# EVALUATION OF THE SMALLHOLDER FARMERS' PRODUCTION MODEL FOR *JATROPHA CURCAS* L. IN CHIBOMBO DISTRICT IN ZAMBIA

**By**

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# DEDICATION

I dedicate this work to my family and friends. Thank you all for your support.

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# ACRONYMS

| | |
|---|---|
| BAZ | Biofuels Association of Zambia |
| CCJDP | Catholic Centre for Justice Development and Peace |
| CLUSA | Cooperative League of the USA |
| CSO | Central Statistical Office |
| DACO | District Agricultural Coordinator |
| DAPP | Development Aid from people to people |
| ERB | Energy Regulation Board |
| FAO | Food and Agricultural Organisation |
| GEXSI | Global Exchange for Social Investment |
| GHG | Greenhouse Gas |
| GRZ | Government Republic of Zambia |
| GTZ | Deutsche Gesellschaft für Technische Zusammanarbeit GmbH (Germany Agency for Technical Cooperation) |
| IEA | International Energy Agency |
| IFAD | International Fund for Agricultural Development |
| ISO | International Organisation for Standardisation |
| LCA | Life Cycle Assessment |
| LINTCO | Lint Company |
| MACO | Ministry of Agriculture and Cooperatives |
| NAS | Natural and Agricultural Sciences |
| NGO | Non-governmental Organisation |
| NL | Netherlands |

| | |
|---|---|
| NPK | Nitrogen Phosphorous Potassium |
| NPV | Net Present Value |
| SBP | Southern Biopower |
| SPSS | Statistical Package for the Social Sciences |
| UNESCO | United Nations Educational Scientific and Cultural Organisation |
| ZANACO | Zambia National Commercial Bank |

## DEFINITION OF OPERATIONAL KEY TERMS

| | |
|---|---|
| JATROPHA: | Jatropha is a large perennial plant which normally grows up to a height of 3 to 5 meters (Achten *et al*. 2008, FAO 2012). The plant bears black seeds with a high oil content of between 27 and 40% (Achten *et al.* 2007a). Consequently in recent years, it has been promoted as a biofuel plant. In addition to being used as a biofuel feedstock, the plant has many other attributes. Firstly, its stems and leaves are toxic. As such, it has long been used as a live fence around crops to offer protection from animals (Zahawi 2005). Secondly, the plant has been upheld as a solution to soil erosion and reclamation of marginal land (Ogunwole *et al.* 2008). Last but not least, for many years, the plant has been used has a remedy to treat a number of ailments in many parts of the world (Kumar and Sharma 2008). |
| OUT-GROWER SCHEME: | An out-grower scheme is a practice where farmers are in contract with large–scale enterprises to grow crops on their own land and get different services, inputs and price guarantees in return (Abwino and Rieks 2007). |
| SMALLHOLDER: | In the agricultural context, the term 'smallholder' is used as a "broad equivalent to family farmer, and captures the huge diversity of farming systems where agricultural activities are mainly based on family labour" (Toulmin and Guèye 2003 cited in Vermeulen and Cotula 2010). Often times, smallholder is used interchangeably with 'small-scale', 'resource poor' and sometimes 'peasant farmer' (Department of Agriculture Forestry and Fisheries 2012). |

# ABSTRACT

The early 2000s witnessed a global awareness on adoption of renewable and environmental friendly energy with anticipated socio-economic benefits in developing countries. In Zambia, investments in biofuel feedstock mainly focused on smallholder production using out-grower schemes. *Jatropha curcas*. L. (Jatropha) was the main bioenergy crop adopted for production in the out-grower schemes. In addition to producing biofuel, Jatropha, branded a “poor-mans” crop, was claimed to improve rural livelihoods, grow on marginal land, have minimum input requirements and adapt to varied climatic zones and soil types. Nonetheless, recent studies have reported abandonment of Jatropha production the world over, including Zambia. This study therefore investigated the barriers to continuity of Jatropha production in Chibombo District of Zambia. Using snowball sampling technique and household survey, 110 smallholder farmers were selected for the study. Data on the effectiveness of out-grower schemes for Jatropha production among the smallholders who have continued or discontinued with Jatropha production were collected using face-to-face questionnaire administration and interviews. Furthermore, an assessment of the environmental and socio-economic implications of producing Jatropha using out-grower schemes, the costs and benefits involved in jatropha production and the effects of out-grower production of Jatropha on food security and land tenure were conducted. The collected data were analysed using non-parametric (summated rating scales principles, Chi-square) statistics.  From the findings, more than ninety percent of the respondents reported that they have not earned any income from the sale of Jatropha due to lack of market. Additionally, all the respondents have not used Jatropha oil as a source of energy. Consequently, 97.3% of the respondents have discontinued production of Jatropha. It was also established that out-grower production of Jatropha had caused significant deforestation with 24.5% of the respondents opening up new forest land for Jatropha production. However, more than 90% of the respondents reported that Jatropha did not affect their food production and that they still have their land i.e. customary land rights are still held in the community. The general conclusion was that out-grower production of Jatropha in Chibombo District was ineffective. In addition to the environmental and socio-economic factors, abandonment of Jatropha production in Chibombo was mainly driven by lack of market for the produce. This was merely as a result of non-commitment of the sponsoring firm to the contractual agreements between the sponsoring firm and the smallholders. These occurrences were due to non-existent of policies and legal frameworks that regulate out-grower schemes. To achieve optimal performance of out-grower schemes in production of Jatropha for bioenergy in Zambia, there is need for a supporting policy environment and legal frameworks that enforce compliance to the contract agreements, create market opportunities and regulate prices for the produce, and monitor activities of the concerned parties.

**Key words: Jatropha, Production, Out-grower scheme, Smallholder farmers, Chibombo District**

# CHAPTER 1 : INTRODUCTION

## 1.1 Background to the Study

Between 2003 and 2005, the world witnessed an unprecedented increased interest in renewable energy sources . This was due to a global preoccupation of finding ways to secure the supply of renewable and environmental friendly energy, while at the same time mitigating climate change (German *et al.* 2011a). Consequently, biofuels have over the years featured prominently in strategies concerning mitigation of climate change and the security of energy (IEA 2008). As a result, there has been global increase of biofuel plantations, with focus on oil seed crops (German *et al*. 2011b). According to Howarth *et al*. (2009) cited in Ariza-Montobbio and Lele (2010), global biofuels production had grown three-fold by 2007. Duvenage *et al*. (2012) added that by 2012, biofuel cultivation had an annual growth of 40%, an estimate suggesting that 1-2% of the total world land was being utilised for growing of biofuel feedstock.

The arguments in favour of biofuels have mainly been the inherent potentials in reduction of carbon emissions and enhancement of energy security (German et al. 2011b). Additionally, the interest in biofuels was deepened by the aspirations of governments in least developed countries to harness this emerging market with a view to enhance the agricultural and national economies (Johnson and Rossilo-Calle 2007, German e*t al*. 2011c) .

As the interest in biofuels escalated, some southern African countries implemented policy, institutional and legal frameworks that would address biofuel production so as to attract foreign investors and facilitate their access to land (Liu *et al*. 2013). This enabled them to benefit from the developing biofuels market. The policy shift allowed biofuel feedstocks to penetrate into rural communities and forested landscapes (von Maltitz and Setzkorn 2013) of many poor countries including Zambia.

The expansion of biofuel feedstock in Zambia was driven by private companies that largely focused on smallholder production using out-grower schemes. *Jatropha curcas*. L. (Jatropha) took the central stage as the main bioenergy crop adopted for production in the out-grower schemes. Jatropha occupied this special place because in addition to producing biofuel, it also enhanced socio-economic development and improved production capacity of degraded and marginal lands (Francis *et al*. 2005, Sinkala and Johnson 2012). Unlike fossil fuels, Jatropha was claimed to be a plant that does not contribute to depletion of natural carbon stocks and ecosystem services (Achten *et al*. 2010a). In addition, contrary to growing food crops such as soya beans, corn and sugar cane for biofuel, the non-edible and toxic characteristic of Jatropha is an advantage for food security (Robinson and Beckerlegge 2008). This is because growing Jatropha for biofuel would not be taking away the use of the crop as food. Furthermore, the resistance of Jatropha to pests and drought (Achten *et al*. 2007a) are production advantages to local farmers.

In spite of all the opportunities offered by the Jatropha plant, recent studies have revealed abandonment of production in various parts of the world including Sub-Saharan Africa (Liyama *et al*. 2014). In Zambia, for instance, despite the Jatropha hype in the mid-2000s, many of the firms sponsoring Jatropha projects across the country had abandoned such projects by 2011 (German *et al.* 2011a) leaving the smallholder farmers with no option but to also abandon Jatropha production. Similarly, India and China encouraged millions of farmers to plant Jatropha in 2003 and 2006 respectively (Duvenage *et al*. 2012) to meet their transportation energy needs. However, Kant and Wu (2011) reported discontinuity by 85% of the Jatropha farmers in India and China by 2011. The reasons for discontinuity of Jatropha production were various, ranging from unsuitable production model, poor implementation of the production project to limited markets for the Jatropha seeds.

### 1.1.1 Out-grower Schemes in Zambia

According to Eaton and Shepherd (2001), out-grower schemes are a partnership between the sponsoring company (usually an agri-business firm) and farmers which requires long-term commitment from both parties to succeed. The trend of such partnerships in Zambia dates back to the late 60s and early 70s when the government of Zambia established the Lint Company (LINTCO) of Zambia and encouraged farmers to cultivate cotton using an out-grower system. However, when the marketing boards closed down, there was a phase out of both the liberalised marketing and the central planning economy, allowing private companies to spearhead out-growing using contract farming (Abwino and Rieks 2007). Currently, out-grower schemes in Zambia are spearheaded by private firms.

## 1.2 Problem Statement

Zambia is a landlocked country that is highly dependent on imported petroleum (German *et al*. 2011b). In recent times, the country has suffered shocks of escalating prices for petroleum products thereby worsening the energy, and socio-economic problems faced by the country. For instance, in 2014, the Energy Regulation Board (ERB) announced an increase in fuel pump prices by 7.22% for petrol, 8.75% for diesel and 9.54% for Kerosene (Mupuchi 2014, Kunda 2014) .

High fuel prices, coupled with high poverty levels especially in the rural parts of the country and the demand for environmentally friendly fuel, have given rise to the need for an alternative energy source which can also be a driver for poverty alleviation (CSO 2010, Nyström *et al*. 2010).

Jatropha was identified as a bioenergy crop that could generate economic, social as well as environmental benefits in Zambia. Cultivation of Jatropha through a strategy that centred on smallholder production using out-grower schemes suddenly promised these benefits especially with improvement to local rural livelihoods and enhancement of energy security. However, many of the expected social and economic goals with respect to Jatropha production have not been achieved (Endelevu Energy 2009).

After some years of cultivation, the boom in Jatropha production has experienced a number of challenges leading to its abandonment. The use of unproven biofuel feedstock and production systems in Zambia saw many Jatropha investors leave the country while others went into hibernation (German *et al.* 2011b). Consequently, most of the involved smallholder farmers also abandoned the Jatropha project. Therefore it was necessary to critically evaluate the production models as well as challenges that lead to failures of the smallholder Jatropha projects in Zambia from both environmental and socio-economic perspectives.

## 1.3 Aim of the Study

The aim of this study was to investigate the reasons behind abandonment of Jatropha projects through evaluation of the Jatropha Production Model adopted among smallholder farmers in Chibombo District of Zambia.

## 1.4 Specific Objectives and Research Questions

The specific objectives and research questions that this study sought to answer were to:

I. Examine the effectiveness of the out-grower scheme for Jatropha production in Chibombo District, Zambia.

a) How effective is the out-grower scheme for Jatropha production in Chibombo District, Zambia?

II. Assess the environmental implications of Jatropha production in Chibombo District, Zambia.

a) What are the environmental implications of producing Jatropha using out-grower schemes in Chibombo District, Zambia?

III. Assess the costs and benefits involved in Jatropha production by smallholder farmers in Chibombo District.

a) What direct and indirect benefits and costs do the smallholder farmers accrue from Jatropha production?

IV. Examine the effects of smallholder Jatropha production on the food security, and land tenure of smallholder farmers in Chibombo District.

a) Has Jatropha production led to competition for agricultural land and abandonment of food crop production?

b) What is the land tenure situation among the smallholder farmers involved in Jatropha production in Chibombo District, Zambia?

## 1.5 Justification of the Study

In Sub-Saharan Africa, the Jatropha propaganda affecting many smallholder farmers are yet to be assessed (NL Agency 2013). Only few studies have critically examined the crop's somewhat disorganised promotion and failures in other African countries (Liyama *et al*. 2014) but none on the production models adopted in smallholder production in Zambia. Duvenage *et al*. (2012) discovered that choosing the right production model is very important for the viability of Jatropha projects. Furthermore, other authors have revealed that there is limited research and knowledge for reliable commercialisation of Jatropha production (Duvenage *et al*. 2012). Following an observation made by German *et al.* (2011b), the environmental and socio-economic costs and benefits of biofuel production vary according to the types of feedstocks, models of business used and landscape. In this regard, results from a study in one country cannot be generalised to other countries thus necessitating the need for a Zambian specific study.

The issue disconcerting Jatropha production and marketing in Zambia is complicated with lack of a comprehensive policy on out-grower schemes (Catholic Centre for Justice Development and Peace (CCJDP) 2006). Therefore, in addition to contributing to the empirical body of knowledge on the environmental and socio-economic costs and benefits of smallholder Jatropha production in Zambia, this study is also aimed at contributing to knowledge on the factors leading to the collapse of Jatropha projects in Sub-Saharan Africa which have in fact not been thoroughly investigated (von Maltitz *et al*. 2014). Such a study will offer policy makers baseline information to formulate policies on out-grower schemes.

Lastly, Jatropha production was once a source of livelihood for smallholder farmers in Zambia. As such, it's important to find out the reasons behind abandonment of its production. This is with a view to making appropriate recommendations on the existing models relevant to application elsewhere.

## 1.6 Layout of Dissertation

This dissertation is comprised of six chapters. Chapter one is an introductory chapter which introduces the study. It consists of the background to the study, problem statement, objectives, research questions and justification of the study. Chapter two reviews literatures on Out-grower schemes, Jatropha production, the global status of Out-grower Jatropha production and the conceptual framework on which this study was based. Chapter three presents description of the study area and research methodology. Chapter four presents the results followed by discussion of the findings in chapter five. Chapter six presents the conclusions based on findings of the study and recommendations for adequate intervention.

# CHAPTER 2 : LITERATURE REVIEW

## 2.1 Introduction

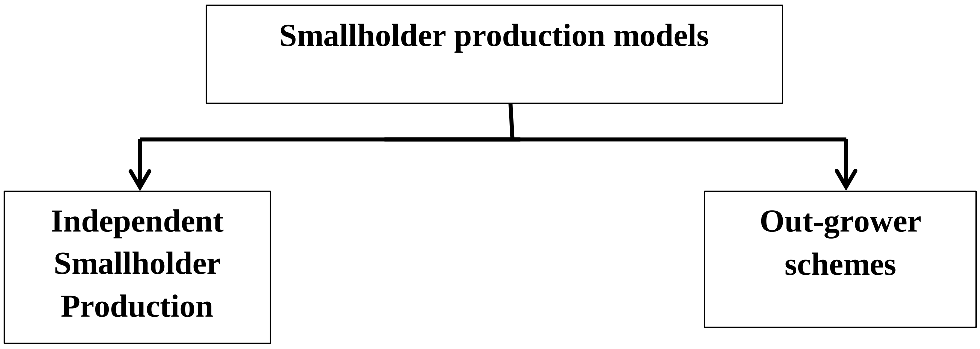
This chapter gives a synopsis of the literature that is pertinent to the research and subject matter. The chapter first reviews literatures on the smallholder production model, different types of out-grower schemes, then proceeds to present the impacts of producing Jatropha using out-grower schemes, related studies on abandonment of Jatropha production and finally the theory upon which this study is based.

## 2.2 The Smallholder Production Model

In the agricultural context, the term 'smallholder' is an equivalent of family farmer and encompasses the diverse farming systems where family labour is the main form of labour for the agricultural activities (Toulmin and Guèye 2003 cited in Vermeulen and Cotula 2010). It is often used interchangeably with 'small-scale', 'resource poor' and sometimes 'peasant farmer' (Department of Agriculture Forestry and Fisheries 2012).

The term smallholder is relative in nature and generally refers to the limited resource endowments of a family farmer in relation to other farmers in the area (Dixon *et al.* 2004 cited in Vermeulen and Cotula 2010). As such, the definition of smallholder differs between agro-ecological zones and between countries. For instance, in densely populated areas, smallholder often refers to those who cultivate one hectare of land or less while the same term may refer to those who cultivate 10 hectares or more in areas that are semi-arid (Vermeulen and Cotula 2010). Generally, smallholder farmers are defined as "those that own small-based plots of land on which they grow subsistence crops and one or two cash crops relying almost exclusively on family labour" (Department of Agriculture Forestry and Fisheries 2012: 1).

According to Brittaine and Lutaladio (2010), the smallholder production models are in two categories i.e. Out-grower schemes and Independent smallholder production. Figure 2.1 is a hypothetical diagrammatic representation of the types of smallholder production models.




**Source:** Adapted from Glover and Kusterer (1990); Eaton and shepherd (2001); Abwino and Rieks (2007)

*Figure 2.1: Types of smallholder production models*

The absence of both contractual purchase agreements with industry and support resulting from being in contract with industry makes independent smallholder production different from out-grower schemes (Brittaine and Lutaladio 2010; Liu *et al.* 2013). In Zambia, smallholder Jatropha production has taken the form of Out-grower schemes.

## 2.3 The Out-Grower Scheme

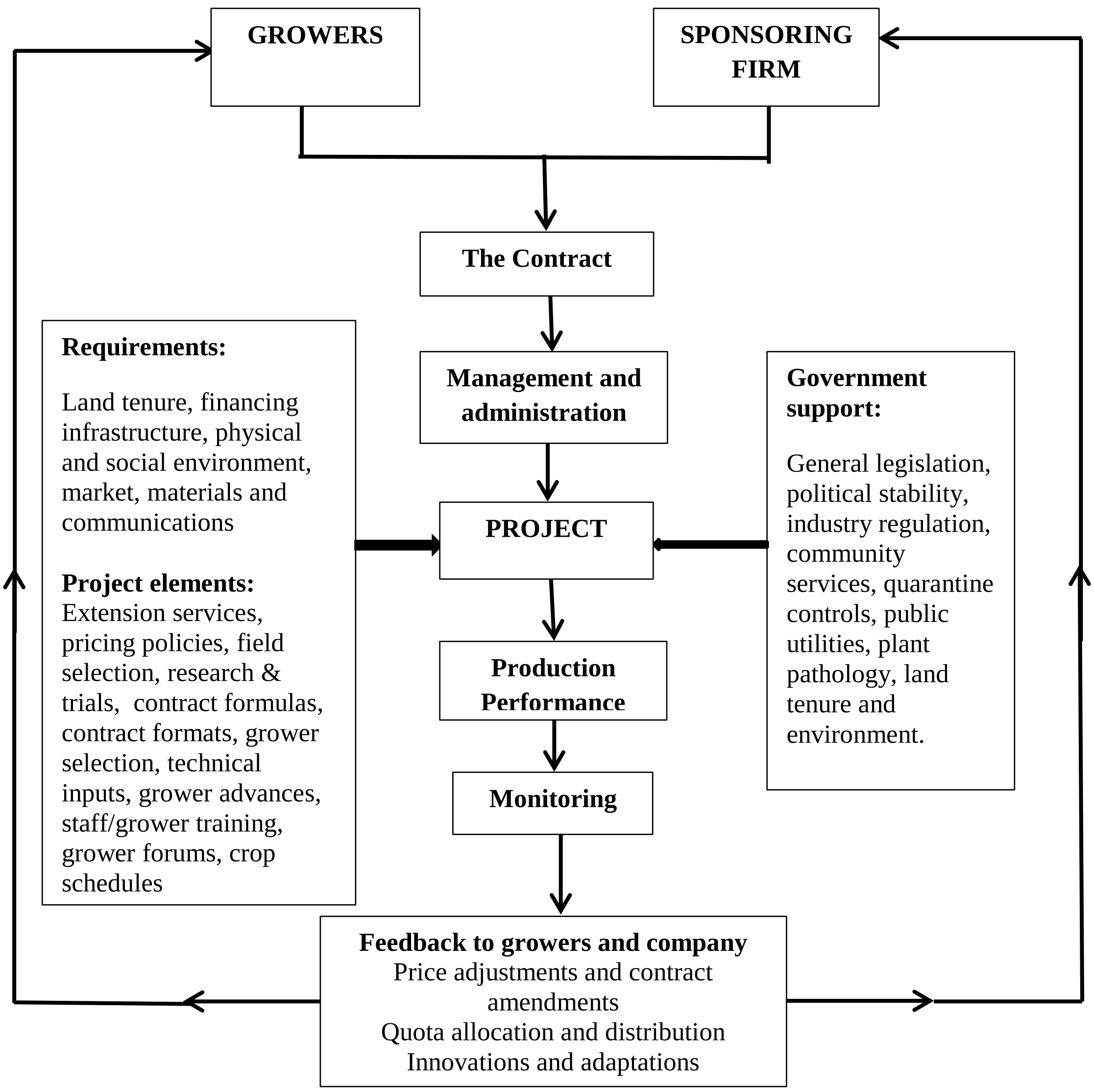
### 2.3.1 Definitions

As defined by Glover and Kusterer (1990) , the out-grower scheme broadly refers to a situation where a government parastatal enterprise acting either on its own or as a joint endeavour with a private firm purchases crops from farmers. Abwino and Rieks (2007) defined out-grower schemes as a practice where farmers are in contract with large-scale enterprises to grow crops on their own land, and get different services, inputs and price guarantees in return. In the private sector, the out-grower scheme is also referred to as 'contract farming' (Glover and Kusterer 1990, Felgenhauer and Wolter 2009) . In this regard, the terms 'out-grower scheme' and 'contract farming' are used interchangeably. This agrees with the definition of contract farming, which is defined as "an agreement between farmers and processing and/or marketing firms for the production and supply of agricultural products under forward agreements, frequently at predetermined prices" (Eaton and Shepherd 2001:2). Eaton and Shepherd (2001) further explained that, this agreement requires that the firm supports the growers by for instance providing technical advice, supplying inputs, marketing the produce among many other forms of support.

Glover (1990) observed that out-grower schemes consist of harmonisation, where the farmers are responsible for supplying the produce while the firm is responsible for provision of technical support and marketing. The contract terms in this partnership outline the quantity of the produce that will be bought by the sponsoring firm and at what price.

### 2.3.2 Preconditions for Out-grower System Establishment

According to Abwino and Rieks (2007), an out-grower system ought to only be introduced prior to meeting certain basic conditions. Figure 2.2 diagrammatically illustrates a hypothetical framework of an out-grower/ contract farming system where aspects to be considered during the planning and implementation of a project are outlined.




**Source:** adapted from Eaton and Shepherd (2001):4

*Figure 2.2: An out-grower/contract farming framework*

An essential aspect of out-grower farming is a competent management system. Management must have the required ability and organisation to handle a project comprising of numerous smallholder farmers (Eaton and Shepherd 2001). No form of venture would be a success without this.

Other basic conditions that need to be met before introducing an out-grower system include identification of a profitable market for the producers, valuation of the physical and social environments of the proposed contract area and lastly, assessment of the probable support that the government is likely to provide.

With respect to profitability, the role of the sponsoring firm is to identify a market for the production and have confidence that out-growers in a specific locality have the capacity to lucratively supply such a market. On the other hand, farmers must find the risks involved in such a scheme to be tolerable and must also be attracted to the potential returns of such a scheme more than to the returns of alternative activities/enterprises (Abwino and Rieks 2007).

Suitable physical and social environments entail that the topography, climate, soil nutrient, water availability and location of the out-growers are generally and particularly suitable for the product to be produced. There must be availability of sufficient utilities and communication including access roads, electricity and water for agro-processing. Tenure and access to land must not be restrictive so as to allow the famers with whom the firm is in contract to freely access the land they cultivate. Additionally, agricultural inputs must be assured, firms must understand local practices, and the obligations of the farmers under contract ought not to conflict with the cultural practices and attitudes of the local community (Abwino and Rieks 2007).

Government support involves the establishment of a legal framework that takes into account the conditions for the legal agreement in the out-grower system.

Figure 2.2 also shows that at the end of the production cycle, production performance must be monitored and feedback given to both the farmers and the sponsoring firm. Monitoring of production involves monitoring both the quantity and quality of the produce as well as the performance of the sponsoring firms' employees (Eaton and Shepherd 2001). If the necessary quantity and quality requirements are not met, processing efficiency can be reduced hence jeopardising markets. On the other hand, exorbitant production could result in reduction of quotas (Eaton and Shepherd 2001).

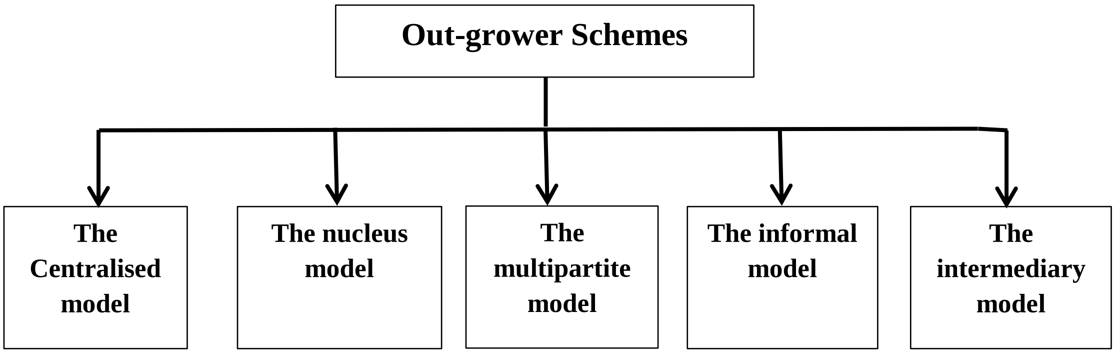
### 2.3.3 Evolution of Out-grower Schemes

Out-grower schemes have been in existence since time immemorial. The practice was widespread in ancient Greece where stated proportions of specific crops were used as a means of paying debts, tithe and rent (Eaton and Shepherd 2001). Similarly, diverse models of sharecropping were also recorded in China during the first century. In the United States of America (USA), contracts were employed by the USA banana companies even as late as the end of the nineteenth century (Rehber 1998). Like in ancient Greece, shared crops in the USA were also used as a means of payment where between one-third and one-half of the shared crops would be taken out and paid as rental to the owner of the land. These ancient practices have been described as a form of bondage which promoted permanent farmer indebtedness (Eaton and Shepherd 2001).

At the turn of the twentieth century, colonies controlled by the European powers saw the establishment of formal farmer-corporate agreements. One such example is that of farmers in Central Sudan's Gezira, who went into a cotton growing contract that was part of a bigger agreement on tenancy. This venture provided a model out of which various smallholder contract farming schemes later developed (Eaton and Shepherd 2001). Accordingly, the out-grower scheme approach has since been used in the production of fruits, vegetables, poultry, piggery, dairy, tree and other cash crops (Eaton and Shepherd 2001) around the world.

### 2.3.4 Types of Out-grower Schemes

Out-grower farming is very diverse. Its diversity is not limited to the crops that can be contracted but also extends to the various ways in which it can be executed. Figure 2.3 shows a hypothetical diagrammatic representation of the types of out-grower schemes.



**Source:** Adapted from Glover and Kusterer (1990); Eaton and shepherd (2001); Abwino and Rieks (2007)

*Figure 2.3: Types of out-grower schemes*

Out-grower schemes are generally categorised into five broad models namely: the centralised model, the nucleus model, the multipartite model, the informal model, and the intermediary model. These models are described below.

i. **The centralised model:** This is one model that is coordinated vertically in that it involves a centralised processing firm which buys from an enormous number of smallholder farmers. In this model, control of the quality of produce is very tight and it also involves quota allocation. Main products in this model include annual crops, tree crops, dairy and poultry. Furthermore, products in this model often require a high degree of processing. These include tea or vegetables for canning or freezing. Participation of the processing firm in production is variable. The processing firm can either contribute minimal input or take control of most production aspects (Abwino and Rieks 2007).

ii. **The nucleus estate model:** This is a variation of the centralised model. The difference between the centralised and the nucleus models lies in the fact that the sponsoring firm operating under nucleus model also manages a nucleus plantation. Though the nucleus plantation is sometimes only for the purpose of research or breeding, it also provides a guarantee of throughput for the processing plant. Most times this model is used with transmigration or resettlement schemes and encompasses a noteworthy provision of management inputs and material (IFAD 2011).

iii. **The multipartite model:** This model frequently involves statutory bodies though it may incorporate diverse organisations. It can branch from either the centralised or nucleus estate models where for instance farmers are organised into cooperatives or where a financial institution is involved (Eaton and Shepherd 2001).

iv. **The informal model:** Individual entrepreneurs or small companies are a characteristic of the informal model. It encompasses contracts for informal production, usually on a seasonal basis. This model frequently demands services such as research and extension from government and presents a high risk of extra-contractual marketing (Abwino and Rieks 2007).

v. **The intermediary model:** Under this model, sponsoring firms are involved in subcontracting linkages with farmers to intermediaries. The model poses risks such as firms losing production control and also losing control of produce quality, not forgetting prices received by farmers (Eaton and Shepherd 2001).

The centralised model is the most common way of contracting crops to smallholder farmers in Africa (Jackson and Cheater 1994 cited in Mansur *et al.* 2009) . However, smallholder Jatropha farmers in Chibombo District and the rest of Zambia were contracted under the nucleus estate model (Gumbo 2005, CCJDP 2006). As reported by Eaton and Shepherd (2001), nucleus estates are a variation of the centralised structures where the sponsoring firm is also in possession of an estate plantation typically located in close proximity to the processing plant. Ideally, the nucleus plantation should be vast enough to guarantee and cater to a certain level for provision of the plant input. In cases where it is comparatively small, it serves as a demonstration and trial farm (Abwino and Rieks 2007). The nucleus estate model is approached by initially commencing with a pilot estate by the sponsoring firms. Once the trial period is over, the farmers (sometimes called "satellite" growers) then undergo training on the technology and management techniques of the particular crop. It is recommended that tree crops such as oil palm and Jatropha be produced using this model because such crops require technical knowledge to be transferred through demonstration (Eaton and Shepherd 2001).

A characteristic of nucleus estates is their frequent connection with transmigration or resettlement schemes, where smallholder farmers residing near the estate grow crops on their own land or utilise estate land that has not been in use for some time and sell their crops to the estate for further processing (Abwino and Rieks 2007). Under the nucleus estate model, processing of estate produce may be priority. Therefore, farmers may be made to wait before their produce is bought and this can be a problem for farmers, which often leads to a decreased quality of the product produced by the farmers. The advantage to farmers is that they often benefit from the training, inputs, medical, social and transport provided by the estate (Abwino and Rieks 2007).

## 2.4 Merits and Demerits of Out-Grower Schemes

### 2.4.1 Merits

With effective management, out-grower schemes or contract farming may bring about market development and promote the transfer of technical skills in such a way that both the farmers and the sponsoring firm benefit (Eaton and Shepherd 2001). For smallholder farmers, out-grower schemes guarantee a significant potential for rural development and incorporation of smallholder farmers into the national economy (Glover 1984). Additionally, out-grower schemes are likely to considerably raise the smallholders' income by virtue of them being a source of information about new technologies on cropping (Warning and Key 2002). Furthermore, out-grower schemes often offer the inputs, services and credit that smallholder famers require to grow and market profitable non-traditional crops (Glover 1984). Out-grower schemes might also generate positive multiplier effects for the development of employment and infrastructure in the local economy (Warning and Key 2002).

Possible merits for the sponsoring firms include risk sharing with the farmers, consistency in the quality of the products, overcoming land constraints and production reliability (Eaton and Shepherd 2001). Additionally, sponsoring firms are advantaged if they involve smallholder farmers since out-grower schemes are viewed as a politically acceptable farming system compared to large plantations (Abwino and Rieks 2007). Furthermore, smallholder out-grower schemes reduce several risks related to large-scale monocultures (Achten *et al*. 2010b). They do so by firstly, conveniently offering a farmer the opportunity to regulate his/her initial risk by individually limiting start-up investment. Secondly, smallholder out-grower schemes are a limited initiative. As such, their environmental impact risk on ecosystem functions, hydrological balance and biodiversity is minimal. Thirdly, a community-based approach is unlikely to drive farmers to unsustainably convert arable or natural lands to Jatropha at large scale (Achten *et al*. 2010b).

### 2.4.2 Demerits

Despite having a number of merits, out-grower schemes can also be a disadvantage to both the rural smallholder farmers and the sponsoring firms. Critics of the model tend to put emphasis on the unequal distribution of decision making powers in the relationship between farmers and sponsoring firms. Sponsoring firms have a stronger position relative to that of the smallholder farmers (Abwino and Rieks 2007). According to Little (1994), the out-grower scheme essentially benefits the sponsoring firms in that they acquire cheap labour and transfer risks to the farmers. In the African set-up, out-grower schemes have also been identified as one of the systems that intensify strains in the households of farmers by disturbing power relations particularly between male household heads and their wives and children (Carney and Watts 1990). In addition, farmers face the risk of both production problems and market failure when growing new crops thus they end up obtaining excessive advances from the sponsoring firms which can result in the farmers being indebted to the sponsoring firms (Abwino and Rieks 2007). Furthermore, farmers may become overly dependent on their contract crops after which exploitation by the sponsoring firms can occur (i.e. they may be forced to accept unfair contract terms) (Warning and Key 2002, Abwino and Rieks 2007).

The major problems that sponsoring firms can face as a result of out-grower schemes include; constraints of land availability (sometimes farmers might not have land suitable for cultivation of the contracted crops), cultural and social constraints, diversion of inputs, discontent farmers and extra-contractual marketing (Eaton and Shepherd 2001).

## 2.5 The Jatropha Plant

### 2.5.1 Botany of the Jatropha Plant

The genus *Jatropha* belongs to tribe Joannesieae in the Euphorbiaceae family and contains approximately 170 known species (Kumar and Sharma 2008, Divakara *et al*. 2010). It is a perennial large shrub which normally grows up to a height of 3 to 5 meters (Achten *et al.* 2008), but can attain a height of 8 to 10 meters when cultivated under favourable conditions (Kumar and Sharma 2008) (Figure 2.3). The life expectancy of Jatropha is about 50 years (Devenage *et al*. 2012, Achten *et al*. 2008, Openshaw 2000).

In its initial stage, the Jatropha plant first grows four peripheral roots and a deep taproot (Kumar and Sharma 2008). The taproot may possibly prevent landslides by stabilising the soil whereas the purpose of the peripheral roots is to regulate soil erosion caused by wind or water (Achten *et al*. 2008). Jatropha is a deciduous woody plant that has smooth green leaves 4 -7 lobed and 10 – 15cm in width which it sheds in the dry season (Kumar and Sharma 2008). Figures 2.4 and 2.5 show the Jatropha plant with leaves and after it has shed its leaves respectively.

*Figure 2.4: A Jatropha plant with leaves in Chibombo District*

*Figure 2.5: Deciduous stage of a Jatropha plant in Chibombo District*

The Jatropha plant has articulate growth with a straight trunk and thick branchlets (Divakara *et al*. 2010). It flowers in the wet (Raju and Ezradanam 2002). In regions that are continuously humid, flowering occurs throughout the year (Kumar and Sharma 2008). Jatropha is a monoecious plant with terminal inflorescences containing unisexual flowers (Achten *et al.* 2008). Brittaine and Lutaladio (2010) observed that the plant has an average male to female ratio of 29:1 thus, Jatropha has more male than female flowers. However, this proportion decreases as the plant grows older (Prakash 2007) hence, fruiting ability may decrease with the age of the plant (Brittaine and Lutaladio 2010).

Pollination of Jatropha flowers is by insects; primarily honey bees (Kumar and Sharma 2008). After pollination, each inflorescence forms a cluster of approximately 10 green ellipsoidal fruits (Tewari 2007). The fruits are about 40mm long each and contain three seeds. Nevertheless, the fruits may sometimes have four to five seeds (Fact Foundation 2010). Once flowering has occurred, the seeds of Jatropha take three to four months to mature. Flowering and fruiting are an on-going process, therefore, immature and mature fruits are borne together (Brittaine and Lutaladio 2010). If the rainfall conditions are good, the nursery plants of Jatropha may bear fruits after the first rainy season while directly sown plants after the second rainy season (Kumar and Sharma 2008).

As reported by Fact Foundation (2010), the seeds are black, with the following average measurements; 18 mm long, 12 mm wide and 10mm thick. Furthermore, the seeds comprise of a hard shell and soft white inner kernel which respectively account for 37% and 63% of the seeds' total weight (Fact Foundation 2010). When dry, the seeds' moisture content is around 7% while their oil content ranges from 32 to 40% with an average of 34%. On average, each seed weighs 0.727 grams and 1, 375 seeds make a kilogram (Kumar and Sharma 2008). Examples of Jatropha seeds are shown in Figures 2.6 and 2.7.

*Figure 2.6: Harvested Jatropha seeds*

*Figure 2.7: Jatropha seeds on the ground*

As a plant that can grow under many different conditions, seed yield in Jatropha varies widely (Jongschaap *et al*. 2007). Annual yields of individual trees are reportedly in the range of 0.2 to 2.0 kilograms (Francis et al. 2005). Based on area, Heller (1996) reported seed yields of between 0.1 and 8.0 tonnes per hectare while Openshaw (2000) reported yields of between 0.4 and 12 tonnes per hectare. However, these figures come with little or no information on age, tree spacing, genetic provenance, propagation method, rainfall, pruning, and soil fertility or soil type thus should be interpreted with caution (Brittaine and Lutaladio 2010).

The seeds, seedcake and oil of Jatropha contain high levels of curcin, phorbol esters, phytates, trypsin inhibitors and lectins which are toxic. As such, they are poisonous and require detoxification (Makkar 1998 cited in Achten *et al*. 2008).

### 2.5.2 Geographical Distribution and Ecological inclinations of Jatropha

Jatropha originally comes from the tropics of America (Divakara *et al*. 2010). However, Openshaw (2000) and Jongschaap *et al*. (2007) observed that the plant is today found in most tropical and sub-tropical regions of the world. It is assumed that from the 16$^{th}$ century onwards, the Portuguese seafarers through Guinea Bissau and the Cape Verde Islands brought the plant to other tropical regions; especially Asia and Africa (Heller 1996).

While Jatropha grows well in lower temperatures and can endure a light frost, the plant thrives in hot environments, thus the reason it is found in tropical and subtropical regions with cultivation limits at 30ºN and 35ºS (Brittaine and Lutaladio 2010). It is a plant that is easy to establish, drought tolerant (Openshaw 2000) and adapts well to dry environments (Kumar and Sharma 2008).

With respect to soil type preferences, Kumar and Sharma (2008) point out that Jatropha grows almost anywhere (including sandy, saline and gravelly soils) except on waterlogged lands. It grows on soils that are well-drained and aerated with a soil pH of between 6.0 and 8.0/8.5 (Fact Foundation 2010). Additionally, it is well adapted to marginal soils with low nutrient content (Openshaw 2000). Conversely, formation of the roots of the Jatropha plant reduces on heavy soils (Kumar and Sharma 2008).

With regard to water requirement, Jatropha has a tremendously low requirement for water (Fact Foundation 2010). Moreover, its mechanism of shedding leaves to minimise the loss of water through transpiration enables it to endure prolonged periods of drought (Fact

Foundation 2010). The plant grows under a wide range of rainfall regimes from 250 to over 1200mm per annum. However, at least 600mm of rainfall is needed for flowering and fruit yield (Katwal and Soni 2003).

## 2.6 Value of Jatropha

The Jatropha plant has many attributes, multiple uses and considerable potential. Being a hardy plant capable of withstanding prolonged drought periods and growing on wasteland, (Kumar and Sharma 2008), the plant was in the early 2000s promoted as a plant that is useful in averting soil erosion and reclaiming marginal land (Ogunwole *et al*. 2008). To avert soil erosion, it is advised that Jatropha be cultivated in contour hedgerows. The stems and leaves of the Jatropha plant are toxic thus it has long being used as a live fence around crops offering protection from animals (Zahawi 2005). Furthermore, numerous parts of the world have since time immemorial used Jatropha as a remedy to treat a number of ailments (Kumar and Sharma 2008). As much as it has served various functions over the years, the recent global popularity of the Jatropha plant has risen from its potential to be used as a biofuel feedstock. The Jatropha plant produces seeds with a high oil content; between 27 to 40% of oil (Achten *et al.* 2007a) which can be used as bio-diesel in conventional diesel engines or as fuel for Kitchen stoves (Achten *et al*. 2008). Jatropha gained popularity as a biofuel plant because of the claims on the ground which include that it enhances energy security, does not pose a threat to food security, contributes to the development of rural areas and contributes to mitigation of climate change. Based on this, many small-holder Jatropha projects were implemented in many countries throughout Central and South America, Asia, and Africa (Srinivasan 2009) with Zambia not being an exception.

## 2.7 Environmental and Socio-economic Implications of Jatropha Production in Out-Grower Schemes

As the impetus for out-grower Jatropha investment increased, there was also an increase in the issues over the possible impacts that widespread cultivation of Jatropha could have on the environment and household livelihoods (Mponela *et al*. 2011). These issues are as a result of the fact that, in addition to the uncertain environmental and socio-economic effects of producing Jatropha using out-grower schemes, biofuels production is a debated subject as it could result in local negative social and environmental effects as well as positive ones (Skutsch *et al*. 2011).

### 2.7.1 Environmental Implications

The issue of environmental impacts arising from Jatropha cultivation is a controversial topic. This often involves obscure polemics where scholarly studies have presented arguments both for and against Jatropha production.

Several studies have evaluated environmental impacts of Jatropha production using the Life Cycle Assessment (LCA) approach (Axelsson and Franzén 2010). LCA; a part of the ISO 14000 family of standards (Ndong *et al.* 2009) is a famous method that is often applied for environmental management to show the total environmental impacts of a production system during its whole life cycle. It could be utilised as a calculator of a variety of environmental impact categories. These include land-use change, the energy balance, greenhouse gas (GHG) emissions and their contribution to global warming. LCA determines system processes that contribute to most environmental impacts and also identifies areas of improvement in the system (Achten *et al.* 2010b). Some of the environmental impacts arising from Jatropha production are described below.

#### 2.7.1.1 Direct and Indirect Land-use Change

Like industrial-scale plantations, Jatropha production by smallholder farmers in out-grower schemes has exhibited a number of environmental impacts, among them direct and indirect land-use changes (German *et al*. 2011c). Land-use change due to Jatropha production has both positive and negative impacts. The positive impacts include carbon sequestration, prevention of soil erosion and improved soil structure (Achten *et al*. 2007b) . The negative ones include displacement of different sizes of permanent cropland (perennials, annuals, rainfed and irrigated), forests and fallows (Achten *et al*. 2007b). For instance, a case study carried out by German *et al*. (2011b) in Zambia revealed that smallholder Jatropha production had caused significant deforestation with 22% of the respondents reporting that they had opened up mature natural forests for Jatropha and 20% of the respondents claiming indirect deforestation from relocation of displaced food crops (German *et al*. 2011b). This study showed that about 44% of the area cultivated with Jatropha at the study site came at the expense of forests (German *et al.* 2011c).

Land-use change is recognised as an activity that contributes to atmospheric carbon-dioxide ($CO_2$). However, atmospheric $CO_2$ associated with land-use change resulting from production of biofuel feedstock depends on the production site, forest type, yield and feedstock (German *et al.* 2011c). As such, several studies have been conducted to compare different biofuel feedstocks. Despite contributing to deforestation, a study comparing production of Jatropha, soybean and Oil palm in different agricultural eco-regions revealed that Jatropha cultivated in Zambia created a significantly low carbon debt (39 – 496 tonne/ha $CO_2$ eq.,) compared to Oil palm (254–1579 tonne/ha $CO_2$ eq.,). Soybean had a carbon debt ranging from 57 to 574 tonne/ha $CO_2$ eq., (German et al. 2011c). On the contrary, a study to calculate carbon debt for smallholder systems in Chiapas and Michoacan cities of Mexico revealed exceptionally high figures (German *et al*. 2011c).

Biodiversity impacts are dependent on the type of land-use that Jatropha plantations replace (Achten *et al*. 2008). A positive impact on biodiversity can arise if cultivation is on infertile fallows as this can help with regeneration of biodiversity (Achten *et al*. 2008). Conversely, negative impacts can arise if natural or semi-natural vegetation is replaced particularly in monoculture cultivation of Jatropha (Achten *et al.* 2007b). If Jatropha is cultivated as a hedge, or in intercrop or agroforestry systems, the effect on biodiversity is insignificant (Achten et al. 2007b).

#### 2.7.1.2 Energy Balance

A system is said to have a positive energy balance if the energy output is greater than the energy input (Axelsson and Franzén 2010). Nevertheless, the quality of energy and the efficiency of various carriers of energy also affect the energy balance. Therefore, if the input energy is of low quality and the output is a high-quality energy carrier such as a liquid fuel usable for vehicle operation, a high energy input is acceptable. Biodiesel production from Jatropha is reported to give a positive energy balance (Tobin and Fulford 2005, Prueksakorn and Gheewala 2006). On the contrary, Jatropha cultivation gives different energy balances on the basis of cultivation inputs. Higher cultivation intensity does not guarantee a higher production of energy hence to achieve a maximised positive energy balance, optimisation of inputs and yields is required. For instance, the LCA of the Jatropha system using intensive cultivation, fertiliser application and irrigation is reported to result in a less positive energy balance than that of a system using low input cultivation (Achten *et al.* 2007a). Therefore, improvement of the energy balance of Jatropha production begins with optimisation of inputs and yield in the cultivation stage (Achten *et al*. 2008).

#### 2.7.1.3 Global Warming Prospective

The global warming impact of a production system is determined by comparing the impact that the production and use of a product has on global warming to the LCA reference system (Achten *et al*. 2007b). Studies have shown that during the production of Jatropha, utilisation of irrigation and application of fertiliser in the cultivation process are the stages that contribute the largest share of GHG (Achten *et al.* 2007b). Therefore, intensifying the cultivation of Jatropha will result in increased global warming. To attract an optimised GHG balance, it is thus necessary to optimise inputs (Achten *et al.* 2007b). On the contrary, some scholars have reported that the main contributor of GHG emissions and responsible for 90% of total life cycle is the end use of Jatropha i.e. use of biodiesel from Jatropha (Prueksakorn and Gheewala 2006). Nevertheless, GHG emissions from Jatropha are reportedly less than those from fossil diesel (Prueksakorn and Gheewala 2006).

Achten *et al.* (2007b) contend that in accounting for the global warming potential of Jatropha, GHG emissions resulting from the conversion of one original land-use to Jatropha cultivation should also be accounted. As mentioned earlier, the type of initial land-use that is replaced by Jatropha is the main determinant of the quantity of GHG emissions arising from the change of land-use. If for instance Jatropha replaces a natural dryland forest, this would result in substantial GHG emissions that the new plantations of Jatropha may not compensate as Jatropha yields are rather unpredictable. Allocating wasteland to Jatropha should hence be perceived as the option with the lowest risk (Achten *et al*. 2007a).

Despite having the potential to contribute to GHG emissions, the Jatropha biomass also has the potential for carbon fixation thus contributing to saving greenhouse gases. This dwells on the fact that with Jatropha, only the seeds are harvested while the biomass may remain standing for a long period of time. A study by Struijs (2008) reported a total carbon uptake in mature Jatropha plants (above and below ground) of 39.6t/ha. Assuming plant life of 20 years, this translates into an average annual sequestration of approximately 7.26t$CO_2$/ha (Ouwens *et al.* 2007).

#### 2.7.1.4 Impacts on Water

Jatropha has been widely publicised as a crop that can grow in drought conditions and on degraded land. However, studies have shown that the crop thrives when irrigated and cultivated on fertile land. This has led to increased requirements for water to irrigate Jatropha. Irrigation of Jatropha plantations puts stress on the limited water resources in water-scarce areas resulting in conflicts between water use for production of energy crops and water for use in other agricultural production and domestic use (Axelsson and Franzén 2010). For instance, production of Jatropha in India revealed that the Jatropha plant competed for scarce water resources with other crops which could negatively influence food production (Ariza-Montobbio and Lele 2010). Another example is that of smallholder famers contracted to grow

Jatropha by D1 Oils in Swaziland. Swaziland is a water scarce country and farmers have reported their frustrations with regard to Jatropha water requirements. Experience has shown that for Jatropha to thrive, it needs weekly watering (Burley and Griffith 2009). As reported by Burley and Griffith (2009:11) one Swazi smallholder farmer had this to say:

> "*My children wish I had not taken the Jatropha seedlings. D1 Oils had said the Jatropha wouldn't need water. But they need to be watered three times a week or they wither and die. Now I have to send my children to water these trees. I feel guilty because we are struggling to get water for domestic use and they have to walk long distances to fetch the water. This has set me against my children.*"

In addition to the conflicts that arise between water requirements for energy crops and that required for domestic use, there are no full studies on the overall impact of intensive Jatropha cultivation on the water table (Jongschaap *et al*. 2007). The full impact of Jatropha cultivation on the water table therefore requires further investigation. On a positive note, the ability of Jatropha to germinate and survive in drought environments and increase the vegetation cover on degraded lands provides an opportunity for channelling water which earlier evaporated from the ground into positive transpiration (Axelsson and Franzén 2010). However, a potential negative implication of this is that as the evapotranspiration from the plantations increases, there's likely to be a decrease in the supply of water downstream (Axelsson and Franzén 2010).

### 2.7.2 Socio-Economic Impacts

Like environmental impacts, socio-economic impacts of cultivating Jatropha in out-grower schemes can also be positive and negative. According to Skutsch *et al*. (2011), alienation of farmers from their land and displacement of food production are some of the negative social impacts resulting from smallholder Jatropha production. The positive ones include generation of income, creation of employment, diversification of livelihood strategies and consequential alleviation of poverty.

Out-grower schemes have given varying socio-economic results in different locations even when used to produce the same type of crop. For instance, in their study carried out in Tamil Nadu, India, Ariza-Montobbio and Lele (2010) established that Jatropha production using out-grower schemes did not alleviate poverty. Instead, they created a suitable environment for brewing differences between the government and farmers and between different social classes. On the other hand, a study conducted by Sulle and Nelson (2009) in Tanzania found that production of Jatropha using out-grower schemes offered positive models for local livelihoods as the model has not had undesirable bearings on access to land. It can thus be stated that socio-economic effects of producing Jatropha using out-grower schemes are site specific and mainly depend on the planning, implementation and value chain of a particular project.

## 2.8 Global Status of Smallholder Jatropha Production

Over the years, many claims made regarding Jatropha have proven to be highly exaggerated (Endelevu Energy 2009) and Jatropha studies conducted in countries such as India, China Kenya, Tanzania, Zambia, Zimbabwe and many others have revealed that Jatropha projects have actually been abandoned (Ariza-Montobbio *et al.* 2010, German *et el* 2011a, Liyama *et al.* 2014) due to various reasons. Some of the studies on this matter are outlined below.

### 2.8.1 An Insight of Smallholder Jatropha Production in India, China, Tanzania and Mali

In 2003, the planning commission of India announced mandatory blending of fossil diesel with biodiesel over a large part of the country (Kant and Wu 2011). Kant and Wu (2011) further reported that Jatropha was selected as the feedstock to provide the desired biodiesel in the country. This blending was to reach 30% blending status by the year 2020 thus a massive planting programme was embarked upon. Through very eye-catching schemes, an unparalleled number (in millions) of landless and smallholder famers were motivated to grow Jatropha across India. Inspired by India, China also turned to Jatropha in 2006 and decided to grow over 1 million hectares of Jatropha on marginal lands with the hope of meeting 15% of her transportation energy needs with biofuels by 2020 (Kant and Wu 2011). In other developing countries, akin programmes concerning millions of smallholder farmers were implemented with the hope that, in addition to providing renewable energy, Jatropha would also enhance the incomes of the smallholder farmers. For instance, Wahl *et al*. (2009) reported that Tanzania employed more than 10,000 smallholder farmers to establish Jatropha plantations, with the rest of East Africa engaging many more farmers. By 2008, Jatropha had already been planted over an estimated 900,000 ha globally of which an overwhelming 85% was in Asia, 13% in Africa and the rest in Latin America, and by 2015 Jatropha was expected to be planted on 12.8 million ha worldwide (Brittaine and Lutaladio 2010).

Follow up studies of these Jatropha developments have revealed discouraging results. In India, the provisions of mandatory blending could not be enforced as seed production fell far short of the expectation. A recent study has reported discontinuation by 85% of the Jatropha farmers in India (Axelsson and Franzen 2010, Kant and Wu 2011) . In China, very little production of biodiesel from Jatropha seeds actually took place (Kant and Wu 2011). Like in India and China, the results in Tanzania are also very disappointing. A research study conducted on a five year Jatropha plantation investment in Tanzania established a negative Net Present Value (NPV) with a loss of US$ 65 per ha on lands with yields of 2 tons of seeds per ha (Kant and Wu 2011). Kant and Wu (2011) further contended that the five year investment was only slightly beneficial at US$9 per ha with yields of 3 tons of seeds per ha. However, the average expected Jatropha seed yield on poor barren soils is only 1.7 to 2.2 tons/ha. Even on normal fertile soils (average seed yield 3.9 to 7.5 tons/ha) Jatropha was no match for sunflower (Baur *et al.* 2007, Wahl *et al.* 2009).

In Mali, GTZ. (2002) launched a Jatropha project where a "Jatropha system" was developed to support renewable energy, control erosion and improve soil structure, promote women empowerment and reduce poverty. Women empowerment was through installation of engine-driven grain mills which essentially improved their traditional soap production methods from Jatropha, reduced the tediousness of their work and increased their cash incomes (Brittaine and Lutaladio 2010). One year later, Brew-Hammond and Crole-Rees (2004) established and reported that Jatropha oil was not competitively priced and as a result, the GTZ project was terminated  (Baur *et al.* 2007, Brittaine and Lutaladio 2010).

### 2.8.2 The Zambian Context

Small-holder Jatropha investment in Zambia was championed by Marli Investments Limited (Marli Investments). Marli Investments started its Jatropha project with a few farmers in Kabwe District, Kasosolo settlement of Chief Chamuka's area in Central province. It is a joint initiative between Zambian, South African and Indian investors (Farioli and Ippolito February 6, 2012). Marli Investments initiated operations in 2004 and by 2008; it operated in all then nine (9) and now ten (10) provinces of Zambia (GEXSI. 2008, Desai 2009).

According to Desai (2009), Marli Investments signed contracts with more than 25,000 small-holders throughout Zambia and distributed over twelve million (12,650,000) seedlings/seeds to smallholder farmers throughout the country. The company, which as at 2010/2011 had an estimated excess of 12,000 ha in plantation and approximately 6,500 ha in seedling stage, planned to expand the area under cultivation and consequently obtained 600,000 ha from the Government of the Republic of Zambia for the core estate (Liu *et al.* 2013). To succeed in its *modus operandi*, Marli Investments deployed 96 field officers and more than 180 coordinators (Liu *et al*. 2013) who worked to promote the Jatropha project (Desai 2009). In addition to the investments made by Marli Investments, other biofuel companies such as D1 Oils, Southern Biopower (SBP), among others also made large-scale smallholder Jatropha project investments across the country.

From the foregoing, recent studies have also shown abandonment of Jatropha cultivation in Zambia like in many other countries. One company is reported to have abandoned farmers completely, after delivering only seed and technical support out of many promised benefits (German *et al.* 2010). German *et al.* (2010) further reported that efforts reinforced by nongovernmental organisations to provide an alternative market to farmers, had contributed about US$ 15 per annum to average household incomes. However, when labour was factored in, costs were found to be considerably higher than benefits. The problem of Jatropha abandonment is prominent in Zambia. As such, investigation of the factors behind this abandonment is imperative for future Jatropha production projects in the country and elsewhere.

### 2.8.3 Policy and Legal Framework

The Jatropha production programme in Chibombo District and other parts of the country was introduced and implemented in a policy and legal vacuum. Neither a national policy nor legal framework existed to guide how this investment would be regulated for the benefit of all parties involved. As such, the course of action was impromptu and erratic.

However, in 2008, the Zambian government reviewed the 1994 National Energy Policy in order to accommodate biofuels and to consider the country's changing political, environmental, social and economic situation in general (GRZ 2008a). Zambia's energy policy was reviewed with a view to harnessing the potential of the energy sector to reduce poverty and drive economic growth (GRZ 2008a) and making biofuels an attractive option for Zambia. In addition to reviewing the energy policy, the government of the Republic of Zambia also put in place biofuels legislation (Sinkala and Johnson 2012); and through the Energy Regulation Board (ERB), enabled biofuels standards to be drafted. Furthermore, the government aided the formation of the Biofuels Association of Zambia (BAZ) which encompasses individuals, companies and firms that are involved in/or planning to be involved in biofuels production in Zambia.

Like the biofuels policy which falls under the bigger umbrella of the National Energy Policy, out-grower schemes in Zambia are also covered by the National Agriculture Policy (2004 – 2015) (MACO 2004) whose vision is *"to promote development of an efficient, competitive and sustainable agriculture which assures food security and income*". The Zambian National Agriculture Policy does not comprehensively address all aspects of out-grower schemes (Catholic Centre for Justice Development and Peace (CCJDP) 2006) thus regulation of out-grower schemes in the country is met with a *laisser-faire* approach.

## 2.9 Theoretical Framework

Reviews of out-grower systems in Sub-Saharan Africa have revealed numerous factors that influence social and environmental outcomes. It has been revealed that the social and environmental outcomes of out-grower schemes are influenced by the nature of the crop, land tenure system and land availability, farmers' income diversification and prior experiences with large-scale investors (Glover 1990). Glover (1990) adds that other factors include methods of staff recruitment by investors, the way products are graded and priced, communication, terms of contract, as well as pricing policies and diversification of market outlets. In this regard, there is a close relationship between livelihoods, the environment and bioenergy crops. Therefore, this research will be guided by the political ecology of biofuels.

### 2.9.1 Political Ecology of Biofuels

Political ecology is a combination of ecology consents and an economy that is politically broadly defined (Blaikie and Brookfield 1987). It strives to expose how environmental access, management and transformation are driven by political forces (Robbins 2012). Political ecology goes beyond home-grown and bordering analysis of causes of degradation of the environment and disruption of social welfare in the sense that through "chains of explanation" and by investigating at various scales, it links causality to broader systems (Blaikie and Brookfield 1987, Dakubo 2010). According to Dakubo (2010), political ecology presents three (3) issues relevant to debates on biofuels: (1) unequal sharing of costs and benefits arising from environmental change; which then (2) strengthens or lessens prevailing economic and social inequities; and consequently (3) embraces political repercussions leading to further alteration of power relationships. The concept of political ecology includes the fact that debates of conflicts of the environment often see local communities expressing different economic discourses (Duvenage *et al*. 2012). However, Martinez-Alier (2009) points to privileges that the leaders holding power have and their consequential suppression of other value types as the dominant discourse. This tendency also exhibits itself in the context of biofuels (Duvenage *et al*. 2012). In the development of biofuels, those whose only interest is cultivation of biofuels often develop sustainability frameworks without the involvement of persons that have different value perceptions and those whose livelihoods get affected by changes in land utilisation (Dauvergne and Neville 2010, Duvenage *et al.* 2012).

Governments and local people in Sub-Saharan Africa have had their confidence in foreign investments injured due to unequal sharing of costs and benefits, imbalanced representation and a lack of participation for local actors in agro-development programmes in the past (Doussou-Bodjrenou *et al.* 2010) . Challenges like these are also observed in cultivation of biofuels (Duvenage *et al*. 2012). As such, German *et al*. (2010) conclude that engaging smallholders in the production of feedstock in biofuel industries that are still in their infancy does not give real benefits. Additionally, growth towards sustainable development in emerging biofuel industries has been hindered by deficiencies in the implementation of biofuels sustainability frameworks and corruption (Janssen and Rutz 2011).

German *et al*. (2010) revealed that in countries (e.g. Ghana and Zambia) where there is recognition of customary rights law and chiefs are capable of declining or conceding leases of land and assign permanent land ownership, there is a common occurrence of irregularities. Henceforth, Duvenage *et al*. (2012) pointed out that occurrences such as the failure of new policies that promote a new eco-friendly crops can be explained through analysis of external factors which include peak oil and price of energy, state institutions and global markets. These also give the basis upon which national and local actors behave the way they do. In this regard, political ecology will aid this study in exploring the interactions between political structure, social welfare, and environmental degradation in the development and implementation of Jatropha projects in Chibombo District, Zambia. It will also serve to explain the current environmental and socio-economic status of Jatropha production in Chibombo District.

## 2.10 Chapter Summary

In this chapter, literatures regarding the smallholder production models, types of smallholder production models and types of out-grower schemes were reviewed. It was established that the smallholder production models are in two categories i.e. Out-grower schemes and

Independent Smallholder production models. It was further established that Out-grower schemes can be categorised as either the centralised, nucleus, multipartite, informed or the intermediary model depending on the level of involvement by the sponsoring firm. Literatures on how out-grower schemes have evolved over time and the pre-conditions required for out-grower schemes to be a success were also reviewed.

Furthermore, literatures on the merits and demerits of out-grower schemes for both the famers and the sponsoring firms were reviewed to find out to what extent the farmers and the sponsoring firms can benefit from out-grower schemes and also the extent to which they are both disadvantaged when engaging in out-grower schemes. Also reviewed were literatures on the botany of the Jatropha plant, its geographical distribution and ecological inclinations and its value. This information helped to determine the suitability of the plant to the current study. Results of previous studies at local, regional and global levels were also reviewed to establish the environmental and socio-economic implications of cultivating Jatropha under smallholder out-grower schemes. Lastly, the theoretical framework upon which this study lies was outlined.

# CHAPTER 3 : METHODOLOGY

## 3.1 Location of Study Area

Chibombo District is situated in the Central province of Zambia and lies between 1428 and 1429 east of the prime meridian. It has a total surface area extension of 13,670, square kilometres and is bordered by Lusaka on the south, Kabwe on the north, Chongwe on the east and Mumbwa on the west (Chibombo District Council 2010). It lies approximately 95 kilometres north of Lusaka and 45 kilometres south-west of Kabwe on the Great North Road and falls in agro-ecological zone II a (Ndiyoi and Phiri 2010). Figure 3.1 shows the general orientation of Zambia in Africa while figure 3.2 shows the location of Chibombo District in the Central Province of Zambia.


**Source**: Generated by Ingrid Boysen, 2014a.

*Figure 3.1: General orientation of Zambia in Africa*


**Source**: Generated by Ingrid Boysen, 2014b.

*Figure 3.2: Map of Central Province showing the location of Chibombo District in Zambia*

## 3.2 Demographic Information of Study Area

According to the 2010 country census report, Chibombo District has a total population of 293,765 with a gender distribution of 50 percent males and 50 percent females (CSO 2010). At 23.2 percent of the total population of Central Province, Chibombo District has the largest share of the population in the province (CSO 2010). According to the CSO (2010), the district has an annual population growth rate of between 0.3 and 1.2 percent. The district has a high rate of population growth due to immigrations from other provinces and high birth rates. The high rate of population growth has implications such as development of squatter settlements which create environmental problems and exert pressure on existing infrastructure and other social amenities.

The district's population density is quite high at 21.9 percent. Most of the population is scattered in villages with some concentrated along major roads such as Great North Road, Landless Corner to Mumbwa (Old Mumbwa Road), Chitanda – Muchenje Road in chief Mungule's area, Lusaka-Mumbwa Road and townships of Chisamba and Chibombo (Old and new district administrative centres respectively). The district has three constituencies namely; Katuba, Chisamba and Keembe Constituencies. Katuba constituency has a population of 66, 798 with 13,244 households, Chisamba has a population of 100,250 with 18,534 households and Keembe has a population of 126,717 with 22,820 households (CSO 2010).

Chibombo District has a total of twenty-two (22) wards. Chisamba constituency has six (6) wards namely; Muswishi, Mulungushi, Chikonkomene, Chamuka, Chisamba and Liteta. Katuba constituency also has six (6) wards namely; Katuba, Chuunga, Mungule, Muchenje, Chilochabalenje and Kabile while Keembe constituency has ten (10) wards i.e. Chaloshi, Kalola, Kakoma, Ipongo, Chikobo, Chitanda, Chibombo, Mashikili, Keembe and Lunjofwa (CSO 2010). The District is dominated by the *Lenje* ethnic group while other immigrant ethnic groups such as the *Tonga* are in the minority. As such, the widely spoken language in the District is *Lenje* whereas *Tonga* is used in a few areas.

## 3.3 Agro-ecological Description

The climate of Chibombo District is divided into three (3) ecological seasons which are based upon temperature and rainfall (Hutchinson 1974 cited in Cauldwell *et al*. 1998). These are; the warm rainy season, the cool dry season and the hot dry season. The warm rainy season proceeds from December to April, followed by the cool dry season which runs from May to August and the hot dry season is from September to November (Cauldwell and Zieger 2000). Rainfall in the district is controlled essentially by the arrival and departure of the Intertropical Convergence Zone but is also influenced in the early rainy season by the Zaire Airmass (Cauldwell *et al*. 1998) . The district experiences an annual rainfall amount of between 800 and 900mm (Hutchinson 1974 cited in Cauldwell and Zieger 2000). Daily temperature in the area ranges from 23 to 25$^{o}$C during the rainy season, but can reach 32$^{o}$C during the hot season. During the cold season, the minimum temperature is below 10$^{o}$C (Negussie *et al*. 2013) .

With regards to topography, Chibombo District is located on the watershed that lies between the Zambezi and Kafue rivers without perennial streams (Cauldwell and Zieger 2000) . The area is drained by dambos which are seasonally waterlogged drainage lines without clear water channels (Bolnick 1995 cited in Cauldwell and Zieger 2000). The topography of the area consists of gently undulating terrain.

Similar to the rest of Central province, the most dominant vegetation type in Chibombo District is the central dry miombo woodland (Chidumayo 1988). Miombo is a local term used to describe the woodlands dominated by the genera *Brachystegia*, *Julbernadia* and/or *Isoberlinia* in central, southern and eastern Africa (Campbell 1996). Characteristically, mature undisturbed miombo woodland is generally temporarily deciduous. It commonly occurs on geologically old, nutrient poor soils.(Campbell 1996).

## 3.4 Socio-economic Situation

Chibombo District has a total number of 54,598 households and just like in other rural areas of Zambia; poverty is widespread in the district. The main source of livelihood in the district is subsistence agriculture (Chibombo District Council 2010) with about 90 % of the population engaged in peasant farming and cultivating an average of 2.5 ha of land. They grow crops like maize, tobacco, vegetables, fruits, cowpeas, paprika a, cassava, sweet potatoes, beans and groundnuts. There are a few commercial farmers who are concentrated along the Great North Road. The district is divided into six (6) agricultural blocks namely; Chibombo at the centre, Chisamba on the eastern side, Katuba on the southern end, Kalola in the south-western part, Keembe on the western part and Muswishi on the northern part. The agricultural blocks are further subdivided into 30 agricultural camps. In terms of numbers, the district has about 256 commercial farmers mainly concentrated in the Chisamba area with an average of 450 hectares each. The commercial farmers mainly grow maize, tobacco, vegetables and fruits. The commercial farmers are also involved in game ranching and livestock rearing. Coming to the smallholder and medium-holder farmers, the district has about 41,000 smallholders and about 5,100 medium-holder farmers. The total area cultivated by the smallholder farmers is about 200,000 hectares (Chibombo District Council 2010).

Besides agriculture, other economic activities include small-scale fishing on the Lukanga swamp, transport services, retail trading and self-help projects and a small population is in formal employment. The major industries are meat and dairy processing plants at Fringilla and Zambeef as well as quarries and brick making plants at Patel and Katuba farms respectively. Hotel services are offered by Fringilla, Protea hotel, Bed and Breakfast and Ibis Gardens. Additionally, there are two crocodile farms namely Kalimba and Shiwang'ando farms. Trade is mainly in agricultural products. Since 2004, some smallholder farmers in the district have been contracted by out-growers such as Marli Investments to produce Jatropha and they sell their produce to the same sponsoring firms.

The district only has one bank; Zambia National Commercial Bank (ZANACO) which is located in Chisamba. In terms of education, Chibombo District has one hundred and seventeen (117) registered primary and basic schools, four (4) high schools, one (1) secondary school and one (1) private secondary school. The district also has one hundred (100) registered community schools. Despite having so many schools, the illiteracy levels in the district are high. The CSO (2010) point out that only 48 percent of the people in the district are literate.

## 3.5 Research Design

This study utilised mixed methods approach. This approach was used because it allows for combination of elements of quantitative and qualitative research approaches in order to have a broad and deep understanding of phenomena and also corroboration (Johnson *et al.* 2007 cited in Teddlie and Tahsakkori 2011) .

The qualitative approach was appropriate for this study because it significantly draws on social relations (Flick 2014). According to Creswell (2013), qualitative research helps to understand particular social situations, events, roles, groups or interactions. Flick (2014) further argues that social researchers in today's world are increasingly confronted with new social contexts and perspectives, resulting from diversification of life worlds that arise from rapid social change. Consequently, the traditional deductive methodologies are failing due to the differentiation of objects (Flick 2014), thus the need for qualitative research to verify and enrich the quantitative data.

The quantitative approach allowed the utilisation of structured questionnaires (Saunders *et al.* 2012) , hence facilitating statistical inferences to be made on the data collected (Sandelowski 2000). This research design also facilitated for triangulation, enabling the use of different methodological perspectives to complement each other thus compensating for the weaknesses of any single method (Flick 2009).

### 3.5.1 Sampling Procedure

The study sample comprised of smallholder farmers that were involved in out-grower production of Jatropha in Chibombo District and one key informant; a representative from Development Aid from People to People (DAPP). The key informant and the smallholder farmers were selected using snowball sampling; a non-probability sampling method. Non-probability sampling is applied in situations where the sampling frame is unavailable and the population is widely dispersed (Emmanuel 2013). Contrary to non-probability sampling, the basis of probability sampling is a sampling frame (Monette *et al*. 2013), in this case a list of all smallholder Jatropha farmers in Chibombo District. However, neither such a list nor the number of smallholder farmers participating in the Jatropha project in Chibombo District was available.

As indicated by Atkinson and Flint (2004), snowball sampling technique is used to identify potential subjects in studies where subjects are hard to locate. Therefore, this technique was ideal for this study because the study area has a high probability of Jatropha abandonment cases hence it was difficult to identify the desired population (i.e. farmers who were involved in contract Jatropha production). Using snowball sampling method, the researcher accessed informants through contact information that was provided by other informants (Noy 2008). This process was essentially repetitive as the informants constantly referred the researcher to other informants, who were contacted by the researcher and then the researcher was yet referred to other informants and so on. For this reason, snowball sampling is also referred to as chain referral sampling (Biernacki and Waldorf 1981).

In the present study, the first smallholder Jatropha farmer was identified with the help of an Agricultural Extension Officer. This farmer then referred the researcher and the research assistants to other farmers and so on. The targeted farmers are located in the Keembe constituency of Chibombo District. This constituency has a rural set up without a well-defined grid of roads and some of the farmers forming part of the desired population live in areas unreachable by vehicles. Therefore, in some instances, the researcher and research assistants had to walk long distances, hire a bicycle or motor cycle to reach the farmers.

Over time, snowball sampling method has suffered an image problem in the social sciences given that it opposes many of the assumptions underpinning conventional concepts of random selection and representativeness. Nevertheless, the technique offers advantages for accessing populations such as the deprived, the socially stigmatized, the elite and hidden populations (Atkinson and Flint 2004).

### 3.5.2 Sample Size

The sample size of this study was 110 smallholder farmers who participated in out-grower production of Jatropha. This sample size can be justified using observations made by Saunders *et al.* (2012) who observed that a sample size of 30 or more usually results in a sampling distribution for the mean that is very close to a normal distribution. As such, statisticians give a minimum number of 30 as a useful rule of thumb for the smallest sample size for statistical analyses (Stutely 2003). Nonetheless, a larger sample size is generally more representative of the population from which it is drawn (Saunders *et al*. 2012). Sarantakos (1998) argues that sample size and representativeness differs with homogeneity of population, type of research and availability of resources. This study had a limited budget and the respondents were widely dispersed thus a sample size of 110 respondents was deemed representative enough to answer the research questions and achieve the objectives of the study. This sample size also gave a sample distribution that is very close to normal distribution and adequate for statistical analyses.

### 3.5.3 Data Collection

Data was collected using both primary and secondary sources. Primary data was collected using field observations and a cross sectional survey that was conducted on the Jatropha farmers in Chibombo using a questionnaire. Cross-sectional survey is defined as a survey that uses a sample or cross section of respondents (O'Leary 2010). The survey was conducted using structured questionnaires that were administered through face - to - face interviews. Before conducting the actual primary data collection, the researcher carried out a pilot study in the study area so as to test the effectiveness of the questionnaire. The pilot study allowed for adjustment of the questionnaire to obtain a reliable and valid research tool. Secondary data was collected from both published and unpublished sources from past research that was relevant to this study.

### 3.5.4 Questionnaire Design

This study utilised a structured household questionnaire (Appendix I) designed to capture all the different facets of the four objectives of the study. The questionnaire was designed to collect information on the following: Household characteristics, the out-grower contract and Jatropha project implementation, barriers to continuation of Jatropha, costs incurred and benefits obtained, natural resources utilised in Jatropha production, social-economic welfare, environmental implications and effects of Jatropha cultivation on food production.

The employed questionnaire utilised both closed and open-ended questions and the likert rating scale. The closed-ended questions were utilised because of their ease to ask, respond and analyse (Nachmias and Frankfort-Nachmias 1992). The open-ended questions were mainly utilised as follow-up questions to closed-ended questions to explain prior answers (Ballou 2008). They were used to measure the opinions of the respondents.

The section on the out-grower contract and implementation of the Jatropha project included questions on when the farmers started cultivating Jatropha and their perceptions on the implementation of Jatropha project. Additionally, the respondents were requested to mention the biofuel firms they signed contracts with, the type of contract they signed, if the content of the contract was interpreted to them by the sponsoring firm as well as indicate their level of contentment with the contract.

Barriers to continuation of Jatropha cultivation, costs incurred and benefits obtained were assessed by asking the respondents questions on sales and profits, technical support from the firms, market availability, and Jatropha interference with food production. On the other hand, to determine the environmental implications of Jatropha cultivation, the respondents were asked questions relating to clearance of forest land and whether they experienced a change in the use of their landholdings i.e. from one land-use to another.

This survey utilised a 4 point likert scale where no indifferent option was available (Bertram 2007). The likert scale was used to measure the attitudes of the respondents towards the effectiveness of Jatropha production in Chibombo District. It was precisely used to measure the perceptions of the respondents with regard to factors that influenced the farmers' abandonment of Jatropha cultivation, the extension services that should have been prioritised, and the farmers' access to general social welfare facilities as a result of cultivating Jatropha.

The indicators for the likert scale were judged through responding to a response format structured as follows; 1 = strongly agree, 2 = agree, 3 = disagree and 4 = strongly disagree. This method was inspired by the recommendation made by Bertram (2007) that in a likert scale, a numerical value is assigned to each level of the scale where the highest indicates strong agreement and the lowest indicates strong disagreement. Likert scales are recommended due to their capacity to cover all significant facets of a concept, reliability, high precision, high comparability and simplicity (Sarantakos 1998).

#### 3.5.5 Household Survey

With the help of research assistants, face - to - face method of questionnaire administration was adopted to eliminate non-responses from the respondents and for appropriate interpretation of the questions. This method of questionnaire administration also allowed for direct observation of the authenticity of responses (Budds 1999). As recommended by Babbie and Mouton (2001), respondents should be interviewed in their most comfortable language. As such, the questionnaire was translated into *Lenje* the local language for the area before being administered.

#### 3.5.6 Key Informant Interview

A Key Informant Interview (Appendix II) was conducted with only one representative from DAPP since other sponsoring firms and their representatives have vacated the community after abandoning the Jatropha project. The interview with the key informant was meant to collect information on the factors that led to the abandonment of the Jatropha cultivation. This information was used to triangulate with the views of the farmers.

### 3.6 Data Analysis

Data was analysed using non-parametric statistics. Both descriptive and inferential non-parametric statistics were utilised using Statistical Package for Social Sciences (SPSS) version 22 and Microsoft Excel. The descriptive statistics, particularly frequencies and measures of central tendency allowed for the variables to be described and compared numerically (Saunders *et al*. 2012). Descriptive statistics also allowed the data to be reduced to meaningful forms (Cramer 1998).

Inferential statistics allowed for statements about the characteristics of the population to be made based only on data collected from the sample drawn from the population (Saunders *et al*. 2012). To test for associations between two categorical variables, the Chi-square test of association was applied using cross-tabulation (Cramer 1998). For example, to test for association between the respondents' level of education and their literacy levels, a cross-tabulation of the two variables was carried out.

The Chi-square goodness of fit test was used to test for differences between the observed and expected frequencies (Nachmias and Frankfort-Nachmias 1992, Bless and Kathuria 1993, Cramer 1998) among categories of some of the nominal variables. These variables included; the perceptions of the smallholder farmers on the contract and the Jatropha project implementation, the effectiveness of Jatropha production in Chibombo District, the natural resources utilised in the Jatropha project and lastly the socio-economic and environmental implication of Jatropha production. It was used to test for significance in the observed and expected frequencies of the respondents.

The chi square equation is shown in equation 1.

$$\chi^2 = \sum \frac{(O-E)^2}{E} \quad \text{.......................................................................} \quad (1)$$

Where ***O*** is the ***O***bserved frequency, ***E*** stands for the ***E***xpected frequency and $\sum$ (sigma) means everything that follows is summed.

## 3.7 Ethical Considerations

As per ethical requirements of the University of Pretoria for all studies involving human beings, ethical clearance for this study was sought from the Faculty of Natural and Agricultural Sciences (NAS) before conducting the research. Research was only embarked upon after the study was approved and cleared by the NAS ethics committee. While conducting research, confidentiality concerning the information provided by the respondents and the respondents' identities were observed; thus respondents were not addressed by name but assigned codes. Additionally, the respondents were not in any way forced to take part in this study and were given the free will to withdraw either themselves or their contributions at any time they wished to do so. To this regard, a consent form outlining the research title, interview procedure and confidentiality matters was presented to each respondent for his/her signature (See Appendix III).

## 3.8 Chapter Summary

This chapter outlined the methodology that this study employed. The methodology started by generally describing the study area including its demographic information, climate, topography, vegetation and socio-economic situation. The description of the study area was then followed by the research design which encompasses the utilised sampling procedure, data collection techniques, questionnaire development and administration and statistical analyses. Lastly, the chapter presented the ethical considerations of this study.

# CHAPTER 4 : RESULTS

## 4.1 Introduction

This chapter presents results of the study. The chapter starts by presenting demographic characteristics of the respondents including age, sex and marital status, level of education, literacy levels and household size. Results on the effectiveness of the out-grower scheme for Jatropha production comprise of: the out-growers contract, implementation of the Jatropha project, Jatropha cultivation, barriers to continuation of the Jatropha project, use of Jatropha as an energy source and income earned from Jatropha. Results on costs and benefits incurred in Jatropha production are also presented followed by those on the environmental implications of Jatropha production. Effects of smallholder Jatropha production on food production and land tenure are also presented. The results are presented in form of frequency tables, pie charts and bar graphs.

## 4.2 Demographic Statistics of Respondents

The demographic characteristics of the respondents are presented in Table 4.1. The smallholder Jatropha growing community in Chibombo District had more males (77.3%) dominating the activity compared to females (22.7%). The age of the respondents ranged between 21 and above 51 years. The majority of the respondents were above 51 years of age while the 21 to 30 years category formed the smallest group representing 49.1% and 3.6% respectively. Out of the 110 respondents, the majority (94.5%) were married while only 0.9% were widowed. With regard to household size, 45.5% of the respondents had a household size of more than 10 people.

On average, 10% of the respondents did not attain any formal education whereas only 3.6% had tertiary education. Consequently, 40% of the respondents could neither read nor write. To examine how education level correlates with literacy level, a cross tabulation of the respondents' level of education and their literacy levels was conducted. These results are presented in Table 4.2.

*Table 4.1: Summary statistics of respondents' demographic characteristics (n = 110)*

| | **Demographic characteristics** | **Frequency** | **Percentage (%)** |
|---|---|---|---|
| 1 | Gender | | |
| | - Male | 85 | 77.3 |
| | - Female | 25 | 22.7 |
| 2 | Age categories (years) | | |
| | - 21 - 30 | 4 | 3.6 |
| | - 31 – 40 | 24 | 21.8 |
| | - 41 – 50 | 28 | 25.5 |
| | - Above 51 | 54 | 49.1 |
| 3 | Marital status | | |
| | - Single | 2 | 1.8 |
| | - Married | 104 | 94.5 |
| | - Divorced | 3 | 2.7 |
| | - Widowed | 1 | 0.9 |
| 4 | Household size (number of individuals) | | |
| | - 5 or less | 13 | 11.8 |
| | - 6 -9 | 47 | 42.7 |
| | - 10 or more | 50 | 45.5 |
| 5 | Education level | | |
| | - Primary | 61 | 55.5 |
| | - Secondary | 34 | 30.9 |
| | - Tertiary | 4 | 3.6 |
| | - Never been to school | 11 | 10.0 |
| 6 | Respondents' literacy levels | | |
| | - Could neither read nor write | 44 | 40 |
| | - Could read only | 11 | 10 |
| | - Could read and write | 55 | 50 |

A cross tabulation of the respondents' level of education and their literacy levels revealed that even though 61 respondents had gone as far as primary level of education, 54.1% of these could neither read nor write. From the whole sample, 40% of the respondents could neither read nor write, 10% could read only and 50% could read and write (Table 4.2).

*Table 4.2: Cross tabulation of highest level of education and literacy probabilities (n = 110)*

| | **Could neither read nor write** | | **Could read only** | | **Could read and write** | | **Total** | |
|---|---|---|---|---|---|---|---|---|
| | Freq. | % | Freq. | % | Freq. | % | Freq. | % |
| Primary | 33 | 54.1 | 11 | 18.0 | 17 | 27.9 | 61 | 55.5 |
| Secondary | 0 | 0.0 | 0 | 0.0 | 34 | 100.0 | 34 | 30.9 |
| Tertiary | 0 | 0.0 | 0 | 0.0 | 4 | 100.0 | 4 | 3.6 |
| Never been to school | 11 | 100.0 | 0 | 0.0 | 0 | 0.0 | 11 | 10.0 |
| **Total** | 44 | | 11 | | 55 | | 110 | 100 |

## 4.3 The Jatropha Out-grower Scheme and the Biofuel Firms

### 4.3.1 Commencement of Jatropha Cultivation

The majority (47.3%) of the respondents indicated that they started cultivating Jatropha in 2006 (Table 4.3). Cumulatively, 86.4% of the respondents were growing Jatropha by year 2006. Majority (91.8%) of the respondents in the district indicated that they were members of the out-grower scheme under Marli Investments while only a few (8.2%) farmers indicated to be members of DAPP Scheme (Table 4.3).

*Table 4.3: Cultivation of Jatropha and the firms promoting biofuel production in Chibombo District (n =110)*

| **Year of initial Cultivation** | **Farmer response** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2004 | | 2005 | | 2006 | | 2007 | | 2008 | |
| | Freq. | % | Freq. | % | Freq. | % | Freq. | % | Freq. | % |
| | 33 | 30.0 | 10 | 9.1 | 52 | 47.3 | 6 | 5.4 | 9 | 8.2 |

| **Biofuel Sponsoring Firms** | **Farmer response** | | | |
|---|---|---|---|---|
| | Marli Investments | | DAPP | |
| | Frequency | Percentage (%) | Frequency | Percentage (%) |
| | 101 | 91.8 | 9 | 8.2 |

### 4.3.2 The Out-grower Contract

The majority (82.8%) of the respondents acknowledged that an out-grower contract was presented to them while 16.3% of the respondents had no knowledge of the Out-grower contract and 0.9% could not remember (Table 4.4). Of the 82.8% respondents that had knowledge of the out-grower contract, 75.5% indicated that the contract was not given to them as individuals. Instead, they were requested to form groups and given one contract per group which was then signed by the respective appointed group leader; whom they referred to as the 'Contract Officer'. The remaining 7.3% farmers indicated that they signed individual contracts. The respondents also indicated that the signed contracts were kept by the Contract Officers thus they did not have copies of the contract in their possession. Information obtained through the follow-up interviews revealed that all the respondents that were aware of the Out-grower contract belonged to the Out-grower Scheme under Marli Investments.

*Table 4.4: Distribution of respondents according to types of contract signed, whether contract interpretation was received and satisfaction with the content of the contract (n =110)*

| **Type of contract signed** | **Farmer response** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Individual | | Group | | No contract | | Can't remember | |
| | Freq. | % | Freq. | % | Freq. | % | Freq. | % |
| | 8 | 7.3 | 83 | 75.5 | 18 | 16.3 | 1 | 0.9 |
| **Contract Interpretation Received** | **Farmer responses** | | | | | | | |
| | Received | | | | Not Received | | | |
| | Frequency | | Percentage (%) | | Frequency | | Percentage (%) | |
| | 68 | | 61.8 | | 42 | | 38.2 | |
| **Contract Satisfaction** | **Satisfaction level (%)** | | | | | | | |
| | Very satisfied | | Moderately satisfied | | Not satisfied | | No response | |
| | Freq. | % | Freq. | % | Freq. | % | Freq. | % |
| | 64 | 58.2 | 8 | 7.3 | 22 | 20 | 16 | 14.5 |

With a 40% rate of illiteracy among the respondents, interpretation of the contents of the contract to the farmers by the sponsoring firm was vital. Based on the data from questionnaires, 61.8% of the respondents stated that the Out-grower contract was interpreted to them by representatives from Marli Investments while 38.2% indicated that the contract was never interpreted to them (Table 4.4).

The smallholder Jatropha farmers were asked how pleased they were with the content of the Out-grower contract presented to them. About 58.2% of the respondents were very satisfied with the content of Out-grower contract introduced by Marli Investments while 20% were not satisfied (Table 4.4). Accordingly, the differences in frequencies of the respondents that were satisfied with the Out-grower contract and those that were not satisfied were significant ($\chi^2$ = 94.582, $p < 0.001$). The reasons for contract satisfaction included the conditions stipulated in the Out-grower contract that Marli Investments would provide seed, scions and chemicals and also services such as extension services, market facilitation, transportation of inputs, produce storage, among other benefits. Follow-up interviews revealed that all the respondents signed contracts with Marli Investments because they expected high profit earnings from Jatropha cultivation. However, they all further indicated that their expectations had not been met as Marli Investments neither fulfilled nor implemented the content of the contract. The firm has also left the community and has not returned after introducing the Jatropha project.

## 4.4 Farmers' Experience with Jatropha Project

This aspect of the survey concentrated on the farmers' experience during their partnership with the Jatropha sponsoring firms in the Jatropha Project. The focus was on whether pre-cultivation training was received or not from the Jatropha sponsoring firms, how the farmers integrated Jatropha into their farming system, whether extension services were received or not, the resources that the farmers utilised in Jatropha production and the amount of time invested in the Jatropha project (i.e. from cultivation to post harvest activities).

### 4.4.1 Pre-cultivation Training

With regard to pre-cultivation training, the response options were training in technology (e.g. equipment use), management (e.g. use of inputs, land preparation, etc.), and utilisation (e.g. seed processing, marketing etc.). All the respondents acknowledged having received some training before they started cultivating Jatropha. These results are presented in Table 4.5.

*Table 4.5: Percentage distribution of respondents who received training in technology, management and utilisation (n = 110)*

| Training Received | Farmer response (%) | |
|---|---|---|
| | **Received** | **Not Received** |
| **Technology** | 20.0 | 80.0 |
| **Management** | 100.0 | 0.0 |
| **Utilisation** | 17.3 | 82.7 |

Most of the respondents (80 %) stated that they had not received training in technology (such as equipment use etc.) on production of Jatropha. There were significant differences ($\chi^2$ = 39.600, $p < 0.001$) in frequencies of technology training between recipients and non-recipients of such training. Similarly, the majority (82.7%) of the respondents did not receive training in Jatropha utilisation while 17.3% of the respondents indicated that they had received training in utilisation of Jatropha (Table 4.5). There were significant differences ($\chi^2$ =47.127, $p < 0.001$) in frequencies of the respondents who received training in Jatropha utilisation and those who did not. On the other hand, all the respondents indicated that they had received training in management such as land preparation before they started growing Jatropha.

Follow up interviews revealed that 90% of the respondents received their pre-cultivation training from representatives of Marli Investments while 9.1% of the respondents identified DAPP as the sponsoring firm that provided them with pre-cultivation training.

### 4.4.2 Integration into Farming System

The respondents were asked how they had incorporated Jatropha into their farming system. The most common way of Jatropha cultivation by the respondents was as a single crop where 64.5% of the respondents started a new Jatropha plantation. This was followed by those that intercropped Jatropha (30.9%) with other crops such as maize and lastly those that cultivated Jatropha as hedgerows 4.5% (Figure 4.1)

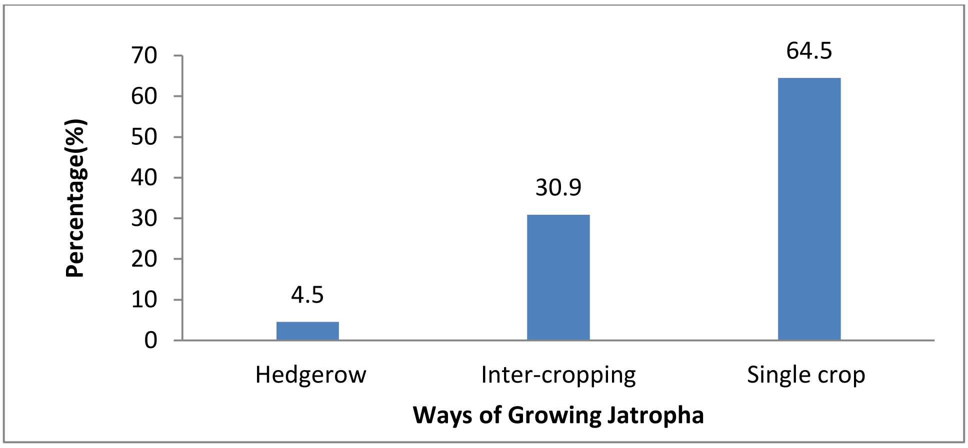



*Figure 4.1: Percentage distribution of respondents who planted Jatropha as hedgerows, single crop and those who intercropped*

### 4.4.3 Extension Services

Regarding extension services, majority (82.7%) of the respondents indicated that they did not receive any extension services after the Jatropha project was introduced and implemented. There were significant differences ($\chi^2 = 124.709$, $p < 0.001$) between the respondents who received extension services and those who did not. One of the respondents, who also happened to be a contracted field extension officer under Marli Investments, indicated that Marli Investments' field officers used to go to the Jatropha smallholder farmers once every week to offer extension services in the early stages of the Jatropha project. However, this ceased when they did not get any communication from Marli Investments. Table 4.6

summarises extension services that the respondents would have loved to receive when they were cultivating Jatropha. The most desired extension service among the smallholder Jatropha growers was marketing of the Jatropha seed (81.8%) followed by post-harvest activities (67.3%) such as seed drying, oil pressing etc. Contract interpretation as an extension service was the least desired (13.6%) on the extension services priority list of the respondents.

*Table 4.6: Most desired extension services by the respondents (n=110)*

| **Extension Services** | **Percentage Response** | | | | | |
|---|---|---|---|---|---|---|
| | **Priority Level** | | | | | |
| | **Very high** | **High** | **Moderate** | **Low** | **Very low** | **Total** |
| Management | 31.8 | 28.0 | 17.0 | 11.0 | 12.2 | 100 |
| Contract Interpretation | 13.6 | 17.3 | 29.1 | 20.9 | 18.2 | 100 |
| Post-harvest activities | 67.3 | 25.5 | 3.6 | 1.8 | 1.8 | 100 |
| Marketing | 81.8 | 11.8 | 4.5 | 0.0 | 1.8 | 100 |

#### 4.4.4 Resources Utilised in Jatropha Production

##### 4.4.4.1 Land, Water, Fertiliser and Pesticides

Land, water, fertiliser and pesticides are some of the resources that are expected to be utilised in the cultivation of Jatropha. Therefore, the respondents were asked how much of their agricultural land was invested in Jatropha cultivation and if at all they ever irrigated and applied fertiliser and pesticides to their Jatropha plants. These results are presented in Table 4.7.

*Table 4.7: Land distribution (tenure) and agricultural inputs utilised in Jatropha production (n=110)*

| **Agricultural Input used** | **Amount of Land Owned (ha)** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ≤ 5 | | 6 – 10 | | 11 – 15 | | 16 – 20 | | ≥ 21 | |
| | Freq. | % | Freq. | % | Freq. | % | Freq. | % | Freq. | % |
| | 39 | 35.5 | 47 | 42.7 | 14 | 12.7 | 2 | 1.8 | 8 | 7.3 |
| | **How Land was Obtained** | | | | | | | | | |
| | Purchased | | Inherited | | Given by the Chief | | | | | |
| **Land** | Freq. | % | Freq. | % | Freq. | % | | | | |
| | 2 | 1.8 | 16 | 14.5 | 92 | 83.6 | | | | |
| | **Amount of Land Invested (ha)** | | | | | | | | | |
| | ≤ 1 | | 2 – 3 | | | | | | | |
| | Frequency | Percentage (%) | Frequency | Percentage (%) | | | | | | |
| | 95 | 86.4 | 15 | 13.6 | | | | | | |
| | **Farmer response** | | | | | | | | | |
| | Utilised | | Not utilised | | | | | | | |
| **Water** | Frequency | Percentage (%) | Frequency | Percentage (%) | | | | | | |

| | | | | |
|---|---|---|---|---|
| | 110 | 100.0 | 0 | 0.0 |
| **Fertiliser** | **Farmer response** | | | |
| | Utilised | | Not utilised | |
| | Frequency | Percentage (%) | Frequency | Percentage (%) |
| | 26 | 23.6 | 84 | 76.4 |
| **Pesticides** | **Farmer response** | | | |
| | Utilised | | Not utilised | |
| | Frequency | Percentage (%) | Frequency | Percentage (%) |
| | 20 | 18.2 | 90 | 81.8 |

With respect to size of land owned by the farmers, the results showed that 42.7% had between six and ten hectares, followed by those that owned five or less hectares of land with 35.5%. Regarding land tenure, the most common land right in Chibombo District is customary land. To this effect, majority of the respondents (83.6%) indicated that the land they owned was given to them by their respective chiefs while 14.5% of the respondents inherited the land and only 1.8% of the respondents actually purchased their land holdings (Table 4.7).

The respondents were conservative with investment of their land in Jatropha production. More than 80% of the respondents invested only 1 hectare or less of their total land holdings into Jatropha production whereas only 13.6% invested between 2 to 3 hectares of their land into Jatropha cultivation. Regarding water use, all the respondents indicated that they had irrigated Jatropha in the early stages i.e. from seeding in the nursery bed to the transplanting stage. Mostly, transplanting was done during the rainy season and thereafter, the Jatropha was rain-fed. On average, irrigation was for a period of 3 months and each plant required about two litres of water per day for irrigation.

On the application of fertiliser and pesticides, majority (76.4%) of the farmers did not apply fertiliser to their Jatropha plants. Similarly, 81.8% of the farmers indicated that they did not apply pesticides to their Jatropha plants (Table 4.7).

### 4.4.5 Time Taken To Realise First Jatropha Seed Harvest and Amount Harvested

The respondents were asked how long it took for them to have their first harvest after planting Jatropha. Table 4.8 shows the various responses given by the respondents.

*Table 4.8: Time taken for the respondents to realise their first Jatropha seed harvest*

| Time frame | Frequency (n = 110) | Percentage (%) |
|---|---|---|
| **2 years or less** | 12 | 10.9 |
| **2 to 3 years** | 87 | 79.1 |
| **More than 3 years** | 7 | 6.4 |
| **Did not harvest** | 4 | 3.6 |

As indicated by majority (79.1%) of the respondents, it took between two to three years for them to have their first harvest of Jatropha seed. About 10.9% of the respondents had their first harvest in less than two years of their initial Jatropha cultivation and of the remaining respondents, 6.4% had their first harvest more than three years after cultivation while 3.6% of the respondents did not harvest at all (Table 4.8). The differences in the respondents' frequencies were significant ($\chi^2 = 172.836$, $p < 0.001$). Follow up interviews revealed that the majority of the respondents (94.5%) obtained more than 9 kilograms of Jatropha seed per harvest.

The farmers indicated that besides cultivating Jatropha, they also cultivated other crops such as maize, cotton, soybeans, sorghum, tobacco, tomato etc. Among the crops cultivated by the farmers, maize ranked topmost (80.9%) whereas tomato was the least cultivated crop (1.8%). The differences in the frequencies of the respondents' cultivation of different types of crops were significant ($\chi^2 = 186.218$, $p < 0.001$). More than half (84.5%) of the farmers indicated that the other respective crops that they cultivate were both for sale and home consumption. From the responses of other farmers, 10.9% indicated that their other crops were only for sale, while 4.5% indicated that the other crops were only for consumption at household level. In addition to cultivating crops, the farmers also engaged in other livelihood activities such as small-scale businesses and pastoral farming.

## 4.5 Continuation and Discontinuation of Jatropha Cultivation

The farmers were asked questions about whether they were still cultivating Jatropha or not. About 97.3% of the respondents have discontinued cultivating Jatropha leaving only 2.7% of the respondents still cultivating the crop. It was established that 40% of the respondents stopped cultivating Jatropha in 2009 and cumulative percentage showed that this proportion escalated to 97.3% by 2013 (Table 4.9). A follow up interview revealed that the farmers that were still cultivating the crop were no longer maintaining their plantations. Reasons for keeping the plantations even though no outcome is expected include provision of soil fertility to the land and crop protection by the hedgerows.

In addition to finding out whether the farmers were still cultivating Jatropha or not, it was fundamental to find out for how long the farmers had cultivated Jatropha before they eventually abandoned it. Their responses are presented in Table 4.9. Majority (64.5%) of the respondents cultivated Jatropha for a period of 4 to 6 years before abandoning it. A small percentage (2.7%) cultivated the crop for more than 10 years. The differences in the frequencies of the respondents' Jatropha cultivation period were significant ($\chi^2 = 99.818$, $p < 0.001$).

*Table 4.9: Period of cultivation of Jatropha by the respondents (n = 110)*

| Stopping year | Frequency | Percentage (%) |
|---|---|---|
| **2009** | 44 | 40.0 |
| **2010** | 15 | 13.6 |
| **2011** | 32 | 29.1 |
| **2012** | 8 | 7.3 |
| **2013** | 8 | 7.3 |
| **Still growing** | 3 | 2.7 |
| **Duration of cultivation of Jatropha** | | |
| **3 years or less** | 24 | 21.8 |
| **4 to 6 years** | 71 | 64.5 |
| **7 to 10 years** | 12 | 10.9 |
| **More than 10 years** | 3 | 2.7 |

*Figure 4.2: A smallholder farmer and his wife showing their field of cut down and abandoned Jatropha plants*

### 4.5.1 Barriers to Continuation of Jatropha Cultivation

Barriers to continuation of Jatropha cultivation were assessed by asking the respondents questions on sales and profits, technical support from the firms, market availability, and crop interference with food production (see Figure 4.3). Only 4.5% of the respondents indicated that low profits from Jatropha cultivation had a high to very high influence on their abandonment of Jatropha cultivation. On the other hand, lack of technical support from the sponsors was identified by 95.5% of the respondents with responses ranging from high to very high influence on their abandonment of Jatropha cultivation. There was a significant association ($\chi^2 = 24.915$, $p < 0.001$) between lack of technical support and discontinuation of Jatropha cultivation. With regards to lack of market, 97.2% of the respondents identified this with responses ranging from high to very high influence on their abandonment of Jatropha cultivation. As a follow-up on this, the respondents were asked where they had sold their Jatropha seeds after harvest. The majority (92.7%) indicated that they had not sold their harvested seeds to any of the firms that introduced the crops to them, whereas only 7.3% had sold their produce to DAPP. There was a significant ($\chi^2 = 23.107$, $p < 0.001$) association between abandonment of Jatropha and lack of market.

Regarding the issue of interference of cultivated Jatropha with food production, none of the respondents identified this as a barrier to Jatropha cultivation. Instead, 96.4% of the respondents indicated that this had very low to no influence on their abandonment of Jatropha cultivation. Despite these results, there was a significant ($\chi^2$= 26.426, p < 0.001) association between Jatropha cultivation interfering with food production and abandonment of Jatropha

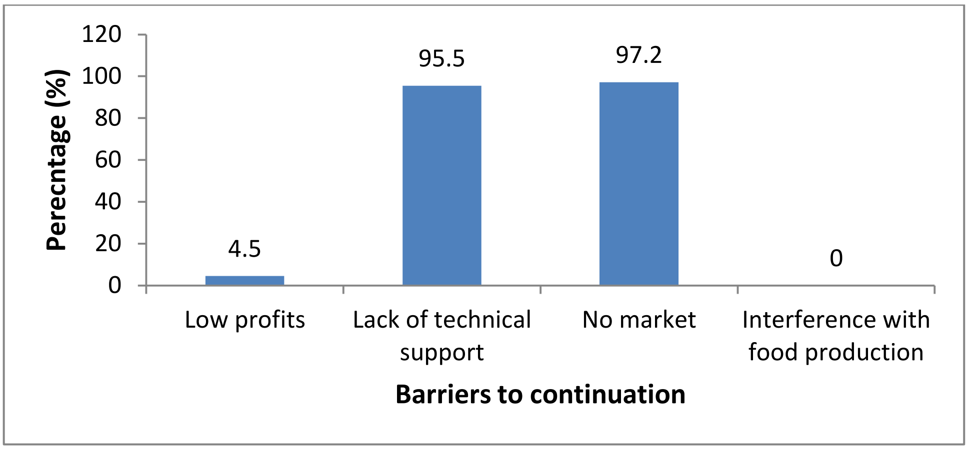



*Figure 4.3: Barriers that influenced the respondents' abandonment of Jatropha cultivation*

## 4.6 Opportunity Costs and Benefits Involved in Jatropha Cultivation

In order to identify the costs and benefits involved in Jatropha production by the farmers, Jatropha cultivation was compared with the cultivation of another major crop grown by the respondents. Maize was found to be the crop grown by all the respondents thus Jatropha was compared against Maize production. The comparison was based on the amount of time invested in the production of a half hectare field of each of the two crops.

### 4.6.1 Time Invested in Jatropha Production

The farmers were asked to specify the amount of time they spent on carrying out different activities (e.g., land preparation, watering, pruning etc.) when growing a half hectare of Jatropha and a half hectare of Maize (see Tables 4.10 to 4.14). It took a day or less to prepare a seedbed for Jatropha while Maize cultivation did not require a seedbed (Table 4.10). Instead, Maize was planted directly onto the actual field. Planting seeds on a Jatropha seedbed also took a day or less. In addition, preparation of half hectare fields of Jatropha and Maize took an average of two to three days for both crops.

*Table 4.10: Time (in days) required to carry out different production activities for both Jatropha and Maize*

| **Activity** | **Crop** | **N** | **R** | **Min** | **Max** | **Mean*** | **S.D** |
|---|---|---|---|---|---|---|---|
| Seedbed preparation | Jatropha | 110 | 4 | 1 | 5 | 1.18 | 0.609 |
| | Maize | 110 | n/a | n/a | n/a | n/a | n/a |
| Planting in seedbed | Jatropha | 110 | 1 | 1 | 2 | 1.08 | 0.275 |
| | Maize | 110 | n/a | n/a | n/a | n/a | n/a |
| Preparing 0.5ha field | Jatropha | 110 | 4 | 1 | 5 | 1.85 | 0.776 |
| | Maize | 110 | 4 | 1 | 5 | 1.73 | 0.676 |
| Planting on 0.5ha field | Jatropha | 110 | n/a | n/a | n/a | n/a | n/a |
| | Maize | 110 | 1 | 1 | 2 | 1.20 | 0.402 |
| Transplanting | Jatropha | 110 | 4 | 1 | 5 | 1.54 | 0.864 |
| | Maize | 110 | n/a | n/a | n/a | n/a | n/a |
| Fertiliser application | Jatropha | 110 | n/a | n/a | n/a | n/a | n/a |
| | Maize | 110 | 4 | 1 | 5 | 1.62 | 1.271 |
| Pesticide application | Jatropha | 110 | n/a | n/a | n/a | n/a | n/a |
| | Maize | 110 | 4 | 1 | 5 | 2.06 | 1.768 |

R = Range, Min = Minimum, Max = Maximum, S.D = Standard Deviation

*1 = 1 day or less; 2 = 2 to 3 days; 3 = 4 to 5 days; 4 = 6 days or more; 5 = No response;

n/a= Not applicable

On average, planting maize seeds on a half hectare field took one day or less. Unlike Maize cultivation, Jatropha was not planted directly on the main field. Instead, it was first planted on a seedbed and then transplanted to the main field. Transplanting Jatropha from a seedbed to a half hectare field took an average of two to three days; an activity that does not apply to Maize production (Table 4.10).

With respect to fertiliser application, a half hectare field of Maize required an average of two to three days. On the other hand, 76.4% of the respondents indicated that they did not apply fertiliser to their Jatropha fields. Five respondents, representing 4.5% took two to three days to apply fertiliser on their Jatropha fields while 19.1% of the respondents took one day or less. With more than 70% of the respondents not applied fertiliser to their Jatropha fields, it can be deduced that the smallholder farmers in Chibombo District did not apply fertiliser to their Jatropha fields.

Pesticide application on a half hectare field of maize took two to three days. On the contrary, the farmers did not apply pesticides to their Jatropha fields (Table 4.10). This is supported by 81.8% of the respondents who indicated that they did not apply any pesticides to their Jatropha fields.

*Table 4.11: Time (in days) required to irrigate both Jatropha and Maize seedbeds*

| Crop | N | Range | Minimum | Maximum | Mean* | Std. Deviation |
|---|---|---|---|---|---|---|
| Jatropha | 110 | 4 | 1 | 5 | 2.91 | 0.894 |
| Maize | 110 | n/a | n/a | n/a | n/a | n/a |

*1 = 30 days or less; 2 = 31 to 60 days; 3 = 61 to 90 days; 4 = More than 91 days; 5 = No response; n/a = Not applicable

Jatropha required irrigation for an average of 60 to 90 days (Table 4.11). As reported by the smallholder Jatropha farmers in Chibombo District, Jatropha is usually transplanted at the start of the rainy season. This entails that Jatropha is planted a few months before the rainy season during which it requires irrigation. Once it is transplanted, it is rain fed. Maize on the other hand does not require irrigation as it is planted in the rainy season.

*Table 4.12: Time (in days) required to weed and prune half hectare fields of Jatropha and Maize*

| Activity | Crop | N | Range | Min | Max | Mean* | Std. Deviation |
|---|---|---|---|---|---|---|---|
| Weeding | Jatropha | 110 | 5 | 1 | 6 | 1.72 | 1.102 |
| | Maize | 110 | 4 | 1 | 5 | 1.82 | 0.997 |
| Pruning | Jatropha | 110 | n/a | n/a | n/a | n/a | n/a |
| | Maize | 110 | n/a | n/a | n/a | n/a | n/a |

*1 = 1- 4days; 2 = 5-8 days; 3 = 9 - 12 days; 4 = 13 days or more; 5 = No response; n/a = Not applicable

Weeding a half hectare field of Jatropha and a half hectare field of maize required an average of five to eight days for both crops (Table 4.12). Pruning on the other hand is only practiced in Jatropha production and not in Maize production. Nonetheless, about 62.8% of the respondents did not prune their Jatropha trees while 19.1% of the respondents spent five to eight days on pruning Jatropha. With more than 60% of the respondents not having pruned their Jatropha plants, it can be inferred that pruning was not practiced in Jatropha production in Chibombo District.

*Table 4.13: Time (in days) required to harvest from half hectare fields of Jatropha and Maize and also to carry out post-harvest activities for both crops*

| **Activity** | **Crop** | **N** | **Range** | **Min** | **Max** | **Mean*** | **Std. Deviation** |
|---|---|---|---|---|---|---|---|
| Harvesting | Jatropha | 110 | 5 | 1 | 6 | 3.07 | 1.399 |
| | Maize | 110 | 4 | 1 | 5 | 2.35 | 1.177 |
| Post-harvest activities | Jatropha | 110 | 4 | 1 | 5 | 3.95 | 1.207 |
| | Maize | 110 | 4 | 1 | 5 | 2.18 | 1.402 |

*1 = 1-5 days; 2 = 6-10 days; 3 = 11-15 days; 4 = 16 days or more; 5 = Depends on the quantity that is ready; 6 = No response

Harvesting Jatropha from a half hectare field took an average of eleven to fifteen days while harvesting maize from a half hectare field took six to ten days on average (Table 4.13).

In Jatropha and maize production, the main post-harvest activities include removing the Jatropha seeds from their shells and removing the maize grains from the cobs. As shown in Table 4.13, post-harvest activities for Jatropha took up more time i.e. sixteen days or more while post-harvest activities for Maize took six to ten days on average.

Table 4.14 presents a summary of the time (in days) invested in the production of half hectare fields of Jatropha and Maize. It can be deduced that from seedbed preparation to post-harvest activities, a Jatropha farmer needs to invest 117.5 days to manage a half hectare field of Jatropha. On the other hand, production of a half hectare field of Maize takes only 31 days of management. This implies that Jatropha is more labour intensive, especially in its establishment years thus it is more time consuming than maize production.

*Table 4.14: Summary statistics of the time (in days) invested in the production of half hectare fields of Jatropha and Maize (n = 110)*

| | **Time required for each crop (Mean number of days)** | |
|---|---|---|
| **Activity** | **Jatropha** | **Maize** |
| Seed bed preparation | 1.0 | 0.0 |
| Planting on seed bed | 1.0 | 0.0 |
| Preparation of 0.5 ha field | 2.5 | 2.5 |
| Planting on 0.5 ha field | 0.0 | 1.0 |
| Transplanting | 2.5 | 0.0 |
| Irrigation | 75.0 | 0.0 |
| Fertiliser application | 0.0 | 2.5 |
| Weeding | 6.5 | 6.5 |
| Pruning | 0.0 | 0.0 |
| Pesticide application | 0.0 | 2.5 |
| Harvesting | 13.0 | 8.0 |
| Post-harvest activities | 16.0 | 8.0 |
| **Total** | **117.5** | **31.** |

### 4.6.2 Use of Jatropha oil as Energy

The respondents were asked if they use or had used Jatropha oil for domestic consumption. As indicated in Figure 4.4, majority (96.4%) of the respondents indicated that they do not use and had never used Jatropha oil for anything while 3.6% of the respondents pointed out that at some point, they had used Jatropha oil for lighting their homes.

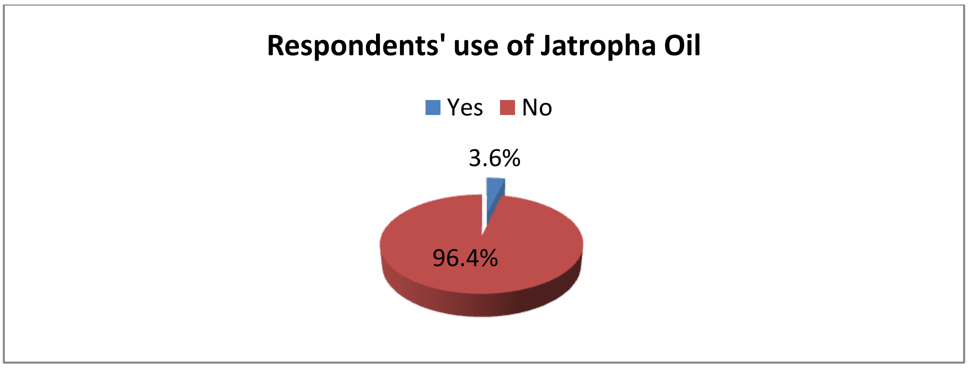



*Figure 4.4: Percentage of respondents who benefited from Jatropha as a source of energy*

### 4.6.3 Socio-economic Benefits from Jatropha Production

The respondents were asked questions to determine how Jatropha had improved their general social welfare. The indicators included provision of job training, credit / finance facilities, transport, tap/pump water, and involvement of the respondents in making decisions concerning Jatropha production. These results are presented in Table 4.15.

*Table 4.15: Social economic benefits from Jatropha production (n = 110)*

| Service received | Yes | | No | |
|---|---|---|---|---|
| | Frequency | Percentage (%) | Frequency | Percentage (%) |
| **Job training** | 72 | 65.5 | 38 | 34.4 |
| **Transport** | 0 | 0.0 | 110 | 100.0 |
| **Credit facility** | 0. | 0.0 | 110 | 100.0 |
| **Involvement in decision making** | 2 | 1.8 | 108 | 98.2 |
| **Tap/pump water** | 0 | 0.0 | 110 | 100.0 |
| **General support** | 2 | 1.8 | 110 | 100. |

The majority (65.5%) of the respondents acknowledged that the sponsoring firm imparted them with Jatropha production knowledge while 34.4% reported not having this knowledge. With regard to the sponsoring firm providing transport, credit facilities and tap/pump water to the farmers for their involvement in Jatropha production, all the respondents indicated that no such facilities were provided. Only 1.8% of the respondents indicated that the Jatropha sponsoring firm had involved them in making decisions concerning Jatropha production while the remaining had not been involved. Overall, only 1.8% of the respondents stated that they received some support from the sponsoring firm as a result of cultivating Jatropha.

## 4.7 Environmental Implications of Jatropha Production

In order to gain insight into the environmental impacts resulting from Jatropha production in Chibombo District, the farmers were asked questions relating to land-use change.

### 4.7.1 Land –use Change

The farmers were asked what type of land they had cultivated Jatropha on and if they had changed any land-use to Jatropha cultivation. These results are presented in Figure 4.5 and Table 4.16 respectively.

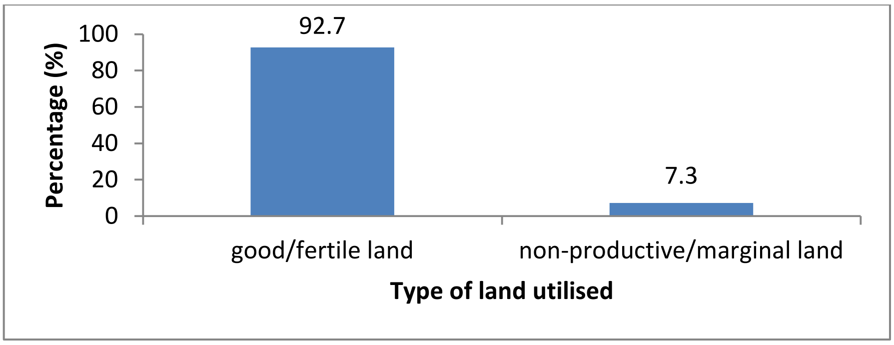



*Figure 4.5: Types of land used by farmers for Jatropha cultivation*

Out of the 110 respondents, 92.7% planted their Jatropha trees on good fertile land whereas only 7.3% cultivated on marginal land (Figure 4.5). There were significant differences ($\chi^2$=80.327, $p < 0.001$) in the frequencies of the respondents who used good fertile land and those who used marginal land for Jatropha cultivation.

The respondents were asked if they had cleared any forest land or changed the use of their landholdings in the process of cultivating Jatropha. As presented in Table 4.16, questions on land-use change revealed that 65.5% of the respondents planted Jatropha on land that was previously used for production of food crops while 24.5% of the respondents reported that they opened up new forest land to plant their Jatropha. Only 10% of the respondents planted their Jatropha on fallow land. The differences in the frequencies of the respondents who changed the use of their land from forest land, food crop production and fallow to Jatropha production were significant ($\chi^2$ = 54.564, $p < 0.001$).

*Table 4.16: Land-use change to Jatropha production (n = 110)*

| Land use | Frequency | Percentage (%) |
|---|---|---|
| **Forest land** | 27 | 24.5 |
| **Growing of food crops** | 72 | 65.5 |
| **Nothing (Fallow)** | 11 | 10.0 |
| **Total** | **110** | **100.0** |

## 4.8 Chapter Summary

The results presented in this chapter showed that production of Jatropha using an out-grower scheme was not effective. Jatropha production in Chibombo District did not alleviate poverty nor enhance energy accessibility among the smallholder famers. At introduction, the smallholder farmers were enthusiastic that the Jatropha project would add to their household incomes and alleviate poverty. However, this was not the case in Chibombo District as the smallholder Jatropha farmers never sold Jatropha at all. The results also show that among other things, the main factor contributing to discontinuation of Jatropha production in Chibombo District was lack of market for the produce. Additionally, the results showed that the smallholder farmers perceived out-grower production of Jatropha to attract more production costs than would give returns or benefits. Nevertheless, the farmers reported that they had more than enough land to accommodate Jatropha production and that Jatropha cultivation did not interfere with their food production. Chapter five (5) that follows discusses these results in relation to the available literature on the subject matter.

# CHAPTER 5 : DISCUSSION

## 5.1 Introduction

This chapter presents the discussions of the results of this study in relation to the available literature on the subject matter. Specifically, the chapter further expatiates the information obtained through the questionnaire on effectiveness of out-grower schemes for Jatropha production, the environmental and socio-economic implications of using out-grower schemes in Jatropha production and the interference of smallholder Jatropha production with land tenure and food security.

## 5.2 Smallholder Farmers and Jatropha Production

### 5.2.1 Demographic Characteristics

The present study revealed that the Jatropha project in Chibombo District was dominated by men with only a few women. This is probably because at a global level, very few women actually have access to land. For example, in Mali where Jatropha is mainly cultivated in hedges, the Jatropha hedges belong to the men who are the owners of the land (Henning 2005). This is also in line with the findings of the Food and Agriculture Organisation (FAO) that women have the least access to agricultural land and associated farm inputs. According to studies conducted by Food and Agriculture Organisation (FAO) (n.d) in India, Nepal and Thailand, less than 10% of women farmers own land. In addition, women in Africa only have a 10% share of farm credit schemes (FAO, n.d). Furthermore, out of the world's total agricultural extension agents, only 15% are women. Thus women make major contributions to crop production and yet they have the least access to the means for increasing yields to move from small-scale farming to large scale market-oriented production.

Analysis of the educational and literacy levels revealed a remarkably high illiteracy of the respondents. Accordingly, CSO (2010) reported that only 48% of the people in Chibombo District are literate. These findings are also supported by those of the United Nations Educational Scientific and Cultural Organisation (UNESCO) (n.d) that 38% of African adults are illiterate; of which two-thirds of these are women. In most African countries, both men and women tend to be poorly educated with the majority being primary school drop outs. With such a high rate of illiteracy, it is not surprising that the smallholder famers in Chibombo District went into a Jatropha production agreement with Marli Investments without fully understanding the terms and conditions of the contract.

This study revealed that the majority of the smallholder farmers who participated in the Jatropha project were over 51 years of age, married and had more than six people in their households. A large family size is generally associated with higher labour endowment thus enabling a household to achieve various agricultural activities on time (Endelevu Energy 2009). One of the reasons for carrying out out-grower schemes in Jatropha production is to reduce labour costs.  Hence a household with more than 6 members is expected to have the required labour force to perform the laborious activities of Jatropha production

### 5.2.2 The Jatropha Sponsoring Firms and Out-grower Contract in Chibombo District

The out-grower production of Jatropha in Chibombo District was championed by Marli investments. However, at the time of this study, it was established that after the Marli Investments departed from Chibombo, DAPP, a non-governmental organisation (NGO) whose aim was to provide market and improve the livelihoods of the Jatropha farmers of Chibombo District established a small scale Jatropha pressing plant to produce biodiesel in the area and bought Jatropha seeds from some of the farmers. Unfortunately, these farmers misunderstood DAPP to be another out-grower scheme. Nevertheless, Marli Investments was the only biofuel company that introduced out-grower production of Jatropha in Chibombo District in the mid-2000s.

Abwino and Rieks (2007) contend that out-grower schemes are characterised by the existence of a contract between an agro-industrial firm and individual farmers or a group of farmers. Similarly, majority (82.8%) of the respondents in Chibombo District acknowledged having had an out-grower contract presented to them by the sponsoring firm (Marli Investments). However, the contract was not given to the farmers as individuals; instead, they were requested to form groups and given one contract per group which was then signed by the appointed group leader whom they referred to as the 'Contract Officer'. The respondents also reported that they did not have copies of the signed contracts in their possession since they were kept by the Contract Officers.

In out-grower system production, the agro-industrial firm agrees to provide production and marketing services to farmers on their own land. This arrangement requires on one hand that the farmer commits to providing a specific commodity in quantities and at quality standards set by the agro-industrial firm, and on the other hand that the agro-industrial firm will support the farmer's production and to purchase their produce (Abwino and Rieks 2007). A copy of the contract signed between Marli Investments and the Jatropha farmers of Chibombo District indicated that Marli Investments was to provide planting materials (such as seeds and scions), farm inputs (implements and chemicals), financial assistance (loans to the growers), and remunerate the farmers with ZMK 300, 000 (ZMW 300) (USD 48.39) for 5ha seeds planted (5000 plants). After planting, each grower was to be paid ZMK75, 000 (ZMW 75) (USD 12) per 5ha per month until the trees started fruiting. To seal the contract between the parties concerned and prevent any violation, it was clearly stated that any breach of the agreement would lead to expulsion from the scheme and liable to court action.

Despite the agreement signed by Marli Investments with the farmers, Marli Investments and its representatives abandoned the Jatropha growing community just after introduction of the Jatropha project and delivery of the seeds to the farmers. In addition, there was no mechanism established for extension services and the farmers did not receive the remuneration as stipulated in the contract. Furthermore, Marli Investments neither secured market for the farmers' produce nor provided loans, general support and production inputs to the farmers. The respondents could not understand the reason behind sudden departure of Marli Investments. In line with these findings, other studies have reported that farmers are often unable to negotiate a fair contract with the sponsoring firm in out-grower schemes, thereby resulting in lack or low commitment of the farmers in the program (Garcez and Vianna 2009, Hospes and Clancy 2011). This issue is partly due to high rates of illiteracy among the participating farmers, as such, the farmers depended on representatives from the sponsoring firm to interpret the terms and conditions of the contract. In this type of arrangement, it is not easy for the farmers to know the procedures for corrective action against the firm when there is breach of contract.

Complaints on failure of sponsoring companies to deliver their promises and act on the interests of the local farmers have been reported for both industrial-scale plantations and smallholder production models that involve a formal agreement (Porter and Phillips-Howard 1997, World Bank 2010, German *et al*. 2011a). Additionally, such arrangements usually result in conflicts over the terms of agreement with a lack of clarity over debt repayment and land ownership (WRM 2009, cited in Skutsch *et al*. 2011).

### 5.2.3 Contribution of Out-grower Jatropha Cultivation to the Livelihoods of the Farmers

#### 5.2.3.1 Job Training and Employment

One significant benefit attributed to out-grower schemes is that they often introduce new technology, enabling farmers to learn new skills (Abwino and Rieks 2007). Similarly, Jatropha has been posed as a biofuel crop that can enhance the livelihoods of the poor rural smallholder farmers by providing them with employment opportunities (Achten *et al*. 2010a). The farmers in Chibombo District acknowledged that before they started growing Jatropha, they received training on technology, management of Jatropha fields and utilisation of Jatropha. Nevertheless, the knowledge gained from the training was not put to practice adequately due to premature termination of the scheme. The issue of premature termination of the scheme further prevented the scheme from realising its goal of job creation and support of livelihoods of Chibombo community members.

#### 5.2.3.2 Jatropha as a Source of Energy

Jatropha is regarded as a potential mechanism to bring modern energy to rural areas, often as a means to generate electricity or as a fuel for what is termed multi-functional platforms i.e. a series of applications such as pumping, milling and power generation that can all be run by a single engine (Sulle and Nelson 2009, Practical Action Consulting 2009, Batidzirai *et al.* 2006, Diaz Chavez *et al*. 2010). Jatropha oil can easily be extracted (Achten *et al*. 2008) with simple and inexpensive (Messemaker 2008) technology and be used for stoves, lamps, among others. Jatropha has the potential to reduce the dependency on fossil fuels while communities without access to fossil fuels would acquire an asset for development since energy is used to increase productivity (Achten *et al*. 2010a).

In contrast to the above mentioned prospects that Jatropha can offer as an energy source, majority (96.4%) of the respondents in Chibombo District reported that they had never used Jatropha oil for home consumption. Similar to the findings of the study conducted in Kenya by Liyama *et al.* (2014), the Jatropha project in Chibombo did not have locally available presses for oil extraction and most farmers were unfamiliar with Jatropha in liquid oil form. In addition, Liyama *et al*. (2014) observed that often times, farmers do not have operative stoves and appropriately designed lamps that utilise Jatropha oil. This is also the case in Chibombo. The failure to utilise Jatropha as a source of energy in Chibombo is an untapped developmental opportunity that could have improved the ways in which the Jatropha growing community of Chibombo cooks and lights their homes. Jatropha oil would have also increased productivity in Chibombo in terms of pumps, mills etc. that run on Jatropha oil.

The inability of Jatropha to be a viable energy source in Chibombo could be attributed to the low yields experienced. Production of one litre of Jatropha oil requires about 5.0 to 5.5kg of seed (Brittaine and Lutaladio 2010). Therefore, efficient extraction of Jatropha oil requires sufficient seed quantity. The farmers in Chibombo District did not produce sufficient Jatropha seed for oil extraction to be viable even at a local level. On average, each farmer produced about 9 kg of seed per harvest and only harvested one to two times in a year. Thus, Jatropha did not enhance energy accessibility among the smallholder farmers of Chibombo District.

#### 5.2.3.3 Socio-economic Development from Jatropha

Out-grower schemes have been framed as a 'win-win' solution (Von Braun and Meinzen-Dick 2009) that provide a number of benefits to farmers including employment, input support, guaranteed markets and grants for community projects (Civil Society Biofuels Forum 2009). In a similar manner, Jatropha has been depicted as a "poor man's biofuel crop" (Skutsch *et al*. 2011). This is because it has the potential to produce biodiesel and reduce dependency on fossil fuel (Fairless 2007). In addition, Jatropha has the potential to enhance the livelihoods of the poor rural smallholder farmers by providing them with employment and adding to their household incomes hence alleviating poverty. In this regard, cultivating Jatropha using out-grower schemes promised a high socio-economic development for the smallholder farmers of Chibombo District.

Nonetheless, besides the training on Jatropha and the Jatropha seeds that the farmers were given by the sponsoring firm, the Jatropha project did not yield other expected benefits to the farmers. Majority of the respondents went through the whole process of planting the Jatropha seeds, transplanting and watering the seedlings for the first three months of the plants' life and properly managed the plants to maturity but their hope was dashed due to unavailable market for their harvested seed. As such, the respondents reported that Jatropha did not add to their household incomes. These results are supported by findings that have been obtained from Jatropha schemes in Tanzania where household economic impacts were found to be negative and therefore raises questions as to the competitiveness of smallholder Jatropha cultivation in relation to other crops (Messemaker 2008).

Furthermore, a study conducted by Soto *et al.* (2013a) revealed that the NPV of Jatropha cultivation is at the breakeven point when the price of seed is USD 210 per ton. However, Jatropha in Chibombo District had zero value. Other studies have revealed the prevailing market price of Jatropha to be in the range of USD 137 – 161 per ton i.e. below the projected seed price for Jatropha to be at the breakeven point. Putting into consideration the resources that are utilised, Jatropha production is thus not profitable (Soto et al. 2013a) .

### 5.2.4 Resources Utilised in Jatropha Cultivation

#### 5.2.4.1 Land

Like the rest of Sub-Saharan Africa, Jatropha investments in Chibombo District focused on the smallholder production model (German *et al.* 2011b). One of the reasons for using this production model was because it offers smallholder farmers the opportunity to individually limit investment of their land and control their start-up risk especially when dealing with a new crop (Achten *et al.* 2010b). Smallholder farmers are able to limit their investment because they do not own huge pieces of land. Accordingly, 35.5% of the respondents in Chibombo District owned 5 or less hectares of land, 42.7% had between 6 and 10 hectares of land while only 12.7% owned between 11 and 15 hectares. Consequently, more than 80% of the respondents in Chibombo District invested only one hectare or less of their total land holdings into Jatropha production

In view of the forgoing, the smallholder production model is a better alternative to large-scale Jatropha investments. As reported in other studies, large-scale Jatropha investments may result in displaced food production and encourage land consolidation by larger farmers and companies (Skutsch *et al*. 2011), which may further marginalise smaller famers (Ariza-Montobbio *et al*. 2010). For example, in Kanker and Bastar districts of Chhattisgarh India, 210 families in 18 villages were displaced from 1059 ha of land forcibly acquired for Jatropha cultivation (Burley and Bebb 2009). An additional 355 tribal families in 27 other Indian villages were displaced from more than 710 ha of their land which they had cultivated for generations. Like in kanker and Baster, this land was taken away from the tribal families for Jatropha cultivation (WRM 2009 cited in Skutsch *et al*. 2011).

With regard to land tenure, land in Chibombo District falls under customary land right. As such, majority (83.6%) of the respondents were given their landholdings by their respective chiefs. A few (14.5%) inherited their landholdings while only 1.8% actually purchased the land they own.

#### 5.2.4.2 Use of Fertiliser, Pesticides and Water

The notion of Jatropha being drought tolerant, having no nutritional value and being resistant to pests and diseases has raised high and possibly unrealistic prospects of fuel production, poverty alleviation, wasteland reclamation and large returns on investments (Jongschaap *et al*. 2007, Achten *et al*. 2010a). In contrast, empirical studies have shown that Jatropha seed and oil yield can be increased by optimal fertilisation and irrigation application (Achten *et al.* 2008). Generally, applying super phosphate or NPK fertiliser reportedly increases the yield of Jatropha (Achten *et al*. 2008). However, majority of the respondents in the present study neither applied fertiliser nor pesticides to their Jatropha plants. The lack of fertiliser and pesticides could have contributed to the low seed yield observed in this study.

With regard to water use, the respondents in Chibombo District reported having irrigated their Jatropha plants for the first 3 months after planting. Thereafter, the plants were left to be rain fed. In Zambia, the rain season lasts from mid-October to mid-April thus the land is dry for about 6 months every agricultural year. With this in mind, it can be said that inadequate water availability could be a contributing factor to the low seed yields experienced by these farmers since Jatropha has been shown to have a high water footprint (Ariza-Montobbio and Lele 2010). Each unit of energy that is produced from Jatropha is reported to have a water consumption that is 1.5 times higher than soybean and 5 times higher than ethanol from sugarcane or maize (Gerbens-Leenes *et al.* 2009). A study conducted by Ariza-Montobbio and Lele (2010) in Tamil Nadu India where productivity of rainfed Jatropha was compared against that of irrigated Jatropha found that the survival rates in rainfed plots were statistically lower than those in irrigated plots. This study further established that the average number of seeds per plant was twice as high in irrigated plots as compared to rainfed ones (Ariza-Montobbio and Lele 2010).

As reported in earlier studies, the Jatropha plant only needs water primarily during the first year and if rains are irregular. This means that irrigation is only essential for initial survival (Paramathma *et al*. 2007). However, Ariza-Montobbio (2010) shows that irrigation clearly makes a difference in growth and yield as compared to rainfed Jatropha plants. Tomomatsu and Swallow (2007) added that irrigating the Jatropha plants on a continuous basis determines the number of fruiting periods per year. The fruiting periods are subject to the frequency of irrigation and can vary from one to three (Tomomatsu and Swallow 2007).

#### 5.2.4.3 Opportunity costs in Jatropha Production: Time and Labour

Jatropha is a low-value crop when compared to other cash crops (Liyama *et al*. 2014), as well as to some food crops such as maize. Endelevu Energy (2009) pointed out that Jatropha is a non-food crop with high risks and low returns. However, it requires intensive management just like other high-value crops. Therefore, growing Jatropha could require reallocating limited family labour from other activities to Jatropha (Liyama *et al*. 2014).

In the present study, a comparative analysis of the amount of time invested in carrying out all the activities involved in the production of a half hectare plot of Jatropha and that invested in carrying out all the activities involved in the production of a half hectare plot of maize was carried out. It was established that in the production of a half hectare plot of Jatropha, carrying out all the production cultural practices from seedbed preparation to post-harvest activities requires 117.5 days while production of a half hectare plot of maize takes only 31 days of management. Farmers that invested in Jatropha production were found to have spent a considerable amount of time in nursery management (mainly watering), land preparation and planting ( including the clearing of all trees and stumps and digging of separable holes for each Jatropha plant), harvesting and post-harvesting handling. These results are in accordance with the findings of Endelevu Energy (2009) who pointed out that Jatropha is more management intensive; especially in its establishment years thus it requires more labour and time than maize production. Despite having spent a considerable amount of time on the management of Jatropha fields, the smallholder farmers of Chibombo District had poor harvests. This was partly due to the absence of extension services and market, which led to reduction in adoption of other cultural practices (such as weeding and pruning), which are vital for maximising yields.

### 5.2.5 Barriers to Jatropha Production

The study showed that most farmers have abandoned Jatropha cultivation citing lack of market and non-profitability as the reasons for their decision. The respondents also added lack of technical support from the sponsoring firm as a factor that influenced their abandonment of Jatropha production. Studies in India have also shown that Jatropha is neither a profitable nor pro-poor biofuel plant but one that benefits resource-rich farmers while further marginalising smallholder farmers (Ariza-Montobbio and Lele 2010). Similarly, Jatropha production has faced discontinuity in many countries where the Jatropha hype was received with so much enthusiasm. In Mali, the Jatropha farmers who have abandoned the activity cited two main reasons for this decision; 1) the lengthy harvesting period partly coincides with the harvest of the main staple food and cash crops 2) the price of Jatropha seeds was very low (Soto *et al*. 2013b). This shows that Jatropha is currently not profitable enough forcing some farmers to revert to their traditional crops.

### 5.2.6 Interference of Jatropha Production with Food Production

A major critique against biofuel production is that it could divert agricultural production away from food crops, especially in developing countries (GRZ 2008b). Basically, it is argued that energy crops compete with food crops for agricultural rural investment, water, fertilisers, infrastructure, and skilled labour among others. Consequently, this could lead to shortages of food and increased food prices. However, in the present study, 96.4% of the respondents reported that Jatropha production did not interfere with their food production. As such, interference of Jatropha with local food production was not one of the factors that influenced the farmers' abandonment of Jatropha production in Chibombo District. These results agree with the observation made (GRZ 2008b) that the "food versus fuel" controversy is an exaggerated issue and is cite specific. For instance, a study carried out by Ehrensperger *et al*. (2012) in Kenya established that Jatropha did not negatively affect food security in the area. On the other hand, a study by Ariza-Montobbio and Lele (2010), found that 82% of the interviewed households in Tamil Nadu had converted their plots of land on which they previously cultivated food crops to Jatropha cultivation. The study further established that half of the sampled respondents had more than 50% of their total landholding covered with Jatropha, thus further affecting the previous food production of the household.

## 5.3 Environmental Implications of Jatropha Cultivation

An explicit attempt was made to analyse the environmental impacts arising from out-grower production of Jatropha in Chibombo District. The analysis in this study drew from published literature rather than from land cover data. The environmental aspects assessed for this include land-use impact, use of fertiliser, and irrigation application.

From previous findings, it has been reported that replacement of a natural or semi-natural vegetation with monoculture production of Jatropha can have a negative impact on biodiversity (Achten *et al.* 2007b). In the present study, it was established that the most common way of cultivating Jatropha in Chibombo was as a single crop (monoculture) with about 64.5% of the respondents indicating that they cleared forests to establish the Jatropha plantations. With these findings, there is a high risk of the area losing its natural biodiversity to Jatropha. However, it is difficult to determine the extent to which biodiversity was affected due to unavailable land-use data. Despite having a negative impact, land-use change can also have positive impacts such as improved soil structure, prevention of soil erosion and carbon sequestration (Achten *et al*. 2007b). In line with this argument, two smallholder Jatropha farmers in Chibombo District reported that despite having abandoned Jatropha production, they had not removed their Jatropha plants from their fields for the sole purpose of improving soil fertility.

The respondents changed their land-use from forest land and fallows to Jatropha land representing 24.5% and 10%, respectively. Similar findings have been established by German *et al.* (2011b) who reported that Jatropha production in Zambia caused significant deforestation. In their study, German *et al.* (2011b) reported that 22% of smallholder Jatropha farmers they interviewed had opened up mature forests for Jatropha production while 20% claimed indirect deforestation from relocation of displaced food crops. Deforestation is one of the factors that contribute to atmospheric carbon dioxide and consequently global warming. Therefore, to prevent some of the negative environmental impacts such as biodiversity loss and carbon dioxide emissions from deforestation, it is often recommended that Jatropha be cultivated in hedges (Achten *et al*. 2008). Nevertheless, for a Jatropha project like the one in Chibombo District where the aim was production of biodiesel from Jatropha seeds, cultivation of Jatropha in hedges is not likely to produce the required amount of seed for oil extraction. Therefore, for this study, intercropping Jatropha with other crops could be recommended. Intercropping puts both the need for development and environmental management into consideration. With regards to water requirements, irrigation was only for the first three months of the plant's life and no fertiliser was applied. As such, environmental impacts arising from irrigation and fertiliser application were not experienced in the area.

## 5.4 Chapter Summary

This chapter discussed the perceptions of the Chibombo smallholder Jatropha growing community towards the effectiveness of out-grower schemes for Jatropha production. It also focused on the environmental and socio-economic implications of using out-grower schemes in Jatropha production as well as discussions on the interference of Jatropha production with food production and land tenure. The farmers in Chibombo district perceived out-grower schemes as ineffective for Jatropha production. The main reason cited for abandonment of the Jatropha project was lack of market followed by lack of technical support from the sponsoring firm. Marli Investments breached the terms of the out-grower contract which they entered into with the smallholder farmers by failing to provide all that which is stipulated in the contract. The Jatropha project in Chibombo District did not contribute significantly to the socio-economic status of the Jatropha farmers. The farmers put this in simple words: “it was a waste of time and resources”.

With regard to impacts on food production and land tenure, it was established that the farmers took a precautionary approach when investing in Jatropha production in that the majority cultivated Jatropha on less than a hectare of land and this was carried out by clearing forest land. The majority of the farmers opted to open new forest land for Jatropha cultivation instead of replacing it with their food crop fields. Consequently, the main environmental implication of this land clearing was deforestation. These findings agree with most global studies on the impacts of smallholder Jatropha production. Chapter six draws conclusions on the aim and objectives of the study.

# CHAPTER 6 : CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

## 6.1 Introduction

This chapter presents conclusions of the study, limitations encountered during the study and recommendations. Conclusions on the reasons behind the abandonment of the Jatropha project in Chibombo District were arrived at by evaluating the adopted production model (out-grower scheme). The out-grower scheme of Chibombo District was evaluated by assessing its effectiveness in Jatropha production. This was done by assessing the out-growers contract, implementation of the Jatropha project, Jatropha cultivation, barriers to continuation of the Jatropha project, use of Jatropha as an energy source and income earned from Jatropha. The out-grower scheme was also evaluated by assessing the environmental and socio-economic implications arising from smallholder Jatropha production, the opportunity costs of smallholder Jatropha production as well as the effects of smallholder Jatropha production on food security and land tenure. Based on the conclusions arrived at; recommendations on ways to facilitate sustainable out-grower production of Jatropha are presented.

## 6.2 Conclusions

Out-grower production of Jatropha was publicised to the farmers of Chibombo District in the hope that it would alleviate rural poverty in addition to meeting the energy demands of Zambia as a whole. However, the Jatropha project was abandoned just a few years into its introduction. The main factor contributing to abandonment of Jatropha, as mentioned by the farmers, was lack of market for the produce. This was because Marli Investments, the firm that sponsored the Jatropha project in the area, did not return to the community after introducing the project. In addition to lack of market, lack of technical support from the sponsoring firm was another factor that influenced abandonment of Jatropha production.

Besides the highlighted factors that led to the abandonment of Jatropha in Chibombo District, findings of this study have also revealed problems of non-implementation of the contractual agreements between Marli Investments and the farmers as well as environmental and socio-economic impacts arising from this out-grower scheme. With regards to literacy, the study showed a high rate of illiteracy among the farmers. This could explain why the farmers signed contract with Marli Investments while being unaware of the potential risks related to returns on investment or company control with regards to determining the price of Jatropha or land use. It was observed that the contracts were one-sided in that they were only signed by the farmers but not the sponsoring firm. In addition, the contractual agreements can be said to have been exploitative. This is because contract provisions stipulated that land under Jatropha should be made to produce only the Jatropha plants for 30 years and Jatropha be sold only to Marli Investments at the price determined by Marli. Analysis of this revealed that in an event of Marli Investments failing to secure market for the Jatropha seeds, the farmers would lose out. Marli Investments failed to secure market and the farmers actually lost out. DAPP; a non-governmental organisation that tried to help with providing market for the Jatropha farmers of Chibombo District only bought seeds from a small fraction of the total number of farmers that were in contract with Marli Investments. Marli Investments failed to live up to promises stipulated in the contractual agreement. The farmers did not receive any payment for cultivating Jatropha. The stipulated extension services also ceased after the extension officers that Marli Investments had employed realised that Marli had disappeared with no intentions of returning to the community. Therefore, it could be concluded that the out-grower scheme employed for Jatropha production in Chibombo District was ineffective and in fact attracted more costs than benefits.

The findings of this study also showed significant environmental impacts as a result of this scheme. Integration of Jatropha into smallholder farms gave rise to both direct and indirect land-use changes. It was observed that fallows and mature forests were opened up to accommodate Jatropha. In a few instances, fallows and mature forests were also opened up to accommodate the food crops that were displaced by Jatropha. This coupled with tremendously low yields is a recipe for a high environmental price per unit of biofuel in this situation where the smallholders received insignificant technical and financial support. Comparing the findings of this study to those by Achten and Verchot (2011) and those by (German *et al*. 2011b), it can be concluded that the supposed climate benefit of Jatropha are not likely to materialise under such schemes especially if yields remain poor. Therefore, land-use change and deforestation are some of the major environmental implications of such schemes.

An evaluation of the impacts of smallholder Jatropha production on the food security and land tenure of the smallholders showed no significant impact. The respondents reported having the same food production quantities as before they started producing Jatropha. However, the food security risks associated with Jatropha production due to the fact that smallholders have scarce labour and Jatropha is labour intensive cannot be overlooked.

Additionally, Jatropha production poses a risk of displacement of food crops. With regards to land tenure, the land on which Jatropha was produced in Chibombo District remained in the hands of the farmers (i.e. customary rights holders).

In conclusion, out-grower production of Jatropha in Chibombo District turned out to be ineffective with lack of market and technical support being the main reasons for the abandonment of the project in the area. The farmers did not utilise Jatropha for anything and were never paid for growing it. As such, the Jatropha project was conclusively very costly and a total waste of time in terms of returns to investment. The farmers invested a lot of time and labour with no meaningful benefits. The observed environmental implications of such schemes in Chibombo District include deforestation and land use change which are likely to contribute to atmospheric carbon dioxide especially in situations where the crops replacing the forest (Jatropha in this case) turns out to perform poorly in terms of growth and yield. On a positive note, this scheme did not negatively affect the food production of the smallholders and the farmers did not lose their land. With these positive outcomes, ways of improving the performance of such schemes must be explored.

## 6.3 Limitations of the Study

A number of limitations were encountered during this study. Firstly, this was a retrospective study thus the researcher faced difficulties in informant recall. Most of the respondents were having difficulties with remembering information regarding the Jatropha project under Marli Investments. What the majority of respondents could remember was the fact that Marli Investments only introduced the project and disappeared from the community. On a number of occasions, some respondents were taken as far back as 1984 when this same community was engaged in another Jatropha programme under the Cooperative League of the USA (CLUSA). It took the researcher and the research assistants to bring the respondents to the Jatropha project of the 2000s thus in some instances, questionnaire administration took longer than average time.

Secondly, the smallholder Jatropha farmers in Chibombo District were very enthusiastic about the Jatropha project under Marli Investments and held on to the hope that one day there would be market for their produce. This hope and enthusiasm made them mistake the researcher and her assistants for government officials who were in the area to survey and probably also buy their produce. The researcher together with the research assistants took time to explain that the study was purely academic. This revelation made some of the respondents lose interest in being interviewed thus their responses were incoherent. On the other hand, some respondents did not believe that the study was purely academic and as such they gave socially desirable responses. One lady who was never a part of the out-grower scheme actually volunteered to be interviewed because she thought there would be incentives for the interview.

Lastly, efforts to interview a representative of Marli Investments proved to be futile. Employees of Marli Investments could not be located thus this study only presents the views and perceptions of the smallholder farmers whose responses were triangulated with those of a representative of DAPP. Information on Marli Investments was therefore only obtained from published literature.

## 6.4 Recommendations

Based on the irregularities observed in the Jatropha project of Chibombo District, the following recommendations are made:

i. The most important element for successful biofuel investment is a supporting policy environment. As stated by FAO “there is yet no country in the world where a bio-fuels industry has grown to commercial scale without a clear policy or legislation in place to support the business”. Subsequently, there is need for a supporting national bio-fuel policy and strategy in Zambia.
ii. Government and developmental agencies should move away from the tradition of only providing awareness and introducing smallholders to out-grower schemes. They should emphasize more on the actual management and operation of out-grower schemes. Out-grower schemes should take into consideration all aspects of the out-grower system which include reliable and cost-efficient inputs such as seeds and credit, extension services, mechanization services, and guaranteed and profitable markets (Abwino and Rieks 2007).
iii. In the Chibombo Jatropha project, it was observed that the farmers engaged in long term contracts with the sponsoring firm while unaware of the limited benefits and significant risks involved. Therefore, concerted efforts should be made to improve the farmers’ legal literacy in the area.
iv. The smallholders of Chibombo District bore almost all the risks that came with the Jatropha project in the area. To minimise the risks to smallholders, efforts to regulate involvement and contribution of the sponsoring firms should be made. Regulation can include studying the contract negotiation processes and the contract terms closely (i.e.

contract length, weighing and pricing practices and grading), setting standards for the operations of the sponsoring firms and demanding that sponsoring firms show viable demand for their produce prior to the implementation of an out-grower scheme (ECI Africa Consulting 2006).

v. Efforts to engage smallholders in decision making concerning the terms under which out-grower schemes operate are critical. In this study, it was observed that all the decisions making authority was retained by the sponsoring firm leaving out the smallholder farmers, consequently making them liable to very high production risks.

vi. Fundamentally, a well-organised Jatropha market chain is crucial for enhancement of marketing the produce. This can be achieved by putting in place a well-coordinated information flow on appropriate Jatropha production and marketing methods. The information should be able to reach both the growers and consumers. Proper marketing of Jatropha has the ability to bring about rural development, increase income and provide employment.

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# APPENDICES

## APPENDIX I: QUESTIONNAIRE FOR SMALLHOLDER CONTRACT JATROPHA FARMERS IN CHIBOMBO DISTRICT

THE UNIVERSITY OF PRETORIA

CENTER FOR ENVIRONMENTAL STUDIES

FACULTY OF NATURAL AND AGRICULTURAL SCIENCE

Dear respondent, you have been randomly selected to be part of my sample that will help provide information on the implication of using the smallholder production model to produce Jatropha in Chibombo District. Note that this research is purely academic and therefore feel free to answer all questions without prejudice and as honestly as possible. Kindly be assured that all responses will be treated with utmost confidentiality.

Instructions:

Please tick (√) your appropriate answer or fill in the blank spaces provided.

SECTION A: PERSONAL INFORMATION

Q1. Age categories (years):

1) Less than 20 [ ] 2) 21 to 30[ ] 3) 31 to 40[ ] 4) 41 to 50[ ] 5) Above 51 years [ ]

Q2. Sex: 1) Female [ ] 2) Male [ ]

Q3. Marital status: 1) Single [ ] 2) Married [ ] 3) Divorced [ ]

4) Widowed [ ]

Q4. Highest level of education: 1) Primary [ ] 2) Secondary [ ] 3) Tertiary[ ]

4) others (specify)……………………………………

Q5. Can you read/write?

1) Can neither read nor write [ ] 2) Can read only [ ] 3) Can read and write [ ]

Q6. Household size

1) 5 or less [ ] 2) 6 to 9 [ ] 3) 10 or more [ ]

**SECTION B: THE CONTRACT AND PROJECT IMPLEMENTATION**

Q7. Are you still growing Jatropha?

1) Yes I am still growing Jatropha [ ] 2) No I used to grow Jatropha but stopped [ ]

Q8. When did you start growing Jatropha?

1) 2004 [ ] 2) 2005 [ ] 3) 2006 [ ] 4) 2007 [ ] 5) 2008 [ ] 6) 2009 [ ]

Q9. Which biofuel company are/were you in contract with?

1) Marli Investments [ ] 2) Southern Biopower [ ] 3) Northern Biopower [ ]
4) D1 Oils [ ] 5) DAPP [ ]

If you are still growing Jatropha, please go to Q12.

Q10. When did you stop growing Jatropha?

1) 2009 [ ] 2) 2010 [ ] 3) 2011 [ ] 4) 2012 [ ] 5) 2013 [ ]

Q11. On a scale of 1 to 5, please rank how the following influenced your abandonment of Jatropha production (1 = very high influence, 2=high, 3= moderate, 4 = low, 5 = very low)

Low profits [ ]

Lack of technical support from the sponsors [ ]

No market [ ]

It interfered with food production [ ]

Q12. What has motivated you to continue growing Jatropha?

1) High profits [ ]
2) Readily available markets [ ]
3) Support and commitment from the sponsors [ ]

Other(specify)

……………………………………………………………………………………………

……………………………………………………………………………………………
……………………………………………………………

Q13. What type of out-grower contract do/did you have?

1) Individual [ ] 2) Group contract [ ] 3) No contract

Q14. How long is/was your contract?

1) Less than 5 years [ ] 2) 6 to 10 years [ ] 3) 11 to 15 years [ ]
4) 16 to 20 years [ ] 5) More than 21 years [ ] 6) Did not specify years

Q15. Can you please show me the contract so that I can see its content?

1) Yes [ ] 2) No, I do not want to show you [ ] 3) No because I have no copy [ ]
4) Did not sign any contract [ ]

Q16. How satisfied are/were you with the contract?

1) Very satisfied [ ] 2) Moderately satisfied [ ] 3) Not satisfied [ ]

Q17. (Explain you response to Q16)

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

Q18. What are/were your contract expectations?

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

Q19. Have/were all your expectations met? 1) Yes [ ] 2) No [ ]

Q20. Explain your response to Q19.

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

Q21. Did you receive any training before you started growing Jatropha?

1) Yes [ ]  2) No [ ]

Q22. If you received any training, what type of training did you receive?

1) Technology (e.g. equipment use, etc.) [ ]
2) Management (e.g. use of input, land preparation, etc.) [ ]
3) Utilisation (e.g. processing, marketing, etc.) [ ]
4) Contract interpretation [ ]

Q23. Who provided the training?

1) Marli Investments [ ]  2) Southern Biopower [ ]  3) Northern Biopower [ ]
4)D1 Oils [ ]  5) DAPP

Q24. Do/did you normally receive extension services?

1) Yes [ ]  2) No [ ]

Q25. If yes to Q24, who provides/provided the extension services?

1) Ministry of Agricultural and Livestock [ ]
2) Marli Investments [ ]
3) Southern Biopower [ ]
4) Northern Biopower [ ]
5) DAPP [ ]

Q26. How many times in a year do/did you receive extension services with regards to Jatropha production?

1) Once [ ]  2) 2 times [ ]  3) 3 times [ ]  4) 4 times [ ] 5) more than 5 times [ ]  6) Never [ ]

Q27. What was the basis of the extension services?

Q27. What was the basis of the extension services?

1) Technology (e.g. equipment use, new species etc.) [ ]
2) Management (i.e. use of input, land preparation, etc.) [ ]
3) Utilisation (i.e. processing, marketing, etc.) [ ]
4) Other (specify) ……………………………………………………………

Q28. Are/were you satisfied with the extension services?  1) Yes [ ]  2) No [ ]

Q29. On a scale of 1 to 5, please rank how much priority should be/have been given to the following during extension services (1 = very high, 2=high, 3=moderate, 4=low, 5=very low)

1) Contract interpretation [ ]
2) Management (e.g. land preparation, weeding etc.) [ ]
3) Post-harvest activities (e.g. seed drying, oil pressing etc.) [ ]
4) Marketing (e.g. sale of seeds, price determination etc.) [ ]

**SECTION C: EFFECTIVENESS OF JATROPHA PRODUCTION IN CHIBOMBO DISTRICT.**

Q30. For how long have you grown / did you grow Jatropha?

1) Less than 3years [ ]
2) 4 to 6 years [ ]
3) 7 to 10 years [ ]
4) More than 10 years [ ]

Q31. After how long did you have your first harvest?

1) 2 years or less [ ]
2) 2 to 3 years [ ]
3) More than 3 Years [ ]

Q32. How many times do/did you harvest Jatropha seed in a year?

(1) 2 times or less [ ] (2) 3-5 times [ ] (3) 6-8 times [ ]

Q33. How many kilograms of Jatropha seed do/did you obtain per harvest?

1) 2 Kilograms or less [ ] 2) 3 to 5 Kilograms [ ] 3) 6 to 8 Kilograms [ ]
4) More than 9 Kilograms [ ] 5) Never harvested [ ]

Q34. What is/was the price of the Jatropha seed per kilogram?

1) Between K3 and K5 [ ] 2) K6 and K10 [ ] 3) K11 and K15 [ ]
4) K16 and k20 [ ] 5) Don't Know [ ]

Q35. To whom do/did you sell your Jatropha seed?

1) Sold to the sponsoring firm only [ ]
2) Sold to any interested company [ ]
3) Sold to any interested individual [ ]

4) Did not sell to anyone [ ]

Q36. Is /was Jatropha your only source of livelihood?

1) Yes it is/was [ ] 2) Yes but after abandoning Jatropha, I had to find other livelihood activities [ ] 3) No I have/had other livelihood activities [ ]

Q37. If you have other sources of livelihoods, kindly state these sources of livelihoods

1) Small scale business [ ] 2) Charcoal burning [ ] 3) Growing different types of crops [ ] 4) Pastoral farming [ ]

Q38. Besides Jatropha, do/did you grow any other crops?

1) Yes [ ] 2) No [ ]

Q39. If yes to Q38, Kindly mention one (1) other main crop that you grew/grow besides Jatropha.

1) Maize [ ] 2) Cotton [ ] 3) Soy beans [ ] 4) Sorghum [ ]
5) Tobacco [ ] 6) Tomato [ ]

Q40. What is/was the main use of the other crop that you grew/grow?

1) For home consumption only? [ ] 2) For sale and home consumption? [ ]

3) For sale only? [ ]

4) Other (Specify)……………………………………………………………………

Q41. If you also sold/sell the other crop, what is/was your annual income from the other crop?

1) K0 [ ] 2) K1 to K500 [ ] 3) K501 to K1000 [ ]
4) K1001 to K5000 [ ] 5) K5001 to K10000 [ ] 6) Above K10001

Q42. In your opinion, is/was Jatropha more profitable than other crops?

1) Yes [ ] 2) No [ ] 3) Cannot tell because I never sold Jatropha [ ]

Q43. In your opinion, do you agree that growing Jatropha has increased /did increase your alternative sources of livelihood?

1) Strongly Agree [ ]
2) Agree [ ]

3) Disagree [ ]

4) Strongly disagree [ ]

Q44. Please explain your response to Q43.

…………………………………………………………………………………………………

……………………………………………………………………………………………..

Q45. Besides selling the Jatropha seed, what else do you use/were you using Jatropha for? (Tick more than one if necessary)

1) Seedcake for fertiliser [ ]
2) Oil for home consumption [ ]
3) Soap manufacturing [ ]
4) Other (specify) ……………………………………………………………………

Q46. Do/did you use Jatropha oil for home consumption? 1) Yes [ ] 2) No [ ]

Q47. If you use/used Jatropha oil, what do/did you use it for?

1) Lighting the house [ ] 2) Cooking (in oil stoves) [ ]

3) Other (specify)………………………………………………………………………

Q48. If you use/used Jatropha oil for home consumption, has/did that improve your access to lighting / cooking (tick whichever is appropriate) energy compared to before you started growing and using Jatropha?

1) Strongly agree [ ]
2) Agree [ ]
3) Disagree [ ]
4) Strongly disagree [ ]

Q49. Please explain your response to Q48.

…………………………………………………………………………………………………

……………………………………………………………………………………………………..

Q50. What was your source of lighting / cooking (tick the appropriate) energy before you started growing and using Jatropha?

Lighting……………………………………………………

Cooking……………………………………………………….

Q51. If you don't use Jatropha as a source of energy, kindly estimate your monthly energy cost.

1) K100 or less [ ]
2) Between K101 and K300 [ ]
3) Between K301 and K500 [ ]

**SECTION D: NATURAL RESOURCES UTILISED IN JATROPHA PRODUCTION**

Q52. How much agricultural land do you own?

1) 5 hectares or less [ ] 2) 6 to 10 hectares [ ] 3) 11 to 15 hectares [ ]
4) 16 to 20 hectares [ ] 5) More than 21 hectares [ ]

Q53. How did you obtain the land on which you plant Jatropha?

1) Purchased [ ] 2) Inherited [ ] 3) Rented in [ ] 4) freehold [ ] 5) Given by the chief [ ]

Q54. How much of your agricultural land are/were you using for Jatropha growing?

1) 1 hectare or less [ ] 2) 2 to 3 hectares [ ]
3) 4 to 5 hectares [ ] 4) 6 hectares or more [ ]

Q55. How have you incorporated/did you incorporate Jatropha growing into your farming system?

1) As hedgerows [ ]
2) Inter-cropping with other crops [ ]
3) Planted with tree crops like fruits [ ]
4) As a single crop (plantation) [ ]
5) Other (specify)…………………………………………….

Q56. How is water supplied to Jatropha plants?

1) Irrigated [ ] 2) Rain fed [ ]

Q57. If irrigated, how many litres of water are required for one (1) Jatropha plant per day?

1) 1 to 2 litres [ ] 2) 3 to 4 litres [ ]
3) 5 to 6 litres [ ] 4) More than 7 litres [ ]

Q58. How is water supplied to your other main crop?

1) Irrigated [ ]  2) Rain fed [ ]

Q59. If irrigated, how many litres of water are required for one (1) plant of your other main crop per day?

1) 1 to 2 litres [ ]  2) 3 to 4 litres [ ]

3) 5 to 6 litres [ ]  4) More than 7 litres [ ]

Q60. In the Table below, kindly give an estimate of time in person days required for the production of Jatropha on a 1 acre piece of land and also indicate household members mostly responsible for the listed activities.

| Activity | Time required (hours, days, weeks, months) | Employees (hired labour) | Household members mostly responsible for the activities | | |
|---|---|---|---|---|---|
| | | | Children (≤ 18 years) | Adult male | Adult female |
| Seed bed preparation | | | | | |
| Seeding | | | | | |
| Preparation of field | | | | | |
| Transplanting | | | | | |
| Irrigation | | | | | |
| Fertiliser application | | | | | |
| Weeding | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Pruning | | | | | |
| Pest control | | | | | |
| Harvesting | | | | | |
| Post-harvest activities | | | | | |

Q61. If labour is/ was hired, give an estimate cost for one acre of work.

……………………………………………………………………………………….

Q62. In the Table below, kindly give an estimate of time in person days, required for the production of your other main crop on a 1 acre piece of land and also indicate household members mostly responsible for the listed activities.

| Activity | Time required (hours, days, weeks, months) | Employees (hired labour) | Household members mostly responsible for the activities | | |
|---|---|---|---|---|---|
| | | | Children (≤ 18 years) | Adult male | Adult female |
| Seed bed preparation | | | | | |
| Seeding | | | | | |
| Preparation of field | | | | | |
| Transplanting | | | | | |
| Irrigation | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Fertiliser application | | | | | |
| Weeding | | | | | |
| Pruning | | | | | |
| Pest control | | | | | |
| Harvesting | | | | | |
| Post-harvest activities | | | | | |

Q63. If labour is/was hired, give an estimate cost for one acre of work.

………………………………………………………………………………………….

**SECTION E: SOCIAL NETWORK**

Q64. Do you belong to any association or organisation? 1) Yes [ ] 2) No [ ]

Q65. If yes, which organisation do you belong to?

| Name and type or organisation (code 1) | Degree of participation (code 2) | Code 1 | Code 2 |
|---|---|---|---|
| | | Farmer association……….1<br>Cooperative………………2<br>Traders association……….3<br>Credit group………………4 | Leader…………………….1<br>Very active (board member 2<br>Active…………………….3 |
| | | | |
| | | | |
| | | | |
| | | | |

| | | | |
|---|---|---|---|
| | | NGO involved in Jatropha production……………….5 | Give help from time to time 4 |
| | | | |
| | | Jatropha women's group…………………….6<br><br>Other(specify)……………..7 | Not active………………..5 |

Q66. With respect to Jatropha production, how does the association/organisation help you?

1) Provision of loans to pump into Jatropha production [ ]
2) Marketing Jatropha [ ]
3) Management of Jatropha fields [ ]
4) No help [ ]

Q67. With respect to Jatropha production, please rate your access to the services listed below on a scale of 1 to 5.

(1 = very good, 2 = good, 3 = moderate, 4 = poor, 5 = very poor)

a) Job training/employment [ ]
b) Agricultural extension [ ]
c) Transportation [ ]
d) Credit/finance [ ]
e) Decision making involvement[ ]

f) Tap water/ pump water [ ]
g) Irrigation water [ ]
h) conflict resolution [ ]
i)Security/police services/justice[ ]
j) general support [ ]

**SECTION F: ENVIRONMENTAL IMPLICATIONS AND EFFECTS ON FOOD PRODUCTION**

Q68. Before you started growing Jatropha, what was the use of the land that Jatropha occupied/occupies?

1) Forest land [ ] 2) Growing of food crops [ ]

3) Pasture land [ ] 4) Nothing (fallow) [ ]

Q69. Has/ did growing Jatropha affect your food production?

1) Yes [ ] 2) No [ ]

Q70. Explain your response to question 69.

.....…………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

Q71. On what type of land do/did you grow Jatropha?

1) On good/fertile land [ ]
2) On non-productive/marginal land [ ]
3) Other (specify)……………………………………………..

Q72. Did you have to clear new forest land to accommodate Jatropha or did you have to clear new forest land to accommodate the crop displaced by Jatropha?

1) Yes I cleared new forest land for Jatropha [ ]
2) Yes I cleared new forest land for displaced crop [ ]
3) No I did not clear any new land [ ]

Q73. What was your experience with:

Growth of Jatropha plant

…………………………………………………………………………………………………
…………………………………………………………………………………………………
………………………………………………………………

Pests and disease attack on Jatropha

…………………………………………………………………………………………………
…………………………………………………………………………………………………
………………………………………………………………

Effects of Jatropha on other crops

……………………………………………………………………………………………

……………………………………………………………………………………………

Thank you very much for you time!

## APPENDIX II: QUESTIONNAIRE FOR JATROPHA SPONSORING FIRMS IN CHIBOMBO DISTRICT

THE UNIVERSITY OF PRETORIA

CENTER FOR ENVIRONMENTAL STUDIES

FACULTY OF NATURAL AND AGRICULTURAL SCIENCE

Dear respondent, you have been randomly selected to be part of my sample that will help provide information on the use of the smallholder production model to grow Jatropha in Chibombo District. Note that this research is purely academic and therefore feel free to answer all questions without prejudice and as honestly as possible. Kindly be assured that all responses will be treated with utmost confidentiality.

Instructions:

Please tick (√) your appropriate answer or fill in the blank spaces provided.

SECTION A: PERSONAL INFORMATION

Q1. Name of sponsoring firm: ………………………………………………………….

Q2. Occupation: …………………………………………………………………………

Q3. Age categories (years):

1) Less than 20 [ ] 2) 21 to 30[ ] 3) 31 to 40[ ] 4)41 to 50[ ] 5) Above 51 years [ ]

Q4. Sex: 1) Female [ ] 2) Male [ ]

Q5. Marital status: 1) Single [ ] 2) Married [ ] 3) Divorced [ ]

4) Widowed [ ]

Q6. Highest level of education: 1) Primary [ ] 2) Secondary [ ]

3) Tertiary [ ] 4) other (specify)……………………………………………...

SECTION B: THE JATROPHA PROJECT

Q7. When did you initiate the Jatropha project in Chibombo District?

……………………………………………………………………………………

Q8. Are you still promoting Jatropha production? 1) Yes [ ]  2) No [ ]

If your answer to Q8 is yes, please go to Q16.

Q9. If No to Q8, when did you abandon the Jatropha project? ………………………………

Q10. Why did you abandon the Jatropha project?

……………………………………………………………………………………………
……………………………………………………………………………………………

Q11. Now that you have abandoned the Jatropha project, have your contracted farmers also abandoned the project?  1) Yes [ ]  2) No [ ]

Q12. Who initially abandoned the Jatropha project (Farmers or the sponsoring firm?)

1) Farmers [ ]  2) Sponsoring firm [ ]

Q13. If the answer to Q12 is Farmers, why did the farmers abandon the Jatropha project?

1) Low profits [ ]  2) Lack of support from sponsoring firm [ ]

3) No market for Jatropha seed [ ]  4) other (specify)………………………………

Q14. Were the farmers involved in the Jatropha project compensated in any way after the abandonment?  1) Yes [ ]  2) No [ ]

Q15. If yes to Q14, in what way were the farmers compensated? (Please skip to Q17)

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

Q16. What has motivated to continue promoting Jatropha when others have abandoned it?

……………………………………………………………………………………………
……………………………………………………………………………………………

Q17. How many Chibombo smallholder farmers are/were you in contract with? ......................

Q18. How long is / was your Jatropha growing contract?

1) Less than 5 years [ ]
2) 6 to 10 years [ ]
3) 11 to 15 years [ ]
4) 16 to 20 years [ ]
5) More than 21 years [ ]

Q19. Can you please show me a copy of your Jatropha production contract?

1) Yes [ ] 2) No, I do not want to show you [ ] 3) No because I have no copy [ ]

Q20. In your opinion, do you think the farmers are/were satisfied with the contents of the contract? 1) Yes [ ] 2) No [ ]

Q21. (Explain your response to Q20)

……………………………………………………………………………………………….
……………………………………………………………………………………………….

Q22. What is/was the price of the Jatropha seed produced by farmers per kilogram? ………

Q23. How is/was the price of Jatropha seed produced by the smallholder farmers determined?

……………………………………………………………………………………………….
………………………………………………………………………………………………..

Q24. Are/were the farmers provided with all farming input for the Jatropha project?

1) Yes [ ] 2) No [ ]

Q25. On what type of soil is/was Jatropha grown?

1) On good/fertile land [ ]
2) On non-productive/marginal land [ ]
3) Other (specify)……………………………………………..

Q26. Did the farmers have to clear new forest land to accommodate Jatropha or did they have to clear new forest land to accommodate a crop displaced by Jatropha?

1) Yes they cleared new forest land for Jatropha [ ]
2) Yes they cleared new forest land for displaced crop [ ]
3) No they did not clear any new land [ ]

Q27. Do/did the farmers have to apply fertiliser to the Jatropha plants to obtain high yields?

1) Yes [ ] 2) No [ ]

Q28. Has/did growing of Jatropha affected the farmers' production of food crops?

1) Yes [ ] 2)No [ ]

Q29. Explain your response to Q28

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Q30. How do/did farmers incorporate Jatropha into their farming systems?

1) As hedgerows [ ]
2) Inter-cropping with other crops [ ]
3) Planted with tree crops like fruits [ ]
4) As a single crop (plantation) [ ]
5) Other (specify)……………………………………………………………….

Q31. Besides selling the Jatropha seed to you, how else do/did farmers benefit from the Jatropha project?

1) Jatropha seedcake for fertiliser [ ]
2) Oil for home consumption [ ]
3) Soap manufacturing [ ]
4) Other (specify) ………………………………………………………………….

Q32. What are/were your expectations from the Jatropha project?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Q33. Have /were your expectations been met? 1) Yes [ ] 2) No [ ]

Q34. Explain your response to Q33.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Q35. What were your expectations from the farmers?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Q36. Have/were your expectations been met? 1) Yes [ ] 2) No [ ]

Q37. Explain your response to Q36.

…………………………………………………………………………………………………
…………………………………………………………………………………………………

Q38.When you started the Jatropha project, how many kilograms of Jatropha seed were you expecting per acre per harvest? ..........................................................................................

Q39. How many kilograms of the Jatropha seed are/were harvested per acre per year? ..................................................................................................................................

Q40. How many times in a year do /did the farmers harvest Jatropha seed? ..............................

Q41. What methods are/ were used to motivate the farmers to improve their yield of Jatropha?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

Q42. How often do/did you offer extension services to the Jatropha farmers in a year?

1) 1 to 2 times [ ]
2) 3 to 4 times [ ]
3) 5 to 6 times [ ]
4) More than 7 times [ ]

Q43. After the Jatropha seed is/was harvested, how is/was it transported to the processing plant?

…………………………………………………………………………………………………
…………………………………………………………………………………………………

Q44. Who bears/bore the cost of transporting the harvested Jatropha seed?

1) Smallholder farmer [ ]
2) Sponsoring firm [ ]
3) Other (specify) [ ]

Q45. How many litres of oil do/did you realise from one (1) kilogram of Jatropha see?

………………………………………………………………………………………….

Q46. Does/did the realised amount of oil from a kilogram of Jatropha seed meet your expectation? 1) Yes [ ] 2) No [ ]

Q47. Kindly explain your response to Q46.

……………………………………………………………………………………………………
……………………………………………………………………………………………………

Thank you very much for your time.

## APPENDIX III: CONSENT AND ASSENT FORMS

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

**Date……………………………………**

**A - INFORMED CONSENT TO PARTICIPANTS (OFFICIALS FROM THE MINISTRY OF AGRICULTURE AND LIVESTOCK IN CHIBOMBO DISTRICT, AGR-BUSINESS FIRMS THAT INVESTED IN THE JATROPHA PROJECT IN CHIBOMBO DISTRICT AND LOCAL COMMUNITY MEMBERS (MEN AND WOMEN) WHO ARE/WERE INVOLVED IN THE JATROPHA PROJECT.**

I am a Master's student in the Faculty of Natural and Agricultural sciences, University of Pretoria. I am working on a research project entitled **'EVALUATION OF SMALLHOLDER PRODUCTION MODEL FOR *JATROPHA CURCUS L.* AT CHIBOMBO DISTRICT, ZAMBIA'**. This study will assess the Jatropha production model adopted for smallholder Jatropha production in Chibombo District, Zambia through analysis of the socio-economic and environmental out-comes of Jatropha production in Chibombo District.

For the purpose of this study, I kindly request you to participate in an interview discussion. Your participation will enable me collect relevant information that will help me achieve the goals of the study. I therefore request you to read the information provided below before you make an informed decision regarding your participation in this study.

### RESEARCH PROCEDURE

***1. Title*: "Evaluation of Smallholder Production Model for *Jatropha Curcus L.* at Chibombo District, Zambia".**

***2. Purpose of the study*:** The purpose of this study is to identify the factors influencing the unsustainable production of Jatropha among smallholder farmers in Chibombo District through analysing the environmental and socio-economic outcomes of the production model adopted for smallholder Jatropha production in Chibombo District. Henceforth, the study will contribute to the empirical body of knowledge on the environmental and socio-economic costs and benefits of smallholder Jatropha production in Zambia.

***3. Procedures***: Semi-structured and structured interviews will be conducted within an hour each. During this process, you are allowed to withdraw either yourself and/or your contribution at any time you wish to do so. You will not be forced to provide information related to this study. All information that you supply will remain confidential and your identity will not be revealed to other participants or in the final draft report.

***4. Benefits:*** The findings of this study are expected to be useful to the government, policy makers and other stakeholders that are interested in knowledge on the suitability of out-grower schemes in smallholder Jatropha production. Furthermore, it is hoped that this study will provoke further research so as to identify production models that are suitable for smallholder Jatropha production.

## DECLARATION

**I....................................................................... (Name) of............................................. (Address) agree to participate in the study mentioned above. I understand that I have the right to withdraw myself from participating in the study at any time when I feel to do so.**

| YES | NO |
|---|---|
| | |

**I understand that my personal information and identity will be kept confidential and it will not be disclosed without my authority.**

| YES | NO |
|---|---|
| | |

**I am giving my consent fully aware of the possible risks that may be associated with this study.**

| YES | NO |
|---|---|
| | |

**Participant's (Code)................................Signature............................Date..........................**

**Chibuye Florence KUNDA** **Signature..................................**

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**Dr. Folaranmi Dapo BABALOLA** **Signature.................................**
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**Prof. Paxie W. CHIRWA** **Signature…………………………..**
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