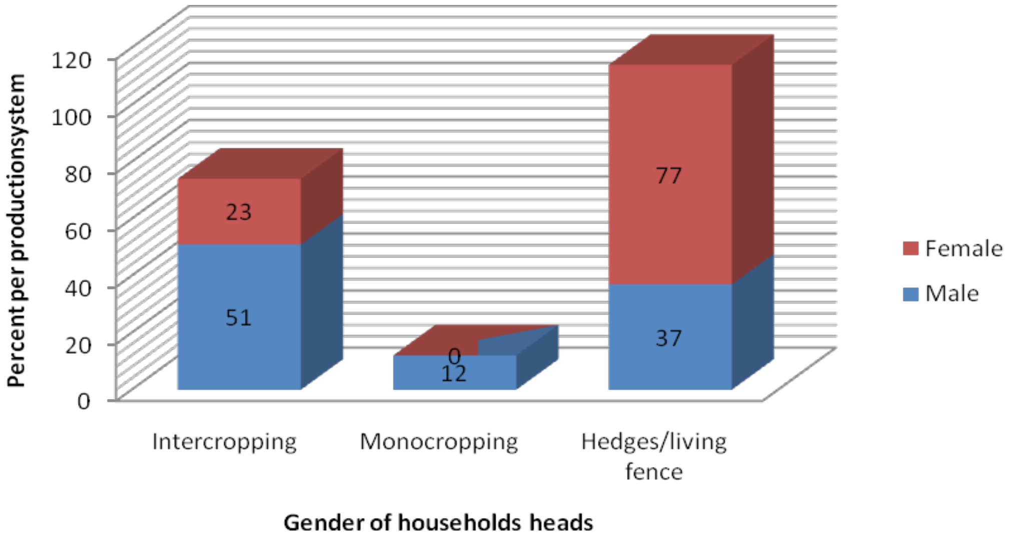

Figure 3: Percent of heads household per production systems

4.2.2 Farm size under Jatropha and other crops

The average land area under Jatropha cultivation owned by a household was 0.25 ha for living fence, 0.73 ha for intercropping and 0.65 ha for mono-cropping (Table 6). The farm size of the cultivated area has implication on the revenue of the household in terms of improvement of standard of living and alleviation of energy problems and income poverty, as people's lives depend entirely on the farming activities. Living fence/hedge production system , which was found in Monduli and Arumeru districts in the cultivation of Jatropha, did not seem to involve large areas which would otherwise be used for food crops because the Jatropha is found on the fences of the farms only. Farmers in these areas have an opportunity to improve agricultural production and increase land productivity because the available areas, which are not used for Jatropha, have the mean of 2.27 ha per household in Monduli and 2.76 ha per household in Arumeru (Table 6).

Mpanda district needs special attention on land management, because the district is located within one of the “Big five” food producing regions in Tanzania. Farmers found in the area were smallholders who owned small pieces of land for both intercropping and mono-cropping production systems. The results reveal that, on average, households owned pieces of land with farm size of 2.22 ha for intercropping and 1.93 ha for mono-cropping systems (Table 6). Most of the farmers in Mpanda owned relatively small pieces of land in which different crops were grown including Jatropha. In this regard, when *Jatropha curcas* attain maturity, farmers would not be able to grow other crops in the same pieces of land as competition of resources among the crops is expected to be high.

Table 6: Farm size per production system

Production systems	Mean (Ha)	Standard deviation	Minimum (Ha)	Maximum (Ha)
Living fence Jatropha	0.25	0.21	0.02	1.44
Intercropping Jatropha	0.73	0.78	0.2	5.05
Mono-cropping Jatropha	0.65	0.23	0	1.21
Maize, beans, cassava (Mpanda1)	2.22	0.01	0.4	15.38
intercropping maize, beans, cassava (Mpanda 2)	1.93	0.45	0.4	4.86
Living fence maize, beans (Monduli)	2.27	0.07	0.81	4.86
Living fence maize, beans , banana (Arumeru)	2.76	0.13	0.81	4.86

Note: Mpanda 1= farmers that intercropped Jatropha with food crops
Mpanda 2=Farmers that did not intercropping Jatropha with food crops

4.2.3 Land acquisition

The ownership of land is an importanat factor in the cultivation of Jatropha in the study area. This is attributed to the fact that landowners do not allow other farmers to plant perenial crops on their fields (Mutayoba, 2005). In this study, it was foundt that

38% of the household heads had inherited land, 29% bought the land while 11% had obtained the land freely and 22% had been given the land by the village governments. These results imply that most of the people in the study area, especially those who grow perenial crops, had inherited the land from their ancestors. Other had acquired the land through purchasing, and the rest obtained the land freely through been given by the village government (Table 7).

The living fence system had many households (25.3%) that obtained land through inheritence compared to intercropping (11.8%) and mono-cropping (0.5%) systems. This implies that some money obtained by individuals from off-farm activities were used to buy land. However, those who owned the inherited land, or land given by the local government as well as those who bought the land grew Jatropha on large areas with the prospects of earning good economic returns from the Jatropha production. Based on this information, the land owened by households was relatively small and dedicated to farming.

Table 7: Land acquisition in the study area

Mode of land acquisition		**Production systems used in cultivation of Jatropha**			**Total**
		Intercropping	**Mono-cropping**	**Living fence**	
Inherited	Number of respondent	22	1	47	70
	Percentage	11.8	0.5	25.3	37.6
Given by the village government	Number of respondent	23	2	17	42
	Percentage	12.4	1.1	9.1	22.6
Accessed freely	Number of respondent	6	3	11	20
	Percentage	3.2	1.6	5.9	10.8

Bought	Number of respondent	35	12	7	54
	Percentage	18.8	6.5	3.8	29.0
Total	Number of respondent	86	18	82	186
	Percentage	46.2	9.7	44.1	100.0

4.3 Yields from Jatropha Production Systems

Seeds are the major output that determined the profitability of Jatropha production systems for small-scale Jatropha farmers in the study area. The survey reveals that there are differences in the number of Jatropha seeds per each kilogram. The data from Monduli and Arumeru districts indicated that a kilogram of Jatropha contains 1 500 air-dried seeds. Moreover, one meter of living fence would have 6-8 Jatropha plants. In the living fence that was mainly found in Monduli and Arumeru districts, the average yields were 733 kg per hectare of dry Jatropha seeds in the growing season of 6 months with 377.5 mm and 496.5 mm of rainfall respectively (Fig. 4).

It was also found out that intercropping system increased the yields significantly as opposed to other production systems. The average yields from Jatropha plants were 1 573 kg per hectare of the dried seeds in the growing season of 7.5 months with 388.2 mm of rainfall in the intercropping systems. These yields were from the Jatropha plants aged 3-5 years of planting. The average yields for mono-cropping system in Mpanda district, were 102 kg /ha for a growing season of 7.5 months with 388.2 mm of rainfall. Mpanda district farmers planted *Jatropha curcas* for economic reasons. It was observed that one kg contain 1 200 air dried seeds and one fruit contained 3 to 4 seeds. The plant spacing for *Jatropha curcas* in mono-cropping and intercropping systems was 2.5m x 2.5m and 3m x 3m respectively.

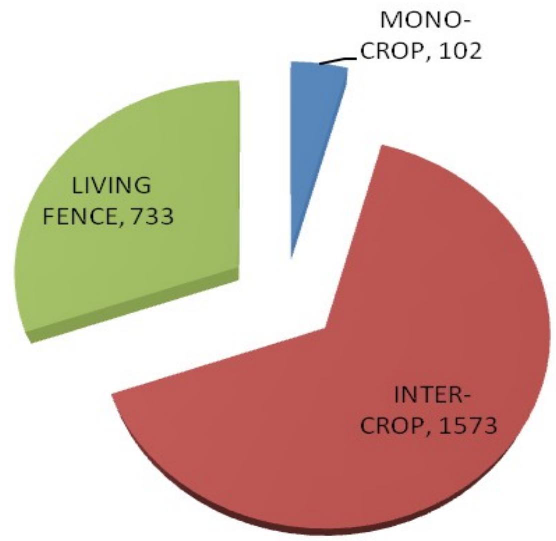

Figure 4: Yield per hectare per production system for season of year 2009

4.4 Gross Margins from Jatropha Production

4.4.1 Jatropha gross margins from different production systems

The study results reveal that there were differences in income generated from the Jatropha production at different production systems. The differences were typical in production costs and output per hectare in all the areas studied. The results indicate that the average producer price per kilogram in Monduli and Arumeru districts was Tsh 100.00 and Tsh 200.00 in Mpanda district. The gross margins per hectare were about Tsh -8 743.32 for mono-cropping, Tsh 4 588.25 for intercropping, and Tsh 268 052.62 for living fence. The results furthermore reveal that the cost of production per hectare in intercropping was relatively higher than in mono-cropping and living fence systems. However, the gross margins for intercropped and mono-cropped systems were negative which implies that the variable costs of production are greater than the income (Table 8).

Morever, there were complains from the farmers and districts officials on the low profit farmers gain from Jatropha production in all the studied areas. It was found that the gross margins and the benefit cost ratios of mono-cropping were very small. This means that it takes time for the household to attained profits. It was also found out that the profitability of Jatropha in living fence was higher than in the intercropping and mono-cropping systems. These findings imply that in the first five years, farmers do not benefit from the crop, hence living in poverty and get discouraged from growing Jatropha. This was contrary to farmers' expectation that they would earn a lot from Jatropha production in terms of income through selling seeds and processing of seeds for soap making.

Table 8: Gross margins analysis for production systems

Item	**Mono-cropping**	**Intercropped**	**Living fence**
Total Jatropha output (kg) (a)	284.81	2 451.49	2 978.06
Total area hectare (b)	11.61	59.81	21.17
Output/ha (a/b) (c)	24.52	40.98	2 978.06
Average price (Tsh/kg) (d)	200.00	200.00	100.00
Revenue/ha (Tsh) (c x d) (e)	4 904.19	8 196.95	297 805.76
Preparation	11 296.36	13 849.48	39 251.74
Planting	7 384.67	6 364.52	28 692.41
Weeding	7 359.64	15 236.21	35 992.24
Harvesting	42 716.53	50 726.17	200 468.80
Sub total	68 757.19	86 176.38	304 405.19
Other costs	21 000.00	43 500.00	21 000.00
Total variable costs (Tsh) (f)	158 514.39	215 852.77	629 810.38
Cost/hectare (Tsh) (f/b) (g)	13 647.52	3608.69	29 753.14
Gross margin/hectare (e-g)	-8 743.32	4 588.25	268 052.62
Benefit Cost Ratio:	0.03	0.04	0.47

4.4.2 Mean difference analysis for gross margins

The mean difference analysis of Jatropha gross margins was done to determine the most profitable production systems. An Independent Samples T–test was used for comparing intercropping, mono-cropping and living fence production systems (Table 9).

Table 9: Mean of gross margins for Jatropha production

Production systems	n	Gross margins mean	Std. Deviation	Std. Error Mean
Living fence	86	74 0 281.85	3 320.80	358.10
Mono-cropping	18	-22 790.31	17 636.05	4 156.86
Intercropping	82	9 367.08	10 135.10	1 119.20

It seems from the Table 9 that there were significant differences between intercropping, mono-cropping and living fence production systems at $p < 0.01$ level of significance in relation to mean gross margin per hectare. Therefore, there is enough evidence to reject the null hypothesis in favour of the alternative hypothesis for the production systems that profits from the Jatropha intercropping are higher than both mono-cropping and living fence.

Moreover, it was found that there is a statistically significant difference between the mean gross margins (as living fence had higher mean of gross margin than intercropping) and the mono-cropping Jatropha production systems (i.e. $t = 650.37$; 376.85, $p = 0.000$) respectively, followed by intercropping and mono-cropping systems (Table 10).

The living fence had higher value and this indicates that the use of living fence production procedures plays a positive role in the alleviation of poverty because it contibutes to household income (Table 10). Intercropping and mono-cropping on the other hand contribute little or no amount to income. Therefore, Jatropha plants do not produce yields to the maximum capacity. Farmers were not using good agronomic practices. This is because neither the district council nor the companies dealing with Jatropha production provided any training on Jatropha production to farmers. .

Table 10: Means difference of gross margins between production systems

Impact outcome	Group statistics	Living fence	Intercropping	Total
Gross margins	N	86	82	
	Mean	740 281.85	9 367.08	
	Std	3 320.79	10 135.09	
	Mean difference			749 648.93***
	95% CI of Difference	Lower		747 373.19
		Upper		751 924.66
	T=test			650.37
		Living fence	**Mono-cropping**	
	N	86	18	
	Mean	740 281.85	-22 790.31	
	Std	3 320.79	17 636.05	
	Mean difference			763 072.15***
	95% CI of Difference	Lower		759 055.84
		Upper		767 088.46
	T-test			376.85
		Intercropping	**Mono-cropping**	

n	82	18	
Mean	9 367.08	-22 790.31	
Std	10 135.09	17 636.05	
Mean difference			13 423.23***
95% CI of Difference	Lower		7 336.53
	Upper		19 509.93
T-test			4.38

Note: *, ** and ***, significant at 0.1, 0.05 and 0.01 levels respectively

The study results also indicate that living fence improves farmer income unlike the intercropping and mono-cropping systems and thus the former contributes to poverty reduction in the study area (Table 10).

4.4.3 The gross margins from intercropping production system

It was also revealed that from year one to year three of Jatropha production, some crops could be intercropped. In Mpanda district, Jatropha plants are intercropped with crops such as maize, beans, groundnuts and cassava (Plate 2).

Plate 2: Jatropha crop intercropped with maize and beans in Mpanda district.

As a result, farmers would earn some income at different growth stages of Jatropha. The beans were found to be the crop that had the highest gross margin of Tsh 288 437.10, followed by maize whose gross margin was Tsh 148 981.81 (Table 11). Although maize and beans, which were intercropped with Jatropha, gave good incomes, they were not sustainable because the intercropping would not go beyond the fifth year of Jatropha growth. Through intercropping system, Jatropha compete with other crops in terms of land size, nutrients uptake, light and water. For the benefits of farmers getting enough food, Jatropha should not be intercropped with other crops, especially food crops.

Table 11: The gross margins for intercropping production system

Item	Intercropped Jatropha	Maize	Beans
Total Jatropha output (Kg) (a)	2 451.49	98 400.00	65 350.00
Total area hactare (b)	59.81	187.44	187.44
Output/ha (a/b) (c)	40.98	524.97	348.64
Average price (Tsh/Kg) (d)	200.00	450.00	950.00
Revenue/ha (Tsh) (cxd) (e)	8 196.95	236 235.60	331 212.65
Land preparation	13 849.48	1 125 000.00	1 125 000.00
Planting	6 364.52	21 100.00	21 100.00
Weeding	15 236.21	169 000.00	169 000.00
Harvesting	50 726.17	141 000.00	141 000.00
Sub total	86 176.38	1 456 100.00	1 456 100.00
Other costs	43 500.00	14 898 750.00	6 561 750.00
Total costs (Tsh) (f)	215 852.77	16 354 850.00	8 017 850.00
Cost/hactare (Tsh) (f/b) (g)	3 608.69	87 253.79	42 775.55
Gross margin/hectare (e-g)	4 588.25	148 981.81	28 8437.10
Benefit Cost Ratio:	0.04	0.01	0.04

4.5 Regression Analysis Results

4.5.1 Regression results

The results show that the total factor productivity from the production systems has a significant ($p < 0.05$) for Jatropha production systems. Moreover, the R^2 value of 0.568 indicates that the model is explained by about 56.8% of the regression line approximates. The real data and the output variable's variance are explained by the input variables' variance (Table 12). Therefore, the regression model was strong in explaining the relationship between dependent (total factor productivity (Y) variable and independent (age of household head (x_1), age of *Jatropha curcas* plant (x_2), production systems (x_3), the area cultivated (x_4), size of the household (x_5), accessibility to extension services (x_6) and level of education of the head of household (x_7)) variables.

Table 12: Regression results for total factor productivity of Jatropha production

Variables	Coefficient	Std. Error	t-value	Sig.
Constant	0.388	0.150	2.579	0.011
Age of household head	-0.005	0.001	-3.389	0.001
Age plants	0.013	0.010	1.281	0.202 ns
Production systems	0.065	0.030	2.191	0.030
Area(ha)	0.000	0.011	-0.027	0.978 ns
Households size	0.030	0.013	2.255	0.025
Extension services	0.088	0.051	1.733	0.085 ns
Education level	-0.065	0.027	-2.421	0.016

Note: ns = not significance
R^2 = 0.568 and Adjusted R^2 = 0.539 F-value = 18.543

The coefficients of the age of Jatropha crop and the areas cultivated were not statistically significance save for the rest of the variables. Also, the results indicate negative coeficients for the variables on the age of responendts (x_1), and level of education of the household head (x_7). The negative signs on the age of head of household implies that for each unit of increase in age, there was a decrease in the producer profitability.

The head of household's age can influence the level of confidence in crop production and hence influence production outputs. In other words, with more experience, a farmer can become more or less risk-averse when taking decisions regarding input use in crop production. This relationship was significant at $p < 0.01$ in Jatropha production. The other production systems (intercropping, mono-cropping and living fence) revealed statistical significant of Total Factor Productivity for *Jatropha curcas* production. This indicates that the farming model has significant impacts on TFP. The coefficient of size of the household was significant ($p < 0.05$) for TFP on Jatropha production. The larger the size of the family the higher the labour used in farming, in collection of Jatropha fruits and seeds and in the removal of the seeds/ fruits coat. Family members contribute to production by providing the needed labour force, and in so doing generate incomes.

It was observed that the farmers, who own comparatively large farmlands, used more hired labour than family labour. The farmers with small farmlands usually used more family labour than hired labour. Since farmers in large farmlands use comparatively less labour (man-day/ha), the TFP was positive.

On the other hand, the provision of extension services had significant impacts on TFP. The farmers who access extension services are more likely to adopt technologies than those who do not access such services.

Moreover, the coefficient of education level of household heads had a negative value, and with a significant influence on TFP for Jatropha production. This shows that as the number of years in schooling increase, the possibility of farmers to cultivate Jatropha decreases. Some farmers prefer short-term projects and early pay back periods rather than long-term project as is the case with Jatropha production. These analyses imply that the farmers in Jatropha production have an opportunity to increase agricultural productivity, and hence, increase their income for them to come out of energy and income poverty through agricultural production. The adoption of improved technologies through extension services provision would contribute to changes of production level. Involvement of farmers in the Jatropha value chain would contribute to the rate of adoption of the Jatropha production technology at different levels of education. Low production in Jatropha in some areas may be because there is knowledge gap among farmers about Jatropha production and its economic values.

4.5.2 Mean difference analysis

The mean difference analysis was carried out to test the TFP mean difference in the Jatropha production systems, in oreder to find the most profitable production system. Independent Samples T–test was used in analysis the means diffrences for intercropping, mono-cropping and living fence Jatropha production systems (Table 13).

Table 13: Means and standard deviations of TFP

Production systems	n	TFP Mean	Std. Deviation	Std. Error Mean
Living fence	86	0.436	0.376	0.041
Intercropping	82	0.132	0.138	0.015
Mono-cropping	18	0.015	0.019	0.005

The results showed that there were statistically significant differences among living fence, intercropping and mono-cropping Jatropha production systems at $p < 0.01$ level of significance in relation to total factor productivity per cultivated hectare. Furthermore, the living fence system has positive outcomes. There were significant difference between the mean TFP for living fence and intercropping and mono-cropping systems (i.e. t = 6.884, 4.725, p = 0.000). The Intercropping systems was the second after Living fence followed by mono-cropping production systems (Table 14). Living fence and intercroppingping had higher values and this implies that both of them contribute to household income.

Table 14: Mean difference of total factor productivity

Impact outcome	Group statistics	Living fence	Intercropping	Total
Total factor productivity	n	86	82	
	Mean	0.4362	0.1323	
	Std	0.37631	0.13779	
	Mean difference			0.30383***
	95% CI of Difference	Lower		0.21669
		Upper		0.39097
	T-test			6.884
		Living fence	**Mono-cropping**	
	n	86	18	
	Mean	0.4362	0.0153	
	Std	0.37631	0.01905	

Mean difference			0.42083***
95% CI of Difference	Lower		0.24417
	Upper		0.59749
T-test			4.725
	Intercropping	**Mono-cropping**	
n	82	18	
Mean	0.1323	0.0153	
Std	0.13779	0.01905	
Mean difference			0.11700***
95% CI of Difference	Lower		0.05267
	Upper		0.18184
T-test			3.581

Note: *, ** and ***, significant at 0.1, 0.05 and 0.01 levels respectively

4.6 Oil Content in Jatropha Seed

The *Jatropha curcas* air-dried seeds had different amounts of oil contents. Each sample used for analysis contained 100 seeds. The weight of samples from Arumeru had the highest weight of 72.77 grams, which yielded 21.06 grams (28.94%) of oil. The average weights of samples from Monduli and Mpanda districts were 67.89 grams and and 65.49 grams respectively, which yielded 20.48 grams of oil (30.17%), and 16.76 grams (25.54%) of oil contents respectively (Table 15).

It was also found that air-dried seeds of *Jatropha curcas* from Monduli district had the highest percentage of oil content, followed by the samples from Arumeru district. Both districts are located in the northern part of Tanzania in the same region, Arusha. Most of the *Jatropha curcas* crop was planted in Arusha for about the past sixty years; and farmers planted the crop for controlling soil erosion, livestock grazing, and demarcation of their pieces of land. This trend may be contributed by the soil factor (nutrients), as most of the areas studied have volcanic soils and a lot of animal dung, which is rich in nutrients. The seeds from Mpanda district had the least oil content of 25.54%. This area is located in the southern highland of Tanzania. People in Rukwa region started to grow the *Jatropha curcas* in their pieces of land in recent years.

These percentages of oil contents, which ranged from 25.54% to 30.17%, in the study area were the same as those reported by Brittaine *et al.* (2010) and Villancio (2006) that show that Jatropha oil contents range between 25% to 40%. However, these results differ from those reported by Jongschaap *et al.* (2007), Van Loo *et al.* (2008) and Pant *et al.* (2006).

Based on these findings, Jatropha oil contents from Monduli and Arumeru districts in which the living fence production system is found were 221.15 and 212.13 Litres per hectare respectively. Furthermore, the results reveal the oil contents that in the intercropping and mono-cropping production systems in Mpanda district, were 733.01 L/ha and 26.05 L/ha respectively.

The sample from Mpanda, which was collected from the Jatropha yields of 2009/2010 season, showed that much of the land was in the third and fourth year since the planting.

Table 15: Amount of oil content in the Jatropha seeds

Study area	Weight of seed (g)	weight of sample (g)	Weight of seed coat(g)	weight of kernel (g)	Percent kernel	Weight of oil (g)	% oil from sample
Arumeru	0.81	72.77	25.26	47.51	65.28	21.06	28.94
Monduli	0.68	67.84	25.23	42.62	62.79	20.48	30.17
Mpanda	0.71	65.49	23.59	41.90	63.86	16.76	25.54

4.7 Credit Services

According to Philip (2001), credit services to small-scale farmers is needed for them to be able to purchase inputs and pay for additional labour requirements that are associated with the use of agro-chemicals such as fertilizers, pesticides and herbicides. Nowadays, access to formal rural finance facilities is limited in Tanzania. Out of 186 heads of households farmers, only 4.3% who participate in Jatropha production had access to credit facilities. Furthermore, the remaining percentage in both segments had no access (Table 16). The proportion of the head of household who had no access to credit facilities was relatively higher (95.7%) than that of the rest of the head of household. This can be attributed to the fact that most farmers had low income to be eligible to the financial services provided by most of the financial insitutions. The conditions set by financial insitutions were difficult to be met by the farmers. Also the results indicate that most of the farmers lack awareness about credit, due to low level of education and the fact that extension services were inaccessible to these farmers. The farmers had expected that the companies dealing with Jatropha would assist them in getting credits which they (farmers) would use in improving production and rid themselves out of income and energy poverty. However, according to group discussion with farmers, farmers' expectation was not met by the finacial sinstitutions.

Table 16: Number of household accessible to credit

Parameter	Response	Percent
Acquisition of credit	Yes	4.3
	No	95.7
Reasons for not		
	Difficult conditions	31.2
	Lack of awareness	19.4
	Low income	43.5

4.8 Extension Services

Extension services are important for productivity of agricultural enterprise. The survey results indicate that a small proportion (12.4%) of the heads of households household heads in all production systems had access to extension services. However, these extension services were only extended to them once per year, also because is not common practice for farmers to visit extesion officers for advice. Majority (87.6%) of the households were not provided with extension services. The problem of accessing extension services seem to be more serious in living fence system where the households were to be visited by extension staff.

It was further indicated that 87.6% of the household heads who claimed to have not received extension services, were from areas where the extension personnel were not available. However, the services provided by the extension staff were completely inappropriate to Jatropha production in terms of good agronomic practices. Most of the services provided by the companies dealing with Jatropha production is limited to improving production rather than procesing (group discussion with farmers). Also most of the extension staff claimed that food production is the priority of most of the districts. Therefore, there were no extension staff allocated for Jatropha production in the districts. Extension staff considered *Jatropha curcas* as a crop that compete with food crops for resources like land, fertilizers, water and labour (group discussion with extension staff).

4.9 Access to Energy

The study results indicate that about 97% of the households use kerosene as the main source of energy for lighting, 1.1% use solar power, 1.1% use straight Jatropha oil, while only 0.5% use both kerosene and straight Jatropha oil as sources of light. Out of 186 households, 37.1% were easily accessing the main source of light, the rest (62.9%) could not easily access any sources of energy (either kerosene, solar, or Jatropha) (Table 17). The factors that contribute to poor access to sources of energy include low income of the farmers as well as the price of kerosene, which is unaffordable to most of the farmers. It was believed that Jatropha production could be an alternative source of energy and could reduce dependency on fossil fuel for domestic uses. However, the results reveal that 94% of the households use firewood as the main and only source of energy for cooking, 3.8% use charcoal and only 2.2% use both fire wood and charcoal as sources of energy. Even the generators that use Jatropha oil installed at Leguruki and Engaruka villages are no longer in use due to the high costs of operation. Villagers through group discussions revealed this.

Farmers in the study area are not satisfied with the energy available for cooking in terms of quantity, the type, and accessibility. Almost 51.6% of the households were not getting sufficient energy for cooking, and the rest (48.4%) of the households were satisfied with the energy available for cooking. Jatropha oil could complement the country's fuel demand and reduce dependency on fossil fuel for domestic use.

Table 17: Sources of energy and their availability

Description	Variable	Percent
Sources of domestic energy for light	Kerosene	96.8
	Solar	1.1
	Jatropha	1.1
	Kerosene and solar	0.5
	Kerosene and generator	0.5
Sources of domestic energy for cooking	Firewood	94
	Charcoal	3.8
	Firewood and charcoal	2.2

Majority of the households used firewood as the only source of energy for cooking. Jatropha production and processing within the country would provide alternative energy for cooking, that is, Jatropha charcoal (Plate 3). One kilogram of Jatropha charcoal, which is under research by Diligent in Arusha is enough for cooking in a household of six members for a day. The charcoal from Jatropha by products does not make soot and has less carbon emission as opposed to firewood. Furthermore, charcoal from Jatropha has high level of efficiency as opposed to firewood and the charcoal from other trees (group discussions with Diligent).

Plate 3: Briquette and charcoal from Jatropha

4.10 Weather Conditions

Rainfall data collected from different weather stations by Tanzania Meteorological Agency (TMA) reveal that farmers in the study area experienced bad weather conditions and less rainfall which led to low yield in different crops. This resulted into farmers having low income due to low yeilds. Farming activities in the study area highly depend on rainfed agrciulture. Furthermore, the study results indicate that Monduli district had the total rainfall of 411 mm, 707.3 mm and 377.3 mm for year 2007, 2008 and 2009. Mpanda district had relatively low rainfall (565.9 mm) in year 2008 as opposed to other districts, although in 2007 the situation was better off. The Arumeru district on the other hand had relatively higher rainfall (998.6 mm) in year 2008 unlike in year 2007 (617.9 mm) (Table 18). In the year 2009, the recorded data reveal that in the whole of the study area the rainfall was relativelly less than what was recommended for different crops including Jatropha (Jangschaap, 2007).

Table 18: Total rainfall (mm) for six months in three seasons from study areas

Year	Monduli	Mpanda	Arumeru
2007	411	641.6	617.9
2008	707.3	565.9	998.6
2009	377.5	388.2	496.5

Source: Tanzania Meteorological Agency

4.11 Problems Encountered in Jatropha Production

The heads of households indicated that there were many problems facing agricultural enterprise. The main problem reported by about 48% of the househoulds in all production systems included low farm gate price for Jatropha seeds. This implies that the prices given by the companies dealing with Jatropha led to low revenue which was less than the cost of production which was Tsh 250.00, Tsh 100.00, Tsh 200.00 per kg of dry seed in Monduli, Arumeru, and Mpanda ditricts respectively and this also reflected on the gross margin per hectare.

About 21% of the households reported to have experienced the problem of diseases and pests for Jatropha plants and fruits, which in turn affected the yields. Most of these households were not in a position to bring such problems under control because of the low income and lack of technical know how (Table 19; Plate 4). Also the results reveal that there is lack of awereness and knowledge about the benefits of cultivating Jatropha. Some of the farmers cannot grow other crops like maize, cassava, beans, groundnuts as they are used to do in the same areas because of the growth stage reached by Jatropha crop, (that is, 3rd to 4th years since the planting date) and which could not allow intercropping (Plate 5). It was expected by farmers that the companies dealing with Jatropha would have provided them with the assistance in the production process of the crop. In particular, the farmers expected to be assisted by the campanies with such things as hand hoes, harvesting materials, training, pesticides; however the results show that 22% of households complained of not being supported by these companies.

Table 19: Problems encountered in Jatropha production in percentage

Variables	Percent
Lack of assistance from the companies(hand hoes, harvesting equipments, diseases and pests control)	11.8
Lack of knowledge and awareness for Jatropha	19.4
Diseases and pests	21.0
Low price given by the company	47.8
Total	100.0

Plate 4: Jatropha fruits and leaves affected by diseases and pests

Plate 5: Jatropha intercropped with maize and beans Mpanda Tanzania

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

5.1.1 Prices and profit margins obtained by the households in the production systems

(i) The findings of the study indicate that the prices and margins obtained by the housedholds in the biofuel production varied significantly. The price of the

Jatropha seeds from the living fence is higher and also obtained significantly higher profit margins dispite the high production costs incurred. Since most of the value addition through production and semi processing is undertaken at this stage, it can be concluded that production and semi processing are effective ways of generating profits.

(ii) The study found out that smallholder farmers from all the production systems have household characteristics common to most rural household settings elsewhere in Tanzania. Most of the farmers had attained at least primary education. Furthermore, most of the male farmers owned farms, although both males and females as well as hired labour all partcipated in all Jatropha production activities. The study shows that there are companies and Non-governmental institutions that promote Jatropha production and marketing in the study area. Most of these are imparting knowledge and skills for Jatropha husbandry and processing to obtain Jatropha oil. Farmers cannot continue with the processing stage due to high costs and unavailability of the needed materials and equipment.

5.1.2 The existing opportunities in Jatropha production

There are a lot of opportunities explored during this study.

(i) Majority of rural dwellers lack sustainable sources of fuels for business and domestic use such as lighting, electification, cooking, and in operating light industrial machines like milling machine.

(ii) Jatropha oil is used for different purposes such as soap making, blending with diesel to run different engines, and in making charcoal and fertilizers (especially for Jatropha by products).

(iii) Other uses as perceived by different stakeholders include growing living fence/hedges in demarcating plots and protecting farms from animals invasion. Other uses include controling errosion.

(iv) Apart from the profits that can be generated through biofuel production; increased demand for energy; unstable prices of fossil fuel; global warming; and current environmental conservation issues have, to large extent accelarated the biofuel production to complement the existing energy sources.

5.1.3 Major constraints faced by small scale farmers in Jatropha production

The major constraints as perceived by different stakeholders were found to be

(i) Low Jatropha seed prices, poor pests and disease control, lack of working capital, lack of processing plants and lack of extension services.

(ii) At the macro level, there is lack of laws and regulation which could provide incentives for producers to improve production.

(iii) The challenge ramains on how to improve biofuel production (Jatropha) at household and macro levels within the country.

(iv) The land owned by farmers, characteristics of Jatropha production and uses of Jatropha products and by-products within the country at all levels were found to be another challenge.

(v) The potential economic impacts are still speculative but could be substantial. Biofuel production can increase the demand for agricultural input such as land and water, and this can jeopardize the production of food crops.

5.2 Recommendations

Based on the major findings of the study, the following are the recommendations geared towards improving the performance of the biofuel production:

(i) As far as low Jatropha prices given to famers are concerned, the government should enact policy, laws and regulations that would guide the biofuel value chain to ensure sustainability. To be effective to the benefit of majority, it is recommended that research on the gaps identified should be conducted and involve all aspects and stakeholders in Jatropha production. Prices should refflect the costs of production to have a win-win situation among the stakeholders. Also there should be boards of biofuels crops that would be responnsible for all issues concerning biofuel including setting up the price.

(ii) Pests and diseases control were observed as one of the major constraints to biofuel production. To control pests and diseases, capacity building in agronomic practices should be promoted to all famers involved in the production so as to increase productivity and hence improve livelihood of the people.

(iii) Majority of the heads of households pointed out lack of extension services as one of major the constraints. The study recommends that the government should enhance efficiency among the extension services by strengtherning the linkage between farmers, extension personel and researchers through the provision of working facilities. This would facilitate the flow of information from the researchers to the farmers and vice versa (proper communication) which is important for the development of relevant technologies. Moreover, the government should recruit many extension personnel in order to provide extension services in all villages. Companies dealing with biofuels should contribute to the provision of extension services.

(iv) The use of biofuel products and by-products as a complement to energy consumption. Processing of biofuel within the country was found ot be limited and thus hindering the use of this energy source at all levels. The government and non govenmemtal organisation should develop simple techologies by involving farmers at every stage of development and implementation for better results that can be used by small holder farmers on the process and use of Jatropha oil. By so doing, farmers would be encouraged to grow more Jatropha and add value to the products and by-products and hence improve their livelihood.

(v) There should be separate pieces of land for growing *Jatropha curcas* and for growing other crops because the intercropping cannot be practiced longer because the crops would, in the end, compete for resources. The study recommends that the small scale Jatropha farmers should adopt the Jatropha living fence production system since the income gained from participation in the living fence system was found to be realistic than that from intercropping and mono-cropping systems. This would depend very much on the area of the living fence.

REFERENCES

Ariza-Montobbio, P., Lele, S., Kallis, G., and Martinez-Alier, J. (2010). The political ecology of Jatropha plantations for biodiesel in Tamil Nadu, India**:** *Journal of Peasant Studies* 37(4): 875–897. [http://www.atree. org/ sites/default/files/articles/bio_fuel.pdf] site visite on 24/5/2011.

Awasthi, K. and Mishra, S. (2006). India Environment Portal: *Knowledge for Change*. [http://www.indiaenvironmentportal.org.in/node/42085] site visited on 13/8/2009.

Bailey, D. K. (1998). *Method of Social Research*. The press Collier. Macmillan Publisher, London. 478pp.

Brittaine, R. and Lutaladio, N. (2010). Jatropha: A smallholder bioenergy crop , the potential for pro-poor development. *Integrated Crop Management* 8: 1-114. [http://www.fao.org/docrep/012/i1219e/i1219e.pdf] site visited 25/3/2011.

Barua, P. K. (2011). Biodiesel from Seeds of Jatropha Found in Assam, India. Department of Energy Tezpur University Assam, India. *International Journal of Energy, Information and Communications* 2(1): 53-65. [http://www.sersc.org/journals/IJEIC/vol2_Is1/5.pdf] site visited 24/5/2011.

El Gamassy, I. (2008). Feasibility study on growing *Jatropha* utilizing treated wastewater in luxor. Agricultural Research Center (ARC), Cairo, Egypt. [http://www.iwrmeg.org/reports/Report/Report%2057%20 Feasabilty%20Study%20on%20%20Growing%20JATROPHA.pdf] site visited on 26//2011.

FAO (2008). The State Of Food And Agriculture Biofuels*: prospects risks and opportunities*, Rome, Italy. [ftp://ftp.fao.org/docrep/fao/011/i0100e/ i0100e00.pdf] site visited on 19/8/2009.

Foerster, E. R., Assmann, D., Clashausen, C., Kerckow, B., and Fritsche, U. (2008). Liquid Biofuels for Transportation in Tanzania Potential and Implications for Sustainable Agriculture and Energy in the 21st Century. [http://www.gtz.de/de/dokumente/en-biofuels-for-transportation-in-tanzania-2005.pdf]. site visited on 18/8/2009.

Gohil, R. H. and Pandya, J. B. (2008). Genetic diversity assessment in physic nut (*Jatropha curcas* L.) Discipline of Phytosalinity, Central Salt and Marine Chemical Research Institute (CSIR), Bhavnagar, India. *International Journal of Plant Production* 2(4): 321-326. [http://www.gau.ac.ir/Jm/Programs/JurnalMgr/VolumArticle/EN_125_5.pdf]. site visited on 24/5/2011.

GEXSI (2008). *Global Market Study on Jatropha*. Final Report. Prepared for the World Wide Fund for Nature (WWF), Global Exchange for Social Investment, London/Berlin, 8 May, 2008. 187pp. [http://www.Jatropha-alliance.org/fileadmin/ documents /GEXSI Global-Jatropha Study FULL-REPORT.pdf]. site visited on 20/10/2008.

Hofstrand, D. (2009). *Understanding profitability*. Extension value-added agriculture. Iowa State University, USA.. [http://www.extension.iastate.edu/agdm/wholefarm/pdf/c3-24.pdf] site visited on 7/7/2010.

Heller, J. (1996). Physic nut. *Jatropha curcas* L. Promoting the conservation and use of underutilized and neglected crops. Institute of Plant Genetics and Crop Plant Research, Gatersleben / International Plant Genetic Resources Institute, Rome, Italy. [http://www.bioversityinternational.org/publications/Pdf/161.pdf site visited on 16/8/2009.

Henning, R. K. (2007). Identification, selection and multiplication of high yielding *Jatropha curcas L.* plants and economic key points for viable Jatropha oil production costs. [http://www.Jatropha.de/documents/Henning-paper-high-yielding-plants.pdf] site visited on 17/8/2009.

Henning, R. K. (1996). Combating Desertification: The Jatropha Project of Mali, West Africa [http://ag.arizona.edu/OALS/ALN/aln40/Jatropha.html] site visited on 12/08/2009.

Jongschaap, R. E. E., Corré, W. J., Bindraban, P. S and Brandenburg, W. A. (2007). Claims and Facts on *Jatropha curcas L.* Global *Jatropha curcas* evaluation, breeding and propagation programme, Wageningen, Netherlands. [www.fact-foundation.com/] site visited on 15/8/2009.

Kgathi, D. L. and Mfundisi, K. (2009). *Potential Impacts of the Production of Liquid Biofuels on Food security in Botswana*. Proceedings of Compete and RE Impact Workshop on “Bioenergy for Rural Development in Africa and Asia,” CCH-Congress Centre, Hamburg, 30 June 2009. [http://www.ceg.ncl.ac.uk/reimpact/Related%20 Documents/Presentations/Kgathi_BotswanaBiofuelsImpacts.pdf] site visited on 15/8/2009.

Kempf, M. (2007). Jatropha Production in Semi-Arid Areas of Tanzania Is the growing and processing of Jatropha in the semi-arid Central Corridor of Tanzania a way to improve the income of rural households and thereby enhance their livelihood? [http://www.tnrf.org/files/EINFORLDC_Jatropha_Production_in_SemiArid_Areas_of_Tanzania_2007.pdf] site visited on 25/8/2009.

Kamanga, K. C. (2008). The Agrofuel Industry in Tanzania: a critical enquiry into challenges and opportunities. Land Rights Research and Resources Institute (LARRRI), Joint Oxfam Livelihood Initiative for Tanzania (Jolit), Dar es Salaam. 66pp.

Loos, T. K. (2009). Socio-economic Impact of a Jatropha-Project on Smallholder Farmers in Mpanda, Tanzania. Dissertation for Award of MSc Degree at University of Hohenheim, Germany, 157pp. [https://troz.uni-hohenheim.de/fileadmin/einrichtungen/troz/Documents/Bioenergy/M. Sc.Loos_Tansania.pdf] site visited on 28/11/2009.

Mshandete, A. M. (2011). Biofuels in Tanzania: Status, Opportunities and Challenges University of Dar es Salaam. *Journal of Applied Biosciences* 40: 2677 – 2705. [http://m.elewa.org/JABS/2011/40/4. pdf] site visited on 30/5/2011.

Mshandete, A. M. and Parawira, W. (2009). Biogas technology research in selected Sub-Saharan African countries: A review**.** *African Journal of Biotechnology* 8 (2): 116-125. [http://www.ajol.info/index.php/ajb/ article/view/59749/48029] site visited on 4/6/2011.

Muok, B. (2008). Feasibility study of *Jatropha curcas* as a biofuel feedstock in Kenya, Nairobi, Kenya. [http://www.pisces.or.ke/ pubs/pdfs/ Jatropha %20Feasibility%20Study%20Final.pdf] site visited on 26/8/2009.

Mutakubwa, E. B. (2007). Production and marketing analysis of cassava in the coast region of Tanzania. Dissertation for Award of MSc Degree at Sokoine University of Agriculture, Morogoro, Tanzania. 81pp.

Mtui, F. (2007). Strengthening rural oil seed processing in Tanzania. [http://www.betuco.be/agroforestry/Jatropha%20System.pdf] site visited on 25/8/2009.

Mcharo, H. (2009). Policies in Tanzania governing Biofuel. [http://www.envirocaretz.com/index2.php?option=com_content&do_pdf=1&id=74] site visited on 15/8/2009.

Milder, J. C., McNeely, J. A., Shames, S. A. and Scherr, S. J. (2008). Biofuels and ecoagriculture: Can bioenergy production enhance landscape-scale ecosystem conservation and rural livelihoods? *International Journal of Agricultural Sustainability* 6(2): 105–121. [http://www.ecoagriculture.org/documents/files/doc_282.pdf] site visited on 2/06/2011.

Messemaker, L. (2008). The green myth? Assessment of the Jatropha value chain and its potential for pro-poor biofuel development in Northern Tanzania.[http://www.lodemessemaker.nl/Jatropha/docs /Messemaker2008TheGreenMyth-small.pdf] site visited on 15/8/2009.

Mushi, S. S. (1993). Nutrition relevant actions in Tanzania. Country case study. *Journal of nutrition* 3: 210 – 224.

Mutayoba, V. (2005). Economic analysis of vanilla production and marketing: A case study of Bukoba District, Kagera Region. Dissertation for Award of MSc Degree at Sokoine University of Agriculture, Morogoro, Tanzania, 85pp.

Nhemachena, C., Hassan , R. And Chakwizira, J. (2010). Economic Impacts of Climate Change on Agriculture and Implications for Food Security in Southern Africa. Brummeria, Pretoria, South Africa. 33pp.

Osogo, D. (Ed.) (2010). *Jatropha curcas-Derived Biofuel Industry in Africa.* Proceedings in the Network of African Science Academies (NASAC) Conference, Nairobi, Kenya, 22–23 February, 2010. 57pp. [http://www.interacademies.net/File.aspx?id=10706] site visited on 20/5/2011.

Otieno, R. (1995). *Institutional Credit and Efficiency of Resource Use Among Small Scale farmers in Kenya*. Justus –Lie berg University press, Giessen. 214pp.

Practical Action Consulting (PAC) (2009). *Small-Scale Bioenergy Initiatives: Brief description and preliminary lessons on livelihood impacts from case studies in Asia, Latin America and Africa*. Prepared for PISCES and FAO by Practical Action Consulting, January 2009. 142pp. [http://www.acts.or.ke/dmdocuments/PROJECT_REPORTS/FAO_PISCES.pdf] site visited on 29/7/2010.

Philip, D. (2001). Economic analysis of medium scale agricultural enterprises in a predominantly smallholder agriculture sector. Dissertation for Award of MSc Degree at Sokoine University of Agriculture, Morogoro, Tanzania, 247pp.

Pant, K. S., Khosla, V., Kumar, D. and Gairola, S. (2006). Seed oil content variation in *Jatropha curcas* Linn. in different altitudinal ranges and site conditions in H.P.India. *Lyonia a Journal of ecology and Application* 11(2): 33-134. [http://www.lyonia.org/downloadPDF. php?pdfID390.487.1] site visited on 9/6/2010.

Peter, G. (2006). *The Potential for diversification in coffee exporting countries: Tanzania case study*. Natural Resources Institute. International Coffee Organization (ICO) Workshop. [http://www.ico. org/event _pdfs/ilimanj.pdf] site visited on 15/08/2009.

Philip, H. D. (2007). An Exploration of the Potential of Producing Biofuels and the Prospective Influence of Biofuels Production on Poverty Alleviation among Small-Scale Farmers in Tanzania, Rheinischen Friedrich-Wilhelms-University of Bonn, PhD dissertation. [http://hss.ulb.uni-bonn.de/diss_online elektronisch publiziert.] site visited on 25/8/2009.

Parikh, V. and Shah, G. (1994). *Empirical Studies of Size, Structure and Efficiency in Agriculture.* Boulder, West view press. 231pp.

Parawira, W. (2010). Biodiesel production from *Jatropha curcas*: A review. *Scientific Research and Essays* 5(14): 1796-1808. [http://www. academicjournals.org/sre/PDF/pdf2010/18Jul/Parawira.pdf] site visited on 4/6/2011.

Rweyemamu, D.C. (2001). Economic analysis of cash crop production and marketing in Tanzania under a liberalized market economy: A case study of tobacco in Songea district. Dissertation for Award of MSc Degree at Sokoine University of Agriculture, Morogoro, Tanzania, 148pp.

Salé, N. A. C. and Dewes, H. (2009). Review Opportunities and challenges for the international trade of *Jatropha curcas*-derived biofuel from developing countries. Centre of Studies and Research in Agribusiness (CEPAN), and of Biophysics Department of Biosciences Institute of Federal University of Rio Grande do Sul (UFRGS), Porto Alegre- RS – Brasil – CEP 90010-460. *African Journal of Biotechnology* 8(4): 515-523.

Sulle, E, and Nelson, F. (2009). Biofuels, land access and rural livelihoods in Tanzania, IIED, London. 85pp. [http://pubs.iied.org/pdfs/12560 IIED.pdf] site visited on 25/3/2011.

Sumbi, P. E. (2004). Community Perceptions of Costs and Benefits of Different Forest Management Approaches at Udzungwa Mountain Forests and the Surrounding Miombo Woodlands. Unpublished Dissertation for Award of MSc. Degree at Wales University, United Kingdom, 63pp.

Tomomatsu, Y. and Swallow, B. (2007). *Jatropha curcas* biodiesel production in Kenya Economics and potential value chain development for smallholder farmer, Nairobi, Kenya. [http://www.worldagroforestry. org/downloads/publications/PDFs/WP15396.PDF] site visited on 18/8/2009.

URT (2009). Jamhuri ya muungano wa Tanzania sekretariati ya mkoa wa Arusha. [http://www.arusha.go.tz/kurasa/kutuhusu_anuani/kutuhusu/index.php] site visited on 25/8/2009.

Van Loo, E. N., Jongschaap, R. E. E., Montes Osorio, L. R. and Azurdia, C. (2008). *Jatropha curcas* L.: Genetic diversity and breeding. Temasek Life Sciences Laboratory. In: *Jatropha International Congress*. 17-18 December 2008, Singapore. [Singaporehttp://www.pri.wur. nl/NR/rdonlyres/90AF26A1-47D5-4F2F-9E96D413C2933685/ 80410/congresssingapore.pdf] site visited on 8/2/2011.

Villancio, V. T. (2006). *Jatropha curcas* as biofuel: *Jatropha curcas* (Tubang bakod) seed production biofuel. *TubangGatong Series* 1(2): 1-5. [http://www.bar.gov.ph/biofuelsinfo/downloads/Tubanggatong.pdf] sites visited on 12/3/2011.

Von Lampe, M. (2006). Agricultural Markets Impacts of Future Growth in the Production of Biofuels: Working paper on agricultural policies and markets, directorate for food, agriculture and fisheries, OECD. [http://www.oecd.org/dataoecd/58/62/36074135.pdf] site visited on 7/7/2010.

Wahl J. N., Baur, H., Aichi K., and Iiyama, M. (2008). Economic viability study on *Jatropha curcas* L. plantations in Northern Tanzania: Assessing farmers' prospects using cost-benefit analysis. WP XX. Nairobi. World Agroforestry Centre. 125pp.

Wiskerke, W. (2008). Towards a sustainable biomass energy supply for rural households in semi-arid Shinyanga, Tanzania: A Cost/benefit analysis M.Sc. Thesis Utrecht University, Utrecht, the Netherlands, 127pp. [http://www.compete-bioafrica.net/events/events2/event_tanzania/WP3-Meeting/Compete_Tanzania_Dornburg.pdf] site visited on 21/8/2009.

Zeller, V., Perimenis, A., Giersdorf, J., Müller-Langer, F., Thrän, D. and Mulindabigwi, V. (2011). The potential of sustainable liquid biofuel production in Rwanda A study on the agricultural, technical and economic conditions and food security. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. 142pp.

[http://www2.gtz.de/dokumente/bib-2011/giz2011-0017en-biofuels-rwanda.pdf] site visited on 29/5/2011.

Zinck, J. A., Berroterán , J. L., Farshad, A., Moameni, A., Wokabi, S. and Van Ranst, E. (2002). Approaches to assessing sustainable agriculture. Enschede, The Netherlands. *Ciencia del Suelo* 20 (2): 55-68. [http://www.suelos.org.ar/publicaciones/vol_20n2/zinck_55-68.pdf] site visited 01/6/2011.

APPENDICES

Appendix 1: Farmer Questionnaire for *Jatropha curcas* L. production

BIOFUEL PRODUCTION IN TANZANIA: OPPORTUNITIES AND CONSTRAINTS TO SMALLSCALE FARMERS IN ARUSHA AND RUKWA REGIONS

FRANK

Farmer's questionnaire

Questionnaire No…………..Date of interview…………………….

Name of respondent…………………………..Interviewer's code……………

Section 1: Farmers characteristics

1.1 Village ....

1.2 Division ....

1.3 Gender of respondent…………

1.4 Age of respondent………….

1.5 Marital status 1. Single 2. Married 3. Divorced / separated 4.Widowed

1.6 Farmers level of education 1. No formal education 2. Primary education
3. Secondary education 4. Post-secondary education

1.7. Household size…………………………

1.8 Members of the family

ID	Name	Age (year)	Sex	Relationship	Education level	Main occupation

			1=Male 2=Female	1=Head 2=Wife/Husba nd 3=child 4=other	1=Nome 2=Primary 3=O Level 4=A level/certifi cate 5=diploma 6=Degree and above	1=Child2=Sch ool 3=Farmer 4=Govt employee 5=House 6=Private sector employee 7=others
			CODE	CODE		
1						
2						
3						
4						
5						

1.9 Total resident members……………………….

Section 2. Opportunities for Jatropha production

2.1 Major sources of household income…………………

2.2 Major reasons for growing Jatropha i) Income generation

ii) Domestic energy security iii) Fences iv).Others (specify)

………..................

2.3 When did you start to cultivate *Jatropha curcas*?....................................

2.4 What is the size of the land under Jatropha production...?

2.5 How the land was obtained i) Inherited ii) Given by village government

iii) Accessed freely iv) Bought

2.6. How much Jatropha seeds are produced per unit area per year...

2.7 Do you find difficult to sell Jatropha? i) Yes ii). No

2.8 Where do you sell Jatropha seeds?...

2.9 How do you travel to Jatropha market place?

i) On foot ii) Bicycle iii) Motor vehicle- public transport

iv) Motor vehicle, own transport v) Buyers follow to farmer's field

2.10 How far (km) is the selling point for Jatropha market place?............

2.11 To whom do you sell your produce 1.Individual middle man 2. Private companies

2.12 What is the source of domestic energy for cooking?

i) Kerosene ii) Fuel wood iii) Charcoal iv) Fuel wood and charcoal

2.13 What is the source of domestic energy for lightning?

i) Kerosene ii) Solar iii) Jatropha oil

2.14 Does energy mentioned in 2.12 satisfy demand for household? i) Yes ii) No

2.15 Is energy source mentioned in 2.13 easily accessible?

i) Yes ii) No

2.16 Do Non- Governmental Institution assisted in Jatropha farming in your area? i) Yes ii) No

2.17 If Yes, specify the institution, type of assistance and conditions under which assistance is provided.

Institution	Assistance	Condition
1.		
2.		
3.		

2.18 Have you attend any Jatropha field management training? i) Yes ii) No

2.19 Are the Jatropha processing equipments available in your area? i) Yes ii) No

2.20 If yes what are they?...

2.21 Do you know to operate Jatropha processing equipments? i) Yes ii) No

2.22 Are there changes in output from Jatropha for the past three years.

i) Increased ii) Not changed iii) Decreased

2.23 If increased in 2.22 above, the major reasons for the increased output of Jatropha.

i) Increased area ii) Increase in price of seeds iii) Prompt payment to farmers

iv) Awareness of economic value of Jatropha v)Increase production vi)weather conditions

2.24 Do you belong to any Jatropha soap production group / association?

i) Yes ii) No

2.25 Do you use waste land for crop production?

i) Yes ii) No

2.26 Do you use Jatropha seed cake as fertilizer in growing crops?

i) Yes ii) No

2.27 Do you use Jatropha seed cakes for production of biogas or briquettes as a source of fuel? i) Yes ii) No

Section 3. Challenges for Jatropha production

3.1 Is land available for crop farming farm? i) Yes ii) No

a) If yes how much land required for food...................for Jatropha..........extra............

b) If no why?...

3.2 Can you increase the cultivation area of your field? i) Yes How much?.... ii) No

3.3 What are problems facing supply of Jatropha? ....

3.4 What was the biggest means, through which your household get staple food?

....

3.5 Did you divert land or inputs from food crop production to Jatropha production?

i) Yes ii) No

a) How much?................... Why?..

3.6 Did you face food shortage for the past two cropping seasons i) Yes ii) No

3.7 If Yes, what are the main causes of food shortage that farmer's experienced in the past two years?

i) Drought ii) Crop pests and diseases iii) Poor husbandry iv) Low fertility

v) Others (specify)…..

3.8. Is there any government support for Jatropha production in your area?

i) Yes ii) No

3.9 What agronomic practices do you use in cultivation of Jatropha? ....

3.10 Are the improved Jatropha cooking stoves available in your area? i) Yes ii) No

If yes, since when? ....

3.11 Are the improved Jatropha oil lamps available in your area? i) Yes ii) No

3.12 Do you have contracts with buyers of Jatropha seeds on Jatropha production

i) Yes ii) No

If yes, are you satisfied with those contracts i) Yes ii) No

If no, what are the reasons for your dissatisfaction...

Section 4. Household factors

4.1. Is labour for crop production hired or family labour? ....

4.2 Do you face labour shortage? i) Yes ii) No

4.3 Do you receive extension services? i)Yes ii) No

If yes, how frequently do you receive extension advice?

i) Regular ii) Once per year iii) Twice a year iv) Others (specify)....................

4.5 Did you receive knowledge from other farmers? i) Yes ii) No

4.6 Did you transfer knowledge to other Jatropha farmers? i) Yes ii) No

4.7 Does training received help in increasing Jatropha production? i) Yes ii) No

If yes, what did you do? ....

What was the increase? ....

4.8 List the areas of training received?

i)... ii)..

iii) .... iv) ....

v)...

4.9 Did you acquire credit? i) Yes ii) No

4.10 If Yes, what was the purpose of credit?

i) .... ii) .... iii)………………… ..

4.11 If you have not acquired credit, what were reasons

i)...................................... ii) ....

iii) .... iv) ....

v)....................................

Section 5: Profitability of crop enterprises

5.1 What kind of output you're selling? Seeds, oil soap...............................

5.2 what equipments you use on produce in the mentioned in 5.1 outputs?................

5.3 Give the total output sold and the prices of each of the crop grown for 2007/2008 to 2008 /2009 crop seasons.

5.2. Give amount and unit price of inputs for the past three seasons

	Jatropha						Maize					
	2007	UP	2008	UP	2009	UP	2007	UP	2008	UP	2009	UP
Age												
Output(kg)												
Oil (Liter)												
Soap(bar)												
Acreage (hedge)												

Jatropha						
Year/ seasons	2007		2008		2009	
Inputs	Amount/ha	UP	Amount t/ha	UP	Amount	UP
Seeds						
Hand hoes						
Herbicides						
Insecticides						
Others(specify)						
Total						

5.3 Labour for Jatropha production

Activities	No of people	Amount in hours	Acreage/in hedge	Days
Preparations				
Seeding/sowing				
Weeding				
Harvesting				
Others(specify)				

5.4 Give amount and unit price of inputs for the past three seasons

MAIZE	2007		2008		2009	
	Amount/ha	UP	Amount	UP	Amount	UP
Inputs						
Fertilizers						
Seeds						
Hand hoes						
Herbicides						
Insecticides						
Others(specify)						
Total						

Note: UP = UNIT PRICE

5.5 Labour for maize production

Activities	No of people	Amount (hr)	Acreage	Days
Preparations				
Weeding				
Seeding/sowing				
Harvesting				
Others(specify)				

5.6 What are the price / acre of land bought or hired for production of Jatropha.. ……(Tsh).

5.7 What are the price / acre of land bought or hired for production of Jatropha…... (Tsh).

Section 6: Crop calendar

Please make cells black when appropriate, and specify if requested

Months	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Seasons												
Start principal rains												
Cold months												
Warm months												
Average Temp (°C)												
Wet months												
Dry months												
Precipitation												

(mm)												
Crop characteristics												
1st green leaves												
Last green leaves												
Start flowering												
End flowering												
1st mature seeds												
Last mature seeds												
Crop management												
Planting (normally)												
Pruning												
Harvesting												
Weeding (?)												
Fertilization												
Type												
Rate (kg ha^{-1})												
Irrigation												
Rate (mm)												

ASANTE SANA

Appendix 2: Man-day per hectare

Variable	**Man-day per hectare for living fence systems**	**Man-day per hectare for intercropping systems**	**Man day per hectare for mono-cropping systems**
Preparation	15	5	4
Planting	11	2	3
Weeding	14	6	3
Harvesting	76	19	16

Variable	**Cost of man day for living fence systems**	**Cost of man day for intercropping systems**	**Cost of man day for mono-crop systems**

Preparation	39251.74	13849.48	11296.36
Planting	28692.41	6364.524	7384.67
Weeding	35992.24	15236.21	7359.64
Harvesting	200468.80	50726.17	42716.53

One man day is equivalent to Tsh 2650.00: February 2011, Exchange Rate

US$ 1498