ECONOMIC AND ENERGY BALANCES OF JATROPHA PRODUCTION IN TANZANIA: A CASE OF MONDULI AND MPANDA DISTRICTS

BY

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ABSTRACT

The increase in the use of fossil fuels has led to an increase in Green House Gas (GHG) emissions which are believed to be the main reason for global warming. The world is now encouraged to use bioenergy as a solution in reducing GHG emission from fossil fuels. Jatropha has received much interest as a feedstock for biofuel production because of its minimal adverse effects on the environment and food supply. This crop is now cultivated and processed at both Engaruka and Mpanda study sites as alternative source of energy and income. Jatropha cultivation has economic and environmental impact due to its various products such as seeds and its effects on land use change. Despite the production of the crop in the country, there are no studies which have examined in details its economic and environmental impacts. This makes the assessment of the economic and energy balances of jatropha production in Tanzania using Life Cycle Assessment approach necessary. The objectives understudy include describing jatropha based products, to assess economic benefit of jatropha production to small scale farmers, to assess the energy balance of jatropha production and finally to assess impact of the use of jatropha based products on GHG emissions in the study sites. The findings show that farmers get profit for high yield scenario 135 TZS/kg per metre. Also oil processing using hand press and oil expeller show positive economic return of 1 200 and 1 421 TZS/litre respectively. The environmental performance of jatropha is high due to low input application in the cultivation stage. The ratio of biodiesel energy output to fossil energy input is 4.7. Also results show that production and use of jatropha base products is associated with GHG emission contributes 0.59 kg CO_2 eq, 0.014 kg CO_2 eq and 0.45 kg CO_2 equivalent for cultivation, electricity and charcoal production respectively.

DECLARATION

I, LEONARD KIWELU, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my original work and has not been submitted for a higher degree in any other university.

_____________________________ _____________________________

Leonard Kiwelu Date

(MSc. Candidate)

The above declaration is confirmed by,

_____________________________ _____________________________

Dr. Damas Philip Date

(Supervisor)

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DEDICATION

This work is dedicated to my Lord Jesus Christ who has been my helper and a very trustful friend throughout my life when I am in need of his support. Also to my beloved father Kauwedi Boaz Kiwelu and my mother Uyonyimo Kauwedi Boaz Kiwelu my brothers Amani Kauwedi, Eliangikundi Kauwedi, Rechinald Kauwedi and Flex Kauwedi and my sisters Gladness Kauwedi, Eunice Kauwedi and Sia Kauwedi also special dedication to my relatives and my beloved fiance Beatrice A. Lyamuya who laid the foundation of my education.

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ABN:	African Biodiesel Network
BIA:	Bionergy in Africa
$C0_2$:	Carbon dioxide gas
DISAT:	Dissemination of Sustainable Technology
eq:	Equivalent
FU:	Function Unit
GEXSI:	Global Exchange for Social Investment
GHG:	Greenhouse Gas
GTZ:	*Deutsche Gessellschaft für Technische Zusammenarbeit* (The German Agency for Technical Cooperation)
GWP:	Global Warming Potential
h:	hour
Ha:	Hectare
HP:	Horse Power
IPCC:	Intergovernmental Panel on Climate Change
ISO:	International Organisation for Standardisation
JPTL:	Jatropha Product Tanzania Limited
KAKUTE:	"*Kampuni ya Kusambaza Teknologia*" (The Company for Technology Dissemination and Tranning)
Kg:	Kilogram
Km:	Kilometre
kWh:	Kilowatt hour
L:	Litre
LCA:	Life Cycle Assessment

LCC:	Life Cycle Costing
LCIA:	Life Cycle Impact Assessment
Lde:	Litre of diesel equivalent
Lge:	Litre of gasoline equivalent
M:	Metre
MFP:	Multifunctional platform
MJ:	Mega Joule
mm:	Millimetre
NaOH:	Sodium Hydroxide
NBTF:	National Biodiesels Task Force
SAIC:	Scientific Applications International Corporation
SETAC:	Society of Environmental Toxicology and Chemistry
SJO:	Straight Jatropha Oil
SVO:	Straight Vegetable Oil
TATEDO:	Tanzania Traditional Energy Development and Environment Organisation
t:	Metric Tone
TZS:	Tanzania Shilling
UK:	United Kingdom
UNCHS:	United Nation Centre for Human Settlements (Habitat)
WWF:	World Wide Fund for nature

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

The increase in the use of fossil fuels has led to an increase in Green House Gases (GHG) emissions which are believed to be the main reason for global warming. In addition to increased GHG emission, the increased use of fossil fuel and the fact that the stock for such fuels is limited has led to rapid increase in their prices. High prices for fossil fuels, affect the performance of the economies of countries such as Tanzania which depend entirely on imports for their oil needs. Literature shows that Tanzania is among the countries with no known oil reserves (CIA, 2008). In 2007 about 1.5 billion US$ which was an increase of over 30% compared to 2006 was spent by the country to import oil (BoT, 2008). The 2007 spending on oil imports was equal to 40% of the country total export earnings. This share was likely to increase in 2008 due to continuous hikes of world oil prices. The ever-aggravating situation made the Tanzanian government think about the possibility of displacing fossil fuels with liquid biofuels (Philip, 2007).

The dependence on imported fossil fuel affect national gross domestic Product (GDP) and hence pull down government strategy on eradicating poverty in rural area. Biodiesel was the alternative source of energy emphasised by Intergovernmental Panel on Climate Change (IPCC) presented in 2007 as cited by Philip (2007) that has less negative environmental impact and has positive economic contribution to small scale farmers. Among the important renewable or biofuels is bioethanol which is produced from conversion of starch or sugar-rich biomass like sugar cane, maize and other cereals feedstocks. Also biodiesel which is extracted vegetable plant oils (jatropha, oil palm and rapeseed) after a process of esterification.

Jatropha *curcas L.* as a feedstock for biodiesel production has received much attention in recent years due to its potential to contribute to the reduction of greenhouse gases (GHG). Ndong *et al.* (2009) undertook an LCA with West African conditions that shows that the use of biodiesel leads to 72% savings in GHG emissions compared with conventional diesel fuel. Also jatropha plant has ability to grow in areas with low moisture means it can be produced in semi-arid and arid regions (Francis *et al.*, 2005, Jongschaap *et al.*, 2007). Due to its ability to grow on marginal lands and degraded soils jatropha is often thought of as not competing for land with food crops (CRFA, 2006 and Philip, 2007).

Jatropha plant products (oil and press cake) save as alternative source of energy like electricity generation using strait jatropha oil (SJO) instead of using fossil energy to run the generator. The oil can also be used for lighting while press cake can be used as charcoal for cooking, raw material for biogas production or as fertilizer. Reinhardt, (2007) comment that for jatropha to have positive impact to the environment, press cake should be used effectively. From 2008, Tanzania Ministry of Agriculture Food Security and Cooperatives started to create awareness at all levels (farmers, private sector and government institutions) and identifying potential crops for biodiesel production. Jatropha is one of the crops that have been earmarked for promotion by the Ministry (TGPB, 2009). Monduli and Mpanda are among the districts growing jatropha in plots and hedge farming systems respectively. Also the market of jatropha seeds and its related products as different companies working in these area buy them. Although the market is available and the use of the crop as a source of energy is generally known to reduce GHGs, it is important to estimate the economic and environmental impacts of producing and using the crop in the country as they differ from one country to another due to differences in cots for utilities and the production technology. Therefore, the scope of this study is to assess the economic benefits, and Green House Gas (GHG) emissions in the value chain of jatropha cultivation to end uses.

1.2 Problem Statement and Justification

The rapid growth of utilization of fossil fuels for industrial and transportation sector in the world has negative impact to the climate due to the Green House Gas (GHG) emission which is believed to be the main cause for global warming. The world is now encouraged to use bioenergy as a solution in reducing GHG emissions from fossil fuel. Bioenergy is the energy source that is obtained from biomass. Sugarcane, palm oil, soybeans, Jatropha and rapeseed are the most common feedstocks for biodiesel production. Among these feed- stocks jatropha *curcas L* was chosen as one of the prime crops due to different factors including drought tolerance and its ability to grow in marginal land without replacing food crop (Philip, 2007). In Tanzania different foreign companies including DILIGENT, Sun Biodiesel and PROKON concentrate on jatropha feedstock for bioenergy production. In 2006 the Tanzanian government launched the National Bioenergy Task Force (NBTF) to establish a bioenergy policy as a strategy to steer the investments in this sector. Unfortunately the policy is not yet developed which then hinders serious investment (WWF, 2009).

Although Jatropha grows naturally in some parts of Tanzania such as Mpanda, Monduli and Meru districts, its cultivation on industrial scale is a recent venture. Thus it is not surprising that the economic and environmental impacts of jatropha cultivation and processing are not known. Therefore the present study aims to use life cycle assessment and life cycle costing approaches to capture economic benefits of jatropha cultivation as alternative source of income and energy so as to determine the sustainability and economic viability of this crop. Also the study assesses GHG emission and energy balance resulting from using this crop as source of energy so as to compare with GHG emission resulting from the use of fossil fuels.

1.3 Objectives

1.3.1 General objective

The main objective of this study is to assess the economical and environmental impact of jatropha value chains in different environmental and social contexts in Tanzania.

1.3.2 Specific objectives

The specific objective are

i. To describe jatropha based products at Monduli and Mpanda
ii. To assess economic benefit of Jatropha production to small scale farmers at Monduli and Mpanda.
iii. To assess the energy balance of jatropha production
iv. To assess impact of the use of jatropha based products on Green House Gas (GHG) emissions

1.3.3 Research questions

i. What are the main jatropha based product in the study area?
ii. What are the economic benefits obtained form jatropha base products?
iii. How much non-renewable energy is consumed to produce jatropha based products?
iv. How much GHG emitted per basic products?

1.4 Conceptual Framework

The study aims to evaluate the economic potential and GHG emission from jatropha cultivation, processing and utilization processes. In order to determine the effects of the production and use of biodiesel on the environment and the economic impact the methodology of life cycle assessment (LCA) and life cycle costing were chosen. They entail (the two approaches) evaluating the energy and resource consumption and all pollutant emissions over the entire life cycle needed to satisfy a defined function (1 kg of seed produced, 1 kg of oil produced and related aspect). All necessary inventory data for biodiesel were collected from farmers and companies processing different products using jatropha oil and complemented by additional data from literature. The impacts on the environment were then first determined with the greenhouse effect which was assessed from biomass cultivation to its energetic utilization. The selected biomass in this study was jatropha crop as described previously. The co-products were also examined in this study. There are co-products various production stages, which have environmental and economic impacts. Figure 1 shows the conceptual framework on which the study is based.

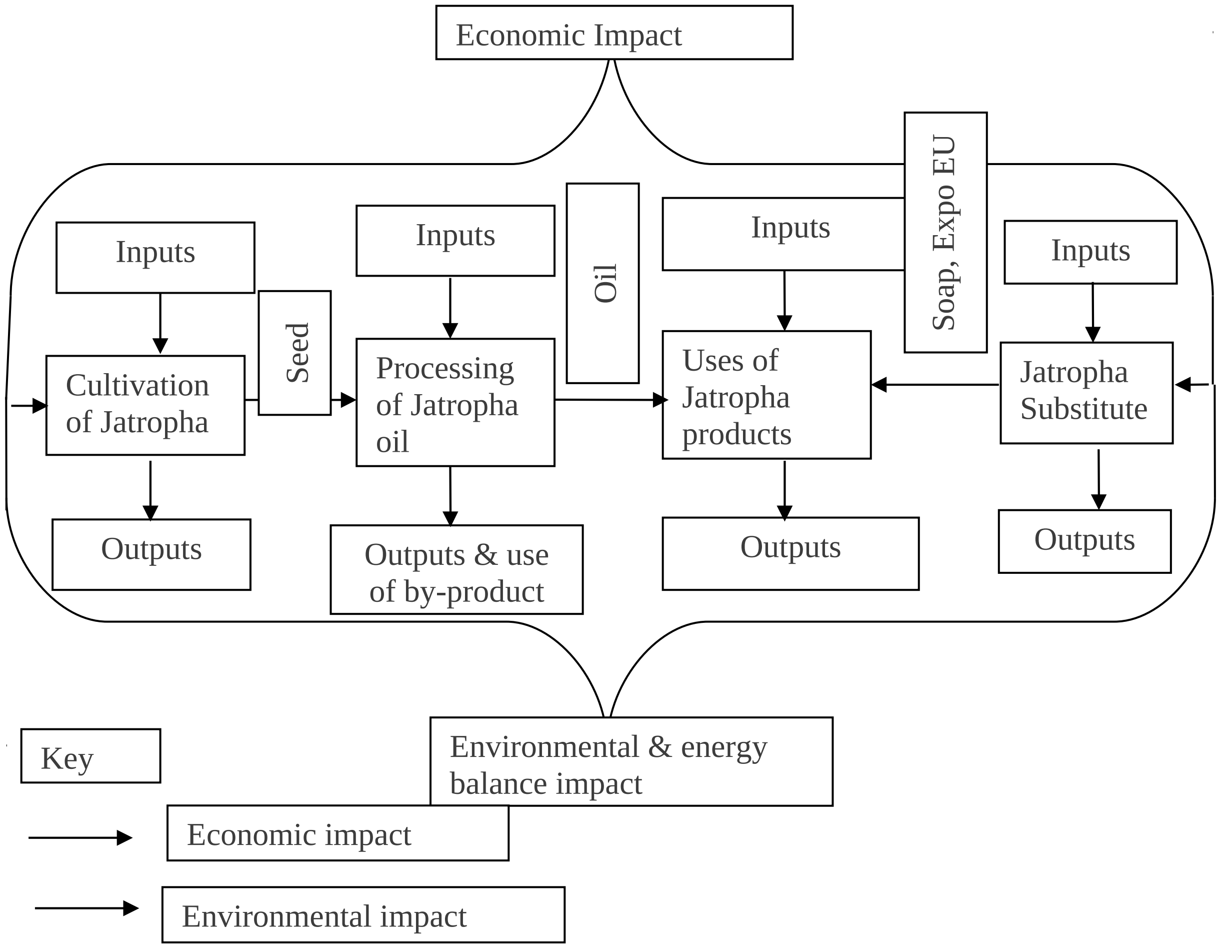

Figure 1: Conceptual Frame Work

Source: BIA-ERD project presentation 2009

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 General Background of Biofuels

Biofuel is defined as source of energy derived from vegetable oils, such as soybean oil, sunflower oil, palm oil and jatropha. Biofuel are in different forms including liquid form, such as energy bioethanol, biodiesel and biomethane (Philip, 2007). This renewable energy source is almost as efficient as fossil diesel but they are used in diesel engine after the engine be modified because of different properties of engine including viscosity of the biodiesel which reported to be low compared to fossil diesel. The biodiesel can be blended with diesel fuel up to 100% and it has a higher flash point. The flash point is the minimum temperature the fuel must be heated to ignite the vapour and air mixture Kenneth *et al.* (2010). As reported by CRFA (2006) biofuels can be produced from a variety of feedstocks. Example biodiesel can be produced from is produced from oil seeds including jatropha seeds, oil palm, rape seeds while ethanol can be produced from starchy and sugar crops like maize, rice, millet, sorghum and cassava, to mention a few. On the other hand, the main sugar crops which are commonly used as feedstocks for producing ethanol are sugarcane and sugarbeet (Philip, 2007).

2.1.1 Feedstock for ethanol production in Tanzania

Tanzania is also rich in feedstock for ethanol production as a substitute for the gasoline consists in sugar or starch. According to Philip (2007) many sugar and starch crops can be found locally in Tanzania such as sugar cane, millet, potatoes, sorghum, sweet potatoes, wheat, cassava or maize. The production of fuel ethanol is only possible in large scale factories because a simple distillation is not enough to remove the water completely.

2.1.2 Bioethanol conventional production

According to IEA (2007) Bioethanol is the most common biodiesel, accounting for more than 90% of total biodiesel usage. Conventional production is a well known process based on enzymatic conversion of starchy biomass into sugars, and/or fermentation of 6-carbon sugars with final distillation of ethanol to fuel grade. According to Philip (2007) Ethanol can be produced from many feedstocks, including cereal crops, corn (maize), sugar cane, sugar beets, potatoes, sorghum, and cassava and. The world's largest producers of bio-ethanol are Brazil (sugar-cane ethanol) and the United States (corn ethanol). Ethanol is used in low 5%-10% blends with gasoline (E5, E10) but also as E-85 in flex-fuel vehicles. In Brazil, gasoline must contain a minimum of 22% bioethanol (IEA, 2007).

2.2 An Overview of Biodiesel Production

Biodiesel is the type of energy which is produced after the reaction of two main inputs that are vegetable oil and wood alcohol (the process of biodiesels production is known as trans-esterification process). This process creates two outputs, biodiesel and glycerol (Kenneth *et al.*, 2010). In case of jatropha Withaker, (2009) adds that 1 kg of jatropha oil produce 0.079 kg of glycerine with energy content of 25.6 MJ/kg. Like other process in biodiesel production, jatropha oil is mixed with methanol (at a methanol to oil ratio of 0.8 v/v) and 1.5 wt% of sodium hydroxide (NaOH) based on the weight of oil. After chemical reaction of 50 ºC for 90 minutes, about 95 % of oil is converted into biodiesel (Lee, 2009). The largest biodiesel producer is Germany, which accounts for 50% of global production. Biodiesel is currently most often used in 5-20% blends (B5, B20) with conventional diesel, or even in pure B100 form (IEA, 2007). Santosh (2007) report that the driving forces behind increasing biodiesel production in the world include low commodity prices for feedstocks used to produce biodiesel, environmental concerns with continued diesel use, and national security concerns about increased usage of foreign crude oil in the country. Example in India the government plans to increase the use of biodiesel due to limited domestic crude oil reserves where about 72% of its crude oil and petroleum products (diesel, aviation fuel) requirement through imports, which are expected to expand further in coming years. Also in US the expansion of use of biodiesel increases after the September 11th 2001 terrorist attack where the federal government considering a renewable fuels standard that increase biofuels usage.

According to David, (2002) report that, biodiesel emissions are essentially free of sulphur and aromatics and have less hydrocarbons, carbon monoxide and particular matter and hence be more environmental friendly than fossil fuel in terms recycle carbon dioxide mitigating greenhouse gas emissions and in turn slow down climate change (Kenneth *et al.,* 2010). GHG emissions cause climate change and substituting fossil fuels by biodiesel is assumed to result in an advantageous GHG balance. Much fossil fuel is consumed in transportation, industrial production and agricultural sector (production of fertilizer and pesticides). Crutzen *et al.* (2008) document that, the use of fertilizer in bioenergy production can lead to N_2O emissions which might offset CO_2 savings because the global warming potential (GWP) of N_2O is 296 times higher than that of CO_2 (Prather *et al.*, 2001). The important feedstock for biodiesel production includes rapeseeds, sunflower seeds, soy seeds, palm oil seeds and jatropha seeds from which the oil is extracted chemically or mechanically.

2.2.1 Feedstock for biodiesel production in Tanzania

There are several promising oil plants available in Tanzania. For the biodiesel production, crops with a low input and a huge oil production are the most valuable. The potential oil crops that can be found locally in Tanzania country are namely jatropha, coconut and castor oil plant. However, exploitation of these crops for oil production is not the priority of the country due to different factors including issue of food security. The most promising crops for the production of plant oil that can be used as feedstock for biodiesel production as describe by Philip (2007) in sub-sections below.

2.2.1.1 Jatropha (*Jatropha curcas L.)*

Jatropha plant is a large shrub which grows in arid conditions and produces an oil bearing fruit and sustain in poor soil and drought resistance crop (Jongschaap *et al.*, 2007). Many land areas are suitable to grow *Jatropha curcas L.* in Tanzania. Currently this crop is grow for economic purpose in Arusha and Rukwa regions while the remaining region cultivate jatropha as a traditional crop for different uses and not as source of energy. This crop is among of the high potential crop in Tanzania because it did not entering into competition with food crop plantations (Philip, 2007). The lifespan of this crop can rich 50 yeas o f age and the more advantage is that is planted once. The oil content of the jatropha seeds ranges between 28% and 42%. The yield of Jatropha plant is still unclear at different part of the world. The oil can be used in modified plant oil engines and also be transesterificated into biodiesel for the normal diesel engine.

The propagation method used in planting jatropha including cutting and seedling. If seedling is used the average space required is 3m x 3m where in a land size with 1 hectare will have a total number of 1 110 trees if the germination is 100% (Blesgraaf, 2009). Atchen *et al.* (2007) pointed out different uses of jatropha plant including living fence and for the farm boundaries or bolder demarcation from one farm to another; other use is medicinal purposes as it is used as an external application for skin diseases and rheumatism and for sores on domestic livestock. In addition, the tender twigs of the plant are used for cleaning teeth, while the juice of the leaf is used as an external application for piles. Finally, the roots are reported to be used as an antidote for snake-bites. Jatropha plant also provides additional uses include source of income to household members by selling seeds and the most profound advantages and uses is the source of energy including electricity generation using jatropha oil.

2.2.1.2 Castor oil plant (Ricinus communis)

Castor is a widespread plant in tropical regions. It is a fast growing, perennial shrub, which can reach a height up to 20 meters. This crop is also characterized by resist to drought season and also can be grown in marginal land. The fruits do not come to maturation at the same time. This makes the harvest complicated because the mature fruit bunches must be selected first and then picked by hand up to five times per year. According to The seeds of castor contain a high amount of oil (up to 60 to 17%) and a high yield of oil per hectare (0.4 to 1.8 tons / ha) can be exploited. Besides the use of biodiesel, castor oil can be used for medicinal and chemical purposes. The oil has a substantially higher viscosity than other plant oils. Therefore, using it for engines could cause technical problems in the fuel injection. In Tanzania this crop is grown in northern part of Tanzania including Arusha and Kilimanjaro.

2.2.1.3 Palm oil

Palm oil is the perennial plant with an average lifespan of 30 years. The main characteristic of this crop include good climatic condition with high humidity and temperature. It is mainly found in costal area where the average yield of palm tree is about 7 tons oil per ha and year. In Tanzania palm plant is grown in Kigoma region and its oil is used for domestic purposes. The utilization of this crop as source of biodiesel production is not in government agenda because it is labour intensive and it competes with food crops. This plant take three years to the harvesting time after planted.

2.2.2 Cost of biodiesel production from different feedstocks

Costs of biodiesels are highly dependent on feedstock, process, land and labour costs, and credits for byproducts, agricultural subsidies, food (sugar) and oil market. Ethanol energy content by volume is two-thirds that of gasoline, so costs refer to litre of gasoline equivalent (lge). Sugar cane ethanol in Brazil costs $0.30/lge free-on-board (FOB). This cost is competitive with that of gasoline at oil prices of $40-$50/bbl ($0.3-$0.4/lge). In other regions, costs can be more than $0.40-$0.50/lge, although potential exists for cost reduction. Ethanol from maize, sugar-beet and wheat cost around $0.6-$0.8/lge (exclude subsidies), potentially reducible to $0.4-$0.6/lge. Biodiesel from animal fat is currently the cheapest option ($0.4-$0.5/lde) while traditional transesterification of vegetable oil is at present around $0.6-$0.8/lde. Cost reductions of $0.1-$0.3/lde are expected from economies of scale for new processes.

2.2.3 Energy input and emissions

Based on IEA, (2007) report, Fossil energy inputs and emissions levels from biodiesel production are sensitive to process and feedstock, to energy embedded in fertilizers, and to local conditions. Production of ethanol from sugar cane (Brazil) is energy-efficient since the crop produces high yields per hectare and the sugar is relatively easy to extract. If bagasse is used to provide the heat and power for the process, and ethanol and biodiesel are used for crop production and transport, the fossil energy input needed for each ethanol energy unit can be very low compared with 60-80% for ethanol from grains. As a consequence, ethanol well-towheels CO_2 emissions can be as low as 0.2-0.3 kgCO2/litre ethanol compared with 2.8 kg CO_2/litre for conventional gasoline (90% reduction). Ethanol from sugar beet requires more energy input and provides 50-60% emission reduction compared with gasoline. Likewise Ethanol production from cereals and corn (maize) can be even more energy-intensive and debate exists on the net energy gain.

Estimates, which are very sensitive to the process used, suggest that ethanol from maize may displace petroleum use by up to 95%, but total fossil energy input currently amounts to some 60-80% of the energy contained in the final fuel (20% diesel fuel, the rest being coal and natural gas) and hence the CO_2 emissions reduction may be as low as 15-25% compared gasoline. Similarly Energy input and overall emissions for biodiesel production also depend on feedstock and process. Typical values are fossil fuel inputs of 30% and CO_2 emission reductions of 40-60% vs. diesel. Using recycled oils and animal fats reduces the CO_2 emissions

2.2.4 Biodiesel companies in Tanzania

Jatropha oil is among of the important feedstock for biodiesel production in different countries in the world including Germany and France. Other countries are India and Malyasia as reported by (Withake; 2009 and Lee; 2009) respectively. The feedstock for this product is available in Tanzania regions as indicated in Table 2.1. In recent years from 2006 many foreign companies stated to invest in different biofuels feedstocks in different part of the country. More than 2/3 of all the companies focus on jatropha as a potential feedstock for biodiesel production. In Tanzania the production of Biodiesel from jatropha oil is not in place currently due to many factors as reported by Philip (2007) including the cost of feedstock, which varies among countries, depending on land availability and quality, agricultural productivity, and labour costs; processing costs, which depend on the feedstock used, plant size and location. Example DILIGENT process jatropha oil and export the oil to European countries while the other companies including PROKON still in the initial stage of machine installation.

Table 2. 1: Examples of enterprises running biofuel projects in Tanzania

Name of enterprise	County of origin	Location	Crop
SEKAB	Sweden	Bagamoyo	Sugarcane
Kakute	Tanzania	Arusha	Jatropha
Diligent	The Netherlands	Arusha	Jatropha
Prokon	Germany	Mpanda	Jatropha
SunBiofuels	Great Britain	Kisarawe	Jatropha
TaTEDO	Tanzania	Arusha	Jatropha
FELISA	Tanzania, Belgium	Kigoma	Oil palm
Abengoa	Spain	Bagamoyo	Sweet sorghum
WILMA	USA	Biharamulo	*Croton spp.*

Source: Loos (2009)

2.3 Biodiesel policy developments in Africa

Before biodiesel boom in 2006, different countries in Africa were in a move of establishing policies on liquid biodiesel as strategy of combating oil dependence economy and climate change. African ministers signed the Statement on Renewable in Africa in Nairobi in 2004, which calls for, inter alia, promoting the sustainable production of biomass and its efficient use in all sectors and enhancing the development of renewable. Then in 2007, the first "High-level biodiesels Seminar in Africa" was held in Addis Ababa, Ethiopia. The seminar concluded with the adoption of the "Addis Ababa Declaration on Sustainable Biodiesels Development in Africa" and an Action Plan (Conliffe and Kulovesi, 2008) as cited by (Wahl, 2009). The plan encompasses the development of ethanol, biodiesel, biogas, biomass gasification, and cogeneration as priority sectors, and contains a number of cross cutting programme areas, including policy and institutional frameworks, financing mechanisms, resource assessments, capacity building and strengthening technical expertise. All these strategies indicate that African countries aim to have biodiesel policy that will guide the effective use of clean energy sources. It is until today their process of biodiesel policy formulation for many African countries is still in the early stage. Wahl, (2009) report that the Kenyan Ministry of Agriculture in collaboration with GTZ (German Agency for Technical Cooperation) recently published a Roadmap for biodiesels in Kenya (MoA/GTZ, 2008) which identify jatropha as a major future biodiesel feedstock.

2.3.1 Why biodiesel policy in Tanzania

The importance for having biodiesel policy in Tanzania base on the fact that, the country has enough potential feedstock for biodiesel production that the Tanzania are not yet benefit on them. Also Tanzania is major fossil fuel importer and for some years the price of fossil fuel contributes to increase in living expenses for low income Tanzanian mostly in rural area while they are in good position of using their local resource in biodiesel production (GTZ, 2005; Sawe, 2007; and Philip, 2007). Fuel imports are a major component in the country’s current account deficit. In response government policy is to promote energy self-efficiency in order to reduce the vulnerability of the country to external forces. In order to achieve this, the use of imported fuel for transportation but also electricity generation should be gradually substituted by domestic production of renewable energy sources based fuels. For this purpose, it now becomes crucial to establish an adequate policy framework that focuses on the promotion of both fossil fuels use efficiency and use and development of biodiesels in the country. In order to develop feasible operational strategies that are viable in the long term, the full system to develop should be beneficial and sustainable.

2.3.2 Biodiesel policy development in Tanzania

Although economics play a significant role in biodiesel production and use, it is often the cases that clear political objectives and commitments will finally lead to success (UNCHS, 1993). As reported in TGPB (2009) the government of Tanzania started to take into consideration the biodiesel production as one of the potential sector that needs improvement. A biodiesel policy task force was developed in 2006 but till the end of 2008 the government remained silent on that policy while the level of private sectors investment in this potential field of production is increasing. The study conducted by UNCHS (1993) comments that bioenergy was not taken serious in developing counties because it is used in rural areas. The study also adds that lack of information is an important factor that hinders policy development. The studies carried in Tanzania by (GTZ, 2005; Sawe, 2007; Philip, 2007; and Messemaker, 2008) unveil important findings on the potential feedstock and the level of productivity of these feedstock as potential for biodiesel viability in Tanzania. The studies also describe the risk and alternative way forward related to biodiesel investment in the country. Base of there findings the government was in good position to use there finding as base to facilitate biodiesel policy development. The lack of biodiesel policy hinders government in benefiting from biodiesels production (GTZ, 2005).

2.4 Jatropha Crop Cultivation and its Productivity

Jatropha is non edible crop that can grow even in marginal land. This crop is potential feedstock for biodiesel production because it did not replace or compete with food crop. GEXSI LLP (2008) conducted a study about Global Market on jatropha and reported that, there are approximately 900 000 hectares of land cultivated in the world for Jatropha and more than 85% of the land cultivated is located in Asia. Africa and Latin America count for approximately 120 000 and 20 000 hectares of cultivated land respectively. In Tanzania there about 17 800 ha of Jatropha cultivated land under large foreign companies including PROKON Company at Mpanda, Sun Biodiesel Company at Kisarawe (Philip, 2007 and Loos, 2008).

Yield from jatropha crop is still unknown. Different studies present yield range from 2 to 9 tons per hectare and year for matured plant of an average of 4 to 6 years. Heller; (1996) and Tewari; (2007) report that, semiarid and cultural wasteland yield range from 2 to 3 t/ha but the yield may rich up to 5 t/ha at optimal environment of annual rainfall 900 to 1 200 mm. While Jongschaap *et al.* (2007) report a yield range from 1.5 to 7.8 t/ha and van der Land (2007) report a yield of 9.9 t/ha/year. The variation of yield reported in different literature are some difficulties to interpretation due to various reasons including farm management system used in the area yield reported, soil fertility and also the propagation method used. In case of Tanzania KAKUTE, Eijck, (2006) (Diligent, Arusha) are among of the companies dealing with jatropha crop for many years. In (2006) KAKUTE report 1 600 kg/ha of jatropha seed yield from the fifth year onwards and Van Eijck (Diligent, Arusha) he also report an average yield of 2 to 3 kg per plant of jatropha which is matured at semi-arid area. The low productivity of jatropha in Tanzania hinders the use of this feedstock for producing biodiesel in Tanzania.

2.4.1 Jatropha oil processing and uses

Hand press machine and screw press machine are common pressing technology used to press jatropha seed. According to Beeren (2007) report that, the efficiency of hand press technology is 71.1% and its capacity is to press 3 kg of jatropha oil per hour where 5 kg of dry jatropha seed produce 1 kg of jatropha oil and 4 kg of press cake. Screw press machine is another type of technology reported by (Beeren, 2007 and jatropha handbook, 2009) which they report that, the efficiency of this technology is 80%. Also Henning (2000) finds that the screw press machine has an efficiency ranging from 75% to 80%. Beeren (2007) adds that 4 kg of seed yield 1 kg of jatropha oil and 3 kg of press cake. Electricity consumption by screw press machine differs according to its capacity.

According to Strujis (2008) jatropha oil has different uses including source of energy in electricity production, transportation, raw material for soap production, medical use and also as insecticide. With the potential uses of jatropha oil it is reported that about press cake is the co-product from oil pressing. This product contain about 50 to 65% of protein so it potential raw feedstock for fertilizer and biogas production. Henning (2000) report that the nutrient composition of press cake is nitrogen 3.2– 4.44%, Phosphorus 1.4-2.09% while Potassium is 1.2-1.68%. The economical use of jatropha press cake was again stressed by Beeren (2007) due to the remaining amount of oil in the press cake. Also the press cake can be used as raw material for charcoal making using retort technology, feedstock for biogas and used as fertilizer. In Tanzania electricity production using jatropha oil pull majority of rural farmers especially Engaruka and Meru to cultivate this crop as alternative energy sources. Electricity production from jatropha oil is described as follows.

2.4.2 The use of jatropha husks materials

Jatropha fruits contain 2 to 3 seeds and have 3 husk shells where 1 kg of jatropha fruits contains 0.6 kg of jatropha seeds and 0.4 kg of husks. Likewise the jatropha husk materials are used as source of fertilizer. After pilling them out the husks are thrown in the field and decompose as organic fertilizer. The nutrients content (NPK) ratio of husk as reported by Jongshaap *et al.* (2007) is N 0.011 kg, P 0.02 kg and K 0.059 kg as compared with cow manure which contains N 0.038 kg, P 0.051 kg and K 0.015 kg. Due to the nutrients contained in husk, they substitute cow manure example 25.5 kg P of cow manure compensate 1 Kg P of husks.

2.4.3 Electricity production from jatropha oil

(Sawe, 2008 and Gmünder *et al.,* 2010) document the potential of jatropha as source of energy in rural area where the national electric grid is not accessed by rural farmer. Gmünder *et al.* (2010) assesses electricity generation using jatropha oil in India where he comment positive environmental saving from energy production using straight jatropha oil as compared to fossil energy. Sawe (2007) report that in 2006 TADEDO Company installs litre Engine coupled to alternator, grain mill, oil seed press, de-husking machines and battery charging facility at Engaruka. The engine has capacity of 10 HP or 7.5 kWh and energy consumption of 2.19 kg SVO per hour. This machine operates at a capacity factor of 33% and save more than 50 to 100 households at the optimal 35% efficiency if 100% load. Similar technology was reported by Gmünder *et al.* (2010) in his study conducted in India. Wijgerse (2007) in his study on Jatropha for rural electrification in Tanzania; a case of Engaruka present that, the cost of press machine is TZS 3.2 Million, filter press is TZS 1.8 million and 1 million for adoption engine while the cost of oil storage is TZS 0.12 million and TZS 2.5 million for seed storage.

2.5 Economic Assessment of Jatropha Cultivation and Processing

This section intend to describe the economic rational of biodiesel feedstock production in Tanzania base cost related to production. According to Kenneth *et al*. (2010) categories the oil feedstock costs are as endogenous and determined within the agricultural model, while biodiesel prices, feedstock processing, capital, storage, and transportation costs are considered as exogenous cost and fixed. In regard of these costs, the biodiesel production costs include costs for labor, overhead, methanol, catalyst, electricity, natural gas, steam, water, waste disposal, local taxes, insurance, and maintenance. The operating costs depend on which oil source is converted to biodiesel. Therefore base on the cost analyses above, the economic analysis of Jatropha cultivation and processing base on the cost of feedstock produced and the price of feedstock as compared to final product. Philip (2007) attributed that, the costs of producing bioenergy are 601 and 648 TZS/L for palm oil and Jatropha respectively. Where if compared with current market price of jatropha oil of 2 500 TZS, and the price of feedstock seeds which is an average of 800 TZS to produce 1liter of jatropha oil there is economic potential in this sector. The study also concludes that, the use of sugarcane and jatropha for producing bioenergy would increase the net returns for the producers of those crops by 28 and 53% respectively. The challenges that face jatropha production are the low price of seeds which is determined by price of fossil energy. According to Tilman *et al*. (2006) report that potential of jatropha production (cultivation and processing) at the household income will be realised if more efficient and modern jatropha processing is imposed.

2.6 Life Cycle Assessment (LCA)

Life Cycle Assessment (LCA) is a technique used to estimate environmental aspects and potential impacts associated with a (system under study) product, process, or service. This is through compiling an inventory of relevant energy and material inputs and environmental releases, evaluating the potential energy balance and greenhouse gas emissions associated with identified inputs and releases; and interpreting the results to support more informed decision making. ISO 14040 and ISO 14044 (2006) describe important aspects to be considered under environmental impact assessment using LCA methodology which includes; *Goal and scope, Life Cycle Inventory (LCI), Life Cycle impact assessment (LCIA) and Interpretation*. According to SAIC (2006) LCA evaluates all stages of a products life. This is similar to what Prueksakorn and Gheewala (2006) reported as one of the most internationally accepted methods to determine the environmental impacts over the entire period of the activities, products, and process for identifying significant environmental aspects is life cycle assessment (LCA). The assessment includes the entire life cycle of the product, process or activity, encompassing extracting and processing raw materials; manufacturing; transportation; and distribution; use/re-use/maintenance; recycling; and final disposal.

There different LCA studies conducted in different part of the world that assesses environmental performance with reference on GHG emission and energy balance result from use biodiesel as source of energy compared to fossil fuel. Such studies include the study conducted by Prueksakorn and Gheewala (2006) that focus on energy consumption and greenhouse gas (GHG) emissions from jatropha biodiesel production and use as compared to conventional diesel fuel for use in transportation in Thailand using a life cycle approach. The result of the study shows that the process of transestrification is among of processing activity that consumes more 40% energy than other energy demand in cultivation process including irrigation 23% and application of fertilizer 22% process. In respect to global warming potential the study report that the dominant global warming potential came from the production or use of fertilizer and irrigation process, about 31% and 26% respectively. In respect to transportation sector Gmünder *et al.* (2010) make a focus on jatropha based rural electrification in India. The study aims to assess the environmental sustainability of that electrification project. In his study it was concluded that the environmental performance result from rural electrification using jatropha oil is only slightly improved due to the high air pollution from pre-heating the jatropha seeds. The study compare with other electrification approaches such as photovoltaic (PV), grid connection and a diesel-fuelled power generator.

Apart from jatropha feedstock there also different studies that compare the performance of biodiesel result from jatropha and other potential biodiesel feedstock such as palm oil and soy beans. Lee (2009) conducts a study on LCA that compare the scenario of palm oil and jatropha oil to biodiesel in Malaysia. The assessment includes the cultivation of crop, oil extraction and biodiesel production. All these stage was compared base on energy balance (input out put) energy and environmental consequences including land use and potential carbon dioxide sequence. The study concludes that palm oil as feedstock for biodiesel production is superior and sustainability compared with jatropha oil in terms of energy balance and carbon sequence. In the study conducted by Zah *et al.* (2007) pinout that not all biodiesel energy sources (feedstock) are environmental friendly. Different criteria were used by LCA studies for potential biodiesel feedstocks. Among of the criteria includes GHG reduction of at least 30% as compared with the fossil reference and no increasing impacts in other relevant environmental impacts as compared with the fossil reference.

2.7 Energy Balance and Greenhouse Gas (GHG) Emission from Jatropha Biofuels in Tanzania

2.7.1 Energy balance

Energy balance is defined as energy stored per energy for production. Energy balance result from jatropha biodiesel is assessed base on land use, cultivation intensity and processing (Achten *et al.,* 2007). The energy required (energy input) is then compared with energy output. Base on this fact cultivation of jatropha is referenced to be energy intensive if the mechanization process in involved including the application of fertilizer, use machine in land preparation and the use of pesticides or irrigation that all of these energy consume fossil fuel in manufacturing process. In the seed harvesting and oil extraction is another area considered in energy input if the farmer use manual labor less energy will be used in harvesting compared to the use of machine in harvesting. Similarly the use of mechanical oil extraction is less energy demand compared to solvent extraction.

In case of developed countries where the process of biodiesel making taking place the transesterification process is reported to consume more energy while the disposal of the wastes product demand enough energy. But what is special under energy balance the comparative analysis on energy consumed in any step of production base on the energy output such as biodiesel, glycerol, seedcake, fertiliser and biogasification. The LCA study conducted by Lee (2009) focusing on energy balance of palm biodiesel and jatropha biodiesel find that the energy balance ratio for palm biodiesel is 2.27 slightly higher than that of jatropha biodiesel 1.92 but the study conducted by (Tobin, 2005, Prueksakorn, 2006 and Achten *et al.*, 2007) find a positive energy balance of jatropha biodiesel after allocating the energy input to the different products (end product and by products) though the report added that the energy balance may also become less positive after transestrerification and without use of by-products as source of energy.

The potential aspect under the focus of energy balance in this study relies on the central point of environmental saving. Since biodiesel is reported to be more environmental friendly the relation of energy produce and consumed are causal in this study as compared with fossil fuel. One may say the energy input is less than energy output but further focus need to trace the MJ per kg CO_2 produced (MJ/kg) which lists the energy produced per kilogram of CO_2 produced. This is a measure of the potential environmental impact of the use of the substance as a fuel with respect of the release of CO_2. The more CO_2 released by a certain type of energy the worse it is for the environment. Achten *et al.* (2007) stress majors' impact on the energy balance is observed when farming inputs like fertilizer or pesticides are applied while Ndong *et al.* (2009) report high 72% performance of jatropha cultivation on energy balance.

2.7.2 Greenhouse Gas (GHG) emission

GHG emission is the central focus on climate change. Different nations develop different strategies to cut down the carbon emission result from the consumption of heavy metal and fossil fuel in production. Base on Achten *et al.* (2008) alternative source of energy (Biodiesel) was established to combat the negative impact result to the use of fossil energy. Biodiesel is carbon neutral and hence it contributes in reducing GHG emission result from the use of fossil energy. Nitrous oxide (N_2O) emissions from fertilizer application, production and transportation could partially offset the CO_2 neutrality. Also fossil energy inputs into biodiesel production and downstream processing reduce net GHG savings from Biodiesel. The overall balance of GHG emissions from biodiesel supply depends on the effective use of by products from Biodiesel conversion such as press cake that could have at least offset the GHG burden from biodiesel cultivation and processing. According to Willem (2008) report that, sustainability in production is an important issue for D1 Oils (a large jatropha investor) and D1 aims to maximize the greenhouse gas emission savings of its Jatropha oil/biodiesel. Besides the internal drive to maximize the greenhouse gas GHG-performance, different nations develop different strategy to cut down the use of fossil fuels to save the environment through establishing or use environmental friendly source of energy (biodiesel). This gives GHG emission an important and valuable parameter in the biofuel market.

Jatropha is the crop that perceived to have significant emissions that offset any GHG savings from the rest of the biofuel production chain. Lee (2009) in the study carried in Malaysia show that jatropha biodiesel has less carbon sequence than palm biodiesel which is 20 times higher than jatropha biodiesel. But the study conducted by (Tobin, 2005 and Prueksakorn, 2006) in Indian plantations of D1 Oils on biodiesel production from jatropha *curcas* show around 30% reduction of GHG emissions compared with fossil diesel. In relation on jatropha cultivation and land use change Achten *et al.* (2008) in his jatropha survey asserts that there is negative effect on the GHG balance of the whole life cycle due to removal of natural forest is a heavy burden on the initial GHG investment, which will take a significant time span before it is paid back with the GHG emission reduction of the use of the bio-diesel. But biodiesel result from jatropha has proved to be environmental friendly compared to fossil fuel.

According to Whitaker and Heath (2008) in there study which examines the blend of diesel blends with 5% and 20% jatropha as well as 100% jatropha biodiesel show that petroleum diesel with a 5% jatropha biodiesel blend could reduce net GHG emissions by

3% per gross ton-kilometre. For the 20% blend the estimated GHG reduction was 12%, and for the pure biodiesel 62%. In reference of all the studies about GHG emission they all relate the aspect of land use impact still there is an obvious need for further focus on GHG emission in all the biodiesel production chain from jatropha crop. Therefore the focus of this section is on land use and all production and processing chain on GHG emission in all the biodiesel production chain from jatropha crop.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Introduction

This chapter presents the methodology used in this study. It includes study site description, function unit (FU) of the study, data sources, research design and sampling techniques, data collection, methods for data analysis. This study employed Net present value (NPV), internal rate of return (IRR) and Life Cycle Assessment (LCA) in order to capture the objectives of this study.

3.2 Description of the Study Area

The study was conducted in Monduli and Mpanda districts in Arusha and Rukwa regions respectively. Monduli district is allocated at longitude 3° 18' 0" South, 36° 27' 0" latitude East and Mpanda is allocated at longitude 30º00’ to 33º31’ East and from latitude 5º15’ to 7º03’ South (District Agricultural Office, 2010). The two districts are the main grower of jatropha crop in different farming system (Fence and Plot) and propagation method such as cutting and seedling. These study sites were selected because they are currently the main producers of jatropha for economic purposes and there are oil processing plant established in the study area.

3.3 Compared System

The information from the jatropha cultivation to oil extraction and use was collected from the Arusha (Monduli) and Mpanda. The study compares different farming systems (plot and fence) based on land use change and use of husk material as manure or fertilizer. Also the study compare different processing technology found in the study area based on the use of main product (jatropha oil) produced and co-product (press cake) obtained. Likewise the study compares electricity production using jatropha oil by considering diesel engine and alternator. Energy input and output was measured based on jatropha oil where with fossil fuel as a reference point. Jatropha soap production was also compared with medicated soap production. The system boundary of this study is shown in Fig 2.

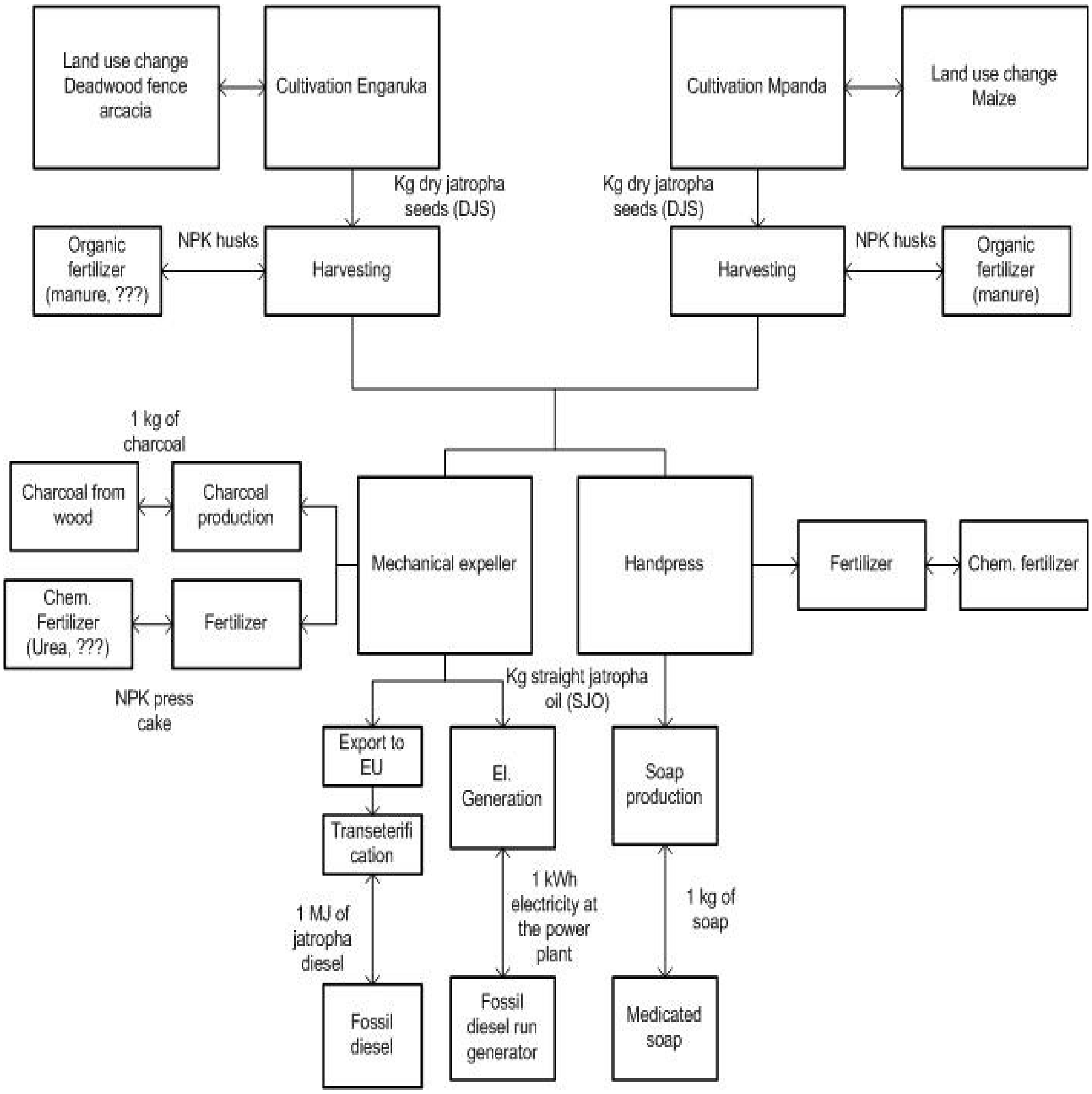

Figure 2: The system boundary of the study

3.4 Function Unit (FU)

A function unit (FU) is defined as a quantified description of the performance of the product systems, for use as a reference unit ISO 14044 (2006). The study compares the different cultivation systems (FU 1 kg) of seed produced, jatropha soap (FU 1 kg) of soap produced, Electricity based jatropha oil (FU 1 kWh) at the village level, Transportation of jatropha based products (1 vehicle x km), charcoal produced from press cake (FU, 1 kg) of charcoal from press cake and NPK ratio of 1 kg press cake fertilizer. The selection of FU base on completion of data in the system boundary, therefore the above FU meet criteria in case of the selected study site in Tanzania.

3.5 Research Design and Sampling Techniques

A cross sectional study design was used in this study where data were collected at a single point in time. The study used simple random sampling procedure to select respondents who cultivate jatropha. Non jatropha farmers selected in the study are those who live near to the jatropha farmers. A total of 260 respondents were selected with 130 Jatropha farmers and 130 non jatropha farmers.

3.6 Data Collection

Specific data for the cultivation and processing of jatropha were collected from the farmers at Engaruka (Monduli) and Mpanda (Usevya and Katumba) and companies processing jatropha based products at both study site that included, TATEDO, KAKUTE, JPTL, DISAT, DILIGENT and PROKON. Structured questionnaire was used to gather information base on jatropha cultivation while the check list questions were used to collect data from the processing companies. Secondary data were extracted from different research reports, generic database of ecoinvent and literatures on energy balance required in jatropha cultivation and GHG emission.

3.6.1 Data collection on labour requirement in farming activities

Jatropha cultivation is very labour intensive no machine was used in farming activities. Labour required for clearing the site, ploughing, pitting, planting, weeding, irrigate, spraying of crop protection chemicals, fertilization and pruning are done by family labour and hired labour. Data for labour cost were collected directly from farmers dealing with Jatropha crop cultivation in the study site. Also the data collected include labour requirements, cost and yields as described in subsection below.

3.6.2 Data collection on cost of jatropha cultivation and processing in Tanzania

The cost involved in this study was collected from farmers and jatropha seed processors. In case of Jatropha cultivation the cost were assessed per hectare in case of plot cultivation and cost per meter in case of fence cultivation. Furthermore the study broke down the cost of seed production per kg of seed produced. Costs of jatropha oil includes processing and making different jatropha products such as soap were collected based on cost of labour, raw material and machine used in production. The cost of marketing of jatropha products and management cost were not covered in this study because of difficulties of accessing them.

3.6.3 Data collection on yield of jatropha seed

The study collect yield from farmers cultivating and harvesting jatropha in the study area. The yield collected was from 2007 to 2009 production season. Also the study collected the information based on age of tree to simplify the computation of yield per age of tree. MS excel was used to compute yield per age of tree per kilogram per metre in case of fence cultivation and per kilogram per metre squire in case of plot cultivation.

3.7 Data Analysis

3.7.1 Descriptive and qualitative study analysis

Descriptive statistic analysis was based frequency and mean of respondents were used to describe the socio economic characteristic such as age, sex, marital status, education level and household size in the study area. Qualitative information was used to cement the result or information obtained.

3.7.2 Description of jatropha based products at study site

Data for jatropha based product were collected to the processing companies that deal with marketing of jatropha seed and processing including DILIGENT, KAKUTE, JPTL, TATEDO, PROKON and DISAT. The description based on the type of technology used by processing companies, capacity, efficiency and related cost for production. Data were collected using check list questions and analysed using content analysis. The description base of the function of the product as related to their substitute products.

3.7.3 Assessment of economic benefit of jatropha cultivation to small scale farmers

The present study also assessed the economic impact of Jatropha cultivation to small scale farmers. Data were collected on the cost factors for the cultivation and on the returns from selling the seeds. These data were entered into a MS Excel sheet to sum up the discounted costs and benefits for every single year up to the tenth year where the study assume constant yield to its lifespan 45 years. This data then built the foundation for the calculation of four economic indicators parameters used included net benefit (NB) which is calculated as the remaining profit after subtracting all costs that incurred within one period from the value of all products produced within the same period. Net present value (NPV) presents today’s value of the whole investment summing up. Also internal rate of return (IRR) was assessed as an indicator of the efficiency of an investment. It is the annualized effective compounded return rate which can be earned on the invested capital. A discount rate has to be set for the calculation of NPV and IRR. The study used discount rate of 13.1% as presented in the BoT (2010) economic bulletin of period ending 30 March 2010. The formulas for NPV and IRR are as described by Hella (2007) as follows.

Net present value (NPV)

The net present value represents the discounted cash flow of an investment over its lifetime. Thus it is the difference of the incremental benefits and costs of a project for all periods and an adequate target rate. The investment is profitable if the net present value is positive. The NPV is expressed in the following formula.

$$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+i)^t}$$

Where

NPV: net present value in Tshs,

n: project life in year

Bt: Benefits in year (t) in TZS /ha

Ct: cost in year (t) in TZS /ha

i: interest rate in %

Internal Rate of Return (IRR)

The IRR represents the maximum interest that a project could pay for the resources used if the project is to recover its investment and operating costs and still break even. It is defined as the interest rate at which the net present value equals zero as presented in the following formula.

$$NPV = 0 = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+i)^t}$$

Where

NPV: net present value in TZS,

n: project life in year

Bt: Benefits in year (t) in TZS/ha

Ct: cost in year (t) in TZS/ha

i: interest rate in %

3.7.4 Determine energy balance of jatropha production

Data on energy balance resulting from jatropha biodiesel was obtained form calculation made by using SimaPro software and other data were adopted from various LCA studies. Energy used during transporting farm inputs to farmers, seed from farmers to the processing plant and energy used in construction of press machine and transporting them to the processing site was not included in the study. This was due to lack of data during data collection. Intensive cultivation using different inputs such as fertilizer and irrigation resulted in a less positive energy balance compared to low input cultivation.

3.7.5 Assessment impact of jatropha cultivation and processing to greenhouse gas (GHG) emissions

Life Cycle Assessment (LCA) methodology was used to estimate environmental impact resulting from jatropha production chain (cultivation, processing, to the end use of the product). The GHG emission was assessed for all inputs and output parameters used in the production chain and estimate the kg CO_2 equivalent result from the whole process. Intergovernmental Panel on Climate Change Global Warming Potential (IPCC, 2007 GWP 100a) method was selected by this study in the calculation of GHG emission.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the findings of the study which are divided into five sections. These are socio economic characteristics of the respondents, description of jatropha based products, assessment of economic benefits of jatropha cultivation, energy balance of jatropha cultivation and processing and GHG emission due to jatropha cultivation, processing and use of its various products.

4.2 Socio-economic Characteristics of the Household Heads

The results in Table 4.1 show that average age of jatropha farmers were 41 years while non jatropha farmers were 39 years with total average of 40 years at both study sites. Total sample size of interviewed farmers was 240 of which 60% are males and 40% are females. In the assessment of marital status, the study found that, 88.8% of respondent were married while 9.2% and 1.9% were single and widowed respectively. The average household size was 7.8 with Engaruka having 6.8 and Mpanda 6.5 which is closely related to the data presented in URT (2002). On the side of education level of respondents in the study area, the result show that the majority 68.5% of respondent had primary education while 1.9% had secondary level and 2.3% had adult education level followed by 27.3% of respondent that had no formal education. These findings are similar to those of the assessment of agricultural marketing information needs study URT (2005) which found that there was large numbers of farmers with primary education and above which implies that introduction of new technologies including Jatropha crop as alternative source of income was easy because majority of respondents have formal education.

Table 4. 1: Distribution of respondents by household characteristics

Variable name		Adopters (N=130)		Non adopters (N=130)		All farmers (N=260)	
		F	%	F	%	F	%
Age	18 - 35	46	35.4	54	41.5	100	38.5
	36 - 45	43	33.1	42	32.3	85	32.7
	46 -60	29	22.3	23	17.7	52	20.0
	>60	12	9.2	11	8.5	23	8.8
Sex	Male	88	67.7	68	52.3	156	60.0
	Female	42	32.3	62	47.7	104	40.0
Marital status	Married	117	90.0	114	87.7	231	88.8
	Single	12	9.2	12	9.2	24	9.2
	Widow	1	0.8	4	3.1	5	1.9
Years of school	Primary	88	67.7	90	69.2	178	68.5
	Secondary	3	2.3	2	1.5	5	1.9
	Adult education	39	30.0	6	4.6	6	2.3
	No formal education	88	67.7	32	24.6	71	27.3
Household size	<3	3	2.3	16	12.3	19	7.3
	3 - 4	24	18.5	30	23.1	54	20.8
	5 - 6	27	20.8	53	40.8	80	30.8
	7 - 8	34	26.2	15	11.5	49	18.8
	>8	42	32.3	16	12.3	58	22.3

4.2.1 Agricultural activities in the study area

For most rural households animal keeping and crop farming are the dominant economic activities. Results provided in Table 4.2 show that 20% of respondents deal with crop production only while 80% deals with crop farming and animal keeping. It was reported (by respondents) that jatropha farmers grow this new crop to increase their incomes. Results provided in Table 3 show that 89.2 % of jatropha farmers do both crop and livestock keeping compared to 70.8 % of respondent who do not grow the crop.

Table 4. 2: Distribution of respondent by crop and animal keeping

Activity	Adopters N=130		Non adopters N= 130		All farmers N= 260	
	F	%	F	%	F	%
Crops	14	10.8	38	29.2	52	20.0
Crop and Livestock	116	89.2	92	70.8	208	80.0

4.2.2 Main crop grown at Mpanda and Engaruka

Table 4.3 describes types of crops cultivated by households in the study area. Majority of households cultivate more than one crop. Maize is the dominant crop at both study sites. Jatropha as a new crop is intercropped with food crops such as maize similar observation was reported by Loos (2008) and Wahl *et al.* (2009).

Table 4. 3: Distribution of respondents by main crop cultivated in the study area

Type of Crop cultivated	Monduli N=120		Mpanda N= 140		All study area N= 260	
	F	**%**	**F**	**%**	**F**	**%**
Maize	8	6.7	47	33.6	55	21.2
Maize & Black beans	112	93.3	0	0	112	43.1
Maize & Groundnuts	0	0	53	37.9	53	20.4
Maize & Beans	0	0	21	15.0	21	8.1
Maize, Groundnuts & Beans	0	0	19	13.6	19	7.3

4.2.3 Type of livestock kept by respondents

Results in Table 4.4 show different types of livestock kept in the study area. The results show that at Engaruka the average number of cattle was 10 heads per household. On the other hand in Mpanda there was an average of 25 herds of cattle kept per household. The average number of cattle at Engaruka was small due to long drought of 2007 to 2009 that led massive death of cattle due to lack of grasses. Other types of livestock kept include goat, sheep and poultry. There are also other important animal kept in both study sites.

Table 4. 4: Distribution of types of livestock kept by respondent in the study area

	Monduli			Mpanda		
Type of livestock	**N**	**Average**	**Total**	**N**	**Average**	**Total**
Local cows	75	10	709	12	25	300
Exotic cows	2	2	4	6	2	9
Local goats	111	16	1807	55	6	328
Exotic goats	0	0	0	13	2	27
Sheep	86	13	1075	3	9	26
Pigs	0		0	16	3	54
Poultry	25	9	232	76	12	895

4.3 Description of Jatropha Based Products at Monduli and Mpanda

4.3.1 Jatropha cultivation in Tanzania

The results show that, jatropha is cultivated in two main farming systems that is fence and plot at Engaruka and Mpanda respectively. The propagation method used to plant this crop differed at the study sites. It was observed that, at Engaruka they use cuttings which are obtained from the older trees while at Mpanda they use seedlings which are distributed by PROKON. Planting space used in fence was not clearly known but at Mpanda a spacing of 3m x 3m is used. Messemaker (2008) report a plant space of 2.5m x 3m at Kikuletwa farm in Moshi. Also the study observes that cultivation of jatropha in the study area use both family labour and hired labour. Apart from long drought that occur at Engaruka since 2007 and affect other types of food crops and animal, jatropha crop produce fruit all the years while no any irrigation is used in this crop.

4.3.1.1 Land use change due to jatropha cultivation in Tanzania

Table 4.5 indicates that land at Mpanda was transformed from crop land, non cropland and bush land to give a chance for jatropha cultivation. About 88.6% used for jatropha production was previously used for crop production while 5.8% was formerly bush land 4.3% and 1.4% of farmers use land that was previously grass land and forest respectively. These findings support the result reported by Loos (2008) on the level in which the new crop “Jatropha” influence land use change in the area.

Table 4. 5: Former land use before jatropha cultivation at the study sites

	Mpanda		Engaruka	
Land use	**Frequency**	**Percent**	**Frequency**	**Percent**
Food crop	62	88.6	0	0
Grassland	3	4.3	0	0
Bush land	4	5.8	0	0
Forest	1	1.4	0	0
Dry acacia fence	0	0.0	60	100
Total	**70**	**100**	**60**	**100**

Effect of land use change due to jatropha cultivation on CO_2 emissions

Due to the above results the study focuses on the CO_2 impact due to land use change as comparing with the potential natural vegetation as a baseline (App 2). That areas getting transformed by man (land transformations) as well as areas forced to maintain their current non-natural state (land occupations) may store reduced amounts of carbon in soil and vegetation, whereby the mobilized carbon is essentially transferred to the atmosphere in form of CO_2, contributing to global warming. Results show that on average per hectare basis, no impact that are observed at Engaruka due to land use change because there is no any impact on land use while at Mpanda results obtained after the calculation using GWP500a and GWP100a show a total of 0.1 and 0.2 CO_2 kg/kg DJS as impact due to land transformation respectively. Likewise the result show that land occupation has positive impact in case of Engaruka where a total of 0.1 and 0.3 CO_2 kg/ kg DJS was obtained using GWP500a and GWP100a respectively. But in case of Mpanda only at GWP100a where a positive 0.1 CO_2 kg/kg DJS impact was observed due to land occupation by jatropha crop.

Table 4. 6: CO2 emissions from Land use change at both study sites

Land use change	**Name**	**Engaruka** Tropical savannas and grassland	**Mpanda** Tropical savannas and grassland
Transformation			
From	land with no impact	1.00	0.89
	PNV	0.00	0.11
	Carbon loss	0.00	6.64
GWP 500a	duration factor (GWP 500a)	0.3	0.3
	Fossil combustion-equivalent	-	2.1
	CO2 (t / ha)	-	7.5
	CO2 kg / kg DJS	**-**	**0.1**
	total (t/ha)	65.98	65.98
GWP 100a	duration factor (GWP 100a)	1.0	1.0
	Fossil combustion-equivalent	-	6.6
	CO2 (t / ha)	-	24.1
	CO2 kg / kg DJS	**-**	**0.2**
Occupation			
Carbon of Jatropha plantation			19.80
	Plot (t C /ha)		
	Fence (t C / ha)	11.48	
GWP 500a	duration factor (GWP 500a)	0.0	0.0
	Fossil combustion-equivalent	0.1	0.1
	CO2 (t / ha)	0.4	0.2
	CO2 kg / kg DJS	**0.1**	**0.0**
GWP 100a	duration factor (GWP 100a)	0.0	0.0
	Fossil combustion-equivalent	0.4	0.2
	CO2 (t / ha)	1.3	0.7
	CO2 kg / kg DJS	**0.3**	**0.1**
Total			
GWP 500a	***CO2 kg / kg DJS***	***0.1***	***0.1***
GWP 100a	***CO2 kg / kg DJS***	***0.3***	***0.3***

4.3.1.2 Jatropha farming systems in Tanzania

The study also assesses farming systems used by farmers for Jatropha cultivation. The results show that all farmers in Engaruka cultivate jatropha in fence. Also in case of Mpanda the farmers use different farming systems for jatropha cultivation. Result provided in Table 4.7 show that majority of farmer intercrop jatropha with other perennial crops. These findings are similar to those of Wahl (2009) where the study observed that jatropha was almost always intercropped with other crops and due to this the cost of farming activities including land preparation and weeding decrease.

Table 4. 7: Farming systems for jatropha cultivation

	Mpanda		**Engaruka**	
Farming system	**Frequency**	**Percent**	**Frequency**	**Percent**
Monoculture	26	37	0	0
Intercropping	44	63	0	0
Fence	0	0	60	100
Total	**70**	**100**	**60**	**100**

4.3.1.3 Type of crop intercropped with jatropha

The study also tried to identify the crops which are intercropped with jatropha in the study area so as to project the impact on food security if intercropping will end after jatropha canopy increase and hence hinder the production of other crops. The results in Table 4.8 show that majority of farmers 82% intercrop jatropha with maize. Mpanda is among the main maize producing area in Tanzania. Maize is sometimes considered as cash crop and also food crop to majority of farmers in the study area. The situation of food security to majority of farmers who intercrop maize with jatropha after five years will be in a problem if there is no other alternative land for food crop production.

Table 4. 8: Crop intercropped with jatropha in Mpanda

Type of crop	Frequency	Percent
Maize	36	82
Sesame	3	7
Groundnuts	5	11
Total	**44**	**100**

4.3.1.4 Pesticide application in jatropha cultivation

Pests and diseases was the main problem that farmers at both study sites face. About 95% and 92.9% of the farmers interviewed at Engaruka and Mpanda report a problem of pests that affect, similar problem was reported by Loos (2008) at Mpanda where about 75% of farmers claim retain jatropha was affected by diseases such as red beetle and leaf spotting. The type of pesticide applied by farmer includes Deltra 600 liters and 187 liters of Bayfidan (*Triadimenol)* which are apllied in total land of 187.21 ha. The cost of Deltra was 17 500 TZS/L Bayfidan (*Triadimenol)* cost 22 500 TZS/L (personal communication with PROKON agricultural office). Public transport (passenger bus) and motorcycle of PROKON extension officers were used to transport farming inputs for store to farmers at Mpanda as indicated in Table 4.9.

Table 4. 9: Description of transportation chain of jatropha seeds and inputs in km

Material	Bus/Truck (km)	Motorcycle (km)
Seed from PROKON to Usevya	260	0
Seed from PROKON to Katumba	0	60
Input from PROKON to Usevya farmers	260	0
Input from PROKON to Katumba farmers	0	60

4.3.1.5 Fertilizer application in jatropha cultivation

The results show that none of jatropha farmers use chemical fertilizer or manure, apply irrigation and use of machine such as tractor in jatropha farm or fence. Results show that about 33.3% of farmers use plough and 66.7% use hand hoe in farming activities at Engaruka while at Mpanda only 7% of farmer use plough and 93% use hand hoe in farming activities. In the focus group discussion conducted in the study area reported that jatropha grow well in the study area without the application of fertilizer or the need of irrigating the crop. It is well documented that the application of chemical fertilizer and use of machine like tractor in farming activities contributes much in GHG emission Whitaker (2009).

4.3.1.5 Fertilizer application in jatropha cultivation

The results show that none of jatropha farmers use chemical fertilizer or manure in jatropha farm or fence. In the focus group discussion conducted in the study area reported that jatropha grow well in the study area without the application of fertilizer. It is well documented that the application of chemical fertilizer contributes much in GHG emission. With this respect jatropha cultivation in the study area without application of this fertilizer save GHG emission in the cultivation stage similar argument was made by Whitaker (2009) on the impact of fertilizer application on GHG emission.

4.3.1.6 Labour cost for jatropha cultivation

Labour is the most important variable under economic analysis for jatropha cultivation. The results show that majority of farmers 90.8% use family labour in farming activities including land preparation, planting, weeding also pruning and harvesting. Only 9.2% of reported to use hired labour. The average variable cost for different farming activities in Table 4.10 were collected directly from farmers. Wiskerke (2008) in his study on assessing the labour used in different jatropha farming activities he founds that jatropha harvesting and marketing consume more labour than other activities. In case of Tanzania since farmers not yet take jatropha farming to be a serious economic activity the cost of production are still low because the crop is mainly done to intercrop with other crop.

Table 4. 10: Labour cost in jatropha cultivation per hectare in TZS

Farming activity	Cost under fence cultivation TZS/ha	Cost under plot cultivation TZS/ha
Preparation	35 000	75 000
Planting	5 000	15 000
Weeding		50 000
Pruning	10 000	
Pesticides		20 834
Harvesting	15 000	
Total cost	**65 000**	**160 834**

4.3.1.7 Yield from jatropha plant

The results Table 4.11 show that base on questionnaire the average yield of jatropha tree from Engaruka with 1, 2 to 3 years old were 0.43, 0.46 and 0.5 kg/ meter fence respectively while the yield of matured jatropha tree with 4, 5 and 6 years old yield were 0.51, 0.56 and 0.67 kg/ meter fence respectively. Results presented by FAO (2010) on yield of jatropha per tree range from 0.2 to 2 kg/metre, also the findings reported by Byiringiro (1995) on jatropha yield was 0.8 to 1 kg of seed per metre of hedge per year and Jongschaap *et al.* (2007) of 1.5 to 7.8 t/ha. All these findings (Byiringiro, 1995, Jongschaap *et al.*, 2007 and FAO, 2010) show that the yield obtained in the study area is low.

Table 4. 11: Jatropha yield scenario at the study site

Year	Engaruka (kg/metre)	Mpanda (kg/metre squire)
1	0.43	0.0054
2	0.46	0.0046
3	0.50	0.0075
4	0.51	0.0043
5	0.56	0.0074
6	0.67	
Average	**0.52**	**0.006**

Results at Mpanda show that, the yield from tree with 1 to 3 years old was 0.006 kg/m^2 which were similar to average yield data of jatropha of tree with 4 to 5 years old. These give the average yield of 0.006 kg/m^2 which are all yield figures harvested by farmers and not potential yields since the plants produce more than shown in Table 4.11). The low yield in the study area can be attributed to the fact that companies which buy the seeds pay very low price which discourage farmers from harvesting all seeds and hence leading to underestimation of the yield.

4.3.1.7.1 Jatropha yield scenario

In order to account for the high uncertainty of yield figures and to assess optimization potentials, three yield scenarios are used within this study. *Low yield scenario***:** The low yield figures considered in this section is the average yield over the whole lifespan of 20 years resulting from the house hold survey. *High yield scenario***:** This is another scenario considered in this study. The high medium yield is obtained from studies conducted different similar climatic condition. With this respect the study conducted by (Openshaw 2000 and Wiskerke 2008) in Mali and Shinyanga region in Tanzania respectively that show the highest yield of 1 kg per metre of jatropha fence in case of Engaruka and yield data documented by Messemaker (2008) and Achten (2008) of 1 kg/ tree in case of Mpanda. *Medium yield***:** This study considers the average yield of low and high yield scenario as presented in Table 4.12.

Table 4. 12: Jatropha yield scenario at the study site

Yield Scenario	Engaruka Kg/m	Mpanda Kg/m^2
Low	0.52	0.03
Medium	0.76	0.75
High	1.00	1.00

4.3.2 Processing of jatropha oil using different technologies

After farmer harvest jatropha seeds they sell the seed to the processing companies for further value addition. The function unit (FU) of oil pressing used in this study was 1 kg of Straight Jatropha Oil (SJO) at the plant. Two main types of technologies are used in the study site for jatropha oil processing. These are oil press using oil expeller and oil press using hand press machine. These technologies were also reported by Beeren (2007).

4.3.2.1 Processing jatropha oil using oil expelling or screw press machine

Oil pressing using oil expeller was used by DILIGENT Company. The capacity of this technology used by this company is 75 kg of jatropha oil per hour. This machine have a life span of 10 years equivalent to 29 200 h of operation. The efficiency of oil expeller technology is 86% where 1 kg of jatropha oil and 3 kg of press cake is obtained from pressing 4 kg of dry jatropha seeds. The oil content of jatropha seed is 35% which has a density of 0.918 kg/l. After oil being produced is then cleared before further uses by using different technologies including press filter and candle filter. The clean jatropha oil is transported by truck from Arusha to Mombasa and shipped to Europe.

Oil cleaning is another important process used to ensure oil quality. Press filter and candle filter are the main types of filter used by DILIGENT Company to clean raw jatropha oil. Press filter composes with multiple filter plates that are sheathed with filter cloth. From 30 litre of raw oil give 25 litre of clean oil after filtering.

Figure 3: Filtration (cloth press) at DILIGENT Company

Figure 4: Candle filter Photo from DILIGENT Company

4.3.2.2 Jatropha processing using hand press machine

Hand press machine and gravity filter (figure 5), are the most appropriate technologies used by small scale jatropha oil processors because they cheap and simple to operate.

According to data collected from JPTL, KAKUTE and DISAT, efficiency of hand press technology is 71.4% and its capacity is to press 3 kg/h. five kilogramme of jatropha seeds produce 1 kg of Jatropha oil and 4 kg of press cake. After oil settle for 4 to 7 days, the oil is filtered by using cloth (cotton) filter with capacity of filtering 20 l/h and efficiency 80%. The filtration system composes plastic material (Bucket and plastic pipe) and cotton cloth material. The lifespan of the hand press machine is 14 600 hrs where 43 800 kg of oil from 219 000 kg of seeds is produced. KAKUTE (2006) and Jatropha Handbook (2009) reported similar findings on oil pressing using hand press machine.

Figure 5: Hand press Machine and Gravity filtration system

4.3.3 Cost for jatropha oil pressing and equipment used

4.3.3.1 Labour cost for jatropha oil processing

The costs of labour employed in oil processing plant in the study area are described in Table 4.13. The data collected at DILIGENT and JPTL company indicate that, the average wage paid for hand press machine operator is 5 000 TZS/day where 1 person is employed to run the machine and 1 watchman who paid 25 00TZS/day. Under oil expeller 2 persons are employed to operate the machine where each is paid 10 000 TZS/day and 4 casual labourers are used to carry different activities in the industry where the average wage for each is 3 500 TZS/day. In both processing technologies the average working hour was 8 where 24 kg/day and 600 kg/day of jatropha oil is produced using hand press machine and oil expeller respectively.

Table 4. 13: Description of labour cost in oil pressing

Type of technology	Labour	Cost in TZS/year
Hand press	Labour cost per year	1 825 000
	Watchman or Casual labour per year	912 500
	Labour cost per year	7 300 000
Oil expeller	Casual labour per year	5 110 000

4.3.3.2 Seed transportation

The seed are transported from the study site to processing plant using passenger bus. The study considers Engaruka as a case study because the data on seed transportation were obtained from this area. The distance from Engaruka to Arusha is 150 km. The bus fare charged in transporting 1 bag of jatropha seed with 65 kg was TZS 3 500 where the cost of loading and off-loading was 200 TZS each. Table 4.14 indicate the cost of transporting jatropha seed per year from Engaruka to Arusha.

Table 4. 14: Cost of transporting jatropha seeds in TZS kg/year

Type of technology	Quantity kg/year	Cost in TZS/year
Hand press	8 760	525 600
Oil expeller	876 000	52 560 000

4.3.3.3 Cost of equipments or machine in TZS with capacity

Table 4.15 provide the cost related to equipments used for jatropha oil pressing using hand press machine and screw press machine. In the interview carried by this study with DILIGENT Company in 2010 find that, the cost of press machine TZS 3.5 Million, cost of press filter is TZS 1.5 Million and cost of candle filter is TZS 1 million. These costs are closely similar to the cost presented by Ferchau (2000) on different equipment required in oil pressing. Oil expeller use 22 kWh of electricity and 1 kWh cost TZS 129 equivalent to TZS 8 286 960 per year. Likewise data collected from KAKUTE, JPTL and DISART indicate that cost of hand press machine was TZS 250 000, cost of gravity filter 10 000 TZS which need to be renewed frequently at least once per month so the cost per year was TZS 120 000 other equipments including oil container cost TZS 10 000 per year, dry wood where the machine is fixed cost TZS 20 000.

Table 4. 15: Description of cost of equipments used in oil pressing

Type of machine	Equipments	Cost in TZS
Oil Expeller	Press machine	3 500 000
	Press filter	1 500 000
	Candle filter	1 000 000
Hand press	Press machine	2 500 000
	Dry wood	20 000
	Gravity filter	120 000
	Oil container	10 000

4.3.4 Jatropha soap production using jatropha oil

The study considers a function unit (FU) of 1 kg of jatropha soap, at the market. The data collected from KAKUTE, JPTL, and DISAT show that 1 litre of Jatropha oil yield 1.08 kg of jatropha soap equivalent to 12 pieces of jatropha soap with 90 gm. The price of one piece of soap is TZS 1 000 which is three times higher compared to most medicated soaps in the market. The inputs required to produce 12 pieces of soap includes 1 kg of Jatropha oil, mixed with water 0.5 litre (tap water) and 0.4 litre of pure NaOH (sodium hydroxide). The soap processors company also report that 1 person whose wage is 5 000 TZS/day make jatropha soap using 20 litres of jatropha oil per day. This implies that in processing 1 kg of jatropha soap require 0.4 man-days. Soap is transported to the market using passenger buses in average distance of 800 km from Arusha to Dare es Salaam or Mpanda to Mbeya. Jatropha soap substitutes other medicated soap in the market.

Figure 6: Equipments used in Soap making (Photo: JPTL Company)

4.3.5 Electricity generation using jatropha oil at Engaruka

The function unit defined in this section is 1 kWh electrical energy at Engaruka. The study find that, MFP Engine with capacity of 7.35 kWh and efficiency of 34% runs using 0.8 kg SVO per MJ of energy consumption equivalent to 6.4% efficiency. Also the alternator with 79% efficiency and capacity of 7.5 KVA produce 50 megawatts electricity which is enough for 50 households. The alternator has lifespan of 50 years with capacity of operating 73 000 h/lifespan. The cost of the MFP technology TZS 3.2 Million for press machine, TZS 1.8 million filter press and TZS 1 million for adoption engine while the cost of oil storage was TZS 0.12 million and TZS 2.5 million for seed storage. These cost were also presented by Wijgerse (2007) in his study on jatropha for rural electrification in Tanzania; a case of Engaruka. Machine alternator and all other facilities were transported using truck from Morogoro to Engaruka with assumed distance 800 km. An average 1 person can manage to run MFP where the average wage paid was 100 000TZS per month where the average working hours were 7 hour per day.

4.3.6 Charcoal production from jatropha press cake

The press cake contains still 25 MJ/kg and thus is suitable for use as a source of energy. In the briquetting machine the cake is pressed in order to increase the density. Due to the lack of information, the same energy consumption (68 kWh/t of produced briquettes) for briquetting was assumed as reported in Thailand where similar technology is used (http://www.retsasia.ait.ac.th/Publications). The cost of this technology figure 7 according to DILIGENT Company is TZS 2.5 Million.

Retort technology used by DILIGENT Company has an efficiency of 60% for press cake after the briquetting process as compared to 35% to 45% for wood residuals because of less compatibility of the residual. Also the result shows that 1.67 kg of briquette yield 1 kg of charcoal and 3.6 kg of wood yield 1 kg of charcoal. Similar findings were reported by Reumerman (2002). The price of charcoal from press cake was 400 TZS/kg which was similar to wood charcoal 400 TZS/kg. The optimisation of press cake as source of energy increase economic value of Jatropha products and save the environment. Figure 8 shows the charcoal obtained from press cake and wood material respectively. In average 1 person is enough to make charcoal using retort technology. Since this type of technology is not yet adopted in the country the cost for labour was not captured in this study.

Figure 7: Photo of Briquette machine from DILIGENT Company.

Figure 8: Charcoal from press cake and wood as taken from DILIGENT and other adopted from World Bank report 2009 respectively.

4.3.7 Press cake from jatropha seed used as fertilizer

Jatropha press cake as a source of fertilizer was assessed based on a function unit (FU) which was 1 kg of press cake. The study found that jatropha press cake materials are used as fertilizer at the processing companies (JPTL, KAKUTE DILIGENT) in their surrounding flower gardening. The nutrient content of jatropha press cake per kilogramme includes N 0.022 kg, P is 0.083 kg and K is 0.1 kg where cow manure contains N 0.038 kg, P is 0.051 kg and K is 0.015 kg (Jongshaap *et al.*, 2007). Therefore press cake can be used as a substitute for cow manure.

4.4 Economic Benefit of Jatropha Production to Small Scale Farmers and Jatropha oil Processors in Tanzania

4.4.1 Net benefit obtained from jatropha cultivation per kg of seed produced

The average price of jatropha seed in the study area was 200 TZS/kg. The results in Table 4.16 indicate that the net benefit obtained by farmers from jatropha cultivation were positive for high yield scenario and negative for low yield scenario at both study sites. Only Engaruka show positive net income at medium yield scenario. The results are similar to those obtained by the study conducted by Wahl N, (2009) in jatropha production in north Tanzania, the low yield scenario found to have negative net income under plot cultivation while the medium and high yield scenario reported to have positive net income. These results prove that if good farming management will be practised by farmers they will earn more than the current situation. The average cost of producing 1 kg of jatropha seeds was 55 TZS/kg at Engaruka while at Mpanda the cost was 94 TZS/kg. The different in cost was due to different farming system. At Mpanda farmers cultivate in plot while at Engaruka farmers cultivate in fence which is less cost.

Table 4. 16: Net income obtained from jatropha cultivation TZS/kg of seed produced

Yield scenario	Fence cultivation TZS/kg	Plot cultivation TZS /kg
Low	41	4
Medium	87	70
High	135	134

4.4.2 Net present value and internal rate of return of jatropha cultivation in different farming systems

Also the study assesses economic viability of jatropha cultivation for different farming systems in Tanzania by focusing on net present value and internal rate of return. Table 4.17 shows that, under fence cultivation low and medium yield scenarios give negative net present value (NPV) at Engaruka and Mpanda while positive NPV was obtained in high yield scenario. In comparing the efficiency of the two farming system internal rate of return (IRR) was considered. The results show that, at both study sites IRR under high yield scenario is greater than the discounting rate of 13.1% while the remaining scenarios IRR were less than the discounting rate mentioned above. This implies that the investment of Jatropha is economically viable for high yield scenario only in both farming systems.

Table 4. 17: Net present value and internal rate of return for different farming system

Yield scenario	Fence cultivation/metre		Plot cultivation/metre squire	
	NPV in TZS	IRR (%)	NPV in TZS	IRR (%)

Low	-495	-	-850	-
Medium	-171	5	-392	-
High	160	20	59	17

4.4.3 Economic analysis of oil pressing using oil expeller and hand press

4.4.3.1 Net income obtained from oil pressing using different technologies

The results for oil pressing using hand press and oil expeller technology show a positive net income of 1 200 TZS/litre and 1 421 TZS/litre of jatropha oil produced using hand press machine and oil expeller respectively from the second year after investment. The average cost of producing 1 litre of jatropha oil was TZS 1 300 and 1079 TZS for hand press and oil expeller respectively. In Tanzania the market price of jatropha oil is 2 500 TZS/litre which is high compared with the price of fossil diesel 1 600 TZS/l at Arusha filling station.

4.4.3.2 Net present value and internal rate of return of oil pressing

Results in Table 4.18 show the net present value (NPV) and internal rate of return (IRR) obtained as a result of processing and selling of jatropha oil using hand press machine and oil expeller. This analysis base on lifespan of the technology used (five years for hand press machine and ten years for oil expeller). The results indicate that, both technologies are economically viable for investment because NPV are positive for both technologies and IRR are greater than the discount rate used in this study of 13.1% for both technologies.

Table 4. 18: NPV and IRR obtained per litre of jatropha oil

Type of machine used	NPV in TZS/litre	IRR in %
Oil Expeller	1 274	55
Hand press	930	24

4.5 Determine Energy Balance of Jatropha Biodiesel Production

4.5.1 Energy efficiency from jatropha oil compared to fossil fuel

The study findings show that jatropha oil is more energy efficient than fossil fuels. This assessment is based on electricity production using SJO. Results show that by using SJO 4 litres of jatropha oil generate electricity for 6 hour which supplied to 23 household compared to 4 litre of fossil diesel using the same machine generate electricity for 5 hours only for the same households. With the interview carried by this study with DILIGENT Company in February 2010 observed that, the company use jatropha oil in land cruiser T 589 AEL where 1 litre of jatropha oil is consumed after 10 to 11 kilometre (km) while by using fossil fuel it run the car for 8 kilometre (km). This result implies that Jatropha oil is more energy efficient than fossil fuel for both areas of utilisation.

4.5.2 Energy balance of jatropha biodiesel compared to fossil fuel

Energy balance is defined as energy stored per energy used for production. The results show that the energy balance for fossil diesel is 0.8 similarly while the energy balance for jatropha biodiesel is 10.2. it should also be noted or pointed out that 10 times more process energy is consumed to make one unit of fossil energy than the energy in the form of jatropha oil. Energy balance for biodiesel made from jatropha is 4.6. Biofuel production requires direct (electricity, fuels, natural gas) and indirect (manufacturing of agricultural inputs and methanol) energy consumption. The total energy required for the production of 1 MJ of jatropha biodiesel was 0.21 MJ, which translates as an energy yield of 4.7. Thus, for each MJ of fossil fuel consumed to produce jatropha biodiesel, 4.7 MJ of jatropha biodiesel energy content are produced.

4.6 Impact of Jatropha Value Chain on Greenhouse Gas (GHG) Emissions

4.6.1 Greenhouse gas (GHG) emissions in jatropha cultivation

The largest percentage of GHG emissions comes from jatropha cultivation at Mpanda through the use of pesticides, and also in the form of direct emissions (such as nitrous oxide). The results obtained from Simapro calculation on jatropha cultivation at Mpanda shows that 0.59 Kg CO_2 eq is emitted to the environment (air, water and soil). The high proportion of Kg CO_2 eq was a result of manufacturing of Deltra pesticides 0.45 Kg CO_2 eq and Bayfidan (*Triadimenol)* 0.14 Kg CO_2 eq. Also transporting farming inputs including pesticides and seeds emits 4.07E-12 Kg CO_2 eq and 1.89E-10 Kg CO_2 eq respectively that contribute to the total emission. Study conducted by Achten (2007) reports that, intensive application of pesticides and fertilizer during Jatropha cultivation result to less energy saving compared to traditional farming system (less input used). The emissions resulting from transportation can be reduced if the processing activity will be carried in the area where the feedstocks are produced. This will also help to reduce energy loss of 2 to 8 % reported by (Tobin and Fulford, 2005).

4.6.2 GHG emission related to electrification

Results show that the environmental impact resulting from generation of 1 kWh electricity using MFP is linked to the emission of 0.014 kg CO_2 eq. GHG emissions was linked with the combustion process of the engine and alternator which released 51% and 37% of emission respectively. Similar findings were reported by Gmünder *et al.* (2010) where the generation of 1 kWh electricity was linked to the emission of 0.27 kg CO_2 eq. GHG emissions was linked to the process chain of jatropha seeds (79.3%), while the cultivation of jatropha seeds itself causes 20.7% of the total emissions. The combustion process of the engine and the construction of the power plant building released 0.11 kg CO_2 eq. (31%) and 0.09 kg CO_2 eq. (26%) respectively.

4.6.3 Jatropha soap and charcoal making

In soap making different inputs produced using fossil fuels are used including sodium hydroxide and plastic material. The results show that jatropha soap making release 0.45 kg CO_2 eq where methyl ester, at service station contributes 0.036 kg CO_2 eq while the remaining is contributed by other substances. Charcoal making from Jatropha press cake is the potential area for effective use of jatropha products. The process of making charcoal also has negative impact to the environment. The results show that about 0.322 kg CO_2 eq is released during the process of carbonisation and during the process of making machine used to make briquetting. Nevertheless this is lower compared to the negative impacts of the conventional charcoal. Thus the government promote charcoal form press cake in order to save deforestation result from charcoal making.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In principle, Jatropha has a significant environmental and economic potential to all players in the production chain. The LCA based on detailed field study on jatropha cultivation and processing in Tanzania show that, regardless of the type of farming system applied in jatropha cultivation the economic benefit will be realized to farmers under high yield scenario. The cultivation of Jatropha is a critical stage in the biodiesel life cycle, along with the land-use change pattern. There was poor performance of jatropha in the country compared to other countries which grow the crop; this is mainly caused by low input application. Cultivation of Jatropha diversifies sources of income to small scale farmers and creating jobs and income in the study area. Thus it is plausible to conclude that with proper management the yield for the crop can increase significantly.

Finally energy balance and greenhouse gas (GHG) emissions due to jatropha cultivation, processing, and use of jatropha based products they were also evaluated. The environmental benefits of cultivating and processing jatropha as potential substitute of fossil fuel are high. The results of the study show that energy balance gain from jatropha value chain is good. Jatropha oil has high energy content. Moreover the results show that the main co-product produced as a result of oil extraction has enough energy content if making it a good source of energy. In addition, as expected, GHG emissions from the cultivation, and processing and utilization of jatropha based products are less than the GHG emission that reported by other studies. This is mainly because the crop is grown by using low external inputs.

5.2 Recommendations

The most important thing for investing in jatropha cultivation and processing is the financial sustainability to all players in the jatropha value chain. Small scale farmers are usually paid per kilogram of delivered seed, the result in the yield chapter indicate that farmer get low yield which reflect less return from selling seeds. General more transport during each step in the production phase contributes to more GHG emissions as well as to additional costs though it depends very much on the magnitude of the area that is covered. Hence due to the above description the study recommends the following:

i. Instead of farmers depend on selling seeds, they can make a profit out of pressing jatropha oil and make different jatropha based products such as jatropha soap and use for electricity production via MFP. This is only possible when the government help jatropha farmers with processing equipments.

ii. Likewise the cultivation of jatropha as living fence shows high economic return than plot cultivation. Therefore there is possibility of increase income hence poverty alleviation under fence cultivation because there will be no competition with food crops as compared with intercrop and monoculture farming system.

iii. In case of Mpanda the study finds that farmers are not aware of the different jatropha base products and how to make and use them including making jatropha soap. Therefore the study recommends that evaluation should be given to farmers so as they can use this crop for generating enough income by pressing and making different jatropha based products.

iv. Large investors that encourage monoculture cultivation should be discouraged by the government by developing strong policy that guide the investment in this sector so as to reduce risk associated with social (food security and household livelihood) or environmental impact.

v. Jatropha processing plants should be installed in the area where raw materials are produced so as to reduce the GHG emission resulting from transporting tons of jatropha seeds. Though for large scale production careful planning on the logistics is needed to reduce GHG emission during transportation phase.

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APPENDICES

Appendix 1: Household questionnaire

Jatropha in East Africa – HH questionnaire
1. GENERAL INFORMATION

Please fill out section 1 before starting the interview.

	Date (DD/MM)	Time (HH:MM)	Completed (cross)	Not completed (cross)
1st. visit	1a	2a		
2nd visit	1b	2b		

Number all printed questionnaires prior to field work using the following code:

Country Code Area Code Questionnaire Number

Ethiopia (ET): 01 = Bati (BA); 02 = Mieso (MI); 03 = Wolayita (WO); 04=Fedis (FE)

001-xxx

Kenya (KE): 05 = Bondo (BO); 06 = Kibwezi (KI); 07 = Shimba Hills (SH) 001-xxx

Tanzania (TZ): 08=Arumeru (AR); 09 = Monduli (MO) 001-xxx

3. Country Code (ET, KE, TZ)___________________ 4. Area code (01-09)__________

5. Questionnaire Number (001)________

6. Division/Woredas/Distrikte___________________ 7. Location:_________________

8. Sub-location/Kebele/Wards: ________

9. *If GPS available*: Longitude __________________ 10. Latitude:__________________

11. Altitude:________________________

12. What is the distance from your house to the nearest tarmac road? __________ km

13. Nearest market?__________ km

2. RESPONDENT’S DETAILS

PROVIDE THE FARMER WITH INFORMATION ABOUT THE PROJECT / QUESTIONNAIRE (separate sheet)

Respondent's Name & Contact (= normally Household Head)

Note: It is mandatory that the household head is informed about the interview and agrees to it. If possible try to arrange for the household head and the spouse to attend the interview. If the household head is not around, interview the spouse. If neither the HH head nor the spouse are available, interview household member, who is able to response (be sure that he is able). Otherwise arrange to pass by again if logistically feasible, otherwise drop household.

14. Respondent's Name________________________ 15. Age:______________________

16. Gender: Male / Female

17. Relation to HH head________________________ 18. Martial status HH head:______

19. Gender HH head: Male / Female

20. Years of school: ______ 21. Mobile Phone No.:______ 22. Postal Address: __________

23. How many people live in your homestead? 24. Female >15 years:_____________25.Male >15 years:_____ 26. Female <15 years:____________27.Male <15 years:________________

28. Type of shelter owned by respondent**.** *(If more than one, please characterize the main building)*

□ Brick walls, tiled or iron sheet roofing

□ Consolidated mud walls, with iron-sheet roofing

□ Simple mud walls with thatched roofing

General Comments: ______________________________________

3. GENERAL FARMING ACTIVITIES

29. Do you grow food crops and/or rear livestock? *(Please select only one answer)*□ Crops □ Livestock □ Both

30. How much land do you own and/or rent?

Description	Size (area)	Value (local currency per area)
Owned land	a.	b.
Rented land	c.	d.
Others:___________	e.	f.

31. What is the total size of your farmland under agriculture (size in acres)?

____

32 - 34. What are the major crops you grew, what were the respective acreage under cultivation, the yields and the usage of your crops? *(Note: If household grows less then three crops, list the crops he is growing and write zero in remaining fields!)*

Description	Name of the crop	Area under cultivation (acres)*	Production costs (labour & other inputs) (local currency/ acre)	Yield (kg/acre)	Selling (kg)
Main Crop 1	32a.	32b.	32c.	32d.	32e.
Main Crop 2	33a.	33b.	33c.	33d.	33e.
Main Crop 3	34a.	34b.	34c.	34d.	34e.

** If intercropped, list only the area of the main crop.*

35. If you cultivate more than three crops, please list the rest:

1) ___________________ 2) _____________________ 3)____________________________

36. How many livestock do you keep and what is their value?

Description	Number of heads	Value (local currency per head)
Local cow	a.	b.
Exotic cow	c.	d.
Oxen	e.	f.
Local goats	g.	h.
Exotic goats	i.	j.
Sheep	k.	l.
Donkey	m.	n.
Horses	o.	p.
Pigs	q.	r.
Poultry	s.	t
Others: ____________	u.	v.
Others: ____________		

37. How much income did you get from selling livestock products last year?

4. JATROPHA FARMING

38. Do you currently grow the following energy crops and if yes, since when?

Energy Crop	Yes	No	Comments
a. Jatropha			d.
b. Castor			
c. Other: ______________			

If household does <u>not grow ENERGY CROPS move to Question 110</u>, otherwise move on to next question.

39. Who introduced you to energy crops? *(Multiple answers possible)*

□ Other farmers in the region started with it

□ A biofuel company proposed to buy seeds from us

□ Government encouraged us to plant energy crops

□ Others*

□ An NGO encouraged us to plant energy crops

**Specify others and provide comments:* _______________

If household <u>does not grow JATROPHA move to Question 102</u>, otherwise move on to next question.

40. Why do you cultivate *Jatropha*? (Multiple answers possible)

□ Rehabilitating degraded land

□Own energy supply

□Hedge for wind breaker/protection

□Diversify income sources

□Other reasons*

**Specify other reason: ___________________*

41	**On how many different plots do you grow *Jatropha*?** *(A plot can be a field or a hedge/fence)*	*Number (0; 1; 2; …)*			If there are more than 2 plots, chose the largest two!
No	**Question**	***Code***	**Plot 1**	**Plot 2**	**Comment**
42	What is the size of the plot?	*Acre (field),* *m (hedge/fence)*	a.	b.	c.
43	What is the land tenure system?	*a = Freehold* *b = Leasehold* *c = communal land* *d = Others**	a.	b.	c.*Please specify others:
44	Which cropping system have you adopted?	*a = monoculture b = intercropping c = hedge d = others**	a.	b.	c.*Please specify others:
45	…if intercropping: what crops are intercropped?	*Name of intercrop*	a.	b.	c.
46	…if intercropping: what land allocation for JC (in %) and what allocation for other crop (in %)?	*Ratio (x% JC; y % other crop)*	a.	b.	c.
47	When did you start growing *Jatropha* on this plot?	*Year*	a.	b.	c.
48	What propagation method did you use?	*A = seeds* *B = seedlings* *C = cuttings*	a.	b.	c.
49	How many trees did you initially plant on the plot?	*Number per total plot*	a.	b.	c.

	(for hedges estimate all trees)				
50	How many trees are currently on the plot? (survival) *(for hedges estimate all trees)*	*Number per total plot*	a.	b.	c.
51	Did you have to increase the size of your farm to grow *Jatropha*?	*a = cleared own land* *b = replaced own cultivated land* *c= bought extra land* *d =rented extra land*	a.	b.	c.
52	What was the land use on this plot before you started cultivating *Jatropha*?	*food crops* (acre)*	a.	b.	c.* What food crop(s)?
		grassland(acre)	d.	e.	
		bush land (acre)	f.	g.	
		forest (acre)	h.	i.	
		degraded (acre)	j.	k.	
		Fallowed (acre)	l.	m.	
53	How many working days did you use to prepare the land for *Jatropha* cultivation (clear and plough)?	***Hired labour*** *(Persondav per total plot area)*	a.	b.	c.**Cost of labour:*
54		***Family labour*** *(Persondav per total plot area)*	a.	b.	
55	How many working days did it take to plant the *Jatropha* seeds/saplings/cuttings/..?	***Hired labour*** *(Persondav per total plot area)*	a.	b.	c.**Cost of labour:*
56		***Family labour*** *(Persondav per*	a.	b.	

		total plot area)			
No	**Question**	***Code***	Plot 1	Plot 2	**Comment**
57	How many working days did you use last year to weed?	***Hired labour*** *(Personday per total plot area)*	a.	b.	c.*Cost of labour:*
58		***Family labour*** *(Personday per total plot area)*	a.	b.	
59	How many working days did you use last year to prune?	***Hired labour*** *(Personday per total plot area)*	a.	b.	c.*Cost of labour:*
60		***Family labour*** *(Personday per total plot area)*	a.	b.	
61	What is the soil type?	a = sandy b = loamy c = clay d = black cotton e = others*	a.	b.	c.* please specify others:
62	How is soil quality on *Jatropha* plots as compared to other parts of your farm?	a=good b=same c=poor	a.	b.	c.
63	Did the soil quality and fertility change on these plots since you started growing *Jatropha*?	a= improved b=stayed the same c=decreased	a.	b.	c.
64	**Fertilizer 1:** What kind of mineral fertilizer is used for *Jatropha* cultivation? *(write "0" if none is used)*	*Name of fertilizer*	a.	b.	c. If only fertilized during the first year, comment!
65		*Amount (kg /plot / year)*	a.	b.	
66		*Personday per year*	a.	b.	
67		*Cost (local currency / kg)*	a.	b.	
68	**Fertilizer 2:**	*Name of*	a.	b.	

		fertilizer			c. If only fertilized during the first year, comment*!*
69	What kind of mineral fertilizer is used for *Jatropha* cultivation? *(write "0" if none is used)*	*Amount (kg / plot / year)*	a.	b.	
70		*Personday per year*	a.	b.	
71		*Cost (local currency / kg)*	a.	b.	
72	What pests and diseases did you encounter in the field?	*A = red spider mite* *B = golden beetle* *C = fungus* *D= powdery mildew* *E = leaf spotting* *F = others**	a.	b.	c.*please specify others
73	**Pesticide 1:** What kind of pesticide did you apply on your *Jatropha* plantations? (write "0" is none is used)	*Name of pesticide*	a.	b.	c.
74		*Amount (kg /plot / year)*	a.	b.	
75		*Personday per year*	a.	b.	
76		*Cost (local currency / kg)*	a.	b.	
No	**Question**	***Code***	**Plot 1**	**Plot 2**	**Comment**
77	**Pesticide 2:** What kind of pesticide did you apply on your *Jatropha* plantations? (write "0" is none is used)	*Name of pesticide*	a.	b.	c.
78		*Amount (kg /plot / year)*	a.	b.	
79		*Personday per year*	a.	b.	
80		*Cost (local currency / kg)*	a.	b.	
81	**Machinery / Plough:** What machinery do you	*Type of machine**	a.	b.	c. * *state if oxen ploughing is used!*

82	use for *Jatropha* cultivation? (i.e. tractor)	*hours per year*	a.	b.	
83		*Cost (local curr. / day)*	a.	b.	
84	**Irrigation:** How many times do you irrigate per year? (write 0 if not irrigated)	*Number of months*	a.	b.	c. *If only irrigated during the first year, comment!*
85		*Frequency per month*	a.	b.	c.* *amount of irrigated water (m3/plot/month):* ________________
86		*Costs to set up irrigation (local curency)*	a.	b.	
87		*Cost to run / maintain irrigation (local currency)*	a.	b.	
88	What irrigation technique did you use?	*a = drip b = spraying c = flooding d = others**	a.	b.	c.**please specify others*
89	How may times did you harvest seeds last year? Yield 2009 (de-husked)	*a = Once** *b = Twice** *d = More** *e = Never*	a.	b.	c.*Specify "more": * In which months?
90	How many person days did you spend to harvest the seeds last year?	***Hired labour*** *(Personday per total plot area)*	a.	b.	c.**Cost of labour:*
91		***Family labour*** *(Personday per total plot area)*	a.	b.	
92	**Yield 2009:** □ husked □ de-husked *(a husk covers usually 3 black seeds)*	*kg / plot*	a.	b.	If possibly fill out the yield per plot (field or hedge) and per tree, if not

					possible at least one!
93		*kg / tree*	a.	b.	
94	**Yield 2008:** □ husked □ de-husked	*kg / plot*	a.	b.	
95		*kg / tree*	a.	b.	
96	**Yield 2007:** □ husked □ de-husked	*kg / plot*	a.	b.	
97		*kg / tree*	a.	b.	

98. Is there a change in the work load after you started cultivating *Jatropha* compared to before? ☐Increased* ☐Stayed the same ☐Decreased*

**What are the reasons for the change in workload?* ___________________________

99. Since you started harvesting *Jatropha* seeds to sell them, did you always find buyers? *(Only one answer possible)* ☐Yes ☐No

100 - 102. How many kg seeds did you sell at what price?

Year	Amount (kg/year)	Husked	De-husked	Price (local currency/kg)	Comments
2009	a.	b.	c.	d.	e.
2008	a.	b.	c.	d.	e.
2007	a.	b.	c.	d.	e.

103a. Are you satisfied with the price of seeds?

☐Yes ☐No*

*b.*If no, what would be the appropriate price in your opinion? (Local currency):*

____

104a. To whom are you mainly selling *Jatropha seeds or products*?

☐Farmers ☐Company* ☐Government

☐Traders (regular) ☐Agents (irregular) ☐Exporters ☐Others*

*b.*Please specify the name of the* company and others. Also indicate how you trade.

____

5. CAPITAL ASSETS

105. Which of the following items does your husehold own? *(Multiple answers possibole)*

☐Car ☐Plough ☐Mobile phone

☐Tractor ☐Television ☐Water tank

☐Motor cycle ☐Satellite dish ☐Bicycle

☐Radio ☐Solar panel/dish ☐Others*

**Please specify others:* ____

106. Do you have the following financial assets?

□Support from children (e.g. in town or abroad) □Savings □Money from credits

6. OFF FARM ACTIVITIES

107. Do you have any of the following sources of off-farm income?

Source of income	Frequency /yr	Income (Local currency per period)	Comment
Salary from employment	a.	b.	
Salary from business	c.	d.	
Salary as agricultural worker	e.	f.	
Salary from public work	g.	h.	
Remittances from family/ friends	i.	j.	
Income from sale of charcoal	k.	l.	
Income from renting land	m.	n.	
Other (Specify):	o.	p.	

7. FOOD PRODUCTION/CONSUMPTION

108. What is your most important staple food? _____________

109. How much of this staple food do you need per week to feed your family? (kg/week)

____

110a. Has the price of staple food changed over the last 3 years?

□Increased* □Stayed the same □Decreased*

*b.*If there was an* *increase/decrease* *in the last 3 years: What are the likely causes of changes in price of this staple food?* ___________________________

111a. Do you think *Jatropha* production in the area had an impact on the food prices?

□Yes* □No □Not sure

*b.*If yes, give reasons how Jatropha influences food prices.* ______________________

112 - 114. How many months of food shortage did your household experience in the last 3 years?

Year	Number of months with food shortage	Comment
2009	a.	b.
2008	a.	b.
2007	a.	b.

115 - 117. What were the main causes for shortage in each year? (Insert codes below)

Year	**Cause**	**Comment**
2009	a.	b.
2008	a.	b.
2007	a.	b.

Codes:

a = weather (drought, ...) b = propagation of energy crops like *Jatropha*

c = poor quality of seeds d = lack of land*

e = lack of on-farm labour* f = conflicts

g = damage from wildlife h = illness I = others

118. How do you cope with food shortage? *(Multiple answers possible)*

□Food aid □Sale of assets □Borrowing

□Gift □Migrate □Others

**Please specify others:* ____

8. ENERGY SECURITY

119. Please rank these energy sources according to their importance for your household?

(rank 1= very important than decreasing importance, Write 0 if not. used)

□*Jatropha* oil □*Jatropha* diesel

□Kerosene □Diesel/Petrol

□Firewood □Charcoal

□Electricity □Other (please

specify):______________________________________

***If d or e, please ask if lack of labour or land is related to Jatropha cultivation:**

120. How much of the following fuels do you consume, for what purpose and how accessible are they?

(Only ask for the fuels indicated in the previous question!)

Energy source	Amount (unit per time period)		Costs (local currency per unit)	Purpose 1: lightning, 2: cooking, 3: heating, 4: transport, 5: communication,6: production, 7: others	Access (distance in km)
Jatropha oil	a	Litres /week	b.	c.	d.
Jatropha diesel	e	Litres /week	f.	g.	h.
Kerosene	i.	Litres /week	j.	k.	l.
Diesel/Petrol	m	Litres /week	n.	o.	p.
Gas(butane/ propane)	q	Cylinders/month	r.	s.	t.
Firewood	u	Loads/week	v.	w.	x.
Charcoal	y	Bags/week	z.	Za.	Zb.
Electricity	Z	Local currency/month	Zd.	Ze.	Zf.
Batteries	Zg	Local currency/month	Zh.	Zi.	Zj.
Others:	Zk.		Zl.	Zm.	Zn.

121. Could energy from *Jatropha* in your opinion play a role to cover the local energy needs? □Yes* □No*

**Why do you think so?* ____

9. COMMUNITY

122a. How do you get information on farming and on *Jatropha* farming? *(Multiple answers possible)*

☐Other Farmers ☐Extension officers

☐Community based organisation ☐Radio / TV

☐Local authorities / local leaders ☐Others*

*b.*Please specify others:-*____________________________

123a. Are you a member of a farmers' association or community based organization?

☐Yes* ☐No

*b.*If yes, please specify what type of association:*

124. What are the main changes that took place in the local community since *Jatropha* is grown in the region?

____

125. What challenges do you face in growing and selling *Jatropha*?

____

126. What in your opinion can be done to deal with the challenges?

____

127. Is there any additional information you'd like to provide us with?

____

THANK YOU VERY MUCH FOR YOUR COOPERATION