Journal of Economics and Sustainable Development
ISSN 2222-1700 (Paper) ISSN 2222-2855 (Online)
Vol.4, No.8, 2013

Comparison of *Jatropha Curcas* Profitability To Selected Crops In Yatta District, Kenya

Carol Munini Munyao[1], Dr. Fred Muisu[1], Jacob Mbego[1], Dr. Nehemiah Kiprutto[2]

1 School of Natural Resources Management, University of Eldoret PO Box 1125-30100, Eldoret, Kenya

2 School of Tourism, Hospitality & Events management, Moi University PO Box 3900-30100, Eldoret, Kenya

* Corresponding Author E-mail: carolmunini@yahoo.com

Abstract

This paper examines the viability of Jatropha curcas production focusing on the economic impacts on smallholder farmers in Yatta District. The study employed causal-comparative research design and quantitative research method was used where questionnaires were administered to 240 respondents selected through multi-stage sampling technique. Gross Margin Calculation was undertaken to compare the profitability of Jatropha cultivation to main crops where means of both gross margins were compared using paired sample t-tests statistic. It was found that gross margin for Jatropha grown in the three different modes was found to be significantly lower compared to pigeon peas and bean. Therefore it is important for farmers to make a balanced choice in using their limited land to engage in Jatropha production before proper policies on biofuels are put in place to ensure high yields, avoid the risks of poor market conditions and increased consumption of biofuels in the country.

Keywords Biofuels, Gross Margin Calculation, *Jatropha curcas*, Kenya, profitability, Yatta District

1. Introduction

The current debate on climate change and rising oil prices has generated a great deal of interest in renewable energy resources such as biofuels. All developing countries desire to be industrialized including Kenya which aspires to be industrialized by 2030 (GOK, 2010). Unfortunately, most of these developing countries have adopted the prevailing model in industrialized countries characterized by over-reliance on fossil fuels. However these fuels are environmentally malignant and the prices are very unstable and rising (Goldenberg & Johansson, 1995). Liquid fuels derived from biomass (herein referred to as biofuels) are emerging as alternative fuels that could help manage the problem of the ever-increasing demand of oil thus providing energy security, mitigate the environmental problems arising from use of fossil fuels and stimulate rural development in Africa (Yamba, 2007).

In recent years, the production of *Jatropha curcas* has been widely promoted by private enterprises, non-governmental organizations and development agencies as one of the most viable candidates for biodiesel feedstock in Africa. While multiple benefits of *Jatropha* production such as a petroleum product substitute, greenhouse gas mitigation and rural development are emphasized, the viability of production at farm level is questioned.

Jatropha production has been promoted for its perceived economic and ecological advantages. Thus *Jatropha* appears to be the potential crop that enables “win-win” relationship among all the actors in the value chain– the biofuel industry to gain profit, society as a whole to achieve GHG mitigation and energy security, and the producers to improve their livelihoods. Benefit to local farmers in small-scale *Jatropha* production is based on

the profitability of *Jatropha* seed production as a farm enterprise. The biofuel industry is interested in *Jatropha* production because it is expected to be less expensive feedstock. Viability of *Jatropha* production in current Kenyan market conditions is by examining the price competitiveness of *Jatropha* in the market and the profitability of *Jatropha* production as a biodiesel feedstock in terms of expected yield, revenue and opportunity cost of production.

There is therefore an urgent need to determine if it is a rational choice for smallholder Kenyan farmers to engage in *Jatropha* production under the current economic situation. The objectives in this paper are to compare the profitability of *Jatropha* production to selected crops in Yatta District, Kenya focusing on the economic impacts on smallholder farmers who engage in the production.

2. Literature review

2.1 Introduction

Jatropha a member of the Euphorbiaceous family is a plant of Latin American origin but currently widespread throughout the tropical regions of the world. It is a drought resistant, perennial plant living up to 50 years, relatively fast growing and can achieve a height of three meters within three years under a variety of growing conditions (Openshaw, 2000). *Jatropha* plant is reported to have more than 1600 uses such as soil erosion control, climate protection, varnishes, illuminants, soap, organic insecticide and medicine for skin diseases, cancer, piles, snakebites, paralysis, dropsy and many more (Henning, 2002). Various parts of the plant have medicinal value, its bark contains tannin, the flowers attract bees thus the plant has honey production, the seed cake is an excellent source of plant nutrients and its wood and fruit parts are used for fuel. Like all trees, *Jatropha* removes carbon from the atmosphere, stores it in the woody tissues and assists in the build-up of soil carbon (Anant, 2008).

2.2 Comparing profitability of Jatropha curcas to food crops

Profitability of *Jatropha* and food crops is compared using GMC a tool used by farmers to help in choosing between different farming systems. It is used to help evaluate the competitiveness of growing *Jatropha* as compared to growing other types of subsistent crops. A gross margin of a crop is the difference between the gross income earned by the crop and the variable or direct costs associated with it (Abbott and Makeham, 1979). For semi-subsistence farmers food security might be more important than gross margins but if a crop has very high gross margin, then it is advisable to grow it and buy food from the returns. Therefore if *Jatropha* has very high gross margin than food crops then it can replace them and its returns used to buy food.

An estimate of costs and returns from cultivation of *Jatropha* plantations/hedgerows' scenarios is crucial to analyzing its adoption in rural areas. Costs, as well as returns are involved at different stages of the growing and harvesting of *Jatropha*. For farmers to adopt *Jatropha* cultivation, the plant must be more profitable than the traditional crops farmers are already used to (Van Eijck, 2006). A study done in Tanzania in 2006 indicated that *Jatropha* crop is more profitable than traditional crops such as maize, wheat bananas among others which led to high adoption of *Jatropha* cultivation in Arusha region. *Jatropha* realized annual revenue of KShs 219,558 per acre which was higher compared to maize that produced annual revenue of KShs 22,884 per acre (Van Eijck, 2006). However, Mitchell (2008) pointed out that Sun Biofuel Company in Tanzania estimated annual *Jatropha* profits to range between 9,720KShs/acre – 19,440KShs/acre which is lower than profit estimations of Van Eijck (2006). In India, Rao *et al.* (2006) reported highest revenue of *Jatropha* per acre per year as KShs 43,800.

Profitability of *Jatropha* is influenced by buying prices and variable costs such as, labor costs in management practices undertaken and input costs since they differ in most regions.

In Kenya, it was reported that revenues from selected cash crops such as mango, green grams and potatoes among others were higher than that of *Jatropha.* Annual gross margin per hectare for green grams was KShs 16,654, for potatoes it was KShs 101,334 and for mango it was KShs 25,200 while that of *Jatropha* ranged between KShs 10,893 – KShs 13,072 (Yuka and Swallow, 2007). *Jatropha* gross margin in the country is lower than most traditional crops hence the low adoption.

Cost of production of *Jatropha* is influenced by management practices undertaken and varies greatly with authors and regions. According to Van Eijck (2006) the annual costs of production per acre in Tanzania was found to be KShs 100 while in India, Rao *et al.,* (2006) indicated it was KShs 1,200. However, Wahl *et al.,* (2009) pointed out that the annual operating costs for one hectare of *Jatropha* in Tanzania and India were found to be approximately KShs 6,073 and while in China to be KShs 12,145. High costs of production reduce the end revenues and therefore influencing adoption.

2.3 Jatropha curcas yields

Yields from *Jatropha* have an influence adoption as they directly impact on revenues. High yields lead to high revenues and low yields lead to low revenue. Reported yields for *Jatropha* differ worldwide. Openshaw (2000) mentions a variation in seed production in monocrop to range between 0.4tonnes/ha/yr to over 12tonnes/ha/yr with a number of plants per hectare varying from 1100 to 3300. In addition, Heller (1996) and Jones and Miller (1992) summarized *Jatropha* yields with an even larger variation in seed yield, from 0.1 tonnes/ha/yr to 15 tonnes/ha/yr. On average, a mature monocrop plantation would yield 4.8tonnes/ha/yr. A *Jatropha* project in Tanzania reported seed yields to be higher with a variation of 5tonnes/ha/yr to 25tonnes/ha/yr or 2kg/plant/yr to 10 kg/plant/yr. In Mali, where *Jatropha* was planted as a hedgerow at a spacing of 1m × 1m, the reported yield was 2.5 tonnes/ha/year and 3.5 tonnes /ha/year (Henning, 2002). *Jatropha* yields are influenced by climatic conditions and management practices.

In optimal conditions, *Jatropha* should yield seeds of up to 8tons/ha/yr resulting in oil yields of up to 2.2tons/ha/yr (Henning, 2006). National Botanical Research Institute (NBRI) in Lucknow came up with a high yielding Hybrid *Jatropha* cultivar in 2006 which would yield up to 17.25tons/ha/yr of seeds at a planting density of 2475 trees per hectare and spacing of 2m × 2m (PTI, 2007). Improved seed varieties have the potential of increasing oil and nut yields.

2.4 Jatropha curcas markets

Market availability is one of the key aspects that influence profitability of *Jatropha* cultivation. Farmers should be able to sell harvests to ready buyers or process seeds themselves in order to intensify *Jatropha* cultivation (Tattersall, 2007). In Tanzania, the availability of ready market for *Jatropha* seeds to either Kakute or Diligent which are NGOs based in Arusha region has led to more farmers engage in cultivation. Market accessibility and availability, market prices and grain bags are important factors to take into account for *Jatropha* trading (Mitchell, 2008).

To enhance returns of *Jatropha* produce, it is important to have a complete value chain with manifold stakeholders involved and their roles well established. In Tanzania for example, there are NGOs promoting

Jatropha cultivation, farmer cooperatives, organizations doing extension services and business support, oil extraction plants, buying organizations, and political institutions supporting renewable energies (Mitchell, 2008).

Mitchell (2008) pointed out that in Tanzania trained women groups on soap production provided substantial market for *Jatropha* nuts. KAMA Herbal Products Ltd. a private company run by several shareholders helped to market the herbal soaps based on *Jatropha* oil in the national and international market. In Tanzania mbinga region, nuns pressed *Jatropha* nuts into pure oil for running gensets of a twelve building complex of the Vincentian Sisters in Mbinga providing market for *Jatropha* nuts (Muller, 2007). Value chain development through increased out-grower schemes can be applied to solve the problem of market unavailability.

While in Mali higher adoption of *Jatropha* cultivation in the 90s was attributed to farmers in a small village of Simiji trained on how to crush *Jatropha* plant seeds and extracting the oil (Tattersall, 2007). This provided huge market for *Jatropha* nuts in Mali and subsequently village residents found a renewable power source that does not conflict with the local food supply. Oil from the *Jatropha* plant powered a small generator and the Simiji village was provided with enough power to run 40 streetlights and give 60 families power at night (Henning, 2006). Availing technology on *Jatropha* by-products processing to farmers or establishment of accessible *Jatropha* oil extraction plants would increase *Jatropha* nuts markets thus more revenue.

3. Study Area

3.1 Location and size

Yatta District covers an estimated area of 2497 Km^2 and is located within a latitude of -1.47 (1° 28' 0 S) and a longitude of 37.83 (37° 49' 60 E). The district borders Thika District to the North Western side, Kitui and Mwingi districts to the Eastern side, Machakos District to the Southern side, Maragwa District to the North and Mbeere District to the North Eastern side. Figure 3.1, indicates the geographical location of the study area in Kenya.

3.2 Climatic conditions

Yatta district lies in Zone V of the Agro-climatic classification of Kenya. Suffice to emphasize this, most parts of Kenya lie in the ASAL zones and they experience perennials droughts, which make it unsuitable for agriculture and therefore *Jatropha curcas* cultivation would be timely since the plant can withstand dry conditions.

The climate of Yatta district is generally warm and dry during most part of the year except for some torrential and erratic rains experienced in the months of March and December. The mean monthly temperature ranges from 29 ^{0}C in the coldest months to 36 ^{0}C in the hottest months resulting in low or no yields in rain-fed agriculture. Despite these low yields, agriculture remains an important source of livelihood in the district currently. The topography of the district is varied and rises from 500 m above sea level on the southern part of the district to 1200 m above sea level in the northern part. There are two rainy seasons, the long and the short rains. The annual average rainfall varies from 350-600 mm with high attitude areas receiving more rainfall than low attitude regions. However there has been gradual decline of rainfall since 1992 (GOK, 2004).

3.3 Research design

This study is descriptive in nature and causal-comparative research design was employed. Both quantitative and qualitative research methods were applied. The quantitative research method entailed use of household (HH) questionnaires and weighing machine while the qualitative research method entailed in-depth interviews, Focus Group Discussions and observations. A systematic and objective approach to the study entailed discussions

with supervisors, pre-testing and revision of questionnaires, the execution of the field data collection, data coding & entry and analysis as shown in Figure 1.

3.4 Sampling method

A multi-stage sampling technique was applied in this study whereby Yatta District was selected purposively since it was one of the districts where *Jatropha* activities were undertaken by promoting agencies. Cluster sampling method was employed to select Yatta and Masinga divisions purposively because they had the highest number of promoting agencies present. Cluster sampling method was further used to choose four locations randomly in the selected divisions. Systematic sampling was used to pick 2 sub- locations from each location whereby first and third names were singled out from each list containing the names of sub-locations in a location provided at the district resources center giving a total of 8 sub-locations. One village was selected from each sub-location on the basis of its location where the east most village was picked. Selection of respondents from each village was done through systematic randomly sampling method. Village shopping centers were used as beginning points then heading west and following identified village roads or paths households were picked at intervals of five whereby after selecting the first household, 5 households were skipped then the sixth household selected as second household the process was repeated until 30 households were picked in each of the 8 villages.

3.5 Data collection

Primary data was collected using a well structured household questionnaire and in-depth interviews employing personal contact with government officials and NGO officials. Hanging weigh scale was used to estimate the weights of *Jatropha* yields per farm while data on variable cost of production of the main agricultural crops in the district, costs of *Jatropha* production and yields for *Jatropha* planted in monocrop and intercrop modes, population, socio-economic activities in the district and climatic conditions of Yatta district was obtained from secondary sources including government reports, annual reports, research papers, study reports, and books.

3.6 Hypothesis testing

$H_0: \mu_1 = \mu_2$
$H_1: \mu_1 \neq \mu_2$

Where;

μ_1 – Mean gross margin of *Jatropha*
μ_2 – Mean gross margins of main crops in Yatta District

Gross Margin Calculations (GMC) was undertaken to compare the profitability of *Jatropha* cultivation to main crops where means of both gross margins were compared. The wages of permanent workers and depreciation of machinery and land cost is normally left out when calculating the gross margins. Calculation of gross margins of main crops and *Jatropha* grown in the three modes of cultivation (hedgerow, intercrop and monocrop) was described as;

Gross margin = Gross income – Variable costs

Where:

Gross income = Annual yield/tree × 15 × stocking density

Average annual yields per tree for different ages were estimated as;

$$\bar{x} = (\sum K/Ji)/n$$

Where;
$\bar{x}$ - Average yield per tree per year
K – Yields obtained per farm
J – Number of *Jatropha* trees in the farm
i – Years of growth
n – Number of farmers

To estimate the gross margin for *Jatropha* the following assumptions were made:

1. One kilometer of *Jatropha* hedgerow had a stocking density of 1000 trees
2. One acre of *Jatropha* monocrop farm had a stocking density of 1000trees
3. One acre of *Jatropha* intercrop farm had a stocking density of 1250 trees
4. The farm gate price of one kilogram of *Jatropha* nuts was 15KShs

Variable costs are costs directly linked to a crop incurred every year of planting and they include cost of seeds, spraying, watering, harvesting, packing marketing, storage among others. Yields and costs of production for monocrop and intercrop farms were obtained from ICRAF (2008) due to unavailability of information in the district. This was so because *Jatropha* plants in these farms during data collection were all less than one year old and had not fruited in Yatta District. Paired-sample t-test statistic was used to compare gross margin means and tables were used to present the results.

4. Results

4.1Comparison of profitability of Jatropha curcas with main crops

Gross margins obtained from growing *Jatropha* in the three modes of cultivation that is monocrop, intercrop and hedgerow was compared with gross margins obtained from major crops in Yatta District. This was achieved by providing variable costs, yield produced and revenues obtained for all crops then calculating gross margins.

4.2 Main crops in Yatta District

Subsistence crop farming was one of the socio-economic activities related to land use in Yatta District. Maize was the commonest crop grown by 86.9% of farmers while 10.4% and 2.7% grew beans and pigeon peas as their main crops respectively.

Maize was mainly grown for consumption purposes because it can withstand the dry conditions and thus assist farmers in coping with frequent famines. The choice to grow maize was as a result of cultural considerations

rather than economic preferences. Maize did not have good market price with a 90-kilogram bag selling at KShs 900 compared to pigeon peas at KShs 2,000 per 90-kilogram bag and beans at KShs 5,000 per 90-kilogram bag. It was found that there was a large variation in the productivity and production costs among the three main crops, as exemplified by the gross incomes and variable costs reported in Table 1.

Variable cost of maize was found to be KShs 4,290 per acre while that of beans was KShs 6,728 per acre and lastly pigeon peas were KShs 7,722 per acre (GOK 2006).

4.3 Estimated cost of Jatropha curcas production

Variable costs incurred in the production of *Jatropha* grown as a hedgerow, intercrop and as monocrop over an 8-year period are provided in Table 2. Monocrop and intercrop data was secondary data obtained from regions in the same agro-climatic zone as Yatta district and therefore only used to indicate expected the trends.

At planting, hedgerow costs were very low at KShs 1,225 compared to reported costs elsewhere for intercrop at KShs 6,177 and monocrop costs at KShs 10,314. All the variable costs in the different modes of cultivation decreased as the plants matured.

4.4 Jatropha curcas yields in Yatta District

Yields reported in Yatta District were significantly lower compared to yields reported in other parts in the same agro-climatic conditions in the country. The observed yield per tree at maturity (8+ years) in Yatta District was 0.125Kg/tree much lower compared to the reported yield of 0.361Kg/tree from other parts of the country as illustrated in Figure 2. The highest observed yield of from year 1 to year 8+ was found to be much lower than the highest yields reported under the same agro-climatic conditions.

Yields in kilograms per tree in the three different modes of cultivation were as shown in Table 3. *Jatropha* yields for monocrop and intercrop were secondary data obtained from ICRAF (2008) reported from other parts of the country lying in same agro-climatic zone as Yatta District since that information was not available in Yatta District and was therefore used to indicate expected trend. At maturity, monocrop mode of production had the highest yields per tree per year at 0.555kg followed by intercrop at 0.165kg and lastly hedgerow at 0.125kg.

4.5 Gross margin of Jatropha curcas cultivation

As shown in Table 4, the gross margin for *Jatropha* planted as a hedgerow was negative for the first three years of production at KShs - 1225 shillings for the first year after planting and KShs - 104 shillings at year 3 of growth indicating that losses were incurred. Positively from year 4, little profits were realized ranging from 330 shillings to 1625 shillings at maturity.

No expected profits for monocrop and intercrop *Jatropha* farms from planting to maturity assuming yields and variable costs reported by ICRAF (2008). The gross margin was negative for monocrop as illustrated in Table 4 implying that farmers made losses of KShs 10,314 during the first year of growth and KShs 900 after maturity

per year. For intercrop, losses made during the first year of growth were approximately KShs 6,617 and KShs 2,463 losses realized after maturity per year.

4.6 Comparison of gross margins for main crops and Jatropha

Gross margin for *Jatropha* grown as an intercrop, monocrop and hedgerow was lower than gross margin of KShs 2,278 for pigeon peas and KShs 3,272 for beans as indicated in Table 5. Growing *Jatropha* as monocrop and intercrop did not realize any profits as opposed to the main crops.

Paired t-test statistic indicated that mean gross margin for *Jatropha* when grown in the three different modes was found to be significantly lower compared to that of pigeon peas and beans ($t = 17.22$, $p = 0.000$). However paired t-test statistic revealed that mean gross margin of *Jatropha* grown as a hedgerow at maturity was significantly higher compared to that of maize ($t = 0.885$, $p = 0.385$).

5. Discussion

5.1 Gross margin of Jatropha curcas cultivation

Economic viability of *Jatropha* production is a factor of production cost, yield, and market price. Farmers' decisions on adopting *Jatropha* production depend upon the returns that they expect to generate. Gross margin of *Jatropha* was not competitive to cultivation of main crops leading to low adoption levels in Yatta District. The comparison of *Jatropha* revenue with other food crops in Yatta District indicated that the production of *Jatropha* is not a rational option under current economic condition and policy framework. This was as a result of its high cost of production especially for intercrop and monocrop *Jatropha* farmers and minimal yield and low market prices of *Jatropha* nuts. Under such economical constraints *Jatropha* is unlikely to substantially increase employment and income in rural areas. The shift from food crop to energy crop should especially be avoided in semi-arid areas that experience production declines due to unpredictable and unstable rainfall.

Gross margin of food crops and *Jatropha* realized in Yatta District was far much lower compared to gross margin of maize at 17,200KShs/acre/year and that of *Jatropha* at 13,200KShs/acre/year reported by Wahl *et al.,* (2009) in Northern Tanzania. This could probably be due to poor climatic conditions in Yatta District compared to Tanzania leading to very low yields due to poor management practices, low farm gate prices and lack of market facilities leading to very low *Jatropha* prices.

Findings from this study agree with Yuka and Swallow (2007) who indicated that *Jatropha* plant is not competitive compared to cash crops such as cashew nuts, mango and maize in addition ICRAF (2008) concur with those findings that it is not profitable to grow *Jatropha* as an intercrop or monocrop in land that would otherwise be used for food crops such as maize, beans. Further GOK (2006) agreed that the gross margins of maize, beans and pigeon peas are higher than the gross margins of *Jatropha* in Yatta, Machakos County.

Considering the amount of attention *Jatropha* had received in the media, government, and the private sector, the results were disheartening. Considering the annual gross margin of KShs 1625 from maturity of *Jatropha* grown as a hedgerow and the negative gross margins obtained when planted as a monocrop or as intercrop implies that planting of *Jatropha* on farms where beans, cow peas or green grams could be grown would be an irrational

choice for the farmers. It is important for farmers to make a balanced choice in using their limited land therefore farmers would be apt to engage in *Jatropha* production only after proper policies on markets are put in place that would be able to avoid the risks of poor market conditions and exploitation by market intermediaries. Cultivation of *Jatropha* hedgerow may provide a supplementary income though the low yields realized would have negative implications its profitability.

5.2 Yields from Jatropha curcas

A main factor determining the income gained from *Jatropha* cultivation is the yield influenced by mode of cultivation. *Jatropha* yields grown as a hedgerow realized in Yatta District were too low compared yields reported in other parts of the same agro-climatic conditions in the country and from around the world. Although it was indicated that optimum yield for hedgerow dry areas in Kenya with no irrigation should be 2.5tonnes/acre/year at a spacing of 1m × 1m (GTZ, 2008), the yields reported in Yatta District at the same spacing were significantly low at 0.2tonnes per acre per year. Comparing these yields to India where Prajapati and Prajapati (2005) estimated *Jatropha* yields in rain-fed and irrigated conditions to range from 1.2 tonnes/acre/year under rain-fed conditions to 3.2 tonnes/acre/year under irrigated conditions yields in Yatta District were minimal. Freim (2008) reported that *Jatropha* yield varies a great deal from 0.3 kg/tree/year to 12 kg/tree/year but indicated that average yield should be 6 kg/year/tree under optimum conditions at maturity.

The decimal performance of *Jatropha* trees in terms of seed yield was probably as a result of inadequate soil moisture content; inadequate soil fertility or poor management practices on the *Jatropha* farms. From the discussion above it is clear that although *Jatropha* can grow in marginal areas, seed yields could be dependent on soil fertility and management practices among other factors. From the yields obtained it is evident that *Jatropha* will take some time before it becomes a reliable biodiesel feedstock.

6. Conclusion

Jatropha curcas did not produce any profits when planted as a monocrop or as an intercrop and lower profits were realized when *Jatropha* was grown as a hedgerow compared to pigeon peas and beans in Yatta District. In conclusion, *Jatropha* cultivation was not profitable compared to main agricultural crops in Yatta district.

References

Abbott J.C. and Makeham J.P., (1979). Agricultural Economics and Marketing in the Tropics. Intermediate Tropical Agricultural Series. Longman Group LTD, London.

Anant, P., (2008). Biofuel and Rural Development – biofuels for accelerating rural development. In proceedings of the 5th conference on biofuels. February 7–8, 2008, New Delhi, India

Freim, O. L., (2009). *"How will small scale farmers in Zambia benefit from growing of Jatropha?",* Norwegian University of Life Science, Department of International Environment and Development Studies, Master Thesis, 2008.

GOK, (2004). *Sessional Paper No. 4 of 2004 on Energy*. Ministry of Energy,

Government of Kenya, Nairobi.

GOK, (2010). *Census report 2009*. Central Bureau of Statistics, Ministry of Planning and National Development, Government of Kenya, Nairobi.

Goldenberg J. and Johansson T. B., (1995). Energy as an instrument of socio-economic development. UNDP: New York.

GTZ, (2008). A roadmap for biofuels in Kenya: Opportunities & Obstacles. ESDA, Nairobi

Henning, R.K., (2002). Using the Indigenous Knowledge of *Jatropha*. The use of *Jatropha* oil as raw material and fuel. Local Pathways to Global Development. *Indigenous Knowledge Notes*, 47, August. The World Bank, Washington, D.C. Available at: www.worldbank.org/siteresources.pdf. (Accessed on 15th July 2007).

Henning, R. (2006). Combating Desertification: The *Jatropha* Project of Mali, West Africa. Arid Lands, http://www.cals.arizona.edu/ *Jatropha*.html (Accessed on 20th September 2008)

Heller, J., (1996). Physic nut, *Jatropha*. Promoting the Conservation and Use of Underutilized and Neglected Crops. International Plant Genetic Resources Institute (IPGRI), Rome, Italy.

ICRAF, (2008). Assessment of the Agronomic and economic viability of *Jatropha* and other oilseed crops in Kenya. *Jatropha reality-check*. Unpublished Report. Endelevu energy and KEFRI, Nairobi.

Jones, N. and Millar, J. H., (1992). *Jatropha*: A multipurpose Species for Problematic Sites, The World Bank, Washington DC USA.

Jongschaap, R.E.E., Corré, W.J., Bindraban, P.S. and Brandenburg, W.A., (2007). *"Claims and Facts on Jatropha L. – Global Jatropha evaluation, breeding and propagation programme"*, Plant Research International B.V., Wageningen Stichting Het Groene Woudt, Laren. Report 158. October 2007.

Mitchell, A., (2008). The implications of smallholder cultivation of the biofuel crop, *Jatropha,* for local food security and socioeconomic development in Northern Tanzania. MSc. Thesis in Anthropology & Ecology of Development, University of London

Muller, A., (2007). A green oil for the world. Sun & Wind Energy. Vol 1 2007. http://www.greenoil.finding/pdf, (Accessed 19th February, 2010).

Openshaw, K., (2000). A review of *Jatropha*: an oil plant of unfulfilled promise. *Biomass and Bioenergy* 19: 1-15

Prajapati, N.D. and Prajapati, T., (2005). *A hand book of Jatropha Linn. (Physic nut).*Jodhpur: Asian Medical Plants & Health Care Trust

Rao, G. R., Prasad, Y. G., Prabhakar, M., Rao. J. V., Korwar, G. R. and Ramakrishna, Y. S., (2006). "Agro-techniques for Biofuel plantations in Rain-fed Areas" Central research Institute for Dry land Agriculture (ICAR), Hyderabad, p.16.

Tattersall, N., (2007). Malian Weed brings light to mud-hut villages. Reuters, 2007. Available at: http://www.reuters.com/article/environmentNews (Accessed on 5th May 2007)

Van Eijck, J., (2006). Transition towards *Jatropha* biofuels in Tanzania. An analysis with Strategic Niche Management, Eindhoven University of Technology, Department of Technology Management: Technology and Policy.

Wahl N., Ramni J., Henning B., Cristel M. and Miyuki I., (2009). Economic viability of *Jatropha* L. plantations in Northern Tanzania: Assessing farmers' prospects via cost-benefit analysis. World Agroforestry Centre 2009, Working Paper no. 97, Nairobi

Yamba, F. D., (2007). Research Needs and Capacity to Support Opportunities and Challenges for Biofuel Development – South Africa Perspective. CTA Workshop paper, CTA, Wageningen, The Netherlands

Yuka T. and Swallow B., (2007). *Jatropha curcas* biodiesel production in Kenya. Economics and potential value chain development for smallholder farmers. Working Paper 54. Nairobi. World Agroforestry Centre.

Tables and figures

Table 1: Estimated annual yields, revenue and variable costs of main crops

Main crops	Average yield (90 Kg bags/ acre)	Gross income (KShs/acre)	Variable costs (KShs/acre)
Maize	5	4,500	4,290
Beans	2	10,000	6,728
Pigeon peas	10	10,000	7,722

Table 2: Estimated annual variable costs of *Jatropha* cultivation

	Variable costs per acre in KShs for different cultivation modes		
Age	Hedgerow	Intercrop*	Monocrop*
1 Year	1,225	6,177	10,314
2 Years	900	4,407	8,580
3 Years	275	5,285	7,478
4 Years	178	4,777	8,154
5 Years	150	5,227	8,624
6 Years	130	4,797	8,194
7 Years	130	5,452	9,197
8 Years	100	5,472	9,217
> 8 Years	100	5,472	9,217

** Source ICRAF (2008)*

Table 3: Estimated annual *Jatropha* yields

	Yields in kilograms per tree for different cultivation modes		
Age	Hedgerow	Monocrop*	Intercrop*
Year 1	0.000	0.000	0.000
Year 2	0.009	0.003	0.0004
Year 3	0.012	0.055	0.016
Year 4	0.034	0.077	0.022
Year 5	0.051	0.154	0.045
Year 6	0.073	0.308	0.089
Year 7	0.085	0.385	0.111
Year 8	0.105	0.462	0.134
>Year 8	0.125	0.555	0.165

* Source: ICRAF (2008)

Table 4: Estimated annual gross margin of *Jatropha curcas*

	Gross margins per acre in KShs for different cultivation modes		
Age	Hedgerow	Monocrop	Intercrop
Year 1	- 1,225	- 10,314	- 6,617
Year 2	- 768	- 8,542	- 4,400
Year 3	- 104	- 6,653	- 4,935
Year 4	330	- 6,999	- 4,359
Year 5	614	- 6,314	- 4,392
Year 6	964	- 3,574	- 3,127
Year 7	965	- 3,422	- 3,365
Year 8	1,625	- 2,288	- 2,968
>Year 8	1,625	- 900	- 2,463

Table 5: Comparison of annual gross margins of main crops with *Jatropha*

Crop	Gross margins in KShs/acre
Maize	210
Beans	3,272
Pigeon peas	2,278
Jatropha (Hedgerow at maturity)	1,625
Jatropha (Intercrop at maturity)	- 2,288
Jatropha (Monocrop at maturity)	- 2,968

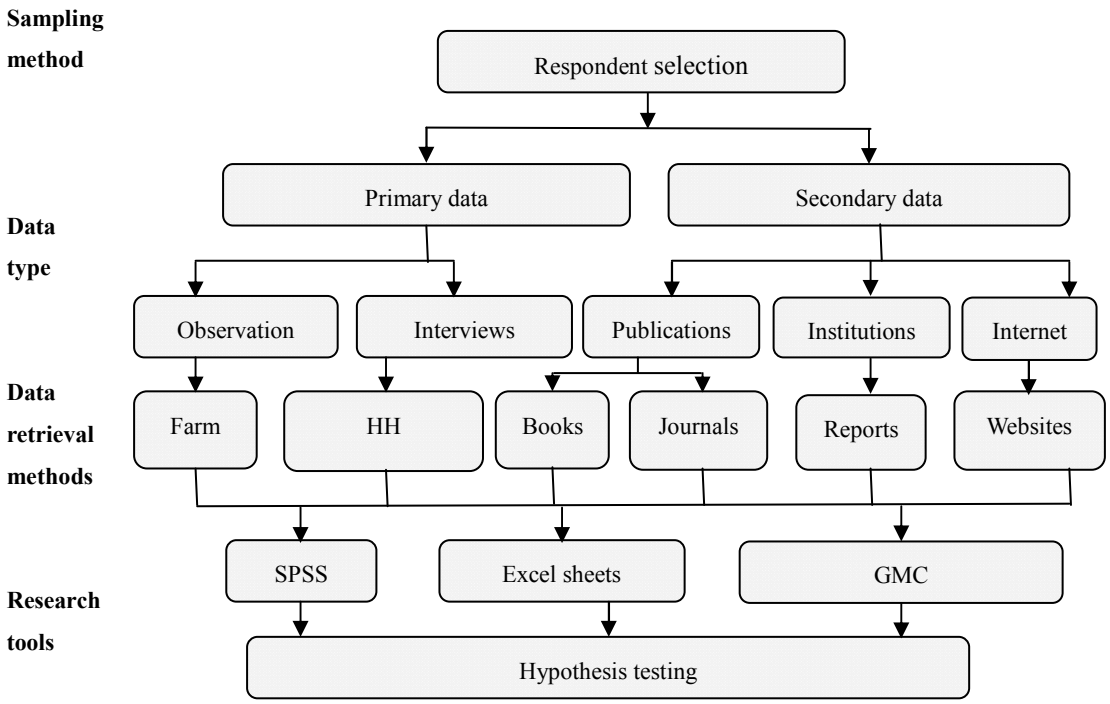

Figure 1: A schematic diagram of the research design

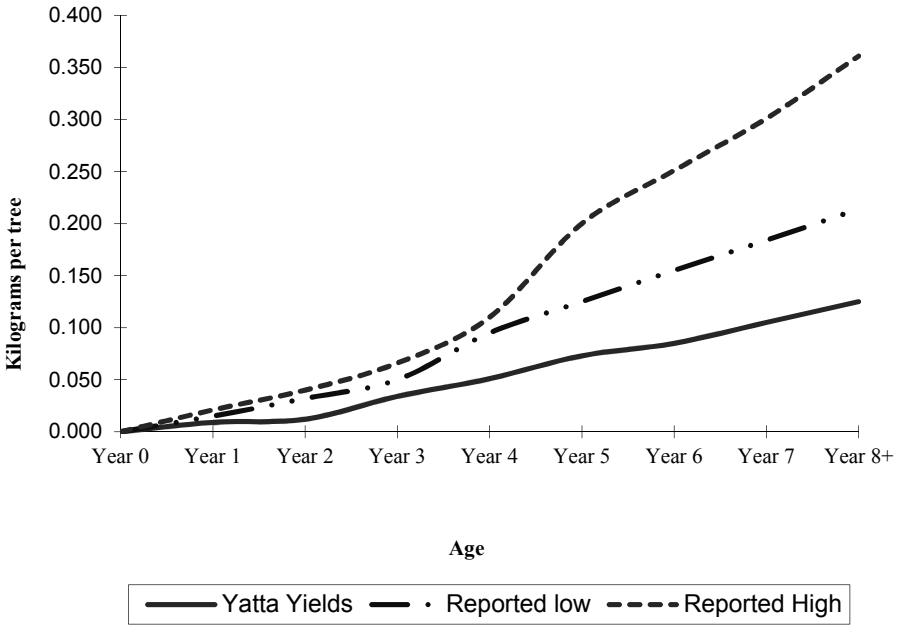

Figure 2: Comparison of annual *Jatropha* yields reported in Yatta District to yields from other parts of the country in the same agro-climatic zone