A SOCIO-ECONOMIC ANALYSIS OF FACTORS INFLUENCING *JATROPHA CURCAS L.* ADOPTION BY COMMUNAL FARMERS IN SHAMVA DISTRICT OF ZIMBABWE

by
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DEDICATION

This is dedicated to my wife, *Revai,* son *David* and daughter *Samantha* for their unfailing love and support they religiously render me.

To God be the Glory.

ABSTRACT

Jatropha curcas L. or physic nut is a plant that has the potential of reducing rural poverty and increasing fuel supply. Worldwide interest in plant oils commenced when it became evident that fossil fuels were depleting and becoming more costly as a fuel resource. In Zimbabwe, the renewed attempt to promote the tree by the Government and other organizations has been met by a slow uptake despite seedlings being made available at affordable prices. This study sought to identify the socio-economic characteristics of smallholder communal farmers of Shamva District to establish how these characteristics influence its adoption by employing the logistic regression model. Noting that the relative advantage of a technology is one of the attributes upon which an innovation is judged and has the strongest effect on the rate of adoption, the study explored the economic relative advantage of *Jatropha* adoption by investigating the economic incentives existing in the current policy environment through the use of the policy analysis matrix. The basic concepts and theoretical foundations of adoption analysis were discussed including a review of empirical evidence on factors affecting adoption of sustainable agricultural practices. An adoption theoretical framework and a sustainable livelihood conceptual framework were used. The study, made up of a sample size of 300, was carried out in ward 12 of Shamva District**.** Study findings revealed that among other socio-economic factors, farm size and off-farm income were the only significant factors determining *Jatropha curcas L.* adoption. An analysis of economic incentives existing in the *Jatropha* system revealed that while *Jatropha* had a positive net present value over its 35 year economic period at both private and economic prices to the tune of US$150/ha and US$1789/ha respectively, there was an overall implicit taxation amounting to US$1638/ha. However, the computed internal rate of return figures when compared to cost of capital revealed that Jatropha was only profitable at economic and not at private valuation of resources. Taken together with the overall implicit tax, the study showed that the current policy environment was not encouraging *Jatropha* adoption. The major conclusions and recommendations from the study were that *Jatropha* should be targeted to farmers with large pieces of land, hedges should be promoted for small land holders,

markets and cheap processing machinery should be introduced in addition to reviewing the Jatropha seed price upwards to promote adoption.

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ACRONYMS

DSGZ	Development Study Group, University of Zurich
GEXSI	Global Exchange for Social Investment
NOCZIM	National Oil Company of Zimbabwe
PAM	Policy Analysis Matrix
PCA	Principal Components Analysis
SADC	Southern African Development Community
SPSS	Statistical Package for Social Scientists
NPV	Net Present Value
IRR	Internal Rate of Return

CHAPTER 1: INTRODUCTION

1.1 Background

Worldwide interest in plant oils or bio-fuels commenced when it became evident that fossil fuels were depleting and becoming more costly as a fuel resource (Mushaka, 1998). The worsening climate change also spurred bio-fuel production across the world as well as the rising real energy prices (Almeida et al, 2007; Wahl *et al*, 2009). By definition, bio-fuels are liquid fuels that are produced from biomass for transport or burning purposes. These are divided into two groups, namely ethanol and biodiesel which account for 90% of total global bio-fuel consumption. The development of bio-fuels is expected to contribute 4.5% of the global consumption of liquid fuels by 2013 (Kgathi, 2007).

In Zimbabwe, the search for plant oil started way back in the 1970s when, as a result of sanctions, the country experienced challenges in accessing fossil fuels in the then pre-independent Zimbabwe. Due to the large number of small-scale farmers, interest in *Jatropha curcas L.* commonly known as *Jatropha* or physic nut or *Mujirimono* or *Umhlafuto* in Shona and Ndebele respectively, has traditionally been confined to that sector. However, as Mushaka (1998) points out, no systematic tests have been conducted to ascertain its full potential in the country as some of the initiatives were abandoned due to technological constraints. *Jatropha* has been grown in Zimbabwe for years especially in areas such as Binga, Mutoko, Shamva, Hwange, Murewa, Mudzi and Nyanga (Matondi, 2008; Mushaka, 1998). It is a bush plant that can grow up to eight metres, which, traditionally, has been grown for its medicinal properties in marginal areas and as a fencing hedge since it cannot be browsed by animals (Henning, 2009). Its production can be used for rural development as it can decrease poverty through promoting women in soap making, using the pressed cake as organic fertilizer, promoting energy supply especially fuel for engines and candles for lighting in addition to reducing soil erosion through planting hedges (Henning, 2009).

The Government of Zimbabwe embarked on a renewed massive *Jatropha* production promotion in 2005/6 agricultural season, principally for two reasons. First was the need to save the country from the rising international fuel prices. Second was the need to guarantee the country of stable fuel supplies in light of the foreign currency shortages that existed then (Matondi, 2008). Mtisi and Makore (2010) further argue reasons of sovereignty and the failure to access or import oil from other countries as a result of poor credit rating. Other equally important reasons for embarking on bio-fuel production include concerns about the need for rural development and reduction in green house gas emissions ((Kgathi, 2007; Parawira, 2010). The National Oil Company of Zimbabwe (NOCZIM) was mandated to implement the biodiesel programme on behalf of the Government of Zimbabwe. Mushaka and Revanewako (2009) contend that the programme, which targeted the smallholder and large scale farmers in arid and semi-arid areas, was institutionalised in NOCZIM in March 2007. Farmers with more than 5 ha of land were made to enter into contracts with NOCZIM. Those with less than 5 ha of land were not obliged to enter into such contracts. In 2008, more than 40 million seedlings were made available for purchase by farmers at a price of US$0.0015 per seedling (Mushaka and Revanewako, 2009). The biodiesel programme aimed at meeting 10% of the country's fuel requirements - approximately 100 million litres per annum - by establishing 120,000 ha of *Jatropha* by 2017 (Mushaka and Revanewako, 2009).

1.2 Problem Statement

Like most African countries, Zimbabwe meets its oil requirements by importing from oil producing countries. Shortages of foreign currency towards the end of the first decade of the 21st century made the country realise that there was need for a reliable alternative source of energy supply. This alternative source of energy supply was to be met through *Jatropha* production. The oil plant production was to achieve the twin objective of fuel supply for the nation and poverty reduction for the rural poor. To this end, the *Jatropha* plant was recommended by the Southern African Development Community (SADC) as an energy crop given its great potential in the Southern African region.

In 1996, the Plant Oil Producers Association, a group of large scale commercial farmers, embarked on the promotion of *Jatropha* production. The programme, however, got off to a slow start because the group noted that the plant could not be mechanically harvested and so it was not in their best interest to pursue it further. Other organisations that have and are still promoting *Jatropha* adoption and production in the country include the Bun Project, Environment for Africa and Binga Trees Projects (Henning, 2009).

But, despite the promotion of adoption of the tree by these organisations and the recent promotion by Government since 2005/6, it appears no massive adoption has been done by smallholder farmers (Matondi, 2008). For example, out of a set target of 65,000 ha that was to be achieved by 2008, only 10,000 ha were planted despite the Government agency, NOCZIM, making available seedlings for production at a giveaway price (Matondi, 2008). Esterhuizen (2010) also notes that adoption of *Jatropha* and establishment of plantations of at least a hectare has been very slow. For example, in 2010, only 30,000 ha out of a projected 120,000 ha by 2017 had been planted. There is thus a need to find out the socio-economic factors which are influencing adoption of this plant. In addition to that, it is critical that a detailed analysis of the economic incentives obtaining in the current environment be investigated to establish whether or not they are promoting Jatropha adoption. The study on *Jatropha* adoption will enable priority setting for research, evaluate distributional impacts of new technology and identify and reduce constraints to adoption. This is very critical if the nation is serious about developing an alternative energy source.

1.3 Research Objectives

The main objective of the study is to analyse the socio-economic factors influencing *Jatropha* adoption in the communal lands of Shamva District of Zimbabwe. The specific objectives are:

(a) To characterise growers and non-growers of *Jatropha* in the communal lands of Shamva District;

(b) To establish the socio-economic factors which determine the adoption of *Jatropha;* and

(c) To evaluate the level of economic incentives or disincentives existing in the current policy environment with respect to *Jatropha* adoption.

1.4 Research Questions

The above objectives derive from these research questions:

(a) What are the characteristics of growers and non-growers of *Jatropha* in the communal lands of Shamva District?

(b) Which socio-economic factors influence the adoption of *Jatropha*? and

(c) Are government policies encouraging the adoption of *Jatropha* production?

1.5 Research Hypotheses

The research questions outlined above will be answered by testing the following hypotheses:

(a) There is no difference in socio-economic characteristics of growers and non-growers of *Jatropha* in the communal lands of Shamva District;

(b) Sex, age, size of the household, literacy level, size of land holding and wealth status of a household affect the adoption of *Jatropha;* and

(c) Current government policies are discouraging *Jatropha* adoption.

1.6 Justification of the Study

Agricultural technology adoption studies are important in a number of ways. They assist in assessing the impact of agricultural research, help in priority setting for research, help in evaluating distributional impacts of new technology and are critical in identifying and reducing constraints to adoption (Doss, 2003). As such, adoption of *Jatropha* as a potential source of fuel and a poverty busting strategy has many merits. Advocates for bio-fuels production believe they have the potential to significantly reduce greenhouse gas emissions that are associated with the use of fossil fuels (Mtisi and Makore, 2010). For example, a fully grown *Jatropha* tree absorbs about 8 kilogrammes of carbon dioxide per year (Muok and Kallback, 2008). Further, the use of bio-fuels can bring about a change in oil prices and help stabilize or reduce them as more and more people start to rely on bio-fuels than fossil fuels. As fossil fuels have over the years become more and more expensive since the prices have been unstable and unpredictable, it is imperative that an alternative energy source be developed, especially for poor countries that use more foreign currency to import oil (Pawarira, 2010). To a large extent, the justification for bio-fuels production is based on their potential to address climate change, energy security and sustainable development of rural areas in addition to being an environmentally friendly biodiesel source (Pawarira, 2010).

In the rural areas of Zimbabwe, it is envisaged that the development of bio-fuel production systems will bring more capital to the rural areas. With Africa being a net importer of vegetable oil, *Jatropha* adoption and production on marginal lands means it does not compete with food crops (Pawarira, 2010; GEXSI, 2008). It is imperative therefore that a study on the socio-economic factors affecting its adoption, given its slow uptake in Zimbabwe, be undertaken to identify and reduce constraints thus improving targeting of participants in the programme while removing any economic disincentives in the current policy regime. The results of the study will add on to the body of knowledge and information on *Jatropha* adoption and production in Zimbabwe and help shape government and private sector involvement in *Jatropha* business.

1.7 Organisation of the Study

Chapter two presents background information to the adoption study. In this chapter, the **o**rigin and distribution of *Jatropha curcas L*. in the world, uses of *Jatropha curcas L*., its agronomic aspects, world production, international trade and a review of the national biodiesel programme in Zimbabwe are presented. Chapter three reviews literature where an outline of the basic concepts and theoretical foundations of adoption analysis are given. Issues relating to the theories of adoption, the speed of technology adoption, the categories of adopters and an overview of the approaches that have been used in the analysis of adoption and diffusion of technologies are presented. A review of empirical evidence on factors affecting the adoption of sustainable agricultural practices ends the literature review chapter. In Chapter four, the research methods that were used in this thesis, including analytical tools such as descriptive statistics, the binary logistic regression model and the policy analysis matrix, are presented. In Chapter five, a characterisation of the *Jatropha* growers and non-growers is given. Chapter six presents an outline of the socio-economic factors influencing *Jatropha* adoption. An analysis of the economic incentives existing under the current policy environment is presented in Chapter seven. In Chapter eight under discussion, the results of the study are compared with results obtained from elsewhere in the world in order to draw parallels. Finally, Chapter nine provides the summary, conclusion and recommendations as well as areas that need further study.

CHAPTER 2: OVERVIEW ON THE ROLE OF JATROPHA CURCAS L.

2.1 Introduction

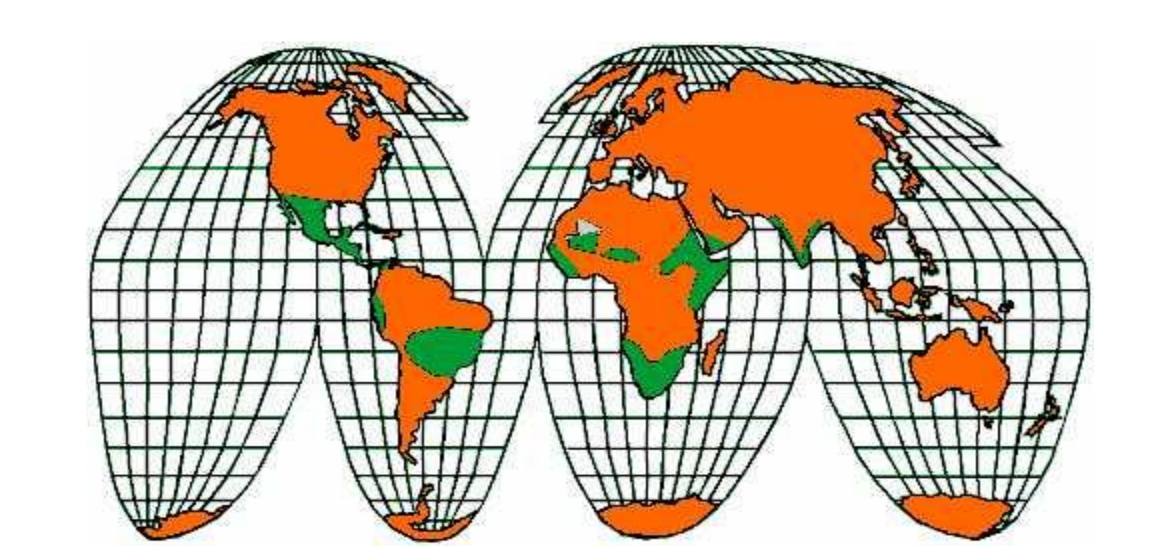
This chapter gives an outline of the origin and distribution of *Jatropha curcas L.* in the world. A detailed description of its uses suffices followed by a section on its agronomy. *Jatropha* world production and international trade is then presented next. The last section of the chapter provides a narration of the national biodiesel programme in Zimbabwe, including *Jatropha* production trends.

2.2 The Origin and Distribution of *Jatropha Curcas L.*

The genus name *Jatropha* derives from the Greek word *jatros* (doctor), *trophe* (food) which implies medicinal uses (Pawarira, 2010). The genus contains 170 known species. *Jatropha curcas L.* seed is toxic to humans, animals and birds hence it is commonly referred to as 'physic nut', 'poison nut tree' or 'graveyard tree'. It is a shrub or small tree with maximum height of 7 – 8 metres though a height range of 3 - 5 metres have been recorded in Zimbabwe (Wegmershaus and Oliver, 1994; Tigere *et al*, 2000). Its fruit is dark brown and 15 - 40 mm in diameter. According to Wegmershaus and Oliver (1994), the seed is composed of 32.7 – 40.6 % oil. It can produce flowers and fruits twice a year or continuously throughout the year in other regions.

The plant originated from the arid regions of Brazil (Mushaka, 1998). It is thought that Portuguese navigators may have introduced it to the Cape Verde Island, where it has been commercially grown since the 16th century. The Arabs used the plant in the 14th century for medicinal purposes. It is thought that the plant was distributed by Arab and Portuguese traders in Africa (Mushaka, 1998; Pawarira, 2010). Today, it is found in most tropical and subtropical countries and islands as shown in Figure 1 (Wegmershaus and Oliver, 1994). The green shade shows its areas of occurrence in both the tropical and subtropical regions of the world.

Figure 1: Main distribution regions of *Jatropha curcas L.*



Source: Wegmershaus and Oliver (1994)

According to the Global Market Study on *Jatropha* by Gexsi (2008), about 900,000 ha were under *Jatropha* in 2008. Of this, 85% of the plantations were in Asia with Africa and Latin America having 13% and 2% respectively. India alone has more than 400,000 ha under *Jatropha*, making it one of the biggest players in the industry. *Jatropha* experts anticipate the area under the plant to increase by 1 – 2 million every year, thus reaching an estimated 12.8 million hectares by 2015 (Gexsi, 2008). Assuming an average investment of between US$300 – US$500 per hectare, a global investment of up to US$1 billion per annum is expected. Although governments across the world have been taking major leading roles in promoting *Jatropha*, in recent years, major oil companies and international energy conglomerates have started to make headway into the industry.

As Gexsi (2008) reports, smallholder farmers play a significant role in most *Jatropha* projects. *Jatropha* production has not led to a reduction in the area under food crops. Only 1.2% of area used for food production has been used for *Jatropha* production. Moreover, neither has it led to the destruction of primary forests, meaning that its promotion has no detrimental effects to the survival of man. Instead, it is expected that its promotion will bring more benefits for the poor and their respective governments.

2.3 Uses of Jatropha

Jatropha or physic nut production is acclaimed internationally for its ability to reclaim degraded sites. It readily establishes itself in extreme environments and requires little management (Mushaka, 1998). It is used extensively in the tropics and subtropics as living fence as it cannot be browsed by animals. The living fence also reduces wind velocity which then becomes effective against wind erosion as witnessed in countries such as Tanzania, Mali and Philippines (Henning, 2009). Besides the living fences or hedges having an anti-erosion effect, the hedges are also resistant to bush fires in addition to improving the soil condition through the accumulation of leaves and fruits which subsequently form organic matter that enriches the top soil.

Jatropha seeds have the potential to produce fuel and oil which are useful for both domestic and industrial use. With the rising fossil fuel prices, *Jatropha* has immense potential as a bio-fuel source. This is because the seed contains up to 40% oil in which 25% can be easily extracted (Mushaka, 1998). Experiments done in Assam, India show that the biodiesel produced in the area was very comparable to the geo-diesel marketed by a local refinery (Barua, 2011). *Jatropha* gives higher oil content per hectare when compared to peanuts, sunflowers, maize, soya or cotton. A tonne of *Jatropha* seed yields 300 litres of diesel (Pawarira, 2010).

According to Peterlowitz (1998) some of the other applications of this multipurpose plant include lubricants manufacture, medicinal purposes, manufacture of candles, soap making, fertilizer manufacture and livestock feeds. Henning (2009) gives a list of specific uses of certain parts of the plant as follows:

- Leaves – pounded leaves applied to horse’s eyes to repel flies;
- Flowers – the species is listed as a honey plant;
- Seeds – used as a contraceptive in South Sudan. Also used for medicinal purposes for skin diseases as well as rheumatic pain (Kgathi, 2007). The oil has been used for illumination, soap making, candles making as well as lubricants, pesticides and softeners manufacture.

- Roots – their ashes are used as a salt substitute;
- Latex – strongly inhibits the watermelon mosaic virus;
- Sap – stains linen. Is therefore sometimes used for marking;
- Shrub – Mexicans grow the shrub for hosting the *lac insect* which is used in medicine as an anti-obesity drug.

Thus, almost every part of the plant is of some importance.

2.4 The Agronomy of Jatropha Curcas L.

2.4.1 Temperature, rainfall and soil

Jatropha curcas L. occurs in hot, dry and tropical regions. But as Henning (2009) mentions, it can also grow in low temperature regions and does resist light frost. It can endure long dry periods due to its deep root system. The plant grows vigorously in damp valleys but it cannot stand water logged conditions for long. Economic returns can be obtained with 200 – 250 mm of rainfall. But higher rainfall amounts of 625 – 750 mm are necessary for higher yields (Wegmershaus and Oliver, 1994). Supplementary water through irrigation may thus become necessary. In terms of soils, the plant requires average to marginal quality, stony to clayey soils. It is cultivated in poor soils with a pH of 4.5 to alkaline. It thrives from sea level to 1,600 m but does particularly well between 450 – 750 m above sea level (Wegmershaus and Oliver, 1994).

2.4.2 Propagation, spacing, land preparation and pruning

The *Jatropha* plant can be easily propagated from seed or cuttings. Seeds can be planted directly into the ground or pre-germinated in sleeves. Planting out is done during the spring or early summer to obtain the fastest growth and take advantage of the first rains. According to Wegmershaus and Oliver (1994), there is no need for ploughing or ripping unless a well known compaction problem exists. Manure application is done two to three weeks after planting. The trees should be pruned to a manageable size of around 1 – 1.5 metres. Removed branches can be used as cuttings or for hedge management. For hedge purposes, plantings are 0.5m inter-row and 0.2 – 0.5m in-row. However, for the general plantations, the spacing is 3 metres inter-row and 1 - 2 metres in row. Arable land should be avoided for food security reasons.

2.4.3 Pests and diseases

Jatropha curcas L. is known as a robust plant. In that regard, not many pests are known to be of economic importance (Henning, 2009). The key pest however is *Pachycoris klugii* Burmeister, which damages the developing fruit. Other pests include grasshoppers, leaf eating beetles, cater pillars as well as leaf hoppers which have got the potential to cause some harm to the plant.

2.4.4 Yields

Competition between *Jatropha curcas L.* and weeds is very little. So is their risk of attack from pests. The life span of *Jatropha curcas L.* plant is about 50 years (Henning, 2009). The plant is in full production at the age of about 5 years. Pollination is by insects. *Jatropha* seed yield can vary, depending on the soil conditions, from 500 – 8,000 kg/ha. Pawarira (2010) alludes that each tree when grown under optimal conditions can produce an average of 4kg of seed per annum. In Cape Verde Islands, yields of 1,750 kg/ha have been recorded for 3 - 4 year old plants. In Malagasy Republic, yields have been as high as 8,000 kg/ha while in India reports of 10 mt per hectare per year have been made (Wegmershaus and Oliver, 1994). According to Henning (2009), in a conference on *Jatropha* held in 2007 in the Netherlands, it was agreed that the yield be put at 3 – 5 mt per hectare of the black dry seed.

2.4.5 Harvesting

Ripe *Jatropha curcas L.* fruits are yellow, that is, the seeds become mature when the colour changes from green to yellow, after two to four months of fertilisation. When the fruit dries, the hull becomes hard and black. The fruits are harvested either as yellow – still containing moisture, or as dry – already black and open. When the fruits are dry, the fruit shell is about 35% of the organic material (Henning, 2009). In Tanzania, it was discovered that the weight of 1,000 seeds was about 680 grammes. Harvesting of *Jatropha curcas L.* is by hand. A *Jatropha* picker – a long wooden stick with a circular comb with a cotton bag attached - is sometimes used on trees that are tall. If the fruits are not picked, they dry but will not fall to the ground. But if the branch with the dried fruits is shaken, the fruits will fall to the ground. Mechanical harvesting has so far proved to be a bit difficult.

2.4.6 Oil content of seed

The oil content of *Jatropha* seed is between 30 – 35% (Henning, 2009). But Mushaka (1998) reckons that the seed contains up to 40% oil in which 25% can easily be extracted. The seed contain some chemical properties which are poisonous which makes it inedible. The seed or oil was also found to be toxic to rats, goats, sheep and calves (Pawarira, 2010). But while *Jatropha* is acclaimed for its high oil content, farmers in Swaziland have been reported to be complaining of low oil content when the crop is grown on marginal lands (Burley and Griffiths, 2009). To date, no high yielding varieties have been discovered.

2.5 World Production of *Jatropha Curcas L.* and International Trade

The world market for bio-fuels has been steadily growing over the years, with more countries interested in it because of the need to conserve the environment and for security reasons (Muok and Kallback, 2008). There are many crops that can be used to produce bio-fuels depending on local availability, affordability and government incentive. For example, rapeseed oil is preferred in Western Europe while United States of America prefers soyabeans. Brazil on the other hand is fostering a castor oil biodiesel industry despite being the second largest producer of soyabeans.

The use of edible oil in Africa is however not feasible given a huge gap between demand and supply which makes it therefore mandatory to develop non-edible oils for biodiesel production (Pawarira, 2010). *Jatropha* has therefore been recognised as an alternative energy source. Many multinational companies particularly Scandinavian, European, Indian and Chinese are now scrambling for African land to develop *Jatropha* plantations as well as giant wireless communications companies such as Erricsson and MTN, who are using bio-fuel from *Jatropha* and other oils to power their base stations. There are several advantages to using biodiesel. These include provision of a domestic and reliable energy supply, blending biodiesel with diesel which increases fuel efficiency and its non-toxic and degradable state which is environmentally friendly (ibid).

In Africa, countries with major *Jatropha* plantations include Mali, Burkina Faso, Ghana, Tanzania, Malawi and Madagascar, with total length of *Jatropha* hedges estimated at 75,000 km with a potential to yield about 60,000 mt of seed per annum (Muok and Kallback, 2008). Malawi, Zambia and Zimbabwe are the main growing areas in Southern Africa (Kgathi, 2007). While South Africa introduced incentives in the form of a biodiesel fuel exemption levy of 40% in 2005 and tax depreciation write off, the commercial production of *Jatropha* was banned because environmentalists were being cautious about its potential for invasiveness.

In 2002, it was estimated that world production reached 21,841 million litres for ethanol and 1,503 million litres for biodiesel, which by 2005 had reached 3,524 million litres (Muok and Kallback, 2008). With respect to trade, while Western Europe dominated the market with a 95% market share in 2000, this has, in recent years, been reduced to around 80% as new players such as Asian countries come in the fray. Prices of *Jatropha* seed vary among countries. For example, the price per kilogramme of seed in Malawi and Tanzania is US$0.10 while in India it is US$0.16 (Muok and Kallback, 2008).

2.6 Biodiesel and *Jatropha curcas L.* Production in Zimbabwe

2.6.1 Overview of the National Biodiesel Programme

The shortage of foreign currency, among other challenges which Zimbabwe faced from around 2000 meant that the country failed to import adequate petroleum products (Mtisi and Makore, 2010). A political decision was then made to embark on a national biodiesel production programme in 2004. This programme was largely state driven. According to Mushaka and Revanewako (2009), the programme sought to achieve production of biodiesel to meet 10% of Zimbabwe's fuel requirements - roughly 100 million litres per annum - by 2017. It aimed to produce 360 000 tonnes per annum of feedstock base, which yields about 100 million litres, from an establishment of about 120 000 ha of *Jatropha curcas L.* plantations. This meant that *Jatropha* seed was specified and its export was banned (Mujeyi, 2009). A 35 million capacity biodiesel processing plant was commissioned by the Reserve Bank of Zimbabwe on the outskirts of the capital, Harare. This plant was a 50 - 50 joint venture between the Government of Zimbabwe and Malaysia. While the programme is nationwide, it sought to target small and large-scale farmers in arid and semi- arid areas of Zimbabwe.

While the Government of Zimbabwe approved a draft energy policy in February 2008 for the first time since 1980, there is no comprehensive energy policy on bio-fuels that has been formulated (Esterhuizen, 2010). Despite the biodiesel programme being initiated by the Government in 2004, there is no framework that regulates and promotes investment, production, marketing and use of bio-fuels which meant no meaningful incentives were put in place for meaningful development of the bio-fuel sector. Poor coordination of the biodiesel sector also meant lack of meaningful development with the Ministries of Agriculture, Science and Technology and Energy and Power Development having no clear mandates or obligations (Esterhuizen, 2010).

The Zimbabwean experience is in sharp contrast to the Brazilians. These have a very strong policy towards bio-fuel production. While ethanol was currently the main source of bio-fuel contributing 17% of all vehicle fuel in 2006, major efforts were now focused on biodiesel production (Almeida *et al*, 2007). A law has already been put in place to make it mandatory for all fuel to have 2% blend content. In that regard, *Jatropha* has been touted, among crops such as soyabeans, castor and cotton, as one of the feedstocks that are undergoing massive biodiesel experimentation because of its low cost production and high oil content.

2.6.2 Production Trends

Prior to 1998, about 2,000 ha were under *Jatropha* in Zimbabwe. By 2007, 5,000 ha existed as hedges. A total of 10,000 ha were planted in 2007/8 season under NOCZIM's national biodiesel programme (Mushaka and Revanewako, 2009). Today, the current stand of the plant is estimated at 30,000 ha which is way below the targeted 120,000 ha by 2017 (Esterhuizen, 2010).

Given the low adoption of *Jatropha*, the next chapter explores the theoretical foundations of the adoption process and reviews some empirical evidence on the subject.

CHAPTER 3: LITERATURE REVIEW

3.1 Introduction

In this chapter, section 3.2 gives an outline of the basic concepts and theoretical foundations of adoption analysis. Issues relating to the theories of adoption, the speed of technology adoption and the categories of adopters are discussed. Section 3.3 follows with an overview of the approaches that have been used in the analysis of adoption and diffusion of technologies. Lastly, a review of empirical evidence on factors affecting the adoption of sustainable agricultural practices is presented in section 3.4.

3.2 Basic Concepts and Theoretical Foundations of Adoption Analysis

The availability of new technologies plays an important role in economic development in general and in the agricultural sector in particular. The terms adoption and diffusion are interrelated concepts describing the decisions by an economic unit to use or not use a particular innovation. Oladele (2005) defines adoption of an innovation as a decision to apply an innovation and to continue using it. Abera (2008) describes adoption as a decision to use a new technology or practice by economic units on a regular basis. He further describes diffusion as the spatial and temporal spread of the new technology among different economic units. According to Rogers (1995), there are four factors that influence adoption of an innovation. These include the innovation itself, the communication channels used to spread information about the innovation, time and the nature of the society to whom it is introduced.

Adoption or diffusion can be analyzed on a micro or macro-level scale. Micro or individual adoption refers to the degree of use of a new technology in long run equilibrium when the farmer has full information about the new technology and its potential (Abera, 2008). The focus is thus on the individual adopters and a specific innovation or product rather than on large-scale change. Macro or aggregate adoption focuses on the spread of a technology of a new technology within a region (*ibid*).

The adoption process also involves, on one hand, the choice of how resources are to be allocated to the new as well as the old technology, if the technology is not divisible (for example irrigation). On the other hand, the decision will have to involve allocation of land if the technology is divisible, such as fertiliser (Abera, 2008).

3.2.1 Theories of Adoption

Rogers (1995) presented four adoption/diffusion theories. Each of these theories can be considered in the context of either a top-down or a bottom-up adoption/diffusion process and in either macro or micro-level form.

The first theory is the *Innovation Decision Process Theory*. In this theory, potential adopters of a technology progress over time through five stages in the diffusion process. First, they must learn about the innovation (knowledge), second, be persuaded of the value of the innovation (persuasion), they then must decide to adopt it (decision), the innovation must then be implemented (implementation), and finally, the decision must be reaffirmed or rejected (confirmation). The focus here is on the user or adopter.

The second theory, the *Individual Innovativeness Theory* is where individuals who are risk takers or otherwise innovative will adopt an innovation earlier in the continuum of adoption/diffusion.

The third theory is the *Rate of Adoption Theory*. In this instance, diffusion takes place over time with innovations going through a slow, gradual growth period, followed by dramatic and rapid growth, and then a gradual stabilization and finally a decline (Rogers, 1995; Abera, 2008).

The *Perceived Attributes Theory* is the fourth theory put forward by Rogers (1995). In this case, there are five attributes upon which an innovation is judged: that it can be tried out (trialability), that results can be observed (observability), that it has an advantage over other innovations or the present circumstance (relative advantage), that it is not overly complex to learn or use (complexity) and that it fits in or is compatible with the circumstances into which it will be adopted (compatibility).

3.2.2 The Speed of Technology Adoption

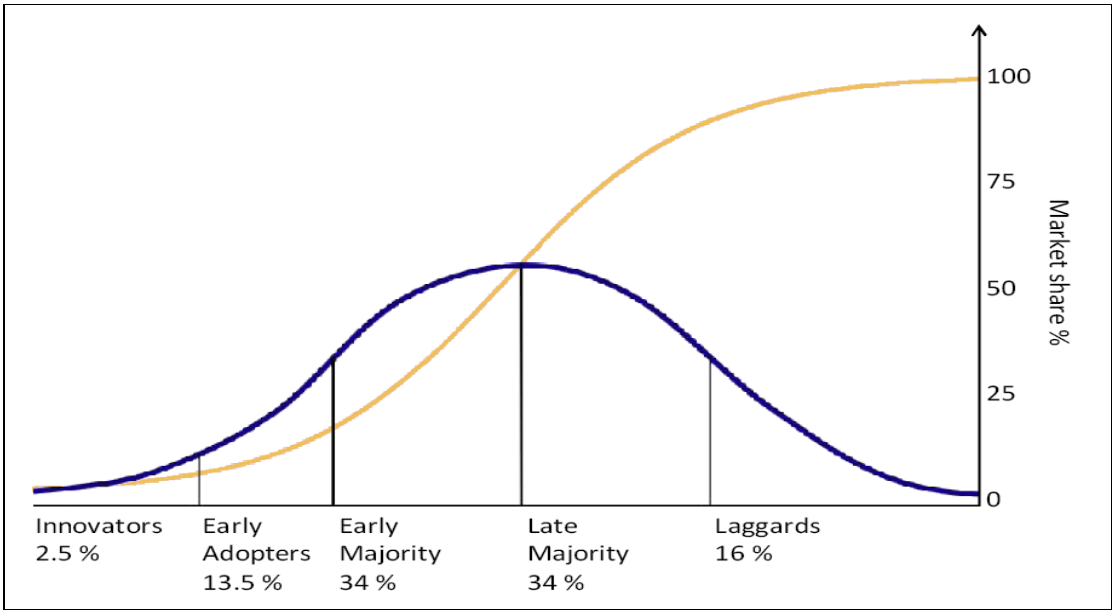
Abera (2008) notes that many adoption studies show great variation in the speed of technology diffusion. Traditionally, it has been argued that the potential perceptions of the attributes of the technology determine the speed of technology uptake. As discussed above, Rogers (1995) identified five attributes upon which an innovation is judged, namely its trialability, observability, relative advantage, complexity and compatibility. The relative advantage, which can be divided into economic and non-economic categories, is regarded as the one with the strongest effect on the rate of adoption (Abera, 2008). The economic category relates to profitability while the non-economic category is a function of leisure and increase in comfort. Adoption of technologies that involve group actions are often slower compared to those which involve individuals because in groups, not all people are interested at the same time.

3.3.3 Categories of Adopters and Stages of Adoption

The traditional adoption/diffusion continuum recognizes five categories of participants according to Moore (1991). *Innovators* tend to be experimentalists. *Early adopters* are technically sophisticated and interested in technology for solving problems. These are usually young and very educated (Abera, 2008). *Early majority* are pragmatists and constitute the first part of the mainstream. *Late majority* are less comfortable with technology and are the sceptical second half of the mainstream. Lastly the *laggards* may never adopt technology and may be antagonistic and critical of its use by others. These are usually old, less educated and not risk takers (Abera, 2008).

The distribution of these groups within an adopter population typically follows the familiar bell-shaped curve as shown in Figure 2 below. Moore (1991) sees these groups as significantly different "markets" in the "selling" of an innovation to adopters.

Figure 2: The traditional diffusion continuum process



Source: Moore (1991)

In the adoption literature, two approaches to agriculture technology adoption have been promulgated. On one hand, farmers can take up the whole technology package. On the other hand, they can take up just a part of the technology and add new components of the technology on a step wise basis (Abera, 2008). The major reasons proffered for sequential adoption of new technologies include profitability, riskiness, uncertainty, lumpiness of investment as well as institutional constraints.

3.3 Approaches to Analysing Technology Adoption and Diffusion

Abera (2008) notes that several analytical frameworks have been used to analyse technology adoption and diffusion. The following sections provide details of the technology diffusion and adoption models.

3.3.1 Models detailing technology diffusion

Models detailing technology diffusion fall into static and dynamic models (Abera, 2008). Static models were commonly represented by the logistic regression model and its variants. The logistic function was specified as follows:

$$\frac{\partial Nt}{\partial t} = gt(N^m - Nt) \quad \text{..(1)}$$

Where $\frac{\partial Nt}{\partial t}$ is the rate of changes in adoption over time *t*

gt is the coefficient of diffusion, which measures how fast diffusion occurs

Nt is the cumulative frequency of adopters at time *t* and

N^m is the maximum number of adopters is a social system over time.

Source: Abera (2008)

This model was used by Griliches in the study of diffusion of hybrid maize in United States (Abera, 2008). But some have questioned the stringent assumptions of the model such as that of constant population and that of fixed adoption ceiling. These assumptions have subsequently been relaxed and better and improved results were obtained (ibid). Further, the static diffusion model has been criticised as providing no rationale for assuming that diffusion follows a particular trend in time and the assumption of fixed ceiling on the adopting population as being unrealistic.

Dynamic diffusion models allow the determinants of the models to be changed every time as time changes, meaning that it captures the rate of adoption more accurately than the static diffusion models (Abera, 2008).

3.3.2 Models analyzing adoption of technologies

Like diffusion, most adoption studies have also used both static and dynamic models. Static models attempts to answer what influences a farmer's choice at any specific place and point in time. Logit or probit models have been extensively used which capture the adoption decision as dichotomous where a functional relationship between the probability of adoption and a set of regressors is econometrically determined. The set of regressors impose effects on the dependent variable but do not measure the degree of intensity of the adoption. The logistic distribution is used in the case of the logit distribution while the normal distribution is used in the probit model (Gujarat, 2004; Abera, 2008). The Tobit model however, is able to measure the intensity of adoption, though it imposes restriction on the variables and coefficients that it uses to compute adoption decisions. Alternatives to these models include the use of the double hurdle models (which include the Heckman Model) which take into account zero observations (Abera, 2008).

Dynamic adoption models allow for farmers' adoption decisions to change with time as they get new information or skills on how to grow the crop or how to improve marketing of the crop. Thus, current market or growing season experiences or experiences from the other farmers are used to improve decisions about production in the next production season (Abera, 2008). That's, the collection of information on profits/losses from other farmers will help farmers shape their perceptions about their excepted return from the new technology. One dynamic adoption model that has been employed is the Bayesian approach which has been used to explain the decision maker's perception about a new technology.

3.4 Review of Empirical Evidence on Factors Affecting the Adoption of Sustainable Agricultural Practices

A wide range of economic, social, physical, technical and institutional aspects of farming influence the adoption of agricultural production technologies. In a review of adoption of agroforestry technologies, Pattanayak *et al* (2002) established that there were five basic categories of determinants of adoption. These were farmer preferences, resource endowments, market incentives, biophysical factors and risk and uncertainty. Farmer preferences include risk tolerance, conservation attitude and intra-household homogeneity. But since these are difficult to model, proxies such as age, gender, education and social status are used instead. Resource endowments include assets which a household has such as land, labour, livestock and earnings. Market incentives relate to either lowering of costs or increase in benefits from adopting the technology. Economic determinants include issues such as prices, transport availability, availability of markets and potential losses or gains. Thus, the likelihood of a factor to increase the net benefits associated with the technology is likely to have a positive influence on adoption. Bio-physical factors relates to the physical production process such as soil quality, slope of farmland and plot size. Lastly risk and uncertainty reflect the unknowns in the market and institutional environment under which decisions are made. Fluctuation in rainfall pattern, commodity prices are some of the risks incurred.

A review by Ruttan (1977) on the adoption of Green Revolution technologies reveal that adoption of high yielding varieties of wheat and rice were undertaken where they were technically and economically superior to local varieties. Further farm size and farm tenure were found not to be serious constraints on the adoption of new high yielding varieties (Abera, 2008). A comprehensive adoption study by Feder et al. (1985) and Feder and Umali (1993) showed that farm size, risk, human capital, labour availability, access to credit and land tenure systems were important factors (ibid). However, studies by Besely and Case (1993b) and Foster and Rosenzweig (1995) using panel data showed that learning from own experience and neighbours' experiences were important factors in determining adoption (ibid).

Recent adoption studies in Europe, Asia and Africa have identified farm and technology specified factors, institutional, policy variables and environmental factors to explain the patterns and intensity of adoption. For example, Oladele (2005) highlights that some studies have shown strong and positive correlation between farming size and adoption while others have shown a positive and significant association between age, farming experience, training received, social-economic status, economic motivation, innovativeness, information source and adoption. Other studies have however shown household size not significantly related to adoption.

Logit results of a survey carried out by D'Souza *et al* (1993) for West Virginia farmers in the United States of America in determining the characteristics associated with the adoption of sustainable agricultural practices indicated that human capital characteristics such as age and education were significant determinants of the adoption decision.

A Principal Components Analysis (PCA) and double hurdle model have been used by Legese *et al* (2009) to investigate the effects of wealth status on adoption of improved maize varieties in Ethiopia. The PCA was used to compute wealth indices while the double–hurdle model was used to analyze factors that influence the probability of adoption and intensity of use the adopted varieties. The results of the study indicated that the gender of the household, number of extension visits, perception of farmers about seed availability, field pest resistance and early maturity were found to be statistically significant in influencing the probability of adoption of the poorly endowed households but were not significant for the well endowed ones.

A lot of multinational companies particularly from Europe and Asia are scrambling for African land to plant *Jatropha* to generate biodiesel to meet their energy requirements (Pawarira, 2010). But despite the scramble for land to grow *Jatropha*, its production still poses many problems. In a study of the constraints perceived by farmers in the adoption of recommended *Jatropha* cultivation practices in the Udaipar District of India, Meena and Sharma (2006) using scores for ranking constraints on 200 farmers found that, in order of importance, the constraints were: lack of information and technical guidance, inadequate training for acquiring skills on *Jatropha* cultivation, lack of suitable *Jatropha* plantation schedule, long gestation period of *Jatropha,* adverse climatic and edaphic factors for survival of plants, lack of knowledge about scientific cultivation of *Jatropha* , and lack of awareness of the economic value of *Jatropha* seeds. The study concluded that lack of technical guidance and information, non-availability of improved *Jatropha* plants and lack of marketing facilities for sale of produce were perceived as the major challenges in the growing of *Jatropha.*

In another study to assess and then compare the levels of adoption of agroforestry technologies between trained and untrained farmers in Zimbabwe, and identify factors that affect adoption of technologies, Parwada *et al* (2010) used a structured questionnaire on 300 smallholder farmers selected by snowballing from villages where change agents had been trained by the International Center for Research in Agro Forestry (ICRAF). The study showed that there were low levels of awareness of agro-forestry technologies among farmers and that formally trained farmers adopted agro-forestry technologies more than the informally trained ones. Furthermore, using the logistic regression model, the study showed that the likelihood to adopt live fence was influenced significantly by land ownership, awareness, training, drought, labour and local institutions. Adoption of trees for nutrition, such as mangoes, was influenced by membership to a farming group, awareness, training, land size and local institutions. Adoption of improved fallows was influenced by employment status, membership of farmer, awareness and land size while factors that influenced adoption of fodder banks were employment status, awareness and training.

In Mozambique, contrary to claims that *Jatropha* is a potential poverty buster, Ribeiro and Matavel (2009) found out that it is planted in direct replacement of food crops by subsistence farmers. Given that around 87% of Mozambicans are subsistence farmers and produce 75% of what they consume, food production was compromised in that case. Moreso, their very weak linkages with the markets and lack of storage capacity, communication and information makes it difficult to benefit from cash crop production. The study thus buttresses the point that *Jatropha* development and adoption should be halted until some of the major development issues surrounding subsistence farming are addressed and rural communities obtain food sovereignty.

In spite of fears of *Jatropha curcas L.* being a threat to the livelihoods of farmers in Mozambique, in another study by Grass *et al* (2008) on the economic viability of *Jatropha* in India's wastelands it was indicated that *Jatropha* viability can be increased through improved breeding of new varieties, lowering of production costs as well as a clear and concise effort towards formulation of a policy regime that supports production and encourage diffusion of the technology. In yet another contradiction to the Mozambican experience, in Brazil, it was discovered that *Jatropha curcas L.* growers had more income compared to their non producing counterparts (Finco and Doppler, 2009).

While in Zimbabwe it was established by Tigere *et al* (2006) that *Jatropha curcas L.* production has a potential to improve livelihoods due to its adaptation to the local environment and fast growth rate, Mujeyi (2009) found out that there were certain important characteristics of households which affected whether they would adopt commercial utilization of the seed or not. These were found to be the size of land, wealth status, access to credit, *Jatropha* tree population and perception about selling prices.

CHAPTER 4: RESEARCH METHODS

4.1 Introduction

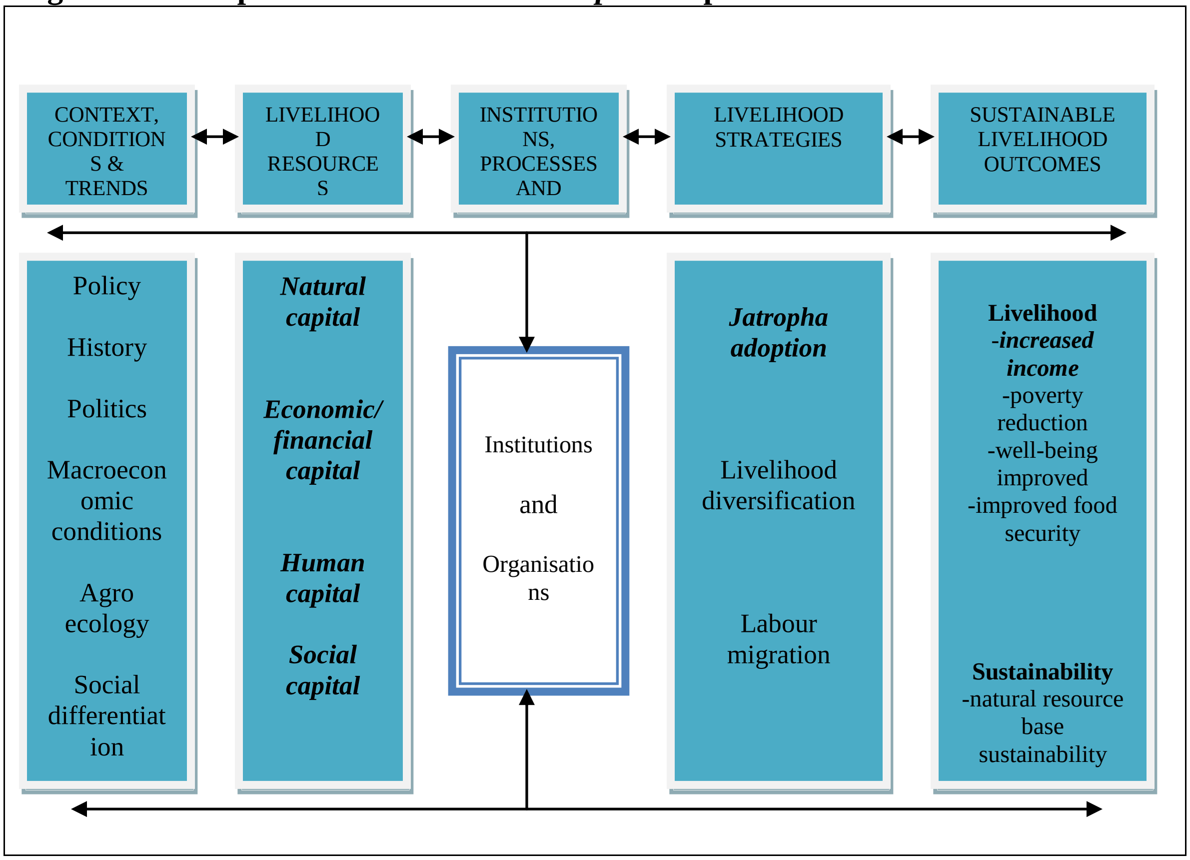
In this chapter, the sustainable livelihood conceptual framework that is used in this study is presented. This is followed by sections on data requirements and a description of the study area and the sampling procedure that was employed. The last section of the chapter presents the analytical tools that are used in the study which include descriptive statistics, the binary logistic regression model and the policy analysis matrix.

4.2 Conceptual Framework

The socio-economic characteristics which affect *Jatropha curcas L.* adoption are explored in this study using the sustainability livelihood framework. According to Scoones (1998) and Elasha *et al* (2005), a livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. It is sustainable when it can cope with and recover from stresses and shocks, maintain or enhance its capabilities and assets, while not undermining the natural resource base. Knutsson (2006) alludes that a sustainable livelihood framework is a fresh vision of a holistic and integrative approach to rural development. People are of paramount importance in this framework as much as their strengths herein referred to as assets or capital (DSGZ, 2002).

This sustainability livelihood framework (SL) within which *Jatropha* adoption is explored is shown in Figure 3. The question which the framework tries to answer is: given a particular context i.e. the policy setting, history, agro-ecology and socioeconomic conditions, what combination of livelihood resources (different kinds of capital) results in the ability to follow what kind of livelihood strategies and with what outcome (Scoones, 1998). Of interest also in the framework are the institutional processes which mediate the ability to carry out such strategies and achieve particular outcomes.

Figure 3: Conceptual framework for *Jatropha* adoption



Adapted from: Scoones (1998)

The ability to pursue different livelihoods strategies depends on the basic material, social, tangible and intangible assets which people have. As shown in Figure 3, four levels of capital are presented which are critical for any adoption of a technology. The natural capital refers to the natural resource stocks (water, air, genetic resources etc) and environmental services (hydrological cycle, pollution sinks etc) from which resource flows and services required for livelihoods are derived. Economic or financial capital refers to the cash/credit, savings, basic infrastructure and production equipment which are necessary for the pursuit of any livelihood strategy. Human capital refers to the skills, knowledge, ability to labour and good health as well as physical capability to pursue different survival means. Social capital refers to the social claims, networks, relations, affiliations and associations upon which people draw when pursuing different livelihood strategies which require coordinated activities. Thus, in order to create livelihoods, people combine different capital endowments which they have access to and control over

(Scoones, 1998). As such, the four levels of capital categorized above as natural, financial, human and social are essential for adoption of any technology, in this particular instance *Jatropha curcas L.*, as a livelihood strategy for increased income as a sustainable livelihood outcome.

Whilst a quantitative description of how the different kinds of capital are linked to *Jatropha* adoption and the consequent livelihood outcomes is vital, it is of paramount importance to understand how these processes are linked to establishment of sustainable livelihoods. A description of institutions and organisations involved in the *Jatropha* system is crucial. Institutions are the rules and norms of a society which can be formal or informal. Organisations are the players of the game. As such, understanding institutions is therefore necessary for the identification of barriers or restrictions and opportunities to sustainable livelihoods (Scoones, 1998).

This study adopted the sustainability livelihood framework specifically focusing on natural, human, social and economic capital as resources that determine *Jatropha curcas L*. adoption at the household level. The sustainability outcome of increased income was brought out under the policy analysis matrix methodology which shows whether income increases or not by embarking on *Jatropha* production as the net economic benefits are very crucial in determining adoption.

4.3 Data Requirements

In order to address the objectives and test the hypotheses presented in Chapter 1, Table 1 captures the analytical tools and the data that will be used**. S**tructured household questionnaires were used for primary data collection backed up by key informant interviews and focus group discussions to establish the circumstances under which *Jatropha curcas L.* production is being done and the factors influencing its adoption. This cross sectional technique makes it possible to capture data on attitudes and behaviours which may have an important bearing on production and adoption (Odhiambo and Nyangito, 2003). The cross sectional study generates basic information about users and non users of a technology (Doss, 2003).

Table 1: Data Analysis Matrix

Objective	Hypothesis	Analytical tool	Data Used
To characterise growers and non-growers of *Jatropha* in the communal lands of Shamva District.	There is no difference in socio-economic characteristics of growers and non-growers of *Jatropha* in the communal lands of Shamva District	*Descriptive statistics*	*Primary data* *- gender* *- marital status* *- level of education* *- age* *- household size* *- farm size* *- farming experience* *- membership of farmer* *- ownership of Jatropha.* *- asset ownership by farmers* *- access to extension services* *- access to credit services* *- crop and livestock production* *- on and off-farm income* *- net farm income* *- Jatropha curcas L. production*
To establish the socio-economic factors which determine the adoption of *Jatropha*	Sex, age, size of the household; literacy level; size of land holding and wealth status of a household affects the adoption of *Jatropha*	*Logistic regression model*	*Primary data* *- Sex of head* *- Marital status* *- Age of head* *- Size of the household* *- Literacy level of household head* *- Size of land holding* *- Membership of farmer* *- Years of experience* *- Wealth category of household* *- Perception on selling price* *- Access to credit* *- Source of income* *- Contact with the extension worker*
To evaluate the level of economic incentives or disincentives existing in the current policy environment with respect to *Jatropha* adoption.	Current government policies are discouraging *Jatropha* adoption.	*Policy analysis matrix (PAM)*	*Primary and secondary data* - Jatropha budget - Domestic prices of inputs and outputs - International prices of inputs and outputs - Social prices of inputs and output

4.4 Study Area

The study was done in Shamva District which is situated in Zimbabwe's Mashonaland Central Province. The location of the district is shown in Figure 4. According to the Government of Zimbabwe Crop and Livestock Assessment Mission of 2008, the district has an estimated population of 104,048 people. It has 24 wards and 21,648 households comprising both the large-scale and small-scale farmers (CSO, 2002). The district, located 90 km north east of the capital Harare in the Mazowe Valley, is characterized by fertile soils. Maize, cotton, tobacco, soyabeans and tropical fruit production are some of the major agricultural activities in the area. The district lies in natural agro-ecological region II, which is characterized by rainfall ranging from 600 – 800mm. It is possible to do intensive crop and livestock production (FAO/WFP, 2010).

Figure 4: Map of Shamva District, Mashonaland Central Province

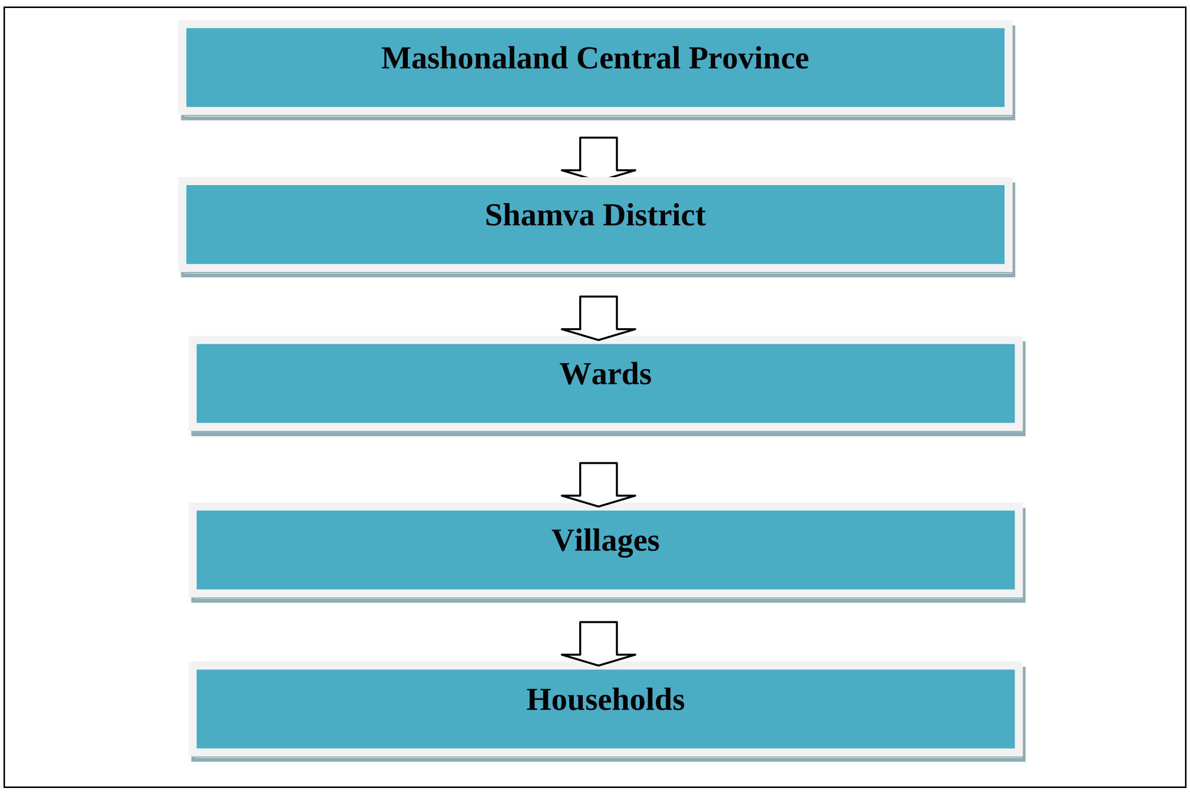
Source: Wikimedia

The district was purposively chosen for a number of reasons. First is that it is one of the pioneering districts in terms of *Jatropha curcas L.* production in the country. Second is that the communal lands of the district are characterized by sandy loams to pure sandy soils which are not very productive in terms of crop production but well suited for *Jatropha curcas L.* production since it thrives well on marginal soils. Third and last was its proximity to Harare which made it convenient in terms of logistical arrangements for the researcher.

4.5 Sampling Technique

The unit of sampling used in this study was the household. Figure 5 shows the sampling technique that was employed in the study. From the district, a ward was chosen in which households within villages were subsequently chosen.

Figure 5: The sampling procedure for the study



As alluded to above, the district comprises of both large-scale and smallholder farmers. Smallholder farmers are found in 13 of the 24 wards i.e. wards 1 – 10, 11, 12 and13. While wards 5, 6, 10, 11 and 13 had some areas where *Jatropha curcas L.* production was occurring, the number of growers was insignificant. The other wards did not have any Jatropha production at all. Sampling was thus confined to ward 12 where 62

Jatropha growers and 411 non-growers were present. This meant that growers of *Jatropha* constituted about 13% of the smallholder communal farmers in the ward. A purposively set sample size of 300 farmers constituting 40 growers and 260 non-growers was selected based on the 13% proportion of *Jatropha* growers. Proportional representation was done to avoid a situation where the sampled farmers do not include any *Jatropha* growers. Since a list of *Jatropha* growers and non-growers in each village for ward 12 was made available by AGRITEX officials, a systematic random sample was carried out to select the respective number of farmers. The technique involved a randomized start which was followed by a predetermined order of selection based on the number of smallholder farmers in ward 12. The systematic random sampling procedure ensures that every unit of the study population has a known and equal chance of being selected which saves time and costs while maintaining the basic features of probability sampling.

A structured questionnaire was then used to collect data from each selected household. The main types of data collected were household characteristics, asset ownership, crop and livestock production and *Jatropha curcas L* production and marketing. This data collecting instrument is shown in Appendix I.

4.6 Analytical Tools

4.6.1 Descriptive statistics

Descriptive statistics were used to characterize sampled smallholder communal farmers who constituted both growers and non growers of *Jatropha curcas L.* These centred on summarizing the following variables, including computations of relevant t-test statistics:

- gender
- marital status
- level of education
- age
- household size
- farm size
- farming experience
- membership of farmer
- ownership of *Jatropha curcas L.*
- asset ownership by farmers
- access to extension services
- access to credit services
- crop and livestock production
- on farm and off-farm income
- net farm income
- *Jatropha curcas L.* production

4.6.2 The binary logistic regression model

The study analyzed dichotomous responses, i.e. whether the farmer grows *Jatropha curcas L.* or not. In that regard, a binary logistic regression model (logit) was used. The model is a useful way of describing the relationship between one or more independent variables (e.g., age, sex, etc.) where there is a binary response variable – ownership of *Jatropha* in this case - which is expressed as a probability. This model was chosen for its simplicity and its ability to take as many regressors as the underlying adoption theory permits. Mujeyi (2009) also alludes to the fact that its parameter estimates are asymptotically efficient and consistent in addition to variables not being necessarily normally distributed.

According to Gujarati (2004), the binary logistic regression model is often represented as follows:

$$L_i = \ln\left(\frac{P_i}{1-P_i}\right) = \beta_1 + \beta_i X_i + \mu_i \qquad \textbf{(2)}$$

Where $Li = \ln\frac{P_i}{(1-P_i)}$ – value of the regressand or logit or the odds value

P_i – Probability of growing *Jatropha curcas L.*

β_1, β_i – Intercept and coefficients, respectively

X_i – All independent variables which can either be continuous and/or categorical. These variables are:

Sex of the household head (1 = male, 0 = female)

Marital status (1 = married, 0 = single)

Age of household head

Size of the household

Literacy level of household head (1 = secondary and tertiary, 0 = primary and no education)

Size of land holding

Membership of farmer (1 = Yes, 0 = No)

Years of experience

Wealth category of household (1 = Rich, 0 = Poor)

Perception on selling price (1 = Attractive, 0 = Not attractive)

Access to credit (1 = Yes, 0 = No)

Source of income

Contact with the extension worker (1 = Yes, 0 = No)

Each of the regression coefficients describes the size of the contribution of that factor to the growing of *Jatropha curcas L.* In other words, the coefficients tell how much the logit changes based on the values of the predictor variables. A positive regression coefficient means that the explanatory variable increases the probability of the outcome, while a negative regression coefficient means that the variable decreases the probability of that outcome. Furthermore, a large regression coefficient means that the factor strongly influences the probability of that outcome, while a near-zero regression coefficient means that that factor has little influence on the probability of that outcome. In this regression model, the Maximum Likelihood Method was used to estimate all the parameters using the STATA computer programme where model appropriateness was analysed through the chi-square test.

4.6.2.1 Wealth Ranking Index

Households are endowed with different assets, each to varying levels which ultimately leads to different statuses (Langyintuo, 2008). This therefore makes it difficult to rank them based on their economic status without normalising (or weighting) the assets in a manner that avoids distortions due to different measurement scales. When normalisation is done, indices can then be used to rank households. The challenge here is in the assignment of weights to relevant asset indicators. While options such as *(a)* assignment of weights based on subjective judgement *(b)* constructing a set of weights based on a common factor which can be applied to all the indicators (e.g. market or shadow prices) and *(c)* avoiding the need for weights by running a multivariate regression analysis with all the indicators as unconstrained variables can be used, these produce biased results. This is because, in option *(a)*, it is impossible to find a common factor which could meaningfully be applied to all assets. Option *(b)* is inappropriate given the highly imperfect markets of most commodities while option *(c)* produces biased coefficients due to multi-collinearity of variables. This leaves us, according to Langyintuo (2008), with the fourth option, called the Principal Components Analysis (PCA) where weights are determined mathematically.

The PCA is a technique for extracting from a set of variables those few orthogonal linear combinations of variables that capture information most successfully (Langyintuo, 2008). The wealth index so derived uses the formula:

$$W_j = \sum_{i=1}^{k} [\mathrm{b}i\ (\mathrm{a}ji - \mathrm{x}i)]/si \quad \text{...(3)}$$

Where W*j* – the standardised wealth index for each household

b*i* – the weights or scores assigned to *k* variables on the first principal component

a*ji* – the value of each household on each of the *k* variables

x*i* – the mean of each of the *k* variables

s*i* – the standard deviations.

According to Langyintuo (2008), the other advantage of PCA besides objectivity is that it estimates the contribution of each variable to the underlying common phenomenon and thus enables the ranking of indicators according to their level of importance in determining a household's wealth status.

From the above formula, a negative index (-Wj) means that relative to the communities' measure of wealth, the household is poor while a positive figure of (Wj) means that the household is well off. A zero figure implies that the household is neither poor nor rich. For the sampled Shamva smallholder communal farmers, the wealth category of each household was determined using the Statistical Package for Social Scientists (SPSS).

4.6.3 Policy Analysis Matrix

Governments all over the world intervene in the agricultural sector for one reason or the other. Promoting income growth through provision of public infrastructure such as roads as well as research and development which increase economic activity is one. The promotion of non-efficiency goals such as achieving equity, price stabilization and the principle of paternalism i.e people cannot be the best judges of their needs are some (Monke and Pearson, 1989). Other reasons include the correction of market failures which manifest themselves as market imperfections, externalities and skewed market power, among other things. To analyze the economic incentives which the current policy environment yields for the smallholder communal farmers, a policy analysis matrix (PAM) methodology was used. Analysis of economic incentives is very vital as it is regarded as one with the strongest effect on the rate of adoption (Abera, 2008).

PAM is a framework for measuring the economic effects of any policy change (Monke and Pearson, 1989). It can be used to compute competitiveness as well as protection indicators and transfers. It is a product of two accounting identities namely profitability at both private and social prices and divergences in product and factor markets. The PAM method was used for the farmers who had already adopted *Jatropha curcas L.* production to measure the extent of transfers caused by the set of policies acting on the *Jatropha curcas L.* system as shown in Table 2 below.

Table 2: Policy Analysis Matrix

	Revenue	**Tradable costs**	**Non-tradable costs**	**Profit**
Private prices	**A**	**B**	**C**	**D**
Social prices	**E**	**F**	**G**	**H**
Divergences	**I**	**J**	**K**	**L**

Adapted from Monke and Pearson (1989)

By filling out the elements in the table, an analyst can measure the extent of transfer occasioned by the set of policies on the system and measure the inherent economic efficiency of the system.

Several studies have used the policy analysis matrix (PAM) methodology to analyse the economic effect of government policy. For example, Joubert et al (2010) used it on the potato industry in South Africa; Mohanty et al (2002) used it in analyzing the competiveness of the Indian cotton industry, while other studies have been undertaken by Alabdullah and Nuppenau (2010) and Masters and Nelson (1995).

4.6.3.1 Valuation of tradable and non tradable costs

Private or financial prices are current market prices with their distortions. Social or economic prices are prices that have been adjusted for market distortions. The social prices of tradables are given by comparable world prices (Pearson et al, 2003). For internationally non-tradable goods such as land and labour, the willingness to pay principle is used (Van Rooyen et al, 2001).

Revenues are incomes realised evaluated at both financial and economic prices. Tradable inputs are all intermediate inputs used in the *Jatropha curcas L.* system. Non-tradable or domestic factors are inputs that add value to the tradable inputs but cannot be evaluated at border parity prices, for example land and labour. Profits are total revenues minus total costs while divergences show the difference between financial and economic prices.

4.6.3.2 Calculation of indicators

From the matrix, private and social profitability are shown by D and H respectively where $D = A - B - C$ and $H = E - F - G$. Net divergences are shown by L. If L is positive, it shows general subsidisation of the sector while a negative figure shows general taxation of the sector. The comparative advantage of the system is shown by the domestic resource cost ratio (DRC) given by $\frac{G}{E-F}$. Other indicators important under PAM include the private cost ratio, nominal protection coefficients (NPC) on inputs and outputs, effective protection coefficient (EPC) on tradables as well as the subsidy ratio to producers. These and other various indicators are calculated to draw policy recommendations to both government and other stakeholders involved in *Jatropha curcas L.* business.

4.6.3.3 Multi period PAM budgets

The above PAM table shows a one time or seasonal period. But *Jatropha curcas L.* is a perennial plant. It follows therefore that to obtain a true picture of PAM there is need for several multi-PAM tables to account for several years (Pearson et al, 2005). While it is known that *Jatropha curcas L.* can survive for up to 50 years, its useful economic life is

35 years. This economic life period was used to calculate private and economic profitability of *Jatropha* by computing the net present values (NPV) as shown in Table 3. Having obtained the figures for net present values (NPV) of revenue, input costs and profit, these figures are then inserted into the ordinary PAM table above (Table 2) where interpretations can then done.

Table 3: Multi-period *Jatropha curcas L.* budgets

Year	Revenue	Tradable inputs	Non-tradable inputs	Profit
Interest rate X%				
0				
1				
2				
3				
...				
35				
Net Present Value (NPV)				

CHAPTER 5: SOCIO-ECONOMIC CHARACTERISTICS OF JATROPHA GROWERS AND NON-GROWERS

5.1 Introduction

The smallholder communal farmers of Shamva District were involved in crop production such as maize, tobacco, sweet potatoes and groundnuts. They were also involved in cattle, goat, sheep, donkey, pig and chicken rearing. Of the 300 smallholder communal farmers sampled, 40 or 13% were *Jatropha* growers while 260 were non-growers. This chapter gives a description of the *Jatropha* growers and non-growers. Growers in this context refer to any farmer who had *Jatropha curcas L.* on his or her farm while a non-grower is someone who did not have the plant. A description of household characteristics such as gender, marital status, level of education, age and farm size is provided to establish if any differences between *Jatropha* growers and non-growers exist. Test statistics are performed to sieve out these differences. The chapter essentially addresses the first objective of this thesis which is that of characterisation of the smallholder communal farmers of Shamva District. The chapter also give a brief description of *Jatropha* production for the sampled farmers with regard to uses of *Jatropha* and constraints being faced by farmers in *Jatropha* production, among other things.

5.2 Household Characteristics of Jatropha Growers and Non-Growers

Results show that 39% of the respondents were female while the remaining 61% were males. This indicates that most households, as is the norm, are male headed. Further disaggregation of the data showed that for *Jatropha* growers, 35% were females while 65% were males and for non-growers, females constituted 39% with males taking up the remaining 61%. This shows that there was no significant difference between *Jatropha* growers and non-growers by gender.

On marital status, 3.3% of the 300 farmers indicated that they were single and all belonged to farmers who were non-*Jatropha* growers.

With respect to education, as shown in Table 4, 18 farmers indicated that they did not attain any formal level of education. This represents 6% of the total respondents, which indicates that the population of Shamva District is at least able to read and write since the rest of the respondents indicated an attainment of at least primary education. The relative frequencies between *Jatropha* growers and non-growers show no significant differences at the different levels of education.

Table 4: Comparison of ownership of *Jatropha* and level of education

Ownership status	**Level of Education**			
	No Education	**Primary education**	**Secondary education**	**Tertiary education**
Non-Jatropha grower	15 (5.7%)	143 (55%)	99 (38%)	3 (1.1%)
Jatropha grower	3 (7.5%)	21(53%)	16 (40%)	0 (0%)

Source: Survey results

Table 5 shows the differences in socio-economic characteristics between growers and non-growers of Jatropha with respect to age, household size, farm size, farm experience and source of income. The absolute mean differences between *Jatropha* growers and non-growers indicate that *Jatropha* growers were a little older, had bigger household size and farm size in addition to having more farm experience. Further *Jatropha* growers had more off-farm and net income per household than their counterparts though they had less on-farm income. Off-farm income related to income that accrued from pensions, regular income, seasonal wages to informal activities like gold panning. On-farm income related to income that derived from the carrying out of farming activities on the farm as it relates to both crop and livestock production. On-farm income was in this context defined as the difference between the total revenue received minus the total costs incurred. Net income was the summation of on-farm and off-income.

But while absolute mean differences between *Jatropha* growers and non-growers existed, it is only the socio-economic characteristics pertaining to size of the farm and off-farm income that were significant at the 95% confidence interval.

Table 5: Comparison of socio-economic characteristics between *Jatropha* growers and non-growers

Variable	Growers mean	Non-growers mean	Average for all farmers	t-test for difference between Jatropha growers and non-growers	
				t-statistic	Sig (2 tailed test)
Age (years)	53.30	49.33	49.86	-1.1734	0.084
Household size	4.95	4.32	4.41	-1.720	0.087
Farm size (ha)	2.812	2.205	2.29	-2.947	0.03
Farm experi (years)	23.05	19.17	19.68	-1.448	0.149
Off-farm income (US$)	432.5	247.6	272.27	-2.204	0.028
On Farm Income (US$)	98	130	125.83	0.525	0.60
Net income (US$)	530.7	377.7	398.09	-1.607	0.109

Source: Survey results

In as far as membership to farmer associations is concerned, the results showed that 85% of all farmers were not members to such organizations. This proportion is similar to 86% of *Jatropha* non-growers who expressed their lack of allegiance to farmer associations. The figure is also comparable to 76% of *Jatropha* growers who were not subscribing to farmer association. In other words, there was no significant difference between growers and non-growers in terms of their membership to farmer associations.

According to Langyintuo (2008), households are endowed with different assets, each to varying levels which ultimately leads to different statuses. In that regard, the assets shown in Appendix II which the sampled farmers were endowed with ranged from cultivated farmland to the number of planters. These assets were used as the basis for the computation of the wealth ranking index using the Principal Components Method. This method uses weights determined mathematically, which gives it its objectivity (Langyintuo, 2008).

By employing the Principal Components Method and using the Statistical Package for Social Scientists (SPSS), 56% of all farmers were classified as poor while the remaining 44% were classified as rich as shown in Table 6. On one hand, farmers who owned *Jatropha* and were poor constituted 11% while those who owned *Jatropha* but were rich constituted 16%. On the other hand, those who did not own *Jatropha* and were poor made up 89% while those who did not own *Jatropha* but were rich constituted 84%.

Table 6: Wealth category and ownership of Jatropha

Jatropha ownership	**Wealth category**		**Total**
	Poor	**Rich**	
Does not own Jatropha	150	110	**260**
Owns Jatropha	19	21	**40**
Total	169	131	**300**
Proportion	**56%**	**44%**	

Source: survey results

This shows that there was no significant difference between ownership of *Jatropha* and wealth category.

In the survey, access to services was in two forms. One related to extension while the other related to access to credit services. Access to these services is summarised in Table 7. Farmers who had contact with extension services within one year were deemed to have had access to extension services. A higher proportion of both *Jatropha* growers and non-growers had access to extension services implying no differences between the two categories existed.

Table 7: Jatropha ownership and access to services

	Access to extension services			**Access to credit services**		
	Accessed	**Did not access**	**Subtotal**	**Accessed**	**Did not access**	**Subtotal**
Does not own Jatropha	257	3 (1.1%)	260	14	246 (95%)	260
Owns Jatropha	40	0 (0%)	40	4	36 (90%)	40

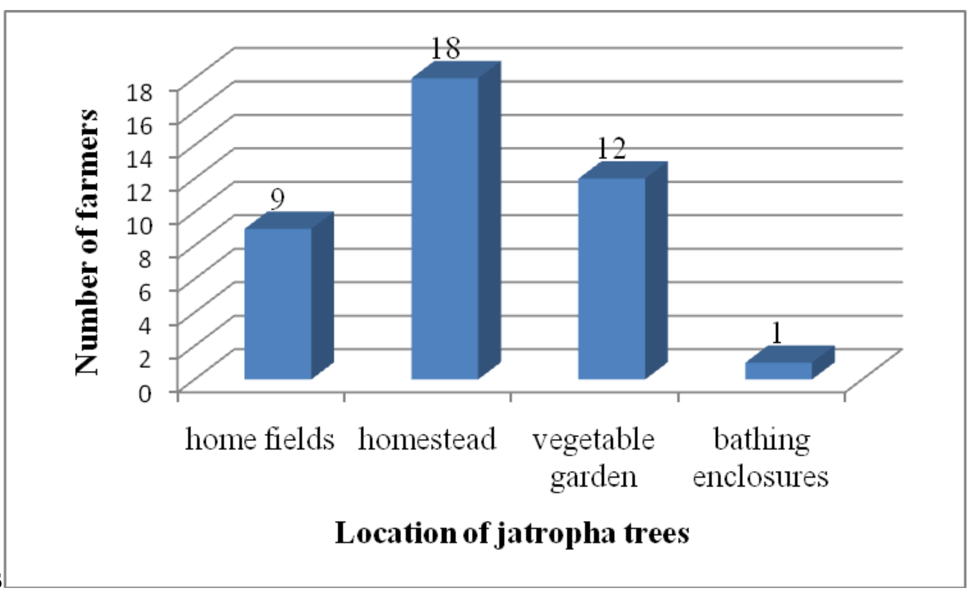
Total	297	3	300	18	282	300

Credit access was defined as having had access to working capital and or subsidised inputs from either government or non-governmental organisations during the 2010/2011 season. Over 90% of both *Jatropha* growers and non-growers had no access to credit facilities meaning that there was no difference in terms of access to credit services between the two groups.

5.3 A brief description on *Jatropha curcas L*. production

As has already been mentioned, 40 out of the 300 smallholder communal farmers interviewed were growers of *Jatropha*. These grew *Jatropha* trees which ranged from a minimum of 10 to a maximum of 350 per household, giving an average of 119 trees per household. Most of these trees, which ranged in height from 1 – 4 metres but averaged 2.4 metres, were around homesteads, as shown in Figure 6. Very few trees were found around bathing enclosures and home fields.

Figure 6: Location of Jatropha trees



Source: Survey results

As far as the spatial arrangement of the *Jatropha* trees is concerned, only two farmers reported *Jatropha* trees intercropped while the rest indicated that they were just acting as a hedge or living fence. With regard to the reproductive method used by farmers, it was quite evident that most farmers preferred the vegetative method as a means of propagating their plants than the use of seeds as 38 out of the 40 *Jatropha curcas L.* growers vegetatively reproduced their plants.

In literature circles, it is well known that *Jatropha curcas L.* has many uses which include soap making, erosion control, oil for cooking and lighting, medicinal uses as well as biodiesel production. However, for the sampled Shamva smallholder communal farmers, all the farmers interviewed indicated that *Jatropha curcas L.* was used as hedge. Only five farmers highlighted that they harvested some seeds with the intention of selling it. The amount of seed (in kg) which they harvested is shown in Table 8. The rest of the farmers did not bother to collect the seed since they cited lack of a market as the major challenge. In fact, 97.7% of both growers and non-growers of *Jatropha curcas L.* expressed the sentiment that the current seed price of US$100/mt was not attractive at all.

Table 8: *Jatropha curcas L.* seed harvested by five farmers

Farmer number	Number of trees grown	Amount of seed harvested (kg)
1	150	20
2	180	30
3	200	60
4	230	100
5	340	175

Source: Survey results

Only 2.5% of the growers deemed the price attractive. The lack of a well developed market to sell *Jatropha* seed and its by-products could probably be the cause for non-harvesting of the seed by many growers.

In terms of constraints faced in *Jatropha* production, the majority of growers (45%) indicated that lack of knowledge on its production was the main problem. This was followed by those who reported termite damage (27%) as the second major problem.

Thirteen percent (13%) expressed that they did not face any problems while 5% apiece mentioned animal damage, poor yields and lack of exposure as the main challenges.

The following chapter investigates whether the differences or lack thereof in the socio-economic factors between growers and non-growers really influence adoption of *Jatropha*.

5.4 Summary

This chapter described household characteristics such as gender, marital status, level of education, age, farm size, household size, farming experience, membership of farmer to associations, wealth status, source of income and access to services. While absolute differences between *Jatropha* growers and non-growers existed, there was no significant difference between the two groups for most of the socio-economic characteristics except for farm size and off-farm income.

The chapter ended with a description of *Jatropha* production where uses of *Jatropha*, constraints being faced by farmers and farmer's price perception among others issues were highlighted. Lack of a market to sell both *Jatropha* seed and its by-products was highlighted by farmers as a major worrying point.

CHAPTER 6: SOCIO ECONOMIC FACTORS INFLUENCING *JATROPHA CURCAS L.* ADOPTION

6.1 Introduction

This chapter employs the logistic regression model to determine the socio economic factors influencing *Jatropha curcas* adoption using the STATA programme. The variables used in the model are sex, marital status, age, size of the household, literacy level, size of land holding, membership of farmer to farmer associations, years of farming experience, wealth status, perception on selling price, access to credit, source of income and contact with extension workers. The next section gives an analysis of multi-collinearity among these variables. This is then followed by a presentation of the results of the logistic regression model. A summary is provided at the end of the chapter.

6.2 Multi-collinearity Analysis

For purposes of removing variables that are correlated to each other, a correlation matrix was run. This yielded results shown in Appendix III. From the Appendix, age and marital status were removed from the model because of high correlation with farm experience and access to extension service respectively. Consequently, all the other variables were used in the model for the determination of the socio-economic factors which have an impact on the adoption of *Jatropha curcas L.*

6.3 Factors Influencing *Jatropha curcas L*. Adoption

Running the logistic regression model with age and marital status omitted because of multi-collinearity, initial results were as follows:

Iteration 0: log likelihood = -117.37071
Iteration 1: log likelihood = -109.21888
Iteration 2: log likelihood = -108.2411
Iteration 3: log likelihood = -108.23936
Iteration 4: log likelihood = -108.23936

Logistic regression	*Number of obs*	=	*297*
	LR chi2(11)	=	*18.26*
	Prob > chi2	=	*0.0757*
Log likelihood = -108.23936	*Pseudo R2*	=	*0.0778*

Jatropha Own.	*Coef.*	*Std. Err.*	*z*	*P>|z|*	*[95% Conf.*	*Interval]*
Gender	*.2636132*	*.4120428*	*0.64*	*0.522*	*-.5439758*	*1.071202*
Educat	*-.0748569*	*.441919*	*-0.17*	*0.865*	*-.9410022*	*.7912885*
Hhdsize	*.119481*	*.0831655*	*1.44*	*0.151*	*-.0435204*	*.2824823*
FmrsGrp	*.0847547*	*.4805418*	*0.18*	*0.860*	*-.8570899*	*1.026599*
FarmSize	*.2909917*	*.1553385*	*1.87*	*0.061*	*-.0134661*	*.5954496*
FarmExperi	*.0126239*	*.0145076*	*0.87*	*0.384*	*-.0158105*	*.0410582*
WealthCat	*.2062947*	*.4014413*	*0.51*	*0.607*	*-.5805158*	*.9931052*
PricePerce	*.1434537*	*1.164542*	*0.12*	*0.902*	*-2.139007*	*2.425915*
CreditAccess	*.2970302*	*.6856668*	*0.43*	*0.665*	*-1.046852*	*1.640912*
OffFarmInc~	*.0007371*	*.0003146*	*2.34*	*0.019*	*.0001205*	*.0013537*
OnfarmInome	*-.0006037*	*.0006251*	*-0.97*	*0.334*	*-.0018288*	*.0006215*
_cons	*-3.838732*	*.638394*	*-6.01*	*0.000*	*-5.089961*	*-2.587503*

ExtensionServ != 1 predicts failure perfectly, ExtensionServ dropped and 3 obs not used

Noting that the overall regression model was not yet significant given that *Prob > chi2 = 0.0757* and that for the *price perception* variable, *P>|z|* was *0.902*, which was the highest, the variable was dropped from the model to yield:

Iteration 0: log likelihood = -117.80234
Iteration 1: log likelihood = -109.8037
Iteration 2: log likelihood = -108.85076
Iteration 3: log likelihood = -108.84916
Iteration 4: log likelihood = -108.84916

Logistic regression	*Number of obs*	*=*	*300*
	LR chi2(10)	*=*	*17.91*
	Prob > chi2	*=*	*0.0566*
Log likelihood = -108.84916	*Pseudo R2*	*=*	*0.0760*

JatrophOwn	*Coef.*	*Std. Err.*	*z*	*P>|z|*	*[95% Conf.*	*Interval]*
Gender	*.216680*	*.4071086*	*0.53*	*0.595*	*-.5812381*	*1.014598*
Educat	*-.1465986*	*.4265671*	*-0.34*	*0.731*	*-.9826548*	*.6894576*
Hhdsize	*.114323*	*.0827881*	*1.38*	*0.167*	*-.0479386*	*.2765846*
FmrsGrp	*.1447989*	*.4740115*	*0.31*	*0.760*	*-.7842466*	*1.073844*
FarmSize	*.3065207*	*.1543112*	*1.99*	*0.047*	*.0040763*	*.6089651*
FarmExperi	*.0076725*	*.0133401*	*0.58*	*0.565*	*-.0184736*	*.0338185*
WealthCat	*.2760816*	*.3847474*	*0.72*	*0.473*	*-.4780094*	*1.030173*
CreditAccess	*.2981932*	*.6846476*	*0.44*	*0.663*	*-1.043691*	*1.640078*
OffFarmInc	*.00074*	*.000315*	*2.35*	*0.019*	*.0001227*	*.0013573*
OnfarmInome	*-.0006072*	*.0006235*	*-0.97*	*0.330*	*-.0018292*	*.0006148*
_cons	*-3.749488*	*.6260994*	*-5.99*	*0.000*	*-4.97662*	*-2.522356*

The above results show that the logistic regression was almost significant having removed the price perception variable. Reverting back to the correlation matrix shown in Appendix III, the next variable with a high correlation coefficient, outside age and marital status, is found between gender and educational level whose correlation coefficient value is *0.3591*. Thus, dropping gender from the logistic regression model makes the overall model significant as indicated below since *Prob > chi2* is less than 5%.

Iteration 0: log likelihood = -117.80234
Iteration 1: log likelihood = -109.94447
Iteration 2: log likelihood = -108.9934
Iteration 3: log likelihood = -108.99204
Iteration 4: log likelihood = -108.99204

Logistic regression	*Number of obs*	=	*300*
	LR chi2(9)	=	*17.62*
	Prob > chi2	=	*0.0398*
Log likelihood = -108.99204	*Pseudo R2*	=	*0.0748*

JatrophOwn	*Coef.*	*Std. Err.*	*z*	*P>|z|*	*[95% Conf.*	*Interval]*
Educat	*-.075951*	*.4065173*	*-0.19*	*0.852*	*-.8727102*	*.7208082*
Hhdsize	*.1152345*	*.0829236*	*1.39*	*0.165*	*-.0472928*	*.2777617*
FmrsGrp	*.1522929*	*.4729001*	*0.32*	*0.747*	*-.7745742*	*1.07916*
FarmSize	*.3025184*	*.1537545*	*1.97*	*0.049*	*.0011651*	*.6038716*
FarmExperi	*.0067586*	*.0132004*	*0.51*	*0.609*	*-.0191137*	*.0326309*
WealthCat	*.3105256*	*.3790444*	*0.82*	*0.413*	*-.4323877*	*1.053439*
CreditAccess	*.3380622*	*.6786805*	*0.50*	*0.618*	*-.9921271*	*1.668252*
OffFarmInc	*.000736*	*.0003143*	*2.34*	*0.019*	*.0001199*	*.0013521*
OnfarmInome	*-.000582*	*.0006254*	*-0.93*	*0.352*	*-.0018077*	*.0006438*
_cons	*-3.639474*	*.5873239*	*-6.20*	*0.000*	*-4.790608*	*-2.488341*

The above results show that at the 95% confidence interval, only two socio-economic factors are statistically significant in determining whether farmers adopt *Jatropha curcas L.* These are farm size and off-farm income. The two socio-economic factors have a positive effect on the adoption of *Jatropha curcas L.* given coefficient values of *0.3025* and *0.0007* respectively. In other words, an increase in farm size is likely to cause an increase in the probability of adoption of *Jatropha curcas L* just as an increase in off-farm income, though the magnitude of the impact is expected to be more from land size than off-farm income. While the size of the household is important at 80% confidence level, it has a positive impact on the adoption of *Jatropha* given its coefficient value of *0.1152*. All the other variables, while not being significant, have a positive impact on the adoption of *Jatropha curcas L.* except the level of education and on-farm income which have a negative impact. Thus, while the other variables are important in so far as being in the logistic regression model, they are not significant at the 95% confidence level.

6.4 Summary

This chapter presented the logistic regression model which enunciated the socio-economic factors which influence the adoption of *Jatropha curcas L.* of Shamva communal farmers. The model showed that education level, household size, membership to a farmers' group, size of the farm, access to credit, farm experience, wealth category of the farmer and the source of income are necessary variables in the determination of adoption of *Jatropha curcas L.* by communal farmers. However, it is only farm size and off-farm income which were statistically significant variables in the adoption of *Jatropha* by communal farmers, in which case they have a positive effect.

Rogers (1995) identified the relative advantage as one of the five attributes upon which an innovation is judged. This relative advantage, which can be divided into economic and non-economic categories, is regarded as the one with the strongest effect on the rate of adoption (Abera, 2008). As previously explained, the economic category relates to profitability while the non-economic category is a function of leisure and increase in comfort. Given this background, the next chapter employs the policy analysis matrix to investigate the level of economic incentives which derives from *Jatropha* adoption.

CHAPTER 7: AN EVALUATION OF ECONOMIC INCENTIVES EXISTING IN JATROPHA CURCAS L. PRODUCTION

7.1 Introduction

This chapter investigates the economic incentives which derive from Jatropha production as these are regarded as one of the attributes of a technology which has the strongest effect on the rate of adoption (Abera, 2008). A policy analysis matrix methodology is employed. First, a financial and economic evaluation of inputs and outputs is done. This is followed by a brief discussion on the economic life and yield estimate of Jatropha. Discounting of financial and economic values of resources then follows whose figures are then imputed in the format of the policy analysis matrix for evaluation of the incentives which the current policy environment yields.

7.2 Physical Input Requirements of Jatropha Production

While *Jatropha curcas L.* require minimum tillage, it is assumed that conventional tillage is done. According to Barua (2011), a hectare of *Jatropha curcas L.* plantation requires 5 kg of seed. At a spacing of *3m*2m*, a total of 1 667 plants suffice in a hectare. Two weedings are necessary in the first year, each requiring 10 people per hectare. Pruning is done once every year up to 5 years and then once every 10 years. To encourage flowering and pod development, gibberellic acid is applied annually from year three onwards.

According to the *Jatropha* production and management guidelines developed by Finealt Engineering Private Limited, a quasi-fiscal organisation created by the Reserve Bank of Zimbabwe to research on *Jatropha*, 25 g of compound D per station are applied during planting. Thereafter 20 g of ammonium nitrate, 120 g of single super phosphate (SSP) and 16 g of MOP are applied per station every year. Given a total of 1667 trees per hectare, this translates to about 42 kg of compound D, 33 kg of ammonium nitrate, 200 kg of SSP and 27 kg of MOP per hectare.

7.3 Economic Life and Yield Estimate of *Jatropha*

While *Jatropha curcas L.* survives up to 50 years if there is no root damage due to rising water table, its economic life ranges from 35 – 40 years (Barua, 2011). An economic life of 35 years is assumed based on Barua (2011). A yield level of 2.4 kg per plant from year three was used. This means 1 667 plants produce an average of 4000 kg per annum (Henning, 2009).

7.4 Financial Valuation of Inputs

Van Rooyen *et al* (2001) contents that financial analysis of a project focuses on the business aspects of a project. It is done using market prices to assess efficiency of resource use and financial contribution of a project. Depreciation, interest payment and tax payments are included in this kind of analysis. The following table gives an outline of each input, its market value and source of information for the price. This provides information that has been used to calculate the financial profitability of *Jatropha curcas L.* production.

Table 9: Financial valuation of *Jatropha curcas L.* inputs

Item	Unit	Unit price (US$)	Information source
Seedlings	1	0.0015	NOCZIM
Land preparation	1 hectare	20	Survey results
Labour	1 Labour day	3	Survey results
Land tax	1 Hectare	2	Ministry of Local Government
Gibberrelic acid	100ml	10	*Farm and City
Compound D	50kg	28	Farm and City
Ammonium Nitrate	50kg	31	Farm and City
Single super phosphate	50kg	20	*InterCrop
MOP	50kg	55	InterCrop
Market interest rate		30.6%	Reserve Bank of Zimbabwe (2011)
Jatropha seed	1 tonne	100	*Finealt Engineering (Pvt) Ltd

*price as at 25 August 2011

7.5 Financial Analysis of *Jatropha curcas L.*

Financial analysis uses market prices to assess efficiency of resource use and financial contribution of a project. The discounted and undiscounted financial information on *Jatropha curcas L.* over the 35 year period were constructed using price information in Table 9 is summarised, from Appendix IV, in Table 10 below. An interest rate of 30.6% was used as the discounting rate (Reserve Bank of Zimbabwe, 2011).

Table 10: Discounted and undiscounted financial analysis of *Jatropha* production

	Benefit	Seed	Land preparation	Gibberellic acid	Fertilizers	Labour requirements	Land Tax	Net benefit
Undiscounted	13200	2.50	20	330	4579.12	300	70	7898.38
Discounted	766.28	2.50	20	19.16	448.84	118.765	6.53	150.48

From the above table, financial analysis of *Jatropha curcas L.* shows a net benefit of US$150.48/ha after discounting compared to the undiscounted value of US$7 898.38/ha.

7.6 Economic Valuation of Inputs and Output

Economic analysis determines the economic efficiency of resource use in a project. In other words, project benefits and costs are evaluated at prices that reflect the relative scarcity of inputs and outputs i.e. opportunity costs. These prices are also known as shadow prices (Van Rooyen *et al*, 2001).

Shadow prices are generally classified into three groups. The first one is the world price group. This group includes the cost, insurance and freight (CIF) and the free on board (FOB) prices. CIF is the price of imported goods and services that are internationally traded. FOB price is the price of exported goods and services that are internationally traded. The CIF and FOB prices in essence reflect the opportunity cost of goods and services where the opportunity of international trade exists. The second group of shadow prices is the opportunity cost. This approach is recommended where CIF and FOB prices for inputs and outputs do not exist. The third group is the willingness to pay category. This reflects or shows the willingness of society or groups to pay for goods and services. It is used where the first and the second approaches are not practical to implement (Van Rooyen *et al*, 2001).

In economic analysis, depreciation, tax payments and interest payments are not included since they are transfer payments for resource use. As a result, all externalities are assumed to have been captured in the shadow values of costs and benefits. Inflation is assumed to affect all costs and benefits in the same manner and thus do not lead to any changes in the relative value of prices. Table 11 shows the items whose prices have been adjusted to reflect the shadow prices of inputs and *Jatropha* seed output. Given that no processing of Jatropha seed was reported, it is only the value of the seed that was considered in the valuation of the output.

Table 11: Economic values of Jatropha curcas L. inputs and output (US$)

Item	Unit	Market Unit price (US$)	Valuation method	Assumption	Tax rate	Shadow price after adjust. (US$)	Information source
Seedlings	1	0.0015	Willingness to pay	Tradable good rendered non-tradable by government policy	15%	0.00128	NOCZIM
Land preparation	1 ha	20	Willingness to pay	Internationally non-tradable good	0%	20	Survey results
Labour	1 Lab. day	3	Willingness to pay	Internationally non-tradable good	0%	3	Survey results
Land tax	1 Ha	2	Willingness to pay	Internationally non-tradable good	0%	2	Ministry of Local Government
Gibberrelic acid	100ml	10	World price approach	Good is internationally tradable	15%	8.50	*Farm and City
Compound D	50kg	28	World price approach	Good is internationally tradable	15%	23.80	Farm and City
Ammonium Nitrate	50kg	31	World price approach	Good is internationally tradable	15%	26.35	Farm and City
Single super phosphate	50kg	20	World price approach	Good is internationally tradable	15%	17	*InterCrop
MOP	50kg	55	World price approach	Good is internationally tradable	15%	46.75	InterCrop
Interest rate		30.6%	Willingness to pay	Reflects the time preference of money for society and other groups	-	10%	Reserve Bank of Zimbabwe (2011)
Jatropha seed	1 tonne	100	Willingness to pay	Tradable good rendered non-tradable by government policy	-	100	Finealt Engineering Pvt Ltd

*Market price as at 25 August 2011

7.7 Economic Analysis of *Jatropha curcas L* Production

Using the shadow prices presented in Table 11 for both inputs and outputs, Table 12 summarises, from Appendix V, the discounted and undiscounted economic costs and benefits over the 35 year period. A discount rate of 10%, deemed the true economic interest rate, was used according to the Reserve Bank of Zimbabwe (2011).

Table 12: Economic Analysis of *Jatropha* production (US$)

	Benefit	Seed	Land prep	Gibberrellic acid	Fertilisers	Labour requirements	Land	Net benefit
Undiscounted	13200	2.13	20	280.5	3892.25	300	70	8635.12
Discounted	3163.45	2.13	20	67.22	1086.98	179.29	19.29	1788.54

As in financial evaluation of *Jatropha curcas L.* production, the undiscounted economic values have higher absolute figures compared to the discounted ones having taken into account the time value of money. The table shows that *Jatropha* production is still profitable, in real terms, to the tune of US$1788.54/ha over the 35 year period.

7.8 Evaluation of Economic Incentives in *Jatropha Curcas L.* Production

In order to instigate the economic incentives existing in *Jatropha* production, a policy analysis matrix was used. Because undiscounted values lead to wrong analysis and conclusions because they do not take into account the time value of money, only discounted values were used for calculating the various indices for interpretation. Thus, Table 13 shows the policy analysis matrix for *Jatropha curcas L.* production using the discounted values.

From the table, using private or financial valuation of inputs and outputs, *Jatropha* production is profitable to the tune of US$150.48/ha, having subtracted tradable input costs of US$468.00/ha and non-tradable input costs of US$147.80/ha from a total revenue value of US$766.28/ha. Similarly, using economic values, a total profit of US$1788.54/ha is realised. Recalling that divergences represent the difference between private and economic values, it is noted that revenues diverge by about a negative US$2397/ha, tradable inputs by - US$686/ha and non-tradable inputs by - US$73/ha. It means therefore that with regard to revenues, farmers are receiving less than what they ought to receive by –US$2397/ha. With respect to tradable inputs, farmers are paying much less that what they owe to pay by an amount of US$686/ha, which in itself in an incentive. This incentive is also noticed in the non-tradable factors of production where farmers are paying less than what they ought pay to the tune of US$73/ha. But overall, the net effect of these divergences amount to a total of -US$1638/ha as funds that ought to have been received by *Jatropha* producers over and above what they get under private valuation of resources. In other words, there is an implicit tax of US$1638/ha which is being levied on *Jatropha* producers indicating that the current policy environment is not providing adequate economic incentives for *Jatropha* production.

It is also important to note that an Internal Rate of Return (IRR) value of 9% was obtained under private valuation of inputs and outputs against a cost of capital figure of 30.6% according to the Reserve Bank of Zimbabwe (2011). While a profit or a Net Present Value of US$150/ha was obtained, the IRR figures of 9% is below the cost of capital which means that *Jatropha* production is not a viable business to embark on under the current policy environment. But, by adjusting the current prices of inputs and outputs to remove distortions, an IRR value of 35% is obtained against a 10% cost of capital. This indicates that under economic valuation of inputs and outputs, embarking on Jatropha production is a worthwhile exercise. A change in the current policy environment therefore needs to be done to provide real economic incentives for farmers to be able to adopt *Jatropha* production and produce on a commercial scale.

Table 13: Discounted *Jatropha curcas L.* policy analysis matrix

	Revenue	Tradable Inputs						Non Tradable Inputs					Profit
		gibberrelic acid	D	AN	SSP	MOP	Sub total	Seed	Land prep	Labour reqts	Land	Sub total	
Private Values	***766.28***	19.16	23.52	66.86	261.42	97.05	***468.00***	2.50	20.00	118.76	6.54	***147.80***	***150.48***
Economic values	***3163.45***	67.22	19.99	167.72	655.80	243.47	***1154.21***	2.13	20.00	179.29	19.29	***220.70***	***1788.54***
Divergencies	***-2397.17***	***-48.07***	***3.53***	***-100.86***	***-394.39***	***-146.42***	***-686.21***	***0.38***	***0.00***	***-60.52***	***-12.75***	***-72.90***	***-1638.06***

NB**: Internal Rate of Return (IRR) at Private Prices: **9% *Internal Rate of Return (IRR) at Economic Prices: **35%***

For furtherance of calculation of various indices, the following paragraph describes the various ratios that were calculated from the above policy analysis matrix table.

Nominal Protection Coefficient On Output = $\frac{766.26}{3163.43}$ = **0.24** This ratio is less than one which means that there is no incentive for farmers to produce *Jatropha curcas L.* as they are getting less than what they ought to be getting.

Nominal Protection Coefficient on Tradable Inputs = $\frac{468.00}{1154.21}$ = 0.41. Since the ratio is less than one, it means the value placed on the inputs by farmers is less than what it ought to be. In other words, *Jatropha* farmers are paying less than what they ought to be paying i.e, they are getting incentives.

Effective Protection Coefficient =$\frac{766.28-468.00}{3163.45-1154.21} = 0.38$. The less than one ratio means that the government is not providing any economic incentives for *Jatropha* producers as they are getting less than what they ought to be getting.

Profitability Coefficient = $\frac{150.48}{1788.54} = 0.08$. This means that private profits are just 8% of economic profits. In other words, private profits are lower than what they ought to be pointing to implicit taxation of the sector.

Domestic Resource Cost Ratio =$\frac{220.70}{3163.45-1154.21} = 0.11$. Since the ratio is less than 1, it means Zimbabwe has a comparative advantage in the production of *Jatropha curcas L.*

Social Cost /Benefit Ratio = $\frac{1154.21+220.70}{3163.45} = 0.43$. The ratio of less than 1 indicates generation of profits, since for every US$0.43 used, US$1 is generated as revenue.

Overall Taxation of the *Jatropha* System = US$150.48 – US$1788.54 = **-** US$1638.06/ha. Over the 35 year economic period of *Jatropha curcas L.* production, farmers would have been deprived of about US$1638/ha. With reference to objective ***(c)*** and hypothesis ***(c)*** of this thesis, farmers are therefore being implicitly taxed to the tune of US$1638/ha. In other words, the current policy environment is not providing adequate economic incentives to *Jatropha curcas L.* production to a desired level, despite the country having a comparative advantage in its production. From the various indices calculated, it is apparent that there is need for an upward review of *Jatropha* seed price to encourage production.

7.9 Summary

This chapter presented a financial and economic evaluation of *Jatropha curcas L.* production over a 35 year economic life using the policy analysis matrix. It was noted that *Jatropha* production generated profits at both financial and economic valuation of resources. However, calculation of an IRR shows that it is not profitable in the current policy environment as the IRR of 9% is less than the cost of capital of 30.6%. Adjusting the market prices for distortions not only gives a positive net present value but also gives a higher IRR rate than the cost of capital. Divergences between private or financial and economic values indicated that there is an overall implicit tax of US$1638/ha. It was therefore concluded that the current policy environment therefore needs to be revisited and re-aligned, especially regarding the upward review of *Jatropha* seed price to make it more attractive, if its widespread adoption is to take off the ground.

CHAPTER 8: DISCUSSION

8.1 Introduction

The preceding three chapters presented results as they were obtained from the sampled farmers, which included the use of both primary and secondary data. This chapter explores those results further by drawing parallels from experiences from other countries or regions. As such the next section discusses the socio-economic characteristics of Jatropha growers and non growers. This is followed by a discussion on the factors influencing *Jatropha curcas L* adoption and then by a discussion on analysis of economic incentives in as far as they encourage Jatropha adoption.

8.2 Socio Economic Characteristics of *Jatropha* Growers and Non-Growers

8.2.1 Household Characteristics

Of the total sample size of 300, 39% of the respondents were female while the remaining 61.4% were males. Further disaggregation of the data showed that for *Jatropha* growers, 35% were females while 65% were males and for non-growers, females constituted 39% with males taking up the remaining 61%. This shows that there was no significant difference between *Jatropha* growers and non-growers by gender and the ratios followed the proportion of female respondents. Moreso, 10 or 3.3% of the respondents who were single were all males confirming that females usually marry early compared to their male counterparts. Furthermore, these indicated that they were non-*Jatropha* growers, suggesting that *Jatropha* production is for an elder generation.

With regard to education, the study showed that only **e**ighteen or 6% of the farmers indicated non-attainment of formal level of education, confirming that the majority of population in the sampled district is at least able to read and write. This shows that most of the growers and non-growers of *Jatropha* would at least be able to understand *Jatropha* production as the technology is imparted to them by extension workers. The relative frequencies between *Jatropha* growers and non-growers showed that there were no significant differences at the different levels of education meaning that access to education was not a constraint to *Jatropha* adoption.

The absolute mean differences between *Jatropha* growers and non-growers indicated that *Jatropha* growers were a little older, had slightly bigger household size and farm size in addition to having more farm experience. Furthermore, *Jatropha* growers had more off-farm and net income per household than their counterparts though they had less on-farm income. Off-farm income related to income that accrued from pensions, regular income, seasonal wages to informal activities like gold panning. On-farm income related to income that derived from the carrying out of farming activities on the farm as it relates to both crop and livestock production. It was thus defined as the difference between the total revenue received minus the total costs incurred. Consequently, the net income was the summation of on-farm and off-income. But while absolute mean differences between *Jatropha* growers and non-growers existed, it is only the socio-economic characteristics pertaining to size of the farm and off-farm income that were significant at the 95% confidence interval. Since growers had more land and more off-farm income than non-*Jatropha* growers, it may as well suggests that those with more land were comfortable with growing *Jatropha* as a hedge to avoid use of convention fencing system. Moreso, the higher off-farm income suggests that these farmers spend most of their time away from their plots and thus would be more comfortable with a more permanent fencing type to protect their homestead from straying animals.

On access to extension services, 85% of the respondents did not have any allegiance to farmers' unions. This is probably because while farmers may like services of these unions, they are not willing to part with their hard earned income as subscriptions. This is buttressed by the fact that most farmers, 56%, were poor according to the Principal Components Wealth Ranking Index and that on average, farmers were getting more income from off-farm sources than on-farm. The resource scarcity of the farmers is further evidenced by their 99% access to extension services which is provided free of charge by Government**.**

Over 90% of the growers and non-growers of Jatropha had no access to credit be it from government or non-governmental organisations during the 2010/2011 season. The lack of access to credit between the two groups rendered the variable non-significant in as far distinguishing between them.

8.2.2 *Jatropha* curcas *L* production

Of the 40 *Jatropha curcas L.* farmers, 38 of them used cuttings as a vegetative propagating means. Use of cuttings by Shamwa farmers was synonymous with smallholder farmers in Tanzania who also used cuttings rather than seedlings as these were found to have lower investment costs (Wahl *et al*, 2009). However, the Shamva findings are in sharp contrast to the findings of a study done in Makosa Ward of Mutoko District of Zimbabwe where it was found that the main method of propagation was seed (44%), followed by cuttings (22%) and then both cutting and seed which constituted 34% (Tigere et al, 2006). The use of cuttings by growers of *Jatropha*, which are relatively cheap, could perhaps explain why these plantations were established without any injection of external capital. This is similar to Tanzania smallholder farmers who also self financed themselves in establishing *Jatropha* plantations (Wahl *et al*, 2009).

Whilst *Jatropha curcas L.* has many uses such as reclamation of wastelands, prevention of soil erosion as well as medicinal purposes, the communal farmers of Shamva District only appeared to restrict its use to live fencing around the fields and the homestead while seemingly ignoring some of its important uses (Barua, 2011). Perhaps this tallies with 45% of *Jatropha* growers who reported lack of knowledge as the main challenge in its production. But this live fence attraction is not akin to this district only. In Mutoko district, similar results were also found where the majority of the farmers used it as live fence (43%) where 67% was around homesteads, 20% around gardens and 13% around fields (Tigere et al, 2006). These results were also confirmed by a report in the state owned newspaper, *The Herald*, which stated that for the 2009/2010 agricultural season, about 99% of *Jatropha* seedlings, which were being distributed by NOCZIM, were taken up by communal and A1 farmers and largely planted as hedges (*The Herald*, 25

September 2009). Elsewhere in the world, hedges are also popular in India, Tanzania and Ghana (Wahl *et al*, 2009; Barua, 2011; Aduse-Poku *et al*, 2003).

While some *Jatropha* growers collected seed but did not process it, similar studies in Mutoko District reveal other uses of *Jatropha* besides performing the traditional hedge function. These include soap making, medicinal purposes, lubricants manufacture and manure production (Tigere et al, 2006). Manure from *Jatropha* was shown to have more nitrogen, phosphorus and organic matter when compared to chicken and cattle manure (Tigere *et al*, 2006). Only five farmers out of the 40 harvested some seeds with the intention of selling it. The rest of the farmers did not bother to collect the seed since they cited lack of a market as the major challenge. In fact, 97.7% of both growers and non-growers of *Jatropha curcas L.* expressed the sentiment that the current seed price of US$100/mt was not attractive at all.

All *Jatropha* farmers interviewed did not plant their *Jatropha* in areas where food was planted. Rather they planted it around fields and the homestead. It appears they have heeded the call by government not to plant *Jatropha* on arable land. This is different from a study by Wahl *et al (*2009) in Tanzania who noted that 9 out of 12 farmers planted *Jatropha* on areas where food crops were previously planted. In Mozambique, almost all of the *Jatropha* planted was on arable land in direct replacement of food crops (Ribeiro and Matavel, 2009). Similarly, in Swaziland *Jatropha* was being grown on arable lands by farmers contracted by D1 Oils, a UK based oil company (Burley and Griffiths, 2009). In Kenya, while intercropping was found to be the most common planting regime, it was established that for the average plot size of one acre, intercropping and monoculture were found to be unprofitable due to the low output levels of less than 1kg per tree (Iayama *et al* , 2009). The fencing planting regime nonetheless showed some slight profitability after five years of production. It was thus concluded that smallholder farmers should not massively invest in *Jatropha* production due to the uncertainties in low yields and underdeveloped markets for the product.

As far as agronomic practices on *Jatropha* production were concerned, all farmers interviewed did not bother to use fertiliser, proffer any irrigation nor attended to pruning as well as pests and disease control. Lack of fertiliser application has however been reported in countries such as Tanzania by smallholder farmers where only 3 out of 12 farmers used manure (Wahl *et al,* 2009). Lack of irrigation has been reported in India to cause low yields which consequently renders *Jatropha* production unviable (Ariza-Montobbia et al, 2010). In Mozambique, pests have been reported to require a considerable amount of chemicals to control. Moreover, it was noted that *Jatropha* could possibly habour viruses harmful to cashew nut trees (Ribeiro and Matavel, 2009). The pests and diseases problems have also been reported in Swaziland which consequently cause low yields (Burley and Griffiths, 2009).

Unlike in Tanzania where smallholder *Jatropha* farmers were very close to the marketing points, in Shamva these were not close by (Wahl *et al*, 2009). The marketing problem was also exacerbated by lack of knowledge about its uses and its economic potential. Such lack of adequate knowledge was also reported in Mutoko District of Zimbabwe and in Mozambique where many farmers who planted *Jatropha* in 2007 abandoned it after failing to access markets (Tigere et al, 2006; Ribeiro and Matavel, 2009).

8.3 Factors Influencing *Jatropha curcas L.* Adoption

8.3.1 Level of Education

The survey results indicated that education negatively affects adoption of *Jatropha curcas L*. This means that the more one is educated the less likely they are to grow *Jatropha*. This could probably be explained by the fact that Shamva District does not have a well defined market for *Jatropha* and so farmers do not quite see any value in growing the tree as the perceived benefits are deemed minimal. However, for the nearby Mutoko district, it was found that the level of education positively affected the commercial utilisation of *Jatropha* though the magnitude of the positive effect was not significant (Mujeyi, 2009). The two results however agree on the fact that the level of education is not significant is as far as influencing adoption of *Jatropha* and its commercial utilisation, respectively. A study in West Virginia, United States of America showed that education was an important determinant in the adoption of sustainable agricultural practices (D'Souza et al, 1993). A study on adoption of agroforestry technologies by Parwada *et al* (2010) showed that formally trained farmers adopted agro-forestry technologies more than the informally trained ones.

8.3.2 Household Size

Household size showed a positive effect on the adoption of *Jatropha curcas*. This means a larger household is more likely to adopt *Jatropha curcas* production as it provides a source of labour which is needed in planting, weeding, pruning and picking of *Jatropha* seeds for processing. Mujeyi (2009) also found in his commercial utilisation study, that household size was positively affecting commercial utilisation of *Jatropha*. However, like Mujeyi's study, this variable was found not to be significant in affecting adoption of *Jatropha curcas*. However Parwada's *et al* study (2010) on agroforestry adoption found labour supply to be significantly important in determining adoption.

8.3.3 Membership to a Famers' Group

Belongingness to a farmer's group was found to be positively affecting *Jatropha curcas* adoption. This means that farmers who belonged to any farmer association were likely to adopt *Jatropha curcas* production compared to those who did not belong. However, as the descriptive chapter demonstrated, 85% of the sampled farmers did not belong to any farmer association. It follows therefore that ensuring that farmers belonged to farmer associations is a necessary but not a sufficient condition for adoption of *Jatropha* to occur as this variable was found, like the household size, to be statistically insignificant.

8.3.4 Farm Size

The size of farm was found to have a positive effect on adoption of *Jatropha*. Given that on average the communal farmers have a hectarage of 2.3 ha, this poses a significant constraint on the adoption of *Jatropha* plantations. This probably explains why NOCZIM was only entering into contracts with farmers who had at least 5 ha of land for *Jatropha* production. Any increase in the size of the land therefore means an increase in the adoption rate of *Jatropha curcas* as farmers have more land not only for *Jatropha* production but even for the production of other crops such as maize, groundnuts, beans and sunflowers. This variable was found to be significant at 95% confidence interval. While Mujeyi (2009) found the land size to be significant at 1% level, it was negatively rather than positively affecting the commercial utilisation of *Jatropha curcas L*. His explanation for this was that the small land size of smallholder farmers meant fewer trees being grown which therefore meant that the amount of seed picked was also low. Consequently, this did not justify any commercial utilisation of the crop. Other studies have also found land size not to be an important determinant in adoption of technologies (Abera, 2008).

8.3.5 Farm Experience

Farm experience, like farm size had a general positive effect on the logistic regression model with a coefficient of 0.007. This literally means the more experienced a famer is, the more he/she is likely to adopt *Jatropha curcas L*. Whilst having a positive effect on *Jatropha* adoption, the variable did not have a statistically significant effect. This could have been because there was no significant difference between *Jatropha* growers and non-growers in terms of farm experience. But other studies on adoption showed attainment of farm experience to be an important determinant of adoption (Abera, 2008).

8.3.6 Wealth Status of a Household

With regard to the wealth category of a farmer, the results indicated that a rich household was likely to adopt *Jatropha curcas*, according to the Principal Components measured wealth index. While the wealth status was found to be positively but insignificantly affecting adoption of *Jatropha* in this study, Mujeyi's study (2009) found this to be significant (at 5% level) and negatively affecting the commercial utilisation of *Jatropha*. The differences in the results could be that while resource rich household have assets which help them adopt a technology, it becomes a different case with regards to its commercial utilisation as the same households begin to view the exercise as a preserve of the poor, and as such would not want to be associated with it.

8.3.7 Access to Credit

Access to credit showed a positive effect but not a significant effect on adoption of *Jatropha curcas*. This is buttressed by survey results which indicate that only 6% had some access to some inputs which were not used on *Jatropha* despite 13% of the survey respondents being Jatropha growers. Mujeyi (2009) also found access to credit not to be significant and positively affecting the commercial utilisation of *Jatropha*. The non-significant status of access to credit with regards to *Jatropha* could be emanating from the fact that *Jatropha* needs a low start up capital as it is easily propagated through vegetative means. Abera (2008), however highlights access to credit as an important determinant in adoption of technologies.

8.3.8 Source of Income

The source of income was categorised for the purpose of this study into on-farm and off-farm. While off-farm income had a positive effect on *Jatropha curcas* adoption, on-farm income had a negative effect. The explanation could be that those farmers who get most of their income away from the farm would want to have *Jatropha* around their homes and fields as hedges as they don't have time to be mending the conventional fence as often as they should. Off-farm activities such as gold panning which were reported in survey area needs more time away from home. Contrary to that, those who rely mostly on on-farm income are usually resident on the farm most of the time and so can easily attend to their fences and are thus not worried about erecting a *Jatropha* live fence.

8.4 Evaluation of Economic Incentives on Adoption of *Jatropha Curcas L.*

In literature, the level of profit is defined as total revenue minus total costs. Total revenue is represented by *number of units produced*price per unit* whereas total costs is shown by *number of units of inputs used*costs per unit*. As alluded to before, for the purpose of calculating the profit or the net present value (NPV) and the internal rate of return (IRR), only *Jatropha* seeds were considered as an output, given that no processing was reported.

For yield levels of 4 mt/ha, profit levels or net present values (NPV) of US$150.48/ha and US$1788.54/ha were realised at private and economic prices for the 35 year period.

The positive NPVs illustrate that *Jatropha curcas* production is a worthwhile activity. However, further analysis of the internal rate of return (IRR) shows that at discount rates of 30.6% and 10% for private and economic prices, IRR figures of 9% and 35% were obtained respectively. Thus, at private prices, the IRR is lower than the cost of capital rendering *Jatropha* production a non-profitable enterprise. At economic prices, however, it is a very lucrative business as the rate of return to investment is higher than the cost of capital. In Egypt, a financial analysis of *Jatropha curcas L* production for a 20 year period showed a positive NPV at 25% discount rate and an IRR of 47%, suggesting great potential of the crop (USAID, 2008). But the development of irrigation in India has resulted in the crop being labelled a preserve of the resource rich farmers as the irrigation requires a considerable investment for one to get meaningful yields (Ariza-Montobbia et al, 2010). Similarly, in Swaziland, Burley and Griffiths (2009) notes that it is hard to find anyone who has become rich because of growing *Jatropha* thus rendering the crop an unlikely livelihood mainstay. Ribeiro and Matavel (2009) are of the opinion that for Mozambique, *Jatropha* claims that it increases farm income and is a potential driver for rural development is misinformed at best and dangerous at worst. Because of the low NPV of *Jatropha,* Wahl *et al (*2009) alludes that the crop is not very profitable and as such is uncompetitive when compared to others crops such as sunflowers and potatoes.

Further analysis of the policy analysis table shows that revenues diverge by a negative US$2397/ha, tradable inputs by - US$686/ha and non-tradable inputs by - US$73/ha. For revenues, farmers are thus receiving less than what they ought to receive, indicating an implicit tax on output. For tradable and non-tradable inputs, however, an implicit subsidy is observed, which in a way, is an incentive. The net effect of these divergences amount to a total of -US$1638/ha as funds that ought to have been received by *Jatropha* curcas L. growers over and above what they would have got under private valuation of resources.

The Nominal Protection Coefficient on Output of 0.24 confirms the lack of incentives for farmers to produce *Jatropha curcas L.* as they are getting less than what they ought to be getting. The following table indicates that *Jatropha* growers in other countries were getting on average US$281 per tonne of seed in 2007 which went up to an average of

US$606 per tonne in 2008. This is in sharp contrast to Zimbabwe farmers who are getting US$100 per tonne. The output market price thus suggests a need for a radical upward review of *Jatropha* seed prices if the country is to entertain any hopes of large stocks of *Jatropha* feedstock for biodiesel production.

Table 14: Jatropha seed prices in selected countries (US$/mt)

	2007		**2008**
Country	**US$ /mt**	**Country**	**US$ /mt**
Malaysia	300	South Korea	750
Pakistan	160	China	550
India	375	India	625
German	300	Canada	500
Average	**281**	**Average**	**606**

Source: USAID (2008)

The nominal protection coefficient on tradable inputs was found to be less than one which meant that farmers were paying less than what they ought to be paying. This implies an implicit subsidy on tradable inputs. But the subsidy the farmers are receiving on inputs is outweighed by the implicit tax on output. This is why the effective protection coefficient is 0.38. The less than one ratio means that the government is not providing any incentives for *Jatropha* growers as they are getting less value addition at private prices compared to economic prices. The profitability coefficient value of 0.08 means that private profits are just 8% of economic profits. However, the domestic resource cost ratio of 0.11 indicates that Shamva communal farmers have a comparative advantage in the production of *Jatropha curcas L.*

The social cost benefit ratio of 0.43 indicates generation of profits since for every US$0.43 used, US$1 is generated as revenue. However, the difference between private and economic profits shows an overall taxation of the *Jatropha* system. This is shown by *US$150.48/ha* less *US$1788.54/ha* which gives a negative *US$1638.06/ha*. Thus, over the 35 year economic period of *Jatropha curcas L.* farmers would have been deprived of about *US$1638/ha*. Overall, the economic incentives prevailing in the current policy environment are not adequate to encourage *Jatropha* adoption.

As has been demonstrated above, the main area that has been the source of the divergences is the low value of output. There is a need to review the output price upward if *Jatropha* production is to be competitive and be able to compare favourably with other crops such as sunflowers and potatoes.

CHAPTER 9: SUMMARY, CONCLUSION AND RECOMMENDATIONS

9.1 Summary

The smallholder communal farmers of Shamva District were involved in crops such as maize, tobacco, sweet potatoes and groundnuts. They were also involved in cattle, goat, sheep, donkey, pig and chicken rearing. Of the 300 smallholder communal farmers sampled, 40 or 13% were *Jatropha* growers while the other 260 were non-growers. Results showed that 39% of the respondents were female while the remaining 61% were males while on marital status, 3.3% of the 300 farmers indicated that they were single and all belonged to farmers who were non-*Jatropha* growers. With respect to education, 6% of the total respondents indicated no attainment of formal education. The relative frequencies between *Jatropha* growers and non-growers showed no significant differences at the different levels of education.

The absolute mean differences between *Jatropha* growers and non-growers indicated that *Jatropha* growers were a little older, had bigger household size and farm size in addition to having more farm experience. Further *Jatropha* growers had more off-farm and net income per household than their counterparts though they had less on-farm income. But while absolute mean differences between *Jatropha* growers and non-growers existed, it is only the socio-economic characteristics pertaining to size of the farm and off-farm income that were significant at the 95% confidence interval.

In as far as membership to farmer associations was concerned, the results showed that 85% of all farmers were not members. This proportion is similar to 86% of *Jatropha* non-growers who expressed their lack of allegiance to farmer associations. The figure is also comparable to 76% of *Jatropha* growers who were not subscribing to farmer association. As a result, there was no significant difference between growers and non-growers in terms of their membership to farmer associations.

Using the Principal Components Method, it was shown that 56% of the farmers were poor while the remaining 44% were rich. The results showed that there was no significant difference between ownership of *Jatropha* and wealth category.

Access to extension services among farmers was as high as 99%. But access to credit services was only 6% for all the farmers. Consequently, there were no significant differences between growers and non-growers of *Jatropha* in terms of the access to these services.

Most of the *Jatropha* trees which were planted by farmers were around homesteads, with very few being found around bathing enclosures and home fields. All the farmers interviewed indicated that *Jatropha curcas L.* was used as hedge. Only five farmers highlighted that they harvested some seeds with the intention of selling it. The rest of the farmers did not bother to collect the seed since they cited lack of a market as the major challenge. Lack of knowledge on *Jatropha* production was cited as the main challenge.

The logistic regression model was used to identify the socio-economic factors which were affecting *Jatropha curcas L* adoption. The model showed that education level, household size, belongingness to a farmers' group, size of the farm, access to credit, farm experience, wealth category of the farmer and the source of income were necessary variables in the determination of adoption of *Jatropha curcas L.* by communal farmers. However, it is only farm size and off-farm income which were significant variables in the determination of *Jatropha* adoption by communal farmers at the 95% confidence interval.

The study used a *Jatropha* yield level of 4 mt/ha to calculate the net present values (NPV) and the internal rate of return (IRR) using the policy analysis matrix. NPV was found to be US$150.48/ha and US$1788.54/ha at private and economic prices for the 35 year economic period. The positive NPVs illustrated that *Jatropha curcas* production had a potential to boost rural income. However, further analysis of the internal rate of return showed that at discount rates of 30.6% and 10%, according to the Reserve Bank of Zimbabwe, for private and economic prices, IRR figures of 9% and 35% are obtained respectively. Thus, the IRR at private prices was lower than the cost of capital rendering *Jatropha* production a non-profitable enterprise. At economic prices, however, it is a very lucrative business as the rate of return to investment is higher than the cost of capital. Further analysis of the policy analysis table showed that revenues diverged by about a negative US$2397/ha, tradable inputs by -US$686/ha and non-tradable inputs by -US$73/ha. With respect to revenues, farmers were thus receiving less than what they ought to receive, indicating an implicit tax on output. For tradable and non-tradable inputs, however, an implicit subsidy was observed, which in a way, is an incentive. But despite a comparative advantage in the production of *Jatropha*, the net effect of these divergences amounted to a total of - US$1638.06/ha, which indicated overall taxation of the sector. Thus, the current policy environment was not providing adequate economic incentives to encourage *Jatropha* adoption.

9.2 Conclusion

The lack of adequate land, knowledge on *Jatropha* production and access to markets seem to have confined most *Jatropha* growers to planting it as hedges. If farmers with small pieces of land are targeted, then only hedges should be recommended as these ensure that the plant will not compete with other crops for land. The study findings reveal that the source of income, in this case, off-farm income, had a positive and significant effect on *Jatropha curcas* adoption. It can be generally concluded that targeting of *Jatropha* plantation or hedges should be focused on those farmers who rely less on farm income and those with large tracts of land.

The study showed that using private or financial valuation of inputs and outputs, *Jatropha* production was profitable to the tune of US$150.48/ha, while using economic prices it was profitable to the tune of US$1788.54/ha. Positive production incentives were found in both tradable and non-trade inputs while the output side showed an implicit tax. Overall, the *Jatropha* system showed net divergences amounting to -US$1638/ha, which is an implicit tax on Jatropha farmers over the 35 year economic life of the plant. It is also important to note that an Internal Rate of Return (IRR) was found to higher than the costs of capital under economic valuation of resources than under private or financial valuation. The two measures of cost benefit analysis points to the fact that the current economic environment is not providing adequate incentives to encourage *Jatropha* production. A change in the current policy environment therefore needs to be done to provide real economic incentives for farmers to be able to adopt *Jatropha* and produce on a commercial scale. One such change is a raise in the price of *Jatropha* seed and encouragement of value addition through processing.

9.3 Recommendations

The following are some policy recommendations arising from the study. These have been subdivided into short term, medium term and long term:

Short-term policy recommendations

1. Because of the land constraint, *Jatropha* should be planted as hedges to avoid competition with food for land.
2. There is need for an upward review of *Jatropha* seed price to enhance its competitiveness.
3. There is an urgent need for an introduction of marketing points for farmers to be able to sell their Jatropha seed.
4. There is need for provision of cheap processing machines such as mechanized oil expressers by government and other *Jatropha* promoting players to encourage processing of the seed which encourage value addition. Farmers will be able to further utilize the pressed cake as a rich nitrogen source for other crops which they grow as well as for biogas production.
5. Better agronomic practices such as use of fertilizers, pruning as well pest and disease control need to be adopted to improve yields.
6. Information dissemination on *Jatropha* production needs to be stepped up by extension workers.

Medium term policy recommendations

1. Promotion of large-scale adoption of *Jatropha* should be targeted to farmers with large pieces of land.
2. There is need for more research on *Jatropha* yield levels to improve revenue inflows and minimize cost of production.

Long term policy recommendations

1. A biodiesel plant should be set up in Shamva District.

9.4 Areas for Further Study

The following are the areas where further study is required.

1. An analysis of the full range of Jatropha by-products need to be undertaken to examine its full economic potential.
2. Environmental analysis of the costs and benefits of *Jatropha curcas L* production needs to be done which take cognisance of other potential benefits such as erosion control and carbon dioxide sequestration.
3. There is need to use panel data to capture dynamic changes in adoption patterns rather than cross sectional approaches to technology adoption.

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APPENDIX 1

QUESTIONNAIRE ON THE STUDY OF THE SOCIO-ECONOMIC FACTORS INFLUENCING *JATROPHA CURCAS L.* ADOPTION IN SHAMVA DISTRICT, ZIMBABWE

Contents

Section A:	Household Characteristics
Section B:	Asset Schedule
Section C:	Crop and Livestock Production
Section D:	Jatropha curcas L. production
Section E	Prices and market information
Section F:	Services
Section G:	Farmer's recommendations and Insights

Questionnaire No**.**

Date
Province
District
Ward
Village

Name of interviewer
Organization
Address
Telephone number
Mobile number
Fax number
Email address

Section A: Household Characteristics

1. Name of household……………...……………………………………………
2. Sex of respondent ☐M ☐F *(please tick)*
3. Age of respondent ☐ *Years*
4. Marital status: ☐ *Married* ☐ *Single* ☐ *Widow* ☐*Widower* ☐ *Divorced*
5. Level of education attained ☐*Primary* ☐*Secondary* ☐ *Tertiary*
6. Size of household ………………*children/members*
7. Age and sex of household members

Name	***Sex***	***Age (years)***
a.		
b.		
c.		
d.		
e.		
f.		
g.		
h.		

8. Do you belong to a farmers' group? : ☐*Yes* ☐ *No*
9. Size of farm ☐*ha* Arable land ☐ *ha*
10. Years of farming experience of household head ……..*Years*

Section B: Asset Schedule

Asset	***Quantity***	***Asset***	***Quantity***
Cattle		Bicycles	
Goats		Radios	
Sheep		Television	
Donkeys		Drinking well	
Pigs		Access to mechanical labour	
Chickens		Lorries	
Scotch-carts		Cultivators	
Wheel barrows		Harrows	
Ploughs		Planters	
Tractors		Cars	
House rooms		Cultivated farmland	

11. Based on PCA, wealth category of household *Poor* ☐ *Rich* ☐

Section C: Crop and Livestock Production

12. Revenue schedule

Crop	*Area (ha)*	*Yield (mt/ha)*	*Price/mt ($)*	*Value ($)*
a.				
b.				
c.				
d.				
e.				

Expenditure schedule

Crop	*Expense incurred ($)*	*Total ($)*
a.		
b.		
c.		
d.		
e.		

13. Animals sold in September 2010 – August 2011

Type	*Quantity*	*Unit Value ($)*	*Total value ($)*
a.			
b.			
c.			
d.			

Costs incurred

Type of animal	*Nature of cost*	*Total ($)*
a.		
b.		
c.		
d.		

Section D: Jatropha curcas L. production information

14. Do you have any Jatropha plantation? ☐ *Yes* ☐ *No. If no, proceed to question 30.*
15. Who owns the plantation? ☐ Husband ☐ Wife
16. Number of trees ……………………….
17. Area under trees ……………………..…*ha*
18. Where is the tree planted? ☐ *home fields*
    ☐ *homestead*
    ☐ *vegetable garden*
    ☐ *bathing enclosures*
    ……………………….*others (specify and tick*)
    ………………………..
    ………………………..
19. Spatial arrangement of the Jatropha curcas L.

Pattern	***Tick***	***Remarks***
Natural	☐	………………………
Hedge/living fence	☐	…………………….....
Monoculture	☐	………………………
Intercropping	☐	………………………

20. Age of plants …*1 – 2 yrs* ……*3 – 5 yrs*……*5 – 10 yrs*……*10 - 20yrs* ….. *>20yrs*
21. Average height of trees*: 0 -1m* ☐ *1 – 2m* ☐ *2 – 3m* ☐ *3 – 4m* ☐ *4 – 5m* ☐
22. How were the tress reproduced?
    ☐ *Vegetative reproduction*
    ☐ *Generative reproduction (seeds*)
23. Any intercropping of Jatropha curcas L. ☐ *Y* ☐ *No* If yes, provide details of crops
    ……………………………………………………………………………………
    ……………………………………………………………………………………
    ……………………………………………………………………………………...
24. When was Jatropha curcas L. introduced in your area? ………….(*Year)*
25. Production costs for the current season (2011)

Item	***Amount/ Qty used***	***Costs (value)***	***Time activity done***	***Comments***
Seed / seedlings/ cuttings				
Land preparation – hoe, plough, tractor, none				
Amount paid for land use (local authority)				
Planting - labour				
Weeding - labour				
Pruning – labour				
Watering - labour				
Fertilizer used (*compound D*)				
AN				
Other (*specify*)				
Pests and disease				
Seed picking labour (ld/20kg)				

26. Production output

Output	***Quantity obtained***	***Time harvested***
Amount of seed harvested (kg)		
Other by-products (*specify*)		

27. Perceived constraints in establishing and maintaining *Jatropha curcas L.(tick where appropriate)*

Water availability	☐	Poor yields	☐
Lack of knowledge	☐	Lower price	☐
Termite damage	☐	Very late fruition period	☐
No constraints	☐	Lack of exposure	☐
Animal damage	☐	Frequent drought after sowing	☐
Slow growth rates	☐		

28. Previous use of land before Jatropha curcas L.

☐ *Natural vegetation. What: ……………….……………Since:…………………*
☐ *Crops Which: ……………….……………Since:…………………*
☐ *Nothing Reason: …………………………………………………….*
☐ *Livestock which: …………………………………………………*
☐ *Other (specify) ……………………………………………………………*

29. Local use of Jatropha curcas L.

☐ *Medicinal*	☐ *Proportion (%)*
☐ *Soap*	☐ *Proportion (%)*
☐ *Hedge*	☐ *Proportion (%)*
☐ *Cooking and lighting (oil)*	☐ *Proportion (%)*
☐ *Biodiesel*	☐ *Proportion (%)*
☐ *Organic fertilizer*	☐ *Proportion (%)*
☐ *Erosion control*	☐ *Proportion (%)*

30. If you don't have a *Jatropha curcas L.* plantation, why is that so?

Reasons:
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
………………………………

31. What do you think about the price of Jatropha seed? ☐ *Attractive* ☐ *Non-attractive*

In both cases, specify why (*specify the price in your answer*)
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
……………………………..…………………………………………………..
……………………………………………………………………………………

Section E: Prices and market information

32. Product, prices and market information

Product	*Price (per unit)*	*Market where sold*
Jatropha seeds		
Biodiesel		
Soap		
Herbs (medicinal use)		
Other (specify)		

Section F: Services

33. Did you receive any credit from financial institutions? ☐Yes ☐No.
34. If yes, which institution, and the purpose for which the credit was used for

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

35. Where do you normally get your household income ☐On-farm ☐ Off-farm. *If off-farm specify the nature of activity*

Source of off-farm income	*Total ($ / annum)*
Pensions	
Head regular salary	
Spouse salary	
Seasonal wage	
Sons/ daughters wages	
Rent equipment out	
Other activities (specify)	

36. How often do you receive extension services

☐ At least once in three months
☐ Once in 6 months
☐ Once a year
☐ Never

Section G: Farmer's recommendations and Insights

37. What do you think are the major problems with *Jatropha curcas L.* production?
    ....
    ....
    ....
    ....
    ....
    ....
    ....
38. What should farmers do to solve the major problems cited?
    ....
    ....
    ....
    ....
    ....
39. What should be the role of the government in the rectification of the major problems?
    ....
    ....
    ....
    ....
    ....
    ....
40. Do you think that Jatropha curcas L. can really improve the lives of rural people?
    ☐ Yes ☐ No
41. Why and why not?
    ....
    ....
    ....
    ....
    ....
    ....
    ....
    ....
    ....
    ....
    ....
    ....
    ....

APPENDIX II

Assets used in computation of wealth rank indices

Asset	Number of farmers	Mean
Cultivated farmland (ha)	300	0.82
Cattle	300	2.05
Goats	300	1.42
Sheep	300	0.01
Donkeys	300	0.06
Pigs	300	0.13
Chicken	300	9.83
Scorch carts	300	0.38
Wheel barrow	300	0.43
Ploughs	300	0.70
Number of house rooms	300	3.88
Bicycles	300	0.41
Radio	300	0.53
Television	299	0.19
Drinking well	300	0.37
Cultivators	300	0.21
Harrows	300	0.08
Planters	300	0.01

Source: Survey results

APPENDIX III

Correlation Matrix

	Gender	Age	Marital status	Education level	House hold size	Famers' Group	Farm Size	Farm Experience	Wealth Category	Price Percept.	Credit Access	Extension Service	Off-Farm Income	On-Farm Income
Gender	1.0000													
Age	-0.1574	1.0000												
Marital status	-0.1474	-0.0459	1.0000											
Education level	0.3591	-0.4793	-0.0786	1.0000										
House hold size	0.0133	-0.0423	0.0610	-0.0285	1.0000									
Famers' Group	0.0339	0.1141	0.0790	0.0172	0.1777	1.0000								
Farm Size	-0.0308	0.1882	0.0206	-0.0570	0.2206	0.3117	1.0000							
Farm Experience	-0.2304	0.6675	-0.1577	-0.3328	0.0566	0.1959	0.3963	1.0000						
Wealth Category	0.1332	0.2575	-0.0612	-0.0898	0.1305	-0.0016	0.1853	0.2610	1.0000					
Price Perception	-0.0133	-0.0948	0.0287	0.1468	0.1248	0.1794	0.0989	-0.0346	-0.1361	1.0000				
Credit access	0.0853	0.0286	0.0469	0.0839	0.0371	0.1262	-0.0074	-0.1166	-0.0809	-0.0391	1.0000			
Extension service	-0.0798	-0.1870	0.5412	-0.1248	-0.0745	0.0428	-0.0175	-0.2438	0.0885	0.0155	0.0254	1.0000		
Off Farm Income	0.1131	-0.1429	0.0121	0.3054	-0.1204	-0.0238	-0.1017	-0.2011	-0.1075	-0.0247	0.1745	-0.0056	1.0000	
On Farm income	0.0857	0.0531	0.0028	-0.0797	0.3515	0.0938	0.1112	0.1009	0.2718	0.1070	-0.1259	-0.0082	-0.1649	1.0000

APPENDIX IV: Private valuation of inputs and outputs

Discount rate	0.306	
Discount factor	0.765697	2.39952

	Benefit			Disc ben	seed			Disc	Land preparation			disc	Gibberellic acid				Fertiliser (comp D)			disc
Year	Yield (t)	price/tonne	Total		quantity	price	total		hiring	price	total		Qty	price	total	disc	qty	cost	total	
0	0	100	0	0	1667	0.0015	2.5005	2.5005	1	20	20	20	0	0	0	0	0.84	28	23.52	23.52
1	0	100	0	0	0	0.0015	0	0	0	20	0	0	0	0	0	0	0	28	0	0
2	0	100	0	0	0	0.0015	0	0	0	20	0	0	0	0	0	0	0	28	0	0
3	4	100	400	179.569	0	0.0015	0	0	0	20	0	0	1	10	10	4.48922	0	28	0	0
4	4	100	400	137.495	0	0.0015	0	0	0	20	0	0	1	10	10	3.43738	0	28	0	0
5	4	100	400	105.28	0	0.0015	0	0	0	20	0	0	1	10	10	2.63199	0	28	0	0
6	4	100	400	80.6122	0	0.0015	0	0	0	20	0	0	1	10	10	2.01531	0	28	0	0
7	4	100	400	61.7245	0	0.0015	0	0	0	20	0	0	1	10	10	1.54311	0	28	0	0
8	4	100	400	47.2623	0	0.0015	0	0	0	20	0	0	1	10	10	1.18156	0	28	0	0
9	4	100	400	36.1886	0	0.0015	0	0	0	20	0	0	1	10	10	0.90471	0	28	0	0
10	4	100	400	27.7095	0	0.0015	0	0	0	20	0	0	1	10	10	0.69274	0	28	0	0
11	4	100	400	21.2171	0	0.0015	0	0	0	20	0	0	1	10	10	0.53043	0	28	0	0
12	4	100	400	16.2458	0	0.0015	0	0	0	20	0	0	1	10	10	0.40615	0	28	0	0
13	4	100	400	12.4394	0	0.0015	0	0	0	20	0	0	1	10	10	0.31098	0	28	0	0

14	4	100	**400**	**9.52479**	0	0.0015	**0**	**0**	0	20	0	**0**	1	10	10	0.23812	0	28	**0**	**0**
15	4	100	**400**	**7.2931**	0	0.0015	**0**	**0**	0	20	0	**0**	1	10	10	0.18233	0	28	**0**	**0**
16	4	100	**400**	**5.58431**	0	0.0015	**0**	**0**	0	20	0	**0**	1	10	10	0.13961	0	28	**0**	**0**
17	4	100	**400**	**4.27588**	0	0.0015	**0**	**0**	0	20	0	**0**	1	10	10	0.1069	0	28	**0**	**0**
18	4	100	**400**	**3.27403**	0	0.0015	**0**	**0**	0	20	0	**0**	1	10	10	0.08185	0	28	**0**	**0**
19	4	100	**400**	**2.50692**	0	0.0015	**0**	**0**	0	20	0	**0**	1	10	10	0.06267	0	28	**0**	**0**
20	4	100	**400**	**1.91954**	0	0.0015	**0**	**0**	0	20	0	**0**	1	10	10	0.04799	0	28	**0**	**0**
21	4	100	**400**	**1.46978**	0	0.0015	**0**	**0**	0	20	0	**0**	1	10	10	0.03674	0	28	**0**	**0**
22	4	100	**400**	**1.12541**	0	0.0015	**0**	**0**	0	20	0	**0**	1	10	10	0.02814	0	28	**0**	**0**
23	4	100	**400**	**0.86172**	0	0.0015	**0**	**0**	0	20	0	**0**	1	10	10	0.02154	0	28	**0**	**0**
24	4	100	**400**	**0.65982**	0	0.0015	**0**	**0**	0	20	0	**0**	1	10	10	0.0165	0	28	**0**	**0**
25	4	100	**400**	**0.50522**	0	0.0015	**0**	**0**	0	20	0	**0**	1	10	10	0.01263	0	28	**0**	**0**
26	4	100	**400**	**0.38685**	0	0.0015	**0**	**0**	0	20	0	**0**	1	10	10	0.00967	0	28	**0**	**0**
27	4	100	**400**	**0.29621**	0	0.0015	**0**	**0**	0	20	0	**0**	1	10	10	0.00741	0	28	**0**	**0**
28	4	100	**400**	**0.2268**	0	0.0015	**0**	**0**	0	20	0	**0**	1	10	10	0.00567	0	28	**0**	**0**
29	4	100	**400**	**0.17366**	0	0.0015	**0**	**0**	0	20	0	**0**	1	10	10	0.00434	0	28	**0**	**0**
30	4	100	**400**	**0.13297**	0	0.0015	**0**	**0**	0	20	0	**0**	1	10	10	0.00332	0	28	**0**	**0**
31	4	100	**400**	**0.10182**	0	0.0015	**0**	**0**	0	20	0	**0**	1	10	10	0.00255	0	28	**0**	**0**
32	4	100	**400**	**0.07796**	0	0.0015	**0**	**0**	0	20	0	**0**	1	10	10	0.00195	0	28	**0**	**0**
33	4	100	**400**	**0.05969**	0	0.0015	**0**	**0**	0	20	0	**0**	1	10	10	0.00149	0	28	**0**	**0**
34	4	100	**400**	**0.04571**	0	0.0015	**0**	**0**	0	20	0	**0**	1	10	10	0.00114	0	28	**0**	**0**
35	4	100	**400**	**0.035**	0	0.0015	**0**	**0**	0	20	0	**0**	1	10	10	0.00087	0	28	**0**	**0**

Total			**13200**	**766.28**			**2.5005**	**2.5005**			**20**	**20**			**330**	**19.157**			**23.52**	**23.52**

AN			**disc**	**SSP**			disc	**MOP**			**disc**	**labour requirements**			**disc**				**disc**	**Land**			**disc**		Disc. Net benefit
qty	cost	**total**		qty	cost	**total**		qty	cost	**total**		**weeding**	cost/day	total		**pruning**	cost	total		qty (ha)	price	**total**			
0	0	**0**	**0**	0	0	0	0	0	55	**0**	**0**	0	0	0	**0**	0	0	0	**0**	0	2	**0**	**0.00**		-46.02
0.66	31	**20.46**	**15.6662**	4	20	80	61.2557	0.54	55	**29.7**	**22.7412**	20	3	60	**45.9418**	10	3	30	**22.9709**	1	2	**2**	**1.53**		-170.11
0.66	31	**20.46**	**11.9955**	4	20	80	46.9033	0.54	55	**29.7**	**17.4129**	0	3	0	**0**	10	3	30	**17.5887**	1	2	**2**	**1.17**		-95.07
0.66	31	**20.46**	**9.18494**	4	20	80	35.9137	0.54	55	**29.7**	**13.333**	0	3	0	**0**	10	3	30	**13.4676**	1	2	**2**	**0.90**		102.28
0.66	31	**20.46**	**7.03288**	4	20	80	27.499	0.54	55	**29.7**	**10.209**	0	3	0	**0**	10	3	30	**10.3121**	1	2	**2**	**0.69**		78.32
0.66	31	**20.46**	**5.38505**	4	20	80	21.0559	0.54	55	**29.7**	**7.81701**	0	3	0	**0**	10	3	30	**7.89597**	1	2	**2**	**0.53**		59.97
0.66	31	**20.46**	**4.12332**	4	20	80	16.1224	0.54	55	**29.7**	**5.98546**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.40**		51.96
0.66	31	**20.46**	**3.15721**	4	20	80	12.3449	0.54	55	**29.7**	**4.58305**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.31**		39.79

0.66	31	**20.46**	**2.41747**	4	20	80	9.45245	0.54	55	**29.7**	**3.50922**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.24**		30.47
0.66	31	**20.46**	**1.85105**	4	20	80	7.23771	0.54	55	**29.7**	**2.687**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.18**		23.33
0.66	31	**20.46**	**1.41734**	4	20	80	5.54189	0.54	55	**29.7**	**2.05743**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.14**		17.86
0.66	31	**20.46**	**1.08525**	4	20	80	4.24341	0.54	55	**29.7**	**1.57537**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.11**		13.68
0.66	31	**20.46**	**0.83097**	4	20	80	3.24917	0.54	55	**29.7**	**1.20625**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.08**		10.47
0.66	31	**20.46**	**0.63627**	4	20	80	2.48788	0.54	55	**29.7**	**0.92362**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.06**		8.02
0.66	31	**20.46**	**0.48719**	4	20	80	1.90496	0.54	55	**29.7**	**0.70722**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.05**		6.14
0.66	31	**20.46**	**0.37304**	4	20	80	1.45862	0.54	55	**29.7**	**0.54151**	0	3	0	**0**	10	3	30	**0.54698**	1	2	**2**	**0.04**		4.15
0.66	31	**20.46**	**0.28564**	4	20	80	1.11686	0.54	55	**29.7**	**0.41463**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.03**		3.60
0.66	31	**20.46**	**0.21871**	4	20	80	0.85518	0.54	55	**29.7**	**0.31748**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.02**		2.76
0.66	31	**20.46**	**0.16747**	4	20	80	0.65481	0.54	55	**29.7**	**0.2431**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.02**		2.11
0.66	31	**20.46**	**0.12823**	4	20	80	0.50138	0.54	55	**29.7**	**0.18614**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.01**		1.62
0.66	31	**20.46**	**0.09818**	4	20	80	0.38391	0.54	55	**29.7**	**0.14253**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.01**		1.24
0.66	31	**20.46**	**0.07518**	4	20	80	0.29396	0.54	55	**29.7**	**0.10913**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.01**		0.95
0.66	31	**20.46**	**0.05756**	4	20	80	0.22508	0.54	55	**29.7**	**0.08356**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.01**		0.73
0.66	31	**20.46**	**0.04408**	4	20	80	0.17234	0.54	55	**29.7**	**0.06398**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.00**		0.56
0.66	31	**20.46**	**0.03375**	4	20	80	0.13196	0.54	55	**29.7**	**0.04899**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.00**		0.43
0.66	31	**20.46**	**0.02584**	4	20	80	0.10104	0.54	55	**29.7**	**0.03751**	0	3	0	**0**	10	3	30	**0.03789**	1	2	**2**	**0.00**		0.29
0.66	31	**20.46**	**0.01979**	4	20	80	0.07737	0.54	55	**29.7**	**0.02872**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.00**		0.25
0.66	31	**20.46**	**0.01515**	4	20	80	0.05924	0.54	55	**29.7**	**0.02199**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.00**		0.19
0.66	31	**20.46**	**0.0116**	4	20	80	0.04536	0.54	55	**29.7**	**0.01684**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.00**		0.15
0.66	31	**20.46**	**0.00888**	4	20	80	0.03473	0.54	55	**29.7**	**0.01289**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.00**		0.11

0.66	31	**20.46**	**0.0068**	4	20	80	0.02659	0.54	55	**29.7**	**0.00987**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.00**		0.09
0.66	31	**20.46**	**0.00521**	4	20	80	0.02036	0.54	55	**29.7**	**0.00756**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.00**		0.07
0.66	31	**20.46**	**0.00399**	4	20	80	0.01559	0.54	55	**29.7**	**0.00579**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.00**		0.05
0.66	31	**20.46**	**0.00305**	4	20	80	0.01194	0.54	55	**29.7**	**0.00443**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.00**		0.04
0.66	31	**20.46**	**0.00234**	4	20	80	0.00914	0.54	55	**29.7**	**0.00339**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.00**		0.03
0.66	31	**20.46**	**0.00179**	4	20	80	0.007	0.54	55	**29.7**	**0.0026**	0	3	0	**0**	10	3	30	**0.00262**	1	2	**2**	**0.00**		0.02
		716.1	**66.8569**			**2800**	**261.415**			**1039.5**	**97.0503**			**60**	**45.9418**			**240**	**72.8229**			**70**	**6.54**		150.48
																								IRR	9%

	benefit	seed	**land prep**	**gibberacid**	D	AN	**SSP**	**MOP**	labour reqts	land	Net
Undiscounted	13200	2.5005	**20**	**330**	23.52	716.1	**2800**	**1039.5**	300	70	7898.38
Discounted	766.2798	2.5005	**20**	**19.157**	23.52	66.8569	**261.415**	**97.0503**	118.765	6.53538	150.48

APPENDIX V: Economic valuation of inputs and outputs

Intrest rate	0.1
Discount factor	0.91

	Benefit			**Disc ben**	**seed**			**Disc**	**Land preparation**			**disc**	**Gibberellic acid**				**Fertiliser (comp D)**			**disc**
Year	Yield (t)	price/tonne	**Total**		**quantity**	**price**	**total**		hiring	price	total		Qty	price	total	**disc**	qty	cost	**total**	
0	0	100	**0**	**0**	1667	0.00128	**2.12543**	**2.12543**	1	20	20	**20**	0	8.5	0	0	0.84	23.8	**19.992**	**19.9992**
1	0	100	**0**	**0**	0	0.00128	**0**	**0**	0	20	0	**0**	0	8.5	0	0	0	23.8	**0**	**0**
2	0	100	**0**	**0**	0	0.00128	**0**	**0**	0	20	0	**0**	0	8.5	0	0	0	23.8	**0**	**0**
3	4	100	**400**	**300.526**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	6.38618	0	23.8	**0**	**0**
4	4	100	**400**	**273.205**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	5.80561	0	23.8	**0**	**0**
5	4	100	**400**	**248.369**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	5.27783	0	23.8	**0**	**0**
6	4	100	**400**	**225.79**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	4.79803	0	23.8	**0**	**0**
7	4	100	**400**	**205.263**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	4.36184	0	23.8	**0**	**0**
8	4	100	**400**	**186.603**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	3.96531	0	23.8	**0**	**0**
9	4	100	**400**	**169.639**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	3.60483	0	23.8	**0**	**0**
10	4	100	**400**	**154.217**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	3.27712	0	23.8	**0**	**0**
11	4	100	**400**	**140.198**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	2.9792	0	23.8	**0**	**0**
12	4	100	**400**	**127.452**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	2.70836	0	23.8	**0**	**0**

13	4	100	**400**	**115.866**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	2.46215	0	23.8	**0**	**0**
14	4	100	**400**	**105.333**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	2.23832	0	23.8	**0**	**0**
15	4	100	**400**	**95.7568**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	2.03483	0	23.8	**0**	**0**
16	4	100	**400**	**87.0517**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	1.84985	0	23.8	**0**	**0**
17	4	100	**400**	**79.1379**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	1.68168	0	23.8	**0**	**0**
18	4	100	**400**	**71.9435**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	1.5288	0	23.8	**0**	**0**
19	4	100	**400**	**65.4032**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	1.38982	0	23.8	**0**	**0**
20	4	100	**400**	**59.4575**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	1.26347	0	23.8	**0**	**0**
21	4	100	**400**	**54.0522**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	1.14861	0	23.8	**0**	**0**
22	4	100	**400**	**49.1384**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	1.04419	0	23.8	**0**	**0**
23	4	100	**400**	**44.6713**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	0.94926	0	23.8	**0**	**0**
24	4	100	**400**	**40.6102**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	0.86297	0	23.8	**0**	**0**
25	4	100	**400**	**36.9184**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	0.78452	0	23.8	**0**	**0**
26	4	100	**400**	**33.5622**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	0.7132	0	23.8	**0**	**0**
27	4	100	**400**	**30.5111**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	0.64836	0	23.8	**0**	**0**
28	4	100	**400**	**27.7373**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	0.58942	0	23.8	**0**	**0**
29	4	100	**400**	**25.2158**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	0.53583	0	23.8	**0**	**0**
30	4	100	**400**	**22.9234**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	0.48712	0	23.8	**0**	**0**
31	4	100	**400**	**20.8395**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	0.44284	0	23.8	**0**	**0**
32	4	100	**400**	**18.945**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	0.40258	0	23.8	**0**	**0**
33	4	100	**400**	**17.2227**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	0.36598	0	23.8	**0**	**0**
34	4	100	**400**	**15.657**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	0.33271	0	23.8	**0**	**0**

35	4	100	**400**	**14.2336**	0	0.00128	**0**	**0**	0	20	0	**0**	1	8.5	8.5	0.30246	0	23.8	**0**	**0**
Total			**13200**	**3163.45**			**2.12543**	**2.12543**			**20**	**20**			**280.5**	**67.2233**			**19.992**	**19.992**

AN			**disc**	**SSP**			disc	**MOP**			**disc**	**labour requirement s**			**disc**				**disc**	**Land**			**disc**		NPV
qty	cost	**total**		qty	cost	**total**		qty	cost	**total**		**weeding**	cost/day	total		**pruning**	cost	total		qty (ha)	price	**total**			
0	26.35	**0**	**0**	0	17	0	0	0	46.75	**0**	**0**	0	3	0	**0**	0	3	0	**0**	0	2	**0**	**0.00**		-42.117
0.66	26.35	**17.391**	**15.81**	4	17	68	61.8182	0.54	46.75	**25.245**	**22.95**	20	3	60	**54.5455**	10	3	30	**27.2727**	1	2	**2**	**1.82**		-184.21
0.66	26.35	**17.391**	**14.3727**	4	17	68	56.1983	0.54	46.75	**25.245**	**20.8636**	0	3	0	**0**	10	3	30	**24.7934**	1	2	**2**	**1.65**		-117.88
0.66	26.35	**17.391**	**13.0661**	4	17	68	51.0894	0.54	46.75	**25.245**	**18.9669**	0	3	0	**0**	10	3	30	**22.5394**	1	2	**2**	**1.50**		186.975
0.66	26.35	**17.391**	**11.8783**	4	17	68	46.4449	0.54	46.75	**25.245**	**17.2427**	0	3	0	**0**	10	3	30	**20.4904**	1	2	**2**	**1.37**		169.977
0.6	26.35	**17.391**	**10.79**	4	17	68	42.2	0.54	46.75	**25.245**	**15.6752**	0	3	0	**0**	10	3	30	**18.6276**	1	2	**2**	**1.24**		154.525

6			**84**				226																		
0.66	26.35	**17.391**	**9.81677**	4	17	68	38.3842	0.54	46.75	**25.245**	**14.2501**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**1.13**		157.411
0.66	26.35	**17.391**	**8.92433**	4	17	68	34.8948	0.54	46.75	**25.245**	**12.9547**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**1.03**		143.101
0.66	26.35	**17.391**	**8.11303**	4	17	68	31.7225	0.54	46.75	**25.245**	**11.777**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.93**		130.092
0.66	26.35	**17.391**	**7.37548**	4	17	68	28.8386	0.54	46.75	**25.245**	**10.7063**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.85**		118.266
0.66	26.35	**17.391**	**6.70498**	4	17	68	26.2169	0.54	46.75	**25.245**	**9.73304**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.77**		107.514
0.66	26.35	**17.391**	**6.09544**	4	17	68	23.8336	0.54	46.75	**25.245**	**8.84822**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.70**		97.7401
0.66	26.35	**17.391**	**5.54131**	4	17	68	21.6669	0.54	46.75	**25.245**	**8.04383**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.64**		88.8547
0.66	26.35	**17.391**	**5.03755**	4	17	68	19.6972	0.54	46.75	**25.245**	**7.31258**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.58**		80.777
0.66	26.35	**17.391**	**4.57959**	4	17	68	17.9065	0.54	46.75	**25.245**	**6.6478**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.53**		73.4336
0.66	26.35	**17.391**	**4.16327**	4	17	68	16.2787	0.54	46.75	**25.245**	**6.04345**	0	3	0	**0**	10	3	30	**7.18176**	1	2	**2**	**0.48**		59.5761
0.66	26.35	**17.391**	**3.78479**	4	17	68	14.7988	0.54	46.75	**25.245**	**5.49405**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.44**		60.6889

0.66	26.35	**17.391**	**3.44072**	4	17	68	13.4534	0.54	46.75	**25.245**	**4.99459**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.40**		55.1718
0.66	26.35	**17.391**	**3.12792**	4	17	68	12.2304	0.54	46.75	**25.245**	**4.54054**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.36**		50.1561
0.66	26.35	**17.391**	**2.84357**	4	17	68	11.1185	0.54	46.75	**25.245**	**4.12776**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.33**		45.5965
0.66	26.35	**17.391**	**2.58506**	4	17	68	10.1078	0.54	46.75	**25.245**	**3.75251**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.30**		41.4514
0.66	26.35	**17.391**	**2.35006**	4	17	68	9.18888	0.54	46.75	**25.245**	**3.41137**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.27**		37.6831
0.66	26.35	**17.391**	**2.13641**	4	17	68	8.35353	0.54	46.75	**25.245**	**3.10125**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.25**		34.2573
0.66	26.35	**17.391**	**1.94219**	4	17	68	7.59411	0.54	46.75	**25.245**	**2.81932**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.22**		31.143
0.66	26.35	**17.391**	**1.76563**	4	17	68	6.90374	0.54	46.75	**25.245**	**2.56301**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.20**		28.3118
0.66	26.35	**17.391**	**1.60512**	4	17	68	6.27613	0.54	46.75	**25.245**	**2.33001**	0	3	0	**0**	10	3	30	**2.76888**	1	2	**2**	**0.18**		22.9692
0.66	26.35	**17.391**	**1.4592**	4	17	68	5.70557	0.54	46.75	**25.245**	**2.11819**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.17**		23.3982
0.66	26.35	**17.391**	**1.32655**	4	17	68	5.18688	0.54	46.75	**25.245**	**1.92563**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.15**		21.2711
0.6	26.35	**17.391**	**1.205**	4	17	68	4.71	0.54	46.75	**25.245**	**1.75057**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.14**		19.3374

6			**95**				535																		
0.66	26.35	**17.391**	**1.09632**	4	17	68	4.286668	0.54	46.75	**25.245**	**1.59143**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.13**		17.5794
0.66	26.35	**17.391**	**0.99665**	4	17	68	3.896698	0.54	46.75	**25.245**	**1.44675**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.11**		15.9813
0.66	26.35	**17.391**	**0.90605**	4	17	68	3.542771	0.54	46.75	**25.245**	**1.31523**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.10**		14.5284
0.66	26.35	**17.391**	**0.82368**	4	17	68	3.220665	0.54	46.75	**25.245**	**1.19566**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.09**		13.2077
0.66	26.35	**17.391**	**0.7488**	4	17	68	2.927886	0.54	46.75	**25.245**	**1.08697**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.09**		12.007
0.66	26.35	**17.391**	**0.68073**	4	17	68	2.661669	0.54	46.75	**25.245**	**0.98815**	0	3	0	**0**	0	3	0	**0**	1	2	**2**	**0.08**		10.9154
0.66	26.35	**17.391**	**0.61884**	4	17	68	2.419972	0.54	46.75	**25.245**	**0.89832**	0	3	0	**0**	10	3	30	**1.06752**	1	2	**2**	**0.07**		8.8556
		608.685	**167.722**			**2380**	**655.803**			**883.575**	**243.467**			**60**	**54.5455**			**240**	**124.742**			**70**	**19.29**		1788.54
																								IRR	35%

	benefit	seed	**land prep**	**gibberacid**	D	AN	**SSP**	**MOP**	labourreqts	land	Net
Undiscounted	13200	2.12543	**20**	**280.5**	19.992	608.685	**2380**	**883.575**	300	70	8635.12
Discounted	3163.4487	2.12543	**20**	**67.2233**	19.992	167.722	**655.803**	**243.467**	179.287	19.2883	1788.54