ECONOMIC INFLUENCES ON BIO-FUEL PRODUCTION IN TANZANIA[1]

AUTHOR: SARAH S. H. MOHAMED[2]

SUPERVISOR: PROFESSOR G. FRASER

Abstract

The importance of bio-fuels as an alternative to oil is growing due to the increasing volatility of oil prices. As bio-fuels increasingly replace oil, their higher demand can be an opportunity for developing underdeveloped countries rich with resources for bio-fuel production to engage in such production and as a result, develop. The feasibility of growing the relevant feedstock, Jatropha curcas, in this case, for the production of bio-fuels, specifically, bio-diesel, in Tanzania is evaluated. The factors, which are investigated, include policy, population density, technology and infrastructure. It was found that the labour characteristics, population density and the state of the available technology provide suitable conditions for bio-fuel production. However, adjustments to policy and investment in infrastructure will be necessary to encourage further such production.

"A BIO-FUEL IS ANY TYPE OF LIQUID or gaseous fuel that can be produced from biomass substrates" (Giampietro, Ulgiati and Pimentel, 1997: 587) and "that can be processed into liquid fuels for either transport or heating purposes" (Dufey, 2006: 1). There are several examples of bio-fuels; bio-ethanol, bio-diesel and methanol (Giampietro *et al.*, 1997: 587). This study is focused on Jatropha plantations for the production of bio-diesel.

Research into bio-fuels is important for two main reasons. Firstly, the recent volatility in the price of oil has led to uncertainty about production costs among producers. This has caused them to look for alternative sources of energy to use as input in production. Therefore, the importance of bio-fuels as an alternative is growing (Borysov, 2008: 1). Secondly, as bio-fuels increasingly replace oil, their higher demand can be an opportunity for developing countries rich with resources for bio-fuel production to engage in such production and as a result, improve their conditions. This would be especially true of countries in which small-scale farming is prevalent (European Association for Bioindustries, 2008).

There are several advantages for developing countries intending to engage in or already engaged in the production of bio-fuels. Once the production of bio-fuels is an established activity, bio-fuels can be significantly cheaper than conventional fuels. This is especially beneficial to consumers at a time when oil prices have been rising to "unheard-of levels" (Mayntz, 2009).

---

[1] Unpublished Honours Project, Department of Economics and Economic History, Rhodes University, Grahamstown, South Africa, 2009.

[2] The financial assistance from the Andrew Mellon Foundation Scholarship towards this research is hereby acknowledged. Opinions expressed and conclusions arrived at, are those of the author and are not necessarily to be attributed to Rhodes University or the donor.

Furthermore, by engaging in the production of bio-fuels, developing countries can benefit from the potential high returns. As the price of oil rises, consumers decrease their consumption of oil and increase their consumption of bio-fuels. This causes their demand and hence their prices to increase. As a result, the return to bio-fuel producers increases (Rittle, 2007: 3).

In addition, the local production of bio-fuels can result in economic stimulation once the necessary infrastructure and manufacturing plants are in place. Firstly, the manufacturing plants create direct employment by hiring employees to work in the plants. Secondly, the agriculture industry benefits too. This is because bio-fuel production increases the demand for suitable bio-fuel crops, which in turn increases employment in the agriculture industry (Mayntz, 2009).

Countries engaging in the production of bio-fuels can help reduce their dependence on other countries for their energy needs and achieve greater energy security "through a diversified energy portfolio" (Dufey, 2006: 37). The recent volatility in the world oil price, uneven distribution of oil among countries, uncompetitive organisations supplying oil and heavy reliance on imported fuels make many countries vulnerable to shocks or sudden changes in supply. "This may impose serious energy security risks, in particular to those countries that are heavily dependent on energy imports" (Dufey, 2006: 37).

However, there are some disadvantages associated with engaging in the production of bio-fuels. There is an on-going debate about whether or not emphasis on bio-fuel production diverts a country's resources away from food production, reducing the supply of food (Rittle, 2007: 3). Although a country may be benefiting directly from engaging in the production of bio-fuels, it may be indirectly depleting the resources necessary for the production of food. Consequently, the price of food may rise and the country may find itself having solved its energy problems but exacerbated its food supplies.

In addition, most of the developing countries, which hold the potential to engage in the production of bio-fuels, lack the communication and transportation systems necessary in order for small-scale farmers who grow crops that feed into the bio-fuel production process to be able to deliver their products where they are required. Expenditure on infrastructure in this case is essential (Rittle, 2007: 5). High initial investments will also be required to build the necessary manufacturing plants to refine bio-fuels to more efficient energy outputs (Mayntz, 2009). However, many of these nations do not have sufficient funds to finance the installation of new infrastructure and manufacturing plants. As a result, they must turn to more developed nations for loans. There are two potential scenarios that could emerge; either the nations will succeed in their investment and be able to pay off the acquired debts or they could fail miserably and not be able to repay their debt, accumulating interest and increasing the size of their debts (Rittle, 2007: 5).

a. Goals of the research

Tanzania has a growing bio-fuels industry. This necessitates the evaluation of the feasibility of such production with a focus on arid and semi-arid regions. The issues that will be considered to evaluate the feasibility of bio-fuel production from an economic perspective are firstly, if potential labour markets and infrastructure can sustain conversion of land to bio-energy production. In addition, an evaluation of the

impact of differences in the number of people living in the populated areas on bio-fuel production will be carried out.

1. LITERATURE REVIEW

Before the production of bio-fuels can be implemented, several conditions need to be present. These include policies conducive to bio-fuel production (Dufey, 2006: 18), sufficient land that can be allocated between food and biomass production (Giampietro and Ulgiati, 2005: 373), a suitable population density (Patel, Pinckney and Jaeger, 1995: 516), a suitable labour force (Swedbio, 2009: 2), sufficient water resources (Giampietro and Ulgiati, 2005: 373), a certain level of technology that can support bio-fuel production (Larson, 2008: 29) and suitable infrastructure (Sapp, 2007).

a. Policy

According to Dufey (2006), one of the most critical conditions that need to be present for the implementation of bio-fuel production is some form of public policy that makes "production competitive in the earliest stages of industry development" (Dufey, 2006:18). She claims that policy tools such as tax benefits, subsidies and loan guarantees are essential in order to encourage the production and consumption of bio-fuels and the development of this market. This is especially because high costs of production discourage producers from entering this line of production. If a mechanism exists in the form of public policy to encourage individuals to engage in the production of bio-fuels, the market for bio-fuels will have more producers, making it competitive. In addition, if bio-fuel production is taking place, it will be possible to realise the positive externalities associated with such production.

Although public policy is deemed vital to encourage individuals to engage in the production of bio-fuels, it may not be beneficial to all. Bio-fuel production has developed in industrialised countries due to protectionist policies defending the domestic bio-fuels industry from international competition from developing countries. Protectionist policies have proved to be costly for developing countries that could potentially become efficient producers or exporters of bio-fuels. Low-income consumers end up paying higher prices for food staples as their prices rise in world markets. This rise is largely associated with distortionary policies (World Development Report, 2008: 2). Even though public policy for the inducement of domestic production of bio-fuels may be a pre-requisite, it may not be beneficial or efficient on a global level.

b. Population Density

Another concern raised by Patel, Pinckney and Jaeger (1995) on smallholder wood production and population pressure in East Africa, is a possible conflict for land between food, crops and an increasing population that needs space to live and work (Patel *et al.,* 1995: 516).

Low population density is a pre-requisite for biomass production. A low population density means that few people occupy a given amount of land, meaning that there is more land available for the cultivation of energy crops. This view is supported by Sielhorst, Molenaar and Offermans (2008). Community land is a vital

resource for many Africans and its private use is "bound to lead to land rights conflicts" (Sielhorst *et al.*, 2008: 35). This is a more likely situation where land is scarce due to high population density, further strengthening the notion that low population density is a pre-requisite for bio-fuel production.

Sielhorst *et al.* (2008) also highlight that low population density will not ensure that land contention does not occur. In sparsely populated areas, which are assumed agricultural land, the population has greater dependence on community land. The cultivation of crops requires a great amount of manual labour. Where the population density is low, there is a lack of labour, hence "labour migration is triggered" (Sielhorst *et al.*, 2008: 35). This will lead to an increase in the population density, creating conflict for natural resources such as water resources, land and fuel wood (Sielhorst *et al.*, 2008: 35).

c. Labour

One of the arguments for labour is similar to that of land. If a certain amount of labour is used to produce bio-fuels, less labour is available to produce food, creating a conflict for another scarce resource (Giampietro and Ulgiati, 2005: 371). Despite the fact that the study conducted by Giampietro and Ulgiati (2005) is in the context of a developed country, they bring up an interesting consideration. Labour, in whatever amount, devoted to the production of bio-fuel results in an opportunity cost. This opportunity cost is the reduction in the labour force that could be devoted to the development of technology (Giampietro and Ulgiati, 2005: 382). This is an important consideration because technological developments are deemed to be an essential factor for the production of bio-fuel. Hence, a trade-off between labour engaged in the actual production of bio-fuels and labour engaged in technological development for bio-fuel production is implied. On the other hand, the development of technology has allowed a given amount of energy to be supplied with less human labour (Giampietro and Ulgiati, 2005: 372) hence this argument is losing substance.

Conversely, according to Dufey (2006), low labour costs in developing countries make the production of bio-fuels an attractive venture (Dufey, 2006: 5). This is because the production of bio-fuels involves great costs. If labour costs, which are a contributor to production costs, can be kept low, the viability of engaging in the production of bio-fuels can increase.

d. Technology

Once the feedstock has been grown, bio-fuel production requires relatively high levels of technology. Usually, technology is capital-intensive, labour minimising and designed for large-scale production to achieve economies of scale. This is mainly because most technological development takes place in industrialised countries, which are capital-abundant. Subsequently, they engage in the development of technology that makes best use of their available resources. Therefore, the technology available for the conversion of feedstock into bio-fuels is specific to a particular kind of feedstock and this may be different from the feedstock produced in developing countries (Larson, 2008: 29). Most developing countries are labour-abundant and they have more suitable growing climates. In order to be able to take advantage of these conditions, they will have to be able to adapt technologies developed in the industrialised world and tailor

them to suit their needs and minimise costs. However, most developing countries find it extremely difficult to do so not only because they lack the necessary skills but also because they lack the necessary capital to design technology (Larson, 2008: 29).

As per Giampietro *et al.* (1997), a higher level of technology will not solve the problems of developing countries. They explain that technology has the ability potentially to result in higher yields of crops grown for feedstock. However, the growth of feedstock on a large-scale, results in smaller yields than would be expected due to problems such as pests, diseases and soil degradation that increase with scale, causing smaller yields (Giampietro *et al.,* 1997: 590).

e. Infrastructure

The growing use of bio-fuels and their increasing prices allow farmers in developing countries to sell their products at these higher prices and earn a sizeable return. However, given countries' current levels of infrastructure, further investment in infrastructure will be necessary to be able to cater for a higher level of production of bio-fuels (Yacobucci and Schnepf, 2007: 8) and as a result, "major agriculture reforms and infrastructure development will be needed to ensure that the increased benefits" are attained (European Association for Bioindustries, 2008). Sapp (2007) explains this by shedding light on the lack of basic infrastructure such as road networks and ports in developing countries, which increase the price at which bio-fuels are delivered to consumers. This in turn "weighs down opportunities for bio-fuel use" (Sapp, 2007). This has caused countries, such as Mozambique and South Africa to start up projects to develop pipelines as a mode of transporting bio-fuels. However, it has been found that many of Africa's major producers of bio-fuels are landlocked, do not "have the transportation infrastructure in place to enable export of the fuels" and do not have immediate plans for infrastructure investment (Sapp, 2007). An alternative consideration would be that these countries might not necessarily have to export the bio-fuels they produce. The domestically produced bio-fuels could simply substitute importation of conventional fuels hence, reducing their reliance on other countries for their energy needs.

2. METHODOLOGY

An investigation was first done to establish which conditions needed to be present in order for bio-fuel production to occur, in general by looking at studies done for other parts of the world. These were discussed in the literature review. After which, the conditions that are actually present in Tanzania were investigated. This was done by looking at policy documents, including:

- secondary statistical data on the proportion of land allocated to specific uses;
- population density of the identified area by looking at consensus data;
- level of employment as a whole and in industries related to the bio-fuel industry;
- the state of bio-fuel production technology by looking at production processes; and
- infrastructure by looking at transport facilities in and around the identified areas.

The limitations in this study were that certain data that was found was not recent. The most recent data dates back to the year 2002. Since then, several changes have taken place in the population structure and the urbanisation of many rural areas has

occurred. Therefore, conclusions arrived at are based on the available data and not necessarily the prevalent conditions at present.

3. RESEARCH RESULTS

a. Policy

As was identified in the previous section, one of the most important conditions that need to be present to induce individuals to engage in the production of bio-fuels is the presence of appropriate policy.

Currently there is no formal bio-fuel policy co-ordination. Investors are operating in a policy vacuum. As a result, the Tanzanian Bio-fuels Task Force (BTF) has been put together in order to produce guidelines for the government in order to design a set of appropriate policy initiatives (Sumbi, 2009). The task force falls under the Ministry of Energy (Janssen, 2006). Other aims of the Task Force include ensuring close co-operation between the different government bodies involved in the development of policies for bio-fuels and providing an information channel between the stakeholders, namely, the government, industry, farmers' associations and non-government organizations (Janssen, Woods, Sawe, Pfortner, 2005: 5). To date, the BTF has performed a strength, weakness, opportunity, threat (SWOT) analysis and prioritized strategic action, produced draft guidelines for bio-fuels development and devised a comprehensive action plan for bio-fuel development (Tanzanian Ministry of Agriculture, Food Security and Co-operatives, 2009).

Due to the lack of formal bio-fuel policy, several external agencies such as the German Technical Co-operation have made recommendations about the kind of policy that the Tanzanian government should adopt. These recommendations include fuel-taxes, carbon-based fuel taxes, vehicle taxes and subsidies to stimulate demand, incentives for investment in bio-fuel production facilities to stimulate supply, initial protection of local manufacturers against cheaper imports in order to develop a strong national bio-fuels industry and the introduction of technology standards that require compatibility with specific mixtures of bio-fuels (Janssen *et al.*, 2005: 115).

Current Policies/Legislation

Tanzania's Energy Policy encourages switching from traditional fossil fuels to alternative environmentally friendly fuels. However, it does not emphasise bio-fuels because at the time that the policy document was drawn up, the idea of bio-fuels was not as prevalent as it is at present as an alternative source of energy (Haikam, 2009). This shows that Tanzanian legislation has not yet caught up with the current needs of the population and this mitigates the further development of bio-fuel production.

A policy of concern that may seem to hinder the development of bio-fuel production is the Land Act. This Act promotes the optimal use of land resources, community ownership and it protects communities facing land acquisition pressures for large-scale commercial bio-fuel production (Haikam, 2009). This policy may be beneficial for bio-fuel production. Rural communities can use the land they own to develop small-scale bio-fuel production initiatives without the threat of having their land being taken away. This would be possible because protection of ownership would

ensure rural communities of long-term ownership and hence, the willingness to invest their limited resources into the production of bio-fuel on a small-scale.

Similar to the Land Act, the National Forest Policy seeks to protect the ownership and management of forest land by communities. However, investment in bio-fuel production can have direct impacts on forests, creating conflict between the National Forest Policy and other policies that indirectly encourage the production on bio-fuels (Haikam, 2009).

The National Environment Policy endorses economic development but not at all costs. This means that poverty in Tanzania is not addressed by any means possible but some regard is given to the environment. Consequently, this policy explicitly suggests the development of alternative energy sources to support growth (Haikam, 2009). Because Tanzanian policy advocates the development of alternative sources of energy, individuals will not be discouraged to invest effort and capital into the production of bio-fuels.

The Agricultural and Livestock Policy acknowledges the fact that agriculture includes the production of both, edible and non-edible oils. Non-edible oils are regarded as feedstock (Haikam, 2009). This acknowledgement gives owners of land unsuitable for the farming of food crops, an incentive to continue the cultivation of crops that yield non-edible oils that can be bought by large-scale bio-fuel producers or can be used by small-scale bio-fuel initiatives in their own communities.

The Agricultural Sector Development Strategy of 2001 aims to create an environment that is conducive to the improvement of productivity and profitability of the agricultural sector (Ministry of Agriculture and Food Security, 2001: 12). The strategy states that the role of the government is to create an environment for medium and large-scale investors to make use of the abundant land resource of the country. In 2006, almost fifty percent of Tanzania's land area was available for agriculture (Janssen, 2006). Because this strategy is not directed at only food crops, it further provides an environment in which bio-fuel production can grow.

In addition, Tanzania's Transport Policy states that the effect of the design and development of transport infrastructure and provision of services must be taken into account at all times (Haikam, 2009). This shows that the Tanzanian government recognises the negative effects of fossil fuels on the environment and is willing to consider alternative sources of energy, which do not degrade the environment to such a great extent. This provides an incentive to the transport sector to use bio-fuels, stimulating demand for them and encouraging individuals to engage in their production.

Although the policies in existence indirectly encourage individuals to engage in the production of bio-fuels, there are no formal policies in effect that provide a framework in which bio-fuel production can develop. Because bio-fuels are becoming an important source of energy, Tanzanian legislation needs to catch up and provide the appropriate incentives to encourage their production and use.

Furthermore, in the development of policies, the government must keep in mind small-scale bio-fuel producers. This is because when developing policies, governments tend to focus on providing incentives to large-scale producers and large multinational companies. Small-scale farmers require special incentives. These special incentives could include funds, grants and assistance in the establishment of farmers' associations in which small-scale farmers come together and pool their efforts to be able to

compete with large-scale multinationals. Because finance is important for the growth of bio-fuel production, local finance institutions should be encouraged to support small-scale farmers. Finance would be especially vital for the acquisition of "equipment that rural communities could use to process oil crops to oil and convert into fuels that could be used to meet local energy needs" (Sawe, 2009).

b. Population Density and Labour

Table 1 indicates that the three areas with the lowest population densities are Lindi, Rukwa and Ruvuma. The low population density of these areas means that a few people occupy a given amount of land, making more land available for the cultivation of crops. Although a low population density means that there is sufficient land, which people can occupy without contention, it implies that there is a smaller amount of labour available to work on a given amount of land. This means that labour migration will be triggered, leading to an increase in population density, which may lead to conflict for natural resources.

Table 1 Population Density 2002

Regions	**Land Area (km²)**	**Population**	**Population Density (people per km²)**
Kilimanjaro	13,250	1,381,149	104
Dar es Salaam	1,393	2,497,940	1793
Lindi	66,040	791,306	12
Ruvuma	63,699	1,117,166	18
Rukwa	68,635	1,141,743	17
Kagera	28,456	2,033,888	71
Mwanza	19,683	2,942,148	149

Source: Tanzania Population Planning Unit (2002)

In the literature review, it was mentioned that high population density might be beneficial for bio-fuel production due to the availability of labour, which can engage in such production and the high demand for bio-fuels that may result from a bigger population in an area. In Tanzania, the three regions with the highest population densities are Dar es Salaam, Mwanza and Kilimanjaro. However, because these areas have major cities, very little land is devoted to the cultivation of crops thus negating the effects of a high population density on bio-fuel production.

In terms of the proportion of the total Tanzanian labour force, eighty percent is employed in the agricultural sector (Nationmaster, 2009c). This is because the majority of the Tanzanian labour force is illiterate mainly due to unequal access to education between rural and urban areas, as well as within rural areas (Fox, Betcherman, Chandra, Eifert and Adams, 2004: 5). This raises the question of whether there is a trade-off between the amounts of labour used in feedstock or bio-fuel production and that could have potentially been devoted to the development of technology, which can

be used to increase the economy's production efficiency. Since the majority of the labour force is employed in the agricultural sector, at present, the country is making the best possible use of the labour that it has available, given its skills level. Hence, a trade-off does not exist. A large proportion of Tanzania's labour force can be allocated to the production of feedstock for the production of bio-fuels without causing any disturbance in other economic activity.

Furthermore, average salaries in Tanzania is USD 1.07 (NationMaster, 2009c) as compared to USD 51.26 in the United Kingdom (NationMaster, 2009b) and USD 138.57 in the United States of America (NationMaster, 2009a). This shows that labour costs in Tanzania, in general, are very low, creating an incentive for investors to take advantage of the low labour costs. In addition, low labour costs also benefit small-scale farmers because they can afford to employ labour in order to grow their operations and small communities can receive energy from bio-fuels at a low cost.

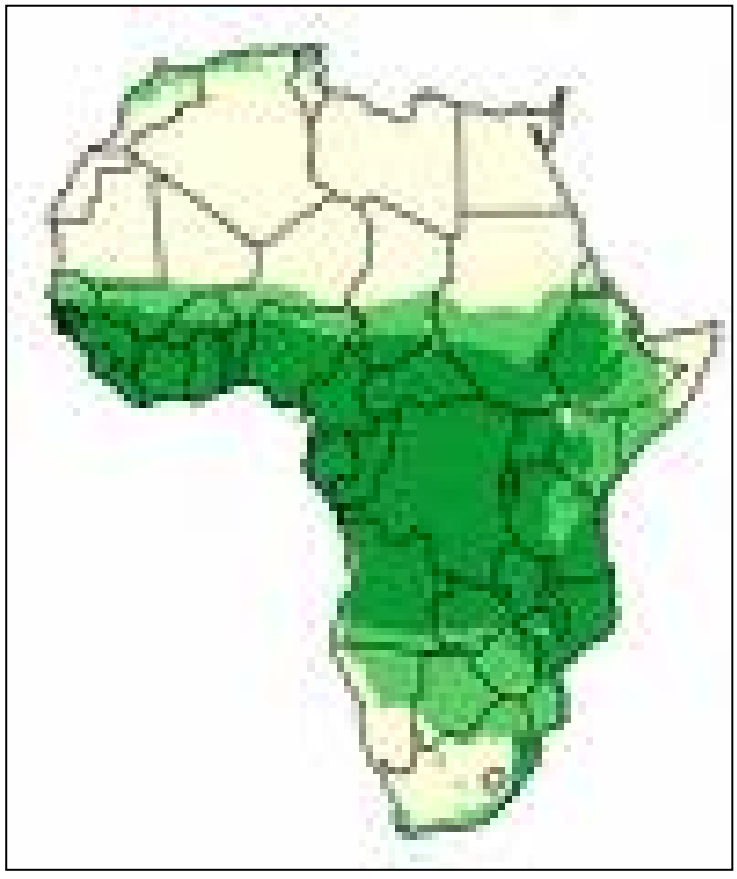
Therefore, a low population density in the rural areas of Tanzania, a major proportion of the labour force being employed in the agricultural sector and low labour costs create suitable labour conditions for bio-fuel production.

c. Infrastructure

At present, the main forms of transportation of fuel in Tanzania include road, rail, water and air. Pipeline use is very small; the TAZAMA pipeline carries crude oil and runs from Dar es Salaam to the Ndola refinery in Zambia (Mkiaru, 2003: 6). The Songos Pipeline, which runs from Songo Songo Island, off the coast of Tanzania, to Dar es Salaam carries natural gas which is used "as the principal fuel supply for five gas turbine electricity generators" (Tanzania Petroleum Development Corporation, 2009).

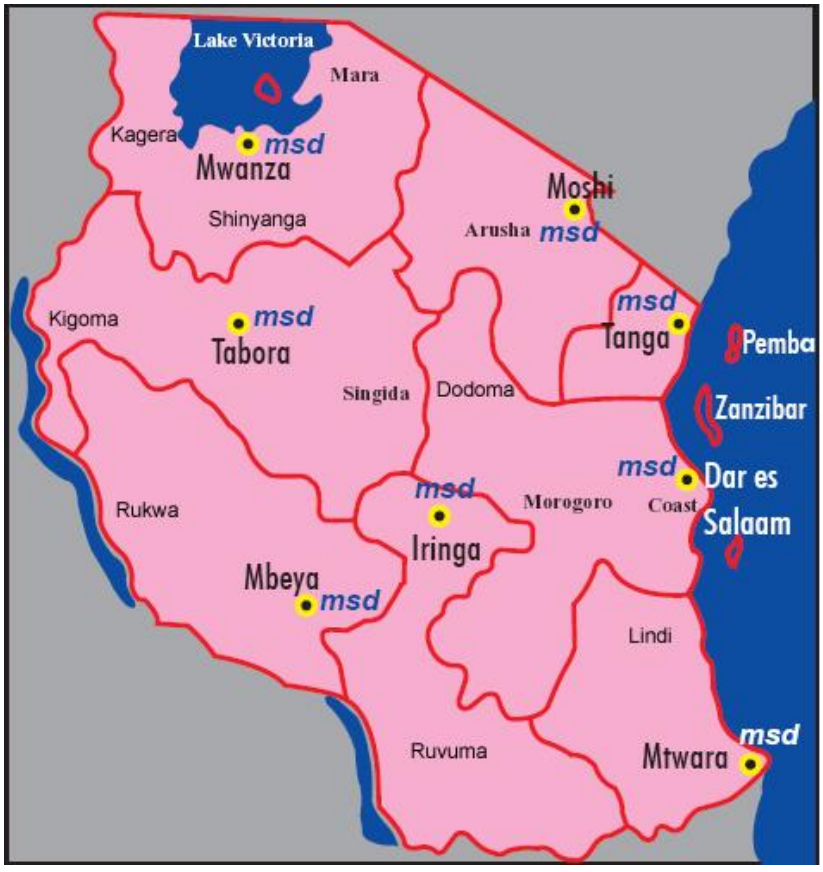
As can be seen in the maps, the majority of the land in Tanzania is suitable for establishing *Jatropha curcas* plantations. These areas include the Mwanza Region, which includes Kagera, Shinyanga and Mara; the towns of Kigoma, Tabora, Mbeya, Rukwa, Ruvuma, Lindi, Mtwara, Morogoro; areas around Dar es Salaam City, Tanga, Arusha and Moshi. All the areas identified have access to road, rail or maritime transport except for the Lindi Region in southern Tanzania. The majority of the western part of the region is a game reserve, the Selous Game Reserve. This Game Reserve has been declared a world heritage site by the United Nations Educational, Scientific and Cultural Organisation (UNESCO, 2009). This means that the conversion of this piece of land into a Jatropha plantation would be impossible.

Figure 1. Land Suitable for Jatropha Plantations



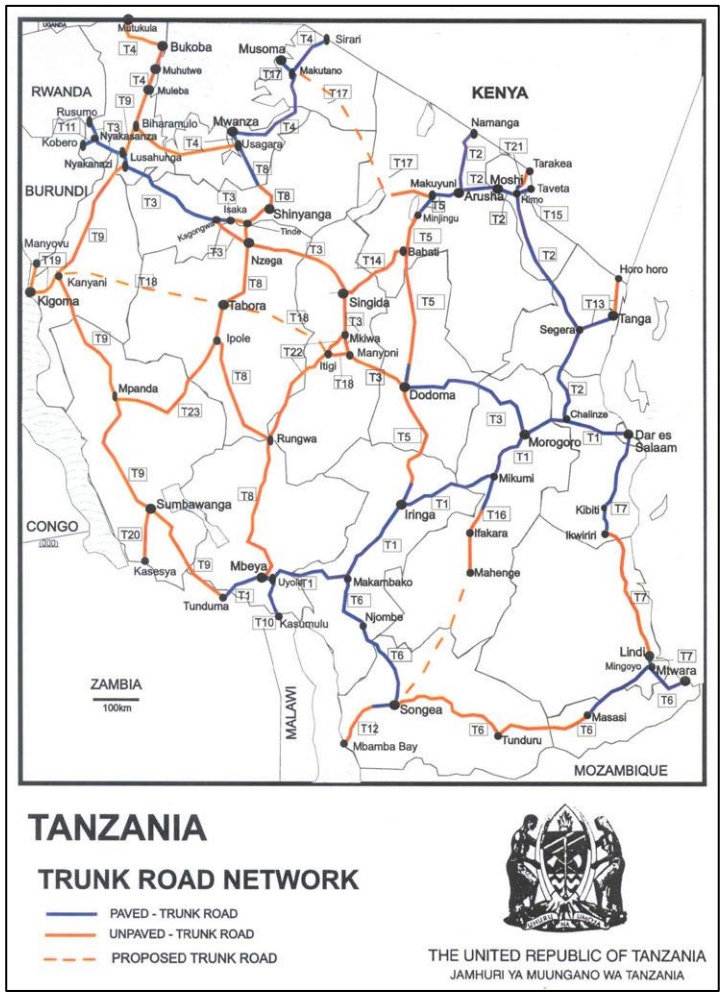
Source: Jatropha in Gambia (2007)

Figure 2. Tanzanian Regions



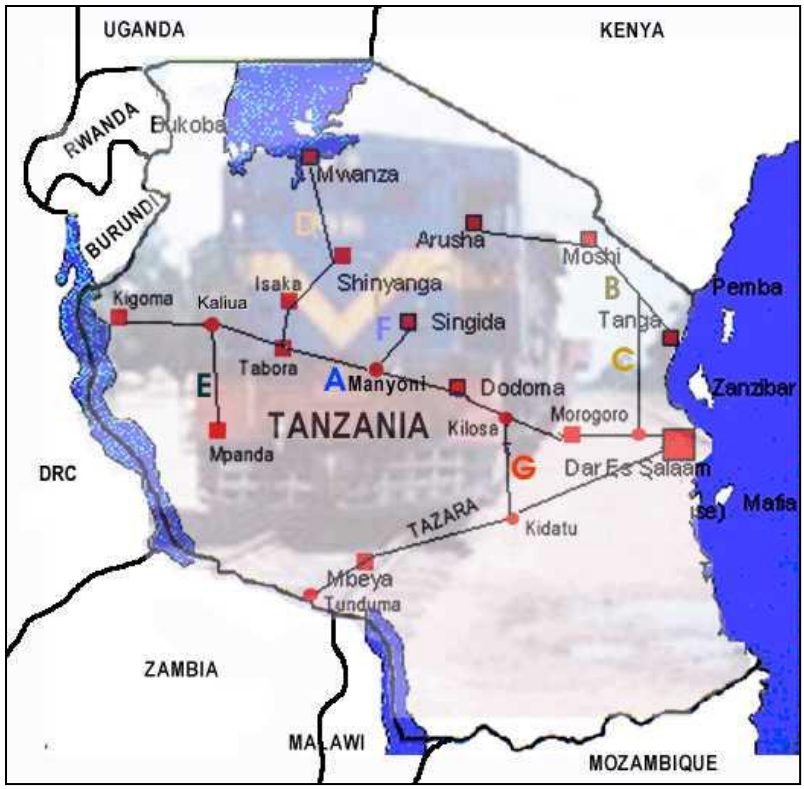
Source: Medical Stores Department (2009)

Figure 3. Road Network



Source: Tanzania Roads Fund Board (2007)

Figure 4. Rail Network



Source: Tanzania Railways Corporation (2002)

The fact that a lot of the transportation depends on road, rail and water, high fuel costs make the transportation of bio-fuels an expensive endeavour. This means that the Tanzanian government ought to consider investing in the building of pipelines similar to the Songos Pipeline, allowing small-scale farmers to supply their product at a reduced cost once a major bio-fuels sector has been established. This would work to reduce the cost of transporting bio-fuels.

The situation is that the feedstock grown in small farm could be aggregated and supplied to larger centres where it could be processed into bio-fuel by those who have the necessary technology and means to bring it to the domestic market or export it.

d. Technology and skills

As with any crop that is grown commercially, on a large or small-scale, certain skills need to be available. With regard to the Jatropha curcas, these skills include proper management of planting techniques, pruning and disease and pest control, the ability to identify appropriate cultivation zones and proper genetics selection. In terms of technology, in order to grow the Jatropha curcas, water management and fertilization are important (Volckaert, 2009: 11). At present, these services are being provided by either non-government organisations or private external companies.

The oil extraction process is not a complicated one. Jatropha oil can be extracted from the seeds when they are ready using oil presses, which are either electrically powered or manually driven. Traditionally, oil was extracted from the seeds using implements by hand. Currently, the Sayari oil expeller is being developed in Tanzania for oil extraction. This is similar to a conventional oil press but has a much greater capacity (Vyahumu Trust, 2009b). A conventional oil press capable of processing twelve kilograms of Jatropha seeds per hour, would cost € 200, whereas a Sayari expeller is able to process seventy kilograms per hour, and would cost € 2,200 (Beerens and de Jongh, 2008: 5).

Technology transfer has been occurring in Tanzania especially through non-government organisations such as the Vyahumu Trust and private companies such as Diligent Tanzania Limited. The Vyahumu Trust has the objective of providing small-scale farmers with oil-expelling services to help them increase their returns from their oilseed production. Due to the trust's efforts, agricultural processing methods are being modernised and small rural industries have developed in the areas of mills, which use the oil produced from the entire process (Vyahumu Trust, 2009a). Companies such as Diligent Tanzania Limited contribute to the technology transfer process through a similar process as the Vyahumu Trust (Diligent Tanzania Limited, 2009).

Products of Jatropha grains include biodiesel, briquettes and fertiliser. This means that the Jatropha curcas is not only useful for bio-fuel but can be used for other marketable products. This is being realised by small-scale farmers through the help of agencies, which are establishing themselves in Tanzania (Volckaert, 2009: 30). The Jatropha-based biodiesel not only has a local market but an international one too. In December of 2008, Diligent Tanzania provided Tanzanian farmers with technology to produce biodiesel and helped them become the first suppliers of Jatropha-based jet fuel for a commercial Air New Zealand flight (Diligent Tanzania Limited, 2008: 1). This shows the potential that can be achieved from engaging in the production of Jatropha oil.

4. CONCLUSION

Engaging in the production of bio-fuels can be beneficial for developing countries in terms of being suppliers of an alternative to conventional fuel, potentially obtaining high returns from its sale, reducing their dependency on foreign countries for their energy supplies and economic stimulation emanating from the bio-fuels industry. However, there are disadvantages associated with engaging in the production of bio-fuels. The most important of which is the great amounts of funds that most developing countries require for the initial investment for the establishment of bio-fuel production. These funds will most likely be borrowed from developed countries. If the projects undertaken to grow the bio-fuels industry are unsuccessful, these developing countries will have acquired high levels of debt. Therefore, a country must perform cost-benefit analyses and determine whether it should invest in developing this industry.

Tanzania has decided to develop its bio-fuel industry. In evaluating the economic environment that will foster such production, four factors were investigated, namely, policy, population density and labour, infrastructure and technology. With regard to policy, Tanzanian legislation indirectly promotes the production of bio-fuel. However,

with the growing importance of this industry, Tanzania must produce legislation that specifically addresses this question. At present, the BTF is working on making recommendations to inform this policy.

Since this research has focussed on the arid and semi-arid regions of Tanzania, the low population density in these areas was found to be a favourable factor for the production of bio-fuels. In addition, because a large proportion of the Tanzanian labour force is already employed in the agricultural sector, labour resources will not be diverted from other activities. Low labour costs are another feature in Tanzania that makes the production of bio-fuels attractive.

The infrastructure that is currently available in Tanzania makes the transportation and storage of feedstock and bio-fuels an expensive endeavour. The government or private companies will need to look into not expanding infrastructure to make markets more accessible to small-scale farmers but at how the costs of transportation could be reduced.

The production of bio-fuels is technology-intensive as well as at least a semi-skilled workforce. Technology transfer from developed countries has been occurring in Tanzania, which means that the technology for bio-fuel production is available in Tanzania.

Thus, the labour characteristics, population density and the state of the available technology provide suitable conditions for bio-fuel production in Tanzania. However, adjustments to policy and investment in infrastructure will be necessary further to encourage such production.

REFERENCES

BEERENS, P. and DE JONGH, J., 2008. *Note on Jatropha Pressing for FACT Pilot Projects.* Groene Woudt Foundation. [Online]. Available: http://www.fact-foundation.com/media_en/Note_on_Jatropha_pressing_for_FACT_pilot_projects . [Accessed 16 September 2009].

BORYSOV, S., 2008. *Perspectives of Biofuel Market Development in Ukraine.* Leibniz Institute of Agricultural Development in Central and Eastern Europe Forum, 25–27 June. Halle (Saale), Germany.

DILIGENT TANZANIA LIMITED, 2009. *Introduction.* [Online]. Available: http://www.diligent-tanzania.com/. [Accessed 16 September 2009].

DILIGENT TANZANIA LIMITED, 2008. *Diligent Tanzania Provides Technology and Helps Tanzanian Farmers to be Prime Supplier in First Sustainable Bio-fuel Flight.* [Online]. Available: http://www.diligent-tanzania.com/assets/images/20081126%20testflight/Diligent%20Air%20New%20Zealand%20visit%20press%20release%20formatted.pdf. [Accessed 16 September 2009].

DUFEY, A., 2006. *Biofuels production, trade and sustainable development: emerging issues.* Report for the International Institute for Environment and Development, London.

EUROPEAN ASSOCIATION FOR BIOINDUSTRIES, 2008. *Biofuels & Developing Countries.* [Online]. Available: http://www.europabio.org/Biofuels/Developing%20Countries_Biofuels%20factsheet.pdf. [Accessed 29 March 2009].

FOX, L., BETCHERMAN, G., CHANDRA, V., EIFERT, B., ADAMS, A.V., 2004. *Realizing the Potential of the Labor Force in Africa: Barriers and Opportunities.* World Bank.

GIAMPIETRO, M., ULGIATI, S. and PIMENTAL, D., 1997. Feasibility of Large-Scale Biofuel Production. *BioScience.* 47, 9: 587 – 600.

GIAMPIETRO, M. and ULGIATI, S., 2005. Integrated Assessment of Large-Scale Biofuel Production. *Critical Reviews in Plant Sciences.* 24, 365–384.

HAIKAM, 2009. *What other policies say about bio-fuel in Tanzania.* Citizen Journalism in Africa. [Online]. Available: http://www.citizenjournalismafrica.org/node/1349. [Accessed 16 September 2009].

JANSSEN, R., WOODS, J., SAWE, E. and PFORTNER, R., 2005. *Liquid Bio-fuels for Transportation in Tanzania: Potential and Implications for Sustainable Agriculture and Energy in the 21st Century.* Study Commissioned by the German Technical Cooperation. Munich: German Technical Cooperation.

JANSSEN, R., 2006. *Opportunities for Bio-fuels in Tanzania.* WIP – Renewable Energies, Germany. [Online]. Available: http://www.gfse.at/fileadmin/dam/gfse/gfse%206/PLENARY_IV/5._WIP_GFSE-6_Presentation_Rainer_Janssen.pdf. [Accessed 16 September 2009].

JATROPHA IN GAMBIA, 2007. *Benefits.* [Online]. Available: http://images.google.co.za/imgres?imgurl=http://jatrophagambia.files.wordpress.com/2007/04/map-jatropha-in-africa.jpg&imgrefurl=http://jatrophagambia.wordpress.com/category/benefits/&usg=__GerfmUFQjI15I6ZW7BQ1byXm764=&h=327&w=275&sz=15&hl=en&start=2&tbnid=0wZCaZki0HfZOM:&tbnh=118&tbnw=99&prev=/images%3Fq%3Dland%2Bsuitable%2Bfor%2Bjatropha%2Bplantations%2Bafrica%26gbv%3D2%26hl%3Den [Accessed 1 July 2009].

LARSON, E.D., 2008. *Biofuel production technologies: status, prospects and implications for trade and development.* Paper for United Nations Conference on Trade and Development. New York and Geneva.

MAYNTZ, M., 2009. *Advantages and Disadvantages of Biofuels.* Green Living. [Online]. Available: http://greenliving.lovetoknow.com/Advantages_and_Disadvantages_of_Biofuels. [Accessed 8 March 2009].

MEDICAL STORES DEPARTMENT, 2009. *Distribution.* [Online]. Available: http://www.msd.or.tz/pages/distribution.html. [Accessed 1 July 2009].

MKIARU, E.S., 2003. *Tanzania Paper on Transport and Communications Infrastructure Development and Transit Trade Facilitation.* Dar es Salaam: Ministry of Communications and Transport.

NATIONMASTER, 2009a. *American Labor Statistics.* [Online]. Available: http://www.nationmaster.com/red/country/us-united-states/lab-labor&all=1. [Accessed 16 September 2009].

NATIONMASTER, 2009b. *British Labor Statistics.* [Online]. Available: http://www.nationmaster.com/red/country/uk-united-kingdom/lab-labor&all=1. [Accessed 16 September 2009].

NATIONMASTER, 2009c. *Tanzania Labor Statistics.* [Online]. Available: http://www.nationmaster.com/red/country/tz-tanzania/lab-labor&all=1. [Accessed 16 September 2009].

PATEL, S.H., PINCKNEY, T.C. and JAEGER, W.K., 1995. Smallholder Wood Production and Population Pressure in East Africa: Evidence of an Environmental Kuznets Curve? *Land Economics.* 71, 4: 516 – 530.

RITTLE, A., 2007. *Economic Advantages and Disadvantages of Biofuels: A Pathway to Success in Poverty-Stricken Pakistan and Afghanistan.* World Food Prize. [Online]. Available: http://www.worldfoodprize.org/assets/YouthInstitute/07proceedings/Conrad_Weiser_%20Rittle.pdf. [Accessed 8 March 2009].

SAPP, M., 2007. *Big Potential and Challenges for Biofuels.* Inter-Press Service. [Online]. Available: http://ipsnews.net/news.asp?idnews=39431. [Accessed 29 March 2009].

SAWE, E.N., 2009. *Liquid Bio-fuels: Pertinent Issues, Smallholder Farmers and Bio-fuels Development Potential in Tanzania.* Tanzania Traditional Energy Development and Environment Organisation. [Online]. Available: http://www.tatedo.org/news/biofuels.htm. [Accessed 16 September 2009].

SIELHORST, S., MOLENAAR, J.W. and OFFERMANS, D., 2008. *Biofuels in Africa: An Assessment of Risks and Benefits for African Wetlands.* Report for Wetlands International. Netherlands: Wetlands International.

SUMBI, P., 2009. *WWF's Perspectives on bio-fuels and the Current Situation in Tanzania.* World Wide Fund for Nature. [Online]. Available: http://cmsdata.iucn.org/downloads/08_wwf_tanzania_regional_biofuel_workshop_nairobi_20_april_2009_small.pdf. [Accessed 16 September 2009].

SWEDBIO, 2009. *Biofuels – Potential and Challenges for Developing Countries.* Swedish Biodiversity Centre. [Online]. Available: http://www.swedbio.com/dokument/factsheet-biofuel-en.pdf. [Accessed 1 May 2009].

TANZANIAN MINISTRY OF AGRICULTURE AND FOOD SECURITY, 2001. *Agricultural Sector Development Strategy.* Tanzanian Policy Document. Dodoma: Ministry of Agriculture and Food Security.

TANZANIAN MINISTRY OF AGRICULTURE, FOOD SECURITY AND CO-OPERATIVES, 2009. *Tanzania Government Perspective on Bio-fuels.* Ecole Polytechnique Federale du Lausanne. [Online]. Available: http://cgse.epfl.ch/webdav/site/cgse/shared/Biofuels/Regional%20Outreaches%

20&%20Meetings/2009/East%20Africa/Govt%20Tanzania.pdf. [Accessed 16 September 2009].

TANZANIA PETROLEUM DEVELOPMENT CORPORATION, 2009. *Song Songo Gas-to-Electricity Project.* [Online]. Available: http://www.tpdc-tz.com/songo_songo.htm. [Accessed 16 September 2009].

TANZANIA POPULATION PLANNING UNIT, 2005. *Population Density.* Ministry of Planning, Economy and Empowerment. [Online]. Available: http://www.tanzania.go.tz/ppu/pdensity.html. [Accessed 16 September 2009].

TANZANIA RAILWAYS CORPORATION, 2002. *Raiway Network.* [Online]. Available: http://www.ntz.info/gen/b00630.html. [Accessed 1 July 2009].

TANZANIA ROADS FUND BOARD, 2007. *The Tanzania Road Network.* [Online]. Available: http://www.roadsfundtz.org/web/images/map.jpg. [Accessed 1 July 2009].

UNESCO WORLD HERITAGE CENTRE, 2009. *Selous Game Reserve.* United Nations Educational, Scientific and Cultural Organisation. [Online]. Available: http://whc.unesco.org/en/list/199. [Accessed 16 September 2009].

VOLCKAERT, V., 2009. *Jatropha Curcas: Beyond the Myth of the Miracle Crop.* D1 Oils Plant Science. [Online]. Available: http://www.ascension-publishing.com/BIZ/4ABVolckaert.pdf. [Accessed 16 September 2009].

VYAHUMU TRUST, 2003a. *Muster Tanzania.* FAKT Consult for Management, Training and Technologies. [Online]. Available: http://www.jatropha.org/tanzania/vyahumu.htm. [Accessed 16 September 2009].

VYAHUMU TRUST, 2003b. *Production of an Oil Expeller.* FAKT Consult for Management, Training and Technologies. [Online]. Available: http://www.jatropha.org/tanzania/expeller.htm. [Accessed 16 September 2009].

WORLD DEVELOPMENT REPORT, 2008. *Biofuels: The Promise and the Risks.* World Bank. [Online]. Available: http://siteresources.worldbank.org/INTWDR2008/Resources/2795087-1192112387976/WDR08_05_Focus_B.pdf. [Accessed 8 March 2009].

YACOBUCCI, B.D. and SCHNEPF, R., 2007. *Ethanol and Biofuels: Agriculture, Infrastructure, and Market Constraints Related to Expanded Production.* Congressional Research Service Report for Congress. Washington, D.C.: United States of America.