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Assessing the Implication of Liquid Bioenergy Production from Food Crops on Food Security in Tanzania: The Case of Dodoma Region

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Abstract
Tanzania is in the process of promoting the production of liquid bioenergy from non-staple food crops. According to the government, this would give the country a unique opportunity to address both food and energy security. However, there is a concern that using food crops to produce bioenergy could jeopardize food security in the country. This study puts forward these opposing arguments based on the literature review and field research. A total of 100 respondents were selected randomly for interviews in Dodoma Region, Tanzania. The key question to address was whether producing liquid bioenergy from food crops will enhance or jeopardise food security in the country. Findings from the literature review are inconclusive while the field results show that 80% of the respondents indicated dissatisfaction with the policy proposal with reasons that it could lead to allocating all productive land to bioenergy production, the lack of money to purchase food, poor market infrastructure and the temptation to sell all food for bioenergy. To achieve a *win-win* situation, the government should undertake zoning for bioenergy and food production areas and enhance agricultural productivity. The policy also should emphasize local processing of liquid bioenergy for value addition, employment and rural development.
Keywords: liquid bioenergy, transport, food security, Tanzania, Sub-Saharan Africa

1. Introduction

The development of technology to utilize biomass as a source of energy has taken place in many countries across the world, from the production of transport fuels such as biodiesel from vegetable oil to the production of bioethanol from sugar, starch and cellulose-rich crops (Sims *et al* 2006). Many countries in the world are formulating bioenergy targets, and many have put incentives in place. The interest in bioenergy is concentrated in the largest fuel-consuming markets of the EU, North America and China as well as in profitable feedstock production regions of South America and South East Asia (Sims *et al* 2006). In Sub-Saharan Africa governments are promoting bioenergy for energy security and to save on the demand for foreign currency to import fossil fuels. Consequently, many countries in the region are in the process of installing policies or guidelines to manage the development of large-scale bioenergy feedstock projects. In East Africa, Kenya is targeting liquid bioenergy production to meet the needs of its domestic market before considering exporting it and the same applies to Tanzania.

The promotion of bioenergy in the world has been prompted by a number of environmental, social and economic concerns. The finitude of fossil fuels, concerns about energy security and the need to respond to climate change have led to a growing interest worldwide in bioenergy production (Koh and Ghazoul, 2008). Bioenergy is viewed by many as a key to reducing reliance on foreign oil, lowering emissions of greenhouse gases and meeting rural development goals. Globally, biomass currently provides around 46 EJ of bioenergy in the form of combustible biomass and waste, liquid bioenergy, renewable municipal solid waste, solid biomass/charcoal, and gaseous fuels (Sims *et al* 2006).

In Tanzania, bioenergy is a rapidly growing sector, which the government is committed to promoting. The investment climate has improved, which will attract investors, and a policy for liquid bioenergy is being prepared, which goes hand-in-hand with the formulation of laws and regulations for the development of the bioenergy economy in the country. However, what is most interesting for Tanzanians is the uniqueness of the Liquid Bioenergy Policy. Unlike many other developing countries targeting bioenergy production from non-edible or from second and third-generation feedstock, the Tanzanian government aims to produce liquid bioenergy from non-staple food crops. It is argued that bioenergy production from food crops will enhance both food and energy security through commercialized agriculture, improved market access and intensive farming.

Consequently, there has been growing interest in investing in bioenergy in the country. A number of investors, both local and multilateral companies, are acquiring big portions of land in the country, some in the range of 400,000 hectares (Silayo *et al* 2008, Mwakaje 2012). It is argued that the production of liquid bioenergy for transport and for running stationary engines will have a positive impact on poverty alleviation and rural development. The question however is whether such a policy will indeed achieve the stated objectives of energy and food security in a country with numerous challenges in the agricultural sector and chronic food insecurity in some parts of the country.

The main objective of this study was to test the hypothesis that bioenergy production from non-staple food crops will lead to food insecurity in the country. Specifically, the study sought to:

1. Review studies on the impact of liquid bioenergy on food security,
2. Investigate the factors determining food security
3. Assess whether liquid bioenergy production from food crops will enhance food security
4. Investigate the community's awareness and perception of bioenergy production and food security.

The findings from this study will inform policy and decision makers on how best the bioenergy economy could lead to a *win-win* situation of energy and food security in the country. It also contributes to the body of knowledge on the emerging but highly contentious literature on bioenergy, food security and environmental management.

2. Bioenergy development in the world

2.1 Defining liquid bioenergy

Liquid bioenergy is any kind of liquid derived from matter that has recently been alive and that can be used as fuel, and that fuel should contain more than 80% of renewable material (GreenFacts, 2013). The most widely used liquid bioenergy for transport is ethanol and biodiesel. Ethanol is a type of alcohol that can be produced using any feedstock containing significant amounts of sugar. These include crops such as sugarcane or sugar beet, and starchy crops, such as maize and wheat. Biodiesel is produced by combining vegetable oil or animal fat with alcohol. Biodiesel can be blended with traditional diesel fuel or burnt in its pure form for use in compression ignition engines (Agarwal, 2007).

2.2 Why liquid Bioenergy?

The increased interest in bioenergy has come about for a number of socio-cultural, economic and environmental reasons.

2.2.1 Environmental concern

The rapidly growing consumption of fossil fuel in the transport sector in the last two centuries has led to increased greenhouse gas emissions, growing energy dependency and supply insecurity all over the world and one approach to resolving these problems has been to increase the use of bioenergy (Ajanovic, 2011). It is argued that biomass energy is close to being 'carbon neutral', as it produces energy while only releasing carbon into the atmosphere that has been captured during the growing cycle of the plant (Sims *et al* 2006). Studies show that bioenergy from land-rich tropical countries may help displace the foreign petroleum imports of many industrialized nations, providing a possible solution to the twin challenges of energy security and climate change (Gibbs *et al* 2008). Bioenergy is also expected to reduce dependence on imported petroleum, reduce greenhouse gas emissions and other pollutants, and revitalize the economy by increasing the demand for and price of agricultural products (Demirbas, 2009).

Nevertheless, research findings are starting to question the benefits of bioenergy for the environment. For instance, it has been realized that in order to manufacture corn ethanol a large quantity of fossil fuels is used, which creates doubt as to whether its continued use will bring any clear economic and environmental benefits (Granda *et al* 2007, Nkala, 2012). A study by Blottnitz and Curran (2007) reports that bioethanol results in a reduction in resource use and global warming, although the impacts of acidification, human toxicity and ecological toxicity, occurring mainly during the growing and processing of biomass, are often unfavourable rather than favourable. In developing countries like Tanzania, bioenergy farms are being developed by clearing intact Miombo woodland with some parts containing threatened endemic species (WWF, 2008), thereby counteracting the whole purpose of mitigating climate change. Indeed, others are warning that no foreseeable changes in agricultural or energy technology will be able to achieve meaningful carbon benefits if crop-based biofuels are produced at the expense of tropical forests (Gibbs *et al* 2008). Such arguments are based on the fact that the share of ethanol in the overall demand for fuel is small and therefore, its impact on lowering pollution and enhancing fuel security will be minimal (Li and Chan-Halbrendt, 2009; Chakravorty *et al* 2009).

2.2.2 Economic motive

The pattern of energy use in the world is changing with the industrialization of the economies of South-East Asia, Brazil, China and India (Sims *et al* 2006). This has driven an increase in the demand for energy, and hence for fossil fuel, at the rate of 3% per annum (Hirsch, 2005). Increases in the price of fossil fuel have been a burden, especially on developing economies, and this has encouraged the development of alternative and increasingly economic sources of energy that will be carbon neutral, which include biomass (Sims *et al* 2006). Bioenergy has become a leading alternative to fossil fuel because it can be produced domestically by many countries, it requires only minimal changes in retail distribution and end-use technologies and it has the potential to spur rural development (Sims *et al* 2006).

Price-wise, bioenergy appears to be cheaper than fossil fuels. The cost of producing biodiesel from vegetable oils ranges between US$0.52 and 0.62 L^{-1} (IATA, 2012). The cost of producing ethanol from the raw material is usually between 25% and 40% of total production costs. In Europe, the range is US$22–61 dry t^{-1} and US$12–18 dry t^{-1} in North America (von Sivers and Zacchi, 1996). The cost of producing ethanol from cereals is around US$0.32 L^{-1} (S and T, 2004) while from sugarcane it is less at US$0.20 L^{-1} in Brazil, and since 1999 it has remained below the cost of gasoline (Goldemberg and Johansson 2004). Studies also show that used cooking oil and animal fat feedstock produce cheaper biodiesel at around US$0.40–0.60 L−1 (S and T, 2004). Developing more efficient and innovative processes may reduce biofuel production costs further.

The future market for bioenergy is also promising. The EC Bioenergy Directive of 2003 required a voluntary market share of 5.75% of bioenergy for each member state by 2010 (Dukulis *et al* 2008). The Netherlands, India, China, Thailand and New Zealand, and individual states in the USA and Canada, have since established mandatory bioenergy targets, while others have removed excise taxes (Jumbe *et al* 2009). Such policies should result in the production of a greater amount of bioethanol and biodiesel. It could also open up more market opportunities for developing countries, which have for a long time been struggling to sell their agricultural crops to European and North American markets.

2.5 Liquid bioenergy and food security

The literature on the effects of bioenergy production on food security in Africa is sharply divided and inconsistent (Jayne 2002). Food security refers to the availability of food and one's access to it. A household is considered food-secure when its occupants do not live in hunger or fear of starvation (FAO, 2008). One of Africa's most urgent needs today is for food security, as food production is not keeping pace with population growth, leading to a continuing decline in its already low per capita production of food (Breman and Debrah, 2003). Cereals (e.g. barley, wheat, oats, maize and rye) are used to produce ethanol. Starch and sugar crops (e.g. potato, sugar beet and sugarcane) can also be used to produce ethanol by fermentation, which is then used directly as fuel, as in Brazil, or more normally it is mixed with gasoline. Some of the common energy crops are oil crops (e.g. oilseed rape, linseed, field mustard, sunflower, castor oil, olive, palm, coconut and groundnut). Vegetable oils from these crops can be used directly as heating fuel or refined to become transport bioenergy such as biodiesel esters (Sims *et al* 2006).

However, political and public support for bioenergy has recently been undermined by environmental and food security concerns (Koh and Ghazoul, 2008) and by reports questioning the rationale that bioenergy will substantially reduce carbon emissions (Nkala, 2012). For instance, studies in China show that the current bioenergy development path could have a significant impact on China's food supply and trade, as well as the environment (Young *et al* 2009). Preferred feedstocks for the current first-generation bioenergy production are corn, wheat, sugarcane, soybean, rapeseed and sunflowers. These are also important food crops in many countries, especially in Sub-Saharan Africa.

In Tanzania, liquid bioenergy production will come from food crops. But what does this imply? The major challenge is that these feedstocks are also used for food production (Ajanovic, 2011). Will bioenergy production from food crops improve food security or jeopardize it? What is the precondition for having both food and bioenergy security in a *win-win* situation for a country like Tanzania? These are some of the issues this study tries to address. Many studies analyzing the relationship between biofuels and food prices reveal that the competition for limited land for the production of fuel and food results in major consequences, such as malnutrition and food shortages, especially in poorer regions (Chakravorty, 2009).

2.6 Food security in Tanzania

The Tanzanian economy is heavily dependent on agriculture. Between 1970 and 2005 the sector accounted for over 33% of GDP and employed 82% of the labour force in 2001. In recent years, however, the contribution of the sector to GDP has dropped to less than 25% and the proportion of employees fell to 75% in 2006 (Keratu *et al* 2011). This was due mainly to the emergence of other economic opportunities, such as minerals and natural gas.

Tanzania is also on the official UN list of Least Developed Countries (LDC), Highly Indebted Poor Countries (HIPC), and more pertinently Low Income Food Deficit Countries (LIFDC). The majority of its over 44 million people live in poverty (Hakiardhi, 2008) and its position was 151 in the Human Development Report with a Human Development Index Score of 0.53 (Keratu *et al* 2011). The per capita income is US$1,300 and 36% of the population live on less than a dollar a day (Keratu *et al* 2011, URT 2008). However, although the country is well endowed in terms of land with the potential for agricultural development, productivity has remained very low. Agriculture in Tanzania is predominantly regarded as a smallholder business, with farms ranging in size from 0.9 to 3 hectares, dedicated to subsistence farming with limited marketable surpluses (Mwakaje *et al* 2013). Furthermore, the agricultural sector is characterized by traditional farming methods with a low level of technology, low utilization of modern inputs and inefficient resource allocation (Mashindano and Kaino, 2009; Runyoro, 2006). It has poor linkages with other domestic sectors, a poorly developed marketing system in general, and a lack of infrastructure that affects access to both the domestic and international market.

The agricultural sector's weakness results in an unsatisfactory level of food security and consequent widespread poverty and poor quality of life (Mashindano and Kaino, 2009). Food production has remained low, failing to meet household and national requirements (Runyoro, 2006). Food insecurity is concentrated in the coastal regions of Pwani, Lindi, Mtwara and Tanga, together with the semi-arid regions of Arusha, Manyara, Dodoma and Singida and some parts of Shinyanga, Morogoro, Kigoma and Mara (Ashimogo, 1995). Although food production has been increasing marginally and in some years exceeded the theoretical overall food requirements, the nation's nutritional energy requirements are far from being met on a sustainable basis (URT, 2012). Importing food has been constrained by inadequate foreign currency reserves due to other sectors (minerals and cash crops) producing little for the international market. Although the overall situation has improved significantly in recent years, this is only in aggregate terms, as in actual terms some regions have remained food insecure (Keratu *et al* 2011). While the proposed liquid bioenergy production from food crops could stimulate agricultural productivity, it is not clear whether this will automatically address the problem of food security in the country.

2.7 Staple food in Tanzania

The government of Tanzania intends to produce liquid bioenergy from non-staple food crops. However, the so-called staple non foods in the country differ from one location to another and from one tribe to another. Tanzanians' diet is largely based on starchy food such as millet, sorghum, beans, pilaf and cornmeal. A meal that could be considered the country's national dish is maize meal (known locally as *ugali*). This is normally stiff dough made from cassava flour, cornmeal (maize), millet or sorghum, and is usually served with a sauce containing meat, fish, beans or cooked vegetables. Maize is the main staple, accounting for a third of caloric intake (Minot, 2010). Cassava is second and rice is third, contributing 8% of caloric intake. Wheat and sorghum each represent 4%.

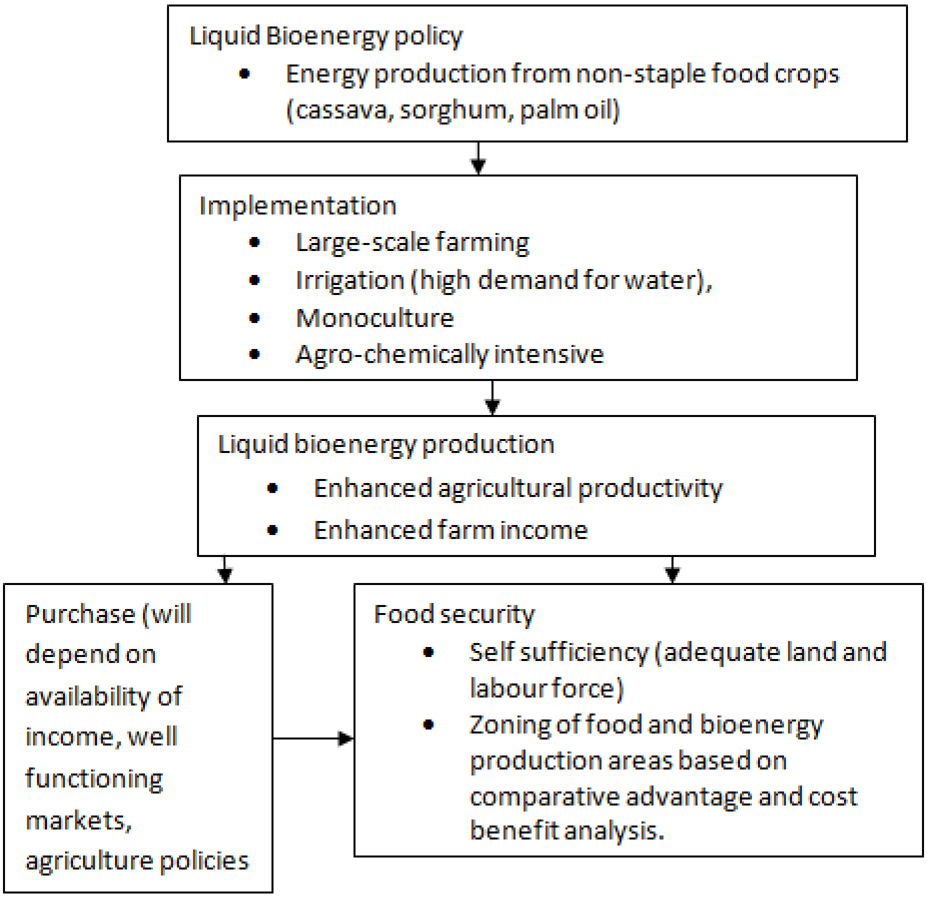
In terms of per capita consumption, rice comprises about 16kg, contributing 8% of caloric intake among Tanzanians (Minot, 2010). The per capita consumption of maize and cassava is estimated to be 73kg and 157kg, respectively. According to Kadigi (2003), the bulk of paddy consumed in Tanzania is produced in five regions, namely, Shinyanga, Mwanza, Morogoro, Mbeya and Tabora. Region-wise, staple rice is consumed more along the coast where it is eaten with green vegetables (*mchicha*), fish or meat. In the interior of Tanzania, people eat cooked or steamed green bananas (*matoke*) or maize and millet meal eaten with relish made from beans, fish or meat. Maize cooked with beans or meat (*makande*) is the staple food of several tribes, especially the Pare of Kilimanjaro Region. In Central Tanzania, which is basically a semi-arid area, the main staple is cassava and sorghum and this also applies in the southern regions of Mtwara and Lindi as well as Coast region. Liquid bioenergy production in Tanzania is targeting mainly these two food crops. What is the likely implication for such a policy is the focus of this study.

This review of staple food suggests that it varies from one region to another. While the government is planning to produce liquid bioenergy from what is called non-staple food, such as cassava and sorghum, these crops are in fact staple food for 30-40% of the Tanzanian population, especially in semi-arid areas. One would ask whether it is really proper to call cassava and sorghum non-staple. The most important point however is that in a well performing market the income from liquid bioenergy could be used to purchase food. However, available information shows that most of the food consumed in Tanzania is produced locally (self-sufficiency). Maize imports and exports are quite small, partly due to frequent bans. Cassava and sorghum are essentially non-tradable while rice imports account for 8% of domestic requirements. Only wheat is imported in larger amounts and re-exported to interior countries (Minot, 2010). Maize prices are localised and therefore not closely linked to world prices. For example, in 2007 the price remained high even after the world price declined (Minot, 2010). This suggests that even if the income from bioenergy crops will be enhanced, it is not clear whether food imports will meet the country's demand for food. Studies also suggest that although biofuel crops such as cassava, castor oil and sweet sorghum can be grown in unfavourable environmental conditions, the energy efficiency of these crops is low (Chakravorty, 2009). This implies that liquid bioenergy production from food crops could demand a large quantity of food to produce it. Apart from this hypothetical thinking, what is the likely implication of producing liquid bioenergy from food crops?

2.8 Conceptual framework for liquid Bioenergy and food security

The conceptual framework for this study is presented in Figure 1. The government of Tanzania has developed a policy to produce liquid bioenergy from non-staple food crops. This implies that agricultural farming will be transformed into commercial farming, which will involve large-scale, intensive farming with the use of a high level of agrochemicals, and a great demand for water for irrigation as well as labourers. It is anticipated that commercialized agriculture will lead to increased productivity per unit of land that will enhance farm incomes. Increased farm productivity could also enhance food security either through self-sufficiency or through purchasing food using the income earned from bioenergy production. However, food security from purchasing could only be achieved if the market will work efficiently. This is again a policy issue, whereby trade barriers need to be limited or eliminated and infrastructure such as roads, telecommunications and vehicles improved. Failure to do so could lead to food insecurity in the country (Figure 1). Food security could also be enhanced through zoning based on comparative advantage and a cost benefit analysis of different land uses.

Figure 1: Conceptual framework



3. Material and methods

3.1 The study area

Dodoma Region lies between 4° to 7° latitude south of the Equator and 35° – 37° longitude east of Greenwich. It is located in the central part of Tanzania. Much of the region is comprised of a plateau, rising gradually from some 830 metres in the Bahi Swamps to 2000 metres above sea level in the highlands in the north. The region has four rural districts and one urban district, namely: Dodoma-Rural, Kondoa, Mpwapwa, Kongwa and Dodoma Urban. Dodoma region is the 12th largest in the country and covers an area of 41,310 sq. Km, equivalent to 5% of the total area of Tanzania Mainland. The region's population is estimated to be 2.08 million (URT, 2012).

Dodoma Region has a savannah type of climate, which is characterized by a long dry season lasting between late April and early December, and a short single wet season occurring during the remaining months. In the long dry season, persistent desiccating winds and low humidity contribute to high evapo-transpiration and soil erosion.

The average rainfall for Dodoma rural is 570mm, and about 85% of this falls between December and April. Apart from the rainfall being relatively low, it is unpredictable in frequency and amount. It is this unreliability of rainfall that has caused a pattern of risk aversion to traditional agriculture and is a serious constraint to present efforts to improve crop yields (WRC, 2013). Food insecurity is also linked to degraded land, whose soil fertility is low and lacking in organic matter, and because it is shallow it does not have the capacity to hold much rainwater. This has resulted in low yields per unit area of the staples, namely sorghum and millet (URT, 2013). The major crops grown and consumed in the study area are sorghum, pearl millet, cassava, sweet potatoes, groundnuts, simsim, grapes, and sunflower seeds. The study area is generally facing a chronic shortage of food and thus perpetually depends on relief food aid (URT, 2013). It is not clear whether the proposed bioenergy production from food crops in this region will improve or worsen food security.

3.2 Data collection

The study was based on the literature review and fieldwork. Different sources were used to collect information, including the internet, archives, reports and journal articles. The main objective of the review was to gain an understanding of the impact of producing liquid bioenergy from food crops on food security. In addition, there was random sampling of 100 respondents, comprising 50 urban and 50 rural farmers in Dodoma rural district. There was also a focus group discussion and key informant interviews. These involved policy makers in the Ministries of Energy and Minerals, Agriculture, Food Security and Cooperatives, Water, and Lands, Housing and Human Settlements Development. The purpose of the consultation and fieldwork was to gain an understanding of the policy in relation to bioenergy and food security, strategies for achieving both food and energy security and people's awareness of and views on the subject. Structured and semi-structured questionnaires were used to gather information. The data was analysed using the Statistical Package for Social Sciences (SPSS) and the results presented in tables and figures.

4.0 Results and discussion

Generally, the study came up with inconclusive findings with regard to the literature review but there was a consistent response from the respondents that using food crops for liquid bioenergy production would not be the best policy option, especially for Sub-Saharan African countries like Tanzania, where food insecurity has remained a chronic problem. The following sections discuss the findings in more detail.

4.1 Findings

4.1.1 Liquid bioenergy vis-a-vis food security

As discussed earlier, there are several reasons why bioenergy is being considered relevant to both developing and industrialized countries. These include energy security, environmental concerns, foreign exchange savings, and socio-economic issues relating to the rural sector (Demirbas, 2007). Food security exists when people all the time do not have physical, social and economic access to sufficient amounts of safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (Faaij, 2008). According to the author, there are four dimensions of food security: availability, access, stability and utilization.

There is a belief that the opportunity to generate income and expand agricultural production through bioenergy development may provide welfare gains that could improve purchasing power with regard to food and energy and reduce vulnerability to price shocks (Ewing *et al* 2009). Although bioenergy production may increase the income of rural farmers and this income is a critical determinant of food security for the poor, it may have effects on food security that are not mediated by income and prices (Faaij 2008). Martin (2008) reports that a quarter to a third of price increases in recent years can be explained by the increased production of energy from land. Studies further indicate that food prices are expected to continue to rise over the next decade in response to bioenergy consumption targets adopted in the US and EU (Ewing *et al* 2009). Also the income gained from bioenergy may not keep pace with food availability in developing countries.

Furthermore, the findings from the literature review revealed that the large-scale production of new types of crops dedicated to energy is likely to induce a structural change in agriculture and change the source and level of farm incomes (Rajagopal *et al* 2007). In China for example, studies show that the current level of bioethanol production consumes 3.5–4% of all the maize produced in the country, reducing the availability of maize for other uses by about 6% (Yang *et al* 2009). It is projected that depending on this type of feedstock, 5–10% of the cultivated land in China would need to be devoted to meeting the bioenergy production target of 12 million metric tons by the year 2020 (Yang *et al* 2009). The author further explains that even if all the crops, forests and grasslands not used currently were used for bioenergy production they could not possibly substitute the fossil fuels used for transport today. The implication of this is that the market for bioenergy is limitless and this may threaten food security. Quite often it is argued that income from bioenergy would enable rural farmers to purchase food, but what is not given weight is that if everyone were to produce bioenergy crops would the money be used to buy food?

Converting agricultural land for growing food crops into bioenergy agriculture could threaten food security (Campbell *et al* 2008). According to Rathmann *et al* (2010), the emergence of agro-energy has altered the land use dynamic, with a shift in areas traditionally used to grow foods to growing crops to produce bioenergy. This has contributed to raising food prices. Liquid bioenergy production has indeed contributed to that and is in the near future likely to continue to weaken access to adequate food or to the resources by which vulnerable people can feed themselves (Naik *et al* 2010). Studies have identified linkages between the usage of feedstocks for bioenergy production and an increase in international food prices (Ewing and Msangi, 2009). In addition, these studies indicate that food prices are expected to continue to rise over the next decade in response to bioenergy consumption targets adopted in the US and EU. While studies suggest that sweet sorghum has the greatest potential, in Tanzania this crop grows well on marginal land or in semi-arid areas (Li and Chan-Halbrendt, 2009) and is the major staple food.

Based on this literature review the general impression is that it is inconclusive as to whether bioenergy will enhance or adversely affect food security in the world. Most of the arguments in the literature reviewed are speculative rather than scientific. It is dangerous to rely on speculation concerning sensitive issues such as food security, especially for poor countries in Sub-Saharan Africa.

4.2 Findings from the field

4.2.1 Socio-economic characteristics

The study revealed that out of the 100 respondents, 60% were male and 40% were female. Education-wise, the majority had completed form four (45%) while those having had primary and tertiary education were 30% and 25%, respectively. About 50% of the respondents were urban dwellers and 50% were farmers. The urban dwellers were involved in different income-generating activities, such as employment (38%), petty trade (40%) and both employment and petty trade (22%). Regarding farmers, the major economic activity was farming (100%). However, 30% of the farmers were also involved in non-farm income-generating activities including petty trade. Farmers were growing a number of crops including maize, cassava, cashew nuts and sorghum.

4.2.2 Awareness of liquid bioenergy production from food crops

The respondents were asked to indicate whether they are aware of the technology for producing liquid bioenergy from food crops for transport, including running stationary engines. A high proportion of the respondents (70%), especially the farmers (90%), indicated a lack of awareness and only 30% of the total sample were aware of the technology (Table 1). This was new to most of them. The researcher attempted to explain in detail that it is possible to use food crops (such as maize, cassava and sorghum) to produce liquid bioenergy for transport and that the government of Tanzania is intending to use food crops to produce liquid bioenergy. It was further explained to them that such a policy intends to increase agricultural productivity, farm incomes and energy security. Despite that, only 20% of the farmer respondents agreed that the policy was good while the remaining 80% questioned the rationale of the policy. As regards the urban respondents, 60% and 40% agreed that the policy was good and bad, respectively. The puzzling issue for a high number of the respondents was how food could be used to produce liquid bioenergy in a country where food insufficiency is a chronic problem.

In a multiple response question the respondents were asked to explain why they are so certain that this policy would jeopardize food security in the country. Eighty five percent said they are concerned because it will inflate food prices in the country and it is the poor who will suffer the most. In addition, 65% said they would not have the cash to buy food and this was especially true of farmers (90%). Other people argued (74%) that even if the bioenergy economy were to enhance food productivity in the country, there would be a tendency to sell all the food and all the money gained would be used for other purposes, so that when the need to buy food arose they would have no money. The respondents were also concerned about losing their land to large-scale bioenergy production investors (70%).

Table 1: Issues Respondents are concerned about regarding Bioenergy and food security

Food security issues	Urban dwellers (%)	Farmers (%)	Total (%)
	n=50	**n=50**	**N=100**
Level of awareness of bioenergy from food crops	50	10	30
Agree that the policy is good for food security	60	20	40.0
Why so concerned?			
Likely to inflate food prices	80	90	85.0
Will lead to food scarcity	70	90	80.0
Lack of money to purchase food	40	90	65.0
Desire to sell all food for money	65	90	72.5
Lose land to large-scale Bioenergy investors	80	60	70.0

5.0 Discussion

The findings presented above from the literature review are rather inconclusive. However, the message from the respondents was very clear that using food crops for bioenergy production could lead to food insecurity in the country. The respondents gave a number of reasons including the danger of allocating productive land to bioenergy production leading to food scarcity, the lack of money to purchase food, poor market infrastructure, the temptation to sell all the produce but not spend it on food and that it could lead to land grabbing by large scale bioenergy producers.

This last argument by the respondents partly supports what was reported by Naik *et al* (2010) that at least two things contribute significantly to an increase in food prices. First, the need for economies of scale has led to land being turned into plantations for production, leading to the eviction or marginalisation of vulnerable groups and individuals. Second, indigenous people and other groups with insecure titles to the land on which they make their living have also been harmed and are likely to be so in the future. A number of villagers in Tanzania have already lost their land to bioenergy investors in the country (Hakiaridhi, 2008).

While there is an argument that money is a means for the application and transfer of social power for accomplishment (Jacobs, 2012), if not used properly it could destroy social settings and cause conflicts. More importantly, in accordance with African culture whereby cash crops are handled by men and food crops by women, the bioenergy economy could lead to food insecurity at family level as women will lose control of food crop land and will also not benefit from bioenergy income (Mwakaje, 2012).

While economically food security does not necessarily come from food self-sufficiency, nevertheless, in many developing countries, including Tanzania, food security is synonymous with food self-sufficiency. Many farmers do not have enough savings to purchase food during scarcity. Instead, they spend most of their time selling their labour for food instead of working on their farms, thereby perpetuating the poverty cycle (Mwakaje, 2005). A high proportion of urban dwellers can attain food security through buying, but the question is whether food will always be available to purchase at a competitive price that everyone people will be able to afford. Food is the major item consuming the income of the poor.

5.1 Possible solutions for addressing food and liquid bioenergy security

5.1.1 Zoning for food and bioenergy production areas

One of the Liquid Bioenergy Policy propositions is zoning for liquid bioenergy and food production areas in the country and this initiative is highly commended. This zoning process should be based on comparative advantage and be supported by a cost benefit analysis of different land uses.

On the other hand, zoning for bioenergy production areas will only help to achieve the two objectives of food and energy security if it is properly implemented and the zones are honoured by the policy and decision makers. Undertaking the zoning exercise will need large sums of money. So far it is not clear how much money has been budgeted for the exercise and for monitoring implementation of the policy. Tanzania like many other developing countries has good policies and laws, but frequently there is a failure to implement them, due to a number of factors including the lack of funds. For example, the regulations governing artisanal and small-scale mining in Tanzania are fairly comprehensive and yet environmental pollution caused by artisanal and small-scale mining has remained high, thereby threatening human and environmental health (Mwakaje, 2012). Also the Environmental Management Act (2004) has failed to address adequately the issue of environmental management compliance by development projects due mainly to inadequate capacity (human and resources) of the National Environmental Management Council (NEMC). To make bioenergy zoning and monitoring work, they will need to have their own budgets.

4.1.2 Improve rural infrastructure for national market integration

Despite the fact that the country has adequate food security in aggregate terms, some parts of the country has remained chronically food insecure. The food secure regions include areas of the four regions of the Southern highlands, Morogoro and Manyara while the coastal region and the central and some northern parts are food insecure. The food trade across these regions is a problem mainly due to the poor infrastructure, which continues to be a challenge to Tanzania's agricultural development. Studies show that infrastructure constraints are responsible for about 34% of the lack of productivity of Tanzanian firms over the period 2002 -2006 (Shkaratan, 2012). Transportation is reportedly the constraint that weighs most heavily on Tanzanian firms, with water a close second. Infrastructure contributed 1.3% to Tanzania's annual per capita GDP growth during the 2000s, while from 2003 to 2007 infrastructure contributed only 1.4% (Shkaratan, 2012).

Nevertheless, in recent years Tanzania has been devoted to investing in infrastructural development. The main trunk roads are the one from Dar es Salaam to Dodoma and north-west to Mwanza, going on to Uganda and Kenya, the one from Dar es Salaam to Mbeya, Malawi and Zambia and the one from Dar es Salaam to Moshi in Kilimanjaro, going on to Kenya are all in good condition. The western part of the country is reached by rail from Dar es Salaam and by road to Kigoma on Lake Tanganyika although this one has remained unreliable. Tanzania is also improving road connections with the neighbouring countries of Kenya, Uganda, the Democratic Republic of Congo, Malawi, Zambia, Rwanda and Burundi. Furthermore, power distribution and ICT infrastructure have improved remarkably in recent years (Shkaratan, 2012). Its domestic air transport market is also improving gradually, such as the recently opened Songwe International Airport in Mbeya region, Southern Highlands. This will facilitate the opening up of international trade in agricultural commodities in the southern part of the country. While most of the regions are currently connected by tarmac roads, most of the districts where food is produced have poor roads and other infrastructure. Consequently, food market integration has remained a challenge in the country

The African Development Bank decided to increase funding for the East African Road Network in Tanzania by \$100 million (160 billion shillings) in the 2012-2013 fiscal year in an effort to boost the regional economy (Balile, 2012). However, available information suggests that Tanzania would need to invest \$2.9 billion annually for 10 years to meet its infrastructure targets. Spending at that level would absorb over 20% of the country's GDP (ADBG, 2011). The 2013/14 budget was only 8.2% of this target. Tanzania needs to make a greater effort to improve the road network so as to integrate food and other agricultural markets.

5.1.3 Improve food market through reduced cross border trade barriers

The liberalization of food markets will impact food prices as well as the competitiveness of bioenergy (Chakravorty, 2009). However, concern over the negative impacts of staple food price fluctuations limits the extent to which governments in low-income countries are willing to liberalize their agricultural markets (Pinckney, 1993). According to the author, these concerns are legitimate as such price fluctuations can lead to high transactions costs for poor consumers in the short run and low growth in the long run. According to Fafchamps (1992) farmers' food security in the developing world is best assured by food self-sufficiency.

In Malawi, studies show that agricultural liberalization has adversely affected smallholder farmers who are net food buyers, low-income or wage earners in urban and semi-urban areas and smallholder farmers in remote areas (Chilowa, 1998). Most smallholder farmers sell their farm crops during harvest and therefore receive low prices. This happens because of the high demand for cash to meet other needs such as education, health and religious ceremonies. Farmers are also cheated by dishonest traders who do not use standard measuring scales in their transactions, or who simply estimate the weight of a heap of goods.

In this situation it is advised to adopt the regulated warehouse receipt system, which will curtail cheating on weights and measures, ease access to finance at all levels in the marketing chain, moderate seasonal price variability and promote instruments to mitigate price risks (Coulter and Onumah, 2002). It will also reduce the need for the Government to intervene in agricultural markets, and reduce the cost of such interventions (Coulter and Onumah, 2002).

For quite some time now, Tanzania has been prohibiting farmers from selling food to neighbouring countries in what is claimed to ensure food security. Nevertheless, there is evidence that trade liberalization offers potential benefits for national food security by enabling a rapid increase in food supplies following a shortfall in domestic production (Dorosh, 2001). The importance of bioenergy is that it will increase agricultural productivity and rural economic growth so that poor rural households are provided with enough money to buy food (Dorosh, 2001). Tanzania is likely to achieve food security by reducing cross-border trade barriers with international markets. Quite often rice and wheat imported from Asian countries is much cheaper than that produced locally. Indeed, Tanzania could capitalize on its comparative advantage by producing liquid bioenergy for export and using the income from it to purchase food. In other words, politicians should change their minds about thinking that food security must come from food self-sufficiency.

5.1.4 Increase agricultural productivity in a sustainable manner

Bioenergy is being developed in the context of three broad economic and policy drivers: reducing greenhouse gas emissions, increasing energy security, and supporting agriculture (Thomas *et al* 2009). Practices and technologies that are more sustainable may have substantial benefits for the rural poor (Pretty *et al* 2003). Crop and livestock production must be managed as an ecosystem, with management decisions being fully informed of the environmental costs and benefits (Robertson and Swinton, 2005). There is a positive feedback effect between export performance and food security on the one hand and agricultural productivity on the other (Frisvold and Ingram, 1995). In low-input systems the additional use of N fertilizer may be required to increase yield level and yield stability (Spiertz, 2010). Developing technology that can convert cellulosic materials into bioenergy efficiently will also help defuse the demand for traditional food supplies worldwide (Daniel *et al* 2007). Practising organic agriculture to avoid the negative environmental effects of conventional agriculture could sustain agricultural productivity (Muller, 2009). However, the question is whether organic farming could meet a significant part of the global demand for energy as productivity might be lower than that of intensive commercial farming, with its use of agrochemicals. For instance, in Malaysia and Indonesia, which are the world's largest producers of biodiesel after the EU, current palm oil yields amount to 4 tons per hectare, but they could potentially be increased to 6 tons per hectare with available know-how. In China, studies show that the average sugarcane yield is only 60 tons per hectare but it has the potential to rise to approximately 85 tons per hectare (Chakravorty, 2009). Countries like Tanzania are producing below agronomic recommendations because farmers use the hand hoe, which is inefficient, use hardly any fertilizer and depend on rain–fed agriculture (Mwakaje, 1999). Addressing these challenges could lead to increased agricultural productivity, farm income and rural development.

5.1.5 Use of second and third-generation technologies

The adoption of second-generation technologies may make bioenergy more beneficial to society (Rajagopal *et al* 2007). Due to the sensitivity of producing liquid bioenergy from food crops and land acquisition, there has been a growing interest in promoting liquid bioenergy production from second and third-generation technologies. According to Chakravorty (2009), when only first-generation biofuels are modelled, corn and oil seed prices rise by 76% and 66%, respectively. The author argue that, when there are improvements in second-generation bioenergy and productivity, these percentages fall to 45% and 49%, respectively, and with crop productivity improvements the price effect is even smaller, although still significant.

It is possible that wood, straw and even household waste could be economically converted into bioethanol

(Demirbas, 2007). Indeed, Karp and Richter (2011) suggest that the use of high-input food crops to produce liquid transport fuel needs to be phased out and replaced by the use of crop residues and low-input perennial crops, which will have multiple environmental benefits. Research by Antizar-Ladislao and Turrion-Gomez, (2008); Havlík *et al* (2011); Giuliano *et al* (2010); Nigam *et al* (2011) and Nigam and Singh (2011) has identified a number of second and third-generation bioenergy production options. Second-generation bioenergy from forest and crop residues, energy crops and municipal and construction waste will arguably reduce net carbon emissions, increase energy efficiency and reduce energy dependency, potentially overcoming the limitations of first-generation bioenergy (Antizar-Ladislao and Turrion-Gomez 2008). Research interest is also growing in microalgae being promoted as an ideal third-generation bioenergy feedstock because of their rapid growth rate, CO_2 fixation ability and high production capacity of lipids. In addition, they do not compete with food or feed crops, and can be produced on non-arable land (Giuliano *et al* 2010). The authors further argue that microalgae have great bioenergy potential as they can be used to produce liquid transportation and heating fuels, such as biodiesel and bioethanol. The advantage of second-generation bioenergy is that it will not compete directly with food but it requires several energy-intensive processes to produce them, and it will also increase land-use change, which reduces its environmental and economic feasibility (Singh *et al* 2011). On the other hand, the production of third-generation bioenergy avoids the issues faced by first and second-generation bioenergy, namely food–fuel competition, land-use change, etc., and so it is considered a viable alternative energy resource (Singh *et al* 2011). In Tanzania, there have been attempts to utilize second and third-generation bioenergy to produce liquid bioenergy although on a small scale. This involves producing ethanol from bagasse in sugarcane-processing plants, using animal oil and other waste. Tanzania may need to undertake more research on the second and third generation instead of focusing on non-staple food crops which its definition has proved to be controversial.

5.1.6 Using abandoned agricultural and marginal land for bioenergy agriculture

According to the literature reviewed, there is a possibility of producing liquid bioenergy on abandoned degraded agricultural land (Campbell *et al* 2008). Degraded and marginal land is defined in terms of the amount of rainfall and vegetation cover and possibly soil quality. However, the so-called marginal lands in Tanzania are not useless, although it has limited water and fertility and are susceptible to drought. Most of them are useful for wildlife and livestock keeping and therefore converting it to bioenergy production will require major policy changes as regards livestock keeping and wildlife management. However, on the other hand one would ask how could a policy be based on the marginal land and yet be able to achieve its objective of reducing imports of fuel from abroad? This apparent contradiction means that such a policy of producing liquid bioenergy from food crops cannot work. Commercial production of bioenergy will need all the best ingredients to boost production if the policy has to meet both local and international demand. By concentrating on marginal lands only for bioenergy crop production may become not feasible economically. On the other hand, the global potential for bioenergy produced on abandoned agricultural land is also not promising, as less than 8% of the current global demand for energy is met (Campbell *et al* 2008). To ensure that society benefits from bioenergy production, governments, researchers and companies will need to work together to carry out a comprehensive assessment, map suitable and unsuitable areas, and define and apply standards relevant to the country (Phalan, 2009). Also studies show that second-generation biofuel feedstocks, such as switchgrass and miscanthus, can be grown on marginal land that is unsuitable for traditional agricultural uses (Hochman *et al* 2008). However, their production costs are still high compared with the cost of producing first-generation bioenergy (Rajagopal and Zilberman, 2007). Thus the issue of producing liquid bioenergy on abandoned and marginal agricultural lands may need a comprehensive analysis of the pros and cons relative to the policy objectives and food security in the country.

6.0 Conclusion

This study attempted to analyse the impact of producing liquid bioenergy from food crops on food security in Tanzania. Using both literature and field study the results show that bioenergy production from food crops is likely to cause food insecurity in the country. The reasons provided by the respondents were diverse including that it could inflate food prices and respondents questioned whether money would be available to buy food, especially for the rural poor. Others argued that if liquid bioenergy crops fetch a high price, there might be a temptation to sell all the crops and others were concerned about losing land to large-scale bioenergy investors and about the market not working efficiently in the country.

Thus in order to achieve a *win-win* situation for liquid bioenergy and food security, it is recommended that the government should undertake zoning for bioenergy production areas while other areas should remain solely food-producing areas. It should also improve rural infrastructure for national market integration, reduce trade barriers and improve food productivity at the small-scale level. This should be done by applying sustainable agricultural methods, improving markets for inputs and outputs and improving extension services. The author is also in agreement with the argument of Escobar *et al* (2009) that a rise in the use of bioenergy is inevitable and that international cooperation, regulations and certification mechanisms must be established regarding the use of land and the mitigation of environmental and social impacts caused by biofuel production. To stimulate rural development in Tanzania it is recommended that local processing to at least the 50% level should be mandatory for reasons of employment creation and rural development. The author also supports Ajanovic's (2011) recommendation that the co-existence of bioenergy and food production seems possible especially for second-generation bioenergy if sustainability criteria are seriously considered. In this respect it is recommended that Tanzania should focus more on second and third-generation liquid bioenergy production.

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