<u>**Reality or romantism? Potential of *Jatropha* to solve energy crisis and improve livelihoods**</u>

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Reality or romantism? Potential of *Jatropha* to solve energy crisis and improve livelihoods

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Abstract
This paper evaluates the potential of *Jatropha curcas Linnaeus (Jatropha)* as an alternative source of energy for rural households. The plant is said to have potential to diversify rural incomes, reclaim unproductive lands, reduce importation of fossil fuels, and consequently accumulation of green house gases in the atmosphere. A cost benefit analysis was employed to evaluate the feasibility of producing *Jatropha* as a biodiesel feedstock in relation to other crops in Kwale district. An IRR of 11 percent, BCR of 0.62 and a NPV of (28267.56) showed that production of *Jatropha* is not feasible at the moment. However we conclude that the plant has a potential to achieve its intended purpose if there is coordination in research and development along the *Jatropha* value chain and if technical and financial support is accorded to actors at the production level of the chain.

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1. Introduction

Energy demand and supply imbalance is a global challenge to development. Majority of the world's energy is generated from non-renewable sources such as oil, coal and gas while renewable energy sources account for only 13 percent of the total energy supply (IEA, 2007). Increasing human population and economic development in fast growing countries like India aggravates the balance between energy supply and demand as consumption increases (Economic survey, 2008). As a result it is projected that the total world consumption of energy will increase by 50 percent from the year 2005 to 2030 The largest increase in demand is expected to take place in developing countries where the proportion of global energy consumption is expected to increase from 46 to 58 percent by the year 2030 (IEA, 2007). As demand for energy increase supply of major non renewable sources declines as a result of lack of capacity to replenish them by nature.

Kenya like most developing countries relies on imported fossil fuel as well as inefficient natural resources such as firewood for energy supply. Despite being a dominant energy source conventional fossil fuels are limited and unevenly distributed with the most important reserves located in politically unstable regions of the world[1] (EU, 2006). Kenya imports at least 75000 barrels of oil every day and depends on natural resources to provide for 60 percent of its primary energy demand. High fuel importation bill is burdensome to the country's gross domestic product while over-extraction of natural resources for energy supply causes degradation and loss of biodiversity in extreme cases. Additionally use of insufficient energy sources such as firewood produce life threatening and environment polluting gases such as carbon monoxide, benzene and

[1] Fossil fuel producing regions include unstable Middle East countries like Iraq, Iran, Saudi Arabia and Kuwait

nitrogen oxide on one hand while negative impacts on the environment, price volatility and unreliable supply of fossil fuels make them unfavorable choice for energy.

These energy challenges and negative impacts on the environment call for exploration of other sustainable and environmental friendly sources of energy. Except for high costs involved in accessing them renewable sources like solar, wind, and biofuels have been identified as alternative sources with the greatest potential to solve energy crisis in low income countries. Among them biofuels are most economical for tropical countries as they have a comparative advantage in cultivating them (Van Eijck and Romjin, 2007). A number of feedstock including, *Ricinus comminis*, commonly known as castor, Croton megalocarpus, *Jatropha curcas* among others are being evaluated for biofuel production. However there are conflicting results about their potential as commercial feedstock .This makes it inadequate to justify their value without case specific study of each feedstock. Nevertheless there is a general agreement that any biofuel feedstock should solve energy crisis as well as provide positive energy balance to lifecycle environmental benefits (Farrell et al., 2006; Hill et al., 2006).

This paper reports on some important recent feasibility study of a specific biofuel feedstock (*Jatropha*) carried out in Coastal Kenya. The main questions addressed here are: What are the existing farming systems, to what extent is the value chain developed and what are the challenges to its development, how do costs of production compare with benefits from *Jatropha* and what is the unutilized potential in the *Jatropha* value chain.

A cost benefit analysis was employed to establish the feasibility of producing *Jatropha* relative to main crops in the area. The main aim of any feasibility study is to establish the worthiness of engaging in a new enterprise in relation to a situation without the enterprise or other existing enterprises. This method was most appropriate because it provides a means of systematically measuring costs and benefits that occur during the lifespan of an enterprise in different periods of time. It is guided by the principle of welfare economics where society's welfare is measured by aggregating individual utility levels. Welfare economics is in itself rooted in the theory of Pareto efficiency and consumer surplus where an enterprise is considered beneficial if net benefits are greater than net costs or if those who gain from it can compensate those who loose.

The research on which this paper is based involved substantial fieldwork in Kwale district. Field data was gathered through focus group discussions with key informants and household interviews with all contracted *Jatropha* farmers using a structured questionnaire. Existing literature was used as secondary source of information. The output of this research is among the first systematic attempts to empirically clarify information about *Jatropha* production in Kenya.

The paper is organized as follows. Description of *Jatropha* and its value chain activities in Kenya are outlined in section 2. An outline of the cost benefit analysis as applied in the study is given in section 3. Section 4 presents the results while sections 5 and 6 concludes the paper by discussing the results with policy recommendations.

2. Background of *Jatropha*

Jatropha is a small tree or shrub of the family Euphorbiaceae. It is a perennial plant with a lifespan of 50 years and more when established from seed and 15 years or less when established from cuttings. It is believed to have originated from Central America, Caribbean or Mexico but has become naturalized in many tropical and subtropical areas e.g. India, Africa and North America (Heller, 1996; Nyamai and Omuodo, 2007). It has been spread as a valuable hedge as well as a medicinal plant to Africa and Asian countries. In Kenya it is grown in Western, Central

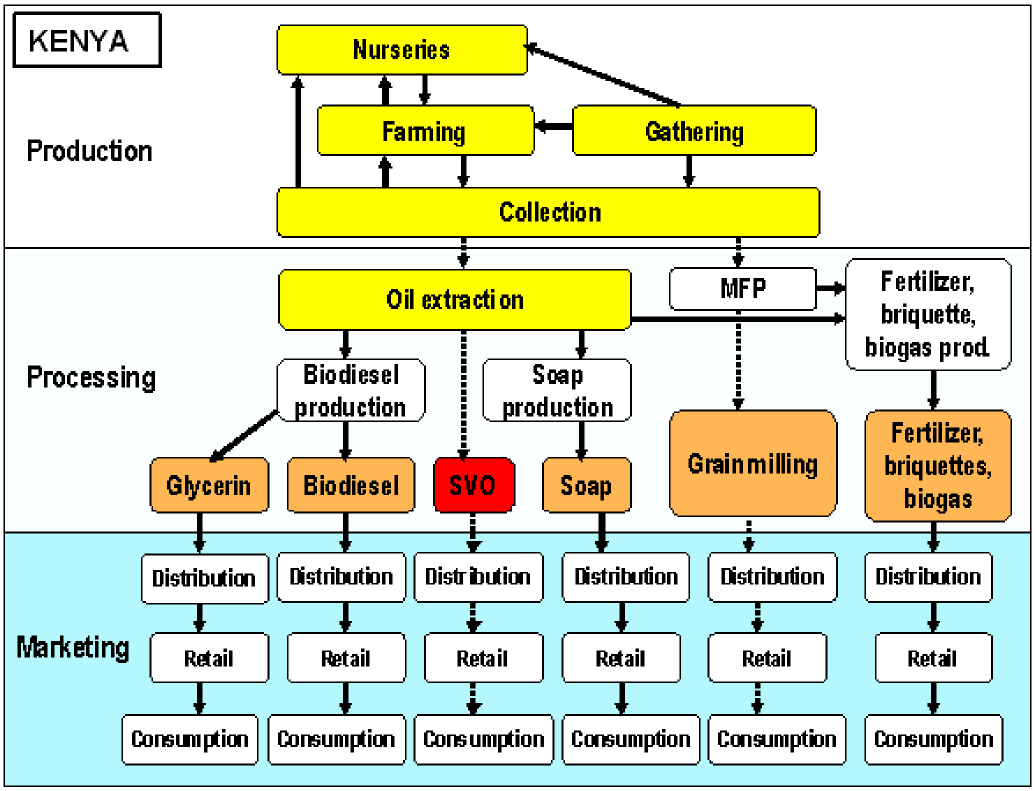
Eastern and Coastal parts of the country in attitudes of between 0-1650m (Maundu and Tengnus, 2005). Most farmers use seed and sometimes cuttings for propagation. Propagation by seed is encouraged because plants propagated from seed have a longer lifespan of 50 years and more in relation to those propagated by cuttings which have a shorter lifespan of 15 years or less (Nyamai and Omuodo, 2007, Githunguri *et al*., 2008). The most common uses of *Jatropha* include; fencing, cows shelter, income generation and soil conservation. When planted as a cow shelter the plant does not require application of fertilizer or manure. The plants under such use are healthier and produce more seeds per tree in relation to those planted as fence or income generation.

Yields depend on agro ecological conditions; soil conditions, altitude, temperature, water availability and management regimes. Although *Jatropha* is said to grow in marginal areas it is not nitrogen fixing and hence requires nitrogen rich soil for good seed production (Van Eijck 2008). Jones and Millers 1993 estimates yields ranging between 0.1 to 15tons/ha/yr (This is a maximum of 1.2 tons/acre) while Tewari *et al* in Tomamatsu and Swallow, 2007 estimates annual seed production of between 200grams to 2kg per plant depending on the conditions under which *Jatropha* is cultivated.

Although *Jatropha* is multi-purpose we explore its recently discovered use as a biofuel feedstock. Figure 1 shows J*atropha* activities of the value chain in Kenya. The activities are concentrated at the production level where farmers are dedicated to development of nurseries producing planting material and cultivation of *Jatropha* in their farms for seed production. Farmers then harvest seed from their farms or existing wild plants and dry them for processing. The contractor then collects the seeds from the farmers at a price of Ksh 50 per kilogram. At the processing level only a few organization carry out oil extraction for demonstration purposes.

Soap production is taking place but at a very minimal rate as EA speculates the market. The rest of the value chain is undeveloped with no stable market for seeds except for a few individuals who buy for propagation purposes. The only stable market in the research area is Energy Africa (EA) who buys seeds from the contracted farmers. Other preliminary buyers include individual farmers and NGOs who buy seed for establishment of their own nurseries. Potential marketable products include: briquettes, straight fertilizer, soap, and biodiesel.

Figure 1: The *Jatropha* value chain



2.1. *Jatropha* as a biodiesel feedstock

The most popular and recently discovered use of *Jatropha* is as a biodiesel feedstock**.** Its oil content of about 25 to 35 percent makes it favorable for oil production. Kenya aims at using Straight *Jatropha* oil (SJO) to produce biodiesel as a substitute for conventional diesel and other fossil fuel sources as well as for export by the year 2020 (Kenya biodiesel draft, 2008). For SJO to be economically viable it has to compare with conventional diesel by satisfying standards such as density, Viscosity, Iodine number, sulphur content as well as price as defined by the Kenya bureau of standards (KBS, 2008). Currently the market price for conventional diesel is between 65 to 70 Kenya shillings per liter.

On the other hand *Jatropha* seed goes for fifty Shillings a kilogram in Shimba hills. It is estimated that four kilogram of *Jatropha* seeds are required to make a liter of SJO (GTZ report, 2009). At the current seed price (fifty shillings per kilogram) keeping other factors constant the price of *Jatropha* produced diesel is likely to sell at a higher price of 200 per litre. The price will even be higher if other costs incurred in transforming SJO into usable biodiesel are factored in the cost of production (own projections). The price of Ksh 50 only applies to Shimba hills contracted farmers. Higher prices of up to Ksh 2000 have been reported in other parts of the country such as Nyanza and Eastern provinces.

Charging a higher price for *Jatropha* seeds increases the cost of production and renders *Jatropha* biodiesel less competent than the conventional diesel. This would make *Jatropha* enterprise unattractive for investment. For these reasons a price of not more than Ksh 15 per kilogram of seed is appropriate if *Jatropha* is to compete with the conventional diesel.

3. Methodology

3.1. Cost benefit analysis (CBA)

A financial cost benefit analysis was employed to estimate the costs involved in producing *Jatropha* and benefits of either replacing other crops with *Jatropha* or intercropping it with other crops by smallholder farmers in Kwale district. Cost benefit analysis can either be carried out from the farmers' perspective (financial CBA[2]) or from the economy's point of view (economic

[2] In the financial benefit-cost analysis, the unit of analysis is the *project* and not the entire economy

CBA[3]). Since the value chain is only developed up to the production level our methodology approach is designed to capture costs of production up to the seed production level and benefits arising from the sale of seed. The motivation to estimate the potential seed yields was due to the fact that biodiesel production relies greatly on the cost of feedstock production estimated to be 6 percent of the total cost of production Tomamatsu and Swallow (2007). Energy Africa (EA) who buys seeds from their contracted farmers at Ksh 50 per kilogram provides the only reliable and available market.

3.2. Financial Cost benefit analysis (FCBA)

Due to the limitations of the activities of the value chain a financial CBA was the most applicable method for this research. This was carried out from the farmers' perspective and considered costs incurred and benefits obtained from production of *Jatropha* as adopted from (Maina, G, 2009). In this case only costs of feedstock production were considered**.** These included costs of: land preparation, planting, weeding, pruning, harvesting, and disease and pest control. The only direct and measurable benefit was obtained from the sale of seed. These were valued at the prevailing market prices. Future flows of costs and benefits were inflated by five percent and discounted at 18 percent to obtain their present values.

This formula adopted from (Boardman et al., 2001) was used to calculate the Net present values.

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

Where: NPV=Net present value, N=Life time of the project, B_t =Total benefits from *Jatropha* production, C_t=Total costs of producing *Jatropha*, R = real discount rate, T =Production Year

[3]In economic CBA the unit of analysis is the entire economy

The costs and benefits that occur in different years were aggregated and discounted to obtain their present values. The reason for discounting is because people prefer to consume now rather than later. In discounting a cost or benefit that occurs in year t is converted to its present value by dividing it by $(1+r)^{t}$ where r is the social discount rate and t is the year in which the discounting is done. The following equations adopted from Boardman et al (2001) were employed in the analysis.

$$PV(B) = \sum_{t=0}^{n} \frac{B_t}{(1+r)^t} \cdots\cdots\cdots\cdots\cdots\cdots\cdots [1]$$

$$PV(C) = \sum_{t=0}^{n} \frac{C_t}{(1+r)^t} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots [2]$$

$$NPV = PV(B) - PV(C) \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots [3]$$

Three options are available to guide the decision making process of a CBA. Benefit cost ratio, internal rate of return method (IRR) and the net present value (NPV). The NPV criterion is the most appropriate because it always gives the correct answer even if some of the values of the incremental net benefit are negative. The NPV is given as follows:

$$NPV = PV(B) - PV(C) \succ 0 \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots [4]$$

Or

$$PV(B) \succ PV(C) \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots [5]$$

Where PV is the present value, B is the Benefits and C is the costs. In general the decision rule is that if the NPV is positive then the project is said to be feasible and hence potentially Pareto efficient. This implies that as long as the Net benefits are positive it is at least possible that losers could be compensated so that the policy is termed Pareto improving. If there were more than one project the one with the highest NPV would be more Pareto efficient and would be adopted.

For the benefit cost ratio (BCR) an enterprise is considered profitable if the ratio of benefits to costs is greater than 1.0. In the case of IRR method the project with the highest IRR is considered most feasible. Being a new enterprise in Kenya, very little or no impact on the society can be associated with production of *Jatropha*.

The Net present value is the difference between the present value of cash inflows and the present value of cash outflows. It compares the value of a project today to the value of that same project in the future. The current market rate of 18 percent was used to discount both costs and the benefits.

3.3. Data collection

Five key informants in the local administration were interviewed with an intention to elicit an incisive and enlightening opinion about *Jatropha* production in the area. Among them were; the district officer (DO), the district Agricultural extension officer (DAEO), Crop development officer (CDO), a local entrepreneur and the sub chief Matuga sub-location. The key informants were engaged in personal interviews using an open-ended interview guide to obtain information on their views about *Jatropha*. Snowball method was employed among them to identify other resource persons in the area

Three focus group discussions were organized with the identified resource persons, among them staff from World wide fund in conjunction with the United nations development program (WWF and UNDP) who were working on *Jatropha* based projects at that time and Energy Africa operations manager, the second one comprised of a retired chief and other invited guests with interest in *Jatropha* and a last one was made of local administration and representatives from the ministry of Agriculture. For proper facilitation of the discourse, each focus group comprised at least six members. A structured question guide was also used to acquire general information about *Jatropha* from invited members. Information acquired from all the three groups was compared and used in assessment of *Jatropha* management practices.

During the discussions it was clear that Energy Africa had taken root in *Jatropha* activities and had about 200 contracted farmers. For ease of data collection all the contracted farmers were interviewed using a semi structured questionnaire.

The questionnaire was designed to capture information like background and socio-economic status of the farmer, agronomy and management practices, land use and opportunity cost of production and performance of the plant. General information about *Jatropha* production was generated from an open question posed to them to explain their experience in the *Jatropha* industry. Findings from this study are reported as follows: farming systems and management practices, costs of productions, gross margin analysis and feasibility analysis in that order.

4. Results

4.1. Farming and management practices

The dominant farming system was intercropping of *Jatropha* with annual food crops such as cassava, beans and maize. A spacing of two meters by two meters was used along and between *Jatropha* plants. The other common farming system was as hedge around homesteads and fields to protect food crops from destruction by livestock and wild animals. Hedges were also planted as boundaries to demarcate farms owned by different owners and around milking sheds to restrict livestock and provide them with shade. A few famers with large tracts of land practiced monocroping where they planted a pure stand of *Jatropha* giving the plants a large spacing between and along rows.

The average acreage on *Jatropha* is 0.5 acres per farmer with each acre having around 1330 in monocroping and 1000 *Jatropha* plants in intercropping regimes. Low yields of up to 0.1 kilogram per plant have been a major drawback to farmers' expectation from *Jatropha.*

Diseases and pests were managed by spraying plants with duduthrin using a knapsack sprayer. However due to lack of knowledge on proper management practices spraying was done after manifestation of disease and pest on plants. By this time significant destruction will have been caused on the plant especially on the leaves and sometimes the stem and roots. Duduthrin was used on all manifested diseases and pests. Delayed pest and disease management and use of a single pesticide to manage all kinds of diseases was a probable reason for poor plant health and low seed yields.

4.2. Energy use in descending order of popularity

Table 1: Common sources of energy and their use in Kwale district.

Type of energy	Amt per week	Price per unit(Ksh)	Purpose	Distance from source
Firewood	2 loads	50	Cooking	0
Kerosene	1L	70	Lighting	0.5
Charcoal	0.25 bags	350	Cooking	0
Jatropha oil	0.25 L	100	Lighting	0.5
Batteries	1 pair	70	Lighting	0.5

Source: Field work

Table 1 shows the main sources of energy and their use in order of descending popularity. Firewood is the most popular of them all while *Jatropha* oil and batteries are the least used.

Although not popular as a source of energy one liter of *Jatropha* can be used for one month or more depending on the duration of lighting. The main challenge however is its low capillarity and clogging effects on the lamps. Light from *Jatropha* oil lamps is also dim compared to kerosene lamps. However smoke from *Jatropha* lamp is not as chocking as that from a kerosene lamp.

4.3. Cost of production

Being perennial with high initial cost of investment establishment of *Jatropha* incurred the highest fixed costs relative to competing crops maize and oranges. These were costs of purchasing land, farm implements, seeds, land preparation, planting, and cost of replanting in case of failure of germinate during establishment. Being perennial cost of establishment for orange plants were also assumed to be the same as those of *Jatropha* at Kenya shillings 44089 while fixed costs for maize included cost of land and purchase of farm implements amounting to Kenya shillings 30250. All costs were measured in Kenya shillings per acre per year.

Variable costs were highest for maize production amounting to Kenya shillings 6078 and lowest for *Jatropha* at Kenya shillings 3394 per acre per year. Although *Jatropha* had the lowest variable costs it exhibited the second highest total costs amounting to Kenya shillings 47484 due to high costs of plant establishment. Orange production was the most expensive incurring a total cost of Ksh 48339. Being an annual plant production of maize is the cheapest of the three enterprises at a total cost of Ksh 36328. These results showed that *Jatropha* is not a low input plant as initially thought. Just like any perennial plant it has high initial investments and significantly high variable costs. Table 2 compares costs of production for *Jatropha*, maize and oranges.

Table 2: Cost of production per acre

Cost of production			
	Fixed costs	Variable costs	Total costs
Jatropha	44089.90	3394.22	47484.90
Oranges	44089.90	4239.06	48338.96
Maize	30250	6077.77	36327.78

Source: Authors' Calculations

4.4. Gross Margins Analysis

A positive balance between benefits and costs amounts to a gross margin. A ready market for transacting outputs is a prerequisite for achieving a high gross margin. Results of this study showed higher gross margins for oranges resulting from high output from one acre of orange farm. There was a diverse market including wholesale and retail for both maize and orange but limited market for *Jatropha* seed. The GM from oranges amounted to Ksh 22288, Ksh 17790 from maize and was lowest for *Jatropha* at Ksh 3256.

Table 3 shows a breakdown of the gross margins (GM) for the three crops.

Table 3. Gross margin (GM) analysis for the year 2009

Crop	Variable cost	Revenue	Gross Margin
Maize	6077.78	23867.31	17789.53
Oranges	4239.06	26526.62	22287.56
Jatropha	3394.22	6650	3255.78

Source: Author's calculations

4.5. Feasibility analysis

To verify the feasibility of *Jatropha* production the Net present value, internal rate of return and the benefit cost ratio was calculated. Table 4 compares NPV, IRR and BCR of the three plants.

Table 4: A comparison of NPV, IRR and BCR

	NPV	IRR	BCR
Jatropha	(28267.56)	11	0.62
Oranges	98752.70	41	2.33
Maize	130752.70	155	2.53
Discount rate 18 percent			
Inflation rate 5 percent			

Source: Author's calculations

A high NPV for both maize and orange production implies that the two enterprises are profitable to the farmers. On the other hand a negative NPV as well as an IRR of 11 percent (lower than the discount rate) for *Jatropha* production implies that *Jatropha* production is not a profitable venture. A negative NPV is an indication of negative cash flows in *Jatropha* production enterprise. The BCR of 0.62 confirms the riskiness involved in producing *Jatropha*. A lower than 1 BCR implies that the costs incurred during production are greater than the benefits.

4.6. Sensitivity analysis

The IRR on investment depend on certain assumptions determining the margins between costs and revenues. It was therefore critical to check the sensitivity of IRR as well as other indicators of profitability upon changing some important parameters like discount rate, and price. The inflation rate as well as prices of both maize and oranges was kept constant in each analysis. Table 5 shows the gross margins when price of Jatropha seed is doubled i.e. from Ksh 50 to Ksh 100.

Table 5: Gross margin analysis with price of seed doubled.

Crop	Cost	Revenue	Gross Margin
Maize	6077.78	23867.31	17789.53
Oranges	4239.06	26526.62	22287.56
Jatropha	3394.22	13300	9906.22

Source: Author's calculations

When seed price is doubled revenue increases from Ksh 6650 to Ksh 13300.This resulted in a tremendous increase in gross margin from Ksh 3256 to Ksh 9906. The implication is that higher prices for seed positively affect profitability of *Jatropha* seed as the only tradable product at the moment.

Net benefits were also sensitive to changes in price. Table 6 shows the NPV, IRR as well as the BCR when seed prices are changed. By doubling the price of *Jatropha* the NPV becomes positive, both the BCR and the IRR change positively. This is because besides being the only tradable output, seed is also a major input in production of *Jatropha* when direct seeding method of propagation is used or when seeds are used to establish nurseries for later transplantation.

Table 6. Financial analysis with price of *Jatropha* seed doubled

Discount rate	NPV	IRR	BCR
18	27697.73	22	1.23
15	50221.03	22	1.23
10	131609.66	22	2.15
Inflation rate 5 percent			

Source: Own calculations

With double the price the IRR increases from 11 to 22 percent and remains constant at 22 percent at discount rates of 10, 15 and 18 percent. The BCR also increases from 1.23 to 2.15 when the discount rate changes from 15 to 10 percent. The NPV increases as the discount rate decreases. Positive increases are an indication of the financial viability of production of *Jatropha* at higher seed price at all levels of discount rates 18, 15 and 10 percent.

On the other hand the GM changes negatively when price of seed is lowered from Ksh 50 to Ksh 10 per kilogram the recommended price if *Jatropha* biodiesel is to compete with the conventional diesel in the fuel market. Table 7 shows changes in revenue, GM and NPV obtained from *Jatropha* at a seed price of Ksh 10 per kilogram. Revenue decreases to Ksh 1330 resulting to a negative gross margin of Ksh1086. The NPV also decreases tremendously from 27698 to 3682. These results are an indication that *Jatropha* production is not viable at low seed prices.

Table 7. Gross margin analysis with price of seed lowered to Ksh 10.

Crop	NPV	Revenue	Gross Margin
Maize	98753	23867.31	17789.53
Oranges	130753	26526.62	22287.56
Jatropha	3682	1330	(1085.78)

Source: Author's calculations

4.6.1. Break even analysis

A break even analysis was carried out to verify results of the CBA. The fixed costs of Kenya shillings 44089, variable costs of 3394.22 a unit price of Ksh 50 were used in calculating the breakeven analysis. Where BE is break even, FC is fixed costs, SP is selling price per kilogram, VC is variable cost per unit. A *Jatropha* plantation is presumed to be a 50 years investment project (lifespan of *Jatropha*) while one acre can produce about 133 kilograms of seed. Using equation 3.6 to calculate the BE shows that at least 1801.5 kilograms of seed have to be sold in order to break even. At this the farmer will earn Ksh 90075 from one acre of land per year.

$$BE = \frac{FC}{(SP - VC)} = \frac{44099}{50 - 25.52} = 1801.5$$

This is far much beyond the average yield of 0.1 kilograms obtained by the farmers at the moment.

5. Conclusions

Despite the negative net benefits it was concluded that Contract farming is useful in incentivizing farmers to produce *Jatropha*. *Jatropha* could be a solution to energy insecurity, rural livelihoods as well as environment protection. Besides being a potential cash crop it offers Kenya some prospects of self reliant energy supplies with potential economic, social and energy security benefits. Presence of high local demand as well as open minded farmers in Kwale district offers *Jatropha* an opportunity to prove its potential in alleviating rural livelihoods through production and use of *Jatropha* and its products. However negative experience already experienced in *the* industry may derail its progress in achieving the intended purpose. Some of the draw backs Include; high initial costs of production and inadequate financing arrangements surrounding the producers. Without supporting policies from the government it may talk long for *Jatropha* to become economically viable. Technical and financial support to producers may go a great way in developing the Jatropha value chain.

Other constraints to development of *Jatropha* as a biodiesel feedstock are: conflicting interests among foreign investors, lack of knowledge about management of *Jatropha* trees, lack of seriousness among the contracted farmers and lack of a complete and an active value chain. Total revenue earned from *Jatropha* is less than that from other crops because farmers have not accepted the plant as their own. Farmers are opportunistic of the benefits they get from the contracting firm but are not totally committed to cultivating *Jatropha*. The low yields and revenue from *Jatropha* is probably due to inadequate knowledge in the agronomic and management practices by the farmer. These constraints, lack of awareness on optimal management practices, variety traits and many other unknown factors have resulted in *Jatropha* not being economically viable at the moment.

Additionally the misguided conception that *Jatropha* is a magical plant that grows almost naturally without requiring any attention have contributed to low seed yields. There are also uncertainties about the potential of *Jatropha* as a biodiesel plant for example unknown optimal conditions and unpredictable markets. Although *Jatropha* can grow in low fertile soils such as sandy soils seed yields are low implying that yields are highly dependent on soil fertility, moisture and other plant management practices. Low seed yield is a signal that *Jatropha* will take some time before it becomes a reliable biodiesel feedstock per se. Therefore relying on

Jatropha as the only biodiesel feedstock would delay the country's vision of becoming a major producer, user and exporter of biodiesel by 2020.

Even at the farmers' level production of *Jatropha* is a very risky enterprise. It is only interesting to the farmers because they can intercrop it with other food crops during the first years usually up to five years after planting. However the question of what will happen after 5 years when intercropping will not be feasible due to shading effects is unanswered. Other crops like maize and oranges although requiring higher potential areas are more economically viable compared to *Jatropha*. Despite these *Jatropha* is feasible as a fence, as a shelter for cows and as a medicinal plant. Being non edible it is partly a solution to the human wildlife conflict when used as fence to protect other crops from destruction from wildlife and livestock.

Although it has not achieved its intended purpose as yet, *Jatropha* has the potential to increase household income, create employment and ensure energy security in the long run. Whether this potential can be realized will depend on development of markets, active actors along the value chain, research and development and supportive policies. Until *Jatropha* feedstock production is cost effective and high yields are tenable, straight J*atropha* oil (SJO) will not be in a position to compete with conventional biodiesel. A price of less than Kenya shillings 15 per kilogram of *Jatropha* is required to make SJO competitive with conventional diesel. There is a potential for Jatropha oil to substitute kerosene as it takes longer and has positive health effects. However slight modification is required to dealing with low capillarity and clogging effects on lamps. However due to high initial cost of investment and high opportunity cost of labor, land as well as capital farmers may not willing to commit their resources for a price of less than Kenya shillings 50 in future.

A higher price for seeds or support to access farm inputs is required to make *Jatropha* feasible. However a higher yield of more than 5 kilograms per tree may go a great way in achieving a positive gross margin and high revenues for the farmers. High price will however make biodiesel production costly and not competent with the conventional diesel. To solve this dilemma support from the government and other interested parties is required to foresee farmers' education, creation of market and other linkages along the value chain for optimal utilization of the *Jatropha* system at these initial stages. This will go a great way in kicking off the biodiesel industry

6. Recommendations

The following recommendations are essential to counter the high risks involved in the production of *Jatropha:* It is mandatory to carry out feasibility studies to establish the viability of any plant before they are officially adopted by farmers. This would reduce chances of loss and introduction of environmentally harmful plant species. Since *Jatropha* has already been adopted there is need to develop infrastructure to support a rapid scaling up of its production in order to reduce risks and uncertainties surrounding its adoption. Emphasis should be put in creating markets for *Jatropha* products and linking all actors along the value chain to give an incentive for producers to put more effort. Due to the nature of *Jatropha* (high initial investments and takes a long time to yield) a particular emphasis should be put on supporting farmers to access important goods and services as they await income from *Jatropha* to come forth.

To avoid interference with food crop production farmers should not replace food crops with *Jatropha* but instead should cultivate *Jatropha* is areas not occupied by food crops or land that is not feasible for food production. Upon plantation on unfertile land *Jatropha* should be supplied with enough organic or inorganic fertilizer as well as water to support their healthy growth and yield.

Where land is not limiting a wider spacing of at least three meters between plants should be adopted to enable intercropping of *Jatropha* with other food crops for a longer period without interference by the shading effect. For assured supply of food and income it is advisable for farmers to use *Jatropha* for its traditional uses such as fence as they await official release of the biodiesel policy. Production of maize, oranges and economically viable crops should be given more emphasis before consideration of new plants such as *Jatropha*.

The persistent argument that *Jatropha* can grow in unproductive land should be looked at more keenly because: Wild *Jatropha* plants are always very healthy even on poor soil and moisture conditions but when domesticated even in high potential soils they do not seem to be as healthy and mostly attract pests and diseases. However to improve productivity of *Jatropha* across the country there is need for a significant research and development (R&D) to identify means of decreasing production costs, increasing potential seed yields establish optimal conditions for growth. Means of minimizing pests and diseases should also be addressed by research.

To maximize production per acreage *Jatropha* should be intercropped with legumes and other nitrogen fixing plants during the first years and the plant remains left in the farm to supply nutrients to *Jatropha* plants for the rest of their growing season. *Jatropha* seeds should also be harvested and de-husked in the farm and the husks left on the ground to decompose and act as manure. To increase the viability of *Jatropha* all by-products from its processing should be utilized or marketed to earn more income for the producers.

Case specific research should be carried for specific feedstock to identify viable species for particular agro-ecological conditions. A coordinated selection of feedstock should be adapted to their respective favorable conditions to achieve their full potential.

Adequate policies should be formulated to give direction to all actors in the value chain. This will ensure efficiency and reduce potential risks and uncertainties. All actors from farmers, contractors to government should only engage in formal contracts to reduce chances of opportunism and enhance responsibility among themselves. Only seeds with tested and known provenances should be recommended to the farmers for easy establishment of potential yields in different agro ecological zones.

A complete value chain with working links and markets for products have to be developed and linkages incentivized to motivate actors in their respective channels along the value chain.

Finally more research is required to validate available information about *Jatropha* production. All research work should be harmonized and made public to create awareness and to avoid duplication of efforts among researchers.

To establish the exact potential of *Jatropha* plants there is urgent need to carry out provenance trials for all seeds available in the country. After identification of provenances breeding of high yielding and superior varieties may be required to achieve the required seed quality and quantity. Being a new plant evaluation of the impact of *Jatropha* on livelihoods and environment is mandatory to establish its potentials, risks and uncertainties. These will assist in designing ways to optimize potentials and deal with uncertainties. This will in addition establish with clarity the sources of seed to be planted in each particular agro ecological zone in Kenya. More research is needed to establish the optimal conditions for growth of *Jatropha*, potential yields and best management practices in order to maximize the potential of *Jatropha* in achieving its intended goal.

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