

Economic Sustainability of Jatropha Cultivation for Biodiesel Production: Lessons from Southern Africa

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Abstract

Growth of *Jatropha carcus* in southern African countries is a new endeavor. Claims that jatropha has ability to grow in marginal lands, multiple benefits, potential to increase energy security and mitigate climate change, have motivated some governments, private organisations and individual farmers to invest in its production under different business models. This paper presents results of literature review on experiences of southern African countries on economic impact of growing jatropha for biodiesel production. These results provide lessons for the envisaged jatropha biodiesel production in Botswana as well as other countries intending to grow jatropha in the future. While the economic impacts of investing in jatropha production are country and project specific, the review revealed that most projects, especially commercial plantations, are not economically attractive to the extent that they have been abandoned in some countries. The study concludes by recommending the undertaking of agronomic and socio economic research to fully understand the performance of jatropha crop before embarking on large commercial production which may be risky.

Keywords: Jatropha production; Sustainability; Cost benefit analysis; Seed yield

Introduction

The over dependence on and dwindling supply and increasing price of fossil fuels, coupled with concerns on climate change, increasing international trade, have led to a worldwide shift of interest from conventional energy sources to development of biofuels which are viewed as climate smart energy sources. Biofuels are fuels derived from renewable biological materials such as sugar crops (sugarcane, sugar beet), starch crops (corn, potatoes), oilseed crops (soybean, sunflower, rapeseed), and animal fats. Their growth is associated with socio-economic and environmental benefits and costs. The socio economic benefits include improved rural livelihoods through crop diversification, increased export revenue and agricultural employment, while the socio economic ills include eviction of farmers from land used for crop production (especially when jatropha is grown on non-marginal land), and entrapping smallholder farmers in contract conditions where they had less freedom to pursue other market opportunities [1].

Among the environmental benefits of biofuel production is climate stabilisation, while environmental problems include loss of biodiversity ensuing from large scale deforestation, and competition for essential resources such as water and nutrients with other food crops.

Many countries in the sub-Saharan African region have not been an exception in the drive to achieve energy security as they have depended on oil imports for a long time. The move towards energy security has led to increased interest in *Jatropha carcus*, a non-food crop. Jatropha is a large succulent shrub, belonging to the family *Euphorbiaceae*, growing up to a height of 5-7 m. It is native to Mexico and Central America, but now grows widely throughout the tropics and other areas in Latin America, Africa, India and South-East Asia. Interest in growth of jatropha was aroused by its perceived good agronomic characteristics. For instance, Jatropha was general thought to be drought tolerant, resistant to pest and diseases and require low nutritional requirements. Furthermore, jatropha was thought to grow on shallow, low fertility and degraded soils as well as in low rainfall area. It was also reported to perform well on a wide range of temperatures, but very sensitive to

frost. Most of the claims made earlier on these jatropha performance characteristics are contested by recent literature [2,3].

The drive to grow jatropha was also influenced by its multiple uses. In Tanzania, Mozambique and Zimbabwe, the plant has been used as hedge to protect arable fields and homesteads as well as to reduce soil erosion. The oil from processed seeds is used as an insecticide, for making candles, and to provide energy for lighting and cooking. The seed cake produced from the transesterification of oil is used as feedstock for biogas production and later as fertilizer, while glycerine is used in soap making. Seeds, leaves and barks of the plant are used as source of traditional medicines, while woody part such as sticks and poles are used as source of energy for cooking [4].

Like in other developing countries, concerns about energy security, climate change, rural development and lack of foreign exchange are some of the drivers of biofuel development in Botswana. The Government of Botswana continues to rely on imported and conventional sources of energy and the need to develop alternative sources energy with to minimise reliance on fossil fuels has been increasingly realized over the years. In 2007 the Government of Botswana, through the Ministry of Minerals, Energy and Water Resources (MMEWR) undertook a feasibility study to examine the opportunity for the production of both ethanol and biodiesel (EECG Consultants, 2007). According to this study, a large scale production of 50 million litres of biodiesel per year produced from jatropha plant was cost effective and this served as a

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motivation for the government to pursue efforts to produce jatropha for biodiesel production [5-7]. It was envisaged that the private sector and farmers would be engaged in establishing jatropha production to meet the said production capacity. To this effect the Government of Botswana has engaged with the Government of Japan to venture into a project that will develop future commercial production of biodiesel from jatropha. Currently, there is no small or large scale production of jatropha in Botswana. The objectives of the project are to ascertain optimal farming methods for growing jatropha plants in drought and cold-prone areas in Botswana, to determine how to cultivate drought-resilient, cold-resilient and high-yield jatropha varieties, to assess the environmental, social and economic impacts of jatropha production and biomass use in Botswana [8].

Assessment of Economic Sustainability of Jatropha Production

Biofuel production systems are deemed sustainable if they are economically sustainable, conserve the environment and meet the welfare needs of people. Maximising goal achievement across economic, environmental and social sustainability therefore contributes to overall sustainability of a project. In a broader context, avoiding or reducing damage to the integrity of the environment is a goal of environmental sustainability. Thus, project activities that have the potential to result in loss of biodiversity, increased greenhouse gas emissions or other negative effects on the environment, are not deemed environmentally benign. Assessment of social sustainability would consider a range of positive and negative impacts on issues affecting the wellbeing of society such as such food security, local prosperity, working and labour conditions, land rights and gender. For any given projects some members of the society benefit, while others would carry a net loss. A project that results in dispossession or eviction of farmers from their land, increased socio economic disparities, reduced food supply and increases in food prices, may not pass the social sustainability criteria [9].

Economic sustainability can have varied meanings. In the context of this paper, a jatropha production project is considered economically sustainable if it is able to earn cash flow from the sale of seeds or oil to cover the cost of production and make profit over the life of a project, while having minimal negative social and environmental impacts. Cost-Benefit Analysis (CBA) is a common tool used to assess economic sustainability or viability of large-scale and smallholder jatropha projects with a view to assist in better allocation of scarce economic resources. As CBA is limited to quantifying the cost and benefits of projects in monetary terms, some of environmental cost and benefits are not easily quantifiable due to the absence of market prices for these costs and benefits. However, non-market techniques are often employed to estimate their values. CBA also entails efficiency and equity considerations. A project that is economically efficient makes maximum use of resource inputs to produce the highest output per unit of those resources. In the context of jatropha such a project would produce the highest seed yield using minimal labour or other resources. A project is said to yield equitable benefits if the benefits exceed costs for most groups in a society [10].

Projects may be assessed at three stages of i) before an activity takes place (*ex-ante* analysis), ii) during an activity and iii) after an activity has taken place. The purpose of *ex ante* analysis is to help in setting priorities and deciding whether or not an activity should be undertaken. *Ex post* analysis has the objective of evaluating how an activity has performed, as well as to judge whether or not resources should have

been invested in that activity. Assessment carried out during an activity allows monitoring to take place and to provide an opportunity to make changes where necessary [11].

The most common business models where economic assessment is undertaken are smallholder and outgrower model comprises what is often referred to as Type I and Type III projects, while the large industrial farms can be categorized into Type II and Type IV project. Type I projects are characterised by independent production of feedstock for local or commercial use by the smallholder farmer. Projects undertaken under this mode of production are often aimed at improving rural livelihoods especially when the focus of production is on multiple products of jatropha such as using oil for electricity generation or soap production. The smallholder business model also involves the hedge cultivation, a traditional system in which jatropha is grown as live fence for the protection of fields from livestock and for demarcation purposes. Type III projects are characterised by producing feedstock under a contract arrangement between large a commercial company and the smallholder farmers. The large commercial company provides support to contracted farmers in the form of supplying seeds, while the farmer is obliged to plant jatropha on their land and sell seeds to commercial company [12,13].

The large plantation model (industrial farms) is usually characterised by use of large tracks of land used for production (10-1000s hectares), with monoculture as the adopted practice. The primary aim for Type II projects is to produce for own use, while Type IV projects aim to produce for national and international market. The model also engages hired labour used mostly for harvesting [14].

Economic viability of jatropha production in any business model is determined by several factors, including seed yield (which is influenced by climatic conditions and crop management practices such as irrigation, pruning, fertilization weeding etc.), the price of fossil fuels (which determines the competitiveness of jatropha oil and the cost of production inputs such as labour, which has a high demand during harvesting. A key determinant of economic viability that is often not fully accounted for in economic assessment of jatropha production is the opportunity cost of land. The full opportunity cost of land used for jatropha production can be very significant, especially when the same land could be used for growing food crops or used for cultural or social activities [15].

The measurement criteria often used in CBA include the net present value (NPV), the internal rate of return (IRR), the benefit-cost ratio (BCR) and the payback period (PBP). The net present value (NPV) is the sum that results when the expected costs of the investment are deducted from the discounted value of the expected benefits (revenues) (International Fund for Agriculture and Rural Development, 2015). A project is considered to be profitable if it has a positive NPV. The IRR is the rate of discount that makes the NPV equal to zero or the rate of interest that makes a project to break-even. The breakeven is the point at which revenue or sales cover production costs. The BCR is a profitability index, and is the ratio of sum of all discounted costs to benefits. A project with a BCR of greater than one indicates that the project is making profit, while the converse is true. The payback period is the number of years a project takes to repay its investment costs. A long payback period therefore indicates a project that is not economically promising [16-18].

Biofuel projects also provide direct and indirect social benefits or values that stakeholders realise as a result of their participation in the

projects. Indicators for social values or benefits include the number and quality of jobs created, increased household income, improved food security, reduced poverty and improved access to energy by poor households [19-21]. According to Working Group of Sustainable Biomass Utilization Vision in East Asia (2008), indirect benefits or effects of growing biofuels such as jatropha may include additional jobs and economic activity involved in supplying goods and services related to the primary activity or industries related to production and processing of the plant, while induced effects or benefits include employment and other economic activities generated by the re-sponding of wages earned by those directly and indirectly employed in the jatropha related industry [22-25].

Material and Methods

The approach of this study was to review of old and recent literature on the economic sustainability of small and large scale jatropha projects in the southern African region. In this review a range of sources were used including journals, books and government reports/documents. The review covers most countries in southern Africa as all of them import their transport fuel. While variations in the local environment and socio-economic conditions exist between Botswana and other southern African countries, the status of old and ongoing jatropha projects undertaken in some of these countries provide great lessons for Botswana and other countries that are planning to embark of bioenergy projects. Specific case studies of projects in southern Africa were reviewed, but the general discussion also drew from examples of projects undertaken in other parts of the world, especially in countries with long experience of jatropha cultivation.

Results of Economic Impact of Jatropha Production in Southern Africa

Growth of jatropha crop in Africa as a source of energy and other uses is a relatively new venture and therefore not much data exists that shows the crop's contribution to the energy sector of developing countries and rural livelihoods. Most of southern African countries have environmental and socio economic conditions that are generally suitable for growth of most biofuel crops, including jatropha. Countries such as Mozambique, Angola, Tanzania, and Zimbabwe, have great potential for the production of biofuels, while Botswana and Namibia are considered to have a relatively lower potential. Mozambique is considered to be the most suitable country for biofuel production especially due to its proximity to the ocean, which enhances its export potential.

Jatropha project in Mozambique

Biofuels initiatives in Mozambique commenced with small and medium-scale production when Government of Mozambique envisaged that commercial companies would purchase feedstock from farmers, thereby improving their livelihoods thorough rural incomes. The development of the biofuel sector in Mozambique has largely been driven by the availability of large uncultivated land, suitable climate for most biofuel crops, availability of labour and a friendly investment environment that attracted multinational corporations. A national policy and strategy for biofuels was approved by the Government of Mozambique in March 2009. The pilot project on 'Jatropha for local development' in the coastal zone of Cabo Delgado Province in Mozambique was conceptualized in 2005 and implemented in 2007. The goal of the project was to determine the feasibility of enhancing local development using locally produced jatropha oil to run local diesel engines converted to run on pure jatropha oil, as well as for

the local production of soap and lamp oil. Before commencement of the project farmers were planting and using jatropha as a medicinal plant and as a live fence around their homesteads and fields, and this project focused on planting jatropha a live fence. Considering the price of fossil fuel that made jatropha oil competitive and the price of seeds purchased by the project (5 MZN/kg¹), the project was reported to be economically viable. However, the study does not indicate whether the project would still be viable when there is no market for the seed produced and investment cost of extracting oil are considered.

Jatropha project in Namibia

In Namibia, where biofuels have always been considered as sustainable sources of energy, the National Bio-energy Roadmap of 2006 identified jatropha as the most feasible crop for biodiesel production under dryland cultivation in Caprivi, Kavango and Maize Triangle areas. According to the roadmap, it was envisaged that 63,000 hectares of jatropha would have been planted by 2013, with an estimated potential contribution of N\$189 million² to the country's Gross Domestic Product. The Roadmap and action plan aroused a lot of interest among foreign companies who started the process of acquiring land for jatropha production. In 2010, LL Biofuels Namibia, the main investor in Caprivi area, secured 3,00,000 hectares of land for growth of jatropha. A comprehensive study undertaken by the Ministry of Environment and Tourism to determine the suitability of the jatropha plant and other fuel plants in Caprivi and Kavango regions, recommended that large-scale plantation of jatropha should not take place in the country until a Strategic Environmental Assessment (SEA) was undertaken in the said areas.

Tanzania, and Zimbabwe, has great potential for the production of biofuels, while Botswana and Namibia are considered to have a relatively lower potential. Mozambique is considered to be the most suitable country for biofuel production especially due to its proximity to the ocean, which enhances its export potential.

Energy with an estimated of twenty-five percent of total consumption. Fossil fuels continue to provide energy for the country. The use of biofuel crops such as jatropha is expected to reduce environmental cost of global warming and increase energy security for the country. However, the government's Biofuel Industrial strategy developed in 2007 excludes jatropha crop as it is regarded as an invasive plant species to the extent that its production has been banned.

Notwithstanding the current status of jatropha production in South Africa, Borman modeled the economic returns to labour in jatropha production comparing two farming scenarios. In the first scenario, labour was employed in a large scale commercial farming, while in the second scenario family labour was used in the outgrower scheme. A maximum biodiesel factory-gate price equivalent to the cost of purchasing and importing petroleum-feedstock from international markets, which was known as the Basic Fuel Price (BFP) was assumed. The labour wage was calculated from the difference between the farm gate price and farm production cost all divided by the total labour hours in production. The results showed that it would require a biodiesel factory-gate price of 2.7-3.6 times greater than the current BFP to support minimum wages at similar yields in countries such as Zambia and India, where a similar analysis was done. Thus, the income derived from biodiesel production in South Africa would be too low to cover the labour cost in production.

Jatropha project in Zambia

In Zambia, the development of biofuel sector was driven by

the private sector and strong growth in this sector was experienced in the mid-2000s. The National Energy Policy was formulated and adopted in 2007. Most of biofuel investment in Zambia has focused on smallholder contract farming. While interest in development of biofuel has developed fairly recently, Zambians have a long history of growing jatropha traditionally as a live fence. To date the government has not only realised that jatropha based biodiesel production has the potential to stimulate rural development and promote agriculture, but also its contribution to the country's economic diversification.

Cost-benefit analysis was used in the eastern province of Zambia to determine the profitability of growing jatropha in Lundazi District under various assumptions and scenarios. In the first case scenario, the cost of growing jatropha on part of existing land areas of each farmer (1.2 hectares) was compared with the cost of importing diesel to generate electricity. In the second case scenario, the profitability of growing jatropha in a small rural village of Kakoma in a new area of 3.6 hectares in the presence of an NGO (that provided experience and knowledge to villages), was assumed. The analysis showed that economic benefits of both jatropha based biodiesel options were greater than importing diesel. However, when factoring in investment costs, the feasibility was decreased.

Jatropha project in Zimbabwe

In Zimbabwe, jatropha has been grown for a long time as hedge around homesteads, gardens, and crop fields to provide protection against the invasion by roaming animals. However, it was only in 2005 when the Government of Zimbabwe intensified its promotion of growth of jatropha as a potential source of energy and foreign exchange. Due to increased interest in growth and commercialisation of jatropha crop the government banned its export with a view to concentrating on its development. A local company, National Oil Company of Zimbabwe (NOCZIM), was mandated by the government to implement the biodiesel programme which started with contract model of farming in arid and semi-arid areas where farmers with more than 5 hectares of land entered into contracts with the National Oil Company of Zimbabwe. According to the contract agreement, the company provided free seed to farmers to plant jatropha after which farmers would sell seeds to the company for production of biodiesel. According to the study, these initiatives collapsed in late 2008 due to poor planning and lack of financial resources by the company. In addition, the company offered unattractive price of seeds to farmers that were not reflective of the amount of their labour that went into production. As a result of these challenges, the National Oil Company of Zimbabwe and most farmers abandoned the project.

In the Shamva district, in the Mashonaland Central Province of Zimbabwe, jatropha is grown predominantly as hedge to control soil erosion and the oil produced locally is used in soap making, cooking, lighting, biodiesel production. In this district Mukuruba found that growth of jatropha was not financially and economically profitable as the cost of capital was higher than the expected returns from its production. This result was based on the assumption of 35 years of economic life of the jatropha plant and a yield of 2.4 kg per plant per year from the third year.

Jatropha project in Tanzania

Tanzania, like other developing countries in Africa has experienced a significant rise in demand for fuel as it continues to import all of its fuel requirements. Both the government and NGOs have been engaged in promoting biofuels as alternative energy sources as evidenced by

initiatives such as the establishment of the Rural Energy Agency (REA) in 2005 which was tasked with promoting development of modern energy services in rural areas, and the National Biofuels Task Force (NBFT) in 2006 tasked with addressing issues relating to policies, regulatory framework, and legislation. Furthermore, the favourable environmental and socio economic conditions in Tanzania have led to increased interests among local and international organisation to grow jatropha.

A comparative study of a CBA of a large centralised jatropha plantation and a decentralised smallholder (hedge) system organised around a central processor in south east Tanzania. In both cases the study assumed a cultivation area of 80,000 hectares and a 20 year lifespan of the project. In the plantation model two harvest-system scenarios of semi-manual and fully-mechanized were assumed ("semi-manual" and "fully-mechanized"), while in the smallholder model two capacity scenarios of low" base case (82,000 tons of processed seed/year) and a high case (160,000 tons of seeds/year) were assumed. Under the smallholder system jatropha hedge rows were planted around homesteads or farmer's fields using family labour, while the harvested seeds were sold directly or through middle-men to the company. In the plantation model farmers were hired to provide labour and agricultural equipment was used. The results revealed that the "high" scenario of the smallholder model was the more profitable in terms of the IRR (Table 1). The authors however indicate that for a developing country such as Tanzania one of the challenges of smallholder model may be a secured supply of seeds even with contracted outgrowers. In terms of welfare impacts, the plantation model had higher profits per beneficiary as it employed fewer people, while the revenue per person in the smallholder system was less than in the plantation model since more people were involved in production (Table 1).

The technical and economic viability of biofuel production chains in Tanzania, specifically analysing the production costs of biodiesel production from jatropha and palm oil crops. Three potential investment scenarios were simulated of a combined facility for oil extraction and refinery under small-scale (outgrower) production; a combined facility for oil extraction and refinery and production of jatropha crop under estate (10,000 ha) and outgrowers (10,000 ha); and a combined facility of oil extraction and refinery under larger scale (estate) production of jatropha on 80,000 hectares of land. The simulation revealed that the lowest cost for production of jatropha biodiesel was obtained under the first scenario where the cost was estimated at USA \$0.687 per litre of biodiesel. The study argued that while changes in technologies may result in savings in the processing of inputs and utility costs under the commercial scenario, these are significantly less than the price of the feedstock. Another important finding of the study was that since production of jatropha was labour intensive, it would cost producers under commercial scenario 30% more than under outgrower production.

| System | NPV (\$m/ha) | IRR (%) | PBP (yr) | Discounted Production costs US\$/1SVO |
|---|--------------|---------|----------|---------------------------------------|
| Plantation (semi manual, 1t/h) | 15 | 17 | 13 | 1.32 |
| Fully mechanized (1t/h) | -3 | 7 | ≥ 20 | 1.45 |
| Processing with smallholders: Low capacity i.e. 82000 tons of seeds | 8 | 14 | 13 | 1.28 |
| High capacity i.e. 1600 000 seeds | 18 | 18 | 12 | 1.20 |

Table 1: Economic analysis of Jatropha production in South East Tanzania.

The profitability and competitiveness of Jatropha seed production using CBA in three regions of northern Tanzania (Arusha region, the northern part of Manyara region and the northern part of Kilimanjaro region). CBA was carried out under three scenarios of with and without intercropping jatropha with sunflower at 2000 kg/ha, performing sensitivity analysis assuming higher seed yields of jatropha (50% more), and performing sensitivity analysis with a 50% increase in the prices of sunflower. Results indicated that production was economically viable when jatropha was grown as a sole crop and when intercropped with sunflower. Under the second scenario of assuming higher crop yields (i.e., 3000kg per hectare), and intercropping with sunflower, the discounted NPV was small though positive; indicating that under increasing yields jatropha was economically viable. In the third scenario where it was assumed that the prices of food crops were increasing both the cultivation of jatropha and sole cropping of sunflower were found to be economically viable, although sunflower was more profitable as its net discounted NPV was seven times higher than that for the cultivation of jatropha.

In Shinya region, one of the poorest regions in Tanzania, also jatropha oil production was not as economically competitive as a biomass energy supply system when compared to short rotation woodlot. This study showed that rotational woodlots were more profitable with a positive and higher NPV and higher return on labour. Another study undertaken by Tweve in Arumeru district of Tanzania, applied CBA to determine the profitability of jatropha farming compared with maize farming. The results indicated that both the rate of return of jatropha and maize enterprises were greater than the cost of capital, but the cultivation of jatropha was more profitable when compared to the cultivation of maize. Furthermore, a sensitivity analysis on prices and production costs revealed that the cultivation of jatropha was not sensitive to changes in prices of seeds and production costs as maize was.

Contribution of Jatropha production to human wellbeing

The production of biofuels including manufacturing, processing and distribution of their products, can provide several other social benefits to local people. While most studies have found that returns from large plantations are generally not economically attractive due to the large and insurmountable up-front capital requirements and slow maturation of jatropha (up to 5-6 years), 5 of 6 such jatropha plantation projects in Mozambique created jobs ranging from 0.03 upto 1.03 per hectare. The jobs were mostly of permanent-contract nature due to the dominance of the business model, while in other countries such as Tanzania and Mali the jobs were mostly seasonal which are offered during the harvest season. In addition to employment creation, large scale jatropha plantation projects have benefit of social responsibility through contributing to education, health care and infrastructure (Table 2).

An ecosystem service approach was used to understand the impact of a smallholder jatropha farming project led by Bioenergy Resource Limited (BERL) in Malawi, and a larger plantation project led by Niquel Lda (Niquel) in Mozambique. The smallholder producers were growing jatropha as hedgerows (although some farmers used part of their farms for production) and were supplied with seeds and extension service. In the large plantation model, land was cleared for production. The study found that the large plantation model provided employment to full-time 230 workers and 85-150 seasonal workers, while the income from the purchase of seeds by BERL ranged from US \$0-0.27 per households. The study concluded that both projects showed some signs of viability and local poverty alleviation potential.

| Name of Project | Social responsibility programme |
|-----------------|--|
| Mo_PI2 | Constructed over 70 km of roads and bridges, renovated a hospital and created a football team. Plans to build a school, police station, medical clinic and new houses for the community. |
| Mo_PI3 | Restored a police station, fixed a medical clinic and built a community office and a school, also provided water through piping. Plans to build a church, not (yet) realized. |
| Mo_PI4 | Purchased 20 computers for a local school. |
| Mo_PI5 | Built a hospital and a water pump to provide the community with water, sprayed the village against mosquitoes and created a football team. |
| Mo_O1 | Helped build a bathroom in a local school, educated teachers who can teach at local schools. The company extension workers trained outgrowers on the cultivation of jatropha and food crops. The provision of supplies for jatropha cultivation had not been followed up on in every case. |

Table 2: Jatropha project contribution to local development in Mozambique.

In their study, hypothesised that increased participation of women in biofuel production would help reduce widespread poverty among female-headed households in rural areas in Mozambique and used computable general equilibrium (CGE) model to investigate the implications of increased participation of women in jatropha production. Two scenarios were assumed. In the first scenario, the participation of women was simulated to account for 20% of employment in the new biofuels sector, while in the second scenario, women accounted for 80% of employment. The simulation revealed that increased participation of women in jatropha production would lead to increased tradeoff of labour between its production and food availability, consequently leading to increased prices of food. The study also argued that while increased employment may lead to reduced poverty through income earnings, the higher prices of food may imply that the women's ability to purchase food at high prices may be reduced, further increasing poverty.

In the Southern and Central provinces and Copper belt of Zambia, the impacts of the jatropha industry and how the local policies relate to the concept of sustainability. The study, which employed data from literature, workshops discussions, personal contacts and direct interviews of representative communities in these areas, revealed that jatropha project contributed positively to the creation of jobs for local rural communities, and hence reducing unemployment. According to the study, Oval Bio-fuels company provided technical expertise, equipment and capital, for the large scale decentralised biodiesel production. Notwithstanding all these positive impacts on livelihoods, cited lower crop yields of 0 to 400 kg per year and low market price as partially responsible for the low labour returns of less than US\$ 0.06 per day. While potentially contributing to improved wellbeing in some areas, It is reported that smallholder farmers in Chinsali district in Zambia under contract farming were negatively affected by decreases in land allocated to food crops and subsequent decrease in net food production. The other negative effects reported by farmers were the less time they had to engage in other activities as jatropha production has high labour demand.

In Mutoko district in Zimbabwe, where households participated in

production of jatropha as a way of improving livelihoods, about 9.5% of the households were involved in the processing and selling of jatropha products such as soap, candles, and floor polish. Another study carried out three years later in the same district revealed that members of the community continued to benefit from the same by-products of jatropha, and that soap-making made from jatropha oil mixed with caustic soda, dyes and perfume, was sold by a group of women organised and assisted by NGOs. There was also the added benefit of training these women on the process for extracting oil from jatropha seeds. The other reported uses of by-products were lighting from oil, traditional medicine from the green pigment from jatropha leaves and the latex extracted from the stem.

In Tanzania, while the most preferred use of jatropha is providing energy, other important uses include hedging, solid fuel, medicines, marking grave yards, supernatural beliefs, soap-making, fertilizer and biogas production. Farmers in rural parts of Tanzania benefitted significantly from the outgrower scheme where the contracting company (Deligent) required farmers to grow jatropha as hedges for the protection of their fields. The benefits of such a programme included free provision of seeds; training and knowledge development of farmers with possible spillovers to other cultivate crops, income received from sale of seeds, increased value of land and improvements in agricultural productivity due to crop diversification.

Discussion

The review of literature has shown that almost all of southern African countries continue to rely on imports of fossil fuels due to inability to meet their local energy requirement. This situation, coupled with increasing prices of conventional fuels led to increased interest among some of these countries to consider biofuels, and jatropha in particular, as promising and sustainable green energy sources.

Jatropha has been grown in the past in some countries as live fence. However efforts by southern African governments to grow this plant as a source of energy are recent. It is perhaps difficult to generalise about the economic impact of jatropha production in different countries due to different prevailing environmental and socio economic conditions and the nature of each project in each country. However, most of the projects related to the production of jatropha as a source of energy have been reported to be not economically attractive due to various reasons. Some studies indicate that companies with plans to invest in large plantations models of jatropha production were overly optimistic about its agronomic performance as they were driven by a motive to secure or attract funding. Many such projects collapsed and were subsequently abandoned. The reasons for failure and collapse of most jatropha projects in Madagascar, Mozambique, Tanzania, and Zambia include unrealistic business plans, low yields, time-lags in production, underestimated labor/maintenance/transport costs, lack of markets and lack of appropriate policy frameworks to regulate the biofuel sector. Examples of projects undertaken by such companies include the UK based D1 oils which had plans to develop biodiesel in Swaziland, but closed down in 2008; Swedish based BioMassive AB that envisaged production of over 10,000 ha of jatropha in Tanzania, but closed down in 2009; Dutch based Bioshape that acquired a 50 year lease for 81,000 ha to cultivate jatropha in Tanzania, but closed down in 2009 and the German based Flora Ecopower which held a 50 year lease for the production of jatropha and caste bean in Ethiopia, but closed down in 2010. The main reason for the closer of these companies was the significant losses incurred in production.

Recent literature shows that jatropha seed yield, one of the key

determinants of economic viability, has been overestimated to justify the undertaking of large scale jatropha production. Projects carried out without empirical evidence on jatropha seed yields were subsequently not economically viable due to lower jatropha yields. Yield of above 2-2.5 t/ha/yr seems to be the minimum for a plantation system to be economically viable. Claims that jatropha is pest and disease resistant, performs well in marginal areas and requires less water to grow, have not proven to be true. It has now been established that the seed yield of jatropha crop can be significantly improved when the crop is grown in fertile and irrigated soils. The plant has been found to be vulnerable to moisture stress particularly during the early stages of growth (18 months of age), making irrigation a vital crop management practice. Thus, irrigation should be a vital crop management practice for improved yields of the crop. The need for other crop management practices such as fertilizer application, weeding, pruning and control of pests and diseases to contribute to stable and higher high yields, have also been echoed by recent literature.

The review has also showed that large commercial plantations have generally not been economically attractive due to their high capital, labour and environmental costs, while smallholder farming of jatropha with central processing of biodiesel performed well. Small-scale biofuel projects have been labeled as having the potential to contribute positively to human wellbeing through better access to energy, capacity building, poverty reduction and rural development. In support of small-scale biofuel projects, these bioenergy systems use resources more efficiently, involve more stakeholders and offer more opportunities for innovation and learning than their large scale counterparts. Jatropha hedge cultivation has been reported as one of the most economically viable farming business models due to its low inputs and opportunity cost of land. The reason for the low opportunity cost of land emanates from the fact that land used for hedge cultivation is not used to grow food crops. Under this production model, farmers also use family labour which usually has lower or zero opportunity cost than hired labour. There is also the added benefit that live fence protects farmer's food crops from damage by livestock. However, one disadvantage of the system is that the high seed yield is not guaranteed from this production, especially when the objective of production is to supply seed to large scale processing plants.

Conclusion

Given the current poor state of knowledge and experience of growing jatropha in southern Africa and the Government of Botswana's goal of achieving energy security and reliability, there is need to consider inter alia, investing in research in the production of jatropha and other bioenergy resources as well as support experimentation of small-scale cultivation which has been found to be generally more economically viable.

Investing in research on Jatropha

Since the cultivation of jatropha is a new endeavor, the government should support research that is aimed at generating knowledge on the agro-ecology of the jatropha and other biofuel crops. The research should aim to investigate growth performance of local and non-local jatropha varieties under different environmental (including growth on marginal land) and economic conditions. Development and evaluation of new varieties that would be grown in different ecological areas in Botswana should form part of the research agenda. Such varieties should have some traits of pest and disease resistance, water use efficiency, and high yielding in terms of seeds and oil. Higher yielding varieties will inevitably contribute to improved economic viability.

Furthermore, performance evaluation of jatropha under different management practices such as intercropping, irrigation and fertilizer application should be undertaken.

Engaging in such research therefore appears to be a better option now than to embark on large scale commercial production, which has been found to be risky.

Support for smallholder Jatropha production for improved wellbeing

While the Government of Botswana's main goal of jatropha production is energy security, it is also important to consider the added value of or alternative uses of jatropha oil such as soap, lamp oil, lotions, shampoo, bio-pesticides, bio-fertilizer, biogas and briquettes. In this regard, local efforts should be directed towards supporting small-scale jatropha projects such as hedge cultivation as it has been found to be more economically viable and has the potential to increase rural incomes as well as to increase access to energy to the poor. Farmers involved in hedge cultivation may form community trusts which could be assisted to have access to credit in order to acquire small-scale oil extraction equipment. The oil and its added value would generate income for the trust, thereby helping to reduce rural poverty. The oil would also be used as a source of energy for lighting and cooking especially for individual community members who cannot afford the cost of electricity. Non-members of the trust would also be motivated to grow jatropha as market for sale of seeds would be available. The trust could also be assisted to acquire diesel powered generator which would be used for local services such as battery charging. Such services would be provided at a fee, hence contributing to income base of the trust. The oil could be used to make products such as soap that would be sold in the local market. Similarly the seed cake could be used as fertilizer.

Thus, hedgerow cultivation has the potential to offer greater benefits especially to rural communities and contribute to achieving the sustainable development goal of ending poverty in all its forms everywhere.

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