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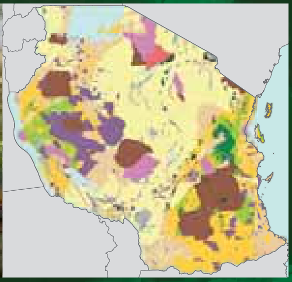
Bioenergy and Food Security

The BEFS Analysis for Tanzania





ENVIRONMENT AND NATURAL RESOURCES MANAGEMENT WORKING PAPER

ENVIRONMENT CLIMATE CHANGE [BIOENERGY] MONITORING AND ASSESSMENT

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Bioenergy and Food Security

The BEFS Analysis for Tanzania

Edited by: Irini Maltsoglou and Yasmeen Khwaja

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ENVIRONMENT AND NATURAL RESOURCES MANAGEMENT WORKING PAPER

ENVIRONMENT CLIMATE CHANGE [BIOENERGY] MONITORING AND ASSESSMENT

BEFS
Bioenergy and Food Security Project

The Bioenergy and Food Security Project
Food and Agriculture Organization of the United Nations

FOREWORD

Bioenergy developments are high on many countries' agendas today in an effort to improve energy access, energy security and in the context of concerted efforts towards lowering global green house gas emissions. Over time, however, serious concerns on the food security impacts, social feasibility and sustainability of bioenergy have arisen, especially with first generation bioenergy. In this context FAO, with generous funding from the German Federal Ministry of Food, Agriculture and Consumer Protection (BMELV), set up the Bioenergy and Food Security (BEFS) project to assess how bioenergy developments could be implemented without hindering food security.

Over its term, the BEFS project has been supporting Peru, Tanzania and Thailand in assessing the feasibility of the bioenergy sector, potential impacts on food security, growth and poverty. In this effort, BEFS has constructed an Analytical Framework that can assist countries with the development of bioenergy policy and/or clarification of the potential impacts of the bioenergy developments.

The analysis presented in this document is the implementation of the BEFS Analytical Framework in Tanzania. As part of its activites, BEFS is also running training programmes in the countries to ensure full ownership, replicability and potential extensions to the analysis presented.

Heiner Thofern
Senior Natural Resources Management Officer
BEFS Project Coordinator

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Appreciation also goes to the many government bodies, academic institutions and individuals that saw this analysis through and provided very useful feedback along the way. We are heavily indebted to the Ministry of Agriculture, Food Security and Cooperative and the Ministry of Energy and Minerals in the United Republic of Tanzania and all the participants of the BEFS workshop held in Dar Es Salaam, Tanzania, in February 2009.

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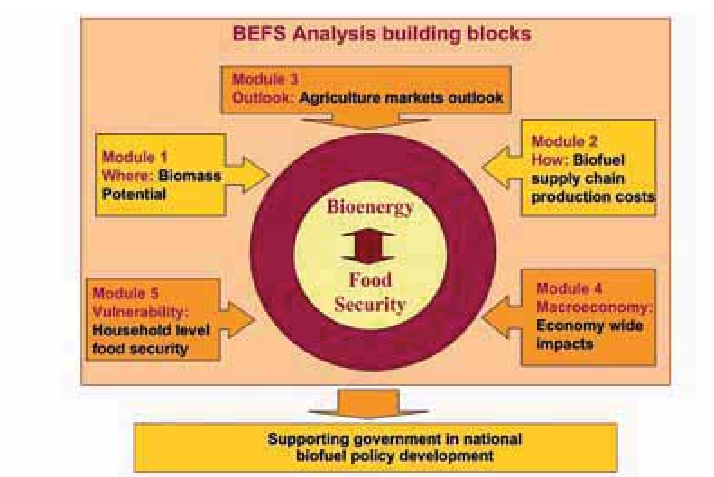
THE BEFS ANALYSIS IN TANZANIA: A SUMMARY

Bioenergy developments are high on the agendas of many countries today in an effort to improve energy access, energy security and in the context of concerted efforts towards lowering global greenhouse gas emissions. In addition, bioenergy offers enormous potential to boost agricultural growth. Decades of inadequate public investment has resulted in a stagnant sector characterized by declining productivity with serious implications for long-term food production. Biofuel developments in Tanzania could provide an important vehicle through which to revitalize agriculture by bringing a variety of investments needed to boost productivity. However, although the arguments for promoting bioenergy are strong, over time serious concerns about the environmental and social feasibility and sustainability of bioenergy have arisen, especially with first generation bioenergy.

In this context, the Food and Agriculture Organization (FAO) of the United Nations, with funding from the Government of Germany, has established the Bioenergy and Food Security (BEFS) Project to strengthen developing countries' technical understanding of how best to mitigate the impact of bioenergy development on food security. Under the project FAO has developed a quantitative and qualitative framework to analyse the interplay between bioenergy and food security. The BEFS Analytical Framework (AF) provides the tools that permit policy-makers to make informed decisions with respect to bioenergy.

The BEFS Approach.



The BEFS AF consists of five building blocks (See Figure above):

- *Module 1: Biomass Potential*
- *Module 2: Biofuel Chain Production Costs*
- *Module 3: Agriculture Markets Outlook*
- *Module 4: Economy-wide Effects*
- *Module 5: Household-level Food Security.*

These five components of BEFS provide the ***technical basis for information that can feed directly into policies and regulations for bioenergy development.***

Using the BEFS analytical framework, the two key elements for a country-specific BEFS analysis are:

1. **The feasibility of producing bioenergy**
   BEFS allows the country to identify:
   - the areas potentially most suitable for bioenergy production excluding those that are environmentally protected or are under alternative uses.
   - the smallholder-integrated production chains that are technically viable and most competitive;
2. **The economy-wide and food security effects of bioenergy development**
   BEFS allows the country to assess:
   - how the agriculture markets will evolve and how bioenergy might impact them;
   - the extent to which bioenergy developments in the country can lead to economic growth and poverty reduction;
   - the nature of trade-off that arise from pursuing particular bioenergy pathways;
   - household level food security and vulnerability;
   - the extent to which bioenergy crop production might compete with food production.

The analysis focuses on a number of crops. After consultation with the Government of Tanzania the analysis investigates the following crops for potential bioenergy development: ***cassava, sugar cane, palm oil, jatropha, sweet sorghum*** and ***sunflower***. The most important food security crops were selected on a per capita calorie consumption basis. In the case of Tanzania these are ***maize, cassava and rice***.

These crops underpin the entire analysis, although each Module may have focused on particular crops because of the nature of the analysis as well as issues of data availability. It is important to note that the BEFS analysis is not confined to these crops or these bioenergy sources but can be used for other crops too. Training provided by BEFS in the country will allow the country to examine a wider range of crops when required. The work in the other BEFS countries which are at a different stage in bioenergy developments serves as an important illustration how the BEFS analytical framework may be extended to consider, for example, water and biomass residues.

Finally, it should be noted that the results derived, as far as possible, reflect the on-the ground reality in Tanzania. Nevertheless, they are based on a strict set of assumptions. As countries use BEFS to provide further analyses, it is clear that these assumptions will change in order to reflect changing policies and realities.

Module 1: Biomass Potential in Tanzania

Module 1 extends the Agro-ecological Zoning (AEZ) approach developed by FAO in order to determine land suitability and potential production.

Land suitability assessment consists of two steps. First, the Land Resource Inventory (LRI) is compiled, with information on climate, soil and landform. Second, the Land Utilization Types (LUTs) are defined in terms of crop type, production system and input level. For each LUT, a set of agroclimatic, agro-edaphic and landform suitability criteria is formulated and applied to the LRI to determine land suitability.

The analysis shows that land suitability can be improved through more sustainable agricultural practices (medium-term) and through a change in input levels (long term). Agriculture in Tanzania is currently characterized by tillage systems with low input levels and a reliance on natural rainfall patterns. Under these conditions, Module 1 shows high land suitability across the country for cassava and sunflower, some suitability for sweet sorghum and limited suitability for sugar cane and palm oil. The analysis shows that the opportunity to develop the bioenergy sector lies in the improvement of bioenergy crop production mainly through a change in agricultural practice towards conservation agriculture in the medium term and with the application of high level inputs in the long term. These improvements will influence the performance of the whole agricultural sector.

Module 2: Biofuel Chain Production Costs in Tanzania

Module 2 assesses bioenergy productions costs where smallholders are integral to the industrial set-up. Four feedstocks are analysed in this module: sugar cane (juice and molasses), cassava, palm oil and jatropha. Module 2 assesses the local knowledge base and the manufacturing capacity available in order to define different processing systems. These processing systems are then screened against potential investments in discussion with the country to generate a final set of biofuel production scenarios. These scenarios include industrial set-up, plant scale and feedstock origin features. Based on this, the technical and economic viability of biofuel production is determined.

The analysis finds that technological capability in Tanzania is limited and new investment is required to build up human capital and the associated supplier network to support the development of the biofuel industry. Taking this into consideration, the recommended technological "entry point" for producing biofuels in Tanzania corresponds to the intermediate (second) level of technological development for ethanol and the conventional (first) level technology option for biodiesel production. Ethanol costs from dried cassava are low and competitive. Ethanol production from cassava is recommended because it permits the inclusion of smallholder farmers (outgrower) in production but conditions need to be put in place to enable their participation. Biodiesel production from palm oil is not economically viable. It also places too much risk on palm oil uses for food. The lowest cost for production of biodiesel is obtained from jatropha, where feedstock is supplied by outgrowers which, at the present time, represent a more viable option than estate production. However, jatropha-based biodiesel development poses many risks because of the many uncertainties in jatropha productivity. It is recommended that Tanzania also explores the possibility of developing other oilseed crops for biodiesel production such as moringa, castorbean, and cotton.

Module 3: Agriculture Markets Outlook in Tanzania

Module 3 focuses on domestic agriculture markets and can assist Tanzania in understanding the impact of international and domestic biofuel policies on its domestic markets. This Module assesses the impacts of domestic and international bioenergy developments on domestic food production and how bioenergy developments may affect food production trends. The Module is based on an OECD-FAO outlook tool covering a ten-year outlook period. The baseline for Tanzania was developed in discussion with the country. Building on country requests, scenarios were developed to simulate the effects of biofuel development on domestic agriculture markets. The main distinguishing feature between the two sets of scenarios is the scale of production. The first set of scenarios is devoted to biofuel development to meet domestic demand. Domestic demand is set by a 10 percent mandate on ethanol and a 5 percent mandate on biodiesel. In the second set of scenarios production far exceeds domestic demand permitting entry into the international markets for exports. The sensitivity of the industry low oil prices was investigated in this scenario set by considering high and low oil prices. Additionally, the module discusses the effects that changes in international biofuel policy may have on Tanzanian markets.

The analysis shows that, given relatively strong income and population growth Tanzania could be relying more on imports to meet its domestic demand even in the absence of biofuel production. The biofuel consumption mandate would have slightly negative impacts on food security if no new lands, above the outlook projections, are brought into production. On the other hand, if Tanzania could slightly increase cultivated lands and yields for biofuel feedstock then this could offset any impact on the projected food security.

If the land required by investors to develop the biofuel industry were identified as available, then even with the presence of a consumption mandate, Tanzania would be a significant exporter of biofuels. In this case, scenario analysis of lower oil prices displays how agricultural markets are sensitive to changes in oil prices and that Tanzania would actually rely even more on imports to meet domestic demand. Finally, the analysis exemplifies how biofuel markets and agricultural markets are sensitive to changes in government biofuel policies, whereby if support is reduced and world commodity prices decrease, then Tanzania increases its imports.

Module 4: Economy-wide Effects in Tanzania

Drawing on the detailed production cost estimates developed in Module 2, this part of the analysis uses a dynamic economy-wide model of Tanzania to estimate the growth and distributional implications of alternative pro-poor biofuel production scenarios. Based on the results from Module 2, these scenarios differed in the feedstock used to produce biofuels (sugar cane [juice and molasses], cassava and jatropha), the scale of feedstock production (small-scale outgrower versus larger-scale plantations), and the way in which feedstock production is increased (yield improvements versus land expansion).

Model results indicate that while some individual farmers may shift resources away from producing food crops, there is no national-level trade-off between biofuels and food production in Tanzania. Rather it is traditional export crops that will be adversely affected by a sizeable appreciation of the real exchange rate. Indeed, it is the large size of Tanzania's agricultural export sector that prevents food production from contracting. This is because the amount of land displaced by biofuel feedstock is smaller than the lands released by declining traditional export crops. As a result, food production increases slightly under most biofuel investment scenarios. Overall, national GDP rises and new employment opportunities are created in biofuel sectors. This leads to welfare gains throughout the income distribution, albeit following a possible period of adjustment in which prices, farm workers and non-biofuel experts adapt to new market conditions.

Findings suggest that, while all biofuel production scenarios improve household welfare, it is the small-scale outgrower schemes, especially for typical smallholder crops such as cassava and jatropha, which are most effective at raising poorer households' incomes. Tanzania should therefore explore opportunities to engage smallholders in the production of biofuels, possibly through mixed small- and large-scale production systems. However, supporting evidence indicates that these mixed systems may reduce the profitability of biofuels in Tanzania and reduce the reliability of feedstock supply for downstream processing. Here these findings confirm the welfare gains from producing feedstock through yield improvements rather than land expansion. Given its strong pro-poor outcomes and greater profitability, these findings favour a cassava-based biofuel industry for Tanzania.

Module 5: Household-level Food Security in Tanzania

Developing a domestic biofuel sector takes time. The establishment of a new industry typically requires a medium- to long-term perspective. However, food prices in Tanzania have been changing. Changes in food prices can have a significant impact on households' food security, especially for the most vulnerable segments of the population. In this context, it is important to realize that, while there may have been no significant bioenergy developments within the country to date, international biofuel mandates have been gaining steam. Changes in food prices are a result of international and domestic supply and demand shocks, which include additional biofuel demand. Thus, households, in the short term, can still suffer food security impacts due to domestic price movements caused by biofuel policies being implemented elsewhere. Furthermore, medium-term and long-term food prices may rise because of domestic biofuel policy decisions unless adequate supply response is stimulated through agriculture investment and research and development.

Cassava and maize are the main food commodities in Tanzania. Over recent years, Tanzania has fluctuated from being a slight net importer to net exporter of maize, while cassava is not a traded commodity. Maize and cassava prices have been steadily increasing in the country since 2000. Investigation of the maize and cassava price trends suggest that the maize and cassava markets are interconnected in the medium term, although less so in the short term. Between 2003 and 2008, maize and cassava prices increased by approximately 50 percent in real terms.

In the case of Tanzania, it was not possible to carry out a country representative household level analysis as the Tanzanian household budget dataset does not contain detailed agriculture income by crop. Nevertheless, in order to illustrate the steps of the analysis and the type of questions that can be addressed here, a partial dataset was used which was collected from the rural areas of the Ruvuma and Kilimanjaro regions. Although this dataset offers an example of what the analysis can accomplish it is not possible to draw country level conclusions, nevertheless it allows illustrating the diversity of impacts across household groups. In conclusion, it was not possible to assess whether price increases in maize and cassava would benefit the poor in Tanzania overall. A country level dataset would allow the analysis to determine this. There might still be some segments that lose and would potentially need to be assisted, in view of an overall country level welfare gain.

The BEFS analysis in Tanzania represents the start of a discussion on the extent to which biofuels is not only feasible but whether it can also enhance food security and reduce poverty levels by providing a boost to the agricultural sector. The analysis should not be seen as comprehensive or definitive. Rather it serves as a starting point for the kind of analysis needed to underpin the realization and implementation of a bioenergy sector that is consistent with Tanzania's policy goals on poverty reduction and food security. The tools developed under BEFS are to be seen as dynamic, whereby data can be updated, with crops and other components added to reflect recent policy changes or outlooks.

Given the agriculture status quo, the analysis finds that:

- **Cassava** has large production potential throughout Tanzania. The analysis shows that cassava-based ethanol schemes, linked to outgrowers, would be a viable option for biofuel development that would lead to economic growth and poverty reduction. What remains to be assessed is whether cassava production can be scaled up from an agronomic point of view, to ensure large-scale production is viable and diseases are controlled. This again underscores the need for investment in agriculture and agricultural research and development.

- **Sugar cane** potential under rainfed conditions is limited, irrigation could change this significantly. Nevertheless, ethanol from sugar cane is a competitive option in Tanzania but requires a large-scale industrial set up. While this type of biofuel supply chain could be good for economic growth it would not have a poverty reduction effect. However, increased investment in agriculture aimed at increasing yields from smallholders would allow production linked to outgrower schemes to be economically viable. This may have poverty reducing effects.

- Ethanol from **molasses** may prove to be too risky in the case of Tanzania, and if pursued, would need further investigation. The analysis undertaken so far shows that molasses is an unstable source of feedstock in the case of Tanzania. It is recommended that prior to pursuing the use of molasses for biofuel production, further investigation in competing uses for molasses is carried out in order to assess the most effective market.

- The land suitability assessment for **sweet sorghum** showed that there is high potential. Sweet sorghum presents a possible alternative to sugar cane because of its lower water requirements but this is a new crop that would need investigation. Tanzania might be interested in further analysing this crop in order to understand if this crop might be a relevant solution for some areas of the country. Sweet sorghum is a multi-use crop which may hedge against risk and volatility in food and energy markets.

- The analysis carried out for **palm oil** shows that there is little suitability across the country for this crop under rainfed conditions. The crop is currently imported. Biodiesel from palm oil is not economically viable.

- The land suitability assessment for **sunflower** has shown that there is high potential for this crop throughout the country even with low inputs and tillage agriculture, reflecting the status quo in Tanzania. In order to assess what impacts biodiesel development from sunflower could have it would be important to run further analyses.

- Some analysis on **jatropha** was carried out and presented. This has shown that it has potential to induce economic growth and target poverty reduction in a smallholder based system. Nevertheless, this crop presents a number of risks since it is still in quite an experimental stage and the results should be treated with caution. Although jatropha has been regarded as a *wonder crop* in Africa and other parts of the world, the reality is that more research is needed on the agronomy of the crop. Moreover, jatropha has never been planted at large scale so it is difficult to ascertain the degree to which this would be successful.

This analysis has shown that the dividends from investing in biofuels can have positive impacts on poverty reduction and growth. This result rests on the assumption that the necessary public investments needed to support biofuel development will be forthcoming so that profits from the sector are more equitably distributed for the benefit of poor rural populations. It is important that the Government of Tanzania selects a bioenergy pathway that is consistent with existing plans for energy, poverty reduction and food security to avoid misallocation of public funds. The results from this analysis suggest that small-scale cassava production can be an optimal bioenergy pathway in Tanzania. It is recommended that the BEFS analytical framework is used further to explore this option.

In conclusion, Tanzania has enormous potential to develop a bioenergy sector. Biofuel developments can be an important catalyst that regenerates the agricultural sector by bringing in new private, as well as public, investment. There is naturally profound concern that biofuels may compete with food production. High food prices in recent years have strengthened the resolve of the government to promote greater food self-sufficiency. However, food insecurity in Tanzania has been driven by low food crop yields which have been a problem for some time in Tanzania. Increased public spending to address low yields in the agricultural sector are vital to avoid any potential competition with biofuels materializing.

CHAPTER 1

INTRODUCTION

Irini Maltsoglou and Yasmeen Khwaja

Bioenergy developments are high on many countries' agendas today in an effort to improve energy access, energy security and in the context of concerted efforts towards lowering global greenhouse gas emissions. Over time, however, serious concerns on the environmental and social feasibility and sustainability of bioenergy have arisen, especially with first generation bioenergy. In this context FAO, with funding from the Government of Germany, set up the Bioenergy and Food Security (BEFS) project to assess how bioenergy developments could be implemented without hindering food security.

Although strong arguments exist for promoting biofuels - enhanced fuel energy security, climate change mitigation and agricultural rural development, the reality is more complex. Biofuel developments have local, national, regional and global impacts across interlinked social, environmental and economic domains. A key concern for many poor countries is the effect biofuel production will have on food security. The interface between bioenergy and food security is complex. Biofuel production may compete with food production for land and other agricultural resources. On the other hand, biofuel developments could play a pivotal role in promoting rural development through increased local employment and energy supply. Implementing bioenergy production can result in improvements or a worsening in the food security conditions depending on the bioenergy pathway chosen. The precise effects on food security will depend on many factors ranging from the land used for bioenergy production, type of feedstocks, agricultural management practices, the industrial set-up of the sector as well as developments in global agricultural and energy markets.

The majority of Tanzania's poor live in rural areas and continue to rely on conventional biomass for basic energy services. In common with many African countries, Tanzania's dependence on agriculture is likely to remain high for some time to come. But if agriculture is to provide the basis of future growth and poverty reduction, the sector requires urgent modernization in order to improve productivity and generate growth. In Tanzania, there is a real willingness to exploit bioenergy developments to improve energy security which in turn impacts on food security. However, bioenergy developments must be integrated into a wider process of agricultural modernization through better use of land, water, labour and other resources. Failure to do so may result in a bioenergy sector that bypasses the poor. There are strong theoretical arguments for promoting bioenergy but for Tanzania the real issue lies in managing the development of the sector in a manner that promotes more equitable growth.

There is already a sound understanding of this in Tanzania. The National Biofuels Task Force (NBTF) which is charged with the design of a biofuel policy is made up of representations of various ministries which should ensure that developments occur against the backdrop of ensuring food security. The NBTF is comprised of the various ministries including: Ministry of Planning, Economy and Empowerment, Ministry of Energy and Minerals, Ministry of Agriculture, Food Security and Cooperatives, Ministry of Labour, Employment and Youth Development, Ministry of Finance, and the Vice President's Office – Division of Environment.

It is against this context that the FAO developed the BEFS project to create a set of tools that permits an exploration of the interface between food and bioenergy in order to reveal significant policy directions. The BEFS assessment for Tanzania enables a comprehensive consideration of the conflicts and synergies in the food security-bioenergy nexus in order to contribute to a more informed policy process that in Tanzania will contribute to the formulation of a biofuels policy. The BEFS Analytical Framework generates information on how the development of the bioenergy industry can positively or negatively impact on food security and poverty. Through this analysis, policy-makers are able to consider alternative pathways of bioenergy development that are consistent with Tanzania's own poverty reduction strategy.

Importantly BEFS does not restrict itself to an analysis of the feasibility of the bioenergy sector. Rather, the Analytical Framework is more rounded with a clear recognition that the basis of this industry is rooted in the agricultural sector, which in Tanzania, has been performing weakly for some time. Naturally there are concerns that competition with a bioenergy sector will compromise the traditional role of agriculture to provide food. However, the development of a bioenergy sector at the cost of food security in Tanzania holds little ground. This is because food insecurity everywhere in Africa is driven by low yields. Improving food crop productivity would do much to allay any arguments that food was competing with fuel. Secondly, in Tanzania, land is currently being used for export crops such as coffee and tea and this has not raised the same concerns as for potentially using land for bioenergy. The BEFS tools help to untangle the many considerations involved in developing a new bioenergy sector. BEFS cannot provide all the answers but it can point a way forward by helping policy-makers to understand key relationships between bioenergy development and food security.

Currently there are three partner countries, namely **Peru**, **Tanzania** and **Thailand**. These three countries provide a comprehensive analysis of the interaction between bioenergy developments and food security at different stages of bioenergy developments and the countries' economic development. Furthermore, although the assessment presented here is limited to a selected number of crops, Tanzania will be able to look at the analyses undertaken within Peru and Thailand to see how BEFS can extend into other forms of bioenergy, other crops and other constraints such as, for example, water.

Finally, for other interested countries, the examination of the BEFS analysis provides a good example, at similar stages of development, on how to handle the development of a bioenergy sector whilst promoting food security or ensuring continued food security.

The BEFS analysis for Tanzania is structured as follows:

Chapter 2 introduces the bioenergy and food security nexus and provides the intuition that underpins the BEFS Analytical Framework. This section presents an overview of the five technical Modules that constitute the BEFS analysis approach. Chapter 3 sets the context against which the bioenergy sector will be developed in Tanzania. This section illustrates the macroeconomic performance of the country, the agriculture and energy sector, the food security situation and the respective policies. The bioenergy guidelines and the status of the bioenergy policy in Tanzania are presented. A real case scenario is presented to illustrate the gap between policy and the reality on the ground. Chapters 4 to 8 are the technical chapters of the analysis that contain the results of the five Modules that constitute the BEFS Analytical Framework. Chapter 9 concludes the analysis with showing how BEFS can assist policy-makers on the technical chapters of the analysis.

CHAPTER 2

AGRICULTURE, BIOENERGY AND FOOD SECURITY: USING BEFS TO GUIDE AGRICULTURAL CHANGE

Yasmeen Khwaja and Irini Maltsoglou

2. INTRODUCTION

Agriculture: the need for regeneration

A potent argument for bioenergy development lies in the ability of the sector to unlock agricultural potential by bringing in much needed investments to raise agricultural productivity for the benefits of food security and poverty reduction. By providing the tools that test this thesis, the BEFS project can support the policy machinery in its consideration of whether bioenergy should be pursued and if so how. The starting point for the BEFS analytical framework is the recognition that agriculture remains an important sector for the livelihoods of the most vulnerable and poorest populations. Bioenergy is just one instrument amongst an array of other possible measures that may regenerate agriculture. The project therefore should not be seen as an endorsement of bioenergy. Ex ante, it is not possible to either support or reject bioenergy in a given context. What the BEFS tools offer are an exploration into bioenergy potential for the public good. Thus BEFS extends beyond a feasibility study of the sector. Instead it offers an integrated approach to analysing bioenergy potential that combines the technical viability/feasibility of the sector with the social and economic objectives prevailing in the development agenda of Tanzania. Specifically, the project considers whether the agricultural sector firstly has the capability to support bioenergy developments and if so, can it do so for the benefit of the poor. The feasibility component of BEFS differs from the kind of feasibility analysis carried out by the private sector where principles of profit maximization dominate. By contrast, the BEFS feasibility component deliberately considers the extent to which the inclusion of smallholders in the industrial set-up can be cost competitive. This kind of analysis may provide strong support to governments in the dialogue with the private sector and can support to some extent the harmonization of private objectives with broader social objectives.

The food and energy nexus

The advantages for promoting biofuels in Tanzania are numerous. The diversification of domestic energy supply would lead to increased energy security as well as hedge against energy price fluctuations, overcome energy access shortages and the resulting negative effects on overall development. As Tanzania is a net importer of oil, domestically produced biofuels may remove some of the uncertainty associated with development budgets because of reductions in the oil import bill while increasing foreign exchange savings. The returns generated by the industry could have a positive impact on food security especially if smallholders in rural areas play a key role in supplying feedstocks. Moreover, the dependency on firewood for fuel needs would be reduced. As women have the primary responsibility for gathering firewood, new energy sources would release their time for other more remunerative activities with positive effects for their food security. The development of agro-industry can offer new rural employment opportunities. The combined effect would be to increase the standard of living of the rural poor and also improve the linkages between agriculture and other sectors in the economy. Understandably there are concerns about biofuels because of the competition it creates for the resources needed to produce food crops. Secondly, given the interests of largely private investors there is a risk that smallholders may be overlooked in biofuel developments in favour of large-scale production units. These are valid concerns. However, the issue is less about food-feedstock competition but rather one of how to regenerate a stagnant agricultural sector so that yields increase improving the incomes of poor farmers. Maintaining the status quo of Tanzanian agriculture is not an option. This will not improve livelihoods nor will it protect natural ecosystems. The integration of food crops with biofuel production could offer a solution for sustainable land use. Capital, technology transfer and capacity building are essential ingredients of an agricultural revolution. Biofuel investors can bring in these necessary requisites to Tanzanian agriculture to address both food and energy security.

While biofuel production and processing in Tanzania is in its infancy, in the future there is scope that with the right policies the many smallholders that characterize Tanzania's agricultural landscape may be more involved in biofuel crops. The challenge will be one of how to integrate them in the value chain. Clearly, leaving the industry entirely to market forces could isolate smallholders. Much depends on the route which bioenergy development takes. A poorly considered bioenergy development path could bypass smallholders and severely compromise the food security of the poor. Thus, for Tanzania the key consideration is how best to manage the process of biofuel development in order to maximize potential gains and minimize the costs. The BEFS tools are one instrument that can help guide the policy process in deciding the best pathway for biofuel development.

2.1 UNDERSTANDING THE EFFECTS OF BIOENERGY ON FOOD SECURITY

1. Bioenergy can impact on food security through changes in incomes and food prices. Income is an important element in the food security status of the poor. Income influences both the quantity and quality of food purchased by households. The exact effects of food prices on food security are more complex and require an understanding of whether households are net food producers and net food consumers. In general, higher food prices hurt net food consumers but farmers who are net food producers are likely to benefit from higher prices and increase their incomes, other things being equal. Some people will find they are better off while others are worse off.

2. Bioenergy production is likely to compete for inputs with food production. The main inputs are land, labour, water and fertilizer. Food crops that are used for bioenergy production compete directly with food supplies. In addition, competition for inputs

places an upward pressure on food prices, even if the feedstock is a non-food crop or is grown on previously unused land. The competition for inputs depends on agricultural efficiency which is a function of agricultural investment. The right agricultural management practices coupled with investment could allow for increased food production using fewer resources for a given amount of bioenergy. A system that allows for synergies between food and energy production could improve yields of food crops while addressing energy demand.

3. Bioenergy developments place particular pressures on smallholders and the rural poor. Increased demand for food crops generated by the biofuel sector could lead to increased food prices. The sheer speed of biofuel expansion may generate new pressures on land tenure arrangements, leading to alienation. Poor households may feel pressured to sell their lands or be forced to relocate in the rush to meet the increasing demands of the bioenergy sector for feedstocks. This has happened to some degree in Mukuranga. Contractual arrangements with large-scale biofuel producers could potentially disadvantage smallholders unless comprehensive legal structures exist to protect their rights. With the development of new second generation technologies, the first generation technologies developed in Tanzania may become non-competitive. Finally, much depends on the long-term price trajectory of fossil fuels. Should these come down permanently, the biofuel sector would not be able to compete.

2.2 BIOENERGY, THE ENVIRONMENT AND FOOD SECURITY

Bioenergy development, through its effects on the environment, affects food security indirectly in a number of ways. Environmental constraints can limit the biophysical and technical production of bioenergy and food. Water is a limiting factor in energy crop production. However, where bioenergy crops are grown on marginal land this may improve the quality of the land making previously unproductive agricultural land productive. This has implications for local incomes. Ex ante, it is difficult to say whether the effects of bioenergy on the environment have positive or negative effects. This can only be considered at very local levels. However, there are a number of issues relevant for food security.

1. Sensible use of agrochemicals and fertilizers can increase crop yields. However, widespread use of these inputs has adverse effects on land and water quality. Excessive applications of fertilizer reduce water quality. How agriculture is managed is critical for sustainable food production.

2. Food and bioenergy production face water constraints on their production. Understanding the water needs of crops and how this need can be beneficially altered under diverse agricultural management systems is an important step to maintain and even augment agricultural production be it for food or for bioenergy. Irrigation and new biotechnology can increase yields of crops for food and bioenergy production and should be considered as part of a larger agenda for agricultural improvement.

3. How land is used and for what purpose affects long-term soil productivity. Different crop production techniques alter the soil quality. Soil quality is also affected by livestock grazing which may have implications for the productivity of new lands brought under crops. Intensive agricultural practices deplete the soil of nutrients rapidly impacting on productivity and food availability. Consequently, lower productivity affects the availability of food resources. Some bioenergy crops, notably jatropha, can be grown on poor or marginal lands which can contribute to the improvement of soil quality extending the total area of land under crop production. However, it should be noted that the evidence for the long-term viability of jatropha is largely absent. Whilst in theory it appears to do well on marginal lands much more research is needed to consider the degree to which jatropha can be scaled up and whether productivity levels can be enhanced even on poor lands.

The food and energy nexus is complex especially for a poor country such as Tanzania. Although, global food and oil prices have started to come down, future high prices remain a concern for the country. A focus on agricultural development in Tanzania is critical in order to achieve long-term sustained food security. Can a bioenergy sector serve as a catalyst for wider agricultural growth and development? Bioenergy may yield higher returns on investment compared to conventional agriculture. This could lead to an overall increase in rural investment, making capital available for enhancing agricultural productivity levels of all production systems but particularly those of food. Feedstocks such as sugar cane, cassava and sunflower can be sold in both food and fuel markets and so hedge against the risk of failure in energy markets in particular. Environmental degradation and loss of biodiversity can be reduced depending on the bioenergy system developed.

The Government of Tanzania is enthusiastic about the potential benefits of bioenergy and is doing much to help facilitate new investment in the sector and to ensure that poor farmers are not bypassed (see Chapter 3). The BEFS analysis of Tanzania provides some important directions for policy while the BEFS tools can be used to incorporate new concerns in the analysis of bioenergy. These are discussed in the next sections.

2.3 THE BEFS APPROACH

In order to assist countries in the development of a food secure bioenergy industry, the BEFS project has developed an assessment approach to analyse the impacts of bioenergy developments on food security. The approach uses real country data to run the assessment.

BEFS mainly focuses on **food availability and access**, the strongest links between bioenergy production and food security. While there are clear concerns with respect to utilization and nutrition and price stability, the complexity of the analysis does not permit a full examination of these dimensions. However, as all four dimensions are interlinked, addressing food availability and access will ultimately affect nutrition and long-term food access.

Within the BEFS approach there are two key elements to the BEFS assessment, namely:

a. *The feasibility of producing bioenergy*
This element of BEFS allows the country to identify:

- the areas potentially most suitable for bioenergy production;
- which production chains are technically viable and most competitive;
- how to integrate smallholders competitively into bioenergy production.

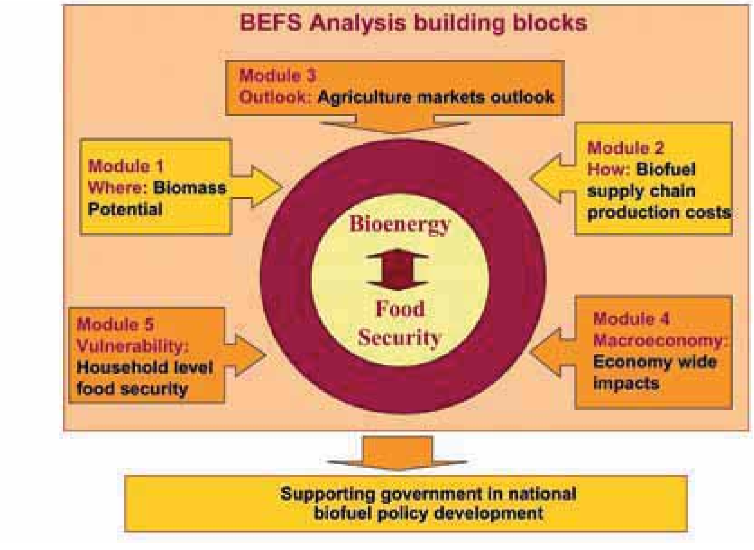
b. *The economy wide and food security viability of bioenergy development*
This element of BEFS allows the country to assess:

- whether bioenergy developments in the country can lead to economic growth and poverty reduction;
- which trade-offs may be in place;
- what the agriculture markets outlook is and how bioenergy might impact this;
- household level food security and vulnerability;
- food-feedstock competition areas.

In order to achieve this, BEFS uses an Analytical Framework which consists of five building blocks, namely *Module 1: Biomass Potential*, *Module 2: Biofuel Supply Chain Production Costs*, *Module 3: Agriculture Markets Outlook*, *Module 4: Economy-wide Effects*, *Module 5: Household-level Food Security.*

Figure 2.1 illustrates the questions answered by each module.

FIGURE 2.1
The BEFS Approach.



These five technical components of BEFS form ***a technical basis that can feed in and support development of bioenergy policies and regulations in Tanzania*** and places policy-makers in the position to make informed decisions. In particular, the BEFS tools are designed to help answer the following key question for guiding bioenergy policies:

2.3.1 THE FIVE MODULES OF THE BEFS APPROACH AND ITS QUESTIONS

Module 1: Biomass Potential

The analysis in Module 1 allows stakeholders to understand better the extent and location of areas suitable for bioenergy crop production under different agricultural production systems and level of inputs. The crops analysed in this module are cassava, sunflower, sugar cane, sweet sorghum and palm oil. Once the crop suitability has been determined, productivity and long-term sustainability of bioenergy developments can be assessed. Overall this will allow stakeholders to structure their land use planning strategy including for bioenergy developments, while identifying key food production areas.

This Module will help:

- identify the areas suitable and available for growing the relevant bioenergy crops;
- establish production and yields of different biofuel crops;
- illustrate the advantages and disadvantages of different agricultural production systems;
- establish in which areas there might be a conflict between food and bioenergy production.

Module 2: Biofuel Supply Chain Production Costs

Module 2 assesses bioenergy productions costs. Five feedstocks have been analysed in this Module, namely molasses, cassava, palm oil and jatropha. Each feedstock is assessed under different processing systems given the following conditions:

- stand alone versus integrated mill and refinery;
- plant scale: large, medium or small;
- feedstock origin: (a) commercial, (b) outgrowers (c) a mix of these two.

Based on the relevant mix of the above points, Module 2 evaluates the technical and economic viability of biofuel production given the local knowledge base and manufacturing capacity. This Module will allow stakeholders to determine which biomass supply chain is technically and economically feasible in Tanzania and to what degree outgrowers can be included; an important component within poverty reduction strategies.

This Module will help assess:

- costs of production of the biofuel at the factory gate and distribution to domestic and international markets;
- accessibility of technology and availability of infrastructure and the required human skills;

- opportunities for rural development through production systems inclusive of outgrower and combined plantations-outgrower schemes;
- processing of waste by-products into valuable co-products focusing on use in local settings.

Module 3: Agriculture Markets Outlook

Module 3 focuses on domestic agriculture markets and can assist Tanzania in understanding the impact of international and domestic biofuel policies on its domestic markets. The Module is based on an OECD-FAO outlook tool that assesses the impact of policies for a ten-year outlook period. The analysis presented investigates the impacts of domestic and international bioenergy developments on domestic food production trends. This Module gives stakeholders an understanding of how international and domestic policies on biofuels may impact the domestic industry with implications for food security.

This Module will help assess:

- what is the domestic market outlook;
- what is the impact of bioenergy development on the domestic agriculture market;
- what is the influence of international policies.

Module 4: Economy-wide Effects

Module 4 builds on the results of production costs derived in Module 2 and links them to the national economy of Tanzania. From a policy perspective, it is important to assess whether the implementation of a new sector, such as bioenergy, can be beneficial for economic growth and poverty reduction. In order to strategically target poverty reduction, linking the production costs results to the economy-wide effects can help policy-makers consider the necessary interventions needed to include small-scale outgrowers in the development of the sector and the preferred combination of large-scale estate and the small-scale outgrowers scheme. This Module utilizes a Computable General Equilibrium model of Tanzania's economy. The structure of the model includes a detailed breakdown of the agricultural sector and of the other sectors of the economy. The bioenergy sector competes for resources (land, labour, inputs and capital) and is initially very small. The sector consequently grows due to investments in the sector. Biofuel scenarios differ according to their production technologies and strategies, namely feedstock, scale of feedstock production and intensive versus extensive strategies.

This Module will help assess:

- the economy-wide trade-offs bioenergy poses;
- which bioenergy production chain is most growth enhancing;
- which bioenergy production chain is most poverty reducing;
- which sector loses and how the allocation of resources change.

Module 5: Household-level Food Security

Developing a domestic biofuel sector takes time. The establishment of a new industry typically requires a medium- to long-term perspective. However, households, in the short term can still suffer food security impacts because of international price movements, some of which may be caused by biofuel policies being implemented elsewhere. It is important to realize that, while there may have been no significant bioenergy developments within the country to date, international biofuel mandates have been gaining steam. Changes in food prices derive from international and domestic supply and demand shocks which include additional biofuel demand. In the short term, household food security is affected by the increase in food prices. From a policy perspective, it is necessary to understand how the price changes can impact the *country as a whole* and which price changes the poorer segments of the population are most vulnerable to. We initially assess which price changes the country is most vulnerable to by investigating the country's macroeconomic net trade position by crop. Secondly, we look at actual price movement in key food crops over relevant time periods.

This Module will help assess:

- the most important food crops;
- recent price trends in key food crops;
- which price changes the country as a whole is most vulnerable to;
- which are the most vulnerable segments of the population.

2.4 BEFS IN TANZANIA: THE POLICY ISSUES

Before deciding on how to realize a bioenergy sector it is important to understand the full range of net impacts of bioenergy pathways on food security issues. The BEFS tools allow for a comprehensive analysis of how different bioenergy pathways can affect poverty and food security. In doing so BEFS can help inform and shape the direction of policy so that it promotes a sector that contributes to inclusive growth and development.

There are a number of conditions that influence bioenergy development at national level. These are:

- the agro-ecological and agro-edaphic conditions and availability of land resources;
- the suitability, productivity and production potential of various biofuels feedstock;
- the technical capabilities needed for the biofuels industry.

These factors determine the *where* and the *how* of setting up an industry. However, any consideration of these factors needs to be accompanied by an analysis of how bioenergy impacts on the agricultural sector, the wider economy and the household. Bioenergy developments have impacts on national food systems which could be positive or negative but require rigorous analysis to determine the precise nature of these effects. Suppose Tanzania chooses a particular pathway for bioenergy development based only on the biophysical and technical feasibility factors because this is the most cost-effective choice.

That pathway may have wider impacts on food security through adverse changes in prices, income and employment. Thus, knowing what the likely impacts *a priori* are of certain choices may alter the *where* and the *how* of bioenergy development. Policy instruments and institutional developments can be constructed in order to adapt to changes or shocks to the food system so that Tanzania's goals on food security and poverty reduction are not compromised.

2.5 THE BIOENERGY AND FOOD SECURITY CROP LIST IN TANZANIA

The analysis within the assessment addresses a number of bioenergy and food security crops. These crops will be the common thread throughout the analysis, although each Module may focus on particular crops because of the nature of the analysis as well as issues of data availability.

The list of bioenergy crops was put forward by the government and includes **cassava, sugar cane, palm oil, jatropha, sweet sorghum** and **sunflower**.

The key **food security crops** were selected on a per capita calorie consumption basis, (Table 2.1).

TABLE 2.1
Calorie contribution by commodity for Tanzania.

Ranking	Commodity	Calorie share
1	Maize	33.4
2	Cassava	15.2
3	Rice (Milled Equivalent)	7.9
4	Wheat	4.0
5	Sorghum	4.0
6	Sweet Potatoes	3.3
7	Sugar (Raw Equivalent)	3.3
8	Palm Oil	3.0
9	Beans	2.9
10	Beverages, Fermented	2.7
11	Milk - Excluding Butter	2.2
12	Bovine Meat	1.8
13	Pulses, Other	1.7
14	Plantains	1.5
15	Millet	1.4
Subtotal share for selected items		88.5
Total Calories per capita		1 959

Source: FAOSTAT

In order to identify the most important food security crops, crops were ranked based on their calorie contribution share. What this means is that the amount of calorie intake by crop for the country as a whole was determined. Based on the calorie contribution ranking, the crops that provide the highest share of calories in Tanzania are, in order of magnitude, maize, cassava, rice, wheat, sorghum, sweet potatoes, sugar, palm oil, beans and plantains. For example, as shown in the Table, maize contributes 33.4 percent of calories to the country as a whole, 15.2 percent comes from cassava, 7.9 percent from rice, 4.0 percent from wheat and 4.0 percent from sorghum. Other crops all contribute less that 4 percent to calorie intake, as for example sweet potatoes, sugar, palm oil and beans. It can be noted that maize and cassava together provide households close to half of their calorie intake.

For completeness, Table 1 also includes non-crop food stuffs as, for example, dairy products and meat, nevertheless the table shows that access to livestock products remains limited.

An overview of the crops by Module is provided in Table 2.2

TABLE 2.2
Crop list by Module of the BEFS Analytical Framework

Module 1	Module 2	Module 3	Module 4	Module 5
Sugar cane, cassava, sweet sorghum (2 types), palm oil (2 types), sunflower	Sugar cane, cassava, palm oil, jatropha and molasses	Coarse grains (maize, wheat, sorghum), rice, roots and tubers (cassava, sweet potatoes), vegetable oils and jatropha	Cassava, sugar cane, molasses and jatropha	Mainly maize cassava and rice

CHAPTER 3

BIOENERGY IN TANZANIA: THE COUNTRY CONTEXT

Jacqueline Cleaver, Rommert Schram and Godwil Wanga

3. TANZANIA[1]

Tanzania, situated on the Eastern Coast of Africa, is one of the continent's most politically stable countries. The country is categorized as a least developed and low-income food-deficit country. Tanzania is in the bottom 10 percent of the world's economies in terms of per capita income. The economy depends heavily on agriculture, which accounts for approximately 25 percent of GDP, provides 85 percent of exports, and employs 80 percent of the work force.

This chapter considers the state of Tanzanian economy against which bioenergy developments have to be considered. The chapter begins by presenting an overview of the economic performance of the country. The following sections consider the agriculture, food security and energy situation in Tanzania. Section 3.5 presents a summary of biofuel investments in Tanzania to date. Section 3.6 offers some concluding remarks.

3.1 THE ECONOMIC CONTEXT OF TANZANIA

Following an economic crisis in the 1970s, Tanzania initiated a series of home-grown economic reforms in 1981. During the 1980s, the Government of Tanzania approached the International Monetary Fund (IMF) and the World Bank for advice and funding. This resulted in further economic reforms implemented through a Structural Adjustment Programme between 1982 and 1986. The Tanzanian schilling was devalued to boost exports, prices were partially liberalized and government expenditure reduced. In 1985, an IMF-supported Economic Recovery Programme was introduced. This led to further liberalization of the economy and monetary tightening. During the 1990s further institutional reforms were undertaken, in particular to the civil service and the privatization of state-owned companies. The 1990s also witnessed political reforms. Tanzania's first multi-party elections were held in 1995. In 2000, Tanzania's commitment to economic reform ensured its eligibility for debt relief under the World Bank's Heavily Indebted Poor Countries (HIPC) initiative, and substantial donor inflows. By 2004, ODA inflow was 15 percent of GDP (UNICEF, 2006).

1 All data presented in these two following sections is extracted from the World Development Indicators 2009 of the World Bank, the Economic Survey of Tanzania 2007 and the CIA World Factbook of 2009.

Tanzania remains a poor country with a per capita GDP of 362 USD[2] in 2008, consistently below the sub-Saharan regional average since 2000, and 58 percent of its population living below 1 USD a day, compared to the regional average of 42 percent. Tanzania's population reached a total of 42.5 million in 2008 and is growing at a rate of 2.9 percent a year. The macroeconomic reforms of the 1980s and 1990s improved economic growth in Tanzania. Between 1987 and 1992, real GDP growth averaged 3.5 percent, more than double than in the previous decade. During the 1990s, growth continued at a very modest 3.7 percent. Since the late 1990s, real GDP growth has continued to climb, and in 2008 reached approximately 7.1 percent.

Inflation, which had averaged 23 percent over the 1990s, fell to 5.2 percent in the period between 2000 and 2007 and subsequently rose to 10.3 percent in 2008. While the growth rate looks promising, the reality is that it is not adequate to sustain the high population growth. The consumer price index is heavily weighted by food prices at around 70 percent, but in late 2004 this weight was reduced to 56 percent. Food prices can be highly volatile due to drought and even the use of the Strategic Grain Reserve only helps dampen but does not usually eliminate this effect.

In 2007 the agriculture sector accounted for 24.6 percent of Tanzania's total GDP, second to the services sector which contributed 47.3 percent, with industry and construction contributing 20.9 percent and fishing with the smallest contribution of 1.6 percent.

Agriculture has performed poorly over the last few decades but still employs most of the population in Tanzania. Tanzania's industrial sector is one of the smallest in Africa accounting for about 22.7 percent of GDP. Most of the industry is concentrated in Dar es Salaam and over 90 percent of industrial activities are dominated by small- and medium-sized enterprises (SMEs). The manufacturing sector primarily focuses on the domestic market with little exports of manufactured goods.

The increase in Tanzania's macroeconomic growth rate has disproportionately benefited its population and increased overall inequality. With a Gini co-efficient of .35, an income share of 42.3 percent held by the highest 20 percent of the population and only 7.3 percent of income held by the lowest 20 percent in 2000, Tanzania exhibits a lack of equality in income distribution.

Further, in spite of promising growth, many households remain very vulnerable to repeated climatic and economic shocks with implications for their food insecurity. According to the 2004/05 Tanzania Demographic and Health Survey, 38 percent of children under five in the country are chronically malnourished, that is, they have stunted height for their age, and over 30 percent of all regions in the country have stunting rates of over 50 percent.

2 Extracted from the WDI. Values are in constant 2000 USD.

On the energy front[3], Tanzania struggles to meet its own energy needs and access to modern energy is still very limited. Over the last ten years, domestic energy demand has grown rapidly due to both the increase in economic activity and population growth. Access to energy is extremely limited and the energy balance is dominated by biomass-based fuels particularly fuelwood (charcoal and firewood), which are the main source of energy to both urban and rural areas.

The estimated total energy consumption is more than 22 million tonnes of oil equivalent (TOE) or 0.7 TOE per capita. To date, a large share of current energy use is still met by traditional biomass, namely 90 percent of total use. The remaining share of energy use comes from fossil fuels, 6.6 percent, gas, 1.5 percent, hydro, 0.6 percent, and coal and peat, 0.2 percent. All of the fossil fuels are imported in Tanzania and 75 percent of these are used by the transport sector.

Tanzania continues to rely on imported petroleum products. Electricity generation is mainly hydro-based, while thermal plants provide electricity for peak loads. Development of natural gas for electricity is ongoing. The dissemination of renewable energy technologies has been limited to the promotion of improved stoves, improved charcoal production techniques, solar, biogas and windmills and to a lesser extent photovoltaics. Initiatives to increase utilization of coal for electricity are being explored.

3.2 POVERTY IN TANZANIA

Income Poverty in Tanzania

Tanzania has been called: "Africa's sleeping giant" because of its steadily rising economic growth. However, the reality has been that the percentage of households living below the poverty line hardly changed between 1991 and 2001, falling by only 3 percent. Today, more than half of the population lives in absolute poverty; 57.8 percent of Tanzanian people survive on less than USD1 a day and 89.9 percent live on less than USD2 a day (GoT, 2005).

Between 1990 and 2007 the Human Development Index (HDI) rose by 1.15 percent annually from 0.436 to 0.530 today. HDI scores in all regions have increased progressively over the years although all have experienced periods of slower growth or even reversals. The HDI for Tanzania is 0.530, which gives the country a rank of 151 out of 182 countries with data (UNDP, 2006).

Eighty-one percent of those living below the poverty line are in households where the main activity of the head of the household is agriculture (GoT, 2005). Many of those living below the national poverty line earn their income through the sale of agricultural products (see Table 3.1).

3 Extracted from the GoT, Tanzania Energy Policy (2000) and IEA (2006).

Table 3.1
Distribution of poverty by main source of cash income in Tanzania

Cash income source	Percent of the poor (%)
Sales of food crops	49.6
Sales of livestock	7.2
Sales of livestock products	1.4
Sales of cash crops	20.5
Business income	8.4
Wages and salaries in cash	3.6
Other casual cash earnings	4.9
Cash remittances	2.3
Fishing	1.5
Other	3.3

Source: NBS Social and demographic statistics (NBS, 2007)

Poverty remains widespread and more than 40 percent of the population lives in chronic food-deficit regions where irregular rainfall causes repeated food shortages. Approximately 1.4 million people are living with HIV/AIDS. The disease has worsened the poverty level, reduced agricultural productivity and the availability of farm labour in several districts. The epidemic affects the capacity of poor households to sustain their livelihoods and remain food secure.

Poverty levels vary across the country but are higher among rural families that rely exclusively on livestock and food crop production and live in the arid and semi-arid regions (IFAD, 2003). Rural poverty levels far exceed the national averages and are much higher than in urban areas. It is estimated that 87 percent of the rural population lives under the poverty line and about 19 percent of rural mainland Tanzanians and 13 percent of Zanzibaris live with less than the minimum food requirement of 2 200 kcal per day (ADF, 2007). Nutritionally, the populations living in the central and northern highlands are found to be the most vulnerable, while the coastal and southern highlands areas register the most acute poverty levels, although by international standards and from a policy point of view all regions are very poor (IFAD, 2003).

3.3 THE AGRICULTURE SECTOR AND THE AGRICULTURE SECTOR POLICY[4]

Despite being the slowest growing sector of Tanzania's economy, the agriculture sector accounted for 24.6 percent of Tanzania's total GDP in 2007, second to the services sector which contributed 47.3 percent, followed by industry and construction which contributed 20.9 percent and fishing with the smallest contribution of 1.6 percent. While the agriculture sector grew at 4 percent per annum in 2007, it represents the slowest growing sector of

4 The sections of Agriculture are adapted from GoT 2006 and GoT 2007 unless stated differently.

Tanzania's economy below that of fishing which had a 4.5 percent per annum growth rate, services which had a growth rate of 8.1 percent, and industry and construction which had the fastest growth at 9.5 percent (Economic Survey, 2007).

According to Tanzania's Economic Survey 2007, 76.5 percent of Tanzania's population was employed in the agriculture sector during 2005/2006. With over 76 percent of the Tanzanian population relying on agriculture for their livelihood and the agriculture sector's 24.6 percent contribution to total GDP, the fact remains that despite decreasing annual growth rates, agriculture is an integral part of the Tanzanian economy. While most of Tanzania's population relies on agriculture for their livelihood, agricultural incomes remain low and are growing at a slow rate which partially explains the small effect that relatively large and consistent macroeconomic growth have had on poverty reduction and food security in Tanzania (Pauw and Thurlow, forthcoming). Stimulating growth in the agriculture sector, through means such as bioenergy development, would therefore have an impact on a large portion of the population, and is consequently essential in the government's goals of reducing poverty and increasing food security.

Of total land available, 9.2 million ha are cultivated annually (excluding permanent crops), 85 percent of which is under food crop cultivation. Food crop production dominates the agriculture economy in Tanzania. The major staples include maize, sorghum millet, rice, wheat, pulses (mainly beans), cassava, potatoes, bananas and plantains. The main export crops are coffee, cotton, cashew nut, tobacco, sisal, pyrethrum, tea, cloves, horticultural crops, oil seeds, spices and flowers. According to the ministry of agriculture, there are ten farming systems: (1) banana/coffee/horticultural; (2) maize/legumes; (3) cashew/coconut/cassava; (4) rice/sugar cane; (5) sorghum/bulrush millet/livestock; (6) tea/maize/pyrethrum; (7) cotton/maize; (8) horticultural based; (9) wet-rice and irrigated; (10) pastoralist and agropastoralist.

Agriculture is mostly characterized by rainfed crop production, thus output levels are very susceptible to rainfall variation and drought. Currently only about 150 thousand hectares are under irrigation, accounting for approximately 1.6 percent of cultivated land (GoT, 2007). Estimated irrigation potential is about 29.4 million hectares with varying potential levels. Attaining sustainable irrigation development is essential in order to assure basic food security, improve the national standards of living and to contribute to the overall economic growth of the country (Got, 2007). The National Irrigation Development Plan and Agriculture Policy are in place to address irrigation issues and the government is investigating the possibility of using irrigation water surcharges for revenues generation.

Only 22 percent of agriculture in Tanzania is commercial. The agriculture sector is dominated by subsistence farming which utilizes approximately 85 percent of the arable land. These small-scale farmers operate average plot sizes of between 0.2 and 2.0 ha and traditional agro-pastoralists keep an average of 50 heads of cattle.

Smallholder production is constrained by low levels of education with 31 percent of heads of smallholder households having received no formal education. Hand hoes are used to cultivate about 70 percent of Tanzania's crop area, ox ploughs are used for 20 percent, and tractors for 10 percent. Hand hoe cultivation is seen as both a cause and symptom of rural poverty (Got, 2007).

Modern inputs such as fertilizer, pesticides and improved seeds are scarcely used, and are in fact either not available or else very costly, reflecting poor infrastructure and high marketing costs. Lack of credit to purchase inputs is also a significant constraint. Most smallholders find that government regulatory boards, trade unions, farmers' associations and cooperatives are a hindrance to market access. Extension advice reaches few households – only 35 percent of 4.8 million smallholder households reported receiving extension advice in 2002/03. In addition, in 2005 less than 6 percent of Tanzanians had access to credit and less than 1 percent of those in the agricultural sector had access.

Agricultural performance

Growth of agricultural production averaged 3.9 percent between 1961 and 1970 and then dropped off in subsequent decades to 2.9 percent (1971-80), 2.7 percent (1981-90) and 1.4 percent in 1991-2000. In 2001-04 growth reached 2.3 percent. Food production followed a very similar pattern of growth. On a per capita basis, agricultural production either stagnated or fell in the years between 1961 and 2000. In 2001-04 per capita agricultural growth averaged 0.3 percent. Growth in per capita food production was similarly weak. Within the agricultural sector, fisheries registered the highest growth, followed by the crop subsector. However, policies relating to agricultural growth have not yet been sufficiently developed in order to realize the agriculture sector's full potential or to create the institutional frameworks needed to lead the process forward.

The agricultural sector grew at a rate of 4 percent in 2007, with subsector growth of 4.5 percent for crops, 2.4 percent for livestock, and 2.9 percent for hunting and forestry. The fishing sector grew at a rate of 4.5 percent in 2007 (Economic Survey, 2007). The production of both food and cash crops fluctuates yearly as do their respective yields. However, a general trend of stagnation in cereal yields is evident with yields hovering just above 1 100 kg per ha from 2001 to 2007, which is down from a peak of 1 506.2 kg per ha in 1990.

With regard to the key food crops, production growth for maize has been fairly steady at 4.5 percent and 6 percent respectively in the 1980s and 1990s and 5.7 percent in the period 2001-05. This translates to about 86 kg/capita between 1990 and 2004. Maize yields rose only slowly from 1.2 tons/hectare in 1975 to 1.7 tons/ha in 2006. Production of cassava stagnated in the 1990s and the 2001-05 period. Per capita production fell from a high of 380 kg/capita in 1983 to 163 kg/capita in 2004. A downward trend in per capita production is also evident for sorghum after 1979 (22 kg/capita in 2004), rice after 1990

(16kg/capita in 2004) and plantain after 1977 (16kg/capita in 2004). These developments are reflected in an across the board gradual decline in per capita food production since about 1980.

Key cash crops had a more mixed performance. Tea production grew fairly steadily from 4.5 thousand tons in 1961 to just over 30 thousand tons in 2004. Sisal production fell from a peak of 234 thousand tons in 1964 to 30 thousand tons in 1986 and has since fallen gradually to about 24 thousand tons. Only cotton and cashews recorded significant jumps in production. Cashew nut production fell from a peak of 145 thousand tons in 1973 to 17 thousand tons in 1990 and subsequently recovered to 121 thousand tons in 2000 after which production again fell off to average 82 thousand tons between 2001 and 2005. Cotton production gradually declined from 79 thousand tons in 1966 to 35 thousand tons in 1985. Thereafter production fluctuated between 40 and 80 thousand tons and in 2004 jumped to 118 thousand tons and 126 thousand tons in 2005. (FAO, 2009)

Food imports, in particular wheat, rice and palm oil, increased after 1992. Maize imports averaged 82 thousand tons between 1981 and 2004 but with considerable fluctuation. Wheat imports started rising in the second half of the 1990s and averaged 107 thousand tons in the 1990s, after annual imports in the 1980s of 25 thousand on average. In 2001-04 Tanzania imported 470 thousand tons annually with a steep upward trend. In 2004 imports stood at 617 thousand tons. Also imports of palm oil have increased markedly in the 1990s and again in the 2001-2004 period. (FAO, 2009)

Explaining poor agricultural performance

This general trend in the stagnation of agricultural yields is indicative of Tanzania's, as well as most of the rest of Africa's, pervasive problem of decreasing agricultural productivity. A number of factors contribute to and affect agricultural production and productivity.

1. **Water:** Access to water as well as the ability to effectively use water resources is an increasingly important issue in agricultural production. Water limits agricultural development. Without irrigation, interventions used to increase food production may not realize their full potential. Efforts are being made to increase irrigation schemes to supplement the rainfed crop production. Irrigated land as a percent of cropland has barely increased for the past 25 years with 1.3 percent of croplands irrigated in 1980 and 1.8 percent in 2005 (WDI, 2009).

2. **Agronomic management:** Tillage-based agriculture which causes considerable damage to the soil and affects future yields is prevalent in Tanzania. Conservation agriculture must become normal practice in Tanzanian agriculture in order to create a sustainable agricultural sector. The application of poorer quality inputs has also impeded productivity. Although for smallholders, poor access to credit or microfinance has been

the determining factor in this.

3. **Agricultural investment:** Decreasing government expenditure on agriculture has been a significant factor explaining poor yields. The sector relies heavily on public investment. The significant decline in world food prices from the 1970s until about 2000 meant that there was little incentive to improve yields. Cheap food imports allowed food needs to be met. By 2008 the picture had changed dramatically and Tanzania, faced with a rising food import bill, understood alongside many food importing countries the need to improve national food yields.

4. **Availability of credit:** Agriculture in Tanzania suffers from lack of credit availability. Where loans are available the interest tends to be very high and beyond the reach of poor farmers.

5. **Infrastructure:** Tanzania has an inadequate road network. This has been a major problem in getting crops to markets. Moreover, irrigation infrastructure remains weak and agricultural productivity is constrained by the reliance on rainfall.

6. **Market access:** Lack of market access both for buyers of agricultural products as well as sellers is a major constraint for agricultural development in Tanzania. This access issue is affected by lack of infrastructure as well as lack of markets.

7. **Plant disease:** Inadequate investment in agricultural research and development has limited progress on controlling crop disease and resistance to pests. For example, cassava, one of the main food crops in Tanzania, suffers huge crop losses because of Cassava Mosaic Disease (CMD) and Cassava Brown Streak Disease (CBSD). These are viral diseases that stunt the growth of cassava crops and rot the roots, respectively. Investment is needed to help smallholders understand the epidemiology of plant disease and how to control it.

3.3.1 AGRICULTURAL POLICY

The Agricultural Sector Development Strategy (ASDS), enacted in 2001, is a strategy for "coordination of participatory planning and implementation and monitoring and evaluation of the agricultural development processes in Tanzania". The objective of the ASDS is to make sure that the agriculture sector grows *at least 5 percent per year*, mostly through the transformation of subsistence agriculture to commercial agriculture. The Agricultural Sector Development Programme (ASDP) is an "operational framework" enacted in 2006 whose main purpose is to implement the ASDS through funding programmes. In support of agricultural policy, the National Strategy for Growth and Reduction of Poverty (NSGRP) places agriculture at the heart of efforts to reduce poverty.

The ASDS sets out the aims of the government for agriculture. The aims suggest a very comprehensive strategy to overhaul the sector in order to improve efficiency. The key aims are listed below:

- To ensure a sustained agricultural growth rate of 5 percent per annum primarily through transformation of subsistence farming into commercial agriculture.
- To create an enabling environment to improve agricultural productivity and competitiveness and to facilitate improvements in farm-based incomes and thus contribute to reducing rural poverty and to improve household food security.
- To strengthen public-private-partnership.
- To increase contract farming (vertical integration).
- To improve delivery of supportive services.
- To promote favourable environmentally sustainable use of new land under production by either medium- or large-scale private investors.

The ASDP sets out the operational aspects of the ASDS. That is, it identifies the mechanisms that will encourage improved productivity in agriculture (see the main elements of the ASDP presented below).

- The use of public investment to achieve faster growth in agriculture to raise incomes and reduce poverty directly by targeting growth bottlenecks and indirectly by improving agricultural business environment and stimulating and facilitating private investment.
- Increase access to rural microfinancial services for subsistence farmers, particularly targeting youth and women.
- Improve transport systems, thus lowering transport costs, and improve marketing to ensure higher profit margins for producers.
- Invest in infrastructure and widen access to markets within the country, region and internationally.

The design of the ASDS and the ASDP illustrate a real commitment to tackle the constraints that have hindered productivity in agriculture over the last 30 years. The policy is an ambitious one but one that recognizes that long-term food security needs to be enhanced by better national food production.

3.4 FOOD SECURITY POLICY

The National Strategy for Growth and Reduction of Poverty (NSGRP) 2005 or Mkukuta as it is known in its Swahili acronym builds on the Poverty Reduction Strategy Paper (PRSP) of 2000. The Mkukuta represents a new, more comprehensive approach to poverty reduction. Although an extension of the PRSP, the Mkukuta puts greater focus on issues such as environmental sustainability that contribute to both poverty reduction and growth. The NSGRP provisions regarding *food security* are within Cluster I, Growth and Reduction of Income Poverty. The emphasis is on improving food *availability* and *accessibility*.

The emphasis of Cluster I is to improve food security through increased per capita production of food crops, to ensure adequate income at the household level and to provide in times of shocks enough reserves to minimize vulnerability. The Strategic Grain Reserve (SGR) is intended to cater for shocks that lead to food insecurity. Operational targets for this goal are:

- increase food crops production from 9 million tons in 2003/04 to 12 million tons in 2010;
- maintain Strategic Grain Reserve of at least four months of national food requirement.

Under the NSGRP, the following strategies will be implemented in order to ensure availability and accessibility of food in both urban and rural areas:

- improving rural roads for access to health care facilities and markets;
- improving access to inputs by subsistence farmers through targeted inputs-subsidy to selected food crops and increasing accessibility to microfinance credit;
- improving stock management and monitoring of food situation;
- reviewing the maize supply chain, management and monitoring of emergency food supplies, including further clarification of regulation and means of enhancing trade;
- encouraging production of crops with high returns; increase access to mechanization and use of appropriate technologies, including rural energy services, that reduce drudgery.

The food security situation in Tanzania is still a critical balance between production and needs. Food production in the country has often failed to meet demand relying on imports and food aid to meet its production shortfalls. Tanzania has enormous agricultural potential given the vast areas of fertile arable land, good climatic conditions, and water resources. Importantly, the NSGRP as well as the ASDS have both recognized the central role of improving agricultural productivity and management as central to the promotion of long-term food security.

3.5 ENERGY POLICY

The National Energy Policy in Tanzania was adopted in 2003 and replaced the previous energy policy from 1992. The policy from 2003 takes into account the structural changes that occurred over the last decade in terms of changes in the economy and political transformations at national and international levels (Arvindson and Nordström, 2006). The national policy objective for the development of the energy sector is: *"...to provide input in the development process of the country by establishing a reliable and efficient energy production, procurement, transportation, distribution and end-use system in an environmentally sound manner and with due regard to gender issues"*.

The main elements of the Energy Policy and strategy are to:

- develop domestic energy resources which are shown to be least cost options;
- promote economic energy pricing;

- improve energy reliability and security and enhance energy efficiency;
- encourage commercialization and private sector participation;
- reduce forest depletion;
- develop human resources.

The Ministry of Energy and Minerals (MEM) drives all energy policy including biofuels.

3.5.1 THE NATIONAL BIOFUEL POLICY AND THE BIOFUEL GUIDELINES IN TANZANIA

Tanzania is in the process of developing a comprehensive biofuels policy. Initially Tanzania had established a National Biofuel Taskforce. The National Biofuel Taskforce had the mandate of developing the National Biofuel Policy. Originally, the National Biofuel Taskforce was formed by a range of representatives, including:

- The Ministry of Planning, Economy and Empowerment (chair of taskforce);
- The Ministry of Energy and Minerals (secretariat of taskforce);
- The Ministry of Agriculture, Food Security and Cooperatives;
- The Ministry of Industry, Marketing and Trade;
- Farmer organizations;
- Representatives from the private sector.

As the development of a biofuel policy would take at least two years and as there was an urgent need to have clear guidance for the developing biofuel industry, the taskforce decided that it would first develop biofuel guidelines. The institutional difference between the Biofuel Guidelines and the Biofuel Policy is that the guidelines are approved by the cabinet and that the policy is to be approved by the parliament. The Biofuel Guidelines are interim guidelines that will be used until the Biofuel Policy is fully developed.

The Government of Tanzania presented the first draft guidelines in a workshop in September 2008. Stakeholders were invited to provide comments to the guidelines. The BEFS project made several contributions to the drafts. In March 2009 the final draft guidelines were submitted to the cabinet for approval. The guidelines were approved in December 2009.

The guidelines address amongst others the following key issues:

- institutional framework;
- application procedures for investors;
- land acquisition and use;
- contract farming;
- sustainability of biofuel production.

The guidelines focus on the institutional framework, the application procedures and key considerations for investors, including land acquisition, contract farming and sustainability.

As the current institutional framework was found not to be conducive for the development of the biofuels industry in Tanzania, the guidelines propose an improved institutional framework. The improved institutional framework will exist of the following:

- A Biofuels One Stop Center will be established under the Tanzanian Investment Center (TIC) which will be responsible for coordination, endorsement and monitoring of biofuel investments.
- A Biofuels Steering Committee (chaired by the Ministry of Energy and Minerals) will be established. The Biofuels Steering Committee shall consist of Permanent Secretaries from ministries that are directly involved in biofuel developments. The Steering Committee will guide TIC and approve biofuel projects.
- The Steering Committee will be assisted by the Biofuels Technical Advisory Group (BTAG). The BTAG will consist of experts from ministries related to energy, agriculture, natural resources (forestry, wetlands), land, land use planning, food security, employment, investment, water, industry and environment, and will be responsible for reviewing all projects related to biofuels.
- A Permanent Secretariat to the Steering Committee will be established led by the Ministry of Energy and Minerals. The members of the Permanent Secretariat shall draw members from sectors of energy and agriculture.

Further details are discussed in Box 1.

BOX 1

THE TANZANIA INVESTMENT CENTRE AND INVESTMENT PROCEDURES IN TANZANIA

1. The Tanzania Investment Centre (TIC)

Foreign investors are referred to the Tanzania Investment Centre (TIC), which was established under the investment act of 1997. The TIC is the primary government agency that coordinates, encourages, promotes and facilitates investment in Tanzania and that advises the government on investment related matters. The TIC was established with the intention that it be the one stop facilitative centre for all (foreign and local) investors.

The TIC is tasked with the following roles:

- Assist in the establishment of enterprises, e.g. incorporation and registration at the Registrar of Companies.
- Obtain necessary licences, work permits, visas, approvals at the line ministries, facilities or services.
- Sort out any administrative barriers confronting both local and foreign investors.
- Promote both foreign and local investment activities.
- Secure investment sites and assist investors to establish EPZ projects.

- Grant Certificates of Incentives and investment guarantees and register technology agreement for all investments which are over and above USD300 000 and USD100 000 for foreign and local investments respectively.
- Provide and disseminate up-to-date information on existing investment opportunities, benefits or incentives available to investors.
- Assist all investors whether or not registered by TIC.

One of the functions of the TIC is to facilitate the acquisition of land for investors. TIC has a land bank in which districts have indicated the amount of land that theyhave available for investors. The land in the land bank is all village land. The TIC assists investors in the acquisition process of the land. As foreign investors are not allowed to own land in Tanzania, the acquisition of land refers to the acquisition of a lease or a right of occupancy of the land. According to the TIC, the acquisition of village land by a foreign investor consists of the following nine steps:

1. Land identification by Ministry of Lands, Urban Authority, District Authority, TIC or an investor.
2. Land gazettement by the Ministry of Lands.
3. Land designation to TIC by the Commissioner for Lands.
4. Submission of application to the Executive Director of TIC.
5. Application approved or rejected by TIC.
6. Notification of investor(s).
7. Preparations of Derivative of Rights for approved application.
8. Registration of Derivative Title.
9. Transfer of Duplicate Derivative Title to occupier of land.

2. Application procedures for investors

The Biofuel Guidelines give a clear description of the application procedures for investors in biofuels, namely:

- All applications for biofuel investments and development will be submitted to the Biofuels One Stop Centre.
- The applications will be screened at the Tanzanian Investment Centre (TIC) and by the Biofuels Technical Advisory Group (BTAG) within ninety days and presented to the Biofuels Steering Committee. The Steering Committee will issue a letter of no objection to the investor once the project is cleared.
- Once no objection is granted the investor will conduct a feasibility study and an Environmental and Social Impact Assessment. The feasibility study will be submitted to the Biofuels One Stop Centre and the Environmental and Social Impact Assessment to the National Environmental Management Council (NEMC) for approval. When the project application is approved by the Biofuels Steering Committee, the applicant will be issued with the endorsement letter by the Biofuels One Stop Centre.

In order to establish the National Biofuel Policy, the Ministry of Energy and Minerals has initiated a project which will develop the Biofuel Policy. The project will not only address the Biofuel Policy, but will also strengthen the legal, regulatory and institutional frameworks to support the development of a sustainable biofuel industry in Tanzania.

The Biofuel Policy Project consists of four components, namely:

1. **Organizational capacity**
   Development of **organizational capacity** of the government – to coordinate, regulate and support the development of plans and legal instruments relevant to the biofuel industry sector.
2. **Assessment capacity**
   Development of the **assessment capacity** of the government and financial institutions – to assess the biofuel industry from a fiscal and financial perspective.
3. **Biofuel policy**
   Development of **policy and legal instruments** – to support and regulate the development of a sustainable biofuel industry.
4. **Public support**
   Promotion of **public support**, participation and awareness regarding the biofuel industry.

The project will be managed by the Ministry of Energy and Minerals, but the implementing team will consist of specialists from the ministries that are involved in the biofuel development, such as the Ministry of Agriculture, Food Security and Cooperatives, the Ministry of Industry, Trade and Marketing and the Ministry of Natural Resources and Tourism. The project team will be trained on the BEFS methodology, described in this assessment, such that the modules as developed under the BEFS project will inform the policy development process.

The capacity of organizations involved in the implementation of the biofuel guidelines need to be developed in order to ensure successful implementation of the guidelines. For instance, the capacity at the National Environmental Management Council (NEMC) needs to be strengthened in order to assess the Environmental and Social Impact Assessments (ESIA) for biofuel projects.There are a number of biofuel investors active in Tanzania. Most of the biofuel investors are developing jatropha projects for biodiesel production, while one is looking at sugar cane for ethanol production. The projects of these investors are currently ongoing in the absence of biofuel guidelines or policy as they started before the drafting of the biofuel guidelines had been initiated. The government has indicated that no new biofuel investments will be approved until the Biofuel Guidelines are passed.

The main current biofuel investors in Biofuels in Tanzania are listed in Table 3.2. The selected investors provide an overview of the different crops, feedstock models, land ownership models, perspectives and potential risks of five biofuel projects in Tanzania.

As illustrated partially in Table 3.2, the investors have different approaches for their feedstock supply model. Some are developing an estate, some are using exclusively outgrowers and some are implementing a combination of estate and outgrowers.

Table 3.2
Five major biofuel investors in Tanzania

Company	Origin Country	Location	Outgrower Scheme	Feed-stock	Land Area Request (ha)	Land Concession (ha)
Sunbiofuels	UK	Kisarawe	Planned	Jatropha	18 000	8 000
Sekab	Sweden	Bagamoyo / Rufiji	Planned	Sugar	20 000 / 200 000	20 000
Diligent	Netherlands	Arusha / Tanzania	Only outgrowers	Jatropha	N.A.	N.A
Bioshape	Netherlands	Kilwa	No	Jatropha	81 000	37 000
Prokon	Germany	Mpanda	Only outgrowers	Jatropha	N.A.	N.A.

There are three feedstock production models, namely estate, outgrowers and a combination of estate and outgrower schemes. In the production of ethanol, the constant supply of the feedstock is very important as the investment in ethanol production facilities is very high. Therefore investors that intend to produce ethanol will require an estate in order to secure feedstock supply to the plant. Between 30 and 50 percent could be supplied by outgrowers, depending on the financing of the project. In this context, sugar cane is not a very suitable outgrower crop as it requires investment in irrigation infrastructure. Other crops such as cassava and sweet sorghum are better suited to outgrower schemes as they do not require irrigation and smallholders are familiar with growing these crops.

As investments in biodiesel facilities are much smaller, the feedstock supply for a biodiesel facility is not as critical. Also biodiesel facilities can be expanded at a later stage with lower costs compared to an ethanol plant. This allows biodiesel investors to start with a small plant and expand it when more feedstock becomes available. This makes it possible to have a feedstock production model based exclusively on outgrowers.

3.5.2 LAND ACQUISITION FOR BIOFUEL INVESTORS IN TANZANIA

For the development of an estate biofuels investors need to acquire land. There are two types of land in Tanzania that are available for the development of an estate, namely: Village land and General land.

Village land

Village land is under the administration of the village and village land cannot be titled for investors. For an investor to get access to village land, the village land needs to be converted from village land to general land. This process is facilitated for investors by the TIC. At the end of the process TIC gives a derivative title to the investor. Once village land is converted to general land, it is most likely that the land will not be converted back into village land, implying that the village has "lost" control over the land. The village does not receive compensation for the change of village land to general land. Compensation of the villagers for the land that they were using is done according to the regulations established under the laws of Tanzania. The villagers are not compensated for their land according to the market price for land. When village land is converted to general land, the rent that is paid for the land by the investor will go to the central government and not the village government. In the conversion process from village land to general land it should be ensured that sufficient village land should remain available to the village for future expansion and requirements The term of lease of village land that has been converted to general land is maximum 99 years, which is perceived by the government and civil society organizations to be very long. The draft Biofuel Guidelines states that for the production of biofuels the lease of village land that has been converted to general land is maximum 25 years. The lead time for the acquisition of village land is very long. In the case of Sun Biofuels it took over three years. For investors this is too long.

General land

General land is under administration of the National Government, more specifically the Ministry of Lands. The issues as described under village land are not as prominent for general land. Sometimes local communities have settled on general land. If this is the case it is essential that the investor engages with the local communities on the land and come to a mutual agreement on the way to proceed with the project. For instance, relocation should be agreed upon and be implemented according to international standards. Furthermore, the affected people should be the first to benefit from jobs that will be provided at the estate. Acquisition through Ministry of Land is possible with assistance from TIC.

3.5.3 THE EXAMPLE OF A BIOFUEL INVESTOR IN THE KISAWARE DISTRICT OF TANZANIA

As an example of a real case scenario, this chapter provides a description of the biofuel project that Sun Biofuels is developing. Sun Biofuels is developing a jatropha project in the Kisarawe district, about 40 km from Dar es Salaam. The project is divided into two phases. The first phase consists of the development of an estate of 8 000 ha. In addition to the estate Sun Biofuels intends to develop an outgrower scheme. In the first phase an outgrower scheme of 8 000 ha is planned. In the second phase the estate will be expanded to 18 000 ha. Depending on how things go, in phase II another area of 8 000 ha outgrower scheme will be developed.

The land acquisition process that Sun Biofuels has gone through and the issues related to the land acquisition process are highlighted. Information from the local communities and from Sun Biofuels has been acquired through interviews of a team[5] from the BEFS project.

The investor and the Kisaware village

Sun Biofuels applied for 18 000 ha of land to cultivate jatropha for the production of biodiesel. This land is located around 11 villages in Kisarawe. For phase I of the development, of approximately 8 000 ha, the company selected and acquired land from six villages, namely Chakenge, Mtakayo, Kurui, Mtamba, Kidugalo, Muhaga, and Majumbo (Table 3.3).

Table 3.3
Sun Biofuels land acquisition for phase I of development

Village	Village Area (ha)	Area for Jatropha (ha)	Village area for Jatropha (%)
Vilabwa	3 637	379	10
Chakenge	3 074	1 094	36
Mtakayo	3 154	1 546	49
Kidugalo	2 254	216	10
Marumbo	7 316	3 268	45
Muhaga	5 761	1 705	30
Total	**25 198**	**8 210**	**30**

Source: Kisarawe District Office

The TIC investor facilitation process and the procedures for land acquisition run less smoothly than expected. According to TIC the acquisition of land is done in nine straightforward steps. In reality, Sun Biofuels had to take at least 20 steps before it received the right of occupancy. The whole process of land acquisition has taken Sun Biofuels three years. Sun Biofuels has documented the steps that were required in the process of acquiring land. A flowchart of the steps is presented in Appendix 3A.

The issue of compensation was discussed with the villagers and with Sun Biofuels. Nevertheless the interviews showed that the villagers could not give concrete information about compensation by Sun Biofuels. Some of the affected villagers only knew their names were on a list and they were not clear about their possible compensation. No contract had been written and no discussions with the village council to conduct any form of negotiation had yet taken place.

The compensation to the villagers was further discussed in an interview with Sun Biofuels. It transpired that 152 people have received compensation for the land that has

5 Implemented by Ms Nazia Habib-Mintz under supervision of Rommert Schram with kind assistance from the Ministry of Agriculture and Food Cooperatives of Tanzania.

been converted from village to general land. A total of 1 765 acres (ca 700 ha) of village land that has been converted to general land was being used by villagers (almost 9 percent). The compensation for this land is based on the land law, the values for the land and assets on the land that are gazetted.

According to Sun Biofuels, each individual who had indicated to Sun Biofuels that he owned land in the area, had been compensated. The calculation of the compensation was based on the size of the land, the value of the crops and the value of a structure on the land. Based on the calculated value, each individual had received a personal cheque with the compensation. According to the information provided by Sun Biofuels, the average compensation per person was USD1 644. This is about USD350 per ha. An official at the Ministry of Agriculture indicated that the market value of the land should be worth around USD570 per ha. However, this could not be verified.

Despite the global concern over food versus fuel, the villagers do not perceive a conflict between food crop and jatropha production. The company supporters in the villages expect that jatropha will earn them a high income and a stable market in comparison to cassava and other food crops. Farmers indicated that they will intercrop jatropha with cassava and even monocrop. They believe that growing jatropha is less labour intensive and moreover provides additional time to devote to working for the estate. Others thought if income from jatropha seeds is much higher than producing food crops, they will devote 100 percent of their land in the outgrower scheme and live off the income.

The focus group participants were unaware of the employment promises Sun Biofuels made in 2006, despite the fact that the company made its promises publicly, in the presence of a political figure. According to the focus group participants Sun Biofuels promises to create employment, however confusion arises over the exact number of jobs that will be offered. Figures ranging from 1 000 to 4 000 jobs were mentioned. In an interview with Sun Biofuels it was stated that the company estimates to provide 1 500 permanent jobs. The daily fee that is going to being paid is 5 000 TZS, which is above the minimum wage of 65 000 TZS per month. During the establishment of the estate the number of jobs will be higher as Sun Biofuels will employ people for land clearing and construction.

The land acquisition process in the case of Sun Biofuels has taken over three years. On one hand this long procedure ensures that village land cannot easily be converted to general land (to protect the village), but on the other hand the foresight of going through a procedure which takes three years before they can start their project is not very appealing to investors. The TIC land bank only includes village land, so when an investor is interested in land from the land bank, he will have to go through the same time consuming process as Sun Biofuels.

Table 3.3 shows that out of six villages, two gave up more than 40 percent of their land. Most of the land that is being given away is land where trees have been cut to produce charcoal.

At the moment most of this land is not being used for agriculture. The average percentage of the land that is being given away over the six villages is roughly one third. It can be questioned whether this percentage is not too high as the land is given away for 99 years and the village population will grow considerably in that period. Also it is not sure whether after 99 years the land will return to be village land. Based on the 2.1 percent yearly population growth rate in Kisarawe, the village population is likely to double in 33 years. At this rate, demand and pressure on available land will probably grow.

However, as part of the land acquisition procedure the Ministry of Lands has verified that the villages will still have sufficient land after the transfer of the earmarked village land to general land. The question is how the Ministry of Lands has assessed the future land requirements for the villages, which method they used and whether this procedure was transparent. A clear and transparent procedure should be used to prevent future problems due to land shortage. As the perception in the village is that land is abundant and little knowledge exists on how much land actually is owned by the village, local communities will not be able to make an informed decision on how much land can be given away.

In one instance, in the case of Chakenge Village, villagers filed a formal objection when they found out that more land than anticipated was earmarked for the Sun Biofuels development. The villagers were concerned that the village would not have sufficient land in the future. District officials reviewed the case. Due to bureaucratic time lag nothing was done for a year, until a new District Commissioner took the matter seriously and unilaterally renegotiated the contract again and reduced the land allocation.

The interviews with the villagers on one hand and the interview with Sun Biofuels on the other hand suggest that there are controversies on compensation of land as well as on employment. For instance, the villagers stated in the interviews that they had not been compensated while Sun Biofuels claims to have compensated all individuals who were using village land that was going to be converted to general land. Perhaps there was a misunderstanding among the villagers of which land would come into consideration for compensation, or perhaps the compensation took place after the interviews of the BEFS team with the villagers. In any case, the villagers were not aware of the compensation they could expect. Also in the case of employment the villagers were not aware of the number of possible jobs that would be created by Sun Biofuels. This can be attributed to poor communication between Sun Biofuels, the district government, the village government and the communities. This could be a basis for social unrest and negative sentiment towards the company.

Finally, monocropping jatropha at the household level may impact the food security when the land formerly under food crops is 100 percent converted into jatropha. Jatropha only yields oilseeds after three years. Also as the Jatropha plant is a new cash crop, the yield levels that can be expected are uncertain. Therefore it is uncertain if the household will be able to purchase sufficient food from the revenues of the jatropha seeds. Literature suggests that jatropha could be a host of the cassava mosaic virus as jatropha and cassava are from the same family of euphorbia. This could have negative impacts on food security as cassava is one of the main food staples in Tanzania.

It could be questioned whether it should be the investor who should go through this procedure. It may be more suitable if the Government of Tanzania would identify agricultural areas and in consultation with the local communities set aside village land and initiate the conversion process. In this way, the government would be made responsible for the whole process, including the issue of compensation. This way the government could also ensure that investments in biofuels are made in areas which they think are suitable. In this the BEFS project could assist the Government of Tanzania.

3.6 CONCLUDING REMARKS

Rising fossil fuel prices, concerns over the increased CO^2 and other greenhouse gas emissions, climate change, and concerns over the depletion of global oil reserves have all contributed to interest in bioenergy developments. There has been a growing interest in liquid biofuels, in Tanzania and worldwide, because they can be blended with fossil fuels and are compatible with current transport structures. Biofuel developments have enormous potential to contribute to the Millennium Development Goals (MDGs) by providing greater energy security and reducing poverty through improved agricultural productivity of (energy) crops.

The most significant benefit of biofuels will be enabling the poor rural to have access to modern energy services using their land and labour capacity. Access to modern energy services could enable the rural poor to be more productive. However, while biofuels offer potential in terms of growth and poverty alleviation, it is important that Tanzania implements appropriate biofuel policies and regulations that complement the food security goals of the country. Particularly important is the need to integrate biofuels with other development initiatives aimed at self-sufficiency in food and fuels at the national levels.

Investment in biofuels is risky in Tanzania because the returns on the investment as well as the socio-economic impacts have not been fully explored. Given its potential for biofuels production and the lack of biofuels policies and regulations, Tanzania is a good example for a variety of developing countries worldwide, which currently are in the early stages of investigating the biofuels option. At present, however, the development of the bioenergy sector in Tanzania is restricted by a lack of information about biofuels at all levels from government to the general public. This, in part, explains the absence of clear policies and regulations for biofuels production and use in Tanzania although the biofuel guidelines have recently been approved. The Biofuels Task Force was set up precisely to develop a framework that is the outcome of close cooperation between different government departments and other stakeholders engaged in the promotion of liquid biofuels in Tanzania. The BEFS assessment and the tools provided by the analytical framework provide a strong basis on which to formulate a biofuels policy that is consistent with the existing development strategies of Tanzania while also promoting a more sustainable energy sector.

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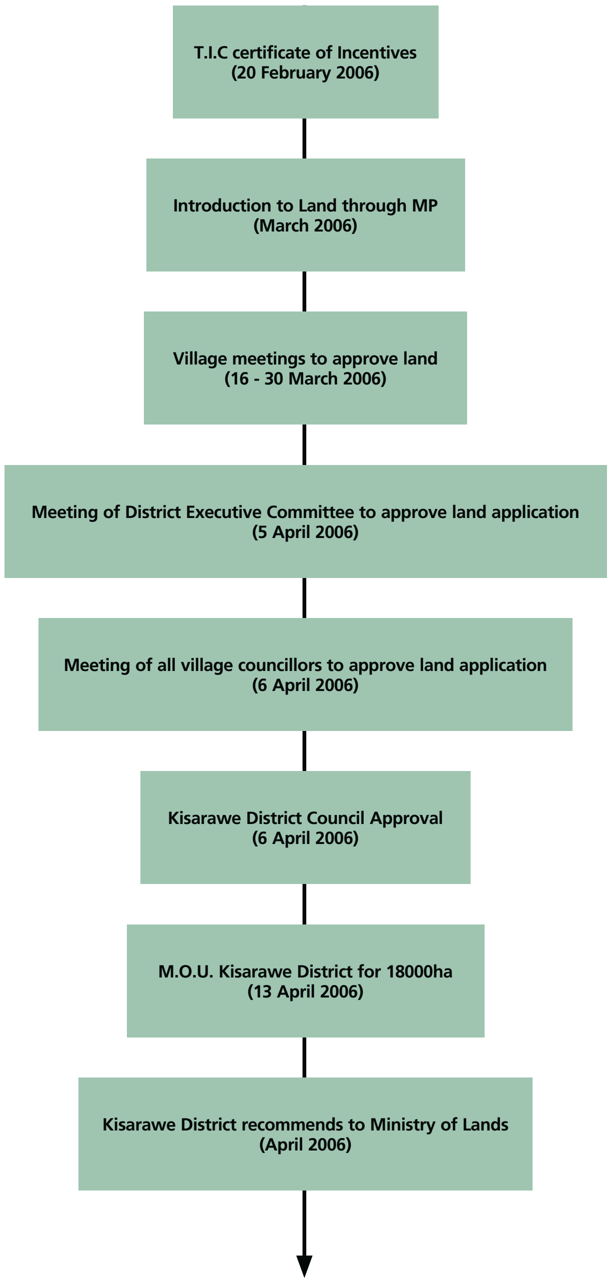
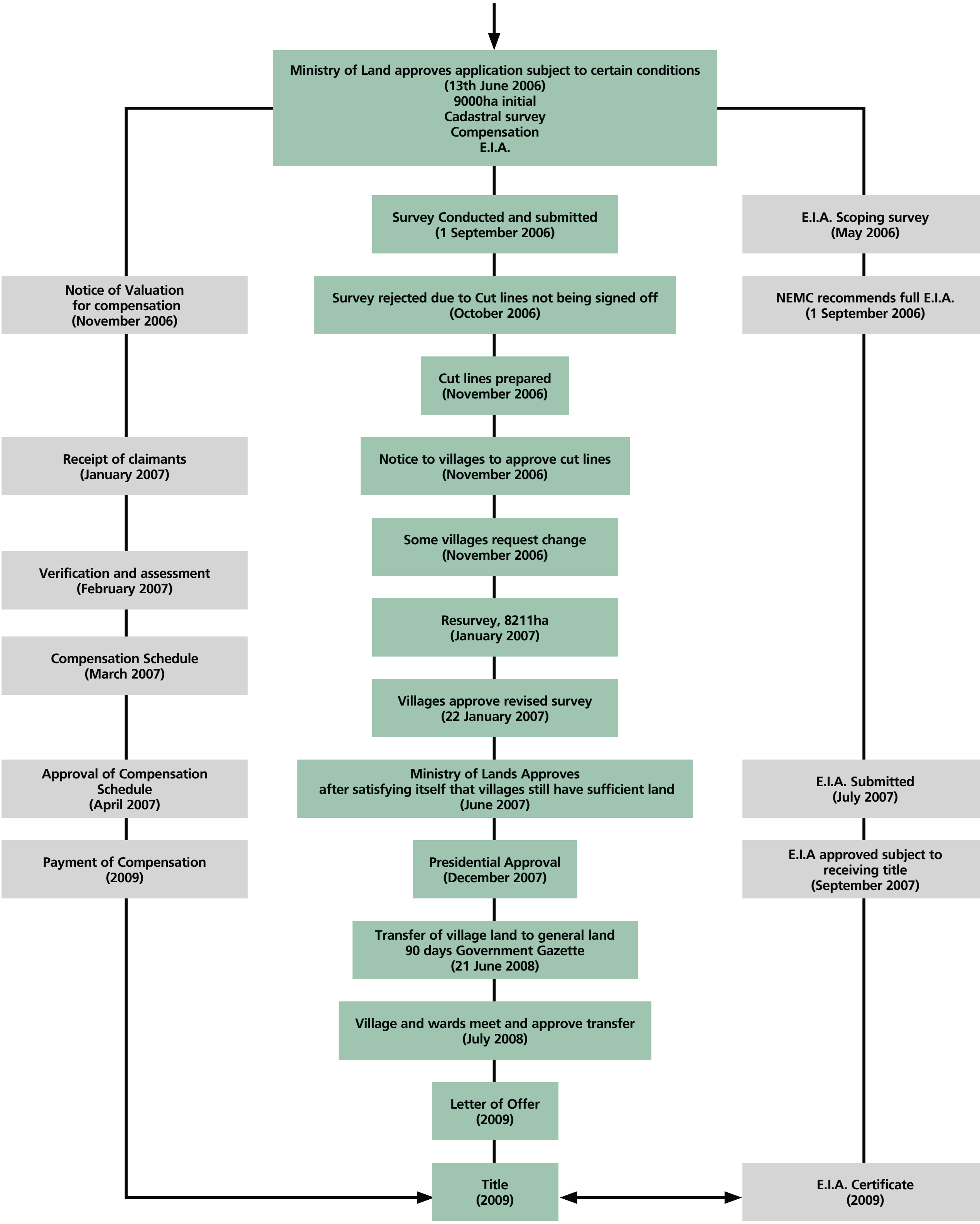
APPENDIX 3 A

FLOW CHART LAND ACQUISITION




Ministry of Land approves application subject to certain conditions
(13th June 2006)
9000ha initial
Cadastral survey
Compensation
E.I.A.
Survey Conducted and submitted
(1 September 2006)
E.I.A. Scoping survey
(May 2006)
Notice of Valuation
for compensation
(November 2006)
Survey rejected due to Cut lines not being signed off
(October 2006)
NEMC recommends full E.I.A.
(1 September 2006)
Cut lines prepared
(November 2006)
Receipt of claimants
(January 2007)
Notice to villages to approve cut lines
(November 2006)
Some villages request change
(November 2006)
Verification and assessment
(February 2007)
Resurvey, 8211ha
(January 2007)
Compensation Schedule
(March 2007)
Villages approve revised survey
(22 January 2007)
Approval of Compensation
Schedule
(April 2007)
Ministry of Lands Approves
after satisfying itself that villages still have sufficient land
(June 2007)
E.I.A. Submitted
(July 2007)
Payment of Compensation
(2009)
Presidential Approval
(December 2007)
E.I.A approved subject to
receiving title
(September 2007)
Transfer of village land to general land
90 days Government Gazette
(21 June 2008)
Village and wards meet and approve transfer
(July 2008)
Letter of Offer
(2009)
Title
(2009)
E.I.A. Certificate
(2009)

CHAPTER 4

BIOMASS POTENTIAL

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4. INTRODUCTION

The impacts of bioenergy on food security are uncertain. There may be positive or negative effects which depend on how the sector is managed. In order to ensure that food security is not negatively affected with the advent of bioenergy feedstock production it is crucial that staple food crops and their primary growing regions are well understood. At a minimum, this will ensure the potential impacts are clearly understood. Tanzania is a land-rich country and therefore is in a unique position to be able to protect existing and future agricultural production areas, keep tropical forests, conservation areas and biodiversity hotspots intact, all while expanding agriculture to meet new bioenergy demands. Accurate and efficient land planning is the route to achieving this.

Agriculture is a key sector for the Tanzanian economy and for food production. Improving agriculture performance and planning is thus key to ensuring continuing economic growth first and secondly targeting poverty reduction. As part of planning activities, it is essential to optimally plan land use and land allocation. In this context and within the scope of bioenergy developments, this chapter illustrates how land planning and zoning can be carried out. The chapter will focus on bioenergy crops, which is the scope of this analysis, but it is important to note that the analysis presented can be applied to any agriculture crop. Sustainable production would mean production that does not contrast with protected areas, including game reserves, protected forests, biodiversity areas, and key food production or agriculture areas.

To assist in sound decision-making regarding land assessment and planning for the agricultural and biofuel sectors, this module, Module 1 of the BEFS Analytical Framework (AF), provides policy-makers with both the area of suitable land available for bioenergy crops as well as the potential agricultural production from that land. Further, before deciding whether the suitable area identified can be exploited for bioenergy crop production potential environmental or food production conflict areas need to be identified. Thus, both the environmental and social effects need to be factored in the decision to use that land and how changing land use may affect food security and livelihoods.

The methodology framework of Module 1 is based on FAO's Agro-ecological Zoning (AEZ) approach (FAO, 1978) and allows to pinpoint where bioenergy crops can be cultivated under

1 Special appreciation goes to Rommert Schram for his feedback and comments on the chapter.

varying degrees of suitability from an agro-ecological perspective. The assessment is carried out over four combinations of agricultural production systems and input levels. Special attention is paid to conservation agriculture which will enhance sustained agricultural production while promoting long-term sustainability, food security, or environmental protection. An important consideration in the analysis relates to whether Tanzania should consider expansion into new lands for bioenergy developments, the intensification of current lands under agricultural production or a combination of both.

This chapter of the analysis proceeds as follows. Section 4.1 provides an overview of the methodology. Section 4.2 illustrates the set-up of the analysis in the Tanzanian context. Section 4.3 discusses the main features of agriculture production in Tanzania. Section 4.4 discusses the results. Section 4.5 shows how the results should be balanced against other location specific information available. Section 4.6 concludes.

4.1 ASSESSMENT OF BIOENERGY CROP POTENTIAL: THE METHODOLOGY

The methodology framework of Module 1 is based on FAO's Agro-ecological Zoning (AEZ) approach (FAO, 1978). This part of the analysis is used to assess the actual *availability of suitable land* that can be used to grow bioenergy crops.

The methodology presented here has two core elements to it (see Figure 4.1):

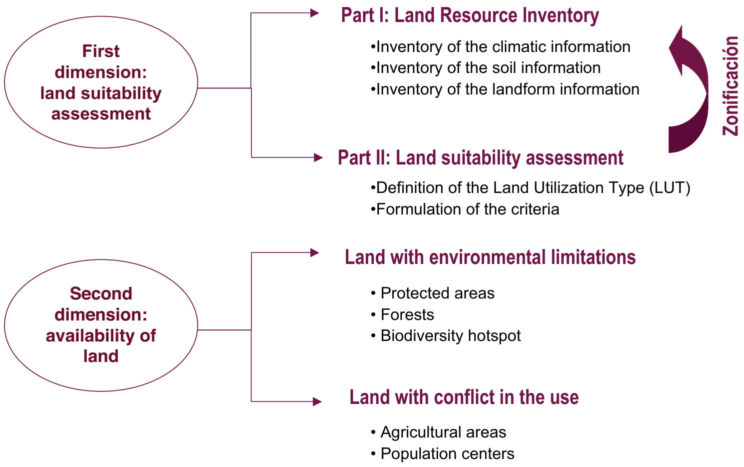
1. **suitable land area** is assessed;
2. **suitable land available** is calculated by excluding all environmental and agriculture land.

In the analysis, suitability is classified based on a suitability index. The suitability index categorizes, in percentage terms, the capability of a specific location. Capability to produce is defined in terms of the maximum attainable yield. The maximum attainable yield is defined as the full potential yield achievable in the specific location being studied under a specific agriculture system and input level. This is based on expert agronomic knowledge. Note that the maximum attainable yield is generally only achievable under laboratory conditions.

In general, the suitability index has six classes: not suitable (0 percent), very marginally suitable (0-20 percent), marginally suitable (20-40 percent), moderately suitable (40-60 percent), suitable (60-80 percent) and very suitable (80-100 percent). However, in the analysis presented here, these six classes have been collapsed into four classes for analytical ease (see Section 4.4).

Within the first dimension, the AEZ methodology is used to assess the suitability of land. Suitability is defined as the capability of a specific location to produce a specific crop based on the agroclimatic and soil conditions of the specific location. The first part of the analysis has two steps to it: the set-up of the Land Resource Inventory (LRI) and the Land Suitability Assessment (LSA). The LRI is a set of geo-referenced data of climatic, soil and landform resources. The LRI includes the climatic resource inventory (thermal zones, length of growing period zones, rainfall patterns and dry spell areas) and soil and land resource inventory. In the second part, the LSA, the Land Utilization Types (LUTs) are specified. The LUTs are defined as combinations of crop types, production systems, and input levels. For each LUT specific criteria are formulated[2] and applied to the LRI database. This combination will result in the identification of the suitability index in each locations (*zoning*).

Figure 4.1
Methodological Framework



Following the suitability assessment, the second dimension of Module 1 focuses on determining whether the suitable areas are **actually** available for use and therefore for bioenergy crop production. In fact, not all land that is found to be suitable for bioenergy crop production may actually be available for use. Some of the suitable land might be currently used for human settlement, or be covered by protected forests or for food production[3]. Through this second stage of the analysis, the areas that pose potential environmental, food production or other conflicts are identified. Note that additional no-go zones could be added based on the policy goals of the policy-makers. A dedicated set is presented here but in further analysis more specific considerations could be incorporated, for example the inclusion of pastoral areas as an exclusion area. The policy-maker needs to examine which policy goals to prioritize.

Finally, the results obtained from the assessment should be used in conjunction with other location specific information sets and analyses, an important step in concerted policy analyses. Through the integrated approach policy-makers will be in a position to narrow down the total suitable land based on existing land use, infrastructure and government priorities. An example of this is provided and discussed in Section 4.5. In addition, while the focus of this analysis is on the potential to grow bioenergy feedstocks, the same framework can be utilized to assess all

2 Note this step of the analysis requires expert information provided by agronomists and soil scientists.
3 Note that food production considerations include both current and future food needs.

forms of agriculture in Tanzania, be it crops for food, animal feed, fibre or fuel. This is essential in the context of optimal land planning, whereby every specific location is used to its full potential. The methodology for Module 1 can be utilized broadly for energy and environment to agriculture and food security policy in the context of land use planning across Tanzania.

4.2 SETTING THE SCENE FOR TANZANIA

The first step required to implement the analysis is the set up of the LRI, i.e. of the climatic resource inventory and the soil and land resource inventory (see methodology section above). Details of the creation, data source and results of the LRI for Tanzania are presented in Appendix 4A.

In Tanzania the LSA analysis is run under rainfed condition as this best describes the current agriculture management practice in the country[4]. The same methodology can be applied to assess suitability under irrigated conditions. In this case, geo-referenced data on currently irrigated areas and water availability are required. Irrigation schemes could help unleash the potential of some crops that are currently limitedly suitable under rainfed conditions.

Secondly, the LUTs are defined as combinations of crop types, input levels and production systems. In Tanzania, the analysis focuses on five crops. The crops were selected following consultation with government officials and key stakeholders. The crops analysed are cassava, sugar cane, sweet sorghum (two varieties), palm oil (two varieties) and sunflower. Cassava, sugar cane, sweet sorghum are ethanol crops while oil palm and sunflowers can be used for biodiesel production. Input use is considered in terms of low and high levels in order to represent the two extremes of the inputs' spectrum. However, the analysis can be modified to consider a range of intermediate input levels. Inputs include fertilizer, pesticides, mechanization and capital.

For each crop, the assessment is carried out under two production systems:

1. **Tillage-based** systems (TA).
2. **Conservation agriculture** systems (CA).

Particular emphasis is placed on CA. This agricultural practice is not new to Tanzania as there are a number of farmers currently practising CA (Shetto *et al*., 2007). However, it has yet to be adopted on a wide-scale level and doing so would require a concerted effort by the government to train and support farmers. Box 4.1 describes the principles and the benefits of CA and more details explaining the practice can be found in Appendix 4B. These two agriculture systems represent the two extremes of the agricultural management spectrum. Tillage-based agriculture, and in particular under low inputs and rainfed conditions, largely

4 Note that even if rainfall can be very erratic and water supply in some areas is scarce, current access to irrigation is very limited, whereby both irrigation infrastructure and water supply to the irrigation scheme is restricted. Note that, smallholder farmers have less than 3 percent of the planted area for annual crops under irrigation, whereby irrigation is mainly for cereals, fruits and vegetable crops. The majority of irrigated lands are held by large commercial estates, mainly dedicated to sugar-cane production (NBS, 2006).

represents the current status quo in terms of agricultural practice in Tanzania. The alternatives to the current production systems are meant to represent possible development paths for the Government of Tanzania. Further analysis might consider more production system options that lie between tillage and conservation agriculture.

In the case of Tanzania, this results in four agricultural configurations and the primary features are described in Table 4.1.

1. Tillage-based at low inputs (**TA-L**).
2. Tillage-based at high inputs (**TA-H**).
3. Conservation agriculture at low inputs (**CA-L**).
4. Conservation agriculture at high inputs (**CA-H**).

The following example helps to illustrate some of the points discussed. A specific location might have a suitability of 70 percent for sweet sorghum under TA-L. This means that under TA-L the location is classified as suitable and can achieve 70 percent of the maximum attainable yield (i.e. 70 percent of 4.1 tons/ha resulting in an area with 2.8 tons/ha). Under CA-H, that location might have a suitability of 90 percent, meaning it is classified as very suitable (i.e. 90 percent of 20 tons/ha resulting in an area with a yield of 18 tons/ha).

Table 4.1
Primary features of the agriculture configurations

	Conventional Tillage	Conservation Agriculture
Low Input Level	**Tillage-based system, low input (TA-L)** ■ Subsistence-type production system with low capital input ■ Use of traditional or modern cultivars of crops ■ Tilling uses hand labour and traditional tools only ■ Tillage-based cultivation in rotation with bush, often referred to as 'slash and burn' ■ Excludes the use of: □ Synthetic mineral fertilizer or other agrochemicals □ Large-scale conservation measures	**Conservation agriculture, low input CA-L** ■ Subsistence-type production system with low capital input ■ Use of traditional or modern cultivars of crops ■ Hand labour only, traditional or improved tools for seeding or planting with minimum soil disturbance ■ Crops are planted in rotation with other crops (including legumes) to maintain pest control, soil fertility and productive capacity ■ Residues are retained as much as possible for "in situ" composting ■ *Excludes the use of:* □ *Synthetic mineral fertilizer or other agrochemicals* □ *Large-scale conservation measures* □ *Bush fallows in the rotations and 'slash and burn'*
High Input Level	**Tillage-based system, high input TA-H** ■ Capital-intensive management practices with high-level of input ■ Full use of the most productive and adapted modern cultivars of crops ■ Complete mechanization with plough-based intensive tillage ■ Application of high levels of agrochemicals ■ Full soil conservation measures ■ *Excludes the use of:* □ *Attention to protect or enhance ecosystem services such as increasing carbon sequestration and soil organic matter build-up, or improving water resource quantity and quality*	Conservation agriculture, high input CA-H ■ Capital-intensive management practices with high-level input ■ Full use of the most productive and adapted modern cultivars of crops ■ Complete mechanization with no tillage ■ Use of optimum levels of agro-chemicals ■ 'Permanent' organic-matter soil cover from crop residues and cover crops ■ Cover crops with legumes in the rotations ■ Full attention to ecosystem services to keep production, environmental costs and product price competitively low and productivity and returns high. ■ *Excludes the use of:* □ *Tillage or soil disturbance*

BOX 4.1

THE PRINCIPLES AND BENEFITS OF CONSERVATION AGRICULTURE

Conservation agriculture (CA) is a resource-saving agricultural cropping system that strives to achieve high and sustained production levels while conserving the environment and improving the livelihoods of farmers.

CA is based on enhancing natural biological processes above and below the ground. It utilizes soils for the production of crops with the aim to reduce excessive mixing of the soil and maintaining crop residues on the soil surface in order to minimize damage to the environment. Interventions such as mechanical soil tillage are reduced to an absolute minimum, and the use of external inputs such as agrochemicals and mineral and organic-based nutrients are applied at optimum levels so as not to interfere with, or disrupt, biological processes. CA is characterized by three principles which are linked to each other, namely:

- Continuous minimum mechanical soil disturbance
- Permanent organic soil cover
- Diversified crop rotations for annual crops or plant associations for perennial crops.

Conservation agriculture practices can yield many benefits, including:

Economic: CA can improve production efficiency through time savings, reduced labour requirements, and reduced capital costs (e.g. fuel, machinery operating costs and maintenance).

Agronomic: Adopting CA leads to improvement of soil productivity (organic matter increase, in-soil water conservation as well as improvement of soil structure, and thus rooting zone).

Environmental and social: CA will reduce soil erosion (and thus of road, dam and hydroelectric power plant maintenance costs), improve water quality, improve air quality, and increase biodiversity carbon sequestration, all of which will offer sustained levels of high productivity agriculture for Tanzania.

Source: FAO Conservation Agriculture Web site (www.fao.org/ag/ca)

Moving from TA-L to TA-H requires increased input use, while shifting from TA-L to CA-L implies changes in agriculture management practices. The CA-H configuration represents a mixture of increased input use and changes in agriculture management practices. The results for CA-H will be illustrative of the full potential of the agriculture sector in the country and of where combined agriculture policies focusing on input access and improved agriculture management practices can drive agriculture planning and production.

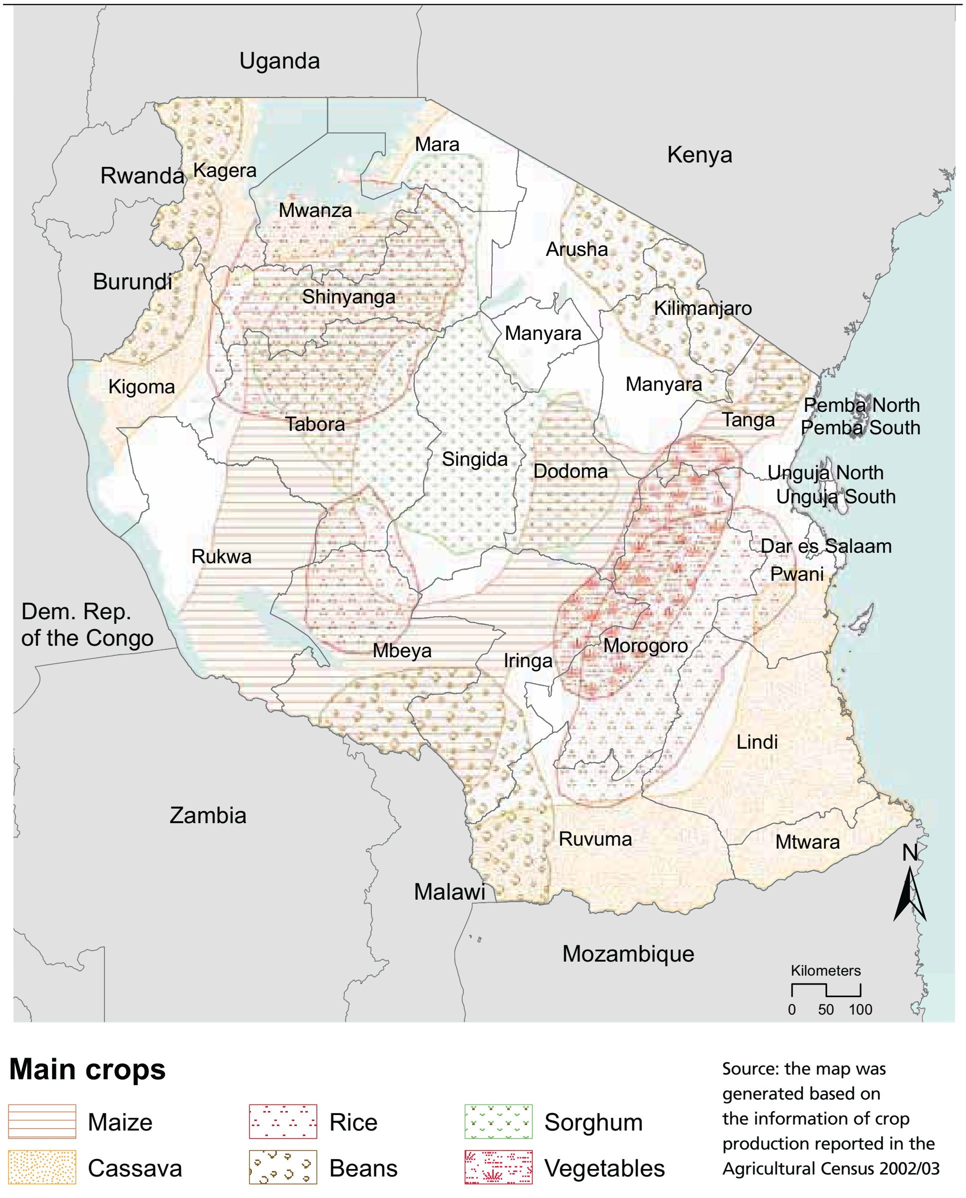
In the second dimension of the analysis a set of filters needs to be identified against which to screen the suitable land so as to define the amount of land available for use. Details of the filters used here are contained in Appendix 4C. This analysis removes all forms of *protected* and *agricultural lands*. Further investigation could apply different land filters based on the government's current priorities and policy options.

4.3 AGRICULTURE AND MALNUTRITION IN TANZANIA

Agriculture production is important to all regions in Tanzania. In terms of area under crops and production volumes, maize, cassava, rice, bean, sorghum and vegetables are the main crops for Tanzania. Furthermore, existing agriculture is mostly smallholder based. The regional coverage for the main crops is presented in Figure 4.2.

Figure 4.2

Primary crop production areas in Tanzania



Source: Agricultural Census 2002/03 (NSB, 2006)

The most important food crops in terms of calorie contribution in Tanzania are maize, cassava and rice. Maize, the primary food crop, is an annual crop and is also the most important in terms of planted area and production. Maize is mainly produced in Shinyanga, Dodoma, Tanga, Iringa, Tabora and Mbeya.

Cassava, the next most important crop in terms of food security, is a subsistence food crop in Tanzania. A large share, 84 percent, of Tanzania's total cassava production is used for food. The rest of production is used to produce starch and feed. However, even though cassava is one of the most important food crops, production could be enhanced significantly by better agriculture practices. Cassava is cultivated and produced in all regions of Tanzania. However, the main producing areas are Mtwara, Ruvuma, Lindi and Pwani in the coastal and southern regions, and Kagera, Kigoma, Mwanza and Mara in the northwest.

Rice production is primarily centered around Shinyanga and Mwanza in the north and in Morogoro. Rice is also grown in other regions such as Tabora, Mbeya, Ruvuma and Pwani, but production is not as concentrated. Beans are produced in the northwest (Kagera and Kigoma) and northeast regions (Tanga, Arusha, Manyara and Kilimanjaro). The central plateau is the primary growing region for sorghum. Vegetable production is in Morogoro, Tanga and Iringa regions and groundnut production is in Dodoma, Tabora and Shinyanga.

There are high levels of food insecurity in nearly all regions of Tanzania. To illustrate this, Figure 4.3 shows regional stunting[5] rates and densities of stunted children under five years of age across Tanzania[6]. Figure 4.3 shows that, with the exception of the Dar es Salaam region and Zanzibar, even the least affected areas still exceed 20 percent childhood stunting, with many regions being much worse off. Kigoma and Ruvuma are the most affected having both high rates and high densities of stunted children. In fact, Kigoma, Ruvuma, Iringa, Mtwara and Lindi all exceed 50 percent stunting rates, with regions such as Rukwa, Dodoma and Tanga not far behind at between 40 percent and 50 percent stunting.

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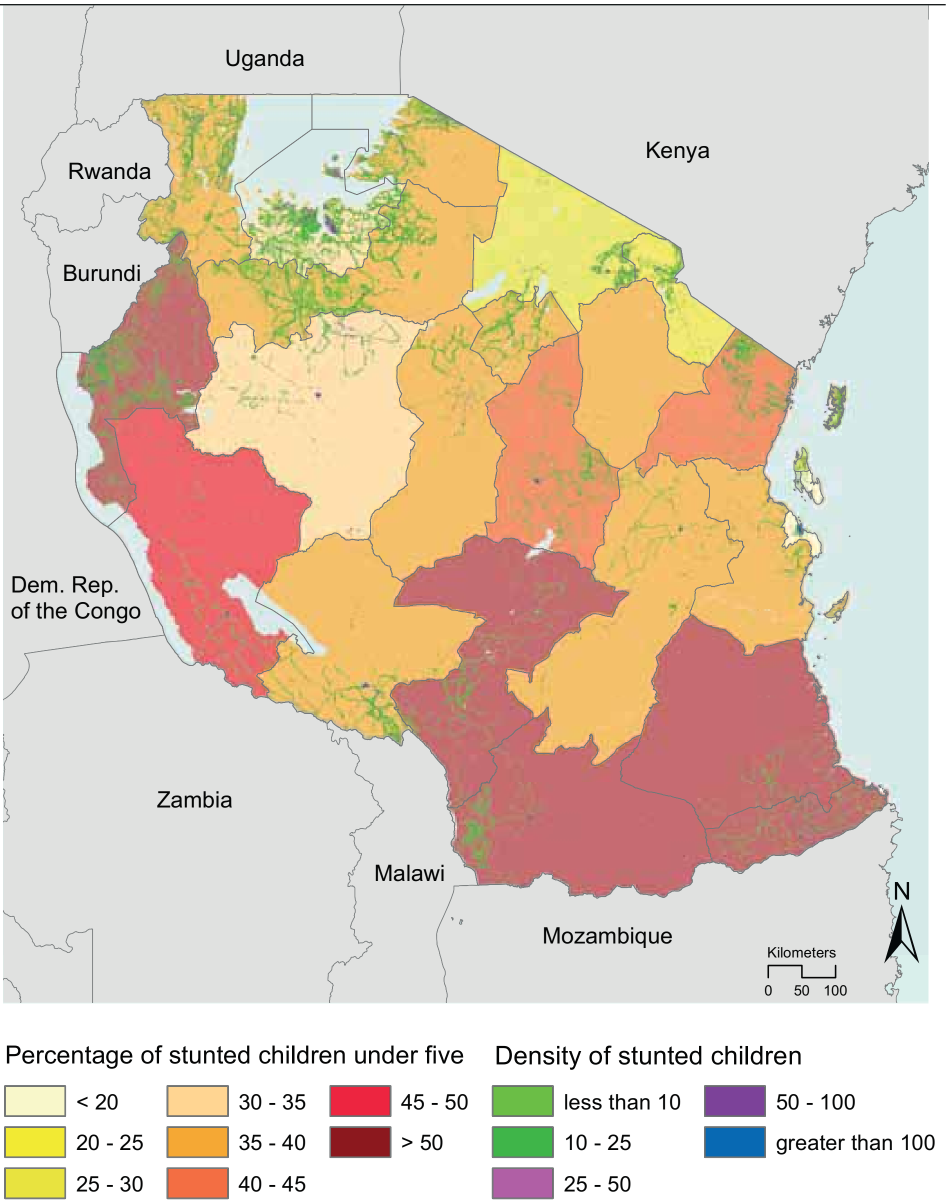
5 Stunting refers to the reduced growth rate of human development, typically brought on by malnutrition in early childhood. The resulting diminutive stature (up to 20cm shorter than expected in moderate stunting of a five-year old) has a negative impact on cognition, susceptibility to disease and labour capacity for the individual. This in turn has a significant impact on household and community productivity, which will further exacerbate regional food security problems in the future.

6 The information presented includes percentage of stunting children under five (DHS, 2005); population under five by district (NBS, 2003), and LandScan Global Population Database (ORNL, 2005).

Figure 4.3
Distribution of stunted children under five

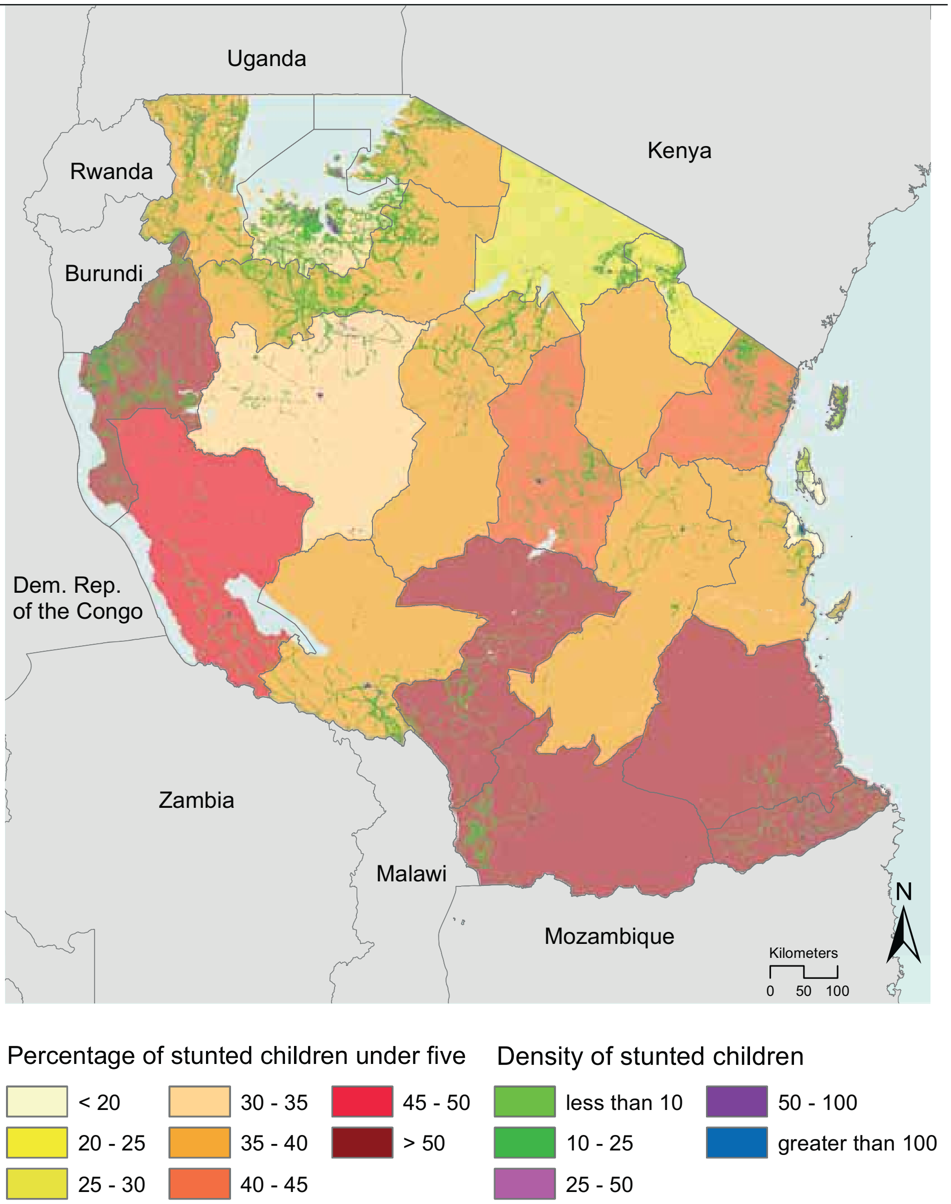


Source: DHS, 2004/05; NBS, 2003; ORNL, 2005.

4.4 RESULTS

This section presents the results for the crop list discussed both in terms of suitable and available areas. Once the actual areas that are available for potential bioenergy development are identified then the production (tons) is calculated based on the suitability of the specific location both on new lands and on lands under crop production. To make the results easier

Figure 4.3
Distribution of stunted children under five



Source: DHS, 2004/05; NBS, 2003; ORNL, 2005.

4.4 RESULTS

This section presents the results for the crop list discussed both in terms of suitable and available areas. Once the actual areas that are available for potential bioenergy development are identified then the production (tons) is calculated based on the suitability of the specific location both on new lands and on lands under crop production. To make the results easier to understand the suitability index is aggregated into four classes:

- Highly Suitable (HS): >60-100 percent of maximum attainable yield.
- Moderately Suitable (MS): >40-60 percent of maximum attainable yield.
- Marginally Suitable (mS): >0-40 percent of maximum attainable yield.
- Not Suitable (NS): 0.

As described, TA-L characterizes the current average agriculture practice in Tanzania. Consequently this represents the baseline against which results have to be compared and discussed. TA-H and CA-L, as medium term options, will be directly compared to the baseline, TA-L. CA-H, the longer term and full potential option, will also be compared to baseline to give a feel for the targets that the agriculture sector can achieve in terms of overall production.

Results are presented based on the following structure:

1. **Total suitable land area**
   The highly suitable and moderately suitable land area is calculated (see part 1 in Figure 4.4). This result is included to give an idea of the magnitude of suitable land (ha) for each crop, nevertheless this area cannot be directly considered for bioenergy development. Land for development will have to be either through expansion or through intensification (see points 2 and 3 below).

2. **Suitable area available for *expansion*[7] and potential production**
   Once the total suitable area that is highly and moderately suitable is identified, the environmental areas, the areas under crop production, and the urban areas are excluded. This yields the total available area for bioenergy crop (agriculture) expansion. As a result of the net area identified, the total production achievable is calculated. Here, the assessment looks only at land that has been found to be suitable and available, and that is not already under existing cultivation of any crops. These results focus on new areas suitable for expansion of bioenergy crops while avoiding competition with existing food crops (see part 2 in Figure 4.4).

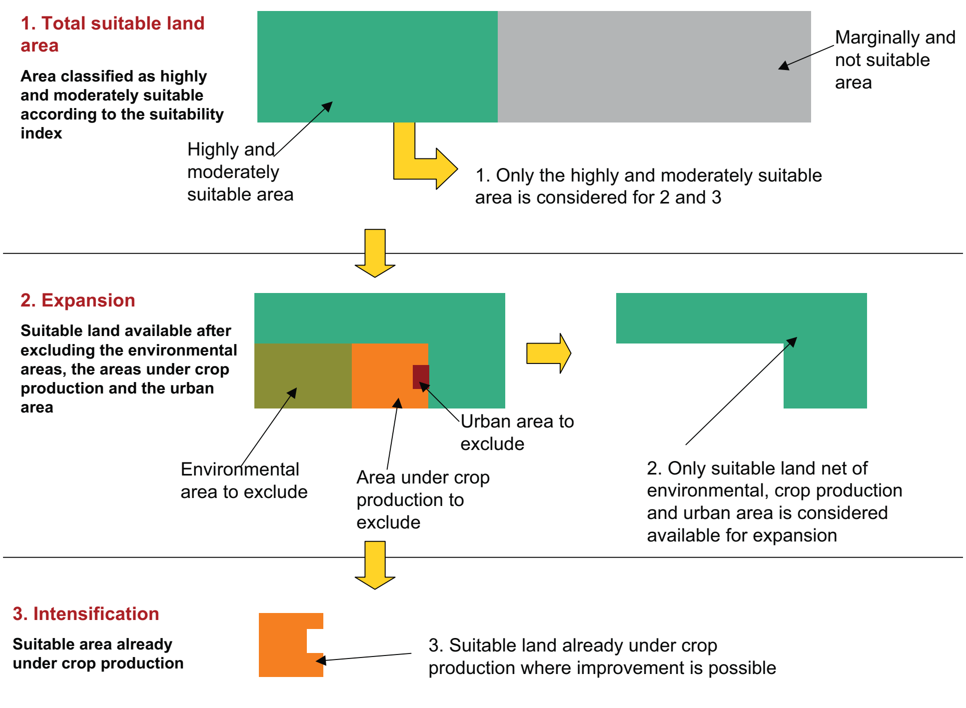
3. **Suitable area available for *intensification*[8] and potential production**
   Part of the total suitable area identified under 1 might already be under crop production. This has the potential to identify areas where better agricultural management practices can increase production. Note though that land already under crop production may not already be growing the bioenergy crop in question. In those cases, bioenergy crops may be displacing food crops. In these areas further analysis, including disaggregate crop production information and social implications of changes in crop production, would be required in conjunction with detailed land planning (see part 3 in Figure 4.4).

7 Expansion refers to agriculture production in new areas based on the criteria selected so far in this analysis. Note that additional criteria, for example exclusion of pastoral areas, might reduce the availability of new land for expansion.

8 Intensification refers to improvement of agriculture production in areas already under crop production. The analysis can show if better agriculture practices can lead to higher target production based on the configuration being considered.

Figure 4.4

Total suitable area, area for expansion and intensification



Note: This is a stylized diagram to explain the steps but no conclusions should be drawn on dimensions of the land components as drawn in the diagram.

The individual crop results are ordered based on the fuel they can produce. First ethanol crops are discussed (cassava, sugar cane, sweet sorghum), then biodiesel crops (oil palm, sunflower).

The results are presented in both map format and summary tables. The maps provide an initial visual screening of the location of suitable land. The summary tables present total area and potential production for the whole country. More detailed tables containing suitable area and attainable production by region are included in Appendix 4D. During the planning stage it will be important to allocate production optimally across regions so as to use each region's potential as fully as possible.

4.4.1 CASSAVA

4.4.1.1 CASSAVA TOTAL SUITABLE LAND AREA

The results show great potential for cassava in Tanzania (see Table 4.2 and Figure 4.5). Table 4.2 contains summary results of suitable land area for the country as a whole. Figure 4.5 offers a visual illustration of the location of suitable areas under all four configurations.

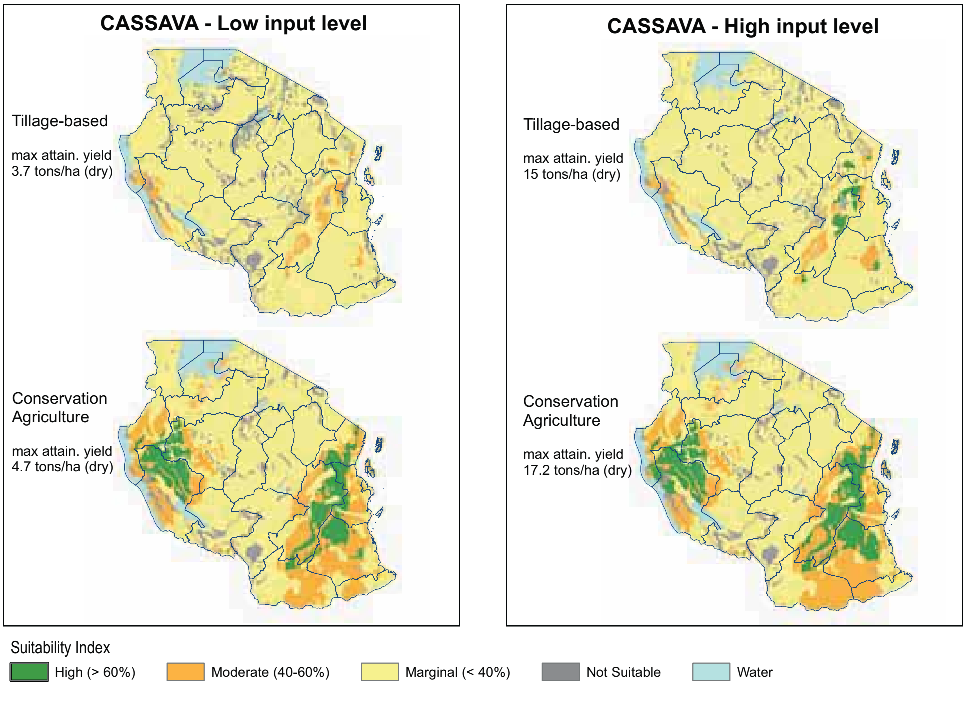
Table 4.2

Suitable land area for cassava

Configuration	Highly suitable area (HS)	Moderately suitable area (MS)	Total suitable area (HS+MS)
	(ha)	(ha)	(ha)
TA-L	2,943,441	6,686,114	9,629,555
TA-H	4,240,709	7,240,429	11,481,138
CA-L	11,630,941	17,023,238	28,654,179
CA-H	12,564,218	17,156,867	29,721,085

Figure 4.5

Land suitability assessment for cassava



Under TA-L, the results show that Tanzania has almost three million hectares of land classified as highly suitable, and another 6.7 million hectares of moderately suitable land for cassava production. The maximum attainable yield in this case is 3.7 tons/ha for dry cassava.

Under TA-H, 4.2 million hectares of land classified as highly suitable, and another 7.2 million hectares of moderately suitable land for cassava production. This represents an approximate increase of 44 and eight percent respectively for HS and MS when compared to TA-L. The maximum attainable yield in this case is 15 tons/ha for dry cassava.

An even larger increase, however, can be realized by switching from a TA-L system to a low-input conservation agriculture system, CA-L. Cultivable hectares will rise to 11.6 million (HS) and 17 million (MS) hectares, an increase of almost 300 percent and 150 percent respectively. The maximum attainable yield in this case is 4.7 tons/ha for dry cassava.

When moving to CA-H, the full potential condition, the total suitable area reaches 29.7 million hectares and a maximum attainable yield of 17.2 tons/ha.

At a regional level, the regions that offer the larger areas of suitable land are Morogoro, Rukwa and Lindi under TA-L. When the agriculture management system changes, Pwani also becomes an important potential contributor to cassava production. The results presented here are kept at an aggregate level to give an overall indication for location and of the potential production that could be achieved. In further stages of the analysis though it will be necessary to go the regional level and given the crops of interest, optimally allocate crops within the region, be it bioenergy, food, feed or other agriculture crops. Further details on area and production are in Appendix 4D.

4.4.1.2 CASSAVA SUITABLE AREAS AVAILABLE FOR EXPANSION AND POTENTIAL PRODUCTION

The results show there is also much room to expand production through increasing the area under cassava cultivation for bioenergy production. It is important to note that the initial results described above do not factor in existing uses of land such as urban development, conservation areas, and existing agricultural areas. It is necessary therefore to filter out lands that cannot be used, as described in Section 4.3. Once protected and other land uses are removed, as seen in Figure 4.6, the overall suitable number of hectares for each configuration decrease by two-thirds on average. The resulting figures are listed in the Table 4.3.

Table 4.3

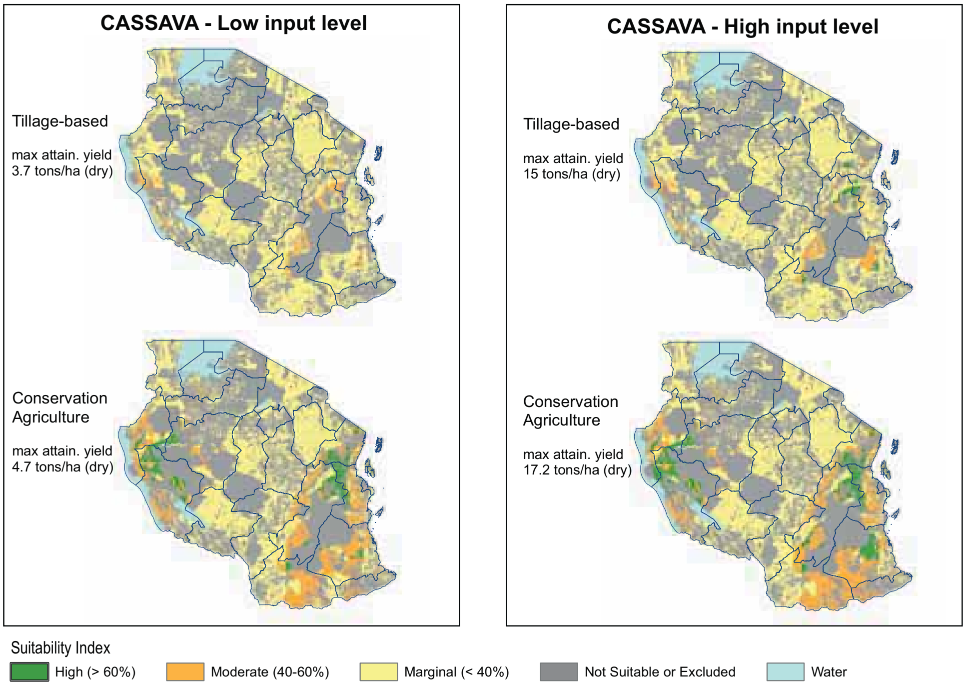
Suitable land area available for expansion and potential production for cassava

Configuration	Highly suitable area (HS)	Moderately suitable area (MS)	Total available suitable area (HS+MS)	Total dry production *
	(ha)	(ha)	(ha)	(ton)
TA-L	1,153,431	2,274,811	3,428,242	7,194,296
TA-H	1,744,818	2,343,195	4,088,013	35,888,320
CA-L	3,965,195	5,584,261	9,549,456	26,634,709
CA-H	4,324,562	5,680,992	10,005,554	102,805,158

** Note that this is an aggregate of areas diversely suitable*

Figure 4.6

Land suitability assessment for cassava excluding environmental and land use constraints



The most striking result from the analysis is that conservation agricultural production systems, even under low input levels, can increase the suitable area for cassava production by more than 9.5 million hectares (HS+MS) providing 26.6 million dry-tons of cassava - an almost threefold increase compared to the baseline. An important distinction to make is that conservation agriculture, while it can modestly increase attainable yields, will not increase yields to the same extent as is possible with the additional of high levels of agrochemical inputs.

However, conservation agriculture at low level of input is still a very attractive production system as number of hectares suitable for cassava production increases immensely while at the same time the overall capital requirements are significantly lower than high-input-based systems. The results for TA-H can also achieve similar levels of dry cassava production using less land, but capital costs are much higher. For details of regional distribution of area and production see Appendix 4.D.

4.4.1.3 SUITABLE AGRICULTURE AREAS AVAILABLE FOR INTENSIFICATION AND POTENTIAL PRODUCTION

The results seem to indicate that the majority of existing cassava agricultural lands can improve their yields simply through better management, given the fact that the average cassava yield in Tanzania is only two tons/hectare.

The area that is currently being used for agriculture[9] and that is suitable for cultivation of cassava is listed in the Table 4.4.

Table 4.4
Suitable land area available for intensification and potential production for cassava

Configuration	Highly suitable area (HS)	Moderately suitable area (MS)	Total available suitable area (HS+MS)	Total dry production*
	(ha)	(ha)	(ha)	(ton)
TA-L	453 476	1 060 760	1 514 236	3 108 850
TA-H	706 232	1 204 563	1 910 795	16 303 090
CA-L	2 067 258	5 195 371	7 262 629	19 213 044
CA-H	2 234 050	5 323 843	7 557 893	73 444 106

** Note that this is an aggregate of areas diversely suitable*

Based on the assumption that the highly and moderately suitable areas that are already under agriculture can be used, under TA-L the total production can reach 3.1 million tons. When moving to TA-H and CA-L, production can go up to 16 and 19 million tons respectively. Target production under CA-H could be as high as 73 million tons.

In the case of cassava, we find that the amount of suitable land that would come through expansion is double the amount from intensification, i.e. land already under agriculture.

Knowing where and at what intensities different crops are grown is critical for understanding what trade-offs will be necessary to encourage bioenergy crop production. Morogoro, for example, has great potential for growing cassava as a bioenergy feedstock, see detailed tables in Appendix 4D. However, land there is already intensively cultivated with high-value vegetable crops. Introducing bioenergy production in this region through government land grants could negatively affect vegetable farmer's livelihoods by displacing high value crop production or by decreasing land values. Accurate land planning will highlight the potential tensions and decisions to be made.

4.4.2 SUGAR CANE

4.4.2.1 SUGAR CANE TOTAL SUITABLE LAND AREA

The results show limited potential for sugar cane in Tanzania under rainfed conditions (see Table 4.5 and Figure 4.7). Table 4.5 contains summary results of suitable land area for the country as a whole. Figure 4.7 offers a visual illustration of the location of suitable areas under all four configurations.

9 Note that, as discussed, the agriculture area being considered for intensification includes all crops, not just cassava.

There are clearly not many areas suitable for sugar-cane production under rainfed conditions. Under TA-L, only about 200 000 ha are assumed to be suitable. Moving to TA-H increases the number of hectares slightly to 220 000 ha. However, if a CA-L were implemented, the number of suitable hectares grows more than ten-fold to nearly 2.5 million ha, mainly concentrated in Tanga, Pwani, and Morogoro, see Appendix 4.D for more detail. The maximum attainable yield ranges from three tons/ha under TA-L to 13.9 under CA-H.

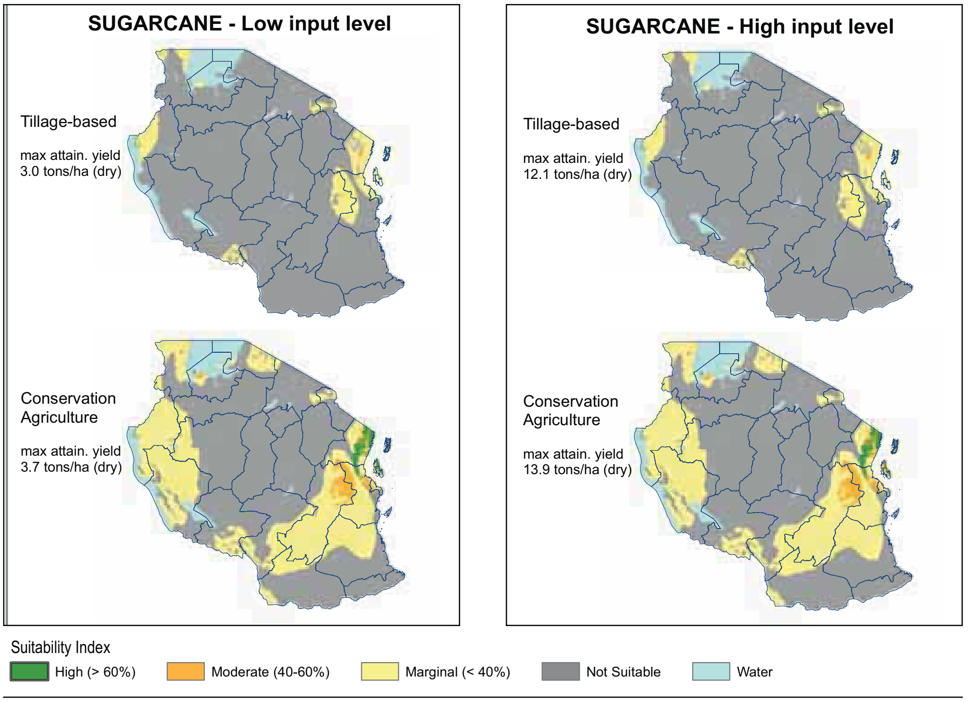
Table 4.5

Suitable land area for sugar cane

Configuration	Highly suitable area (HS)	Moderately suitable area (MS)	Total suitable area (HS+MS)
	(ha)	(ha)	(ha)
TA-L	38,643	164,030	202,673
TA-H	98,620	125,228	223,848
CA-L	935,291	1,533,586	2,468,877
CA-H	947,431	1,540,526	2,487,957

Figure 4.7

Land suitability assessment for sugar cane



4.4.2.2 SUGAR CANE SUITABLE AREAS AVAILABLE FOR EXPANSION AND POTENTIAL PRODUCTION

When looking at the potential for expanding sugar-cane production onto new lands, conservation agriculture holds much more overall potential. Thus, when moving to CA-L total suitable land is 876 578 ha, equivalent to 1.8 million tons of sugar production, as shown in Table 4.6.

In this case due to the limited initial area under TA-L, the real improvement is found by transiting first to a CA-L system and then to CA-H where the full potential would result in a total production of almost 7 million tons of sugar.

Figure 4.8 shows that most of the suitable areas lie along the northern costal areas. Again, it will be up to the policy-makers to optimally allocate specific locations across crops.

Table 4.6

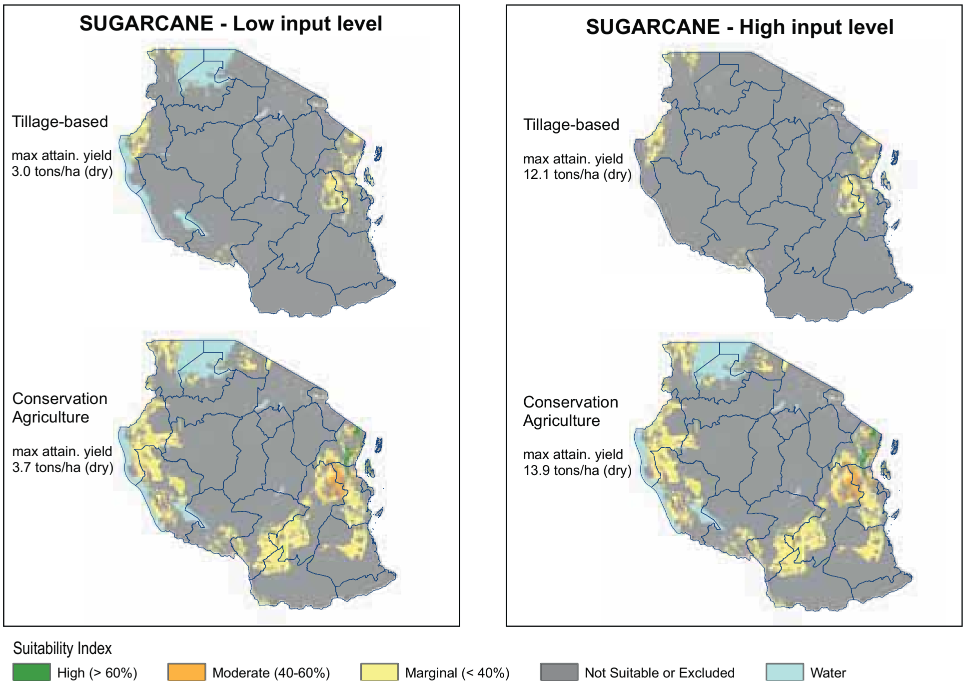
Suitable area available for expansion and potential production for sugar cane

Configuration	Highly suitable area (HS)	Moderately suitable area (MS)	Total available suitable area (HS+MS)	Total sugar production*
	(ha)	(ha)	(ha)	(ton)
TA-L	2,816	19,847	22,663	25,757
TA-H	5,011	12,331	17,342	117,038
CA-L	250,257	626,321	876,578	1,814,696
CA-H	254,364	628,557	882,921	6,873,068

** Note that this is an aggregate of areas diversely suitable*

Figure 4.8

Land suitability assessment for sugar cane excluding environmental and land use constraints



4.4.2.3 SUGAR CANE SUITABLE AREAS AVAILABLE FOR INTENSIFICATION AND POTENTIAL PRODUCTION

When limiting the focus to existing agricultural lands, the results under TA-L show that the majority of the suitable area for sugar-cane production is already used for some form of agriculture production. In fact, some of the land already under agriculture production could already be used for sugar-cane production. Improvements for smallholder sugar-cane production under rainfed conditions through improved management practices could be an important policy direction in this case. These should be integrated with large scale production, although in this case the inclusion of irrigation schemes in the analysis would be an important additional factor.

Table 4.7

Suitable area available for intensification and potential production for sugar cane

Configuration	Highly suitable area (HS)	Moderately suitable area (MS)	Total available suitable area (HS+MS)	Total sugar production*
	(ha)	(ha)	(ha)	(ton)
TA-L	29 950	113 221	143 171	242 587
TA-H	77 346	78 681	156 027	1 130 872
CA-L	539 416	509 019	1 048 435	2 442 030
CA-H	544 386	506 805	1 051 191	9 203 518

** Note that this is an aggregate of areas diversely suitable*

4.4.3 SWEET SORGHUM

4.4.3.1 SWEET SORGHUM TOTAL SUITABLE LAND AREA

Tanzania does not currently produce sweet sorghum, but has long-term experience in the production of sorghum. Two crop types, lowland and highland sweet sorghum, are considered in the analysis. The results show very strong potential for sweet sorghum in Tanzania (see Table 4.8 and Figure 4.9). Table 4.8 contains summary results of suitable land area for the country as a whole. Figure 4.9 offers a visual illustration of the location of suitable areas under all four configurations.

Figure 4.9shows that the most suitable areas for growing sweet sorghum under the TA-L system are almost everywhere *except* the central plateau. Interestingly, once the system steps up to CA-H almost all regions in the country are moderately to highly suitable. Thus, although not currently produced in Tanzania, sweet sorghum could be a very interesting crop for ethanol production, especially since sweet sorghum is a multipurpose crop and therefore can simultaneously be used for food production.

Together, there is approximately 47.5 million ha of suitable land (32.7 million ha of highly suitable and another 14.7 million ha of moderately suitable) under the TA-L system. Moving to a TA-H system would increase the suitable area by approximately 20 percent while a CA-L system would increase the total by 45 percent. It should be noted that production under a CA system is much more distributed across the country and less concentrated in the south (see Appendix 4D for more detail). The maximum attainable yield ranges from 8.1 tons/ha under TA-L to 40.6 under CA-H.

Most regions in the country are found to have large areas of suitable land for the production of sweet sorghum. Under TA-L, the regions that offer the larger areas of suitable land in terms of hectares are Lindi, Ruvuma, Morogoro, Rukwa, Tabora, all exceeding three million hectares of suitable land. Kigoma, Mbeya, Mtwara, Pwani, Shinyanga and Tanga have the potential to offer more than one million hectares of suitable land in each region. Further details on area and production are in Appendix 4D.

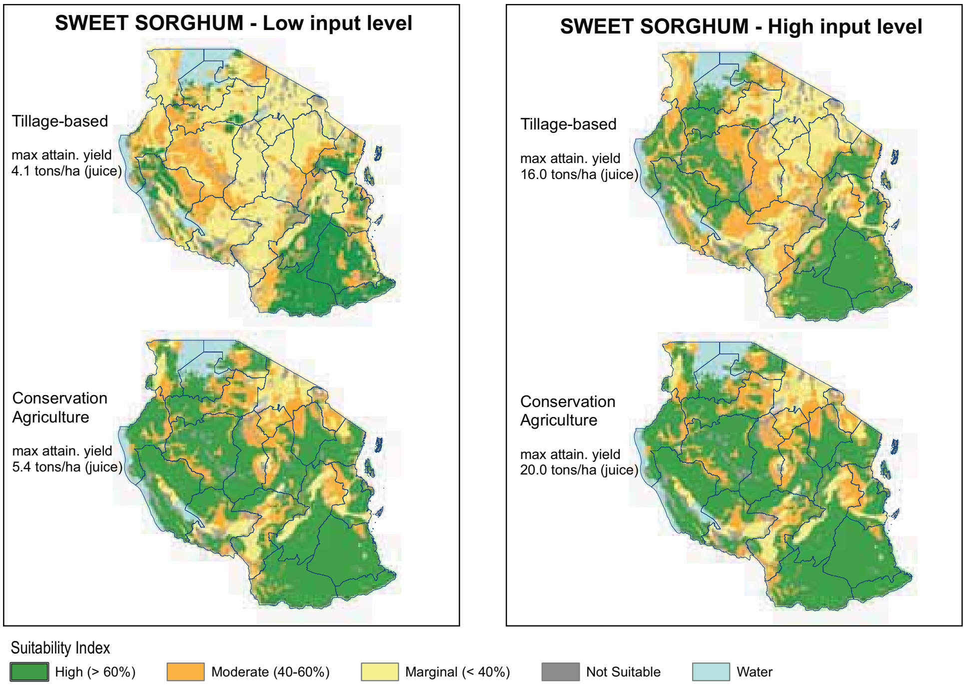
Table 4.8

Suitable land area for sweet sorghum

Configuration	Highly suitable area (HS)	Moderately suitable area (MS)	Total suitable area (HS+MS)
	(ha)	(ha)	(ha)
TA-L	32 797 044	14 793 760	47 590 804
TA-H	44 029 217	12 406 658	56 435 875
CA-L	59 585 708	9 367 269	68 952 977
CA-H	60 127 929	9 369 763	69 497 692

Figure 4.9

Land suitability assessment for sweet sorghum



4.4.3.2 SWEET SORGHUM SUITABLE AREAS AVAILABLE FOR EXPANSION AND POTENTIAL PRODUCTION

After removing excluded lands, as shown in Table 4.9, the total suitable area decreases by approximately 30 percent for each configuration. However, that still leaves a great deal of suitable area that might be used for bioenergy production. Under TA-L total suitable area is 17 million ha, while production is 72 million tons. The results for sweet sorghum show that moving to high inputs under tillage increase production significantly up to 194 million tons, potentially the most relevant medium term strategy in the context of sweet sorghum. The target potential for sweet sorghum is 26 million ha and close to 346 million tons of juice production.

Table 4.9

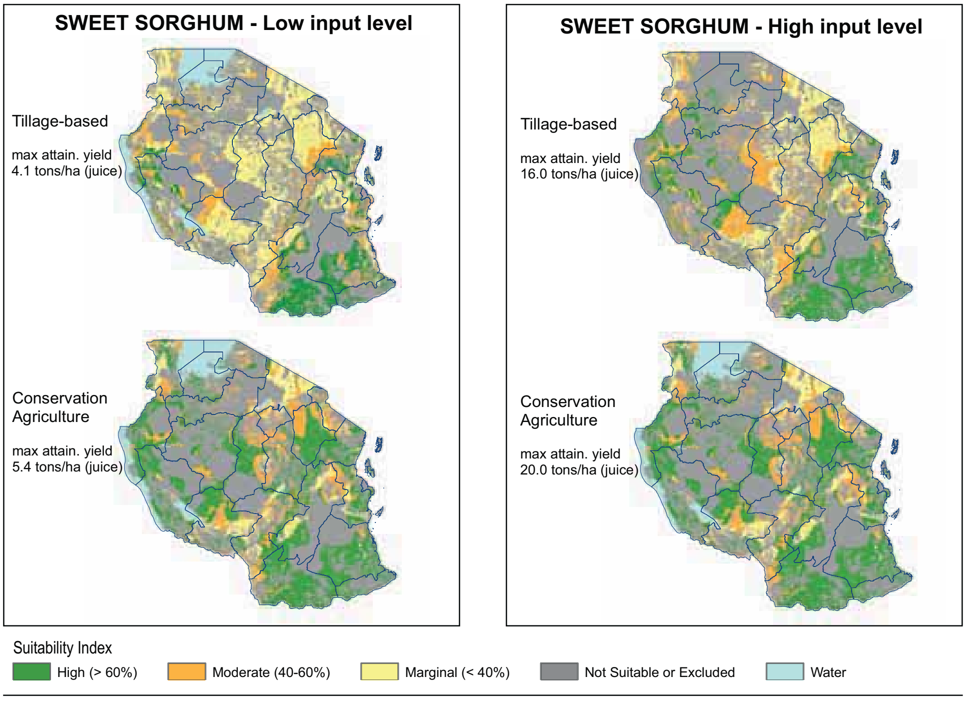
Suitable areas available for expansion and potential production for sweet sorghum

Configuration	Highly suitable area (HS)	Moderately suitable area (MS)	Total available suitable area (HS+MS)	Total juice production*
	(ha)	(ha)	(ha)	(ton)
TA-L	11 052 901	6 027 902	17 080 803	36 315 722
TA-H	15 296 148	5 358 004	20 654 152	193 791 344
CA-L	21 754 588	4 394 268	26 148 856	92 366 959
CA-H	21 951 281	4 442 658	26 393 939	346 149 492

** Note that this is an aggregate of areas diversely suitable*

Figure 4.10

Land suitability assessment for sweet sorghum excluding environmental and land use constraints



4.4.3.3 SWEET SORGHUM SUITABLE AREAS AVAILABLE FOR INTENSIFICATION AND POTENTIAL PRODUCTION

In a TA-L system, the suitable area obtained after removing environmental constraints is divided fairly evenly between new lands (17 million ha) and land already under agriculture (14.5 million ha).

Potential production under TA-H and CA-L systems are also split relatively evenly between existing agricultural lands and new lands. However, as mentioned above, new lands should be prioritized for sweet sorghum if the goal is not to impact existing food production. Overall, sweet sorghum holds massive production potential.

Table 4.10

Suitable areas available for intensification and potential production for sweet sorghum

Configuration	Highly suitable area (HS)	Moderately suitable area (MS)	Total available suitable area (HS+MS)	Total juice production*
	(ha)	(ha)	(ha)	(ton)
TA-L	9 539 463	5 042 315	14 581 778	31 160 854
TA-H	13 289 425	4 685 577	17 975 002	168 399 592
CA-L	18 968 432	3 134 827	22 103 259	79 673 773
CA-H	19 240 855	2 947 058	22 187 913	298 364 388

** Note that this is an aggregate of areas diversely suitable*

4.4.4 OIL PALM

4.4.4.1 OIL PALM TOTAL SUITABLE LAND AREA

Two crop types were analysed for oil palm, the tall and compact. The tall crop type is the most widely used. The compact crop type is a new crop type that is being experimented on that is tolerant to low temperatures and can be used at higher altitudes. The results show limited potential for oil palm in Tanzania under rainfed conditions. Much like sugar cane, the analysis shows that oil palm production is not suitable in most areas of the country. Under a TA-L system there is only 170 000 ha of suitable land. This number grows slightly to 220 000 ha under TA-H, but the overall number of hectares is still quite low. Conservation agriculture can increase the suitable hectares by a factor of 10, to approximately 1.6 and 1.8 million ha respectively under low and high input. Most of the suitable area is concentrated in the same northeastern coastal area as sugar cane.

The little suitable area that is found is mostly located in the Tanga region under TA-L. When the agriculture management system is improved larger suitable areas become available and are also found in Pwani, Mwanza and Dar Es Salaam, nevertheless still small compared to other more suitable crops outlined in this analysis under rainfed condition.

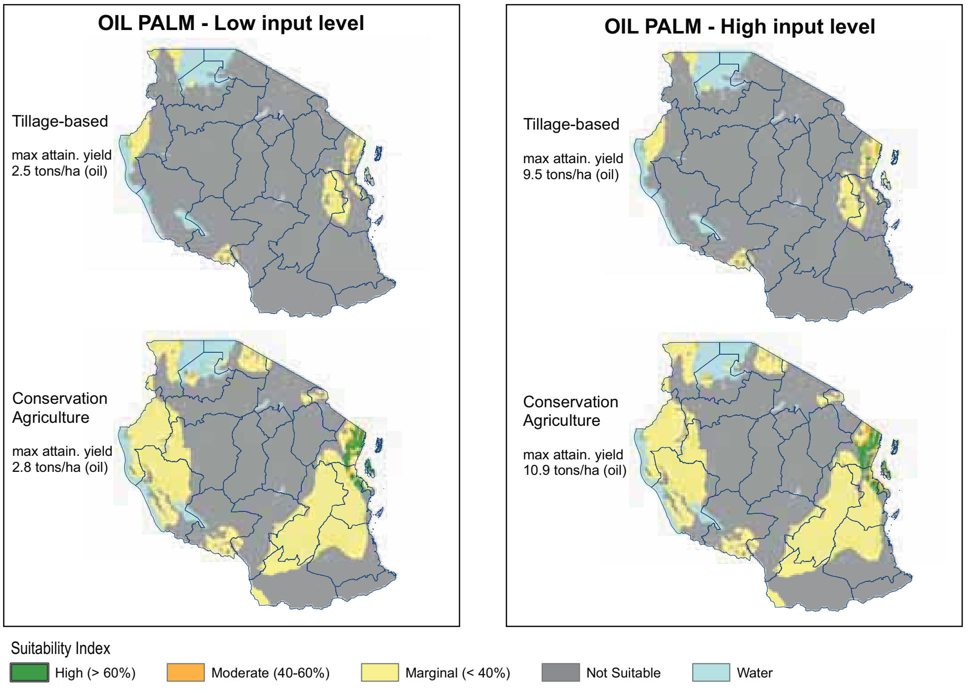
Table 4.11

Suitable land area for oil palm

Configuration	Highly suitable area (HS)	Moderately suitable area (MS)	Total suitable area (HS+MS)
	(ha)	(ha)	(ha)
TA-L	45,756	124,112	169,868
TA-H	88,091	132,659	220,750
CA-L	1,354,625	225,760	1,580,385
CA-H	1,502,780	264,654	1,767,434

Figure 4.11

Land suitability assessment for oil palm



4.4.4.2 OIL PALM SUITABLE AREAS AVAILABLE FOR EXPANSION AND POTENTIAL PRODUCTION

After removing environmental and land use constraints, Table 4.12 shows an approximate 20 percent decrease in the amount of suitable land in each configuration.

Given the overall limitations in area suitable for oil palm production, the CA configurations likely hold the most promise if expansion is the goal. Under CA-L the oil production will yield approximately 800 000 tons on almost 440 000 ha of land. However, under CA-H the overall production would increase up to 2.8 million tons but with a considerable increase of the production cost.

Table 4.12

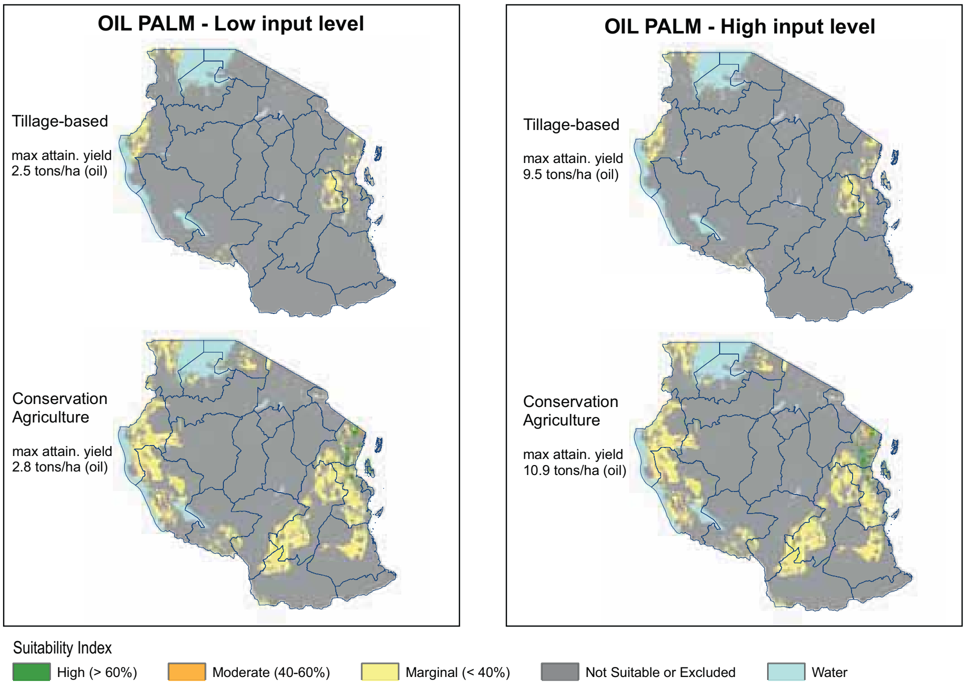
Suitable areas available for expansion and potential production for oil palm

Configuration	Highly suitable area (HS)	Moderately suitable area (MS)	Total available suitable area (HS+MS)	Total oil production*
	(ha)	(ha)	(ha)	(ton)
TA-L	1,926	13,099	15,025	13,594
TA-H	6,836	10,137	16,973	68,313
CA-L	376,644	59,534	436,178	818,538
CA-H	424,940	75,886	500,826	2,712,074

** Note that this is an aggregate of areas diversely suitable*

Figure 4.12

Land suitability assessment for oil palm excluding environmental and land use constraints



4.4.4.3 OIL PALM SUITABLE AREAS AVAILABLE FOR INTENSIFICATION AND POTENTIAL PRODUCTION

Oil palm is not a widespread crop in Tanzania. The potential area on existing agricultural lands is much higher than in the new lands.

Table 4.13 shows that under TA-L the suitable area is 126 000 ha with a potential production of 120 000 tons of oil. Simply increasing the input the suitable area increases slightly but the oil production rises up to 650 000 tons. Moving towards CA, the suitable area increases by eight times with a resulting production of 1.5 and five million tons respectively under low and high level of input.

Table 4.13

Suitable areas available for intensification and potential production for oil palm

Configuration	Highly suitable area (HS)	Moderately suitable area (MS)	Total available suitable area (HS+MS)	Total oil production*
	(ha)	(ha)	(ha)	(ton)
TA-L	37 616	88 416	126 032	121 522
TA-H	70 428	90 331	160 759	654 916
CA-L	709 247	102 208	811 455	1 476 406
CA-H	772 766	115 184	887 950	5 094 252

** Note that this is an aggregate of areas diversely suitable*

4.4.5 SUNFLOWER

4.4.5.1 SUNFLOWER TOTAL SUITABLE LAND AREA

The results show great potential for sunflower in Tanzania. Table 4.14 contains summary results of suitable land area for the country as a whole. Figure 4.13 offers a visual illustration of the location of suitable areas under all four configurations.

Under TA-L the suitable area is almost 38 million ha. The addition of inputs in the TA-H system increases this figure up to 51 million ha. Conservation agriculture can further expand the total number of suitable hectares up to 66.6 million ha, mainly in the central and east regions of Tanzania. Under TA-L, the larger suitable areas are found in Ruvuma, Lindi, Tabora, Morogoro, Shinyanga and Kigoma. A larger area becomes suitable under CA-L and CA-H (see Appendix 4D for more details).

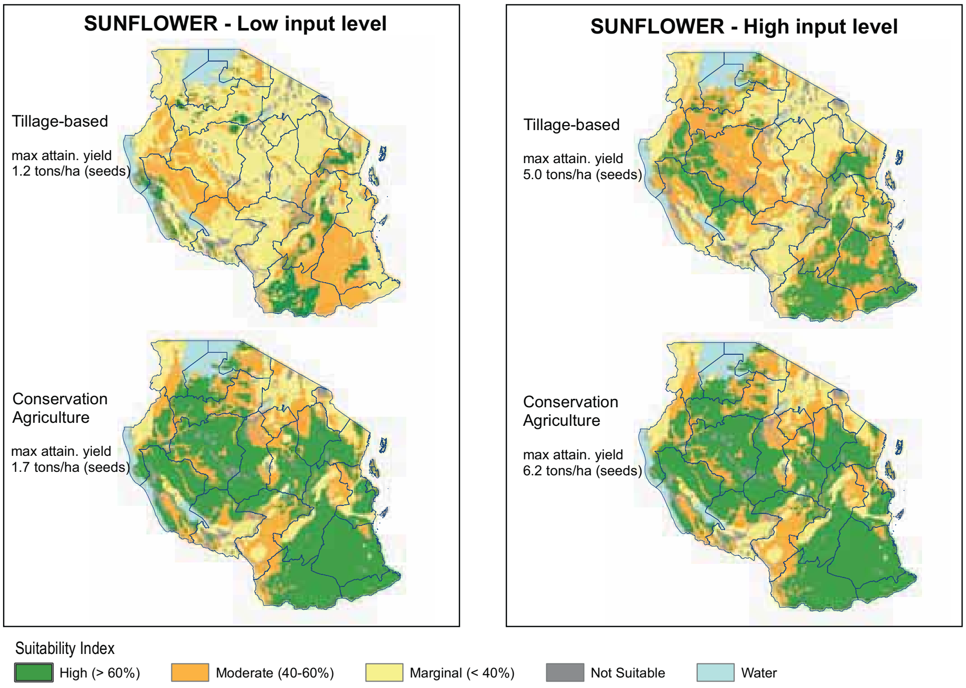
Table 4.14

Suitable land area for sunflower

Configuration	Highly suitable area (HS)	Moderately suitable area (MS)	Total suitable area (HS+MS)
	(ha)	(ha)	(ha)
TA-L	25 657 914	12 338 477	37 996 391
TA-H	35 991 148	14 792 122	50 783 270
CA-L	55 046 419	11 466 714	66 513 133
CA-H	55 249 942	11 365 987	66 615 929

Figure 4.13

Land suitability assessment for sunflower



4.4.5.2 SUNFLOWER SUITABLE AREAS AVAILABLE FOR EXPANSION AND POTENTIAL PRODUCTION

Figure 4.14 shows the land suitability results after excluded areas have been removed. Overall, Table 4.15 shows that the total suitable land decreases by about 30 percent under each configuration once excluded areas have been deducted. This is consistent with most of the other crops.

When limiting the potential identified to new lands, under TA-L it is possible to achieve a production of 11 million tons of seed on almost 14 million ha whereas a more intensive

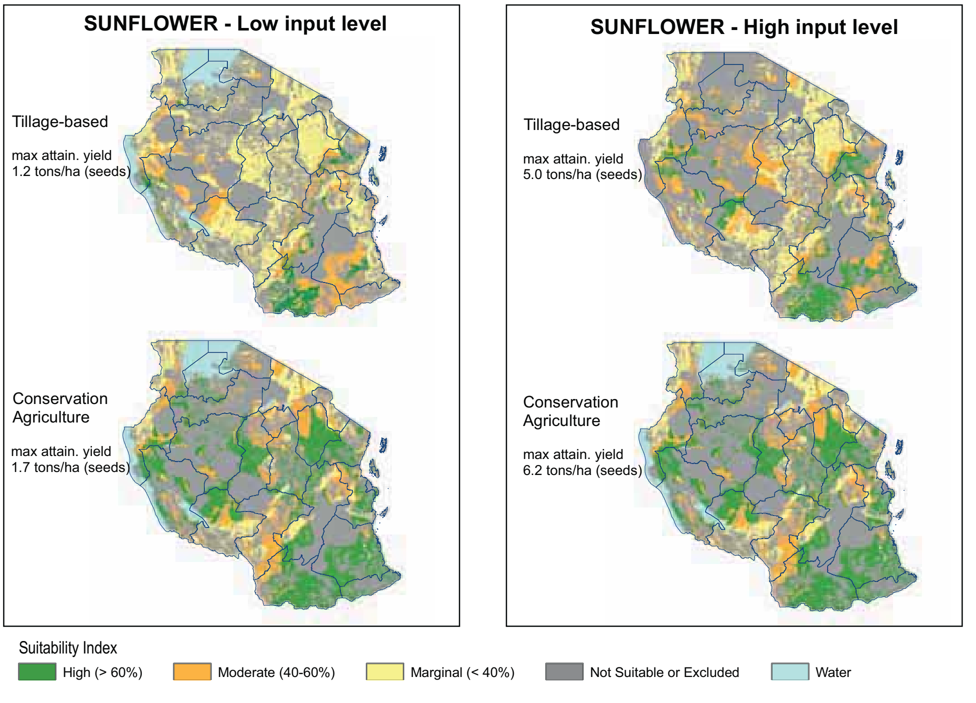
TA-H system would produce approximately 62 million tons of sunflower seeds on 18.3 million ha. Similarly, a CA-L system would result in 32.8 million tons on 25.3 million ha that could rise to 120 million tons on the same amount of land under the more intensive CA-H.

Table 4.15
Suitable areas available for expansion and potential production for sunflower

Configuration	Highly suitable area (HS)	Moderately suitable area (MS)	Total available suitable area (HS+MS)	Total seeds production*
	(ha)	(ha)	(ha)	(ton)
TA-L	8 981 461	4 988 594	13 970 055	11 129 085
TA-H	12 293 909	6 040 167	18 334 076	62 265 452
CA-L	19 831 310	5 448 037	25 279 347	32 872 330
CA-H	19 920 690	5 439 300	25 359 990	120 053 596

** Note that this is an aggregate of areas diversely suitable*

Figure 4.14
Land suitability assessment for sunflower excluding environmental and land use constraints



4.4.5.3 SUNFLOWER SUITABLE AREAS AVAILABLE FOR INTENSIFICATION AND POTENTIAL PRODUCTION

Under TA-L, approximately 12 million ha of land already under crop production could be used for sunflower production resulting in 9 million tons of seed. However, under a tillage-based production system sunflower is not a widespread crop so cultivating it on a large scale on existing agricultural lands could come at the expense of current food crops.

Comparing CA-L to TA-L the suitable area is twofold, however seed production is tripled. At high level of inputs the tillage-based system could achieve 53 million tons of seed production on 15 million ha. Under CA-H the suitable area expands to 21 millions and the production is twice the TA-H production.

Table 4.16

Suitable areas available for intensification and potential production for sunflower

Configuration	Highly suitable area (HS)	Moderately suitable area (MS)	Total available suitable area (HS+MS)	Total seed production*
	(ha)	(ha)	(ha)	(ton)
TA-L	7 495 432	4 396 892	11 892 324	9 348 165
TA-H	10 423 559	5 406 453	15 830 012	53 106 527
CA-L	17 090 625	3 948 557	21 039 182	27 668 763
CA-H	17 232 891	3 817 338	21 050 229	101 056 266

** Note that this is an aggregate of areas diversely suitable*

In the case of sunflower, suitable land is evenly distributed across new lands and lands already under crop production.

4.5 USING THE RESULTS IN THE TANZANIA CONTEXT: AN EXAMPLE

The results discussed so far have shown how some crops hold great potential as an ethanol feedstock crop in Tanzania through both expansion and intensification. However, the results obtained need to be screened against the reality in the country. An example of this process is provided below, relating to the infrastructure limitation problem in the regions of the country. Depending on data availability and government priorities, policy-makers might want to screen the results against other important parameters. The BEFS analysis is only a starting point in this regard, but as better datasets and more specific scenarios are developed, the methodology presented in Module 1 can continue to be used by the government as a key land use planning tool.

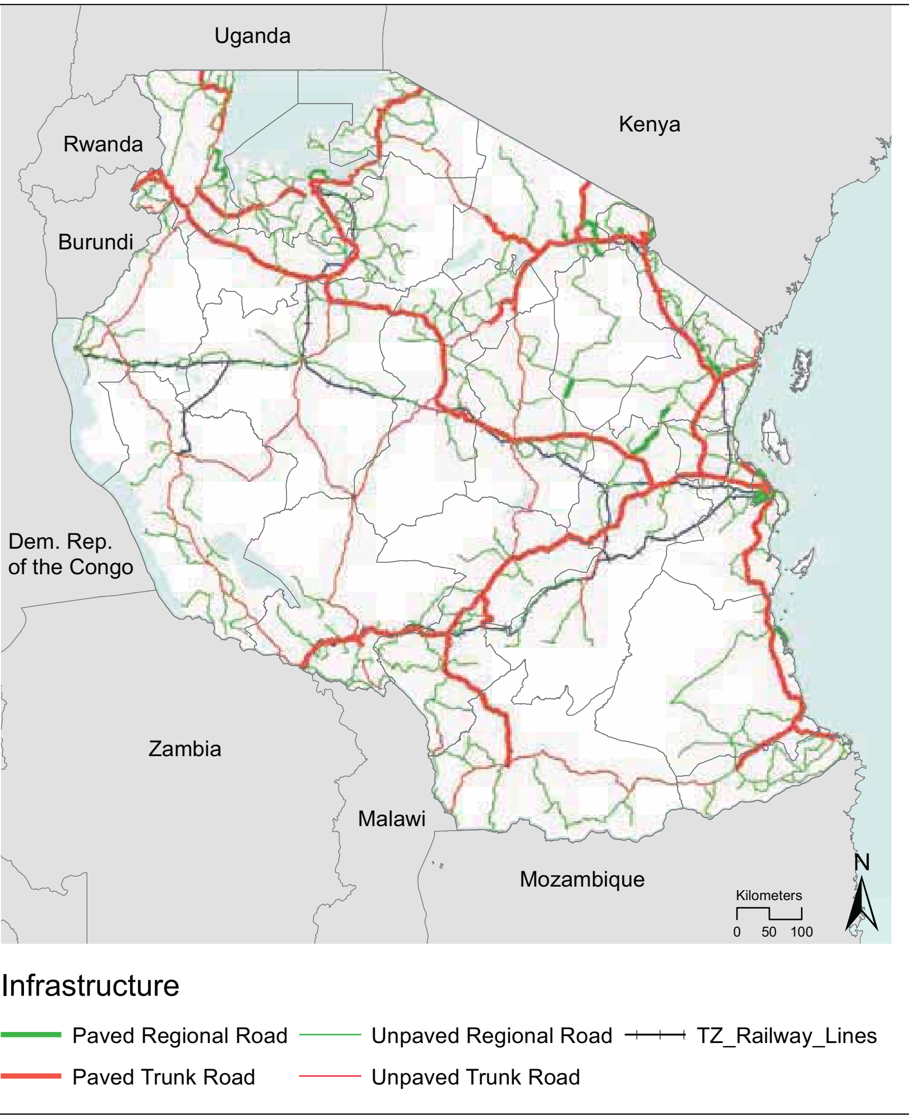
Agriculture in Tanzania continues to be adversely affected by lack of access to competitive markets due to high transport and transaction costs. This can lead to lower producer prices, post-harvest losses of cereals, and an overall lack of regional-specific expert advice and technologies making their way to different parts of the country. There is also a shortage of credit available to farmers. All of these factors exacerbate problems of low productivity and low rural incomes.

Transportation is a particularly acute problem in Tanzania. Figure 4.15 is a map of Tanzania's primary road and rail infrastructure. This map consists of almost 29 000 km of trunk and regional roads (out of 56 000 km of total roads in the country). However, only 16 percent of primary roads are paved (eight percent overall), making market accessibility rather limited (TANROADS, 2006). Simply put, the lack of transportation is the most frequently mentioned obstacle to increasing the livelihoods of rural farmers.

In general, rail, marine, air and road transport networks need to be expanded and maintained to international standards before widespread development can happen.

Figure 4.15

Infrastructures in Tanzania



Source: Database managed by Prime Ministers Office Regional Administration and Local Government (PMO-RALG); financed and provided by World Bank.

4.6 CONCLUSION

Food security is a major concern for Tanzania and it is important to ensure that a future biofuels industry will not adversely impact on the availability of food crops. The analysis here allows policy-makers to be in a position to support the development of biofuels without harming food security, and indeed attempting to improve food production levels.

Tanzania has great potential for bioenergy crop production. The results of this analysis demonstrate that Tanzania has potential for increasing agricultural production, both through the intensification of existing areas under crop production and through the cultivation of new lands dedicated to bioenergy crops.

The analysis presented shows, under rainfed conditions, which bioenergy crops are most suitable for producing in Tanzania and generally in which locations. The analysis presented focuses on cassava, sugar cane, sweet sorghum, oil palm and sunflower. The results for cassava show that Tanzania has significant capacity to produce high volumes of cassava. Nevertheless, as cassava is a very important food crop, careful land planning will be necessary to ensure that production targeted towards the bioenergy industry does not preclude food availability. Other crops of interest might be sunflower, sweet sorghum both of which can be grown on new lands without impacting existing food production. Sweet sorghum and sunflower both have great potential across all of Tanzania. Sweet sorghum would be a new crop, while sunflower might be particularly interesting as it can be used to produce biodiesel to substitute for national diesel consumption. The suitability of sugar cane and oil palm is extremely limited under rainfed conditions. The total amount of land suitable for both crops is relatively small and concentrated along the northwest coast. Adding the irrigation dimension would be essential for the cases of sugar cane and oil palm. The analysis demonstrates the importance of conservation agriculture to the future of Tanzania's agriculture as a long-term sustainable agricultural practice. The specific analysis presented here is meant to represent some of the most likely outcomes of introducing a bioenergy economy to Tanzania. However, the inherent flexibility built into Module 1 makes it easy to rapidly adapt the analysis to address the ever evolving priorities and challenges faced by the Government of Tanzania.

In this, the analysis provides a stepping stone in identifying broad areas of suitability. A much deeper analysis is needed, and at a significantly more disaggregated level, in order to identify how much land can be used. This is necessary to ensure that each region can optimally plan which crops to produce, including food, feed and export crops, so that at the regional level policy-makers can allocate the most effective crop to its most suitable location.

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APPENDIX 4 A

THE LAND RESOURCE INVENTORY FOR TANZANIA

The Land Resources Inventory is comprised of numerous climate, soil and landform data layers that are integrated to assess the overall suitability for agriculture.

The datasets for Tanzania were compiled mainly by FAO GIS experts and then refined based on input from local experts on meteorology and agriculture.

The climate resources inventory, shown in Figure 4A.1, was created from information gathered at nearly 600 meteorological stations across Tanzania (Figure 4A.1a). Historical data from these research stations on temperature, precipitation and evapotranspiration[1] (dating back to 1971) were used in combination with altitude and rainfall patterns to generate the primary climate datasets, thermal zones (Figure 4A.1b) and length of growing period (LPG) zones (Figure 4A.1c).

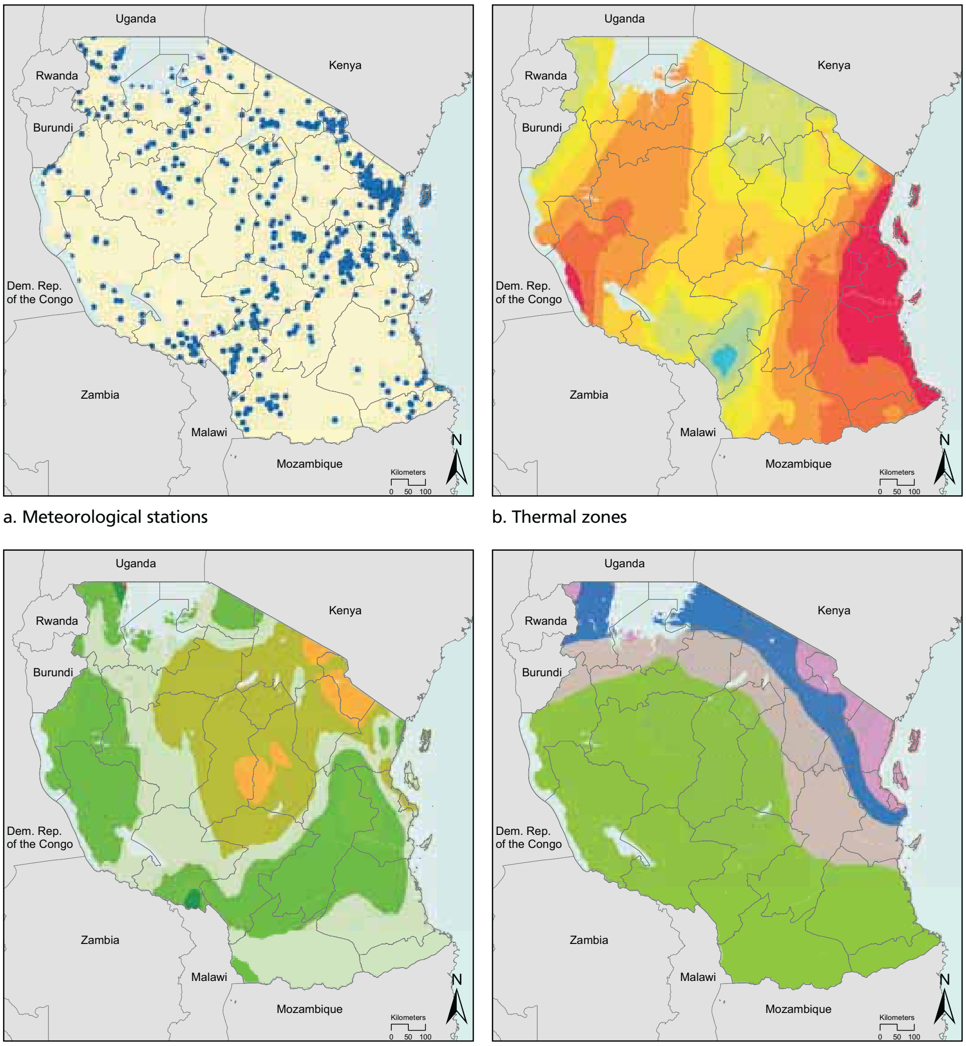
The thermal zones refer to the amount of heat available for plant growth and development during the growing period. In Tanzania the annual mean temperature varies from 10 °C in the southern highlands zone to more than 25 °C in the coastal area (from blue to red in the map). The LGP zones refer to soil moisture conditions, corresponding to the number of days when moisture conditions are considered adequate for crop growth. In Tanzania the LGP varies from 90 days in the central part to 330 days in the lake area.

The resulting information was evaluated by local experts in the Tanzania Meteorological Agency (TMA) to ensure validity and robustness. The contribution of local experts was invaluable to help identify unique climatic variations which are difficult to recognize at the national level. For example, the central region of Tanzania often has short, but numerous dry spells that occur throughout what would otherwise simply be classified as the rainy season (Figure 4A.1d). In this case, local knowledge was critical to properly estimating the overall number of days with moisture in the soil.

1 Potential evapotranspiration is the amount of water that could be evaporated and transpired if sufficient water were available.

Figure 4A.1

Climatic resource inventory



a. Meteorological stations

b. Thermal zones

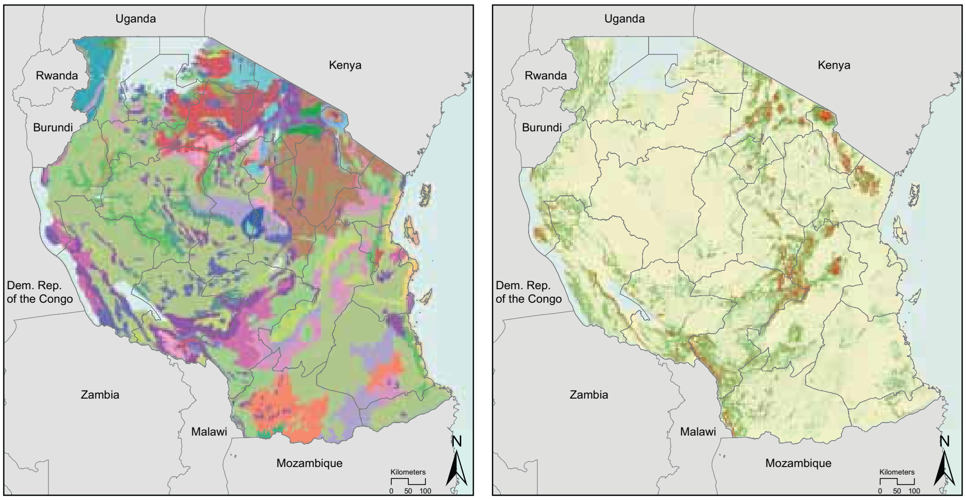
c. Length of growing period zones

d. Rainfall pattern and dry spell area

Similarly, the soil resource inventory (Figure 4A.2) was created using attributes such as soil type and soil texture taken from the Soil and Terrain (SOTER) digital database for Southern Africa. The landform resource inventory uses slope as a proxy for suitability. Land that has a steep slope, such as mountain sides or precipitous hills, is a limiting factor for certain types of production systems and, if not managed carefully, can lead to erosion problems. The slope information is derived from the elevation database and is expressed in percentage. The brown areas of the map are mainly concentrated on the borders of Iringa and Dodoma with Morogoro and in the northeast – Kilimanjaro and Arusha – with more than 15 percent of slope.

Figure 4A.2

Soil and landform resource inventory



a. Dominant soil

b. Slope

APPENDIX 4 B

PRINCIPLES AND PRACTICES OF CONSERVATION AGRICULTURE

CA is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment. CA is based on enhancing natural biological processes above and below the ground. Interventions such as mechanical soil tillage are reduced to an absolute minimum, and the use of external inputs such as agrochemicals and nutrients of mineral or organic origin are applied at an optimum level and in a way that quantity does not interfere with, or disrupt, the biological processes. CA is characterized by three principles which are linked to each other, namely:

1. **Direct seeding or planting**
   Direct seeding involves growing crops without mechanical seedbed preparation and with minimal soil disturbance since the harvest of the previous crop. The term direct seeding is understood in CA systems as synonymous with no-till farming, zero tillage, no-tillage, direct drilling, etc. The equipment penetrates the soil cover, opens a seeding slot and places the seed into that slot. The size of the seed slot and the associated movement of soil are to be kept at the absolute minimum possible. Land preparation for seeding or planting under no-tillage involves slashing or rolling the weeds, previous crop residues or cover crops; or spraying herbicides for weed control, and seeding directly through the mulch.

2. **Permanent soil cover**
   A permanent soil cover is important to: protect the soil against the deleterious effects of exposure to rain and sun, to provide the micro- and macro-organisms in the soil with a constant supply of "food", and to alter the microclimate in the soil for optimal growth and development of soil organisms, including plant roots. Cover crops need to be managed before planting the main crop. This can be done manually or with animal or tractor power. The important point is that the soil is always kept covered.

3. **Crop rotations**
   The rotation of crops is not only necessary to offer a diverse "diet" to the soil micro-organisms, but as they root at different soil depths, they are capable of exploring different soil layers for nutrients. Nutrients that have been leached to deeper layers and that are no longer available for the commercial crop can be "recycled" by the crops in rotation. This way the rotation crops function as biological pumps. Furthermore, a diversity of

crops in rotation leads to a diverse soil flora and fauna, as the roots excrete different organic substances that attract different types of bacteria and fungi, which in turn, play an important role in the transformation of these substances into plant available nutrients. Crop rotation also has an important phytosanitary function as it prevents the carryover of crop-specific pests and diseases from one crop to the next via crop residues.

Conservation agriculture, understood in this way, provides a number of advantages on global, regional, local and farm level:

- It provides a truly sustainable production system, not only conserving but also enhancing the natural resources and increasing the variety of soil biota, fauna and flora (including wild life) in agricultural production systems without sacrificing yields on high production levels. As CA depends on biological processes to work, it enhances the biodiversity in an agricultural production system on a micro- as well as macro-level.
- No-till fields act as a sink for CO2 and conservation farming applied on a global scale could provide a major contribution to control air pollution in general and global warming in particular. Farmers applying this practice could eventually be rewarded with carbon credits.
- Soil tillage is among all farming operations the single most energy consuming and thus, in mechanized agriculture, air-polluting, operation. By not tilling the soil, farmers can save between 30 and 40 percent of time, labour and, in mechanized agriculture, fossil fuels as compared to conventional cropping.
- Soils under CA have very high water infiltration capacities reducing surface runoff and thus soil erosion significantly. This improves the quality of surface water reducing pollution from soil erosion, and enhances groundwater resources. In many areas it has been observed after some years of conservation farming that natural springs that had dried up many years ago, started to flow again. The potential effect of a massive adoption of conservation farming on global water balances is not yet fully recognized.
- Conservation agriculture is by no means a low output agriculture and allows yields comparable with modern intensive agriculture but in a sustainable way. Yields tend to increase over the years with yield variations decreasing.
- For the farmer, conservation farming is mostly attractive because it allows a reduction of the production costs, reduction of time and labour, particularly at times of peak demand such as land preparation and planting and in mechanized systems it reduces the costs of investment and maintenance of machinery in the long term.

Disadvantages in the short term might be the high initial costs of specialized planting equipment and the completely new dynamics of a conservation farming system, requiring high management skills and a learning process by the farmer. Long-term experience with conservation farming all over the world has shown that conservation farming does not present more or less but different problems to a farmer, all of them capable of being resolved. Particularly in Brazil the area under conservation farming is now growing exponentially having already reached the 10 million hectare mark. Also in North America the concept is widely adopted.

APPENDIX 4 C AVAILABILITY OF LAND

The second step in the Module 1 framework is to filter out lands already in use or that have protected status (Figure 4.2). The LSA assigns the degree of suitability in growing a specific crop based on biophysical and management characteristics (climate, soil, mechanization, inputs, etc.) to all the land. To get a true understanding of which lands are available for bioenergy production, the LSA results are refined by excluding environmental, agriculture and urban areas. Equation E1 is applied to exclude environmental areas. Equation E2 is used to exclude agriculture and urban areas, see below.

E1: No_Enviroment = Tot land – Conservation/Protected
E2: No_Ag_Conflict = No_Enviroment – Agriculture – Urban

Before the LSA results can be interpreted, existing and protected land uses must be removed from consideration. To start, the World Database on Protected Areas (WCMC) was used to designate conservation and protected areas for Tanzania. The International Union for Conservation of Nature (IUCN) has defined a series of six protected area management categories. In Tanzania, three of these classes are present, the specifics of which are described in Table 4C.1.

Table 4C.1
Description of Protected Area Classes present in Tanzania

Category	Description
Category II National park	National Park: protected area managed mainly for ecosystem protection and recreation Category II protected areas are large natural or near natural areas set aside to protect large-scale ecological processes, along with the complement of species and ecosystems characteristic of the area, which also provide a foundation for environmentally and culturally compatible spiritual, scientific, educational, recreational and visitor opportunities.
Category IV Game reserve	Habitat/Species Management Area: protected area managed mainly for conservation through management intervention Category IV protected areas aim to protect particular species or habitats and management reflects this priority. Many category IV protected areas will need regular, active interventions to address the requirements of particular species or to maintain habitats, but this is not a requirement of the category.
Category VI Conservation area	Managed Resource Protected Area: protected area managed mainly for the sustainable use of natural ecosystems Category VI protected areas conserve ecosystems and habitats, together with associated cultural values and traditional natural resource management systems. They are generally large, with most of the area in a natural condition, where a proportion is under sustainable natural resource management and where low-level non-industrial use of natural resources compatible with nature conservation is seen as one of the main aims of the area.

Source: IUCN, 2008

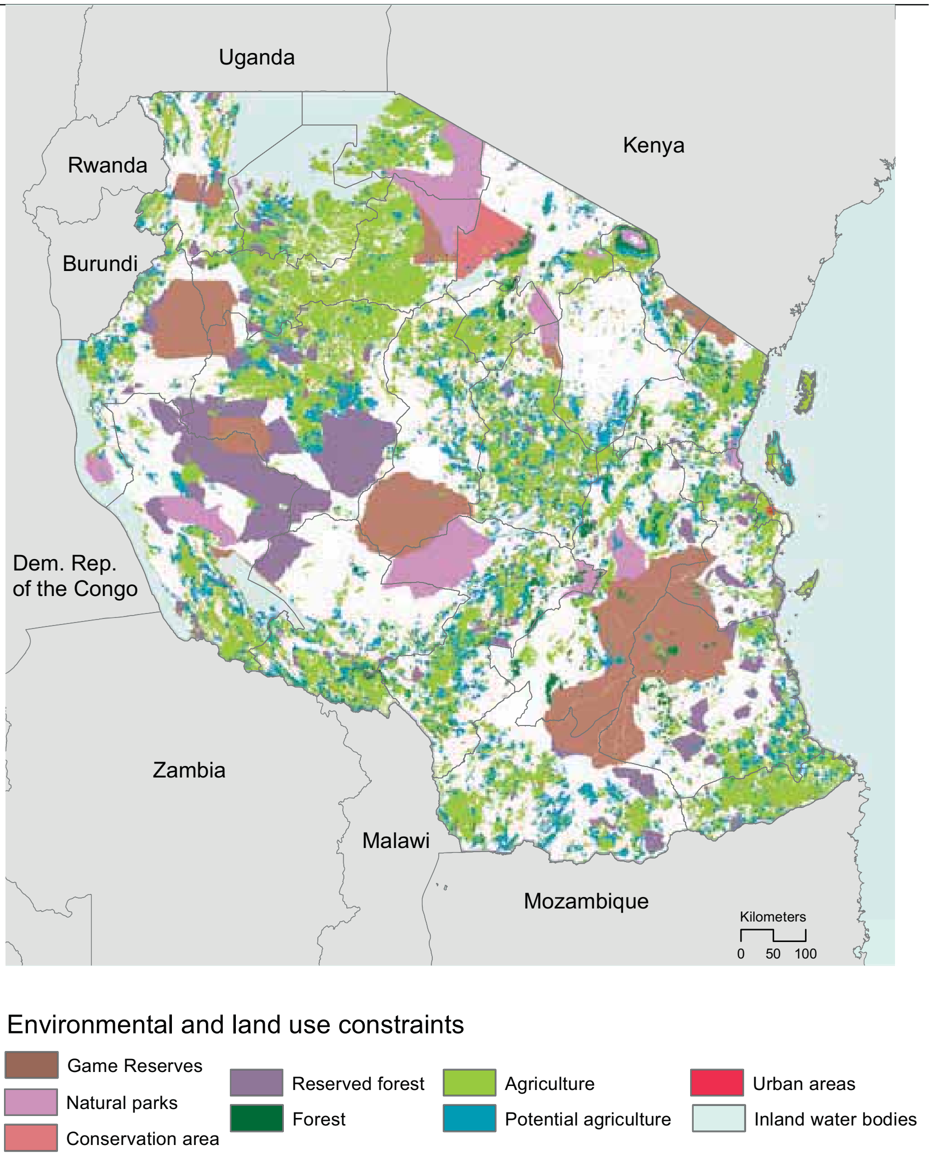
The information on urban settlements and existing agricultural lands were extracted from the Africover Eastern Africa Digital Land Cover database. This database was produced by FAO under the Africover project operational in the period 1995-2002 (FAO, 1995) at 1:200 000 scale and covers ten countries of Eastern Africa. Africover has been produced from visual interpretation of digitally enhanced LANDSAT TM images (Bands 4,3,2) acquired mainly in the year 1997. The land cover classes have been developed using the FAO/UNEP international standard LCCS classification system. For agriculture lands these are considered lands containing more than 60 percent of agriculture, taking into account that the database requires an update since it is symptomatic of a picture of 1997; the potential agriculture are lands containing in 1997 from 20 to 40 percent of agriculture, considering the expansion of the agriculture in the next 20-30 years simply due to the increase of the population.

Figure 4C.1 shows the map of land use constraints for Tanzania. These areas were used as a filter to contextualize the land suitability results.

Once the lands described above are identified and removed from the assessment, the remaining land available for bioenergy production becomes clear. To insure food security is not jeopardized, it is paramount that existing agricultural lands are also considered and protected. However, these lands are not removed in the same way as other existing uses of land as the suitability assessment can estimate the potential for intensification of existing lands as well as agricultural expansion on to new lands.

Figure 4C.1

Protected areas and specific land use



APPENDIX 4 D

TABULAR RESULTS

4D.1 CASSAVA

TABLE 4D.1a

Highly and moderately suitable land for cassava by region (ha)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	-	-	-	-	-	-	-	-
Dar es Salaam	-	4 275	-	6 453	12 741	93 843	13 210	88 707
Dodoma	-	-	-	-	-	30 055	-	30 055
Iringa	35 162	65 400	35 205	65 443	125 503	188 283	125 548	190 363
Kagera	-	6 346	-	38 357	-	189 534	-	195 742
Kigoma	109 011	321 803	157 874	427 992	594 294	1 339 688	625 447	1 366 635
Kilimanjaro	-	-	-	-	-	-	-	-
Lindi	589 589	989 160	730 029	971 533	1 555 758	3 305 362	1 790 380	3 368 327
Manyara	-	-	-	-	-	-	-	-
Mara	12 493	31 274	17 602	55 139	59 350	167 101	61 686	162 984
Mbeya	-	16 314	-	19 772	-	265 791	-	279 020
Morogoro	963 279	1 876 113	1 662 562	1 523 673	3 334 311	1 483 530	3 543 266	1 354 210
Mtwara	-	-	-	-	-	1 004 303	-	1 067 429
Mwanza	292	58 225	292	76 539	29 948	668 190	30 000	683 275
Pwani	290 450	734 777	408 189	860 741	1 511 327	833 535	1 599 219	748 581
Rukwa	658 532	1 501 239	799 252	1 628 023	2 506 520	1 822 710	2 747 292	1 736 460
Ruvuma	89 888	291 287	121 003	336 529	246 212	2 219 703	267 315	2 525 451
Shinyanga	2 476	12 967	2 476	43 381	44 787	693 778	45 733	700 200
Singida	-	-	-	-	-	-	-	-
Tabora	84 354	351 750	84 354	747 826	765 960	1 978 847	834 570	1 920 113
Tanga	107 885	425 184	221 871	439 028	844 230	738 985	880 552	739 315
Total	**2 943 411**	**6 686 114**	**4 240 709**	**7 240 429**	**11 630 941**	**17 023 238**	**12 564 218**	**17 156 867**

TABLE 4D.1b

Expansion: highly and moderately suitable new area available for cassava by region (ha)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	-	-	-	-	-	-	-	-
Dar es Salaam	-	98	-	149	231	24 874	252	20 647
Dodoma	-	-	-	-	-	13 677	-	13 677
Iringa	6 704	14 350	6 746	14 392	23 008	96 978	23 053	98 154
Kagera	-	1 334	-	17 266	-	78 094	-	80 172
Kigoma	73 212	185 630	104 317	227 262	342 160	561 782	359 216	559 193
Kilimanjaro	-	-	-	-	-	-	-	-
Lindi	212 249	219 179	299 660	182 305	372 632	1 135 383	500 608	1 149 668
Manyara	-	-	-	-	-	-	-	-
Mara	1 144	7 331	1 724	9 292	5 290	31 136	5 496	30 303
Mbeya	-	1 514	-	1 671	-	23 852	-	26 064
Morogoro	351 271	577 323	627 529	495 152	1 073 182	485 495	1 141 748	457 505
Mtwara	-	-	-	-	-	201 595	-	224 390
Mwanza	-	6 007	-	7 305	675	101 102	675	102 242
Pwani	134 663	312 850	196 758	327 842	619 943	300 948	651 271	268 116
Rukwa	287 256	595 867	362 073	580 408	1 014 328	606 173	1 092 256	574 010
Ruvuma	41 023	135 987	69 020	175 275	73 035	1 107 302	81 232	1 265 399
Shinyanga	-	180	-	258	258	136 149	258	137 005
Singida	-	-	-	-	-	-	-	-
Tabora	18 442	80 825	18 442	166 936	169 344	422 801	185 379	416 882
Tanga	27 467	136 336	58 549	137 682	271 109	256 920	283 118	257 565
Total	**1 153 431**	**2 274 811**	**1 744 818**	**2 343 195**	**3 965 195**	**5 584 261**	**4 324 562**	**5 680 992**

TABLE 4D.1c

Intensification: highly and moderately suitable area available for cassava already under crop production by region (ha)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	-	-	-	-	-	-	-	-
Dar es Salaam	-	3 784	-	5 707	11 449	54 075	11 801	55 138
Dodoma	-	-	-	-	-	9 382	-	9 382
Iringa	120	1 120	120	1 121	612	27 297	611	28 035
Kagera	-	3 059	-	15 750	-	96 910	-	98 927
Kigoma	12 984	45 262	19 051	52 338	97 869	349 393	103 071	349 888
Kilimanjaro	-	-	-	-	-	-	-	-
Lindi	54 163	44 005	76 816	52 657	116 608	736 211	131 471	774 843
Manyara	-	-	-	-	-	-	-	-
Mara	11 349	19 152	15 878	41 043	53 725	124 975	55 854	121 736
Mbeya	-	14 321	-	17 530	-	105 438	-	112 276
Morogoro	143 596	222 108	233 639	206 500	543 809	190 739	558 992	180 559
Mtwara	-	-	-	-	-	716 663	-	748 460
Mwanza	292	35 243	292	43 024	27 703	507 458	27 755	518 237
Pwani	70 621	180 130	114 738	233 316	384 780	260 640	397 801	247 639
Rukwa	95 104	235 879	123 281	221 238	331 622	296 232	419 769	272 283
Ruvuma	2 845	24 375	4 268	29 863	3 793	564 916	4 268	653 340
Shinyanga	-	1 263	-	1 803	1 803	372 342	1 803	378 835
Singida	-	-	-	-	-	-	-	-
Tabora	6 795	31 917	6 795	58 680	59 090	436 020	65 473	426 624
Tanga	51 187	190 573	103 997	215 154	416 528	317 735	436 756	316 763
Total	**449 056**	**1 052 191**	**698 875**	**1 195 724**	**2 049 391**	**5 166 426**	**2 215 425**	**5 292 965**

TABLE 4D.1d

Expansion: potential production of cassava into new highly and moderately suitable land by region (tons))

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	-	-	-	-	-	-	-	-
Dar es Salaam	-	181	-	1 121	759	58 441	3 034	177 552
Dodoma	-	-	-	-	-	32 139	-	117 614
Iringa	17 362	26 543	70 832	107 926	75 692	227 876	277 539	844 054
Kagera	-	2 467	-	129 462	-	183 508	-	689 427
Kigoma	189 583	343 355	1 095 189	1 704 179	1 125 617	1 320 032	4 324 611	4 808 481
Kilimanjaro	-	-	-	-	-	-	-	-
Lindi	549 614	405 368	3 146 027	1 366 830	1 225 813	2 667 788	6 026 825	9 886 112
Manyara	-	-	-	-	-	-	-	-
Mara	2 962	13 562	18 105	69 684	17 400	73 160	66 164	260 574
Mbeya	-	2 800	-	12 531	-	56 043	-	224 118
Morogoro	909 572	1 067 903	6 588 156	3 712 955	3 843 519	1 140 694	14 938 174	3 933 881
Mtwara	-	-	-	-	-	473 694	-	1 929 576
Mwanza	-	11 112	-	54 783	2 221	237 571	8 126	879 204
Pwani	348 652	578 641	2 065 461	2 458 275	2 209 691	707 081	8 523 451	2 305 428
Rukwa	743 800	1 102 151	3 801 058	4 352 166	3 336 817	1 424 183	13 149 765	4 935 586
Ruvuma	106 238	251 544	724 656	1 314 454	240 270	2 601 931	977 967	10 881 591
Shinyanga	-	334	-	1 932	848	319 929	3 102	1 178 164
Singida	-	-	-	-	-	-	-	-
Tabora	47 722	149 506	193 466	1 251 909	557 088	993 474	2 231 785	3 584 804
Tanga	71 131	252 193	614 688	1 032 475	895 750	603 680	3 423 633	2 214 816
Total	**2 986 636**	**4 207 660**	**18 317 638**	**17 570 682**	**13 531 485**	**13 121 224**	**53 954 176**	**48 850 982**

TABLE 4D.1e

Intensification: potential production of dry cassava into highly and moderately suitable land already under crop production by region (tons)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	-	-	-	-	-	-	-	-
Dar es Salaam	-	6 999	-	42 791	37 666	127 062	142 065	474 150
Dodoma	-	-	-	-	-	22 045	-	80 676
Iringa	309	2 071	1 253	8 402	2 012	64 143	7 364	241 062
Kagera	-	5 659	-	118 080	-	227 722	-	850 701
Kigoma	33 624	83 719	200 013	392 461	321 965	821 000	1 240 873	3 008 756
Kilimanjaro	-	-	-	-	-	-	-	-
Lindi	140 251	81 385	806 441	394 869	383 594	1 729 915	1 582 737	6 663 079
Manyara	-	-	-	-	-	-	-	-
Mara	29 391	35 427	166 694	307 811	176 749	293 671	672 453	1 046 873
Mbeya	-	26 489	-	131 465	-	247 758	-	965 507
Morogoro	371 827	410 845	2 452 874	1 548 451	2 018 678	448 171	7 597 957	1 552 568
Mtwara	-	-	-	-	-	1 683 989	-	6 436 146
Mwanza	757	65 189	3 070	322 649	94 052	1 192 412	344 814	4 456 488
Pwani	182 852	333 182	1 204 545	1 749 607	1 360 635	612 399	5 152 999	2 129 364
Rukwa	246 219	436 244	1 294 046	1 658 766	1 090 893	695 980	5 053 636	2 341 251
Ruvuma	7 368	45 086	44 806	223 949	12 479	1 327 449	51 377	5 618 309
Shinyanga	-	2 335	-	13 526	5 933	874 956	21 714	3 257 801
Singida	-	-	-	-	-	-	-	-
Tabora	17 576	59 037	71 256	440 051	194 388	1 024 549	788 251	3 668 691
Tanga	132 538	352 471	1 091 851	1 613 363	1 374 224	746 555	5 272 689	2 723 755
Total	**1 162 712**	**1 946 138**	**7 336 849**	**8 966 241**	**7 073 268**	**12 139 776**	**27 928 929**	**45 515 177**

4D.2 SUGAR CANE

TABLE 4D.2a

Highly and moderately suitable land for sugar cane by region (ha)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	-	-	-	-	-	-	-	-
Dar es Salaam	-	-	-	-	12 741	6 790	12 672	6 859
Dodoma	-	-	-	-	-	-	-	-
Iringa	-	-	-	-	-	-	-	-
Kagera	-	-	-	-	-	29 049	-	30 021
Kigoma	-	-	-	-	-	-	-	-
Kilimanjaro	-	-	-	-	-	-	-	-
Lindi	-	-	-	-	-	-	-	-
Manyara	-	-	-	-	-	-	-	-
Mara	-	-	-	-	-	-	-	-
Mbeya	-	-	-	-	-	-	-	-
Morogoro	-	-	-	-	-	788 284	-	786 951
Mtwara	-	-	-	-	-	-	-	-
Mwanza	-	17 665	-	41 906	54 297	25 247	56 745	22 819
Pwani	2 544	17 111	8 898	6 049	169 273	476 936	172 393	486 777
Rukwa	-	-	-	-	-	-	-	-
Ruvuma	-	-	-	-	-	-	-	-
Shinyanga	-	-	-	-	-	-	-	-
Singida	-	-	-	-	-	-	-	-
Tabora	-	-	-	-	-	-	-	-
Tanga	36 099	129 254	89 722	77 273	698 980	207 280	705 621	207 099
Total	**38 643**	**164 030**	**98 620**	**125 228**	**935 291**	**1 533 586**	**947 431**	**1 540 526**

TABLE 4D.2b

Expansion: highly and moderately suitable new area available for sugar cane by region (ha)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	-	-	-	-	-	-	-	-
Dar es Salaam	-	-	-	-	231	146	252	124
Dodoma	-	-	-	-	-	-	-	-
Iringa	-	-	-	-	-	-	-	-
Kagera	-	-	-	-	-	14 454	-	14 815
Kigoma	-	-	-	-	-	-	-	-
Kilimanjaro	-	-	-	-	-	-	-	-
Lindi	-	-	-	-	-	-	-	-
Manyara	-	-	-	-	-	-	-	-
Mara	-	-	-	-	-	-	-	-
Mbeya	-	-	-	-	-	-	-	-
Morogoro	-	-	-	-	-	333 247	-	331 955
Mtwara	-	-	-	-	-	-	-	-
Mwanza	-	4 332	-	5 640	6 755	2 856	7 362	2 250
Pwani	1 351	8 647	1 732	2 858	46 147	198 682	44 682	205 187
Rukwa	-	-	-	-	-	-	-	-
Ruvuma	-	-	-	-	-	-	-	-
Shinyanga	-	-	-	-	-	-	-	-
Singida	-	-	-	-	-	-	-	-
Tabora	-	-	-	-	-	-	-	-
Tanga	1 465	6 868	3 279	3 833	197 124	76 936	202 068	74 226
Total	**2 816**	**19 847**	**5 011**	**12 331**	**250 257**	**626 321**	**254 364**	**628 557**

TABLE 4D.2c

Intensification: highly and moderately suitable area available for sugar cane already under crop production by region (ha)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	-	-	-	-	-	-	-	-
Dar es Salaam	-	-	-	-	11 449	5 975	11 263	6 162
Dodoma	-	-	-	-	-	-	-	-
Iringa	-	-	-	-	-	-	-	-
Kagera	-	-	-	-	-	14 726	-	15 328
Kigoma	-	-	-	-	-	-	-	-
Kilimanjaro	-	-	-	-	-	-	-	-
Lindi	-	-	-	-	-	-	-	-
Manyara	-	-	-	-	-	-	-	-
Mara	-	-	-	-	-	-	-	-
Mbeya	-	-	-	-	-	-	-	-
Morogoro	-	-	-	-	-	244 952	-	244 610
Mtwara	-	-	-	-	-	-	-	-
Mwanza	-	6 223	-	18 600	23 578	14 009	25 198	12 388
Pwani	1 057	5 838	5 127	2 703	83 778	135 077	86 619	131 389
Rukwa	-	-	-	-	-	-	-	-
Ruvuma	-	-	-	-	-	-	-	-
Shinyanga	-	-	-	-	-	-	-	-
Singida	-	-	-	-	-	-	-	-
Tabora	-	-	-	-	-	-	-	-
Tanga	28 893	101 160	72 219	57 378	420 611	94 280	421 306	96 928
Total	**29 950**	**113 221**	**77 346**	**78 681**	**539 416**	**509 019**	**544 386**	**506 805**

TABLE 4D.2d

Expansion: potential production of sugar into new highly and moderately suitable land by region (tons)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	-	-	-	-	-	-	-	-
Dar es Salaam	-	-	-	-	598	269	2 451	860
Dodoma	-	-	-	-	-	-	-	-
Iringa	-	-	-	-	-	-	-	-
Kagera	-	-	-	-	-	26 737	-	102 956
Kigoma	-	-	-	-	-	-	-	-
Kilimanjaro	-	-	-	-	-	-	-	-
Lindi	-	-	-	-	-	-	-	-
Manyara	-	-	-	-	-	-	-	-
Mara	-	-	-	-	-	-	-	-
Mbeya	-	-	-	-	-	-	-	-
Morogoro	-	-	-	-	-	616 444	-	2 306 849
Mtwara	-	-	-	-	-	-	-	-
Mwanza	-	4 332	-	34 118	17 494	5 284	71 622	15 637
Pwani	2 835	8 647	14 662	17 291	122 943	367 515	447 641	1 425 893
Rukwa	-	-	-	-	-	-	-	-
Ruvuma	-	-	-	-	-	-	-	-
Shinyanga	-	-	-	-	-	-	-	-
Singida	-	-	-	-	-	-	-	-
Tabora	-	-	-	-	-	-	-	-
Tanga	3 075	6 868	27 775	23 192	515 113	142 299	1 983 372	515 787
Total	**5 910**	**19 847**	**42 437**	**74 601**	**656 148**	**1 158 548**	**2 505 086**	**4 367 982**

TABLE 4D.2e

Intensification: potential production of sugar into highly and moderately suitable land already under crop production by region (tons)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	-	-	-	-	-	-	-	-
Dar es Salaam	-	-	-	-	29 651	11 052	109 573	42 824
Dodoma	-	-	-	-	-	-	-	-
Iringa	-	-	-	-	-	-	-	-
Kagera	-	-	-	-	-	27 240	-	106 523
Kigoma	-	-	-	-	-	-	-	-
Kilimanjaro	-	-	-	-	-	-	-	-
Lindi	-	-	-	-	-	-	-	-
Manyara	-	-	-	-	-	-	-	-
Mara	-	-	-	-	-	-	-	-
Mbeya	-	-	-	-	-	-	-	-
Morogoro	-	-	-	-	-	453 122	-	1 699 884
Mtwara	-	-	-	-	-	-	-	-
Mwanza	-	11 497	-	112 515	61 061	25 914	245 163	86 086
Pwani	2 219	13 078	43 430	16 348	222 577	249 866	863 793	913 064
Rukwa	-	-	-	-	-	-	-	-
Ruvuma	-	-	-	-	-	-	-	-
Shinyanga	-	-	-	-	-	-	-	-
Singida	-	-	-	-	-	-	-	-
Tabora	-	-	-	-	-	-	-	-
Tanga	60 653	155 140	611 563	347 016	1 187 181	174 366	4 463 090	673 518
Total	**62 872**	**179 715**	**654 993**	**475 879**	**1 500 470**	**941 560**	**5 681 619**	**3 521 899**

4D.3 SWEET SORGHUM

TABLE 4D.3a

Highly and moderately suitable land for sweet sorghum by region (ha)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	38 198	241 829	52 593	312 461	80 618	1 534 827	80 690	1 749 355
Dar es Salaam	44 751	69 626	78 386	42 578	134 628	3 403	127 836	10 194
Dodoma	280 234	1 097 916	755 355	1 346 127	2 538 488	762 171	2 594 611	748 606
Iringa	526 777	1 600 795	1 342 330	1 564 821	3 490 695	740 845	3 515 331	726 548
Kagera	342 751	903 601	1 067 621	634 290	1 652 534	406 872	1 652 675	399 196
Kigoma	1 834 490	772 808	2 634 989	256 638	3 130 321	55 870	3 132 373	54 256
Kilimanjaro	-	71 415	-	96 850	52 930	726 626	57 314	748 739
Lindi	5 344 305	462 194	5 828 557	195 797	6 185 911	30 347	6 216 260	-
Manyara	280 565	726 545	467 265	1 068 460	1 864 628	1 784 265	1 965 160	1 785 114
Mara	710 672	272 229	1 160 928	195 027	1 363 306	87 746	1 388 462	77 169
Mbeya	1 379 915	1 160 731	2 189 181	928 709	3 156 360	594 687	3 162 754	594 388
Morogoro	3 138 891	845 416	3 648 663	945 507	4 303 747	992 260	4 309 264	997 204
Mtwara	1 427 386	112 564	1 508 393	46 938	1 636 639	6 840	1 643 478	-
Mwanza	857 605	188 707	1 307 505	122 140	1 510 877	25 983	1 531 446	5 415
Pwani	1 436 982	276 687	1 642 504	491 964	1 857 294	514 728	1 854 058	561 139
Rukwa	3 675 551	650 912	4 176 906	352 326	5 199 091	80 765	5 275 630	5 215
Ruvuma	4 653 447	915 634	5 258 084	502 602	5 946 760	108 984	5 966 122	99 137
Shinyanga	1 569 359	848 884	2 465 917	873 081	3 514 905	330 469	3 658 186	241 894
Singida	361 611	1 640 555	1 545 912	1 449 873	3 423 283	394 211	3 429 565	400 802
Tabora	3 384 271	1 517 460	5 052 524	751 013	6 346 209	17 027	6 363 237	-
Tanga	1 509 283	417 252	1 845 604	229 456	2 196 484	168 343	2 203 477	165 392
Total	**32 797 044**	**14 793 760**	**44 029 217**	**12 406 658**	**59 585 708**	**9 367 269**	**60 127 929**	**9 369 763**

TABLE 4D.3b

Expansion: highly and moderately suitable new area available for sweet sorghum by region (ha)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	35 033	162 989	47 859	208 147	72 614	802 166	72 665	911 696
Dar es Salaam	11 589	13 099	16 993	10 544	33 252	83	31 700	1 633
Dodoma	52 231	275 104	156 703	382 075	713 725	231 390	733 175	223 020
Iringa	211 707	509 232	430 272	625 289	1 371 216	299 173	1 386 052	292 161
Kagera	150 643	413 520	487 626	277 879	707 588	223 206	707 699	217 631
Kigoma	847 325	320 170	1 159 187	111 184	1 368 067	27 010	1 369 736	25 636
Kilimanjaro	-	10 825	-	19 675	10 686	247 783	11 805	258 875
Lindi	1 775 315	164 844	1 945 720	68 462	2 073 778	12 720	2 086 503	-
Manyara	178 870	538 731	311 995	810 648	1 355 203	1 087 745	1 432 083	1 077 542
Mara	99 670	54 675	173 923	50 892	224 931	21 823	230 787	17 845
Mbeya	707 293	817 479	1 316 252	639 896	1 903 675	424 958	1 897 416	434 686
Morogoro	911 894	388 028	1 154 953	439 546	1 464 331	415 498	1 467 583	413 799
Mtwara	286 382	29 012	307 158	12 949	339 995	1 581	341 575	-
Mwanza	100 716	61 001	228 357	23 162	260 817	3 481	264 297	-
Pwani	550 300	98 358	612 494	204 626	686 898	225 394	685 837	242 480
Rukwa	1 247 326	293 211	1 424 707	135 928	1 821 760	26 695	1 845 907	3 297
Ruvuma	2 190 710	388 526	2 440 584	233 758	2 745 039	60 964	2 757 167	57 328
Shinyanga	304 025	159 879	515 805	153 731	718 502	30 484	733 177	18 546
Singida	57 494	737 980	582 920	646 117	1 418 322	204 654	1 422 108	207 868
Tabora	746 110	430 163	1 250 524	220 619	1 604 164	6 616	1 610 780	-
Tanga	588 268	161 076	732 116	82 877	860 025	40 844	863 229	38 615
Total	**11 052 901**	**6 027 902**	**15 296 148**	**5 358 004**	**21 754 588**	**4 394 268**	**21 951 281**	**4 442 658**

TABLE 4D.3c

Intensification: highly and moderately suitable area available for sweet sorghum already under crop production by region (ha)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	198	66 900	283	91 581	1 360	356 542	1 381	370 172
Dar es Salaam	29 827	45 213	54 113	23 436	82 976	3 108	79 811	6 274
Dodoma	223 356	781 347	578 512	889 742	1 669 566	403 743	1 699 829	399 501
Iringa	164 290	373 796	274 774	544 708	849 363	370 205	854 710	367 066
Kagera	165 425	313 504	412 809	231 577	676 804	103 317	676 827	101 150
Kigoma	397 666	240 991	598 283	73 507	732 463	24 121	732 847	23 881
Kilimanjaro	-	57 340	-	72 277	36 722	318 452	39 791	321 316
Lindi	888 054	106 116	1 051 731	32 826	1 142 845	11 496	1 154 335	-
Manyara	99 837	174 978	152 540	234 450	462 496	515 075	483 008	519 598
Mara	367 014	106 341	589 457	86 780	725 340	18 034	742 649	794
Mbeya	366 688	267 214	497 351	228 117	720 266	148 516	735 939	135 288
Morogoro	354 308	119 274	430 186	209 547	529 891	297 335	530 455	297 210
Mtwara	1 020 615	68 458	1 072 069	26 699	1 151 048	4 694	1 155 743	-
Mwanza	647 776	109 539	943 878	94 040	1 100 757	22 015	1 117 709	5 063
Pwani	456 148	55 388	521 536	132 523	570 743	122 629	574 886	119 468
Rukwa	654 469	241 688	759 080	145 504	1 068 233	47 355	1 115 065	699
Ruvuma	1 391 052	351 595	1 634 471	183 564	1 900 182	32 801	1 904 138	29 838
Shinyanga	883 646	495 450	1 402 840	523 418	2 038 249	91 512	2 118 047	14 350
Singida	5 132	194 961	155 378	456 531	729 798	182 791	732 293	186 148
Tabora	743 204	726 972	1 350 476	340 687	1 835 155	10 372	1 845 526	-
Tanga	680 758	145 250	809 658	64 063	944 175	50 714	945 866	49 242
Total	**9 539 463**	**5 042 315**	**13 289 425**	**4 685 577**	**18 968 432**	**3 134 827**	**19 240 855**	**2 947 058**

TABLE 4D.3d

Expansion: potential production of sweet sorghum's juice into new highly and moderately suitable land by region (tons)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	122 277	274 881	667 611	1 379 621	413 480	1 704 484	1 590 537	7 122 182
Dar es Salaam	25 394	20 462	156 202	65 894	118 023	177	404 009	12 760
Dodoma	115 214	429 783	1 381 176	2 387 592	2 408 600	491 621	9 129 198	1 742 099
Iringa	557 985	988 854	4 561 902	5 239 102	6 019 878	699 781	23 011 498	2 546 844
Kagera	411 729	815 301	5 626 726	2 043 185	3 297 152	481 476	12 534 604	1 703 509
Kigoma	2 300 050	610 271	14 140 652	883 262	6 096 419	72 313	22 990 036	260 378
Kilimanjaro	-	16 911	-	122 951	31 788	526 509	129 111	2 022 356
Lindi	4 112 091	257 485	20 102 367	427 513	7 765 672	26 936	29 117 877	-
Manyara	407 002	841 591	2 843 335	5 065 801	4 225 630	2 311 162	16 421 490	8 417 218
Mara	228 756	86 102	1 657 720	320 234	1 068 352	50 127	4 128 252	141 679
Mbeya	1 645 038	1 312 120	13 005 852	4 140 581	6 645 713	908 549	24 553 391	3 411 558
Morogoro	2 182 177	652 720	12 101 009	2 900 236	5 770 260	883 517	21 563 432	3 233 728
Mtwara	655 664	45 321	3 132 282	80 887	1 271 452	3 342	4 742 674	-
Mwanza	227 505	95 295	2 259 751	144 720	973 392	7 384	3 618 286	-
Pwani	1 273 533	153 643	6 205 986	1 278 703	2 552 276	478 930	9 437 924	1 894 243
Rukwa	2 915 838	460 153	14 472 421	854 804	6 730 085	57 529	25 247 133	28 396
Ruvuma	5 256 828	655 548	25 552 765	1 624 075	10 793 241	130 169	40 381 410	449 314
Shinyanga	669 567	249 755	5 040 258	960 657	2 593 785	64 746	9 729 172	144 867
Singida	125 935	1 152 990	5 164 447	4 037 541	5 055 253	434 821	18 712 078	1 623 711
Tabora	1 648 308	672 052	12 407 933	1 378 598	5 969 661	14 047	22 030 639	-
Tanga	1 391 964	251 632	7 457 197	517 799	3 132 450	86 781	11 620 260	301 644
Total	**26 272 854**	**10 042 868**	**157 937 590**	**35 853 754**	**82 932 560**	**9 434 399**	**311 093 009**	**35 056 483**

TABLE 4D.3e

Intensification: potential production of sweet sorghum's juice into highly and moderately suitable land already under crop production by region (tons)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	589	105 044	3 244	574 834	6 245	757 630	24 115	2 891 900
Dar es Salaam	67 476	70 639	503 722	146 444	269 369	6 597	950 301	48 976
Dodoma	489 132	1 220 653	5 070 269	5 559 783	5 820 768	857 803	21 968 930	3 120 607
Iringa	438 575	691 672	2 888 708	4 213 351	3 472 528	827 042	13 183 484	3 035 475
Kagera	439 150	630 460	4 841 582	1 808 190	3 279 176	222 845	12 484 235	793 792
Kigoma	1 309 723	503 985	8 718 296	604 727	3 833 196	61 062	14 668 091	226 501
Kilimanjaro	-	89 589	-	451 710	109 239	676 687	435 174	2 510 212
Lindi	2 046 146	165 769	10 988 012	204 993	4 283 054	24 378	16 016 669	-
Manyara	233 335	273 346	1 447 772	1 465 068	1 465 182	1 094 434	5 632 205	4 059 008
Mara	831 166	166 138	5 870 071	542 202	3 014 837	44 535	11 477 491	9 010
Mbeya	1 132 598	526 628	6 148 063	1 771 743	3 443 898	339 256	13 485 676	1 124 452
Morogoro	857 744	186 454	4 468 689	1 311 436	1 981 623	631 798	7 340 287	2 321 854
Mtwara	2 341 381	106 942	10 975 999	166 758	4 338 456	9 956	16 082 469	-
Mwanza	1 471 757	173 411	9 653 722	592 254	4 070 913	47 013	15 151 944	40 796
Pwani	1 055 009	86 526	5 341 041	828 149	2 124 813	260 574	7 858 704	933 309
Rukwa	1 518 524	378 502	7 612 898	911 192	3 817 941	100 945	15 079 321	6 696
Ruvuma	3 339 780	585 748	16 898 402	1 210 997	7 514 114	71 116	28 089 560	239 140
Shinyanga	1 947 701	773 915	13 432 482	3 270 459	7 382 740	194 300	28 244 479	112 095
Singida	11 222	304 592	1 362 436	2 852 943	2 380 418	388 346	8 802 217	1 453 972
Tabora	1 639 317	1 135 779	12 823 403	2 128 831	6 868 994	22 028	25 326 242	-
Tanga	1 587 829	226 911	8 334 451	400 266	3 450 163	107 761	12 750 313	384 685
Total	**22 758 152**	**8 402 702**	**137 383 264**	**31 016 328**	**72 927 666**	**6 746 107**	**275 051 907**	**23 312 481**

4D.4 OIL PALM

TABLE 4D.4a

Highly and moderately suitable land for oil palm by region (ha)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	-	-	-	-	-	-	-	-
Dar es Salaam	-	-	-	-	73 414	22 672	81 799	21 539
Dodoma	-	-	-	-	-	-	-	-
Iringa	-	-	-	-	-	-	-	-
Kagera	-	-	-	-	-	38 252	-	35 172
Kigoma	-	-	-	-	-	-	-	-
Kilimanjaro	-	-	-	-	-	-	-	-
Lindi	-	-	-	-	-	-	-	-
Manyara	-	-	-	-	-	-	-	-
Mara	-	-	-	-	-	-	-	-
Mbeya	-	-	-	-	-	-	-	-
Morogoro	-	-	-	-	-	-	-	-
Mtwara	-	-	-	-	-	-	-	-
Mwanza	-	19 845	-	25 919	41 992	19 771	48 473	27 026
Pwani	845	13 207	7 950	6 321	290 183	16 814	336 131	21 864
Rukwa	-	-	-	-	-	-	-	-
Ruvuma	-	-	-	-	-	-	-	-
Shinyanga	-	-	-	-	-	-	-	-
Singida	-	-	-	-	-	-	-	-
Tabora	-	-	-	-	-	-	-	-
Tanga	44 911	91 060	80 141	100 419	949 036	128 251	1 036 377	159 053
Total	**45 756**	**124 112**	**88 091**	**132 659**	**1 354 625**	**225 760**	**1 502 780**	**264 654**

TABLE 4D.4b

Expansion: highly and moderately suitable new area available for oil palm by region (ha)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	-	-	-	-	-	-	-	-
Dar es Salaam	-	-	-	-	7 711	1 939	9 288	1 910
Dodoma	-	-	-	-	-	-	-	-
Iringa	-	-	-	-	-	-	-	-
Kagera	-	-	-	-	-	18 847	-	17 419
Kigoma	-	-	-	-	-	-	-	-
Kilimanjaro	-	-	-	-	-	-	-	-
Lindi	-	-	-	-	-	-	-	-
Manyara	-	-	-	-	-	-	-	-
Mara	-	-	-	-	-	-	-	-
Mbeya	-	-	-	-	-	-	-	-
Morogoro	-	-	-	-	-	-	-	-
Mtwara	-	-	-	-	-	-	-	-
Mwanza	-	2 921	-	2 908	4 636	2 998	5 700	3 912
Pwani	351	6 717	4 092	3 085	79 363	4 018	88 029	4 519
Rukwa	-	-	-	-	-	-	-	-
Ruvuma	-	-	-	-	-	-	-	-
Shinyanga	-	-	-	-	-	-	-	-
Singida	-	-	-	-	-	-	-	-
Tabora	-	-	-	-	-	-	-	-
Tanga	1 575	3 461	2 744	4 144	284 934	31 732	321 923	48 126
Total	**1 926**	**13 099**	**6 836**	**10 137**	**376 644**	**59 534**	**424 940**	**75 886**

TABLE 4D.4c

Intensification: highly and moderately suitable area available for oil palm already under crop production by region (ha)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	-	-	-	-	-	-	-	-
Dar es Salaam	-	-	-	-	54 884	17 671	59 547	16 635
Dodoma	-	-	-	-	-	-	-	-
Iringa	-	-	-	-	-	-	-	-
Kagera	-	-	-	-	-	19 509	-	17 856
Kigoma	-	-	-	-	-	-	-	-
Kilimanjaro	-	-	-	-	-	-	-	-
Lindi	-	-	-	-	-	-	-	-
Manyara	-	-	-	-	-	-	-	-
Mara	-	-	-	-	-	-	-	-
Mbeya	-	-	-	-	-	-	-	-
Morogoro	-	-	-	-	-	-	-	-
Mtwara	-	-	-	-	-	-	-	-
Mwanza	-	8 244	-	9 306	15 898	8 761	18 617	15 305
Pwani	468	5 823	3 452	2 875	126 681	5 482	144 346	6 103
Rukwa	-	-	-	-	-	-	-	-
Ruvuma	-	-	-	-	-	-	-	-
Shinyanga	-	-	-	-	-	-	-	-
Singida	-	-	-	-	-	-	-	-
Tabora	-	-	-	-	-	-	-	-
Tanga	37 148	74 349	66 976	78 150	511 784	50 785	550 256	59 285
Total	**37 616**	**88 416**	**70 428**	**90 331**	**709 247**	**102 208**	**772 766**	**115 184**

TABLE 4D.4d

Expansion: potential production of palm oil into new highly and moderately suitable land by region (tons)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	-	-	-	-	-	-	-	-
Dar es Salaam	-	-	-	-	14 068	2 043	43 450	7 716
Dodoma	-	-	-	-	-	-	-	-
Iringa	-	-	-	-	-	-	-	-
Kagera	-	-	-	-	-	18 638	-	75 008
Kigoma	-	-	-	-	-	-	-	-
Kilimanjaro	-	-	-	-	-	-	-	-
Lindi	-	-	-	-	-	-	-	-
Manyara	-	-	-	-	-	-	-	-
Mara	-	-	-	-	-	-	-	-
Mbeya	-	-	-	-	-	-	-	-
Morogoro	-	-	-	-	-	-	-	-
Mtwara	-	-	-	-	-	-	-	-
Mwanza	-	2 512	-	10 090	8 550	4 185	25 822	11 931
Pwani	425	5 776	19 845	10 705	155 602	4 831	527 979	15 988
Rukwa	-	-	-	-	-	-	-	-
Ruvuma	-	-	-	-	-	-	-	-
Shinyanga	-	-	-	-	-	-	-	-
Singida	-	-	-	-	-	-	-	-
Tabora	-	-	-	-	-	-	-	-
Tanga	1 905	2 976	13 302	14 371	559 143	51 478	1 877 916	126 264
Total	**2 330**	**11 264**	**33 147**	**35 166**	**737 363**	**81 175**	**2 475 167**	**236 907**

TABLE 4D.4e

Intensification: potential production of palm oil into highly and moderately suitable land already under crop production by region (tons)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	-	-	-	-	-	-	-	-
Dar es Salaam	-	-	-	-	95 565	17 794	327 813	70 318
Dodoma	-	-	-	-	-	-	-	-
Iringa	-	-	-	-	-	-	-	-
Kagera	-	-	-	-	-	19 104	-	77 632
Kigoma	-	-	-	-	-	-	-	-
Kilimanjaro	-	-	-	-	-	-	-	-
Lindi	-	-	-	-	-	-	-	-
Manyara	-	-	-	-	-	-	-	-
Mara	-	-	-	-	-	-	-	-
Mbeya	-	-	-	-	-	-	-	-
Morogoro	-	-	-	-	-	-	-	-
Mtwara	-	-	-	-	-	-	-	-
Mwanza	-	7 088	-	32 289	27 923	16 375	88 546	34 858
Pwani	564	5 007	16 742	9 972	253 289	6 525	838 195	21 812
Rukwa	-	-	-	-	-	-	-	-
Ruvuma	-	-	-	-	-	-	-	-
Shinyanga	-	-	-	-	-	-	-	-
Singida	-	-	-	-	-	-	-	-
Tabora	-	-	-	-	-	-	-	-
Tanga	44 937	63 926	324 789	271 124	976 409	63 422	3 432 981	202 097
Total	**45 501**	**76 021**	**341 531**	**313 385**	**1 353 186**	**123 220**	**4 687 535**	**406 717**

4D.5 SUNFLOWER

TABLE 4D.5a

Highly and moderately suitable land for sunflower by region (ha)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	332	214 488	593	310 588	920	1 707 562	992	1 730 479
Dar es Salaam	33 765	71 807	46 715	66 122	134 071	3 961	101 973	36 057
Dodoma	272 728	917 386	543 671	1 309 706	2 952 664	463 145	3 031 093	396 760
Iringa	414 702	1 431 995	749 577	1 707 019	2 211 875	2 140 583	2 216 826	2 118 788
Kagera	322 268	557 974	417 183	680 705	933 899	759 519	930 149	763 481
Kigoma	1 117 747	410 967	1 530 332	412 437	2 080 144	298 423	2 077 053	302 559
Kilimanjaro	-	69 393	-	94 827	5 862	341 892	7 665	355 759
Lindi	3 909 123	316 717	5 370 344	382 249	6 121 222	14 174	6 135 399	-
Manyara	271 050	652 679	461 890	1 046 676	1 870 902	1 720 224	1 973 635	1 709 118
Mara	633 139	350 582	935 061	363 334	1 117 931	320 450	1 131 988	314 322
Mbeya	938 509	934 374	1 446 917	1 029 702	2 531 748	730 853	2 468 926	769 571
Morogoro	2 690 869	764 682	3 233 572	901 314	4 155 986	1 098 746	4 156 911	1 097 757
Mtwara	991 850	78 257	1 424 658	99 143	1 621 728	3 112	1 624 837	-
Mwanza	712 728	235 063	1 143 643	182 421	1 432 129	99 624	1 451 821	69 565
Pwani	940 274	391 013	1 428 030	535 628	1 830 468	540 836	1 778 730	598 502
Rukwa	2 963 953	544 131	3 527 829	671 439	4 938 193	12 587	4 937 184	14 216
Ruvuma	4 071 919	625 941	4 807 247	611 116	5 702 722	333 813	5 711 812	325 509
Shinyanga	1 296 683	865 801	2 227 320	885 375	3 514 899	232 454	3 595 188	157 988
Singida	300 063	1 255 969	983 020	1 643 496	3 712 517	213 012	3 729 517	196 033
Tabora	2 804 609	1 066 490	4 426 126	1 255 252	6 346 210	17 027	6 363 236	-
Tanga	971 603	582 768	1 287 420	603 573	1 830 329	414 717	1 825 007	409 523
Total	**25 657 914**	**12 338 477**	**35 991 148**	**14 792 122**	**55 046 419**	**11 466 714**	**55 249 942**	**11 365 987**

TABLE 4D.5b

Expansion: highly and moderately suitable new area available for sunflower by region (ha)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	255	174 238	456	242 921	657	979 239	708	996 231
Dar es Salaam	11 188	12 782	15 614	11 731	33 240	96	27 877	5 456
Dodoma	48 614	229 649	101 262	359 209	830 925	136 594	854 890	116 745
Iringa	156 131	418 945	234 526	536 073	656 292	952 465	662 731	941 176
Kagera	141 463	260 804	180 304	313 023	364 817	406 948	364 542	407 399
Kigoma	515 870	158 976	668 770	171 750	897 993	154 047	897 352	155 394
Kilimanjaro	-	10 477	-	19 327	5 303	103 426	6 937	111 030
Lindi	1 400 131	118 082	1 754 115	126 386	2 062 321	9 856	2 072 183	-
Manyara	176 838	482 929	306 902	797 459	1 362 725	1 030 903	1 441 932	1 012 154
Mara	109 184	63 515	162 170	55 802	199 617	43 794	202 001	44 328
Mbeya	548 990	682 056	953 257	743 189	1 767 288	475 867	1 715 643	513 125
Morogoro	900 569	354 006	991 071	410 469	1 336 155	516 056	1 335 404	516 815
Mtwara	210 761	21 041	281 135	25 003	339 237	1 391	340 629	-
Mwanza	91 720	67 957	207 178	34 584	251 205	12 435	254 683	7 252
Pwani	371 491	133 492	550 426	193 691	678 466	233 573	665 617	250 738
Rukwa	1 003 343	249 761	1 119 493	291 981	1 731 849	9 134	1 732 053	9 346
Ruvuma	1 977 331	257 982	2 245 163	264 613	2 620 511	176 301	2 624 625	173 215
Shinyanga	227 832	177 265	482 046	161 035	718 496	26 973	724 318	20 463
Singida	45 590	564 714	364 271	714 540	1 573 208	96 694	1 582 600	87 321
Tabora	631 563	329 884	1 106 576	340 242	1 604 164	6 616	1 610 780	-
Tanga	412 597	220 039	569 174	227 139	796 841	75 629	803 185	71 112
Total	**8 981 461**	**4 988 594**	**12 293 909**	**6 040 167**	**19 831 310**	**5 448 037**	**19 920 690**	**5 439 300**

TABLE 4D.5c

Intensification: highly and moderately suitable area available for sunflower already under crop production by region (ha)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	77	34 000	137	58 736	263	336 897	284	341 213
Dar es Salaam	20 418	47 588	26 271	44 042	82 489	3 596	63 214	22 873
Dodoma	219 665	650 061	428 678	880 712	1 956 789	205 582	2 004 741	160 842
Iringa	118 172	417 776	157 185	581 101	438 647	974 544	436 753	965 659
Kagera	122 652	168 874	164 720	214 962	339 351	263 576	335 895	267 064
Kigoma	95 140	91 953	109 039	99 537	208 731	110 937	208 616	111 391
Kilimanjaro	-	55 691	-	70 628	559	204 707	728	210 775
Lindi	719 626	68 241	982 299	83 974	1 101 735	1 217	1 102 948	-
Manyara	92 490	157 273	152 258	225 855	462 562	508 401	483 051	509 818
Mara	394 444	117 441	549 808	107 368	684 151	53 696	695 586	47 258
Mbeya	153 780	194 858	188 984	216 368	306 564	234 027	303 256	227 934
Morogoro	329 470	129 152	398 427	163 874	521 892	297 945	521 988	298 110
Mtwara	694 092	46 099	1 026 013	60 770	1 136 989	1 180	1 138 168	-
Mwanza	552 727	143 333	842 800	125 741	1 064 101	56 196	1 081 052	34 893
Pwani	291 069	131 046	432 409	182 392	556 410	136 516	542 361	150 974
Rukwa	548 760	195 455	591 408	222 949	988 947	2 093	988 693	2 526
Ruvuma	1 296 801	243 059	1 497 192	221 076	1 806 412	118 518	1 808 686	116 004
Shinyanga	784 980	595 760	1 237 174	622 894	2 038 248	87 762	2 109 522	18 685
Singida	4 826	162 535	106 241	348 529	857 753	114 176	865 406	106 522
Tabora	672 421	487 078	1 048 796	613 858	1 835 156	10 372	1 845 526	-
Tanga	383 822	259 619	483 720	261 087	702 876	226 619	696 417	224 797
Total	**7 495 432**	**4 396 892**	**10 423 559**	**5 406 453**	**17 090 625**	**3 948 557**	**17 232 891**	**3 817 338**

TABLE 4D.5d

Expansion: potential production of sunflower seeds into new highly and moderately suitable land by region (tons))

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	215	104 533	1 596	607 274	782	832 301	3 074	3 088 135
Dar es Salaam	9 395	7 667	57 412	29 326	47 070	82	131 267	16 913
Dodoma	41 205	137 765	357 072	897 883	1 102 901	116 074	4 140 495	361 823
Iringa	139 896	251 325	874 690	1 340 014	904 968	809 529	3 329 093	2 917 411
Kagera	124 224	156 456	668 382	782 454	462 734	345 878	1 685 760	1 262 835
Kigoma	451 494	95 375	2 579 768	429 321	1 297 103	130 928	4 699 160	481 678
Kilimanjaro	-	6 284	-	48 311	6 311	87 904	30 107	344 172
Lindi	1 260 946	70 822	6 719 265	315 837	3 092 637	8 343	11 297 727	-
Manyara	154 583	289 689	1 119 510	1 993 348	1 699 198	876 150	6 558 786	3 137 256
Mara	95 097	38 099	608 198	139 482	262 667	37 215	965 088	137 406
Mbeya	466 270	409 160	3 562 183	1 857 688	2 337 096	404 384	8 285 873	1 590 382
Morogoro	850 773	212 356	3 978 273	1 025 985	1 977 339	438 612	7 206 128	1 602 027
Mtwara	184 650	12 622	1 041 170	62 488	507 679	1 176	1 855 792	-
Mwanza	81 734	40 767	802 002	86 439	375 283	10 565	1 379 048	22 479
Pwani	325 005	80 077	2 055 100	484 123	989 984	198 523	3 510 429	777 237
Rukwa	886 105	149 829	4 146 094	729 801	2 583 095	7 756	9 309 494	28 965
Ruvuma	1 901 008	154 750	9 021 817	661 389	3 848 359	149 814	14 064 991	536 895
Shinyanga	197 058	106 341	1 804 858	402 524	1 038 675	22 917	3 815 283	63 419
Singida	38 360	338 787	1 285 702	1 786 065	2 206 399	82 161	8 098 100	270 595
Tabora	549 543	197 900	4 295 041	850 488	2 406 056	5 619	8 786 121	-
Tanga	378 924	131 996	2 189 331	567 748	1 095 791	64 272	4 041 745	220 407
Total	**8 136 485**	**2 992 600**	**47 167 464**	**15 097 988**	**28 242 127**	**4 630 203**	**103 193 561**	**16 860 035**

TABLE 4D.5e

Intensification: potential production of sunflower seeds into highly and moderately suitable land already under crop production by region (tons)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	64	20 396	479	146 821	312	286 352	1 230	1 057 731
Dar es Salaam	17 173	28 550	92 899	110 091	101 515	3 052	281 231	70 898
Dodoma	184 726	389 953	1 502 389	2 201 368	2 670 075	174 692	9 992 233	498 439
Iringa	104 540	250 628	579 734	1 452 578	582 955	828 299	2 112 221	2 993 292
Kagera	108 431	101 308	615 094	537 338	441 750	224 017	1 589 495	827 817
Kigoma	82 649	55 163	397 623	248 806	282 000	94 286	1 016 658	345 277
Kilimanjaro	-	33 415	-	176 559	664	173 996	3 155	653 376
Lindi	649 556	40 928	3 841 873	209 866	1 664 319	1 031	6 076 805	-
Manyara	83 428	94 339	578 118	564 543	586 153	432 102	2 235 045	1 580 300
Mara	346 845	70 455	2 135 392	268 340	957 391	45 630	3 519 602	146 476
Mbeya	132 445	116 884	690 078	540 773	403 088	198 892	1 463 953	706 510
Morogoro	313 236	77 477	1 614 604	409 599	775 701	253 236	2 833 858	924 097
Mtwara	603 434	27 652	3 765 434	151 890	1 718 660	997	6 282 681	-
Mwanza	493 216	85 979	3 289 825	314 268	1 573 600	47 737	5 753 572	108 159
Pwani	254 240	78 615	1 627 038	455 926	795 065	116 029	2 801 672	467 990
Rukwa	488 233	117 240	2 192 772	557 229	1 432 177	1 778	5 221 740	7 834
Ruvuma	1 243 230	145 809	5 978 035	552 567	2 576 309	100 706	9 413 784	359 532
Shinyanga	678 104	357 372	4 599 919	1 556 842	2 954 237	74 530	11 117 491	57 912
Singida	4 052	97 512	372 411	871 176	1 104 421	97 017	4 065 943	330 106
Tabora	571 599	292 196	3 870 122	1 534 443	2 749 805	8 811	10 026 242	-
Tanga	351 350	155 743	1 849 060	652 605	942 768	192 608	3 415 088	696 821
Total	**6 710 551**	**2 637 614**	**39 592 899**	**13 513 628**	**24 312 965**	**3 355 798**	**89 223 699**	**11 832 567**

CHAPTER 5

TECHNICAL AND ECONOMIC VIABILITY OF BIOFUEL PRODUCTION CHAINS

Erika Felix, Carlos Ariel Cardona and Julián Andrés Quintero

5. INTRODUCTION

Bioenergy development will depend on how far the existing agro-industry is able to transform biomass to biofuel production, and the roles that public and private investment may have on the development of the sector[1]. These factors are key determinants on the economics of the biofuel industry and are fundamental to determine the potential for the eventual commercialization of biomass-derived fuels, in particular in developing countries. In the case of Tanzania, industrialization for biofuel production will probably bring about the installation and acquisition of new and foreign technologies. A key priority is to fit these technologies more closely to the country's conditions paying particular attention to the availability of local capacity and skills for the maintenance and operation of bioenergy plants. Moreover, if local capacity is low, future perspectives for building capacity and the associated supplier market should be considered. The results of this work provide information on estimates for cost of biofuel production based on local conditions in the country, make recommendations on biomass to biofuel technology pathways that are more adaptable to the country and raise issues and needs to enable and make the sector more competitive.

A technology capacity assessment indicated that the technological capability of Tanzania is limited and as such investment is needed to build human capital to ensure that technical personnel capable of handling industrial equipments and having the ability to solve possible operational problems is available to support biofuel development. Moreover, availability of the necessary skill set will also support the introduction of more advanced technologies to lower production costs and optimize economical profitability which will generate larger taxes from these profits. Furthermore, establishment of co-products (biocompost, biofertilizers and electricity) markets produced from by-products from the biofuel production chain is important because its sales significantly raise the competitiveness of the overall process, making the industry more profitable and bringing additional revenues to the government. In the case of Tanzania, for example, estimated revenue from bagasse-electricity could generate approximately USD5.7 million in sales.

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1 From *Biofuels, Agriculture and Poverty Reduction* published by the Overseas Development Institute in Natural Resources Perspective volume 107 on June 2007.

The detailed breakdown on biofuel production costs indicated that feedstock prices are a significant part of the production costs and as such an important component in the economic viability of biofuel production in Tanzania. If the biofuel promise to rural development is to be realized supportive measures in the agriculture sector to increase yields need to be led by the government and/or in cooperation with potential investors. In particular there is a need to reach out to outgrower producers. Outgrower skills need to be nurtured and technical assistance provided to help maximize yields. As such, greater accessibility to on-farm technology through use of better varieties, access to training, irrigation, could be the means to improve productivity of feedstock and reduce biofuel production costs.

Other challenges that could possibly hinder development of biofuel production chains include the limited rural infrastructure - transportation (roads, rail and); potable and industrial water provision (agroprocessing and biofuel plants) and rural electrification, to effectively support and service the emerging rural industrialization. The availability of efficient and reliable transportation networks to support the connection of the various production components along the supply chain are lacking and are probable key elements to affect the profitability and thus the viability of biofuel production[2].

5.1 METHODOLOGY OVERVIEW

The analysis seeks to establish production costs using technology features and specific crop information. The production cost is analysed according to crop type, fuel type, and based on feedstock production characteristics and industrial technology conversion schemes. Within the analysis, scenarios are identified to determine how much fuel is to be produced, what feedstock is to be used in the process and who is to supply the feedstock i.e. smallholder (outgrower), commercial (estate) or mix of both (outgrower scheme). These scenarios are built based on information collected in the country and to a large extent reflect potential biofuel investment ventures. The production cost is then estimated based on these production characteristics and its competitiveness in the domestic and international markets assessed[3].

5.2 THE TANZANIA CONTEXT

5.2.1 TECHNOLOGY ACCESS CONDITIONS

A three-tier assessment criterion was established to evaluate the technology capacity in the country. The first tier of criteria is based on the human skills that are necessary to support a biofuel processing operation; this includes both skilled and unskilled labour. Areas assessed were engineering capacity in both basic and more specific fields, including microbiology and biochemistry, and technicians (electrical and plumbing). The second tier

2 Biofuel production is defined from here on as the conversion of biomass to biofuel.

3 A techno-economic analysis was prepared by the National University of Colombia at Manizales under the guidance of the BEFS team. The consultant's report was used as a technical background document. The technical document is available upon request.

focuses on access to technologies from local suppliers and provision of services. This tier evaluated the existing capacity for manufacturing and technology development of biofuel processing equipment required. Finally, the third tier focused on access to processing inputs for operating biofuel plants, including chemical, solvents, additives, etc. The results are summarized in Table 5.1.

TABLE 5.1

Assessment of biofuel technology access and human capacity for Tanzania

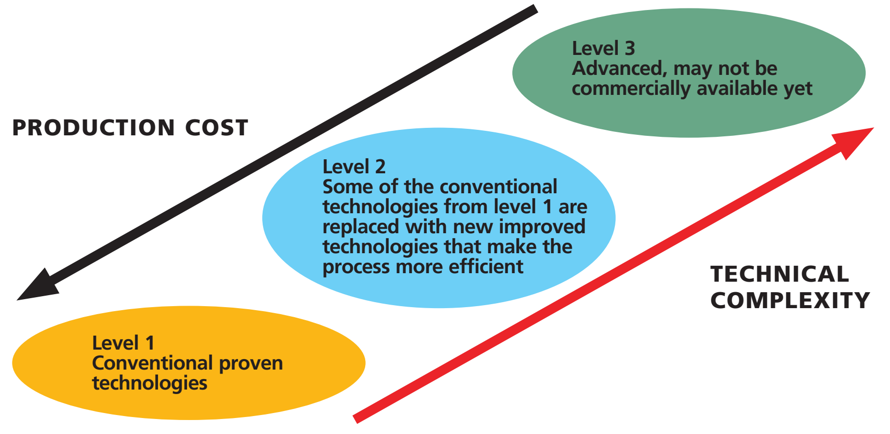
Element of analysis	Qualitative valuation	Summarized description
Tier 1	Insufficient	*Basic engineering:* There are departments of civil, chemical, biochemical and food engineering in six universities. There is one engineer per each 500 inhabitants. Practically, there are no research master's and Ph.D. programmes in the cited careers or areas related to biofuels.
	Deficient	*Microbiology, biochemistry and similar:* there are no evident developments in these areas that could support this type of project.
	Deficient	*Electric and electronic engineering, automatic control:* there is a limited existence of programmes in these areas in the universities. Automatic control is not under research in the country and does not reach the levels required by this type of project.
	Deficient	*Specific engineering:* design and construction of equipment. The country does not have its own developments in this area.
	Deficient	*Local capacity to supply maintenance services for equipment* and basis accessories (pipelines, electric installations, boilers, evaporators, etc.), high-tech equipment (fermentors, distillation and dehydration systems, waste treatment units, etc.) is almost nil.
Tier 2	Deficient	There are no *companies with experience in manufacturing equipment* for fermentation, distillation and dehydration. There are no existing companies in metal-mechanical construction. There is no indication of research and development in the area of equipment construction.
Tier 3	Deficient	Chemicals as solvents, additives, adsorbents, etc. needed for biofuel production are not produced in the country and need to be imported at a high cost.

5.2.2 TECHNOLOGY OPTIONS FOR TANZANIA

Three production technology options suitable for Tanzania were defined (see Appendix 5A for more details). The options are differentiated based on the level of complexity of the technologies involved in each of the industrial processing steps (Figure 5.1).

Figure 5.1

Description of Technology Options for Tanzania



5.3 RESULTS

5.3.1 TECHNOLOGY

The recommended technology option for producing fuel-grade ethanol[4] (for both sugar cane and cassava) in Tanzania corresponds to the **second level** of technological development (see Table 5.2). This takes account of the fact that technology access and transfer conditions and the adaptation of technologies in Tanzania make it more difficult (and involves a higher initial investment) to set up and implement technological schemes based on technology level option 3, i.e. schemes that have high-performance technologies that are proven worldwide generally at the pilot plant level. On the other hand, level 1 technologies option represent the easiest level to be implemented in Tanzania requiring the lowest level of conditioning as it implies already mature conventional technologies proven worldwide, which are however less efficient and potentially less environmentally friendly.

For biodiesel regardless of technology level, the lack of a local network to supply chemical inputs necessary in the production process, such as methanol and sodium hydroxide, contributes to higher production costs. Biodiesel technology level 2 requires significant excess of methanol so access to this input poses a limitation for implementation in Tanzania. Moreover, technology level 3 is in the early commercial steps and their operation is not fully proven yet. Therefore, in the case of biodiesel, the recommended technology is the **first level** of technology development (i.e. conventional biodiesel production plants).

4 Fuel grade ethanol is denatured ethanol meeting the standards and specifications for blending with gasoline for use as fuel in spark-ignition engine. The standards and specifications are defined by legislation in the country.

TABLE 5.2

Recommended technology options

Fuel	Feedstock	Recommended Technology Level
Ethanol	Sugar cane	Level 2
	Cassava	Level 2
Biodiesel	Jatropha & Palm Oil	Level 1

5.3.1.1 NECESSARY CONDITIONS FOR IMPLEMENTING THE TECHNOLOGY OPTIONS

As far as the skill set required for the implementation of a biofuel programme, this includes personnel with technical training capable of handling industrial equipment and having the ability to solve possible operational problems. In particular, there is the need to have graduate engineers and semi-skilled trade-trained personnel such as plumbers, electricians, mechanics, etc. As such, a pre-requisite for Tanzania to implement a long-term sustainable successful biofuel programme requires a well-designed technology transfer that comprises the involvement of universities in the production of biofuels using different technologies and raw materials and technical teaching centres[5] to support the industry. An initial joint venture is suggested with universities to use and prepare texts which, in conjunction with simulation tools, will enable various university groups to investigate technological and scientific issues relating to biofuel production. Note that while this does not require high levels of investment, it is fundamental for solving one of the main technological access barriers facing Tanzania.

5.3.1.2 ISSUES SURROUNDING COST

The economic viability for biofuel production was examined by analysing the production costs associated with the three technology options for each production scenario[6]. The industrial processing of biomass to biofuel generates materials other than the principal product (i.e. ethanol or biodiesel) referred to as by-products. The analysis took into consideration the effect of having these by-products used as a raw material in other processes to generate new products. These newly generated products from the use of by-products are referred to as co-products. For example, a by-product of sugar-cane processing is bagasse; if the bagasse is used in co-generation system then the electricity that is generated by burning the bagasse is a co-product[7]. The co-products markets included exploring energy generation through combined heat and power (co-generation) potential from the use of fibrous waste generated in the biofuel process as well as the production of biofertilizers and biocompost.

5 These include vocational centres offering training on typical trades such as plumber, machinist, electrician among others

6 Production scenarios were adapted to Tanzanian conditions. The scenarios were then simulated using Aspen Icarus Process Evaluator package. In the analysis, the prices for feedstock, service fluids, labour and maintenance, operating, general plant and general administrative costs were taken from secondary sources of information. More detailed assumptions are provided in appendix 5b.

7 By-products are considered waste streams from a process. Co-products are produced from by-products through a further processing to add-value. Co-products in this analysis include biofertilizers (vinasses), biocompost, and co-generated electricity.

5.3.2 ETHANOL PRODUCTION COSTS BY CROP

5.3.2.1 SUGAR-CANE JUICE ETHANOL PRODUCTION COSTS

The sugar-cane ethanol production scenarios below were developed based on country specific data and reflect potential production option in the country (Table 5.3).

TABLE 5.3

Characteristics of sugar-cane ethanol scenarios

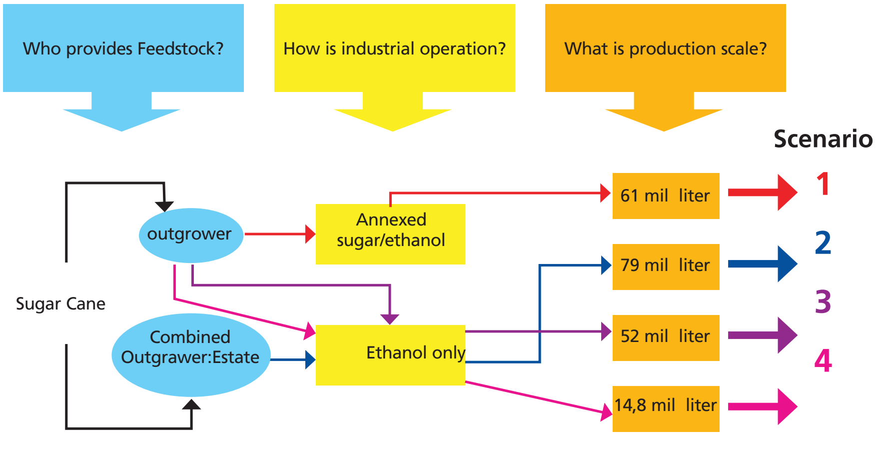
Scenario	Description
Scenario 1 *	■ 61 million litre capacity combined facility with sugar mill production. ■ Ethanol to be produced from molasses and sugar-cane juice. ■ Estimates additional need for 10 000 ha grown by outgrowers.
Scenario 3	■ 79 million litre stand alone facility producing ethanol. ■ Sugar cane comes from estate (12 000 ha) and outgrowers (3 000ha)
Scenario 3	■ 52 million litre stand alone facility producing ethanol. ■ Sugar cane supplied by existing outgrower producers assuming an increased in yield to generate the necessary surplus for ethanol.
Scenario 4	■ 14.8 million litre stand alone facility producing ethanol. ■ Small-scale production refinery located close to outgrower cluster.

** This scenario is representative of the Brazilian ethanol production model whereby ethanol production is largely integrated with sugar mill operations*

The scenarios are schematically represented in Figure 5.2 indicating where the feedstock comes from, how the biomass to biofuel conversion operates and what scale of operation is needed.

Figure 5.2

Sugar-cane ethanol production scenarios



The estimated sugar-cane ethanol production cost for each scenario and each technology option is presented in Table 5.4. The level of technology directly affects the ethanol yield and as such the production cost. Technology level 3 represents the lowest cost of production for all scenarios. Although technology level 3 has the greatest investment expense, the cost of investing in a state-of-the-art technology is offset by a significant increase in the performance of the process which directly affects input materials requirements, in particular feedstock requirements. However, Tanzania's technology access and transfer conditions at present make it more difficult for the adaptation of technology level 3. Therefore over time, as the ethanol industry is built up and matures local conditions to meet the needs for deploying high-performance technologies will be in place to make the industry more efficient.

TABLE 5.4

Sugar-cane juice ethanol baseline production costs (USD/L) at plant gate per scenario for each technology option level *

Scenario	Technology level		
	1	2	3
Scenario 1 *	0.6257	0.6055	0.5309
Scenario 3	0.5129	0.4931	0.4338
Scenario 3	0.6245	0.5857	0.5392
Scenario 4	0.7369	0.6778	0.5940

** The baseline production costs is technology level 2 for ethanol and do not include any potential credits from co-product and co-generation sales.*

Using technology level 2 as opposed to level 1 reduces the cost of production from 3 percent to as much as 8 percent. The most significant difference comes from the cost in the maintenance category; for technology level 1 this cost is nearly three times higher than the cost of technology level 2. For example, the reduction cost between technology options levels 1 to 2 for Scenario 4 has a reduction of about 8 percent. This highlights that technology level option 2 is an economically valuable starting point for Tanzania. Moreover, it is consider that Tanzania's technology access and transfer conditions at present can uptake technology level 2 [8].

The production costs estimated for technology level 2 ranges from USD0.493 to as much as USD0.677 per litre[9]. As such the baseline production costs of production estimated for Tanzania for technology level 2 are higher compared to the cost reported in Brazil and Colombia, where production cost estimates range between USD0.27 to USD0.30 per litre

8 From here on the document discusses technology level 2 for ethanol production as the baseline for Tanzania.
9 The simulated sugar cane to ethanol yield ranges from 68 to 80 litres per ton of sugar cane and is contingent up on the technology level option and production scale.

of ethanol produced using sugar-cane juice as raw material. These costs are however closer to those estimated for India (US$0.48-US$0.55 per litre) and lower than the sugar-based ethanol production costs in the EU (USD0.76-USD0.78 per litre)[10].

Discussion on findings and key issues for sugar-cane ethanol production

- One of the reasons for higher ethanol production costs in Tanzania relates to the high production cost associated with the sugar-cane crop which is twice as costly as in Brazil and Colombia[11]. In the case of Tanzania, the factory gate price of sugar cane (i.e. including transport costs) was estimated to be USD0.027 per kg compared to, for example, the cost of USD0.012 per kg in Colombia. Although the lower cost of sugar-cane crop production could be explained in part by the quality of soils and climate conditions found in Brazil and in the case of Colombia to a full year harvest, the lower production costs are also the result of improvements in agricultural yields. For example, both Brazil and Colombia have supported programmes to produce and introduce new and improved cultivar varieties that are more resistant to drought and pests, along with higher yields and higher sugar contents. Moreover, Brazil's success as the world's most efficient ethanol producer comes from the support on R&D and innovation programme that have helped improve efficiencies in both the agricultural and industrial phases. This programme was first instituted by the government and later on taken up by the private sector[12].

- The economic impact from the sale of co-products reduces the production costs. Assuming a viable existing local outlet market for co-products in Tanzania, a reduction of biofuel production costs can be realized from potential income generation from the sale of co-products and in particular from sales on co-generated electricity. For example, in Figure 5.3, the reduction from co-product credits ranges from as low as USD0.039 to as much as USD0.059 per litre of sugar-cane ethanol. For Scenario 2, the net effect of co-products including co-generation credits shows a reduction of 12 percent over the baseline production cost[13].

- The significance from co-generation credits on sugar-cane ethanol production costs is significant because besides generating additional income from the sale of surplus electricity, it also avoids high energy costs at the plant from purchasing electricity, it also (Figure 5.3). For example, in Scenario 2 the reduction on services, which include the purchase of electricity, is decreased by almost 71 per cent.

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10 Brazil, India and EU production costs are from the 2007 LMC International Starch and Fermentation Raw Materials Monitor Report. Note that since sugar cane is not produced in EU, the sugar-based ethanol production from EU may include sugar from beets and imported sugar from cane.

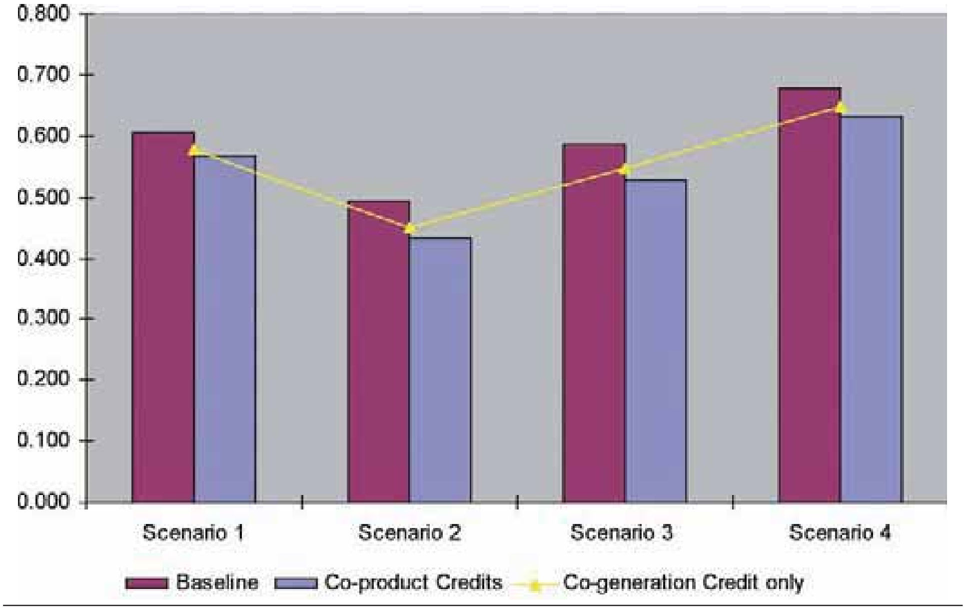
11 The cost of sugar cane production in Colombia comes from Fuel ethanol production from sugar cane and corn: Comparative analysis for a Colombian case publication by Cardona *et al.* The article is published on Energy, volume 33, issue 3 March 2008, Pages 385-399.

12 This information comes from the report on Bioenergy for Sustainable Development and Global Competitiveness: The case of Sugar Cane in Southern Africa published by Cane Resources Network for Southern Africa (CARENSA) in 2008.

13 The baseline scenario comprises ethanol technology level 2 without accounting for co-product credits.

Figure 5.3

Molasses ethanol production scenarios



Why co-products matter?

In countries with advanced biofuel production such as Brazil, Colombia and the USA, the co-products markets are well-developed and generate revenues to the industry. In Colombia the processed vinasse that contains high volumes of potassium, phosphorus, and magnesium, is sold as fertilizer (biofertilizer). The annual vinasse sales return is estimated at approximately USD40 million to the industry. In Brazil the surplus power capacity from bagasse is estimated at 509 MW. At current electricity tariffs ranging from USD66.1 to USD71.1 per MWh, the revenues from co-generation account for approximately 15 percent of the total revenue accrued from sugar and ethanol sales[14]. In Mauritius the bagasse-based electricity exports to the national electric grid were estimated at 53 MW and sale returns estimated at 23 million dollars[15]. To show the economic implications of a co-product market in Tanzania, the potential from Scenario 2 is analysed. Under this scenario there is a surplus electricity of 10 337 kW that can be sold to the grid. The analysis estimated that the cost to co-generate electricity from bagasse range from USD0.040 to USD0.062 per kWh which is lower than the estimated price of USD0.066/kWh that Tanzania currently pays to Independent Power Provider (IPP). Using the above price paid to IPP, the estimated revenue from bagasse-electricity based on Scenario 2 could generate about USD5.7

14 The information comes from the report on Cogeneration Opportunities in the World Sugar Industries, prepared in April 2009 by the International Sugar Organization.

15 Information was taken from Cogeneration Opportunities in the World Sugar Industries published by the International Sugar Organization in April 2009. Note that the data in the report is given in GWh units which were converted to MW by multiplying 1 000 and dividing by 8 760. The recommended sale price per KWh is assumed to be Rs.1.59 which is estimated to be USD0.05.

million in sales[16]. Moreover, cogeneration may also bring additional revenues from Certified Emission Reduction (CER) credits within the terms of the Clean Development Mechanism (CDM) which can help improve market conditions and facilitate recovery of capital investment costs.

5.3.2.2 MOLASSES-ETHANOL PRODUCTION COSTS AT FACTORY GATE

Molasses is a low value by-product of the sugar industry that can be used as raw material for several processes including ethanol production. The molasses-ethanol scenarios developed for Tanzania explore the opportunity for using the molasses generated as by-product from the sugar mill operations in the country for ethanol production (Table 5.5 and Figure 5.4).

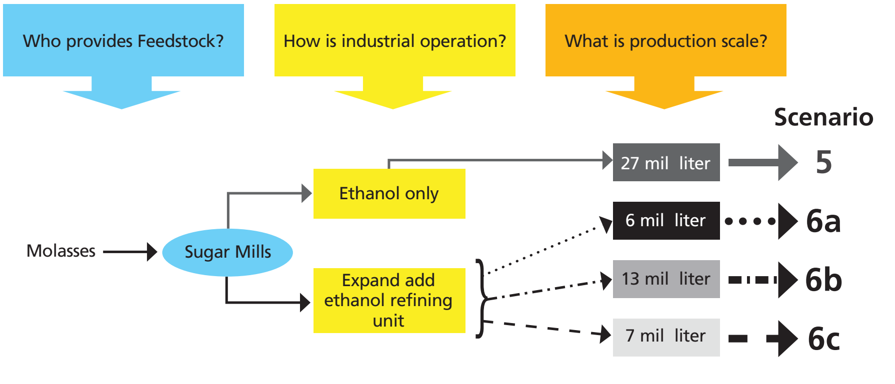
TABLE 5.5

Characteristics of molasses ethanol scenarios

Scenario	Features
Scenario 5	•Centralized facility. •Molasses are purchased from all sugar mills and transported to facility.
Scenario 6a	•Facility co-located to sugar mill A in the country. •Production capacity based on amount molasses from sugar mill A.
Scenario 6b	•Facility co-located to sugar mill B in the country. •Production capacity based on amount molasses from sugar mill B.
Scenario 6c	•Facility co-located to sugar mill C in the country. •Production capacity based on amount molasses from sugar mill C.

Figure 5.4

Molasses ethanol production scenarios



16 The Standardised Small Power Purchase Tariff in 2009 in Tanzania is 85.66 TZS/kWh (or USD0.06/kWh). This tariff is used to calculate the revenue from bagasse-electricity for Scenario 2. The 10 337 kW are estimated to be around 90 552 120 kWh for Scenario 2.

Overall, the lowest production cost per litre of ethanol is for technology level 3 (Table 5.6). Under technology level 3 for Scenario 6c the production price is reduced by 17 percent with reference to technology level 1. This is because in the case of the least developed technology (level 1), the indirect plant expenses could be twice as high as those of technology levels 2 and 3. Technology level 1 is less efficient and needs more supervision to operate within a minimum safety margin while the higher-level technologies involve capital-intensive automated systems that are much more efficient operationally and lessen production cost. Comparing the production costs between level 2, which is the recommended technology for implementation in Tanzania, and technology level 1 it shows that as much as 10 percent reduction takes place when technology level 2 is used.

TABLE 5.6

Molasses ethanol production cost (US$/L) at plant gate per scenario per technology level

Scenario	Technology level		
	1	2	3
Scenario 5	0.7636	0.7352	0.6711
Scenario 6a	0.8225	0.7356	0.6796
Scenario 6b	0.6630	0.6217	0.5686
Scenario 6c	0.7955	0.7104	0.6541

The baseline production cost for the technology level 2 ranges from USD0.621 to USD0.735 per litre of ethanol. These production costs are higher than those reported for other countries such as Brazil, India, South Africa and Thailand (less than USD0.60 per litre) but closer to values estimated for the USA and the EU[17] (between USD0.60 to USD0.70 per litre)[18].

Discussion of findings and key Issues for molasses ethanol production

- The lowest production costs were obtained from Scenario 6b because this sugar mill produces the largest volume of molasses per year in Tanzania and can exploit economies of scale. The production cost for Scenario 6b is close to the molasses-ethanol cost reported by the USA and the EU.
- Scenario 5 is not a viable option at present because the amount of molasses produced in the country is not sufficient to effectively meet economies of scale. Moreover, molasses is a bulky material and for production in a centralized ethanol facility like in Scenario 5 requires transportation. The transport costs, which according to literature in Tanzania can be significant, contribute also to the higher production costs for Scenario 5. Therefore, in the case of Tanzania drawing feedstock supplies

17 Note that molasses used in EU for ethanol production may come from sugar beet.

18 Production prices from Brazil, India, South Africa, Thailand, EU and US are taken from the LMC International Starch and Fermentation Raw Materials Monitor 2007 Report.

from multiple sugars mills to a centralize ethanol refinery operations at one place is impracticable.

- The integration of ethanol distilleries in existing sugar mills is an attractive model because it can help ensure a profitability for the sugar industry by shifting production between ethanol and sugar in response to world market sugar prices. Moreover, in the molasses-ethanol scenarios the lower production costs were obtained for integrated facilities in Scenarios 6a, 6b and 6c when compared to the centralized ethanol facility in Scenario 5. Integrated or combined sugar/ethanol facilities are more advantageous because no transportation of molasses is required.
- The largest share of the production cost for molasses-ethanol is attributed to the price of molasses. The price of molasses for ethanol production is taken to be the opportunity cost from selling molasses for other uses; in the case of Tanzania the market price was used[19]. The prices of molasses are characterized by instability because the sugar producers can sell these at different prices responding to the market. In this case it was advisable to use a value for molasses that cost between USD0.36 to USD0.50 per litre of ethanol. This value is significantly higher than the USD0.25 per litre price of molasses used in the Mozambique study. As such, to fully understand the dynamics of molasses market in the country, it is recommended that policy-makers engage the sugar sector in the country to assess conditions and determine if molasses-ethanol is a viable alternative.
- It is worth noting that sugar producers in the country expressed concerns on the hardships on managing the molasses by-products. The main concerns were related to high transportation costs associated with molasses and their desire to find optional markets for this product. The focus of this analysis only assessed if molasses could be a competitive feedstock for ethanol production. As such, it did not evaluate which alternative market offers the highest economic benefit for handling the molasses. Therefore, ethanol, if at all or under what conditions, is a more economically attractive market for this commodity is still to be determined.

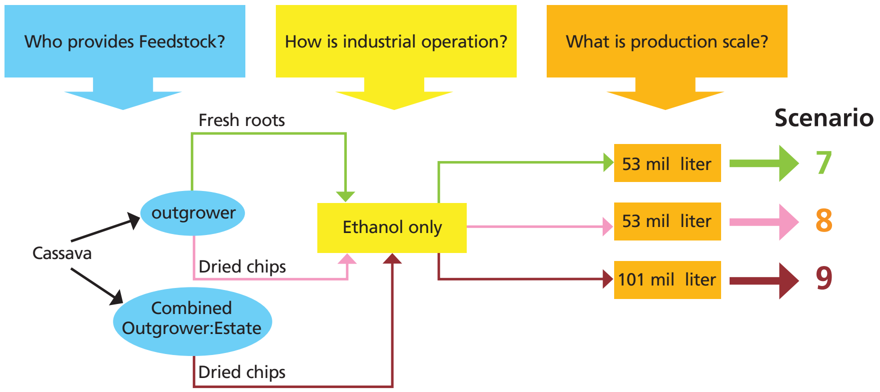
5.3.2.3 CASSAVA-ETHANOL PRODUCTION COST AT FACTORY GATE

Considering cassava's rapid post-harvest deterioration and taking account of infrastructure conditions in Tanzania, it was opted to assess cassava-ethanol production from both fresh and dried cassava feedstock. Moreover, two scenarios assuming feedstock supply by outgrowers and having the same ethanol production capacity were developed but one was set to use dried and one to use wet cassava to evaluate production costs. An additional scenario was run to simulate a higher ethanol production capacity and to assess combined supply of cassava from both outgrower and estate in a 40:60 ratio respectively. The cassava ethanol production scenarios are summarized in Figure 5.5.

19 Country information indicated that at present sugar cane molasses is being sold to neighbouring countries and European markets. Therefore, the price for cane molasses feedstock was taken to be the world market priced minus cost of transportation of molasses to foreign markets.

Figure 5.5

Cassava ethanol production scenario



The production costs of cassava-ethanol for technology level 1 are lower than the cost estimated for sugar cane and molasses ethanol in Tanzania (Table 5.7). The more significant cost reduction factor is the scale of operation. This is illustrated by comparing production costs for Scenarios 8 and 9 for level 3 technologies. Having a larger scale of operation in Scenario 9 results in a 25 percent less production cost when compare to Scenario 8. On the other hand, shifting from technology level 2 to level 3 has relatively smaller difference in production costs when compared to scale i.e. reduction cost between level 2 to technology level 3 for Scenarios 8 and 9 is about 11 and 15 percent, respectively.

It is considered that Tanzania's technology access and transfer conditions at present can uptake technology level 2. The production costs for technology level 2 are about 7 percent less as compare level 1. Therefore, in case of cassava-ethanol technology level 2 also offers a valuable entry point for Tanzania. Furthermore, over time as the ethanol industry matures and local conditions are in place high-performance technologies in level 3 can be implemented in Tanzania making the industry more efficient.

TABLE 5.7

Cassava ethanol production cost per scenario at plant gate per technology level (US$/L)

Scenario	Technology level		
	1	2	3
Scenario 7 Fresh	0.4506	0.4203	0.3604
Scenario 8 Dry	0.5029	0.4695	0.4172
Scenario 9 Dry (larger scale)	0.3907	0.3687	0.3118

The ethanol-cassava production costs estimated for Scenarios 7, 8 and 9 in technology level 2 range from USD0.368 to USD0.469 per litre which is higher than the cost estimated for medium scale wet milling production in Thailand and Vietnam (USD0.34 to USD0.40

per litre), close to production prices in Brazil (USD0.45-USD0.47 per litre), and much lower than those in China and India (USD0.60-USD0.65 per litre)[20].

Discussion of findings and key issues for cassava ethanol production

- Overall results indicated that cassava-ethanol is an attractive option in the Tanzanian context. Results from the analysis also indicate that inclusion of outgrowers in the production of feedstock is a viable alternative and can provide income generation opportunities for smallholder farmers.
- It should be noted that the commercial use of cassava for ethanol production requires supporting the agricultural sector to increase yields beyond the current 2 tons per ha dry basis to make sure that a new demand will not threaten the availability of cassava for food consumption.
- The cassava-ethanol production costs from fresh cassava are slightly lower than for ethanol from dried chips. However, if outgrowers are to supply the feedstock the use of sun-dried cassava chips may be more viable as fresh cassava use may be precluded due to limited transportation infrastructure in rural areas. As such, logistics options for dry processing, storage and transport of feedstock to ethanol refineries will need to be carefully assessed. The BEFS Module 1 can be used as a tool to evaluate areas having high potential for cassava production. These results can indicate the potential for development of bioenergy value chains. Moreover, this can also identify potential logistical options to improve feasibility of the value chain.
- The use of dry rather than fresh cassava is recommended to benefit integration of farmers in isolated areas. As such, Scenarios 8 and 9 provide a more realistic production option whereby fresh cassava roots are first dried to extend the shelf life, collected in centralized sites near the area of production and then the less bulky material is transported to an ethanol processing plant. These scenarios are likely to offer opportunities for smallholders in isolated rural areas to participate in the supply chain.
- The formation of associations of small-scale cassava producers could lead to small-scale agribusinesses being set up to process fresh cassava roots in sun-dried slices. This would ensure an adequate supply of raw material for ethanol production. This point is crucial in the case of cassava, since ethanol production using the fresh roots of the tuber requires a constant supply of raw material, which is difficult because the roots deteriorate rapidly and access to transport infrastructure in rural areas restricts this option.
- Fresh cassava roots, however, could be a suitable raw material in the case of medium producers in the neighbourhood of an ethanol distillery that can associate with estate plantations.

20 The production cost for ethanol from tapioca for Thailand, Vietnam, Brazil, China and India are taken from the LMC International Starch and Fermentation Raw Materials Monitor 2007 Report.

5.3.3 BIODIESEL PRODUCTION COSTS BY CROP

Biodiesel production was assessed from two feedstock palm oil and jatropha. Palm oil was limited to one scenario since there was already concern on the use of palm oil for fuel when Tanzania is already a net importer of palm oil for food. In the case of jatropha, three scenarios representing potential investments were simulated (Table 5.8 and Figure 5.6).

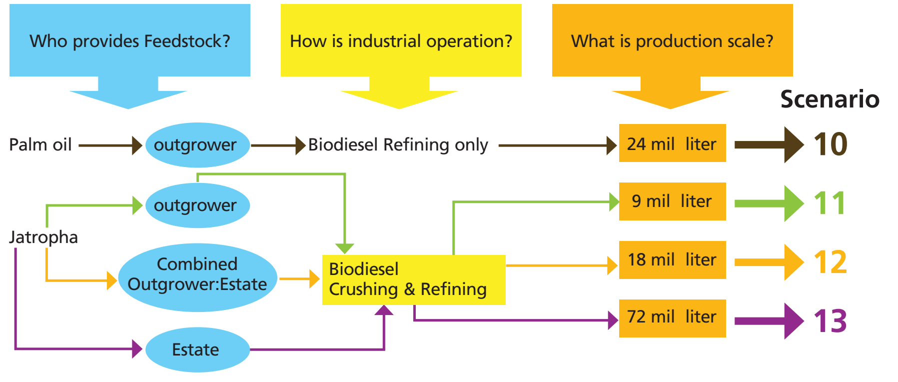
TABLE 5.8

Characteristics of biodiesel scenarios

Scenario	Features
Scenario 10	•Stand alone refinery facility only (no oil extraction), small scale. •Palm oil produced from outgrowers.
Scenario 11	•Combined facility oil extraction and refinery, small scale. •Jatropha from outgrowers (10 000 ha).
Scenario 12	•Combined facility oil extraction and refinery. •Jatropha from estate (10 000 ha) and outgrowers (10 000 ha).
Scenario 13	•Combined facility oil extraction and refinery larger scale. •Jatropha from estate (80 000 ha)

Figure 5.6

Biodiesel production scenarios



Considering the production costs estimated for technology level 1 since this is the recommended technology for biodiesel production in the country, the lowest cost for production of biodiesel is obtained from jatropha ranging from as low as USD 0.66 per litre to as much as USD 0.95 per litre (Table 5.9). In the case of jatropha biodiesel, results indicate that the most significant factor is the origin of the feedstock. Scenario 11, which is based on feedstock from outgrowers, has the least cost of production, followed by Scenario 12, whereby feedstock comes from combination estate: outgrowers production and the highest production cost is estimated for estate production in Scenario 13. Jatropha is a very labour-intensive crop and as such commercial plantations will spend substantially amount of money in hired labour. The difference between Scenarios 11 and 13 is remarkable; it costs 30 percent more to produce biodiesel from estate production than outgrowers. This indicates that integrating outgrowers in the jatropha biodiesel supply chain is a more economically attractive option.

These results indicate that changes in technology have savings on processing inputs and utility costs but these are relatively small compared to the effect of feedstock price. In the case of palm oil the import parity price of crude palm oil was taken to be USD626 per ton and the price of jatropha USD164 per ton for outgrowers and USD270 per ton for estate[21]. Therefore, for both palm oil and jatropha biodiesel feedstock rather than technology is most significant to the cost of production.

TABLE 5.9

Biodiesel production costs at plant gate based on scenario and technology level USD/L

Scenario	Technology level		
	1	2	3
Palm Oil			
Scenario 10	0.8302	0.8101	0.8011
Jatropha			
Scenario 11	0.7439	0.6865	0.6687
Scenario 12	0.8172	0.8171	0.7850
Scenario 13	0.9551	0.9361	0.9274

21 Information for feedstock was collected in the country. The Palm Oil Partity Cost was provided by Mngeta, a potential biodiesel investor. The jatropha buying price from outgrowers was provided by Prokon, a biofuel investor in the country. The jatropha price in commercial (estate) production was assumed to be the production cost. The producton cost for jatropha at commercial (estate) scale was based on values provided by the World Bank in Tanzania.

Production costs of jatropha biodiesel technology level 1 in Tanzania are higher than those estimated for India (USD0.602 per litre)[22] but somewhat lower than the cost estimated for Zambia (USD0.95 per litre)[23] and closer to those estimated for Mozambique (USD0.780 per litre)[24]. In the case of palm oil biodiesel, the production costs are higher than the production costs reported in Malaysia which are estimated at USD0.69 per litre when the market price of crude palm oil is at USD670 per ton[25]. The European biodiesel market projects a lower production cost for biodiesel (USD0.58-USD0.62 per litre) but as the main feedstock is rapeseed oil this is closely linked to the vegetable oil market and could be even higher if the prices of vegetable oil commodities increase[26].

Discussion of findings and key issues for biodiesel production

- The feedstock price is a significant part of the production cost and as such an important component in the economic viability of biodiesel production.
  - In the case of jatropha biodiesel production, feedstock supplied by outgrowers represents a more attractive option than commercial (estate) production.
  - In the case of palm oil the price is very unstable and closely linked to vegetable oil global markets. This severely affects and puts too much risk on the development of the use of palm oil for biodiesel production.
- Limited market accessibility to chemical inputs necessary for the biodiesel production process (such as methanol and sodium hydroxide) contribute to higher production costs.
- It should be noted that the estimated production costs for jatropha biodiesel are very uncertain due to issues surrounding the feedstock availability, the need to better understand the agronomy and concerns with potential risks presented by jatropha to cassava mosaic disease. Therefore at the present time a significant potential of jatropha should be limited to small-scale production and in particular encourage energy uses for local or self consumption. One such option is the use of raw vegetable oil in power generation for domestic use in rural communities.
- It is important for Tanzanian to explore the possibility of developing other oilseed crops for biodiesel production such as moringa, castorbean, and cotton among others.
- If biodiesel production is desired the viability of this should be promoted first at the small-scale rather than at the large scale and for domestic uses rather than export markets.

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22 Production cost for India came from publication by D. Ramesh *et al.*, titled Production of biodiesel from *jatropha curcas* oil by using pilot biodiesel plant.

23 Presentation from Oval Biofuel Limited, September 2009.

24 The production costs for Mozambique are taken from the Mozambique Biofuel Assessment prepared by Ecoenergy International Corporation in May 1, 2008.

25 The production cost for Malaysia came from publication by Gregore Pio Lopez and Tara Laan entitled Biofuels - at What Cost? Government support for biodiesel in Malaysia. In the study the production cost is reported in energy equivalent. This value was adjusted to have cost on volume basis to be able to compare to production cost obtain in this analysis.

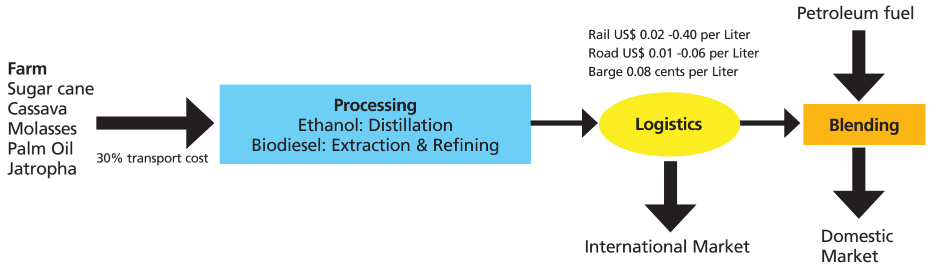
26 The production cost for biodiesel in the EU came from report on Techno-economic analysis of Biodiesel production in the EU: a short summary for decision-makers, Report EUR 20279 EN, May 2002. ftp://ftp.jrc.es/pub/EURdoc/eur20279en.pdf

5.4 MARKET COMPETITIVENESS ASSESSMENT

This section compares the competitiveness of biofuel production in Tanzania in domestic and international markets (Figure 5.7). The analysis focuses primarily on the production of ethanol from sugar cane and cassava. This is performed by looking at the production chain using the biofuel costs from Scenarios 2, 7, 8 and 9 and adding additional logistics costs.

Figure 5.7

Structure of the biofuel value chain



5.4.1 DOMESTIC MARKET

A simple analysis was performed for the purpose of showing how to assess the competitiveness of ethanol fuel in the Tanzania domestic market. This analysis considers transportation of feedstock and ethanol fuel considering truck and rail transport. A more comprehensive transport and distribution analysis should be carried out using detailed information on feedstock production areas generated in BEFS Module 1 and transportation networks in the country. This information can be used to help define the feedstock production areas and the most optimal site for the industrial processing and define the transportation needs, access to transportation networks and as such the transportation costs[27].

For the analysis on the competitiveness of the ethanol fuel, the production costs of ethanol are presented next to the reference sale price of gasoline (Figure 5.8)[28]. The ethanol production costs do not include any profits along the production chain as the decision regarding allocation of profits needs to be considered by the government in their decision-making process. The results indicate that there is a price difference between the production cost of ethanol and price of gasoline which indicates the potential for price margin sufficient in ethanol to cover for investments, taxes and other fees.

A price build up for blended gasoline with 10 percent ethanol was projected to assess how it will fare with gasoline. Two scenarios were defined, one where the blended gasoline

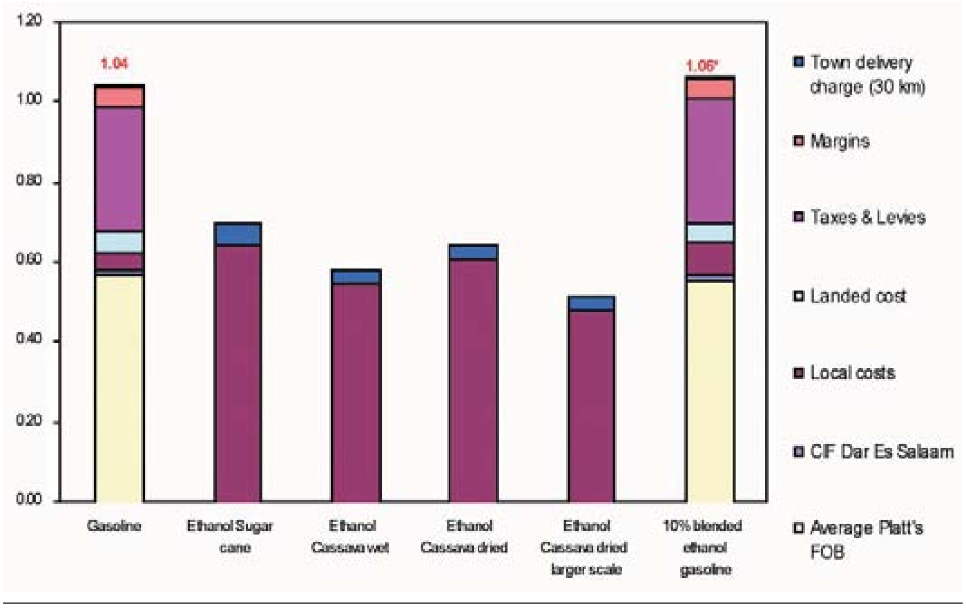
27 The assumption on the logistical cost estimated from factory to end market for sugar-cane ethanol Scenario 2 was USD0.06 per litre and for cassava ethanol Scenarios 7, 8, 9 USD0.04 per litre.

28 The referenced gasoline price was taken from values published by EWURA for October 2009. The ethanol production cost is adjusted to reflect the difference in energy content (30 percent less for ethanol). The blended gasoline with 10 percent ethanol is adjusted to the energy content i.e. 4 percent less energy in the blend as compared to 1 litre of pure gasoline

includes all levies and taxes and one where no levies and taxes were included in the 10 percent portion representing the ethanol. When taxes and levies are not included in the blended gasoline the estimated price is USD1.065 per litre. If full taxes and levies and a five percent margin profit costs are included the price is USD1.10 per litre (not shown in Figure 5.8). These values are indicative only and the main objective here is to show how biofuel production cost can be used to help policy decision in the country.

Figure 5.8

Comparison of production cost of ethanol and imported gasoline in USD per Litre *



* The production cost for ethanol production presented here is adjusted for energy difference between gasoline and ethanol (i.e. 30 percent less energy content in ethanol than gasoline).

5.4.2 INTERNATIONAL MARKET

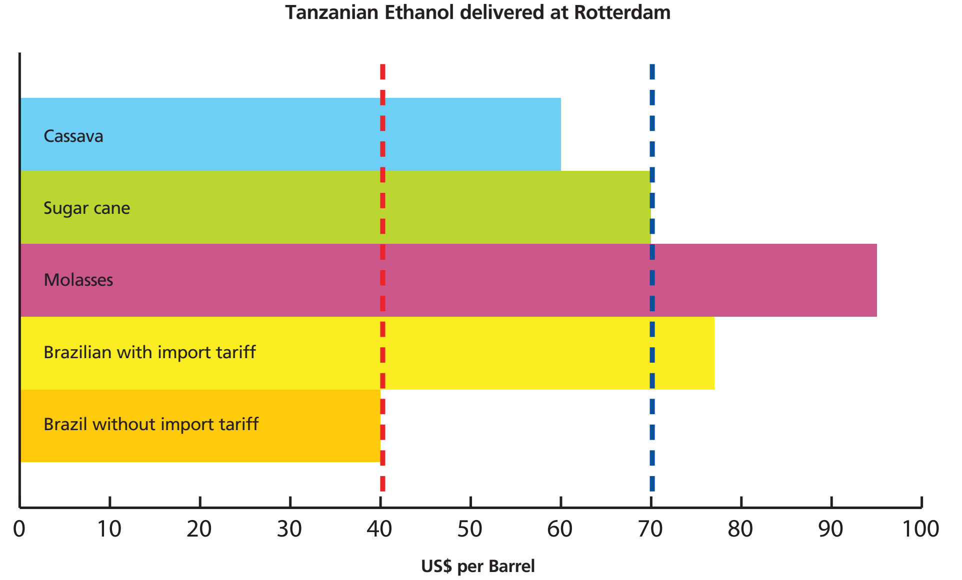
The assumption on the logistical cost estimated to transport ethanol from sugar cane and cassava was USD0.08 per litre. Based on the estimated production cost plus transportation and logistics without profit margin, the cost for delivering one barrel of ethanol to Rotterdam is estimated to be less than USD70 per barrel for ethanol from cassava and sugar-cane feedstock (Figure 5.9). The lowest cost of insurance freight (CIF) cost is obtained for cassava-based ethanol. According to literature the estimated cost of delivery of one barrel of Brazilian ethanol without profit margin to Rotterdam is around USD40 per barrel[29]. However, Brazilian ethanol has to pay an import tariff of about USD37 per barrel which Tanzania is exempt to pay under preferential treatment in the Everything-

29 The cost for Brazilian ethanol is taken by Olivier Henniges titled Competitiveness of Brazilian Bioethanol in the European Union, Department of Farm Management, University of Hohenheim Stuttgart

But-Arms (EBA) Initiative. Therefore, Tanzania's ethanol from both cassava and sugar cane are competitive and attractive options to the European export market.

Figure 5.9

CIF values for Tanzanian ethanol in Rotterdam



Ethanol Cassava: dried scenario 9. Ethanol Sugar cane: Scenario2. Ethanol Molasses: Scenario 6b, Including co-product credit

Discussion of findings on market competitiveness

- The price difference between the production costs of ethanol and the price of gasoline in the domestic market, even without including profits along the biofuel production chain, indicates that ethanol could be a competitive fuel option for the country.
- The potential for price margin in the ethanol production chain appears to be sufficient to cover for investments, taxes and other fees for ethanol.
- Overall, taking into account Tanzania's preferential duty and quota-free entry into European and US ethanol markets makes Tanzanian ethanol production very attractive. For example, in European markets under the EBA[30], Tanzania's biofuel production is competitive with ethanol producers with global ethanol producers who are obliged to pay the entry tariff.
- The question is whether Tanzania could also be competitive with other countries that have the same preferential tariff entry into these markets. For example, a biofuel study for Mozambique conditions estimated the ethanol production cost to be around USD0.30 to USD0.38/litre[31].

30 Under the Everything-But-Arms (EBA) Initiative ethanol produced in Tanzania is exempted from paying tariff. This tariff is estimated to be about US$0.25 per litre (€19.20 per hectorlitre) based on information in Annex A of the OECD-FAO Agricultural Outlook 2007-2017.

31 The cost of ethanol production for Mozambique came from Mozambique Biofuel Assessment prepared by Ecoenergy International Corporation in 2008.

- The CIF export cost for cassava and sugar-cane ethanol suggest that these are the most viable feedstock options. Molasses ethanol on the other hand is the least attractive option.
- Opportunities for improving competitiveness of the Tanzania ethanol production are promising, in particular due to prospects for improving crop yields which can contribute to cost reductions. Therefore, if conditions in the agricultural sector are conducive and improved productivity in feedstock is realized, this can lead to reduction of feedstock prices.

5.5 CONCLUSIONS

Based on this analysis, the scenarios that best match Tanzanian conditions and are recommended for development are the following:

- Ethanol from sugar-cane juice: Scenario 2 at technology level 2 represents the most economical viable option for this feedstock. This set-up consists of feedstock being supplied from combined outgrower-estate (smallholder farmer-commercial) and considers sales for energy co-generation and co-product. The estimated production cost is estimated at USD0.4336 per ethanol litre.
- Ethanol from molasses: the price volatility of molasses may prove to be too risky as biofuel feedstock. However, Scenario 6b has the lowest production cost estimated at USD0.5938 per litre ethanol accounting for co-products sales. Nonetheless, it is recommended that prior to pursuing the use of molasses for biofuel, a trade-off analysis in the context of Tanzania with other uses is carried out to asses the most economically effective market for molasses.
- Ethanol from cassava: the production costs for cassava ethanol were the lowest biofuel production cost for Tanzania ranging from USD0.36 to USD0.46 per ethanol litre. Scenarios 8 and 9 based on the use of dry cassava are recommended for their potential to integrate smallholder (outgrower) in the production chain. This would require the formation of small-scale cassava producers associations necessary to set up small-scale agribusinesses for processing fresh cassava roots to sun-dried slices. Moreover, support to increase cassava yields beyond the current 2 tons per ha (dry basis) is needed to ensure that a new demand will not threaten the availability of cassava for food consumption.
- Biodiesel production from palm oil is not recommended as this is not economically viable and places too much risk on palm oil uses for food.
- Biodiesel from jatropha: the lowest cost for production of jatropha biodiesel is obtained in Scenario 11 estimated at USD0.687 per litre of biodiesel assuming feedstock supplied by outgrowers (small-scale farmers) which at present time seems to represent a more viable option than estate (commercial) production. However, production costs for jatropha biodiesel are based on uncertainty on jatropha production in particular on yields. It is important for Tanzania to explore the possibility of developing other oilseed crops for biodiesel production such as moringa, castorbean, and cotton among others.

Key Issues

If the biofuel promise to rural development is to be realized supportive measures in the agriculture sector to increase yields need to be led by the government and/or in cooperation with potential investors. In particular, there is a need to reach out to outgrower producers. Outgrower skills need to be nurtured and technical assistance provided to help maximize yields. Greater accessibility to on-farm technology through use of better varieties, access to training, irrigation, inputs among others could be the means to improve productivity of feedstock and reduce biofuel production costs.

The price of the feedstock plays a crucial role in ensuring that biofuels produced in Tanzania can be economical. Overall, a 25 to 50 percent reduction in the price of feedstock would allow ethanol produced in Tanzania to become more competitive in international markets[32]. Furthermore, in the case of sugar cane, a 70 percent reduction in the purchase price of sugar cane feedstock will bring the ethanol production costs closer to Brazil's. In the case of molasses, if the price of molasses were reduced by 50 percent or more, the production cost would be closer to the production cost reported in Thailand and India. A 50 percent or greater reduction in price of cassava feedstock will make ethanol production costs very competitive with global cassava-ethanol prices estimated at about USD0.40-0.50 per litre[33].

Increased agricultural yields will also imply a lesser amount of land requirement. For example, to meet 10 percent blending ethanol mandate in Tanzania requires either the expansion of sugar-cane production areas or an increased in yields[34]. Looking at existing sugar-cane yield from outgrowers an increase in their yields from 44 to 70 tons per ha will reduce the land requirement by one-third which consequently lessen competition for land resources. However, more in-depth analysis on yield increase potential vs. land expansion is analysed within the context of BEFS Module 1.

Even in the case whereby the potential for biomass and biofuel production may be significant, lack of transportation networks may become a barrier for its commercialization. In Tanzania the higher cost of production in the agricultural sector is in part attributed to high transportation costs which are on average 30 percent of the crop production costs[35]. A major factor that has been identified as key to the competitiveness and efficiency of ethanol production in Brazil is the level of investment that has been devoted to develop the infrastructure to reduce transportation costs from the mill to consumer centres and ports. Brazil's ethanol infrastructure model did not arise from free market competition but it required huge taxpayer subsidies over decades before it could become viable.

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32 See Appendix 5C for more details.

33 Production costs are taken from LMC International Starch and Fermentation Raw Materials Monitor 2007 Report.

34 Existing molasses production will only provide for half of the demand of a 10 percent blending mandate, as such meeting the reminder demand will required either land expansion or increased productivity of existing sugar cane cultivars.

35 This estimated transportation cost comes from discussions with country experts.

APPENDIX 5 A

MODULE 2 METHODOLOGY DESCRIPTION

The analysis used a process engineering methodology to evaluate the technical and economic aspects associated with a variety of biofuel industrial production systems. The technological options considered in the analysis were designed based on an assessment of the country's ability for technologies. The production systems included a mix of conventional and advanced technologies. It contextualized the technological options to real-life investments project and analysed the relationship between operating cost and technology efficiencies for processing biomass to biofuel. Overall, the results provided a basis on which to assess the most technical adaptable and cost efficient options under the country's economy conditions. The techno-economic analysis was prepared by the National University of Colombia Manizales under the guidance of the BEFS project. The consultant's report was used as a background document for formulating policy recommendations on bioenergy potentials from the viewpoint of conversion technologies for liquid biofuel production.

The application of the methodology starts with the ***information gathering process*** whereby both secondary and country specific data are used to contextualize and adapt the methodology to the country. The next step in the methodology is the selection of feedstock, which in the case of Tanzania was based on the crops in which the country had an expressed interest for bioenergy uses. Then the ***characteristics of the industrial feedstock materials***[36] for processing biofuels are evaluated to determine the chemical composition. First the crop varieties are evaluated to assess the sugar, starch and oil content. Then, the chemical composition of intermediate materials (such as juice, molasses and vegetable oil) is determined to define the theoretical biofuel yield. The chemical composition is also needed to derive thermo-chemical properties to run the simulations. ***Technology capacity assessment*** is carried out to evaluate the countries technology access conditions.

Based on the results from the technology assessment a range of globally ***available technologies for*** biofuels production are evaluated to identify technologies that are most appropriate to Tanzania's capacity. To carry out this exercise, the biofuel production process is broken down into four main processing steps, then the technologies are matched for each one of these steps[37]:

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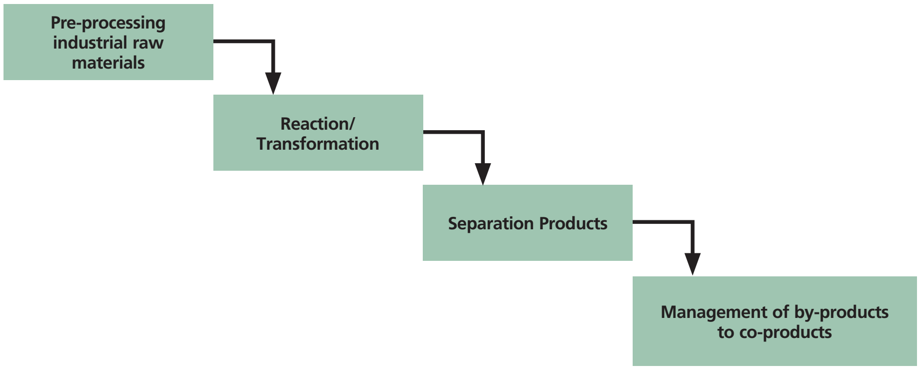
36 The cane juice, molasses and oil extracted from sugar cane and palm oil were considered as the industrial raw materials for ethanol and biodiesel production respectively.

37 Pre-processing may include mechanical i.e. crushing or chemical extraction. Transformations include fermentation in the case of ethanol and transesterification in case of biodiesel. Transesterification is the process of exchanging the alcohol group of an ester compound with another alcohol.

Figure 5A.1



A matrix of potential technologies for each of the processing steps (Figure 5A.1) that are country-specific is generated. These technologies are then matched for each of the processing steps and paired together to define the three technology level options. Prior to running the simulations, a set of production scenarios based on realistic investment projects are developed to define parameters such as the scale and conditions for biofuel production in the country. Simulations are then run using the desired technology configurations for each of the production scenarios. The simulations results are then evaluated based on a set of pre-established criteria. In this case, the criterion are operating cost, potential for management of by-products i.e. beneficial use within the production system or other potential markets, and production efficiency including energy surplus. The results generated from the evaluation are used to develop recommendations on the best alternative and the potential steps needed to develop the biofuel agro-industrial sector in the country.

APPENDIX 5 B

DETAILED ASSUMPTIONS ON THE COSTS OF FEEDSTOCK, PROCESS, CHEMICAL INPUTS AND TRANSPORT.

A. The sugar cane and cassava prices were derived from literature, the jatropha prices were taken from biofuel producers in the country, the molasses and palm oil prices were taken from the market price in Tanzania.

- The price of sugar cane produced by outgrowers was projected to be USD0.027 per kg based on yield 55 ton per ha production and includes transportation costs to the mill. For sugar cane produced in estates, the price was assumed to be USD0.0208 per kg based on 97 ton per ha. The sucrose content for sugar cane in Tanzania is based on varieties cultivated in the country and assumed to be around 13.80 percent.
- The molasses price was estimated to be around USD0.134 per kg for stand alone production facilities (Scenario 5) and USD0.0938 per kg for molasses-ethanol integrated facilities (Scenario 6). The main difference in the molasses price between the two scenarios comes from eliminating the transportation costs in the integrated facilities which are assumed to be annexed to the sugar mills.
- The cassava purchase price was assumed to be USD0.038 per kg for fresh cassava roots (Scenario 7) and for dried cassava chips (Scenarios 8 and 9) was USD0.133 per kg; these came from the One UN Cassava Value Chain Production Report. The price of palm oil feedstock is linked to world market prices for vegetable oil and as such was based on local estimated cost of USD440 per ton of palm oil plus an additional USD111 for transport.
- The price of jatropha was estimated for outgrower 164 USD/ton at 4 ton per hectare and for commercial USD270 per ton based on values provided by World Bank in Tanzania.

B. The biofuel processing cost includes capital and operating costs. The capital costs were estimated based on the scale as set by the level of production and adjusted for each of the production scenarios as necessary. Capital costs were based on global average equipment prices incorporated in the commercial simulator Aspen Plus. The operating costs were obtained from national statistics data and used in the simulation. Operating prices are the same for all scenarios and modified according to consumption as required by each of the production scenarios.

- The local prices reported for processing chemicals needed for biodiesel production were USD811 per ton for methanol and USD1 250 per ton for sodium hydroxide.
- Labour costs were based on the 2006 Tanzania Labor Survey and were estimated to be USD0.29 per hour for unskilled and USD0.44 per hour for skilled labour.

- The price of electricity was estimated to be USD0.03796 kilowatt hour and water price was estimated to be USD0.00038/cubic metre. Both water and electricity prices came from the prices stipulated by the Energy and Water Regulatory Commission.
- The tax rate was assumed to be 30 percent per period. The depreciation period was ten years.
- Construction costs were estimated based on assumed firm clay soil conditions.
- Maintenance and plant overheads were assumed to be 3 percent and 50 percent, respectively.

C. This analysis assumed a 30 percent of the crop production cost for feedstock transport costs from farm to plant gate and was included in the feedstock price.

D. As there is no current biofuel production in Tanzania, the distribution of biofuel to end markets was estimated based on transportation costs for the sugar-cane industry and estimated from the sugar sector study carried out by the Federal Agricultural Research Centre Institute of Farm Economics. The base cost for rail was estimated based on average cost of USD0.017 per litre and the transport costs from Dar es Salaam to Rotterdam Port CIF were estimated to be USD0.08 per litre. The cost for road transport was estimated based on petrol distribution and provided by the Energy and Water Regulatory Authority. Road transport per litre of biofuel was based on a 10 Tanzanian Shillings per 30 km per litre.

E. The following transporting options were considered for each of the scenarios:
- Scenarios: 1, 3, 5, and 6 look at moving ethanol from ethanol-producing sugar mills via rail to Dar es Salaam for either domestic or international markets
- Scenarios 2, 4, 7, 8, 9 and 10 moving ethanol from plants by road to Dar es Salaam for distribution to domestic or international markets.

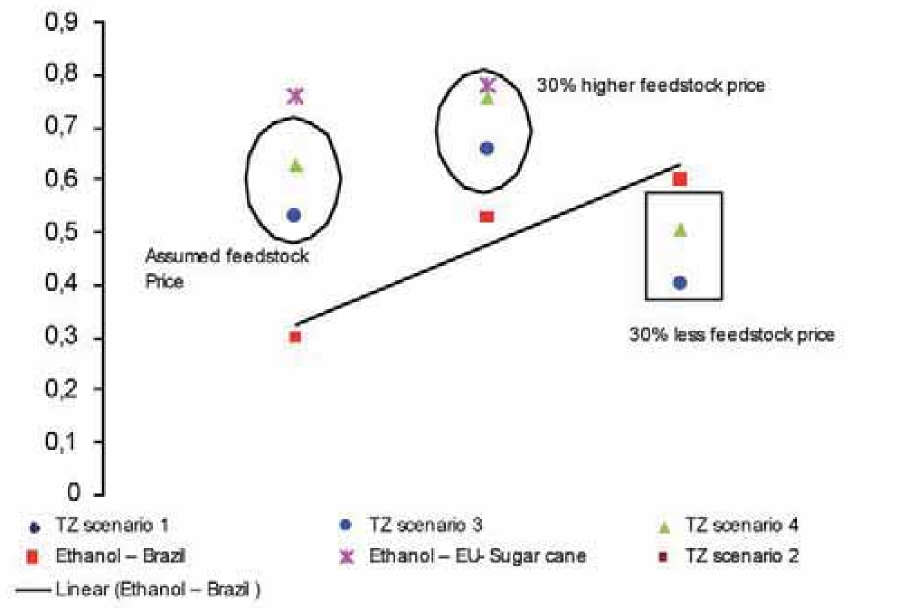
APPENDIX 5 C

SENSITIVITY ANALYSIS ON FEEDSTOCK PRICE

The impacts of a reduction on the feedstock price on ethanol production costs for sugar cane, molasses and cassava for Scenario 3 for sugar-cane juice, Scenario 5 for molasses and Scenario 7 are presented in Figure 5C.1.

Figure 5C.1

Estimated cost of ethanol production and sensitiveness to feedstock price assumptions in USD/L



Results for Scenario 3 indicate that the sugar-cane feedstock prices as simulated in this analysis result in ethanol production costs that are lower than those reported in India and the EU but much higher than those estimated for Brazil and Colombia (about USD0.30 per litre)[38]. A 25 or 50 percent reduction in the price of feedstock indicates that ethanol production costs in Tanzania become more competitive in international markets. A 70 percent reduction in the purchase price of sugar-cane feedstock will bring the ethanol production costs closer to Brazil's.

38 Literature indicates estimated production cost in the range as low as 30 cents per litre in these countries. The cost of sugar-cane production in Colombia comes from fuel ethanol production from sugar cane and corn: Comparative analysis for a Colombian case publication by Cardona et al. The article is published on Energy, volume 33, issue 3 March 2008, Pages 385-399. The production cost for Brazilian comes from LMC International Starch and Fermentation Raw Materials Monitor 2007 Report.

In the case of molasses-ethanol, results on production as simulated in Scenario 5 indicated that the production costs far exceed those reported in other countries. Here reduction in the price of molasses by 50 percent or more will bring production costs closer to production costs reported in India and Thailand. However, it is probable that a greater than 50 percent price reduction is necessary to provide an economic incentive to invest in stand-alone facilities for molasses-ethanol production in the country. For cassava-ethanol the production price estimated was closer to international levels. If the cost of feedstock was overestimated by 25 percent, this implies that the cost for Tanzania cassava-ethanol production is already along the line of estimated ranges for Thailand and Vietnam. A 50 percent or greater reduction in feedstock prices will also make ethanol production costs very competitive with global prices (estimated about USD0.40-0.50 per litre)[39]. These highlight the importance of reducing the costs of feedstock material to make the production costs of fuel-grade alcohol economically viable in global markets.

The reference for global ethanol production cost use throughout the study to compare against the Tanzania simulated production cost are summarized in Table 5C.1.

TABLE 5C.1

Reference Ethanol production cost

Country	Referenced value (US$/Litre)	Source
Brazil	0.53	Estimated OECD-FAO, Ex-distillery Sao Paolo
Brazil	0.30	LMC average of 2005-2007 100% bagasse energy
Brazil- sugar cane	0.60	2006 values LMC
EU- sugar cane	0.76-0.78	2006 values LMC
Brazil- molasses only	0.52-0.54	2006 values LMC
Brazil co-product (molasses/sugar cane)	0.33-0.39	2006 values LMC
EU- molasses only	0.61-0.65	2006 values LMC
US- molasses only	0.65-0.70	2006 values LMC
India Molasses	0.42-0.45	2006 values LMC
India co-product (molasses/sugar cane)	0.48-0.55	2006 values LMC
Thailand Cassava	0.38-0.40	2006 values LMC
Vietnam Cassava	0.34-0.36	2006 values LMC
Brazil cassava	0.45-0.47	2006 values LMC
China cassava	0.60-0.63	2006 values LMC
India cassava	0.61-0.65	2006 values LMC

39 LMC International Starch and Fermentation Raw Materials Monitor 2007 Report

CHAPTER 6

AGRICULTURE MARKETS OUTLOOK

COSIMO Team

6. INTRODUCTION

For any country the production of biofuels from any agricultural feedstock can be a contentious issue with regards to the food versus fuel debate, but it is particularly sensitive for those countries that are already deemed food insecure. It is important for government officials to understand how biofuel demand for feedstock might impact the commodity supply-disposition[1] within their country over time. Agricultural markets are continuously reacting to changes in demand and supply and to comprehend what the plausible impact biofuels might have on commodity markets, it is important to have a picture or outlook of future supply and demand conditions that might materialize. Therefore, this chapter presents the agriculture market outlook for Tanzania over a ten-year period and an assessment of the market implications of biofuel production. This encompasses not only scenarios for Tanzanian biofuel production and blending mandates, but also plausible implications of changing world oil prices and policy risk from foreign countries' biofuel policies. The production of biofuels and blending or consumption mandates in many countries has created a stronger relationship between energy markets, mainly oil, and agricultural markets. The prices of agricultural feedstocks used to produce biofuels are now linked to movements in oil prices. Even in a country where there are no government policies intervening in biofuel markets, domestic biofuel production would remain vulnerable to the movement in world oil prices and the consequential impacts on world crop prices. Likewise, biofuel policies of other countries could possibly change, which could significantly alter the profitability of biofuel production and influence crop prices.

Currently, there are not many impartial, publicly available long-term projections for agricultural markets that are consistent across countries[2]. However, the Organisation of Economic Cooperation and Development and the Food and Agriculture Organization of the United Nations jointly produce an annual ten-year projection for national and global agricultural markets, called the OECD-FAO Agricultural Outlook. This Outlook provides projections for production, utilization (i.e. consumption in the form of food, feed,

1 Commodity supply-disposition refers to beginning stocks, production, imports, consumption, exports and ending stocks and the equilibrium condition that balances the market (i.e. beginning stocks + production + imports = consumption + exports + ending stocks).

2 Many countries produce forecasts for agricultural commodity markets, but these forecasts are from their perspective of the world and are not necessarily peer reviewed for consistency.

fuel or fibre), imports, exports, stocks and prices for the main agricultural commodities and biofuels of the countries influencing world agricultural markets[3]. The Outlook is an important foresighting tool that can highlight important challenges or opportunities in agricultural markets for some countries. It provides a picture of how agricultural markets could evolve over time with respect to a set of macroeconomic[4] conditions, trends and current agricultural policies employed in countries influencing world markets. The value of Outlook is not so much the precision of projected values in any one year, but the dynamics of how markets are expected to evolve over the next ten years. OECD-FAO use a partial equilibrium simulation model called AGLINK-COSIMO to produce the projections of national and global agricultural markets in the Outlook. The model along with the Outlook, which serves as a baseline, is used to conduct market and policy analyses to determine impacts on agricultural markets. The AGLINK-COSIMO model and Outlook provide comprehensive coverage of agricultural commodity markets by country or regions and their respective agricultural policies. This makes it an effective tool to analyse Tanzanian agricultural markets over the next ten years, as well as to conduct scenario analysis with respect to biofuels.

This document first discusses the rationale for analysing and reporting specific commodity markets in Tanzania. The following section then discusses in detail the assumptions and highlights of the baseline produced to analyse Tanzanian agricultural and biofuel markets. The following section sets forth the situation in Tanzania with respect to the possible development of biofuel production and the possible government biofuel blending mandate. This sets the context for the assumptions to be used for scenario analysis. Thereafter, the scenarios undertaken are explained along with the key results. Then considering the influence that foreign countries' biofuel prices have on biofuels and crop markets, the analysis: "Biofuel Support Policies: An Economic Assessment"[5] conducted by the OECD is highlighted to show the risk to Tanzanian agricultural markets presented by foreign policies. The final part of the report provides implications on effects of emerging biofuel developments and policies with respect to food security in Tanzania.

The analysis presented focuses on market projections for coarse grains (maize and sorghum), wheat, sugar, palm oil, rice, sugar cane, roots and tubers (cassava, yams and sweet potatoes) and biofuels. This list comprises both the main food security crops and the bioenergy feedstock, as previously discussed.

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3 For further information regarding commodity and country representation within the OECD-FAO Agricultural Outlook please see it online at www.oecd.org/publishing/corrigenda.

4 Macroeconomic assumptions for growth rates of GDP, inflation, interest rates, exchange rates, population and oil prices are derived from OECD, International Monetary Fund and World Bank estimates.

5 "Biofuel Support Policies: An Economic Assessment" – ISBN-97-89-26404922-2 © OECD 2008.

6.1 TANZANIA BASELINE

Following discussions with key stakeholders in Tanzania, the Outlook has been adjusted in order to reflect more up-to-date sugar cane production levels. This adjusted Outlook is here referred to as the Tanzanian baseline. The baseline represents the current status of agricultural markets in Tanzania in which there is no biofuel production. The scenarios set up in this chapter are assessed against this baseline.

Note that when discussing the baseline it is important to understand that the model assumes that Tanzanian agricultural markets are linked to world agricultural markets through both trade and prices. Domestic prices are determined from world prices and the trade status of the country as a net importer or exporter. The model uses a full price transmission elasticity with modifications for transition between trade positions[6]. Even though prices are important in explaining the behaviour of producers and consumers, it is more important to evaluate the growth paths of production and consumption with respect to price levels rather than any exact price forecast in a given year.

6.1.1 BASELINE ASSUMPTIONS

General Model Assumptions:

- Oil prices to remain at high levels, rising from USD90 in 2008 to USD104 per barrel in 2017.
- The projections run from 2008 to 2017.
- Robust economic growth in emerging economies and moderate growth for OECD countries.

Assumptions on macroeconomic, population and agricultural lands for the projection baseline scenario for Tanzania:

- Annual gross domestic product (GDP) growth is 6.8 percent on average over the Outlook period.
- Inflation for GDP and inflation for the consumer price index (CPI) differ. The average annual inflation rate for GDP is 7.9 percent and for CPI it is 8.1 percent.
- The domestic currency depreciates in nominal terms against the US dollar, at an average rate of 6.7 percent annually. The real exchange rate depreciates by 0.2 percent annually.
- Annual real expenditure (CPI deflated) growth rate is 2.9 percent on average over the Outlook period and food costs rise slower than income.
- Population increases at a 2.38 percent annual rate.
- Cultivated area expands at rate of 1.2 percent annually. On average 16.3 percent of total arable land is cultivated.

6 At the time of the analysis domestic commodity prices were not available. Due to this the model assumes the country is a small country price taker. This entails that domestic prices are determined through world price linkage equations that takes into account the exchange rate, tariffs, transport costs and net trade position. In the cases for which the country is a net exporter, domestic prices will equivalent to the world prices net of transport costs. On the other hand, when the country is a net importer, domestic prices are equivalent to the world prices plus applicable tariffs and transport costs.

6.1.2 HIGHLIGHTS FROM THE BASELINE

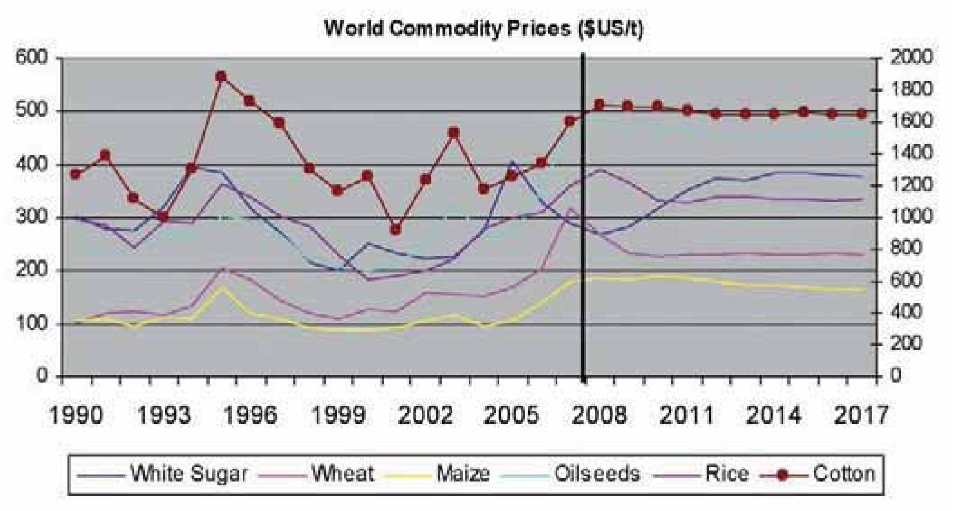
The purpose of the baseline is to show how Tanzanian agricultural markets could evolve over time in the absence of biofuel production or a biofuel mandate. In each key commodity market it is important to comprehend if Tanzania is capable of producing enough food to meet consumption and whether they are relying more on imports or producing surpluses that could lead to increased exports. Obviously this has implications for food security and trade balances, which impact the government balance of payments for Tanzania. The table at the end of the section shows the relative difference between 2007 and 2017 production, consumption and net trade projections and unless otherwise stated the results discussed below refer to differences between 2007 and 2017 and growth rates are computed annual averages[7].

6.1.2.1 WORLD OUTLOOK

The tightening of world supplies (droughts and low stocks) combined with increasing demand for crops, partly from biofuels, and investor speculation has created an upward swing in world agricultural commodity prices. The Outlook is projecting that prices over the next ten years will be on average higher than the previous years as new demand will outpace productivity gains. Crops that are used for biofuels, such as maize, sugar, vegetable oil, are projected to have relatively higher growth prospects than others; however, substitution and competition for cultivated land will have knock-on effects for other crops. Although prices are expected to decrease from recent strong upward swings the long-term average for most crop prices are projected to be at a new price plateau. Figure 6.1 shows the Outlook for world crop prices, but it is important to remember that in the Outlook price projections are based upon market fundamentals of demand and supply whereby markets eventually reach a long-term equilibrium. The Outlook assumes normality and does not project abnormalities, such as droughts or recessions, and it is important to look at trends and not absolute prices. Prices in the Outlook are annual prices and agricultural prices can fluctuate significantly over the course of a year.

7 Growth rates differ from year to year in the baseline but for purpose of discussion of results the annual average growth rate is used.

Figure 6.1
World commodity prices



**Cotton prices are on the right axis.*

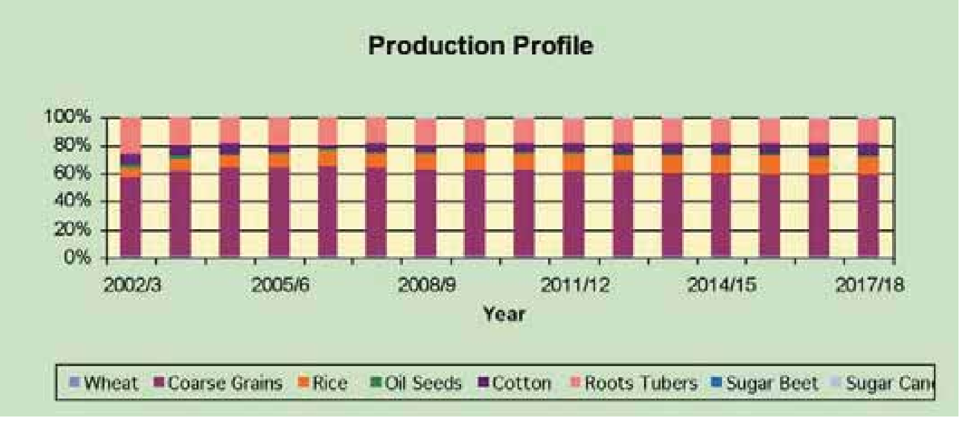
6.1.2.2 TANZANIA OUTLOOK

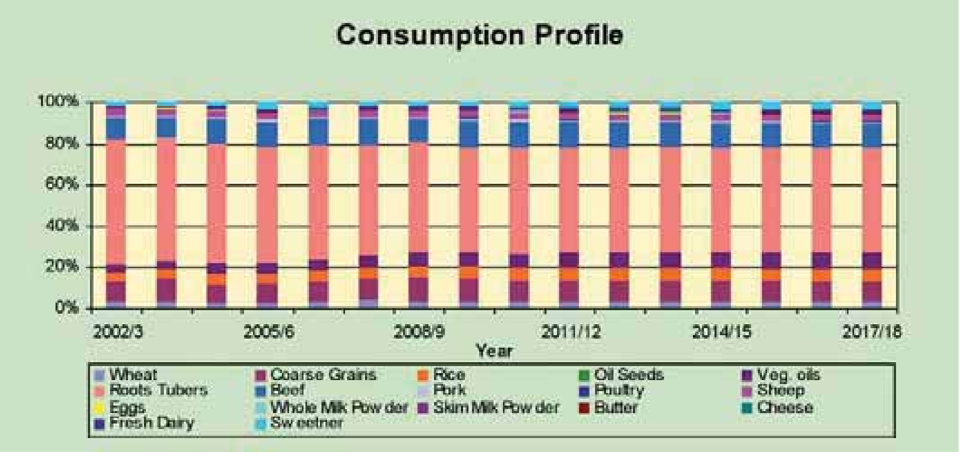
Coarse grains are the most important crops in Tanzania with an average area share of 60 percent (see Figure 6.2). Roots and tubers are the second most important crops with an average area of 18 percent. Rice is the third most important crop with an average area share 12 percent of the area. Relatively strong prices for rice, cotton and sugar over the Outlook encourage increasing shares of production for these crops, but they still have relatively low production shares compared to coarse grains.

Baseline projections on production and consumption trends are presented in Figure 6.2. The production trends indicate that overall sugar cane, wheat and oilseeds will continue to have a small share in the agricultural sector. On the other hand, coarse grain, rice and roots and tubers will be the most important agricultural crops in terms of production. With respect to trade, coarse grains are on average the dominant export commodity over the Outlook period, while wheat has the largest average net imports. With over half of total food expenditure on roots and tubers, it remains the largest commodity for food consumption over the baseline period. However, with income growth there is an increasing share of food expenditure on beef, dairy products and vegetable oils throughout the baseline, albeit these commodities start from a relatively small share of overall food expenditure.

Figure 6.2

Baseline projection production and consumption profile





As illustrated in Table 6.1 the outlook for commodities in Tanzania shows the following:

Coarse Grains

On the production side, the total coarse grains area[8] is assumed to increase 0.33 percent annually and yields increase 1.51 percent annually, which increases coarse grain production by 858 kt[9] from 2007 to 2017. This corresponds to production increasing at the rate of 1.84 percent annually. Better yields explained 80 percent of the improvement in production. For Tanzania, both maize and sorghum are aggregated in the AGLINK-COSIMO model in the coarse grains aggregate[10]. In Tanzania, production of maize is by far the largest coarse grain[11].

8 Area means cultivated or harvested area.

9 kt – thousand metric tons

10 The AGLINK-COSIMO coarse grains aggregate includes maize, sorghum, rye, oats and barley where applicable.

11 National Tanzanian statistics indicate that in 2004, 80 percent of coarse grains came from maize.

In Tanzania, coarse grains food expenditure represents on average 10 percent of their overall food expenditure and is the third largest share in their food budget. Total use or consumption is largely from food consumption with a relatively small share from feed. Total use increases by 1 384 kt over the projection period and is mainly driven by food use (increases by 979 kt).

Although the country is a net exporter of coarse grains from 2007 to 2017, consumption grows faster than production and consequently there is a decrease in net exports of 291 kt.

Roots and tubers

The roots and tubers aggregate includes cassava, yams, and sweet potatoes. In the case of Tanzania this group is mostly represented by cassava[12]. Roots and tubers are the second most important crop group in Tanzania with an average crop area share of 18 percent. The total area covered by roots and tubers increases by 105 000 hectares (ha), or 8.8 percent over the Outlook period. Yields increase marginally at a rate of 0.48 percent annually and reach 7.8 tons per ha by 2017. Throughout the projection period domestic supply fluctuates but overall production increases by 1 251 kt. Yields explained 34.7 percent of the increase in production.

People in Tanzania spend the largest share of their food budget on roots and tubers, an average budget share of 55 percent. Total consumption increases by 1 251 kt, where consumption is mainly driven from increased food use. Considering cassava production is largely subsistence farming, it is assumed that domestic demand will be met by domestic production, which implicitly assumes that roots and tubers are not imported or exported.

Rice

The area harvested for the production of rice increases at an annualized rate of 3.55 percent, whereas yields will remain at less than 1.30 tons per ha with an annual increase rate of 0.61 percent. The projection indicates overall production increases by 408 kt by 2017. Yields explained about 12.4 percent of the increases in production, and therefore, production growth is driven primarily by land expansion.

Total consumption is determined only by rice food consumption as no rice is used as feed and crushing (milling) rice is not considered in the baseline. Total domestic use is projected to increase by 399 kt. Due to higher production gains relative to consumption there is a slight decrease in rice imports of approximately 6 kt, however, Tanzania still needs to import 93 kt by 2017 to fulfil domestic use.

12 In the Agricultural Census 2002-2003 90 percent of the area harvested under roots and tubers in Tanzania was cassava.

Wheat

Harvested area for wheat is to remain relatively unchanged with area harvested reaching 74 000 ha in 2017. However, yields are expected to increase at a rate of 3.45 percent annually over the Outlook period and production increases by 36 kt. Intuitively, yields explained about 83.9 percent of the improvements in production.

Likewise with rice, wheat total consumption is only determined by food consumption, which is projected to grow at an annual rate of 4.13 percent. From 2007 to 2017, consumption of wheat increases by 217 kt. Consumption growth significantly outpaces increases in production and Tanzania becomes a larger importer of wheat over the baseline with an increase in net imports of 284 kt by 2017.

Sugar cane and Sugar

Historical data series were updated with information provided by the Sugar Board of Tanzania. Sugar cane area harvested is projected to increase at an annual rate of 4.84 percent. Yields are projected to go from 71 ton per ha in 2008 to 114 ton per ha in 2017. The projection indicates an overall production increment by 6 095 kt. Yields explained around 83.9 percent of the increase in production.

More than 75 percent of sugar cane goes into production of sugar with the remainder used for molasses production, for which some molasses is assumed to produce ethanol for non-fuel uses (potentially human consumption). There is no projected use of sugar cane for biofuels in the baseline.

The growth in sugar-cane production directly causes sugar production to increase by 348 kt. However, consumption of sugar in Tanzania is projected to increase annually at 4.48 percent, which represents an increase of 284 kt. With production growth outpacing consumption growth, Tanzania decreases its net imports by 55 kt by 2017.

Palm oil

Production of palm oil is assumed to grow from approximately 6 to 7 kt throughout the projection period. There is no trade information for Tanzania in this commodity. Palm oil and oilseeds' oil are estimated but are then aggregated into the vegetable oil market. Tanzania produces a relatively small amount of vegetable oil. The domestic supply of vegetable oil is projected to increase by 1 kt by 2017 and is directly from increased palm oil production.

Total consumption of vegetable oil is from food use and with strong income and population growth, consumption increases by 218 kt by 2017. With little increases in production Tanzania increases net imports by 214 kt for a total of net imports of 511 kt by 2017.

Jatropha

There is no jatropha production during the Outlook period.

Biofuel

The baseline projection assumes no production of biofuels from ethanol and biodiesel. However, it is assumed that there will be production of ethanol, but only for other uses such as human consumption.

TABLE 6.1

Main commodity highlights

Main commodity highlights of 2008 vs 2017 (kt, thousand tonnes)									
	2007	**2017**	**Change**	**%**		**2007**	**2017**	**Change**	**%**
Coarse Grains					**Root & Tubers**				
Production	4 283	5 141	858	20%	Production	8 879	10 130	1 251	14%
Consumption	4 008	5 044	1 037	26%	Consumption	8 887	10 130	1 243	14%
Net Trade*	365	74	-291		Net Trade	0	0	0	
Rice					**Wheat**				
Production	806	1 214	408	51%	Production	64	100	36	56%
Consumption	905	1 304	399	44%	Consumption	434	651	217	50%
Net Trade	-99	-93	6		Net Trade	-270	-554	-284	
Sugar					**Vegetable Oil**				
Production	286	634	348	122%	Production	15	16	1	9%
Consumption	516	800	284	55%	Consumption	310	528	218	70%
Net Trade	-223	-168	55		Net Trade	-297	-511	-214	

**Positive net trade implies a net exporter and negative implies net importer*

6.2 BIOFUEL PRODUCTION IN TANZANIA

6.2.1. ETHANOL FEEDSTOCK

The two feedstocks identified for ethanol production were sugar cane and cassava:

Sugar cane

The expansion of sugar-cane production for ethanol is assumed to come from a development of outgrower schemes, whereby both smallholders and commercial ethanol plantations will provide the feedstock for ethanol production. This expansion of sugar-cane area harvested for ethanol is assumed to reach 66 000 ha by 2017. The yields will gradually increase from 71 ton per ha to 114 ton per ha by 2017 as specified by the baseline. Sugar cane for ethanol production thus is estimated to be about 7.5 million tons by 2017. The conversion factor for sugar cane to ethanol used in the analysis was 69 litres per ton and is based on simulations carried out in Module 2. Molasses from sugar production is also used for ethanol production in the baseline, but this is assumed for non-biofuel markets and is held relatively constant throughout the scenarios as stakeholders indicated they were not planning to increase use of molasses for ethanol production.

Cassava

An expansion of cassava production for ethanol production is also analysed. It is assumed to come from a development of outgrower schemes, whereby cassava comes from smallholders and commercial plantations associated with the ethanol plants. The expansion from outgrowers as well as commercial will each be 50 000 ha by 2017. This will result in an additional 100 000 ha of new cassava area. The yields from smallholders are assumed to be 6 ton per ha from 2009 to 2011 and then increase to 9 ton per ha for the remainder of the projection period. The yields for outgrowers are assumed to be 17 ton per ha from 2009 to 2011 and then to be 20 ton per ha thereafter[13]. This will result in the production of additional 1 450 kt of cassava for ethanol production.

6.2.2 BIODIESEL FEEDSTOCK

The two feedstocks that are considered for biodiesel production include jatropha and palm oil.

Jatropha

The expansion of jatropha production is solely envisioned for its use in biodiesel production. The area devoted to jatropha is expected to reach 126 000 ha by 2017. The yield is assumed to gradually increase from 0 in 2008-09 to 2 tons per ha by 2010, then to 3 tons per ha by 2011 and to 4 tons per ha by 2012-2017. This corresponds to approximately 470 kt of jatropha oil by 2017.

Palm oil

Palm oil expansion is to take place both in small farmer and commercial sites, whereby yields for irrigated commercial sites are assumed to reach 27 tons per ha and rain fed smallholders' yields to reach 9 tons per ha by 2017. The total land expansion goes from a base of 2 000 ha in 2008 to 22 000 ha by 2017, which represents an increase of 20 000 ha. This corresponds to an increase of 414 kt of palm oil by 2017.

6.2.3 LAND EXPANSION DEVOTED TO BIOFUELS

Tanzania has the capacity to expand agricultural production through utilizing new land bases and increasing yield productivity, especially for biofuel feedstock. This along with its

13 Yields were defined from data on the Cassava Value Chain Report

preferential access to the EU market through the Everything-But-Arms (EBA) initiative, attracts potential investment for biofuel development. To this end, foreign investors have expressed interest in producing biofuels in Tanzania. This situation has led to investors and the Government of Tanzanian to explore what lands might be available to produce biofuel feedstock. With respect to land availability, information provided by the stakeholders form the basis for assumptions regarding land devoted to producing biofuel feedstock. This represents actual agricultural land expansion and is assumed to come from lands that are not currently utilized, therefore, this would represent an increase in area harvested compared to the baseline. The total land identified by for possible biofuel feedstock production is approximately 314 000 ha. The following section, 6.3 Scenario development, gives details on the assumptions on land by biofuel feedstock, yields and conversion factors for biofuels derived from the discussions with stakeholders.

6.2.4 THE GOVERNMENT BLENDING MANDATE FOR BIOFUELS IN TANZANIA

The Government of Tanzania does not have as yet an established policy on biofuels. To this end, the only clear action is that the Ministry of Energy (MOE) has been given the legislative authority to set up biofuel blending mandates. The MOE has only expressed a mandate range from 0 percent to as much as 20 percent. In Tanzania the main transport fuels are gasoline and diesel, with the latter representing the largest share. Ethanol and biodiesel would both be a part of a biofuels policy. In consultation with the country teams and national experts it has been proposed to analyse the impacts of a biofuels blending mandate of 10 percent for ethanol and 5 percent for biodiesel. The blending mandates are assumed to come into effect by 2011. Table 6.2 shows the amount of ethanol and biodiesel needed to meet the mandate between 2011 and 2017.

TABLE 6.2

Amount of biofuels required to meet the government blending mandates

Biofuel (Million Litres)	2011	2012	2013	2014	2015	2016	2017
Ethanol	37	39	41	43	45	47	49
Biodiesel	44	46	48	49	51	53	55

6.3 SCENARIO DEVELOPMENT

The scenarios were set up based on scale of production, a combination of domestic demand deriving from domestic biofuel mandates and land expansion due to international investors (see Table 6.3).

TABLE 6.3
The scenarios used in the analysis

Scenario Description	Features
Scenario 1: Biofuels mandate and no land expansion devoted to biofuels	- Biofuel Consumption Mandate of 10% ethanol and 5% diesel - Ethanol Production from 50% sugar cane and 50% cassava - Biodiesel Production from 80% vegetable oil and 20% jatropha - No land expansion except for jatropha
Scenario 2: Land expansion solely for biofuels and government blending mandate	- Biofuel Consumption Mandate of 10% ethanol and 5% diesel - Land expansion solely for biofuel feedstocks: - 66 000 ha sugar cane - 50 000 ha cassava - 126 000 ha jatropha - 20 000 ha palm oil
Scenario 3: As Scenario 2 above with lower oil prices	- Oil prices in 2008 are lined up to actual prices observed in 2008 at USD99 per barrel then reduced to USD68 per barrel in 2017 - Average decrease in oil prices approximately -35% (exception is 2008).

Further, considering that biofuels and crops are sensitive to changes in oil prices, sensitivity analysis to lower oil prices is also included in the analysis. The results from scenarios are then compared with the Tanzanian outlook, which serves as the baseline.

6.3.1 SCENARIO 1: BIOFUELS MANDATE AND NO LAND EXPANSION FOR BIOFUELS[14]

This scenario analyses the implementation the biofuels mandate of 10 percent ethanol and 5 percent diesel, whereby the production of biofuels to meet this mandate must come from feedstocks that are currently produced on the existing land base from the baseline. For ethanol it is assumed that 50 percent of the required amount will come from sugar cane and 50 percent from cassava. With respect to biodiesel, 80 percent will come from jatropha and 20 percent from palm oil. Considering that jatropha production is already being planted, as indicated from consultations with Tanzania, the scenario does allow expansion of land but only for jatropha. This scenario shows the possible impacts of a biofuels policy and its corresponding effects on the commodity supply-disposition of the major commodities and implications for food security if additional land expansion solely for biofuel feedstock is not realized.

14 The exception here is that jatropha was not in the baseline but will be a key feedstock for biofuels, so there is land expansion only for jatropha as it is strictly a biofuel feedstock and not a food crop.

6.3.2 SCENARIO 2: BIOFUELS MANDATE WITH LAND EXPANSION SOLELY FOR BIOFUELS

This scenario shows the impacts of both developing biofuels from land expansion and the implementation of government blending mandate on Tanzania's biofuel market. It shows how much biofuels would be produced, consumed and exported as a result of the land expansion and blending mandate.

6.3.3 SCENARIO 3: BIOFUELS MANDATE WITH LAND EXPANSION SOLELY FOR BIOFUELS AND LOWER OIL PRICES

Projection for oil prices used in the 2008-2017 Outlook was based on rather high prices. The Outlook assumed prices would go from USD90 per barrel in 2008 to as high as USD104. However, new published data from the OECD that takes into consideration the recent economic slow down, indicates that oil prices will be lower than previous projection. This projection ranges from USD99[15] per barrel in 2008 to USD68 per barrel in the final projection year. This scenario shows how lower oil prices could impact Tanzanian's agricultural markets. Scenario 3 is benchmarked or compared to Scenario 2 because the objective of this scenario was to evaluate how changing oil prices would impact both agricultural and biofuel markets. To observe these changes requires using Scenario 2 as the benchmark as it has the same level of prices, production, consumption and trade for Tanzanian agricultural markets as the Tanzanian baseline and the only difference between the baseline and Scenario 2 is the biofuels market.

6.4 DISCUSSION OF SCENARIO RESULTS

6.4.1 SCENARIO 1: BIOFUELS MANDATE AND NO LAND EXPANSION FOR BIOFUELS

The biofuels mandate requires approximately 49 million litres of ethanol by 2017, whereby 50 percent would be produced from sugar cane and 50 percent from cassava. With a conversion factor of 183 litres of ethanol per ton of cassava, implies that by 2017 over 132 kt of cassava is required for ethanol production. Likewise, with a conversion factor of 69 litres per ton of sugar cane, implies that by 2017 over 351 kt of sugar cane will be needed for ethanol production. In terms of how this impacts Tanzania's sugar market is that 351 kt less sugar cane is processed to be sugar and/or molasses, which corresponds into 25 kt less sugar produced. Considering that Tanzanian agricultural markets are assumed to be characterized by the small country price taker assumption (domestic prices are determined by world prices and net trade position) sugar prices remain basically unchanged in reference to the baseline; therefore, consumption of sugar remains the same also because prices do not change[16]. Ultimately, as consumption remains the same but production of sugar decreases with sugar

15 The world price of oil for 2008 was USD99 per barrel and this actual market value was used in this scenario instead of the baseline projection of USD90 and it is thereafter from 2009-2017 that a lower oil price was used for the scenario.

16 The model result is that domestic prices do not change because there is no significant impact on net trade, which could impact prices for the country. However, increased demand in local markets where biofuel production takes place could lead to small price increases for some commodities in local markets, but overall these are likely to be small. If Tanzania markets are efficient then arbitrage will take place and the small country price taker assumption is valid.

cane being diverted to ethanol production, imports of sugar have to increase by 25 kt to meet domestic demand. This means that by 2017 net trade of sugar decreases from -168 kt to -193 kt, which corresponds to a 15 percent decrease. Tanzania could avoid this increase of imports of sugar if yields of sugar cane were to average 81.15 tons per ha with an increased acreage of 4.33[17] thousand ha by 2017. Although this only represents a 5.4 percent increase in acreage compared to the 2017 projection of 79.5 thousand ha, it represents a 20 percent increase if compared to the 2007 acreage of 21.7 thousand ha.

In terms of the market implications from ethanol production using cassava, the story is different because of the fact that roots and tubers are not a traded commodity and therefore, the ethanol demand for cassava will displace food use. To produce 24.3 million litres of ethanol 132 kt of cassava will be needed and this directly displaces 132 kt of food use of cassava, which represents only a reduction of 1.5 percent in 2017. Although the production of ethanol from cassava does displace some cassava that is normally consumed as food, it is relatively a small impact on the overall total consumption. However, it may be a small impact at the country level, but the impact could be very acute at a local level where the ethanol production takes place. It is quite possible that at this local level many people could be adversely impacted by incurring a significant reduction in food availability. A pertinent question will be whether the revenue earned from selling cassava to an ethanol plant will be sufficient to purchase other food crops to offset the reduction. Not only is it a question of sufficient revenue, but also the ownership of the cassava and distribution of the revenue. If it is subsistence farmers' selling their production to the ethanol plant then it is likely they will be able to purchase other foodstuffs to replace this production, otherwise why would they sell the cassava in the first place. However, if the cassava production is owned by landowners then it is uncertain whether farm workers who normally consume the cassava would be compensated sufficiently to purchase other foodstuffs. Again, if Tanzania wanted to avoid food displacement from ethanol production, if farmers could average yields of 7 tons per hectare then by 2017 there would only be a need of an additional 18.9 thousand ha of cassava. This represents only an increase of 1.5 percent in an area harvested for roots and tubers in 2017.

The government blending mandate of 10 percent for diesel would require 55 million litres of biodiesel by 2017, whereby it is assumed 80 percent would be from jatropha oil and 20 percent palm from palm oil. Regardless of which feedstock is used to produce biodiesel the conversion factor for vegetable oil to biodiesel is 1 175 litres of biodiesel per ton of vegetable oil. Considering the assumption that 80 percent of biodiesel will use jatropha as a feedstock then it implies that 44 million litres of biodiesel will be needed and consequently, this translates into approximately 80 kt of jatropha oil. To meet this production level Tanzania would need to average 3 tons of oil per hectare for yields and

17 The average yields required is applied only to the increased area harvested that is necessary to offset the increased demand for the commodity in question and this does not represent the average yield that is projected in the baseline.

would need 26.8 thousand hectares of jatropha. As indicated previously, the baseline assumed there was no production of jatropha, so this implies a significant increase of jatropha acreage and production.

The 20 percent assumption of biodiesel production from palm oil would require 11 million litres of biodiesel, which translates into approximately 9.4 kt of palm oil by 2017. This represents an increase in vegetable oil demand and given that production of vegetable oil remains unchanged as prices remain relatively unchanged, this causes imports of vegetable oil to increase by 9.4 kt and net trade decreases to a total of -520 kt. Considering that Tanzania already imports a considerable amount of vegetable oil the additional 9.4 kt is relatively insignificant as it only represents an increase of 1.8 percent over the baseline. However, relating this demand increase of 9.4 kt to domestic production implies that domestic production would have to increase by 58 percent compared to its baseline projection of 16 kt in 2017. To avoid increasing imports Tanzania would have to average yields of 10 tons per hectare and need an additional 0.94 thousand ha of palm oil production.

6.4.2 SCENARIO 2: BIOFUELS MANDATE WITH LAND EXPANSION SOLELY FOR BIOFUELS

The introduction of 314 000 hectares of additional land strictly devoted to biofuels production results in 1 495 million litres of biofuel being produced in Tanzania by 2017. Table 6.4 shows the planned area expansion by feedstock and Table 6.5 displays the amount of biofuel produced from each feedstock:

TABLE 6.4

Land expansion for biofuel feedstock

Land Expansion for Biofuel Feedstock, thousand hectares									
	2009	2010	2011	2012	2013	2014	2015	2016	2017
Sugarcane	3.0	8.0	13.0	18.0	**27.3**	36.7	46.0	56.0	66.0
Cassava	7.1	19.6	32.1	44.6	57.1	69.6	82.1	94.6	100.0
Jatropha	0.0	22.6	35.1	51.4	66.6	80.7	95.9	111.1	126.3
Palm oil	0.0	9.5	15.8	17.0	18.3	19.5	20.8	22.0	22.0
Total	10.1	59.8	96.0	131.0	**169.3**	206.6	244.8	283.7	314.3

For jatropha and palm oil acreage in the above table, the numbers represent actual harvested acreage. In the case of biodiesel production it does not start until 2010 because of the natural production cycle of both jatropha and palm oil where it takes several years before the crops can be efficiently used for cultivation.

TABLE 6.5

Tanzania biofuel production

Tanzania Biofuel Production, million litres									
	2009	2010	2011	2012	2013	2014	2015	2016	2017
Ethanol	46.8	99.2	160.8	252.5	364.6	486.9	593.2	709.8	800.2
Sugarcane	24.5	50.6	85.9	126.7	205.5	294.6	367.6	451.0	534.4
Cassava	22.3	48.6	75.0	125.9	159.1	192.3	225.5	258.8	265.8
Biodiesel	0.0	55.4	276.9	437.9	523.3	593.2	631.5	669.8	694.8
Jatropha	0.0	18.7	43.4	84.8	109.8	133.2	158.3	183.3	208.3
Palm oil	0.0	36.7	233.5	353.1	413.5	460.0	473.2	486.5	486.5
Biofuel	46.8	154.6	437.8	690.4	887.9	1 080.2	1 224.7	1 379.5	1 495.0

Initially, sugar cane and cassava produce practically the same amounts of biofuel, but larger increases in expected yields of sugar cane leads to a larger share of ethanol production from sugar cane (approximately 67 percent by 2017). For biodiesel, the yields for oil from palm production are substantially higher than jatropha and consequently, palm oil contributes to a larger share of biodiesel production (approximately 70 percent by 2017).

With land expansion there is obviously increased production of sugar cane, cassava (roots and tubers), jatropha and palm oil compared to the baseline. However, the assumption that the increased production is solely for biofuel production translates into increased demand exactly equaling increased supply and therefore, no impact on net trade for these crops. The commodity-supply disposition of Tanzania's agricultural commodity markets do not then exhibit any change from the baseline. But the biofuel markets obviously do exhibit impacts in production, consumption and net trade (see Annex for changes in supply and disposition of key commodity markets). Table 6.6 shows biofuels supply and disposition from 2009 to 2017.

TABLE 6.6

Tanzania Biofuels Supply-Disposition

Tanzania Biofuels Supply-Disposition, million litres									
Ethanol	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production	66.5	119.1	180.5	271.0	383.0	505.4	611.8	728.5	818.9
Biofuel Use	31.3	31.5	68.5	70.7	72.9	75.0	77.2	79.4	81.6
Other Use	31.0	31.3	31.5	31.7	32.0	32.2	32.4	32.6	32.9
Net Trade	35.2	87.6	112.1	2 003	310.2	430.4	534.6	649.1	737.3
Ethanol									
Production	0.0	55.4	276.9	437.9	523.3	593.2	631.5	669.8	694.8
Biofuel Use	0.0	0.0	43.7	45.6	47.5	49.5	51.4	53.3	55.2
Net Trade	0.0	55.4	233.2	392.3	475.8	543.8	580.1	616.5	639.6

Ethanol production reaches 818 million litres by 2017 and the blending mandate translates into 81.6 million litres for biofuel use and other use remains fairly constant at approximately 32 million litres. Tanzanian ethanol production is much larger than domestic demand, which translates into 737 million litres of ethanol that are exported. The story is analogous for biodiesel where production reaches almost 695 million litres and the blending mandate only requires 55 million litres by 2017, which means approximately 640 million litres of biodiesel is surplus to the domestic market and is exported. Total biofuel exports for Tanzania in 2017 would be 1 376 million litres, which means that it would be a significant player in world biofuel markets. Probably the dominant destination export market for Tanzania would be the EU because of its preferential access through the EBA, but other African countries would be in similar positions and Tanzania would need to position itself as cost efficient producer to be competitive in world markets.

6.4.3 SCENARIO 3: BIOFUELS MANDATE WITH LAND EXPANSION SOLELY FOR BIOFUELS AND LOWER OIL PRICES

Implementing lower oil prices into the model shows how agricultural and biofuel markets are sensitive to changes in oil prices. Firstly, lower oil prices cause the demand for biofuels to decrease because of the substitution effect and it results in lower biofuel prices. This ultimately leads to lower biofuel profitability and a decrease in demand for biofuel feedstock such as maize, sugar, wheat, and vegetable oil, especially in countries that export and import into world markets such as Brazil, the European Union and the United States. These decreasing demand side impacts put downward pressure on world crop prices and reflect the new relationship between oil (energy) markets and agricultural markets. However, the traditional relationship of oil prices and supply side impacts still occur, whereby lower oil prices and related fertilizer prices[18] reduce crop costs of production. These reductions in costs cause an increase in crop production profitability and consequently, most world producers respond by increasing production. World supply increases and this also puts downward pressure on crop prices. Even though lower crop prices will negatively impact crop profitability, the relatively larger reduction in crop input costs from lower oil prices still results in overall increased crop profitability. Of course after the initial shock, it takes one to two years before the full impact is felt as crop production characterized by time lags, and likewise, lower prices also cause increased demand. The interactions of supply and demand interact simultaneously and determine a final equilibrium and in this case, this results in lower world commodity prices. Table 6.7 shows the decrease in world crop prices that are particular to Tanzania.

18 Fertilizer prices are highly correlated to energy prices, especially natural gas, and tend to move in tandem.

TABLE 6.7
Change in world commodity prices from lower oil prices

% Change in Commodity Prices from lower oil prices											
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Average
Oil	10.4	-33.3	-34.1	-34.6	-34.6	-34.6	-34.6	-34.6	-34.6	-34.7	-29.9
Maize	1.6	-3.4	-15.5	-19.1	-15.5	-12.7	-14.3	-16.8	-16.8	-15.6	-12.8
Wheat	1.1	-1.9	-11.2	-14.8	-11.0	-7.7	-9.2	-11.8	-11.9	-10.7	-8.9
Oilseeds	2.8	-7.0	-17.0	-18.9	-13.2	-12.8	-14.9	-15.2	-15.2	-15.3	-12.7
Rice	3.6	-9.8	-20.1	-18.6	-12.5	-11.7	-14.9	-16.7	-15.8	-14.6	-13.1
Veg Oil	2.6	-5.9	-12.3	-14.6	-13.5	-13.5	-14.5	-15.1	-15.6	-16.0	-13.4
Sugar	2.0	-8.1	-9.4	-10.3	-11.0	-10.4	-9.5	-9.3	-9.7	-10.2	-8.6

The linkage of Tanzanian to world agricultural commodity markets means that Tanzanian producers and consumers respond accordingly to these lower prices. Lower crop production costs increase production, while lower commodity prices increase consumption, the net effect depends on the relative elasticities of supply and demand for Tanzania. Tanzania has lower elasticity (supply response to prices) than developed countries probably because their producer's ability to expand production is more limited (i.e. production technology, access to fertilizer to increase yields, use of marginal land with mechanized agriculture, etc.). However, Tanzanian consumers are more sensitive[19] (more elastic) to changes in commodity prices than developed countries' consumers, and therefore, Tanzania might have a relatively larger demand response. The net effect on trade will depend on these relative elasticities of supply and demand. The following discussion of results reports the average percentage change from Scenario 3 compared to Scenario 2 from 2008-2017, but it is important to keep in context that it is a percentage of the initial absolute value. For this reason the absolute net impact on net trade for each main commodity is also presented to provide context. To observe the changes supply and disposition in commodity markets from year to year please see the Annex for further details.

Total Area Harvested

The lower oil prices and associated lower input costs cause Tanzania producers to expand and cultivate more land to capitalize on increased profitability. Total area harvested on average increases by 4.6 percent, which represents an increase of 321 000 hectares on average,

19 It has been well documented in the agricultural economic literature that developing countries crop supply elasticities are smaller and demand elasticities are higher than developed countries.

but by 2017 there is a 421 tha increase in area harvested compared to the baseline.

Coarse Grains

Initially, coarse grain production increases faster than consumption and Tanzania exports more coarse grains but by 2011 both food and feed consumption increase more and by 2017 Tanzania exports of coarse grains decrease compared to the Scenario 2. The average (2008-2017) increase in production was 3.4 percent, consumption 4.0 percent and net exports decreased by -23.2 percent or 26 kt.

Wheat

Tanzanian wheat production increases on average by 3.8 percent, consumption increased by 3.5 percent, which leads to net trade to decrease by -3.9 percent or in other words it is importing 17 kt more than Scenario 2. This is an example of where the production percentage increase is larger than the consumption percentage increase, but the absolute value of wheat production (2017 baseline value is 100 kt) is much smaller than the absolute value of consumption (2017 baseline value is 678 kt).

Rice

For Tanzania, rice production is relatively less sensitive to changes in oil-related input costs and production only increases on average by 2.1 percent. However, food consumption is sensitive to lower prices and consumption increases by 4.7 percent. The impact on net trade is a further decrease in net trade by 30 percent or imports increase on average by 29 kt.

Roots and Tubers

Considering that roots and tubers production is mostly for subsistence purposes and is assumed not to be a traded commodity, any increase in production would exactly be offset by the increase in consumption. Lower input costs causes roots and tubers' production to increase on average by 11.5 percent and consumption increases by the same amount. This 11.5 percent increase in production is up and above the amount of increased roots and tubers' production used for biofuels, as Scenario 2 already had this increased acreage. Total production reaches 13 338 kt by 2017.

Sugar

Lower sugar prices directly cause production of sugar to decrease by 0.7 percent, but consumption increases by on average by 1.4 percent and consequently, Tanzania net trade decreases by 7.6 percent or imports increase by 13.1 kt.

Vegetable Oil

Tanzanian vegetable oil production only decreases marginally on average by 0.05 percent because most palm oil production is relatively insensitive to changes in costs of production related lower oil prices. This is mostly due to the fact that palm tree production is perennial in nature. Also, another consideration in the vegetable oil market is that most of palm oil production is for food use, whereas all of the jatropha production is used for biofuels and oilseeds oil production is relatively small. All of these factors basically contribute to the result that vegetable production only decreases very slightly. However, lower vegetable oil prices do cause an average increase in consumption of 1.5 percent. The increase in consumption and slightly lower production causes net trade of vegetable oil to decrease by 2.5 percent or 11 kt.

Biofuel Markets

Table 6.8 shows how biofuel profitability is impacted by lower oil prices in Scenario 3. In terms of the biofuel markets, the assumption for Tanzania is that the land expansion is solely for producing biofuel feedstock for biofuel production, so there is no change in the production of biofuels. There is also no change in the consumption of biofuels considering that the consumption is determined by a government mandate. However, to understand how changes in oil prices impact biofuel profitability a comparison of ethanol sugar-cane profitability and biodiesel vegetable oil profitability are analysed for both the baseline and Scenario 3, which has lower oil prices. Profitability calculations for biofuels are determined by taking the biofuel wholesale price and subtracting net processing costs and capital costs for biofuel production. Net processing costs reflect the actual cost and processing of the biofuel feedstock (sugar cane or vegetable oil) into biofuel, but it also takes into account any by-product revenue[20] from the production process. At the time of developing the AGLINK-COSIMO model an actual production cost for biofuels did not exist in Tanzania and accessing this information had been difficult. The model bases the production cost for ethanol from the global LMC International Starch and Fermentation 2007 Report and used standard industry averages for biodiesel in terms of processing costs and conversion parameters. Biofuel prices for Tanzania are determined as other commodities in the model and are linked to world biofuel prices through a price transmission equation. The Brazilian export price for ethanol is used as the world reference price and adjusted for transport cost and the EU biodiesel price is used as the world reference price for biodiesel. An important characteristic to remember about biofuel prices is that in the absence of consumption mandates that biofuel prices are determined by their relative net energy equivalent in relations to gas and biodiesel and the relative price level of oil or fuel prices. For ethanol it has approximately 67 percent of the energy content compared to gasoline and biodiesel has approximately 89 percent energy content compared to diesel. It is important to understand that these are projections for biofuel profitability and estimates are contingent on the parameters used in the calculations. The parameters used in the model are constant over time, such as fixed levels of quantities of inputs to output relationships, and these relationships could change over time. It is quite possible that biofuel profitability could be different

20 For ethanol production where by-products are produced, such as dried distilled grains from grain ethanol production, these by-products can be sold into feed markets and are a revenue source for ethanol production. In the case for Tanzania there is no information on by-product markets for sugar cane or roots and tubers in ethanol production, so this value is 0. Likewise, biodiesel production from vegetable oil can produce glycerine as a by-product but there is no market information and this value is treated as 0 in the model.

in Tanzania under different assumptions on prices or production technology. However, generally the biofuel profitability indicators used in the model do provide a picture of profitability for countries linked to world commodity prices and technology currently employed in biofuel producing countries.

TABLE 6.8
Biofuel profitability

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Oil	**US$/barrel**									
Baseline	90.0	90.0	91.1	92.8	94.6	96.4	98.2	100.1	102.0	104.0
Scenario 3	99.3	60.0	60.0	60.7	61.9	63.1	64.3	65.5	66.7	67.9
Change	9.3	-30.0	-31.1	-32.1	-32.7	-33.3	-33.9	-34.6	-35.3	-36.1
Ethanol	**tsh**									
Baseline	31 117.4	31 656.2	10 261.8	-19 084	-6 304.1	-4 060.0	-5 312.4	-6 634.6	-6 458.1	-3 845.6
Scenario 3	35 678.9	-631.1	-5 444.3	-8 262.6	-12 445.2	-10 911.1	-11 891.2	-11 781.9	-11 152.4	-10 091.9
Change	4 561.5	-32 287.3	-15 706.1	-6 354.2	-6 141.1	-6 851.1	-6 578.9	-5 147.3	-4 694.3	-6 246.4
Biodiesel	**tsh**									
Baseline	-46 300.9	-42 787.5	-47 080.9	-55 831.9	-61 875.9	-67 243.2	-72 719.4	-78 291.3	-86 400.8	-94 639.9
Scenario 3	-44 102.9	-47 809.9	-55 103.9	-61 982.7	-68 867.3	-75 177.8	-80 372.3	-85 961.8	-93 993.6	-102 982.2
Change	2 198.3	-5 103.3	-7 933.0	-6 150.9	-6 991.4	-7 934.6	-7 652.8	-7 670.5	-7 592.8	-8 342.3

6.4.3.1 BIOFUEL ECONOMIC PROFITABILITY UNDER LOWER OIL PRICES[21]

In the context of the baseline it can be seen that ethanol is only profitable from 2008 to 2010 when oil prices were projected to be relatively high and when sugar-cane prices were relatively low. However, as demand for sugar/sugar cane (food and ethanol) increases relatively faster than oil prices, then ethanol profitability decreases throughout the rest of the projection and is actually negative from 2011 to 2017. The profitability situation even becomes worse in Scenario 3 with lower oil prices as negative margins first appear in 2009 where oil prices fall from USD90 to USD60 per barrel. Lower oil prices cause ethanol prices to decrease and although sugar-cane prices decrease also, it is not as much as ethanol prices, therefore, there is a further deterioration of ethanol profitability into further negative margins for Scenario 3. However, under the EBA Initiative there is the possibility that Tanzanian would have access to the lucrative EU biofuel market tariff free, which would mean the price linkage would be to the EU ethanol market. The EU ethanol market is protected by relatively high tariffs and the domestic ethanol price is much higher than the

21 It is only possible to present the implication of lower oil prices on the economic profitability of biofuels for the cases of ethanol from sugar cane and biodiesel from vegetable oil due to the structure of the AGLINK-COSIMO model.

Brazilian export price, thus this linkage would improve ethanol revenues and profitability. Another consideration would be ethanol profitability from using cassava. At the time there was not sufficient information on production costs and processing to develop equations in AGLINK-COSIMO for ethanol production from cassava. Preliminary results from Module 2 show that cassava could be more profitable than sugar cane.

Biodiesel production profitability that uses vegetable oil indicates the margins would be negative throughout the baseline and even become worse under Scenario 3 with lower oil prices[22]. This is not surprising considering that the vegetable oil price used in the model reflects a vegetable oil price that is used for food use. This price would be analogous to any vegetable oil that is produced from palm oil, maize or oilseeds such as soybean, canola, or sunflower. Vegetable oil has a relatively high price level compared to other agricultural commodities. It is because of the high cost of food-grade vegetable oil that has caused biodiesel refineries to search for cheaper sources of feedstock such as tallow (i.e. animal fat), algae and other varieties of oilseeds that produce lower quality vegetable oils. Jatropha production and processing costs were not available to include in the model at the time of the baseline. If oil produced from jatropha presents lower feedstock costs then biodiesel profitability could substantially increase. As in the case for ethanol where revenues increase through access to higher ethanol prices in the EU, biodiesel revenue would also increase if Tanzania is granted access to the EU biodiesel market.

6.5 GLOBAL BIOFUEL SUPPORT

As forementioned, existing global policies and any additional support for biofuels have important implications to biofuel and agricultural commodities worldwide. Full implementation of future policy developments such as the recently enacted US Energy Independence and Security Act (EISA)[23] or the proposed new EU Directive for Renewable Energy (DRE) among others can have a substantial implication in the production and use of both ethanol and biodiesel. As agricultural commodity prices escalated in 2008 and 2009 there was a considerable amount of accusations that biofuels were a significant factor for the escalation in prices. Many non-government organizations called on governments worldwide to re-think their biofuel policies and its implications on food security. Some governments responded to say that biofuel policies might have to be re-considered in terms of food security and environmental sustainability. This displays the policy risk around existing biofuel markets as without government support some biofuel production would be unprofitable and furthermore, regulations or policies regarding sustainability issues might govern some biofuel markets, which further represents another example of policy

22 The exception is for 2008 when a higher oil price was used to reflect the actual market price rather than the original projection from the baseline.

23 The Energy Independence and Security Act of 2007 established a 136 billion litres Renewable Fuel Standard (RFS) until 2022. While maize based ethanol constitutes the main biofuel in the coming decade and is to increase to 56.8 billion litres until 2015, other biofuels explicitly mentioned include cellulosic biofuels as well as biodiesel. The blending of biodiesel into fossil diesel is required starting with 1.9 billion litres by 2009 and to increase to at least 3.8 billion litres by 2012.

risk. To reflect this foreign policy risk for Tanzania the following discussion highlights analysis conducted by the OECD in the publication: "Biofuel Support Policies: An Economic Assessment", which analysed the impacts of various biofuel policies worldwide. Firstly, the analysis looks at the removal of existing biofuel policies, then, secondly looks at the implications of the new increments in biofuel policy reflected in the US's EISA and the EU's DRE.

6.5.1 REMOVAL OF EXISTING BIOFUEL POLICIES

A removal of the existing[24] biofuel support policies taken into account in this analysis would significantly reduce medium-term biofuel use in major biofuel consuming regions. This decreased world demand for biofuel feedstock would cause a reduction in world crop prices, which are consequently transmitted to Tanzania's domestic prices. The reduction in domestic prices induces changes to demand and supply, where demand increases and supply decreases and both negatively impact net trade. The relative size of the impact will depend on the relative demand and supply elasticities for each commodity. Table 6.9 shows the impact on world prices and the net impact on net trade for Tanzania's main food crops.

TABLE 6.9

Changes in world commodity prices from removing existing biofuel support policies

Elimination of World Biofuel Support Policies											
World Prices % Δ	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**Average**
Maize	-2.2	-3.3	-4.2	-4.7	-5.2	-5.9	-6.2	-6.6	-7.1	-7.2	-5.3
Wheat	-0.8	-2.8	-4.1	-4.5	-4.6	-4.6	-4.9	-5.2	-5.1	-5.0	-4.2
Oilseeds	-2.8	-2.9	-2.1	-2.2	-2.7	-3.1	-3.4	-3.5	-3.4	-3.4	-2.9
Rice	-0.1	-0.4	-0.8	-0.8	-0.7	-0.7	-0.8	-0.8	-0.8	-0.8	-0.7
Veg. Oil	-9.1	-14.2	-14.9	-14.6	-15.1	-15.6	-15.8	-15.9	-15.8	-15.8	-14.7
Sugar	-1.2	-1.0	-0.2	0.8	1.8	2.1	2.1	1.9	1.5	1.0	0.9
Net Trade Δ	**Tanzania Net Trade (kt)**										
Coarse Grains	-34.7	-40.0	-60.0	-75.1	-89.1	-106.3	-115.8	-124.0	-98.4	-95.6	-83.9
Wheat	-4.7	-9.5	-3.9	-5.7	-9.0	-11.7	-15.0	-14.6	-14.0	-16.1	-10.4
Rice	-0.1	-0.9	-1.0	-1.7	-1.2	-1.2	-1.4	-1.1	-1.4	-1.9	-1.2
Veg. Oil	-6.3	-10.9	-12.3	-12.8	-14.0	-15.2	-16.2	-17.1	-17.8	-18.7	-14.1
Sugar	-2.4	-0.2	4.0	8.9	11.9	15.4	17.6	20.0	20.2	19.6	11.5
Cassava*	-0.2	11.2	18.5	22.0	24.6	27.5	31.8	35.4	37.2	31.0	23.9

**Represents change in production but this is offset by exactly same increase in consumption*

24 At the time of the OECD analysis the new EISA and EU directive were just announced so their new incremental impacts are compared in the second part of the analysis referring to first generation and second generation policies.

Vegetable oil prices have the largest percentage decrease from the elimination of biofuel support policies because it is the only biofuel feedstock used for biodiesel, whereas ethanol production uses several different feedstocks. Maize has the second largest decrease, and wheat follows closely behind. Rice has the smallest decrease because it is rarely used for ethanol production and most of the decrease is related to cross price effects. The reduction in prices causes production to decrease and demand to increase, thereby negatively impacting net trade and causing Tanzania to increase imports. For Tanzania, coarse grains incur the largest reduction in net trade and on average the country will have to import 83.9 kt more coarse grains to meet domestic demand and by 2015 Tanzania switches from a net exporter to a net importer. Likewise for wheat and vegetable oil, where net trade decreases further to be on average 10 kt and 14 kt lower respectively. Sugar prices actually increase because in Brazil more sugar cane is diverted to ethanol production because of eventual higher ethanol prices, which directly causes lower sugar production and eventually leads to slightly higher sugar prices. Roots and tubers production increases on average by 23.9 kt because it has a relatively higher return per hectare compared to the other Tanzanian crops due to the fact that the other major crops incur a higher reduction in prices compared to roots and tubers (i.e. cassava).

6.5.2 INTRODUCTION OF NEW POLICIES FOR FIRST GENERATION AND SECOND GENERATION BIOFUELS:

The new polices are the US's EISA and the EU's DRE, whereby there is an increase in the support for first generation biofuels (i.e. biofuel produced from sugar, coarse grains, wheat, vegetable oil, etc.), but also second generation biofuels (i.e. cellulosic). The impacts on the production of main food crops in Tanzania due to implementation of new programmes affecting the global supply and demand of biofuels are analysed. The introduction of new global policies supporting first and second generation biofuel production is evaluated against existing policies. New global policies that increase demand for first generation or traditional biofuel feedstock will cause an increase in world crop prices, but so will second generation biofuels. This occurs because demand for cellulosic feedstock will create further competition for arable land with traditional crops and causes a reduction in acreage planted for certain crops. The combined impact of increased world demand for first generation biofuel feedstock and increased land competition (reduces crop production) from second generation feedstock both contribute to an increase in world prices for crops. Table 6.10 shows the impact on world crop prices and the impact on net trade for the major food crops for Tanzania.

TABLE 6.10

Changes in world commodity prices from new biofuel support policies

Impact of New Incremental Biofuel Support Policies											
World Prices % Δ	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Average
Maize	0.0	0.3	0.9	0.8	1.8	3.7	5.1	7.0	6.7	6.8	3.3
Wheat	0.0	0.2	0.4	0.5	0.7	1.4	2.2	2.9	2.9	2.9	1.4
Oilseeds	0.6	0.2	0.4	1.4	1.9	2.2	2.9	3.9	4.4	4.7	2.2
Rice	0.0	0.0	0.1	0.1	0.2	0.4	0.6	0.8	1.0	1.0	0.4
Veg. Oil	1.9	1.5	1.8	4.7	7.9	9.8	11.6	14.1	16.6	18.4	8.8
Sugar	0.3	0.1	0.3	0.6	1.0	1.2	1.4	1.7	1.9	2.1	1.0
Net Trade Δ	Tanzania Net Trade (kt)										
Coarse Grains	0.2	4.0	11.5	9.9	29.0	54.4	76.0	111.3	115.1	131.4	54.3
Wheat	0.0	0.9	0.9	0.2	2.2	4.5	4.9	5.7	4.8	7.2	3.1
Rice	0.0	0.1	0.1	0.3	0.6	0.9	1.3	1.2	1.5	1.5	0.8
Veg. Oil	1.2	1.0	1.3	3.6	6.3	8.2	10.0	12.5	15.2	17.5	7.7
Sugar	0.7	0.2	0.7	1.7	2.5	3.2	4.1	4.7	5.1	5.3	2.8
Cassava*	0.0	-0.8	-1.3	-3.8	-5.9	-10.2	-18.3	-27.3	-37.7	-41.2	-14.7

**Represents change in production but this is offset by exactly same increase in consumption*

The increase in world prices is transmitted to Tanzania's markets and producers react to these price changes. Relative price changes favour traditional biofuel feedstock such as coarse grains, wheat and rice, but will relatively disadvantage non-traditional biofuel feedstock such as roots and tubers because it is not used in the US or the EU for biofuels. Policies supporting ethanol production have positive impacts on Tanzania production of coarse grain because these global policies increase world prices for coarse grains, but will have negative impacts for Tanzanian consumers. Consumption decreases with these price increases and the net impact is that net trade increases on average by 131 kt by 2017. For Tanzania, by 2017 production increased by approximately 81 kt and consumption decreased by 50 kt. For most of Tanzanian agricultural commodities, the increase in world prices causes Tanzania to increase production and reduce consumption causing increases to net trade. The exception is for roots and tubers where price increases are minimal, so crop producers select to grow other crops that have incurred higher price increases. This corresponds to a reduction of 41 kt of roots and tubers' production by 2017, but this only represents a reduction of 0.4 percent of national production.

It is important that in the development of a biofuel sector in Tanzania stakeholders recognize that biofuel markets are subject to policy risk. Biofuel markets have been largely developed from government policies that help support the market. High oil prices will support the biofuel market but for the most part government policies are a significant factor explaining market growth. These policies are subject to change, in terms of consumption mandates, subsidies, and possible regulations governing environmental sustainability. The above analysis shows how crop markets are sensitive to these policy changes, and although world price changes might not seem to be large they do have impacts on consumption and production. For countries that are sensitive to changes in some staple food crops these changes can have implications for the poor and food security.

6.6 CONCLUSION

The development of biofuels offer both opportunities and challenges. It is important to understand the relationship between biofuels and agricultural markets and how this can change under different conditions. Agricultural and biofuels markets are continuously changing due to shocks such as weather, disease, oil price volatility, and sometimes even government policies. This module examines how Tanzania's agricultural markets are expected to evolve over the next several years in the absence of biofuels. Specifically, the analysis assesses the potential demand for commodities, given projected income and population growth, and the potential supply, given yield productivity and relative crop returns. Policy-makers can analyse these projections in order to determine the extent to which Tanzanian agricultural markets would be able to furnish a biofuel sector with feedstocks without impacting food security. The OECD-FAO Outlook indicates that prices for agricultural commodities are expected to be at a new price plateau when compared to historic averages. In Tanzania, coarse grain demand is expected to increase more than production, which ultimately causes lower exports. In wheat markets where production growth, at present, is fairly limited but demand growth is substantial, this could lead to a significant increase in imports. A similar situation can be expected for vegetable oil in which national demand outstrips supply and the shortfall has to be met through imports. By contrast, production growth in rice increases marginally faster than demand growth reducing net imports. Increases in sugar-cane production outweigh demand growth resulting in a significant reduction in sugar imports for Tanzania. Overall, the projections show that for some food crops Tanzania may have to rely on more imports to meet domestic demand in the absence of biofuel markets.

To understand the possible consequences of implementing a blending mandate for biofuels, a baseline model for Tanzania is set up and then the blending mandates were imposed into the model. The baseline provides a picture into the future given a set of macroeconomic and policy assumptions. It can be used to understand key relationships not only within agricultural markets, but also the linkages to biofuel markets. It should be noted that the results represent projections and not a definitive forecast. There are many factors that could cause markets to change such as adoption of new technology, climate change, trade agreements or economic shocks, which would change the outlook or picture for Tanzania.

The viability of a biofuel sector is very much linked to oil prices and international government biofuel policies. Both are subject to volatility. Lower oil prices would lead to an increase in world crop production, particularly in developed countries, and consequently this would lead to lower crop prices. The results exhibit the vulnerability of agriculture markets, especially biofuel feedstocks, to movements in oil prices. If Tanzania can use biofuel feedstocks with lower input costs or if it can successfully gain access to the EU market then biofuel production margins could be positive. With respect to foreign policy risk, the OECD analysis has shown the consequences if support policies, that is consumption mandates and production subsidies, are removed and how this would adversely impact biofuel markets and consequently, agricultural markets, particularly biofuel feedstocks. It is important to take into account this foreign policy risk if Tanzania is looking to produce biofuels to capitalize on export markets as these policies are subject to change and even sometimes foreign countries seek ways to protect their domestic markets.

In conclusion, this Module is used to show how Tanzania's agricultural markets are expected to evolve over the coming years in the absence of a biofuel market. Tanzania will have to contemplate future demands for agricultural commodities, whether it be food, fibre, or fuel and whether it has the productive capacity to meet all of these demands. Biofuels would represent a new source of demand for Tanzanian crops and could potentially offer a source of export earnings that contribute to balance of payments. However, the development of biofuels could create challenges for food security and imply increased imports, which would not only be economically inefficient but also socially undesirable. Moreover, these results are based on current productivity levels and resent a powerful argument for Tanzania to invest in improving agricultural productivity to avoid the potentially negative impacts of developing a biofuel sector. Under the current situation in Tanzania, biofuels pose risks. However, it is clear that any development of the sector ought to be accompanied by large-scale investments that can supply adequate quantities of feedstock for the industry to be viable without compromising food security.

APPENDIX 6 A

SUPPLY DISPOSITION OF THE MAJOR COMMODITIES FOR TANZANIA.

Coarse Grains											
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production	(thousand tonnes)										
Baseline	4 283	4 377	4 481	4 568	4 664	4 745	4 819	4 905	4 991	5 067	5 141
Scenario 1	4 283	4 377	4 481	4 568	4 664	4 745	4 819	4 905	4 991	5 067	5 141
Scenario 2	4 283	4 377	4 481	4 568	4 664	4 745	4 819	4 905	4 991	5 067	5 141
Scenario 3	4 283	4 309	4 765	4 823	4 821	4 859	4 967	5 096	5 185	5 240	5 310
Consumption	(thousand tonnes)										
Baseline	4 008	4 113	4 201	4 272	4 373	4 503	4 617	4 718	4 830	4 944	5 044
Scenario 1	4 008	4 113	4 201	4 272	4 373	4 503	4 617	4 718	4 830	4 944	5 044
Scenario 2	4 008	4 113	4 201	4 272	4 373	4 503	4 618	4 718	4 830	4 944	5 044
Scenario 3	4 008	4 088	4 264	4 485	4 644	4 724	4 793	4 915	5 077	5 206	5 291
Net Trade	(thousand tonnes)										
Baseline	365	136	143	324	314	207	181	189	140	88	74
Scenario 1	365	136	143	324	314	207	181	189	140	88	74
Scenario 2	365	136	143	324	314	207	181	188	140	88	74
Scenario 3	365	121	205	335	301	179	139	130	72	27	15
Price	(thousand tonnes)										
Baseline	204 004	230 634	231 948	243 881	266 028	283 996	302 444	329 165	358 549	386 131	416 841
Scenario 1	204 004	230 634	231 948	243 881	266 028	283 998	302 446	329 165	358 550	386 184	416 844
Scenario 2	204 004	230 634	231 946	243 874	266 010	283 954	302 391	329 111	358 467	386 009	416 700
Scenario 3	204 004	235 516	220 023	206 266	217 275	242 618	267 470	287 088	303 861	326 068	356 883

Wheat											
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production	(thousand tonnes)										
Baseline	64	94	95	93	93	94	95	96	97	98	100
Scenario 1	64	94	95	93	93	94	95	96	97	98	100
Scenario 2	64	94	95	93	93	94	95	96	97	98	100
Scenario 3	64	93	99	98	97	98	99	101	101	103	104
Consumption	(thousand tonnes)										
Baseline	434	455	483	504	520	541	563	587	609	630	651
Scenario 1	434	455	483	504	520	541	563	587	609	630	651
Scenario 2	434	455	483	504	520	541	563	587	609	630	651
Scenario 3	434	453	486	525	551	564	580	607	637	660	678
Net Trade	(thousand tonnes)										
Baseline	-270	-382	-369	-391	-424	-457	-470	-497	-518	-533	-554
Scenario 1	-270	-382	-369	-391	-424	-457	-470	-497	-518	-533	-554
Scenario 2	-270	-382	-369	-391	-424	-457	-471	-497	-518	-533	-554
Scenario 3	-270	-372	-407	-438	-423	-442	-487	-537	-547	-545	-571
Price	(thousand tonnes)										
Baseline	685 975	586 215	517 268	544 490	602 418	659 513	718 436	778 442	849 789	928 015	1 005 766
Scenario 1	685 975	586 215	517 268	544 490	602 420	659 519	718 444	778 446	849 791	928 018	1 005 771
Scenario 2	685 975	586 215	517 263	544 472	602 368	659 407	718 308	778 311	849 600	927 746	1 005 446
Scenario 3	685 975	592 908	507 283	483 542	513 357	587 151	662 954	706 351	749 712	817 765	898 196

Vegetable Oil											
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production	(thousand tonnes)										
Baseline	15	15	16	16	16	16	16	16	16	16	16
Scenario 1	15	15	16	16	16	16	16	16	16	16	16
Scenario 2	15	15	16	47	215	317	368	408	419	430	430
Scenario 3	15	15	16	47	215	316	368	407	419	430	430
Consumption	(thousand tonnes)										
Baseline	310	330	352	374	396	417	439	461	483	505	528
Scenario 1	310	330	352	374	404	425	447	470	492	514	537
Scenario 2	310	330	352	405	595	718	791	853	887	919	942
Scenario 3	310	328	356	414	606	729	803	866	901	935	959
Net Trade	(thousand tonnes)										
Baseline	-297	-314	-336	-358	-380	-401	-423	-445	-467	-489	-511
Scenario 1	-297	-314	-336	-358	-387	-409	-431	-453	-476	-498	-521
Scenario 2	-297	-314	-336	-358	-380	-401	-423	-445	-468	-489	-512
Scenario 3	-297	-313	-340	-367	-392	-413	-435	-459	-483	-505	-530
Price	(thousand tonnes)										
Baseline	1 775 266	1 762 007	1 832 587	2 011 075	2 199 396	2 423 358	2 648 150	2 890 446	3 161 052	3 455 180	3 742 354
Scenario 1	1 775 266	1 762 007	1 832 587	2 011 075	2 199 671	2 423 633	2 648 388	2 890 692	3 161 313	3 455 456	3 742 646
Scenario 2	1 775 266	1 762 007	1 832 587	2 009 988	2 195 146	2 417 264	2 641 357	2 881 750	3 151 208	3 444 475	3 731 080
Scenario 3	1 775 266	1 806 993	1 724 401	1 763 386	1 873 665	2 090 041	2 285 517	2 464 792	2 675 310	2 906 845	3 133 349

Sugar											
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production	(thousand tonnes)										
Baseline	286	323	328	335	398	458	524	587	601	620	634
Scenario 1	286	323	328	335	375	434	500	563	576	595	609
Scenario 2	286	323	328	335	398	458	524	587	601	620	634
Scenario 3	286	323	325	332	394	453	519	582	596	615	628
Consumption	(thousand tonnes)										
Baseline	516	545	581	608	628	652	681	708	737	767	800
Scenario 1	516	545	581	608	628	652	681	708	737	767	800
Scenario 2	516	545	581	608	628	652	681	708	737	767	800
Scenario 3	516	543	589	618	639	663	692	718	748	779	813
Net Trade	(thousand tonnes)										
Baseline	-223	-222	-251	-271	-231	-196	-161	-123	-138	-150	-168
Scenario 1	-223	-222	-251	-271	-254	-220	-185	-147	-163	-175	-193
Scenario 2	-223	-222	-251	-271	-231	-197	-161	-123	-139	-150	-168
Scenario 3	-223	-220	-264	-283	-244	-213	-177	-138	-154	-167	-167
Price	(thousand tonnes)										
Baseline	505 593	478 754	505 787	623 033	749 883	868 004	935 725	1 055 330	1 149 664	1 247 016	1 342 441
Scenario 1	505 593	478 754	505 787	623 033	750 259	868 416	936 123	1 055 714	1 150 050	1 247 394	1 342 817
Scenario 2	505 593	478 754	505 702	622 781	749 561	867 359	934 616	1 053 763	1 147 768	1 244740	1 340 008
Scenario 3	505 593	488 424	464 869	564 544	672 596	772 114	837 768	954 147	1 041 383	1 123 830	1 203 162

Rice											
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production	(thousand tonnes)										
Baseline	806	850	910	957	966	1 010	1 054	1 104	1 135	1 175	1 214
Scenario 1	806	850	910	957	966	1 010	1 054	1 104	1 135	1 175	1 214
Scenario 2	806	850	910	957	966	1 010	1 054	1 104	1 135	1 175	1 214
Scenario 3	806	850	957	985	972	1 019	1 078	1 135	1 163	1 202	1 249
Consumption	(thousand tonnes)										
Baseline	905	931	1 002	1 056	1 106	1 137	1 172	1 210	1 249	1 279	1 304
Scenario 1	905	931	1 002	1 056	1 106	1 137	1 172	1 210	1 249	1 279	1 304
Scenario 2	905	931	1 002	1 056	1 106	1 137	1 172	1 210	1 249	1 279	1 304
Scenario 3	905	921	1 038	1 135	1 183	1 188	1 222	1 274	1324	1 346	1 365
Net Trade	(thousand tonnes)										
Baseline	-99	-94	-122	-97	-121	-123	-123	-112	-113	-105	-93
Scenario 1	-99	-94	-122	-97	-121	-123	-123	-112	-113	-105	-93
Scenario 2	-99	-94	-122	-97	-121	-123	-123	-112	-113	-105	-93
Scenario 3	-99	-89	-150	-139	-168	-156	-159	-152	-158	-138	-122
Price	(thousand tonnes)										
Baseline	516 549	570 565	541 949	525 349	570 083	640 443	703 512	749 033	808 867	868 280	939 700
Scenario 1	516 549	570 565	541 949	525 349	570 087	640 449	703 515	749 033	808 871	868 288	939 708
Scenario 2	516 549	570 565	541 947	525 344	570068	640 401	703 443	748 970	808 793	868 169	939 549
Scenario 3	516 549	588 850	488 601	423 481	463 957	560 479	620 967	642 596	680 861	745 863	818 634

Roots & Tubers											
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production	(thousand tonnes)										
Baseline	8 879	8 835	8 815	8 876	9 047	9 252	9 423	9 591	9 763	9 937	10 130
Scenario 1	8 879	8 835	8 815	8 876	9 047	9 252	9 423	9 591	9 763	9 937	10 130
Scenario 2	8 879	8 835	8 936	9 141	9 456	9 939	10 291	10 640	10 993	11 349	11 580
Scenario 3	8 879	8 694	9 385	10 004	10 683	11 403	11 835	12 209	12 613	13 044	13 338
Consumption	(thousand tonnes)										
Baseline	8 887	8 835	8 815	8 876	9 047	9 252	9 423	9 591	9 763	9 937	10 130
Scenario 1	8 887	8 835	8 815	8 876	9 047	9 252	9 423	9 591	9 763	9 937	10 130
Scenario 2	8 887	8 835	8 936	9 141	9 456	9 939	10 291	10 640	10 993	11 349	11 580
Scenario 3	8 887	8 694	9 385	10 004	10 683	11 403	11 835	12 209	12 613	13 044	13 338
Net Trade	(thousand tonnes)										
Baseline	-8	0	0	0	0	0	0	0	0	0	0
Scenario 1	-8	0	0	0	0	0	0	0	0	0	0
Scenario 2	-8	0	0	0	0	0	0	0	0	0	0
Scenario 3	-8	0	0	0	0	0	0	0	0	0	0
Price	(thousand tonnes)										
Baseline	448 638	464 351	475 273	525 070	580 082	640 861	708 005	782 186	864 139	954 679	1 054 323
Scenario 1	448 638	464 351	475 273	525 070	580 082	640 861	708 005	782 186	864 139	954 679	1 054 323
Scenario 2	448 638	464 351	475 273	525 070	580 082	640 861	708 005	782 186	864 139	954 679	1 054 323
Scenario 3	448 638	464 351	475 273	525 070	580 082	640 861	708 005	782 186	864 139	954 679	1 054 323

APPENDIX 6

B TECHNICAL NOTE ON AGLINK-COSIMO

The AGLINK-COSIMO model is driven by elasticities, technical parameters and policy variables. All of the major agricultural sectors, including the biofuel sector, are connected and are integrated within the model so that all of the main characteristics of the crops and livestock sectors influence the final equilibrium. The AGLINK-COSIMO model and Outlook projections are reviewed by OECD member countries and FAO to ensure consistency and precision.

DATA SOURCES

The OECD-FAO Agricultural Outlook 2008-2017 serves as the foundation of the baseline to be used for the analysis. The Outlook relies on information from a large number of sources, including experts' judgment when necessary. Data for the model comes from information provided by national statistics sources and supplemented by external sources such as the United Nations and World Bank. This information is aimed at creating a first insight into possible market developments and at establishing the key assumptions to be used in the Outlook. In the case of developing countries agricultural data up to 2006 comes from FAOSTAT and data for 2007 is from databases managed by the Trade and Markets Division at FAO. Extension of the model to include the biofuel sector required technical data. These data came from LMC international . The technical data were used to generate a world commodity database for ethanol and biodiesel, along with country-specific baseline data on different feedstocks and their processing costs of production. An initial review of the OECD-FAO Agricultural Outlook with Tanzanian officials determined that projections for sugar-cane production were too low. Data was collected from the Tanzanian Sugar Board and projections were adjusted to reflect the higher level of sugar-cane production to form a new baseline.

CHAPTER 7

ECONOMY WIDE EFFECTS OF BIOENERGY DEVELOPMENTS

James Thurlow, IFPRI

7. INTRODUCTION

Tanzania's economy performed well over the last half-decade with economic growth exceeding 5 percent per year. However, poverty has not declined significantly, with the national headcount rate falling only slightly from 35.7 to 33.6 percent during 2001-2007 (World Bank, 2010). This persistence in poverty is at aleast partly explained by slower growth in agricultural incomes (Pauw and Thurlow, forthcoming). Indeed, agriculture's performance is particularly important for economic development in Tanzania, given that four-fifths of the labour force work on farms and a similar share of the poor population live in rural areas. Supporting the establishment of a biofuels industry may therefore offer Tanzania an opportunity to reinvigorate agricultural growth, create new jobs in rural areas, and strengthen efforts to reduce poverty.

Evidence from other countries suggests that optimism regarding biofuels may be justified. In Mozambique, for example, Arndt *et al.* (2009) find that proposed biofuel investments will increase economic growth by 0.5 percent each year over the coming decade, causing the national poverty rate to fall by five percentage points. This supports the view held by some that biofuels permit low income countries to overcome their dependence on foreign oil while increasing farmers' participation in the growth process (see Hausman, 2007). This optimism, however, is countered by uncertainty over possible trade-offs between biofuels and food production, and the effects that declining food supplies may have on poverty and food insecurity. This concern has received considerable attention in the biofuels debate (see Oxfam International, 2007). Indeed, shifting resources away from food production could increase households' reliance on marketed foods, and biofuels may not generate sufficient incomes for poorer households to offset rising food prices. Concerns over food security are therefore equally justified.

Possible trade-offs between development objectives have prompted low income countries such as Tanzania, to consider a range of biofuel production scenarios. For example, in evaluating proposals from foreign investors, governments must decide which feedstocks are both economically viable and contribute to achieving national development objectives. Similarly, many governments are encouraging foreign investors to combine smallholder outgrower schemes with larger-scale plantation systems in order to reduce poverty while still ensuring reliable feedstock supplies.

Understanding the consequences of different scenarios is critical to maximizing the private and social benefits of biofuel investments. Accordingly, this paper uses a dynamic computable general equilibrium (DCGE) model of Tanzania to estimate the impact of alternative biofuel production scenarios on economic growth and employment. The model is also linked to a survey-based micro-simulation module that estimates impacts on income poverty. Section 2 reviews the biofuel production scenarios that the Government of Tanzania is considering. Section 3 describes the economic model and how the various biofuel production scenarios are simulated. Section 4 then presents the results, and Section 5 concludes with recommendations for policy.

7.1 OPTIONS FOR PRODUCING BIOFUELS IN TANZANIA

7.1.1 IDENTIFYING BIOFUELS PRODUCTION SCENARIOS

The Food and Agriculture Organization (FAO) of the United Nations has, together with the Government of Tanzania, identified a number of biofuel production scenarios using different feedstock crops and downstream processing plants (see Cardona et al., 2009). In our analysis we focus on a subset of these options in order to capture their core differences. The options identified by FAO and examined in this study are summarized in Table 7.1.

TABLE 7.1

FAO biofuel production options

Feedstock	FAO option	Description
Sugar-cane juice (ethanol)	1	Single large-scale ethanol processing plant with a capacity of 160 000 litres per day using juice from new sugar-cane cultivars produced by smallholders. Production and sale of by-products included.
	2	Single large-scale ethanol processing plant with a capacity of 236-277 000 litres per day using juice from new sugar cane produced on 12 000 hectares of large-scale commercial land and 3 000 hectares of smallholder outgrower land. Production and sale of by-products included.
	3	Single large-scale ethanol processing plant with a capacity of 160 000 litres per day using juice from new sugar cane produced by increasing smallholders' crop yields rather than expanding crop land area. Production and sale of by-products included.
	4	Four small-scale ethanol processing plants with individual capacities of 44-52 000 litres per day using juice from new sugar cane produced by smallholders. Production and sale of by-products included.
Molasses (ethanol)	5	Single large-scale ethanol processing plant with a capacity of 80-85 000 litres per day using existing molasses produced and currently exported by sugar refineries.
Cassava (ethanol)	8	Single large-scale ethanol processing plant with a capacity of 160 000 litres per day using dry cassava chips produced by increasing smallholders' crop yields.
	9	Single large-scale ethanol processing plant with a capacity of 303 030 litres per day using dry cassava chips, 40% of which are produced by increasing smallholders' crop yields and 60% are from on-site large-scale commercial production.
Jatropha (biodiesel)	10	Single large-scale biodiesel processing plant with a capacity of 70 000 litres per day using jatropha produced by smallholders.

Source: Cardona et al. (2009)

The FAO scenarios differ on four characteristics: (1) the type of feedstock used and biofuel produced; (2) the scale of feedstock production (i.e. smallholder versus estate); (3) the way in which feedstock production is expanded (i.e. increasing yields or harvested area). and (4) the scale of downstream biofuel processing plants. These differences are presented in Table 7.2, which shows the various scenarios simulated in this paper.

TABLE 7.2
Simulated biofuels production scenarios

Feedstock	Scenarios		Scale of feedstock production	Feedstock yield level	Land expansion (% of land from displacement)	Scale of biofuel processing
	DCGE model	FAO option				
Sugarcane (ethanol)	Sugar 1	1	Small	Low (43 mt/ha)	Yes (50%)	Large (69 l/mt)
	Sugar 2	2	Small/large mix	Low (43/84 mt/ha)	Yes (50%)	Large (69 l/mt)
	Sugar 3	-	Large	Low (84 mt/ha)	Yes (50%)	Large (69 l/mt)
	Sugar 4	3	Small	High (70 mt/ha)	No (0%)	Large (69 l/mt)
	Sugar 5	4	Small	Low (43 mt/ha)	Yes (50%)	Small (69 l/mt)
Molasses (ethanol)	Molasses	5	Imported	-	-	Large (166 l/mt)
Cassava (ethanol)	Cassava 1	-	Small	Low (10 mt/ha)	Yes (50%)	Large (183 l/mt)
	Cassava 2	8	Small	High (20 mt/ha)	No (0%)	Large (183 l/mt)
	Cassava 3	9	Small/large mix	High (20 mt/ha)	Yes (30%)	Large (183 l/mt)
Jatropha (biodiesel)	Jatropha	10	Small	High (4 mt/ha)	Yes (50%)	Large (350 l/mt)

Source: Own calculations using information from Cardona et al. (2009).

The first five scenarios (*Sugar 1-5*) refer to ethanol produced from sugar-cane juice. In the first scenario (*Sugar 1*) all feedstock is produced by smallholder farmers through an outgrower scheme and is supplied to a single large processing plant. This is equivalent to the first FAO production option presented in Table 7.1. The second scenario is similar to the second FAO option in that it adopts a mixed production system in which one fifth of the feedstock is produced by smallholders and the rest is produced by large-scale estates or plantations. The third scenario does not correspond to a particular FAO option since it assumes that all feedstock is produced on large-scale farms. This additional scenario allows us to contrast the impacts of purely small- and large-scale production systems.

The remaining two sugar-cane scenarios are variations on *Sugar 1*, where all feedstock is produced by smallholders through an outgrower scheme. However, in the *Sugar 4* scenario, sugar-cane production is increased by raising smallholders' land yields (from 43 to 70 tons per hectare) rather than by expanding the amount of land under sugar-cane cultivation. This reduces the amount of land currently used for agriculture that is displaced by biofuel production. The final sugar-cane scenario (*Sugar 5*) still uses low yields but now assumes that downstream processing is done using a number of small-scale plants. As shown later in this section, using small-scale processing plants increases the amount of labour required for biofuel production.

Molasses is another feedstock that could be used to produce ethanol in Tanzania. Molasses is a by-product from sugar-cane refining and all of the molasses currently being produced is exported. Producing ethanol from molasses would thus redirect exports for use as feedstock in the domestic biofuel industry. This means that no additional feedstock needs to be produced. Only one molasses scenario is considered in our analysis and it is equivalent to the fifth FAO production option.

The use of cassava is also considered as a biofuel feedstock. In each scenario we assume that production is by smallholders through an outgrower scheme and that processing is done by large-scale processing plants. The first two scenarios differ in that *Cassava 1* assumes that cassava production is achieved through extensification (i.e. land expansion) while *Cassava 2* assumes that crop yields are increased (from 10 to 20 tons per hectare) thereby limiting the amount of land displaced by the new biofuel industry. The *Cassava 3* scenario assumes a mixed production system, with 40 percent of feedstock obtained from smallholders through yield improvements (i.e. as in *Cassava 2*) and the rest produced by large-scale commercial farmers situated close to a large-scale processing plant. Finally, we consider the use of jatropha oilseeds to produce biodiesel (jatropha). Production is via a smallholder outgrower scheme linked to a large-scale biodiesel processing plant, with high crop yields of 4 tons per ha.

The FAO options in Table 7.1 produce different volumes of ethanol or biodiesel. This complicates direct comparisons of the scenarios. For example, if the *Sugar 2* scenario generates more economic growth than *Sugar 1* then this may be due to either the larger volume of biofuel ethanol being produced or inclusion of more larger-scale farmers. Therefore, to make scenarios comparable we simulate the same volume of biofuels under all scenarios rather than model the varying amounts identified in Table 7.1. More specifically, we model the establishment of a biofuel industry capable of producing 1 000 million litres of ethanol or biodiesel per year (i.e. 3 million litres per day).

7.1.2 ESTIMATING PRODUCTION COSTS AND TECHNOLOGIES

The biofuel scenarios in Table 7.2 contrast the economic impacts of different feedstocks and processing plants. These scenarios will produce different outcomes because they use different technologies (i.e. factor and intermediate inputs) and generate different profit rates for farmers and downstream processing plants. Cardona *et al.* (2009) estimate itemized production costs when they assess the economic viability of the various biofuel scenarios. These cost estimates are shown in Table 7.3 below.

The cost of producing ethanol in Tanzania ranges from USD0.43 per litre under a mixed small- and large-scale production system (i.e. *Sugar 2*) to USD0.74 per litre using molasses as a feedstock. The low-cost scenarios (i.e. *Sugar 2, Cassava 2 and Cassava 3*) compare favourably with current ethanol production costs in countries such as Brazil (USD0.47), India (USD0.52) and the USA (USD0.46). However, the estimated costs of producing ethanol from smallholder-based sugar cane and from molasses suggest that Tanzania is not competitive given current crop yields and the proposed processing technologies. In our analysis we assume that the domestic ethanol price received by processing plants is USD0.56 per litre, implying that processing plants in some of our scenarios run at a loss. Similarly, biodiesel production costs are USD0.83 per litre in Tanzania and are above the landed price at Dar es Salaam harbour (USD0.77) (Johnson and Holloway, 2007).

TABLE 7.3
Production cost estimates for biofuels scenarios

	Sugar 1	Sugar 2	Sugar 4	Sugar 5	Molasses	Cassava 2	Cassava 3	Jatropha
	FAO 1	FAO 2	FAO 3	FAO 4	FAO 5	FAO 8	FAO 9	FAO 10
Cost per litre (US$)	0.567	0.434	0.529	0.632	0.735	0.469	0.369	0.828
Raw materials	0.416	0.310	0.393	0.393	0.514	0.252	0.190	0.700
Service fluids	0.039	0.025	0.027	0.025	0.082	0.086	0.079	0.001
Labour	0.001	0.001	0.001	0.003	0.001	0.000	0.000	0.002
Maintenance	0.014	0.014	0.015	0.025	0.014	0.025	0.020	0.006
Operating charges	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001
General plant costs	0.007	0.007	0.008	0.014	0.007	0.013	0.010	0.004
Administrative costs	0.038	0.029	0.035	0.037	0.050	0.030	0.024	0.057
Capital depreciation	0.063	0.063	0.070	0.150	0.067	0.064	0.045	0.085
Co-products	-0.011	-0.016	-0.019	-0.016	0.000	0.000	0.000	-0.028

Source: Cardona et al. (2009).

Using the above processing costs and farm crop budgets, we estimate the production technologies for the ten biofuels scenarios modelled in this paper. These are summarized in Table 7.4. The top half of the table shows the inputs required and outputs generated for 100 hectares of land allocated to feedstock production. From the first three columns we see that smallholder crop yields (i.e. *Sugar 1*) are lower than larger-scale farmers' yields (i.e. *Sugar 3*), implying that 100 ha of small-scale farm land produces half the output of plantations on the same amount of land (i.e. 4 280 versus 8 400 tons). Small-scale farms are also more labour-intensive (i.e. 0.4 hectares per worker compared to 2.4 ha per worker on larger farms). Increasing smallholders' sugar-cane yields significantly increases production levels per 100 ha of land (i.e. to 7,000 tons), but requires additional labour for weeding and harvesting. Cassava production is also labour-intensive and requires more land per litre of ethanol than sugar cane. The mixed cassava production system (i.e. *Cassava 3*) is more labour-intensive than the equivalent smallholder scenario (i.e. *Cassava 2*) as new commercial farms require additional labourers whereas smallholders increase production by raising yields on their existing farm land. Finally, the jatropha scenario is also labour-intensive, albeit less so than smallholder cassava and sugar cane.

The lower half of Table 7.4 shows the inputs required to produce 100 000 litres of ethanol or biodiesel. The first four columns refer to large-scale processing plants and so the technologies are the same. The *Sugar 1-4* scenarios differ with respect to the scale of feedstock production and, hence, the required amount of land and farm workers. The number of workers used in processing biofuels is much smaller than the number of farm workers used in producing the feedstock (e.g. one processing worker is needed for every 121 farm workers in more labour-intensive *Sugar 1* scenario). The labour-intensity of biofuel processing is, however, higher in the *Sugar 5* scenario, which uses small-scale processing plants. Finally, cassava processing is more labour-intensive, although the large amount of land required to produce the feedstock makes it the most labour-intensive option overall.

In summary, ten biofuel production scenarios are considered in this analysis. These scenarios compare different feedstocks; small/large-scale production structures and intensive/extensive feedstock production options. The study draws on detailed estimates of production costs based on the specific technologies used in each scenario. In the next section we integrate these technologies within an economy-wide model of Tanzania in order to estimate their impacts of growth and poverty.

7.2 MODELLING IMPACTS ON GROWTH AND POVERTY

7.2.1 STRUCTURE OF THE TANZANIAN ECONOMY

Table 7.5 shows the structure of the Tanzanian economy in 2007, which is the base year of the economic model. Agriculture generates one third of national gross domestic product (GDP) and 80 percent of total employment. Most farmers are smallholders with average land holdings of 1.6 hectares. They produce most of the country's food, which dominates

TABLE 7.4

Biofuels production technologies under alternative scenarios

Production characteristics for biofuels (inputs and outputs per 100ha)	Sugar 1	Sugar 2	Sugar 3	Sugar 4	Sugar 5	Molasses	Cassava 1	Cassava 2	Cassava 3	Jatropha
	(FAO 1)	(FAO 2)	-	(FAO 3)	(FAO 4)	(FAO 5)	-	(FAO 8)	(FAO 9)	(FAO 10)
Land employed (ha)	100.0	100.0	100.0	100.0	100.0	n/a	100.0	100.0	100.0	100.0
Crop production (mt)	4,280	7,575	8,399	6,999	4,280	n/a	1,000	2,000	2,000	400
Farm workers employed (people)	225.2	78.4	41.8	81.5	209.5	n/a	215.7	66.6	153.3	130.2
Land yield (mt / ha)	42.8	75.8	84.0	70.0	42.8	n/a	10.0	20.0	20.0	4.0
Farm labour yield (mt / person)	19.0	96.6	201.1	85.9	20.4	n/a	4.6	30.0	13.0	3.1
Land per farm worker (ha / person)	0.44	1.27	2.39	1.23	0.48	n/a	0.46	1.50	0.65	0.77
Capital per hectare (cap. units / ha)	1.76	3.54	3.98	n/a	1.64	n/a	0.72	n/a	1.4	1.3
Labour-capital ratio (people / cap. unit)	1.28	0.22	0.10	n/a	1.28	n/a	2.99	n/a	1.10	1.01
Biofuels produced (litres)	297 078	525 819	582 999	485 847	297 078	n/a	183 328	366 636	366 636	140 008
Processing workers employed (people)	2.33	3.15	3.36	4.18	10.33	n/a	0.45	0.91	0.91	1.36
Production characteristics for biofuels (inputs and outputs per 10 000 litres)	**Sugar 1**	**Sugar 2**	**Sugar 3**	**Sugar 4**	**Sugar 5**	**Molasses**	**Cassava 1**	**Cassava 2**	**Cassava 3**	**Jatropha**
	(FAO 1)	**(FAO 2)**	**-**	**(FAO 3)**	**(FAO 4)**	**(FAO 5)**	**-**	**(FAO 8)**	**(FAO 9)**	**(FAO 10)**
Biofuels production (litres)	100 000	100 000	100 000	100 000	100 000	100 000	100 000	100 000	100 000	100 000
Feedstock inputs (mt)	1,441	1,441	1,441	1,441	1,441	600	546	546	546	286
Feedstock yield (litres / mt)	69.41	69.41	69.41	69.41	69.41	166.7	183.31	183.31	183.31	349.92
Land employed (ha)	33.66	19.02	17.15	20.58	33.66	n/a	54.55	27.28	27.28	71.42
Farm workers employed (people)	75.81	14.92	7.16	16.77	70.51	n/a	117.66	18.17	41.82	92.97
Processing workers employed (people)	0.78	0.60	0.58	0.86	3.48	0.33	0.25	0.25	0.25	0.97
Capital employed (capital units)	105.2	315.8	342.6	183.6	144.9	133.5	214.5	214.5	373.7	40.3

Source: *Own calculations using information from Cardona et al. (2009), Coles (2008), Kapinga et al., (2009), Rothe (2007) and the Tanzania DCGE model.*

Notes: *Sugar 1: Small-scale sugar-cane production (land expansion) with large-scale ethanol processing*
Sugar 2: Mixed small- and large-scale sugar-cane production (land expansion) with large-scale ethanol processing
Sugar 3: Large-scale sugar-cane production (land expansion) with large-scale ethanol processing
Sugar 4: Small-scale sugar-cane production (yield improvements) with large-scale ethanol processing
Sugar 5: Small-scale sugar-cane production (land expansion) with large-scale ethanol processing
Molasses: Large-scale ethanol processing using imported molasses
Cassava 1: Small-scale cassava production (land expansion) with large-scale ethanol processing
Cassava 2: Small-scale cassava production (yield improvements) with large-scale ethanol processing

both the agricultural and manufacturing sectors. However, Tanzania as a whole relies on imported foods (mainly cereals), which account for 15 percent of total imports and 20 percent of all processed foods in the country. This dependence on food imports stems in part from the low crop yields achieved by smallholders due to their reliance on rainfall and traditional farming technologies. Larger-scale commercial farmers are more heavily engaged in traditional export crops, such as coffee, tobacco and tea, which together account for almost a third of total merchandize exports.

TABLE 7.5

Structure of Tanzania's economy, 2007

	Share of total (%)				Export intensity (%)	Import penetration (%)
	GDP	Employment	Exports	Imports		
Total GDP	100.00	100.00	100.00	100.00	9.44	22.01
Agriculture	31.82	82.46	34.89	6.11	13.23	7.28
Food crops	19.06	39.97	2.57	5.83	1.64	10.05
Traditional exports	3.20	12.22	21.50	0.28	63.45	7.08
Biofuel crops	0.00	0.00	0.00	0.00	0.00	13.74
Other agriculture	9.56	30.27	10.81	0.00	14.98	0.00
Mining	3.94	0.17	25.06	4.61	82.26	72.26
Manufacturing	8.84	1.46	12.83	87.88	8.26	61.42
Food processing	5.62	1.12	2.13	10.01	2.00	20.80
Biofuel processing	0.00	0.00	0.00	0.00	100.00	0.00
Other manufacturing	3.22	0.35	10.69	77.87	21.79	83.87
Other industries	10.35	0.99				
Private services	32.36	13.45	27.22	1.40	8.76	1.06
Govt. services	12.69	1.47	0.00	0.00	0.00	0.00

Source: Tanzania 2007 social accounting matrix.

Non-agriculture is dominated by gold mining, which accounts for a third of total merchandize earnings. Mining does not, however, create much employment or value-added, and most non-farm workers in the country are employed in construction ("other industries") and private services. Incomes in many of these non-farm sectors, such as trade, are on average only slightly higher than those in agriculture. This partly reflects the low levels of education and a shortage of skilled labour in the country. Indeed, most of Tanzania's workforce has not completed primary schooling.

The economy-wide model captures Tanzania's initial conditions and its detailed economic structure. This class of economic models is often used to examine external shocks and policies in low income countries. The strength of these models is their ability to measure linkages between producers, households and the government, while also accounting for resource constraints and its role in determining product and factor prices. These models are, however, limited by their underlying assumptions and the quality of the data used to calibrate them. The remainder of this section explains the workings of the DCGE model.

7.2.2 CORE GENERAL EQUILIBRIUM MODEL

We use a DCGE model, details of which are included in Appendix 7A. The DCGE model illustrates how biofuels investments affect economic outcomes in our analysis and how economic growth is linked to household incomes.

7.2.3 MODELLING BIOFUELS PRODUCTION

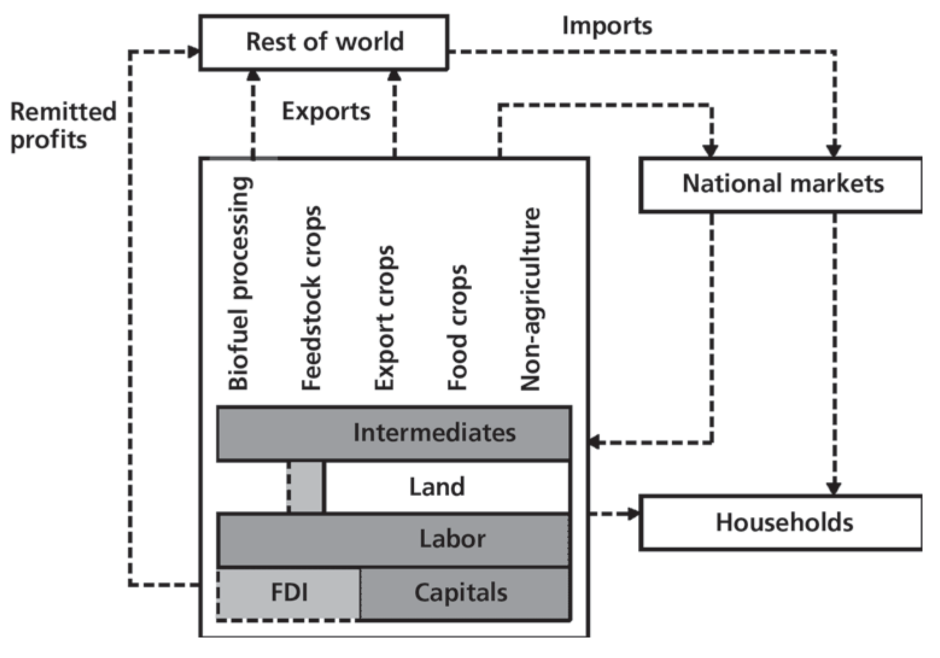
Biofuels are not currently produced in Tanzania and so there is initially no biofuel sector in the 2007 social accounting matrix used to calibrate the DCGE model. However, the production cost information in Table 7.3 and farm crop budgets provide the intermediate technology vectors needed to create these new sectors in the model. Negligibly small feedstock and processing sectors representing different biofuel technology vectors were initially created. The DCGE model is first run forward over the 2007-2015 period assuming no expansion in biofuel production. This produces a baseline "without biofuels" scenario. Then in the biofuel simulations we expand the size of the feedstock and processing subsectors to produce 1 000 million litres of biofuels. A conceptual framework for these simulations is shown in Figure 7.1.

Biofuel expansion is assumed to be driven by foreign direct investment (FDI) and all profits generated in the biofuel sectors are remitted abroad (after applying average corporate tax rates). Biofuel producers must, however, compete with other sectors for intermediate inputs and land and labour resources. In the DCGE model we assume full employment, which means that total labour supplies are fixed and increasing labour demand per unit of land raises workers' wages. Feedstock production also displaces lands used for existing crops, since these lands will be assigned to new biofuel investments and smallholder farmers will also reallocate resources towards feedstock. Thus, while new lands may be available to feedstock producers, it is expected that at least some existing lands will be displaced by biofuel crops. Table 7.2 shows that for most scenarios it is assumed that half of the lands used by biofuel feedstock come from lands already in use by smallholder farmers. There is no land displacement in the *Sugar 4* and *Cassava 2* scenarios as feedstock is produced entirely through intensification (i.e. raising yields). The grey shaded areas in the figure represent new capital and land resources, which cause national production to expand in the simulations.

It is assumed that all biofuels will be exported. However, it is possible that some of the ethanol produced in Tanzania may be blended with imported petroleum for domestic use (see Cardona *et al.*, 2009). However, if the Government of Tanzania does not subsidize domestic ethanol then the difference between increasing biofuel exports or reducing petroleum imports is small (i.e. the effect on the balance of payments is symmetrical). Therefore assuming all biofuels are exported will not change the findings. Similarly, it is assumed that all molasses feedstocks are imported, which offsets the decline in molasses exports required in the molasses scenario. The model includes co-products produced during the biofuel production process, the sale of which helps reduce ethanol and biodiesel production costs. We do not, however, explicitly model markets for co-products, but assume that they are used to reduce fuel and electricity inputs used during biofuel processing.

Figure 7.1

Conceptual framework



7.3 MODEL RESULTS

7.3.1 BASELINE SCENARIO

First the DCGE model is calibrated to track observed trends in key demographic and macroeconomic indicators (see Table 7.6). Population growth is set at 2.5 percent per year during 2007-2015. Skilled labour supply grows faster than unskilled labour in all scenarios, reflecting gradual improvements in educational attainment. Livestock stocks and agricultural land expand at 1 percent each year, capturing rising population density, especially in rural areas. In order to achieve observed growth rates in gross domestic product, total factor productivity growth is set at 2.7 percent per year during the simulation period. The baseline scenario also captures the recent poor performance of the agricultural sector.

7.3.2 CHANGES IN AGRICULTURAL PRODUCTION

In the biofuel simulations the amount of land and foreign direct investment allocated to biofuel sectors is increased. It is assumed that only half of biofuels' land requirements will displace land already being cultivated. An increase is therefore expected in the total amount of land under cultivation. This is shown in the third column of Table 7.6, where the rate of land expansion for smallholders increases from 1 000 percent under the Baseline scenario to 1.26 percent per year under the *Sugar 1* scenario. Conversely, as there is a shift towards larger-scale feedstock production (in *Sugar 2* and *Sugar 3*) the expansion rate of smallholder lands drops below one. This is because we assume that it is smallholders' lands that are displaced when large-scale plantations expand feedstock production. However, no smallholder land is displaced in the *Sugar 4* and *Cassava 2* scenarios since production achieved by improving yields. There is some land displacement in the mixed cassava production scenario (*Cassava 3*), because the portion that is produced by commercial farmers requires additional lands, half of which comes from smallholders. Finally, the molasses needed as feedstock is already produced in Tanzania and so there is no change in land expansion rates under the molasses scenario.

Displacing lands to produce biofuel feedstock causes production of other crops to contract (see Table 7.7). The debate surrounding biofuels in low-income countries centres on their possible negative effects on food production. Findings suggest that, in the case of Tanzania, it is export crops that experience the largest declines in production. This is because in our simulations biofuels eventually account for almost a third of total merchandize export earnings by 2015. It can be assumed that the current account balance is fixed in foreign currency, the increase in exports causes the real exchange rate to appreciate relative to Baseline (see Table 7.6). This reduces the competitiveness of traditional export crops, such as coffee, tobacco and tea, and these exports decline. For example, the amount of land allocated to export crops falls by 191 000 ha in the *Sugar 1* scenario. In the same scenario the land allocated to food crops increases slightly, as farmers reallocate land away from export crops and rising incomes raise food demand. Food crop production therefore increases under most biofuel production scenarios. The only exception is the *Cassava 1* scenario, where a large amount of land is needed to produce the same amount of biofuel, causing food production to fall. However, even in this scenario, the trade-off between food production and biofuels remains small, with export crops more severely affected.

Comparing *Sugar 1* with *Sugar 3* suggests that moving to larger-scale feedstock production does not remove the negative impacts on export crops. This is because the same amount of ethanol exports are produced causing a similar appreciation of the real exchange rate (see Table 7.6). This means that non-biofuel exporters are adversely affected in both scenarios. Larger-scale production technologies do, however, favour food crop production, since the higher yields of large-scale farmers means that less land is needed for biofuel feedstock. This implies that more land previously used by traditional export crops is reallocated to food crops rather than being used to produce biofuels. This finding suggests that any trade-offs that do exist between biofuels and food production are likely to be smaller when feedstock is produced by larger-scale farmers.

Alternatively, when smallholders' yields are increased there is no displacement of land and so traditional export crop lands are reallocated entirely to food crops (see *Sugar 4* and *Cassava 2*). The same is true in the molasses scenario, where no additional lands are needed to produce feedstock. These scenarios clearly indicate that the exchange rate effect is more important than heightened resource competition when determining the overall effect of biofuel investments on food production in Tanzania. Arndt *et al.* (2009) reported similar findings for Mozambique, although biofuel investments reduced food crop production in this country. This difference arises because Mozambique does not have a large export crop sector so at least some lands under food crops are displaced by biofuel feedstock.

7.3.3 IMPACTS ON ECONOMIC GROWTH AND EMPLOYMENT

Table 7.8 shows the impact of biofuel investments on sectors' real GDP growth rates. Foreign direct investment in the biofuel sectors expands agriculture's capital stock and also brings new lands under cultivation. This expansion in resources causes agriculture's growth rate to increase in all of the biofuel scenarios. Larger-scale production of sugar-cane feedstock (i.e. *Sugar 3*) generates larger gains in agricultural GDP than production through smallholder outgrower schemes (i.e. *Sugar 1*). There are also larger gains in the manufacturing sector under the *Sugar 3* scenario, due to its smaller impact on food crops and downstream food processing. However, all sugar-cane scenarios reduce processed food production because the appreciated exchange rate heightens competition in this import-intensive sector (see Table 7.6). Ultimately, the trade-offs from biofuel production are smaller than the gains from new investments and, as a result, national GDP growth rates increase in all biofuel scenarios.

Generally, the more profitable the biofuel processing technology is, the larger its impact on national economic growth. For example, the scenarios with the largest positive gains in total GDP are *Sugar 2/3* and *Cassava 2/3*, which are amongst the more profitable ethanol technologies in Tanzania (see Table 7.3). Improving crop yields rather than displacing existing cultivated lands also generates large economy-wide gains. This is because these sectors enhance the returns to agricultural resources without greatly reducing food production. By contrast, producing ethanol using molasses has little effect

TABLE 7.6

Core macroeconomic assumptions and results, 2007-2015

	Initial, 2007	Baseline scenario	Sugar 1	Sugar 2	Sugar 3	Sugar 4	Sugar 5	Molasses	Cassava 1	Cassava 2	Cassava 3	Jatropha
			(FAO 1)	(FAO 2)	-	(FAO 3)	(FAO 4)	(FAO 5)	-	(FAO 8)	(FAO 9)	(FAO 10)
		Average annual growth rate, 2007-15 (%)										
Population	31,683	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Total GDP	100.00	4.61	4.86	4.95	4.97	4.98	4.88	4.72	4.86	4.97	4.99	4.87
Labour supply	56.07	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12
Primary	42.54	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Secondary	12.17	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Tertiary	1.36	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Capital stock	17.53	2.52	2.62	2.62	2.62	2.63	2.62	2.51	2.59	2.59	2.61	2.55
Livestock stock	2.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Land supply	24.20	1.00	1.24	1.13	1.12	1.29	1.24	1.00	1.38	1.38	1.27	1.50
Small-scale	22.48	1.00	1.26	0.91	0.87	1.00	1.26	1.00	1.41	1.00	0.87	1.54
Large-scale	1.72	1.00	1.00	3.76	4.08	1.00	1.00	1.00	1.00	1.00	3.95	1.00
		Final year value, 2015										
Real exchange rate	1.00	1.07	0.99	1.00	1.00	1.00	1.00	1.05	1.01	1.01	1.02	1.00
Consumer prices	1.00	1.06	1.03	1.03	1.03	1.03	1.04	1.05	1.04	1.04	1.04	1.04
Cereals prices	1.00	1.16	1.13	1.12	1.12	1.12	1.13	1.14	1.15	1.13	1.14	1.16

Source: *Results from the Tanzania DCGE and micro-simulation model.*

Notes: *Sugar 1/2/3: Small-scale / mixed / large-scale sugar-cane production (land expansion) with large-scale ethanol processing*
Sugar 4: Small-scale sugar-cane production (yield improvements) with large-scale ethanol processing
Sugar 5: Small-scale sugar-cane production (land expansion) with small-scale ethanol processing
Molasses: Large-scale ethanol processing using imported molasses
Cassava 1: Small-scale cassava production (land expansion) with large-scale ethanol processing
Cassava 2/3: Small-scale / mixed cassava production (yield improvements) with large-scale ethanol processing
Jatropha: Small-scale jatropha production with large-scale biodiesel processing

TABLE 7.7

Agricultural production results, 2007-2015

	Initial value, 2007	Baseline value, 2015	Deviation from Baseline scenario final value, 2015									
			Sugar 1	Sugar 2	Sugar 3	Sugar 4	Sugar 5	Molasses	Cassava 1	Cassava 2	Cassava 3	Jatropha
			(FAO 1)	(FAO 2)	-	(FAO 3)	(FAO 4)	(FAO 5)	-	(FAO 8)	(FAO 9)	(FAO 10)
Biofuels (1 000 l)	0	0	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000
Crop land (1 000 ha)	8 207	8 887	168	95	86	0	168	0	273	0	50	357
Biofuels crops	0	0	337	190	172	0	337	0	545	0	99	714
Food crops	7 236	7 711	23	60	65	163	20	42	-85	142	45	-155
Maize	2 690	2 812	22	32	33	67	21	17	-14	59	24	-33
Rice	546	592	1	6	6	15	1	4	-12	12	3	-20
Cassava	660	671	4	7	7	17	3	4	-6	15	4	-9
Export crops	970	1 175	-191	-155	-150	-163	-188	-42	-187	-142	-127	-202
Production (1000 mt)												
Biofuels feedstock			14 407	14 407	14 407	14 407	14 407	1 000	5 455	5 455	5 455	2 857
Food crops												
Maize	2 354	2 713	18	38	41	60	18	15	-16	52	21	-14
Rice	1 084	1 268	-1	13	15	19	0	5	-18	15	4	-16
Cassava	5 284	5 873	26	68	73	137	26	35	-56	123	33	-65

Source: *Results from the Tanzania DCGE and micro-simulation model.*

Notes: *Sugar 1/2/3: Small-scale / mixed / large-scale sugar-cane production (land expansion) with large-scale ethanol processing*
Sugar 4: Small-scale sugar-cane production (yield improvements) with large-scale ethanol processing
Sugar 5: Small-scale sugar-cane production (land expansion) with small-scale ethanol processing
Molasses: Large-scale ethanol processing using imported molasses
Cassava 1: Small-scale cassava production (land expansion) with large-scale ethanol processing
Cassava 2/3: Small-scale / mixed cassava production (yield improvements) with large-scale ethanol processing
Jatropha: Small-scale jatropha production with large-scale biodiesel processing

on national GDP since there are no growth linkages to the agricultural sector and only small gains in manufacturing. Moreover, the growth-effects under the mixed cassava production approach (i.e. *Cassava 3*) are not as large as those of the mixed sugar-cane approach. This is because cassava is a land-intensive crop and so establishing new large-scale commercial cassava farms displaces more land from other crops than does sugar cane. Similarly, obtaining cassava feedstock solely by increasing smallholders' yield (i.e. *Cassava 2*) generates larger growth-effects, as no land displacement of other crop lands is necessary. Finally, the jatropha scenario has smaller growth-effects since the sector is less profitable and so generates lower levels of value-added, especially for downstream processors.

Table 7.9 reports impacts on labour employment. The number of new jobs created in the biofuels sector varies greatly across scenarios. The low labour-intensity of large-scale sugar-cane production means that only 72 000 farm jobs are created in the *Sugar 3* scenario. Conversely, outgrower schemes employ far more farmers (see Table 7.4), with 758 000 additional workers producing sugar cane in the *Sugar 1* scenario.[1] Sugar cane is less labour-intensive than cassava production and it is the *Cassava 1* and jatropha scenarios that engage the largest number of workers in feedstock production. Moreover, while improving crop yields amongst smallholders does not require additional lands in the *Sugar 4* and *Cassava 2* scenarios, it still requires additional workers, especially during harvesting. For example, doubling cassava yields in the *Cassava 2* scenario draws an additional 182 000 farmers into cassava production. This result emphasizes an often overlooked dimension of the biofuels debate, which has typically focused on land displacement (especially for food crops) while ignoring the labour "displacement" effects. Thus, even if all feedstock production were to take place on new lands (i.e. no land displacement) non-feedstock crops would still decline due to increased competition over non-land resources (such as labour).

The downstream processing of biofuels creates very few jobs, with almost all employment effects from biofuel investments coming from feedstock production.[2] Moreover, unlike feedstock production, jobs in processing plants are for higher-skilled workers, most of which are sourced from other manufacturing subsectors. Lower-skilled feedstock farmers or labourers mainly come from within the agriculture itself. However, both sugar-cane and cassava have lower-than-average labour-land ratios. This means that reallocating land to these crops effectively reduces demand for agricultural labour. Excess farm workers therefore migrate to the non-farm sector, especially into less skill-intensive trade and transport services.

Establishing a biofuels industry in Tanzania will therefore create new job opportunities for some farmers, but will also impose significant adjustment costs on other workers, especially those in export agriculture.

1 Note that employment numbers do not adjust for under-employment and include unpaid family members.

2 About 620 biofuels processing jobs are created in Sugar 1-3; 860 in Sugar 4; 1600 in Sugar 5; 333 in Molasses; and 248 in Cassava 1-3.

TABLE 7.8

Sector growth results, 2007-2015

	GDP share, 2007 (%)	Baseline growth (%)	Deviation from Baseline scenario growth rate (%-point)									
			Sugar 1	Sugar 2	Sugar 3	Sugar 4	Sugar 5	Molasses	Cassava 1	Cassava 2	Cassava 3	Jatropha
				(FAO 2)	-	(FAO 3)	(FAO 4)	(FAO 5)	-	(FAO 8)	(FAO 9)	(FAO 10)
Total GDP	100.00	4.61	0.25	0.34	0.35	0.37	0.27	0.11	0.25	0.35	0.37	0.26
Agriculture	31.82	2.20	0.21	0.33	0.34	0.50	0.19	0.00	0.25	0.55	0.38	0.67
Food crops	19.06	1.88	0.00	0.13	0.15	0.22	0.01	0.06	-0.17	0.19	0.04	-0.16
Traditional exports	3.20	2.49	-1.49	-0.97	-0.90	-1.11	-1.45	-0.23	-1.61	-0.97	-0.92	-1.61
Biofuels crops	0.00	0.00	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Other agriculture	9.56	2.71	-0.27	-0.14	-0.12	-0.10	-0.26	-0.03	-0.33	-0.08	-0.14	-0.28
Mining	3.94	7.17	-0.02	-0.02	-0.02	-0.02	-0.02	-0.01	-0.02	-0.02	-0.01	-0.02
Manufacturing	8.84	5.49	0.00	1.11	1.25	0.53	0.24	0.51	0.57	0.71	1.52	-0.27
Food processing	5.62	3.82	-0.12	-0.05	-0.04	0.03	-0.12	-0.01	-0.18	0.03	-0.03	-0.14
Biofuels process.	0.00	0.00	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Other manu.	3.22	8.03	-1.16	-1.07	-1.05	-1.03	-1.13	-0.40	-1.01	-0.94	-0.71	-0.98
Other industries	0.31	8.03	-0.97	-0.91	-0.91	-0.87	-0.95	-0.34	-0.79	-0.77	-0.57	-0.73
Private services	45.05	5.35	0.32	0.18	0.16	0.28	0.32	0.08	0.16	0.17	0.14	0.17
Govt. services	0.45	5.18	0.03	0.02	0.02	0.11	0.03	-0.02	0.06	0.12	0.10	0.12

Source: *Results from the Tanzania DCGE and micro-simulation model.*

Note: *Equivalent variation is a measure of household welfare that controls for changes in commodity prices.*
Sugar 1: Small-scale sugar-cane production (land expansion) with large-scale ethanol processing
Sugar 2: Mixed small- and large-scale sugar-cane production (land expansion) with large-scale ethanol processing
Sugar 3: Large-scale sugar-cane production (land expansion) with large-scale ethanol processing
Sugar 4: Small-scale sugar-cane production (yield improvements) with large-scale ethanol processing
Sugar 5: Small-scale sugar-cane production (land expansion) with large-scale ethanol processing
Molasses: Large-scale ethanol processing using imported molasses
Cassava 1: Small-scale cassava production (land expansion) with large-scale ethanol processing
Cassava 2: Small-scale cassava production (yield improvements) with large-scale ethanol processing
Cassava 3: Mixed small- and large-scale cassava production (land expansion) with large-scale ethanol processing

TABLE 7.9

Employment results, 2007-2015

	Employ-ment, 2007	Baseline employ., 2015	Deviation from Baseline scenario final employment, 2015									
			Sugar 1	Sugar 2	Sugar 3	Sugar 4	Sugar 5	Molasses	Cassava 1	Cassava 2	Cassava 3	Jatropha
				(FAO 2)	-	(FAO 3)	(FAO 4)	(FAO 5)	-	(FAO 8)	(FAO 9)	(FAO 10)
Total (1000s workers)	19 010	22 487	0	0	0	0	0	0	0	0	0	0
Agriculture	15 675	18 565	-95	-78	-76	-103	-101	-37	-23	-68	-50	-9
Food crops	7 597	8 977	-76	188	221	178	-55	54	-269	146	-4	-83
Traditional exports	2 323	2 901	-535	-351	-327	-403	-520	-92	-573	-356	-342	-559
Biofuels crops	0	0	758	149	72	168	705	0	1 177	182	418	930
Other agriculture	5 754	6 686	-243	-65	-42	-46	-231	2	-358	-39	-122	-296
Mining	33	54	-5	-5	-5	-5	-5	-1	-4	-4	-3	-4
Manufacturing	278	320	-20	-16	-16	-14	-17	-4	-21	-13	-12	-18
Food processing	212	209	-2	0	0	2	-2	1	-4	2	-1	-3
Biofuels process.	0	0	1	1	1	1	3	0	0	0	0	1
Other manu.	66	111	-19	-17	-17	-17	-18	-5	-17	-15	-12	-16
Other industries	188	240	11	14	14	12	10	3	9	11	12	3
Private services	2 557	2 981	107	84	81	109	111	38	37	72	53	27
Govt. services	280	327	2	2	1	2	2	1	1	1	1	1

Source: *Results from the Tanzania DCGE and micro-simulation model.*

Notes: *Sugar 1/2/3: Small-scale / mixed / large-scale sugar-cane production (land expansion) with large-scale ethanol processing*
Sugar 4: Small-scale sugar-cane production (yield improvements) with large-scale ethanol processing
Sugar 5: Small-scale sugar-cane production (land expansion) with small-scale ethanol processing
Molasses: Large-scale ethanol processing using imported molasses
Cassava 1: Small-scale cassava production (land expansion) with large-scale ethanol processing
Cassava 2/3: Small-scale / mixed cassava production (yield improvements) with large-scale ethanol processing
Jatropha: Small-scale jatropha production with large-scale biodiesel processing

7.3.4 CHANGES IN HOUSEHOLD INCOMES AND POVERTY

Biofuel investments increase national GDP and factor returns, causing households' incomes to rise. While this is true in all of the biofuel scenarios, there are significant differences in the distributional impacts across household groups. Table 7.10 reports changes in households' equivalent variation, which is a welfare measure that controls changes in prices. All rural quintiles benefit from the introduction of a biofuel industry in Tanzania. However, higher-income rural households benefit more under larger-scale production scenarios, such as Sugar 3 and Cassava 3, as most large-scale farmers fall into the higher expenditure quintiles. Lower-income households, on the other hand, benefit more under smallholder outgrower schemes, especially when they are combined with improvements in crop yields.

Urban households also benefit from an increase in the economy-wide returns to labour and capital, and from the higher overall level of economic growth in the country. However, it is typically the middle of the urban income distribution that benefits the most, since these quintiles rely more heavily on labour wages for their incomes. Moreover, these households are typically endowed with semi-skilled labour, which is used more intensively in the biofuel processing sectors (i.e. as operators and technicians).

The national distributional effects of biofuel investments on households' equivalent variation are shown in Figure 7.2. Molasses generates very little additional value-added in the economy and so its effects on household welfare are small. While larger-scale sugar cane-based biofuel production is far more beneficial for households, it is higher-income households that benefit far more than lower-income households (i.e. the curve for *Sugar 3* is upward sloping). By contrast, the welfare gains are more evenly distributed across expenditure quintiles when smallholder outgrower schemes are used to produce sugar cane (i.e. *Sugar 1*). Increasing smallholders' crop yields produces the most pro-poor welfare outcomes. This is reflected in the figure by the higher and downward sloping curves for the *Sugar 4* and *Cassava 2* scenarios. The mixed cassava production approach (i.e. *Cassava 3*) is least effective amongst the cassava scenarios in raising household welfare, with higher-income households benefiting the most in this scenario. This is because the displacement of existing farm land in order to establish commercial farms to produce this land-intensive crop is particularly severe for smallholders. Finally, the jatropha scenario produces large welfare gains for lower-income households since it assumes high crop yields and engages a large number of smallholder farmers.

TABLE 7.10

Household per capita equivalent variation results, 2007-2015

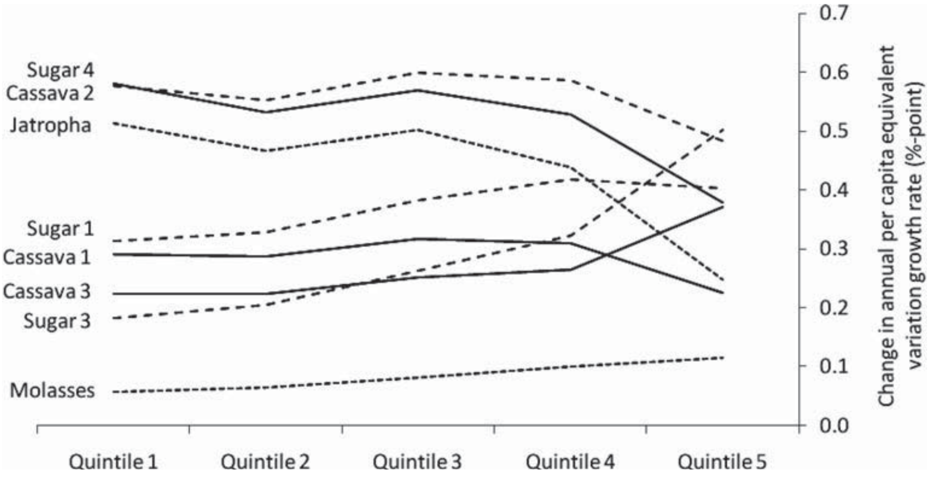
	Per cap. cons., 2007 (US$)	Baseline growth, 2015 (%)	Deviation from Baseline scenario growth rate (%-point)									
			Sugar 1	Sugar 2	Sugar 3	Sugar 4	Sugar 5	Molasses	Cassava 1	Cassava 2	Cassava 3	Jatropha
				(FAO 2)	-	(FAO 3)	(FAO 4)	(FAO 5)	-	(FAO 8)	(FAO 9)	(FAO 10)
Rural	372.4	1.32	0.41	0.57	0.59	0.53	0.41	0.11	0.27	0.45	0.49	0.34
Quintile 1	109.8	0.82	0.31	0.19	0.18	0.58	0.30	0.06	0.29	0.59	0.22	0.53
Quintile 2	198.6	0.97	0.32	0.21	0.19	0.56	0.32	0.06	0.29	0.54	0.22	0.49
Quintile 3	283.7	0.99	0.37	0.25	0.24	0.60	0.36	0.07	0.32	0.59	0.25	0.53
Quintile 4	433.7	1.17	0.40	0.30	0.28	0.59	0.39	0.09	0.32	0.55	0.26	0.48
Quintile 5	967.4	1.31	0.44	0.57	0.59	0.55	0.44	0.12	0.28	0.45	0.47	0.33
Urban	903.2	1.94	0.38	0.38	0.38	0.41	0.38	0.11	0.16	0.28	0.21	0.13
Quintile 1	120.6	1.22	0.35	0.28	0.27	0.43	0.35	0.08	0.22	0.25	0.22	0.15
Quintile 2	211.3	1.28	0.44	0.43	0.42	0.50	0.45	0.14	0.23	0.33	0.26	0.17
Quintile 3	307.6	1.38	0.54	0.53	0.53	0.58	0.54	0.17	0.26	0.41	0.31	0.21
Quintile 4	470.3	1.52	0.52	0.52	0.52	0.56	0.52	0.17	0.25	0.40	0.30	0.20
Quintile 5	1614.2	2.08	0.34	0.35	0.35	0.37	0.34	0.10	0.13	0.25	0.19	0.11

Source: *Results from the Tanzania DCGE and micro-simulation model.*

Notes: *Sugar 1/2/3: Small-scale / mixed / large-scale sugar-cane production (land expansion) with large-scale ethanol processing*
Sugar 4: Small-scale sugar-cane production (yield improvements) with large-scale ethanol processing
Sugar 5: Small-scale sugar-cane production (land expansion) with small-scale ethanol processing
Molasses: Large-scale ethanol processing using imported molasses
Cassava 1: Small-scale cassava production (land expansion) with large-scale ethanol processing
Cassava 2/3: Small-scale / mixed cassava production (yield improvements) with large-scale ethanol processing
Jatropha: Small-scale jatropha production with large-scale biodiesel processing

Figure 7.2

Change in per capita equivalent variation from Baseline scenario by quintile, 2007-2015



Source: Results from the Tanzania DCGE and micro-simulation model.
Note: Equivalent variation is a measure of household welfare that controls for changes in commodity prices. Expenditure quintiles are based on per capita consumption spending.

Finally, Table 7.11 reports changes in national poverty rates for the various biofuel scenarios. The headcount rate, which measures the share of the population under the poverty line, declines the most under the two yield-improvement scenarios. Poverty reduction is also more pronounced for technologies that more heavily engage smallholder farmers. There is little difference in poverty outcomes, however, between the purely large-scale sugar-cane scenario (i.e. *Sugar 3*) and the scenario that produces 20 percent of feedstock using smallholders (i.e. *Sugar 2*). Similarly, the poverty-effects of the mixed cassava production approach (i.e. *Cassava 3*) are also fairly modest compared to the purely smallholder-based approaches. This suggests that increasing the participation of smaller-scale farmers generates significant gains in poverty reduction, especially when additional investments are made to enhance crop smallholder productivity.

7.4 CONCLUSIONS

Considerable uncertainty exists concerning the potential gains from establishing biofuel industries in low income countries. Particular concern is raised over possible trade-offs between biofuel and food production. It is therefore essential that governments in countries like Tanzania understand how different biofuel technologies can contribute to achieving national development objectives. Drawing on detailed production cost estimates, this study developed a dynamic economy-wide model of Tanzania to estimate the growth and distributional implications of alternative biofuel production scenarios. These scenarios differed in the feedstock used to produce biofuels (sugar cane, molasses and cassava), the scale of feedstock production (small-scale outgrower versus larger-scale plantations), and the way in which feedstock production is increased (yield improvements versus land expansion).

Model results indicate that while some individual farmers may shift resources away from producing food crops, there is no national-level trade-off between biofuels and food production in Tanzania. Rather it is traditional export crops that will be adversely affected by a sizable appreciation of the real exchange rate. Indeed, it is the large size of Tanzania's agricultural export sector that prevents food production from contracting. This is because the amount of land displaced by biofuel feedstock is smaller than the lands released by declining traditional export crops. As a result, food production increases slightly under most biofuel investment scenarios. Overall, national GDP rises and new employment opportunities are created in biofuel sectors. This leads to welfare gains throughout the income distribution, albeit following a possible period of adjustment in which prices, farm workers and non-biofuel experts adapt to new market conditions.

Findings suggest that, while all biofuel production scenarios improve household welfare, it is the small-scale outgrower schemes, especially for typical smallholder crops such as cassava and jatropha, which are most effective at raising poorer households' incomes. Tanzania should therefore explore opportunities to engage smallholders in the production of biofuels, possibly through mixed small- and large-scale production systems. However, supporting evidence indicates that these mixed systems may reduce the profitability of biofuels in Tanzania and reduce the reliability of feedstock supply for downstream processing. Here these findings confirm the welfare gains from producing feedstock through yield improvements rather than land expansion. Given its strong pro-poor outcomes and greater profitability, these findings favour a cassava-based biofuel industry for Tanzania.

There are, however, a number of limitations to this analysis. Most importantly, while the scenarios based on yield improvements generated the highest levels of pro-poor growth, the analysis only accounted for the private costs involved in establishing the biofuel industry. It did not include public sector costs, such as the provision of irrigation and farm inputs to improve farmers' productivity. Given the difficulties that the Government of Tanzania has faced in the past in raising smallholders' crop yields, some of the yield-oriented biofuel scenarios may prove overly optimistic. Moreover, in all of the biofuel scenarios the cost of the providing infrastructure or tax incentives that may be demanded by foreign investors to produce biofuels in Tanzania were not taken into account. If these public investments are not in accordance with the government's national development plan then they will incur opportunity costs. In our analysis the benefits of investing in biofuels were not compared vis-à-vis other social and economic sectors. However, excluding public sector costs, our results indicate that establishing a biofuel industry in Tanzania can contribute to achieving the country's development objectives of enhancing economic growth and reducing poverty.

TABLE 7.11

Poverty results, 2007-2015

	Poverty rate, 2007 (%)	Baseline poverty, 2015 (%)	Deviation from final Baseline scenario poverty rate, 2015 (%-point)									
			Sugar 1	Sugar 2	Sugar 3	Sugar 4	Sugar 5	Molasses	Cassava 1	Cassava 2	Cassava 3	Jatropha
				(FAO 2)	-	(FAO 3)	(FAO 4)	(FAO 5)	-	(FAO 8)	(FAO 9)	(FAO 10)
Headcount (P0)	40.00	36.77	-1.36	-1.07	-1.05	-2.18	-1.33	-0.30	-1.28	-2.21	-1.15	-1.81
Rural	44.72	41.34	-1.37	-1.08	-1.05	-2.32	-1.33	-0.29	-1.34	-2.36	-1.20	-1.97
Urban	20.18	17.52	-1.32	-1.07	-1.05	-1.60	-1.32	-0.38	-1.00	-1.57	-0.94	-1.17
Gap (P1)	13.23	12.00	-0.54	-0.36	-0.34	-1.00	-0.53	-0.11	-0.52	-1.04	-0.44	-0.82
Rural	15.01	13.70	-0.60	-0.39	-0.36	-1.12	-0.59	-0.12	-0.58	-1.18	-0.49	-0.93
Urban	5.76	4.89	-0.32	-0.25	-0.25	-0.48	-0.32	-0.08	-0.27	-0.46	-0.25	-0.33
Squared gap (P2)	6.10	5.49	-0.27	-0.18	-0.17	-0.52	-0.27	-0.06	-0.27	-0.54	-0.23	-0.43
Rural	6.97	6.31	-0.31	-0.20	-0.18	-0.59	-0.30	-0.06	-0.30	-0.63	-0.25	-0.50
Urban	2.46	2.07	-0.13	-0.10	-0.10	-0.21	-0.13	-0.03	-0.12	-0.20	-0.11	-0.15

Source: *Results from the Tanzania DCGE and micro-simulation model.*

Notes: *Sugar 1/2/3: Small-scale / mixed / large-scale sugar-cane production (land expansion) with large-scale ethanol processing*
Sugar 4: Small-scale sugar-cane production (yield improvements) with large-scale ethanol processing
Sugar 5: Small-scale sugar-cane production (land expansion) with small-scale ethanol processing
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APPENDIX 7

A CORE MODEL EQUATIONS.

We first present a simplified or core DCGE model to illustrate how biofuels investments affect economic outcomes in our analysis. The equations are presented in the table 7A.1 below.

Producers in each sector s produce a level of output Q by employing the factors of production F under constant returns to scale (exogenous productivity α) and fixed production technologies (fixed factor input shares δ) (eq. [1]). Profit maximization implies that factor payments W are equal to average production revenues (eq. [2]). Labour, land and capital supply s are fixed, implying full employment and intersector mobility (eq. [10]). This means that as new biofuel sectors expand they generate additional demand for factor inputs, which then affect economy-wide factor returns and production in other sectors by increasing resource competition.

Foreign trade is determined by comparing domestic and world prices, where the latter are fixed under a small country assumption. The simple model implements trade as a complementarity problem. If domestic prices exceed world import prices w^m (adjusted by exchange rate E) then the quantity of imports M increases (eq. [3]). Conversely, if domestic prices fall below world export prices w^e then export demand X increases (eq. [4]). To ensure macroeconomic consistency, a flexible exchange rate adjusts to maintain a fixed current account balance b (measured in foreign currency units) (eq. [8]). This implies that as biofuel exports rise (or petroleum imports decline) the exchange rate will appreciate, thus affecting the competitiveness of non-biofuel exports and imports.

Factor incomes are distributed to households using fixed income shares θ based on households' initial factor endowments (eq. [5]). Incomes Y are then saved (based on marginal propensities to save υ) or spent on consumption C (according to marginal budget shares β) (eq. [6]). Household savings and foreign capital inflows are collected in a national savings pool and used to finance investment demand I (i.e. a savings-driven investment closure) (eq. [7]). Finally, prices P equilibrate product markets so that demand for each commodity equals supply (eq. [8]). The model therefore links production patterns to household incomes through changes in factor employment and returns.

The model's variables and parameters are calibrated to observed data from a national social accounting matrix that captures the initial equilibrium structure of the Tanzanian economy in 2007. Parameters are then adjusted over time to reflect demographic and economic changes and the model is re-solved for a series of new equilibriums for the 8-year period 2007-2015. Between periods the model is updated to reflect exogenous rates of land and labour expansion ϕ (eq. [11]). The rate of capital accumulation is determined endogenously, with the level of investment I from the previous period converted into new capital stocks using a fixed capital price κ (eq. [12]). This is added to previous capital stocks after applying a fixed long-term rate of depreciation π. Finally, the model captures total factor productivity through the production function's shift parameter α, with the rate of technical change γ determined exogenously.

The core model illustrates the basic functioning of a CGE model. However, the full model of Tanzania drops certain restrictive assumptions (see Thurlow, 2005). Constant elasticity of substitution production functions allow factor substitution based on relative factor prices (i.e. ◘ is no longer fixed). The model identifies 58 sectors (i.e. 26 in agriculture, 22 industries and 10 services). Intermediate demand in each sector, which was excluded from the simple model, is now determined by fixed technology coefficients (i.e. Leontief demand). Based on the 2000/01 Household Budget Survey (HBS) (NBS, 2001), labour markets are segmented across three skill groups: (1) workers with less than primary education; (2) workers with primary and possibly some secondary schooling; and (3) workers who have completed secondary or tertiary schooling. Agricultural land is divided across small- and large-scale farms based on the 2002/03 Agricultural Sample Survey (MINAG, 2004). All factors are still assumed to be fully employed, but capital is immobile across sectors. New capital from past investment is allocated to sectors according to profit rate differentials under a "putty-clay" specification. This means that once capital stocks have been invested it is difficult to transfer them to other uses.

International trade is captured by allowing production and consumption to shift imperfectly between domestic and foreign markets, depending on the relative prices of imports, exports and domestic goods (inclusive of relevant sales and trade taxes). This differs from the simple model, which assumed perfect substitution between domestic and foreign goods (i.e. homogenous products). This extension captures differences in domestic and foreign products and allows for observed two-way trade. Tanzania is still considered a small economy such that world prices are fixed and the exchange rate (i.e. price index of tradable-to-non-tradable goods) adjusts to maintain a fixed current account balance. Production and trade elasticities are drawn from Dimaranan (2006).

Households maximize a Stone-Geary utility function so that a linear expenditure system determines consumption with non-unitary income elasticities (estimated using HBS). Households are disaggregated across rural/urban and farm/non-farm groups and by per capita expenditure quintiles, giving a total of 15 representative households in the full DCGE model. Households pay taxes to the government based on fixed direct and indirect tax rates. Tax revenues finance exogenous recurrent spending, resulting in an endogenous fiscal deficit. Finally, the model includes a micro-simulation module with each respondent in HBS linked to their corresponding representative household in the DCGE model. Changes in commodity prices and households' consumption spending are passed down from the DCGE model to the survey, where total per capita consumption and poverty measures are recalculated.

TABLE 7A.1

Core model equations

Production function	$Q_{st} = \alpha_{st} \cdot \prod_f F_{fst}^{\delta_{fs}}$		(1)
Factor payments	$W_{ft} \cdot \sum_s F_{fst} = \sum_s \delta_{fs} \cdot P_{st} \cdot Q_{st}$		(2)
Import supply	$P_{st} \leq E_t \cdot w_s^m \perp M_{st} \geq 0$		(3)
Export demand	$P_{st} \geq E_t \cdot w_s^e \perp x_{st} \geq 0$		(4)
Household income	$Y_{ht} = \sum_{fs} \theta_{hf} \cdot W_{ft} \cdot F_{fst}$		(5)
Consumption demand	$P_{st} \cdot D_{hst} = \beta_{hf} \cdot (1 - \upsilon_h) \cdot Y_{ht}$		(6)
Investment demand	$P_{st} \cdot I_{hst} = \rho_s \cdot \left(\sum_h \upsilon_h \cdot Y_{ht} + E_t \cdot b \right)$		(7)
Current account balance	$w_s^m \cdot M_{st} = w_s^e \cdot X_{st} + b$		(8)
Product market equilibrium	$Q_{st} = \sum_h D_{hst} + I_{hst}$		(9)
Factor market equilibrium	$\sum_h F_{fst} = s_{ft}$		(10)
Land and labour expansion	$s_{ft} = s_{t-1} \cdot (1 + \varphi_f)$	*f* is land and labour	(11)
Capital accumulation	$s_{ft} = s_{t-1} \cdot (1 - \eta) + \sum_s \frac{P_{st-1} \cdot I_{st-1}}{\square}$	*f* is capital	(12)
Technical change	$\alpha_{st} = \alpha_{st-1} \cdot (1 + \gamma_s)$		(13)

Subscripts

f	Factor groups (land, labour and capital)
h	Household groups
s	Economic sectors
t	Time periods

Endogenous variables

D	Household consumption demand quantity
E	Exchange (local/foreign currency units)
F	Factor demand quantity
I	Investment demand quantity
M	Import supply quantity
P	Commodity price
Q	Output quantity
W	Average factor return
X	Export demand quantity
Y	Total household income
b	Foreign savings balance (foreign currency units)
s	Total factor supply
w	World import and export prices

Exogenous parameters

α	Production shift parameter (factor productivity)
β	Household average budget share
γ	Hicks neutral rate of technical change
δ	Factor input share parameter
η	Capital depreciation rate
θ	Household share of factor income
κ	Base price per unit of capital stock
ρ	Investment commodity expenditure share
υ	Household marginal propensity to save
ϕ	Land and labour supply growth rate

CHAPTER 8

HOUSEHOLD LEVEL FOOD SECURITY AND VULNERABILITY

Irini Maltsoglou and David Dawe

8. INTRODUCTION

In this section of the assessment, the focus is on the impact of rising food prices on household level food security in Tanzania. There has been widespread concern regarding the surge in staple food prices over the last few years and biofuel developments have been widely recognized, although to a varying degree, as one of the key drivers of the recent price surge and increased price volatility. In this context first generation bioenergy developments represent an additional source of demand for crop production which can lead to price increases, unless followed by adequate supply response.

Furthermore, domestic changes in food prices derive from international and domestic supply and demand shocks which include additional biofuel demand. In fact, it is important to realize that, while there may have been no significant bioenergy developments within the country to date, the globally biofuel mandates have been gaining steam. Therefore, although a domestic bioenergy sector might not yet exist, international policy decisions impact domestic prices which will in turn have an effect on national household food security. Consequently, although developing a domestic biofuel sector is a medium-term plan, households in the short term can still suffer food security impacts due to the changes in prices of the key food staples which are a result of both international and national policies.

Price increase can have a positive or negative impact on countries depending whether they are net food importers or net food exporters. Seemingly, at the household level, price increases are negative for net food consuming households (net-buyers), but positive for net food producing households (net-sellers). The degree to which households will, overall, be made worse or better off depends on the net welfare impact which is based on their overall net position as defined above.

As a concluding remark, it is important to stress that the price changes to which the households are subject are the result of domestic and international supply and demand shocks. Nevertheless, what matters for the households are the domestic price increases. The actual variation in domestic prices will depend on the nature of the commodity being considered, namely if the commodity is a tradable or non-tradable commodity, and therefore on the degree to which international price changes will transmit through to domestic markets. This heavily depends on what domestic trade policies are in place and on exchange rate fluctuations. The degree of transmission is commodity and country specific.

From a policy perspective, it is necessary to understand how these price changes can impact, firstly, the country as a whole and, secondly, household level food security. This will allow the assessment of which price movements to which the country is most vulnerable and which segments, amongst the poor, are most at risk.

A real case scenario should help explain this issue further. Tanzania, for example, has banned the use of maize for ethanol production because it is a key food staple. Nevertheless, due to international biofuel developments, the price of maize has been increasing. This part of the analysis will shed light on the impacts of the resulting increase in the key food staples on different household groups and help identify the vulnerable groups in the country.

The analysis is made up of three main components, namely country level impacts, domestic price movements and household level impacts. At first the focus is on country level impacts in order to understand which price movements to which the country as a whole is most vulnerable. This is done by an assessment on what level domestic price movements are linked to international price movements and a calculation of the price increases in domestic food prices. Thirdly, we focus on household level food security impacts by assessing the impact of increases in food prices on households' welfare. The key crops for the analysis are identified based on their calorie contribution. As maize and cassava are the two most important food crops, the second and third steps of the analysis mostly focus on these two crops.

In order to run the household level analysis a detailed Household Income and Expenditure Survey (HIES) is needed. In the case of Tanzania this dataset is called the Household Budget Survey (HBS). This dataset could not be used as unfortunately agriculture income is not reported by crop. For this reason a regional dataset collected by REPOA, FAO and the World Bank between 2003 and 2004 was used. This dataset only covers rural households from two regions in Tanzania and therefore policy conclusions at the country level cannot be drawn. Nevertheless, the analysis run with this dataset can illustrate the logic behind the analysis and the kind of policy messages that can be drawn from this assessment component.

Following the introduction, Section 2 ranks the food commodities and outlines the net trade position of the country based on the food security list. Section 3 looks at domestic price trends for the two most important food crops, namely maize and cassava. Section 4 provides an overview of the methodology applied for the household level assessment. Section 5 presents the household level welfare impacts and Section 6 concludes.

8.1 FOOD SECURITY IN TANZANIA

The food security analysis presented here focuses on the main food security crops in Tanzania. The list of food security crops is selected based on their calorie contribution as previously discussed (Table 2.1). The relevant list is included here for ease of reference (Table 8.1).

Based on the per capita calorie ranking previously discussed, the most important food crops in Tanzania are maize, cassava and rice. Maize contributes 33.4 percent of calories, cassava accounts for 15.2 percent of calorie intake and rice provides 7.9 percent of the calories.

Table 8.1

Calorie contribution by commodity for Tanzania

Ranking	Commodity	Calorie share
1	Maize	33.4
2	Cassava	15.2
3	Rice (Milled Equivalent)	7.9
4	Wheat	4.0
5	Sorghum	4.0
6	Sweet Potatoes	3.3
7	Sugar (Raw Equivalent)	3.3
8	Palm Oil	3.0
Subtotal share for selected items		88.5
Total Calories per capita		**1959**

Source: FAOSTAT

The analysis begins by looking at the country level effects of increases in the key food staple prices. This allows the analysis to define which specific price changes to which the country is most vulnerable. Initially we investigate a wider range of crops to illustrate the argument. Nevertheless, in the following sections of this chapter the focus will mostly be on maize and cassava, the two most important food crops. In this respect, we calculate the country's net trade position by crop and define whether the country is a net importer or net exporter based on the list of crops in Table 8.1.

At the country level, price increases will hurt or benefit the country respectively depending on whether the country is a net importer or a net exporter of a specific commodity. A net importing country will consume more than it produces and import the surplus needed. A net exporting country will produce more than it consumes and export the surplus produced. A self sufficient country is defined as a country that consumes all that it produces, i.e. a country for which domestic production is equal to domestic consumption. If a country is a net importer of a crop, a price increase in that crop will be detrimental for the country's welfare. On the other hand, if a country is a net exporter, price increases will increase the net gains for the country.

Table 8.2 illustrates Tanzania's net trade position for the calorie ranked food crops listed in Table 8.1. For example, as shown in Table 2, in the case of wheat, Tanzania imports approximately 71 percent of its domestic consumption. Between 2002 and 2005, Tanzania produced 87 133 mt of wheat, it imported 254 732 mt and exported 36 428 mt. This results in Tanzania being a net importer of wheat and very susceptible to price fluctuations in this commodity.

Table 8.2

Trade data by commodity.

Items	Production quantity (mt)	Import quantity (mt)	Export quantity (mt)	Net-importer	Net-exporter
Maize	3 288 000	44 500	98 985	-	0.02
Cassava	7 061 867	0	839	-	-
Rice	957 000	18 846	3 717	0.02	-
Wheat	87 133	254 732	36 428	0.71	-
Sorghum	653 644	0	0	-	-
Sweet potatoes	781 567	0	0	-	-
Sugar Cane	1 374 633	140 895	27 537	0.08	-
Palm oil	63 333	117 272	6 464	0.64	-

Source: FAOSTAT, USDA and Ministry of Agriculture of Tanzania, all data are reported for the period 2002 to 2005.

In the case of the two main food security crops, maize and cassava, the net trade position is different. As shown in Table 8.2, Tanzania produced 3 288 000 mt of maize, it imported 44 500 mt and exported 98 985 mt in 2005. Looking at recent years, generally Tanzania does not trade large amounts of maize, but does fluctuate from being a slight net exporter (as the case reported) to being a slight net importer. Cassava, on the other hand, is a non-tradable commodity. Official statistics report a production of 7 061 867 mt between 2002 and 2005. Nevertheless maize and cassava prices might be connected as consumers can substitute maize for cassava consumption. This is further discussed in the next section.

In conclusion, Tanzania is self sufficient in the production of cassava, sorghum, sweet potato and banana. Tanzania imports large volumes of wheat and palm oil, and the country as a whole would be hurt by price increases for these two commodities. Tanzania is a slight net exporter of maize and beans and therefore could potentially benefit from increases in the price of beans.

Having provided an overview of the crops, the rest of the analysis will mainly focus on maize and cassava, the two most important food crops.

8.2 MAIZE AND CASSAVA PRICE TRENDS IN TANZANIA

Having defined which are the most important food crops in Tanzania, recent price trends must be observed in maize and cassava to understand how and if prices have been increasing and declining generally and by how much. The price data presented here were obtained from the Ministry of Industry and Trade in Tanzania. All prices are reported in 2008 Tanzanian Shillings (TZS), thus adjusting the data for the effects of inflation. This adjustment allows us to compare price levels in different years in a more meaningful fashion.

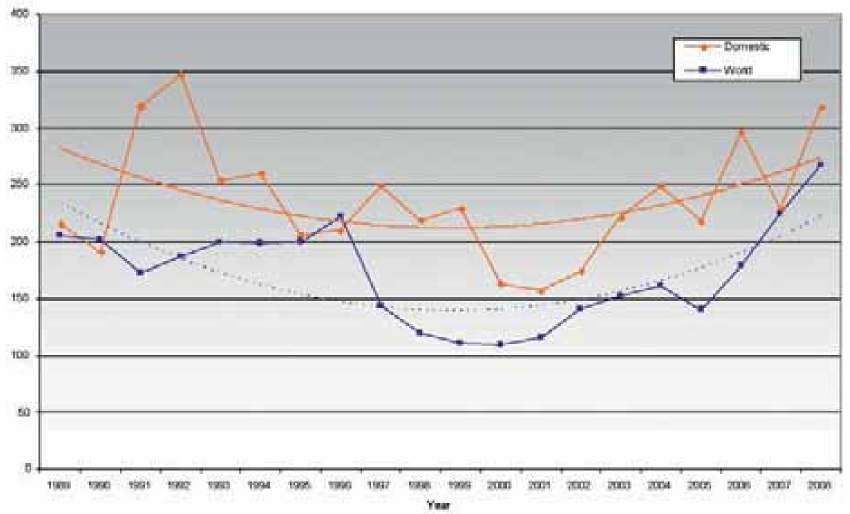
To start with, it is important to take a historical perspective and look at how prices have varied over time in order to understand if the price levels in Tanzania today are comparatively high or low with respect to previous periods. In the case of a traded good, as is the case for maize but not for cassava, it is also important to understand generally how international prices are interconnected with domestic prices. A general sense of this can be felt by plotting the international and domestic maize prices over time.

Long-term maize price movement

Figure 8.1 illustrates maize price movements, both domestically and in relation to the world price, from 1989 to 2008 after adjusting for inflation[1].

Figure 8.1

International and domestic maize from 1989 to 2008 for Tanzania (Real 2008 Schillings)



While the domestic price of maize fluctuates substantially, it was on a generally downward trend during the 1990s. Prices reached their lowest level between 2000 and 2002, before rising again after that. By 2008, prices had more than doubled compared to

1 The time period shown is selected based on the availability of domestic price data. In the case of maize, a much longer and smoother time series was available for wholesale prices (compared to farm and retail prices) and we therefore used this time series for the analysis of long-term trends.

2001. This was partially due to the surge in 2008, but prices had been rising more or less steadily for several years at a rate faster than the rate of inflation.

Between 1989 and 2000 the world price of maize declined by about 90 percent, but it then more than doubled (an increase of 146 percent) between 2000 and 2008. Notice that the broad trends in domestic maize prices have been similar to those in world prices, as shown by the similar quadratic trends in Figure 1. Notice also that the two years when domestic prices were lowest correspond roughly to the trough in world market prices. After this trough, world and domestic prices both started to increase.

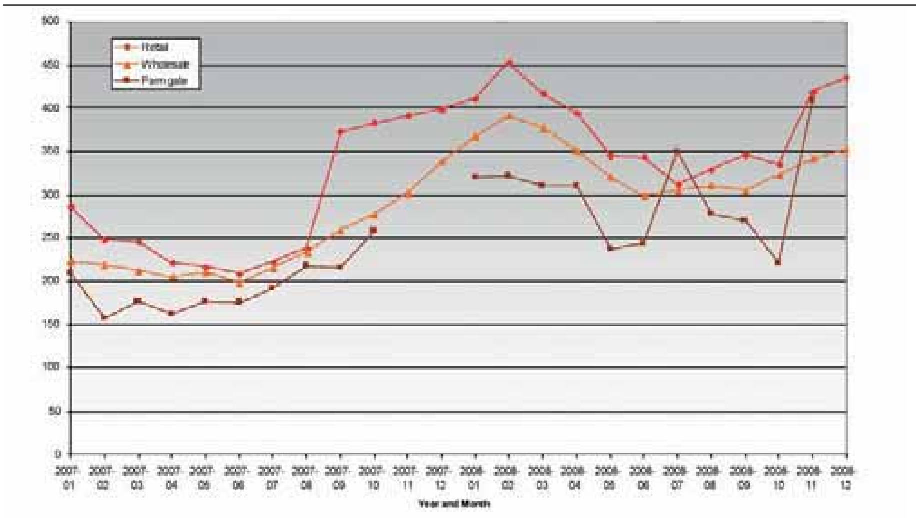
Generally it appears that price movements in the world price of maize have transmitted through to the domestic price, especially from 1996 onwards since both domestic and international prices plateaued and increased thereafter. Therefore it could be expected that international price movements in the price of maize would transmit through to the domestic price of maize.

Recent maize price movements

After gaining a general sense of price movements over the last two decades, the focus is on recent domestic price movements. Figure 8.2 illustrates domestic price movements at the farmgate, wholesale and retail levels between January 2007 and December 2008[2] (prices are reported in December 2008 terms for sake of comparability).

Figure 8.2

Domestic maize prices in Tanzania between 2007 and 2008 in December 2008 Shillings[3].



Source: Ministry of Trade and Industry of Tanzania and the IMF Statistics.

2 Data was available for all three marketing levels only for 2007 and 2008.

3 The domestic prices reported here are for the three levels in the marketing chain, namely the farmgate, wholesale and retail level. The farmgate price is the price at the edge of the farm, the wholesale price is the producer price in the market, the retail price is the consumer price.

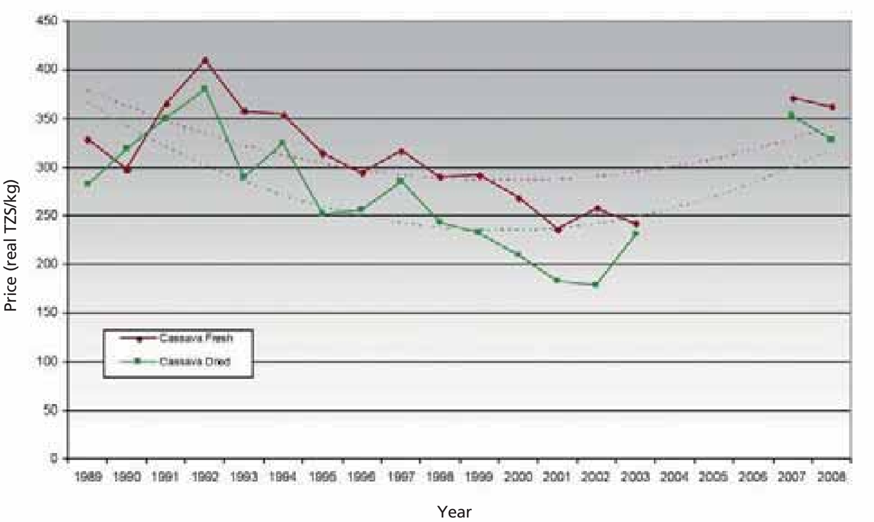
Prices were higher at the end of 2008 than they were in early 2007 at all levels of the marketing system (farmgate, wholesale and retail)[4]. More specifically, prices increased until the beginning of 2008, then tapered off, but started to increase again towards the end of 2008. At their peak in February 2008, domestic retail prices were 80 percent higher than a year earlier. Prices then declined substantially before rising again towards the end of 2008. Farmgate prices have followed a similar pattern. This shows that, although consumers have been faced with increasing prices, farmers have benefited during this time from the price increase.

Long-term cassava price movements

Cassava is generally not an internationally traded commodity so the focus is on domestic price[5] movements between 1989 and 2008.

Figure 8.3

Cassava (fresh and dried) retail prices in Tanzania between 1989 and 2008 in 2008 Shillings



As shown in Figure 8.3, the price of cassava (both fresh and dry) generally increased between 1989 and 1992. From 1992 onwards, the price of cassava was on an overall downward trend for a decade.

Due to missing price data between 2004 and 2007, it is not possible to describe what happened during that period, but prices in 2007 and 2008 were substantially higher than

4 From inspection of the data, in the case of the retail time series there appear to be two significant outliers. These were dropped and replaced with an interpolation of the two neighbouring monthly values.

5 In the case of cassava the retail price for cassava (fresh and dried) was used as it was the longer time series provided in the case of cassava.

in 2003. It is interesting to note, however that the apparent trough in dried cassava prices between 2000 and 2002 happened at the same time as the trough for maize prices.

Cassava short-term price movements and the maize and cassava markets interlinkages

Cassava short-term price movements have been erratic and the data available are limited. Due to this the data has not been presented, but recent real price changes have been reported as shown in Table 3.

All cassava prices have been declining between 2007 and 2008. At the farmgate, fresh and dried cassava prices have declined respectively by 12 and 2 percent between 2007 and 2008. At the retail level prices have also declined by 2 percent for fresh cassava and 7 percent for dried cassava.

TABLE 8.3

Price changes for maize and cassava between 2007 and 2008

Real Percent Change Between 2007 and 2008	Farmgate	Wholesale	Retail
Maize	53	40	32
Fresh Cassava	-12	-	-2
Dried Cassava	-2	-	-7

Maize and cassava are the two most important food crops. Additionally, Tanzania is considering using cassava for ethanol production. For this reason it is important to understand how movements in the maize price transmit through to the cassava prices. As shown graphically above, both maize and cassava prices increased during the past few years. Between 2003 and 2008 domestic maize prices increased by 44 percent, fresh cassava prices increased by 50 percent and dry cassava prices increased by 42 percent as reported in Table 8.4.

TABLE 8.4

Real price changes for maize and cassava over a five year period (2003-2008)

Commodity and Marketing Level	Domestic Retail Fresh Cassava	Domestic Retail Dried Cassava	Domestic Maize Wholesale
Real Percent Change Between 2003 and 2008	50	42	44

The overall increase in both maize and cassava prices suggests that the two commodities are partial substitutes in production, consumption or both over the medium term. It also suggests that domestic cassava prices are indirectly linked to world maize markets, at least in the medium term.

Furthermore, as shown in Table 8.3, note that price changes are similar at different levels of the marketing system for maize (i.e. there are large increases at all levels, with the percentage increase in farm prices being larger mainly because of a lower base on which the percentages are calculated). The same is also true for both fresh and dried cassava. This suggests that there is price transmission between farm and retail markets for both crops.

However, the substantially different price changes from 2007 to 2008 for maize (big increases) and cassava (small decreases) suggest that maize and cassava markets, while connected in the medium term, are less so in the short term.

Finally, since we have shown that the cassava and market prices are closely interlinked in Tanzania, if the country wishes to use cassava for ethanol production it is important to understand the effect this can have on the maize and cassava markets in the case that no additional land area is used for production and agriculture investments are not put in place. Using cassava production for ethanol will add to the domestic demand for cassava. This additional demand will drive up cassava prices. Due to the higher cassava price, some households will substitute cassava consumption with more maize consumption shifting away from cassava. On the other hand, some farmers, due to the higher cassava prices, will produce more cassava and reduce the production of maize. Overall this will result in an increase in maize imports needed to meet domestic demand and an increase in the relative price of cassava to maize *unless* farmers supply response is stimulated. Two solutions are available to the government to ensure that maize imports do not increase and relative prices do not increase. On the one hand, government can foster agriculture research and development and investments that enable farmers' supply response. On the other, new land can be used for the production of the additional cassava required to meet the ethanol demand.

The options of extensification versus intensification have been raised in the previous chapters of the assessment and again apply in this context. From a policy point of view this has strong implications since if new land is not developed or agriculture investments are not set up, food security issues will arise. A more detailed and technical discussion of this argument is presented in Appendix 8A.

8.3 HOUSEHOLD WELFARE IMPACT: METHODOLOGICAL BACKGROUND

After having identified the price changes to which the country is most vulnerable, and the recent price trends for the two most important food crops, we now turn to the household level food security analysis. Thus far, we have shown that prices in the main food staples have increased over recent years in Tanzania. In this second part of the analysis we determine whether these price changes are beneficial or detrimental for households, and if detrimental, we assess which the most vulnerable segments of the population are.

Households have the particular nature of being potentially both producers and consumers of crops. For example, a rural household may grow cassava on their farm but also sell it and consume it. An urban household may only purchase it and not produce it.

Overall, price increases can benefit producers of crops but can hurt consumers of crops. Due to the potential dual nature of the household, it is necessary to understand the net position of a household - whether a household is a net producer or net consumer. A net producer household is defined as a household for which total gross income derived from the crop exceeds total purchases. For net producer households price increases will be beneficial. A net consumer household is a household for which total gross income derived from the crop is less than total purchases. In this case an increase in the price of the selected crop hurt the household. The overall household impact is determined by the effect of the price change on household's net welfare, defined as the difference between the producer gains and consumer losses.

In order to calculate the household net welfare impacts, we apply the methodology as shown in Minot and Goletti (1999) and adapted as discussed in Dawe and Maltsoglou (2009). For further details the reader may turn to Appendix 8B.

The literature and methodology applied to calculate the welfare impacts are based on a 10 percent price increase on the producer side. Module 3 and Module 4 have shown how the development of domestic bioenergy schemes can further disrupt domestic price trends. Based on expert discussions in the country, relevant price changes could be used in the context of the analysis and the crop at hand[6]. Nevertheless, it is important to recall that the methodology shown applies to short term responses not including supply response mechanisms.

8.4 THE HOUSEHOLD LEVEL ANALYSIS

As discussed, in order to assess the net welfare impact of price changes on households the income derived from the production of a crop and the amount spent on a crop must be calculated. Once the welfare indicator is constructed welfare impacts of the price changes across quintiles and location are analysed. The differentiation across quintiles allows us to target the poorer segment of the population and understand which price changes can help the poor and which price changes mostly harm the poor. The differentiation by location,

6 Welfare impact calculations here are based on short term responses and do not include supply and demand elasticities. Some analysis run by the authors has illustrated that he inclusion of supply response does not have very large impacts on welfare calculations. The second round effects created by the development of bioenergy might have larger implications for household welfare. Please see Minot and Goltetti (1999) and Dawe and Maltsoglou (2009)

namely urban versus rural households, allows to further distinguish net producing households from net consuming households. Generally net producing households are more likely to reside in rural areas while net consuming households are mostly likely to be in the urban areas of the country.

Unfortunately, the relevant household level dataset of Tanzania, the household budget survey, does not contain agriculture income by crop. Due to this it was not possible to run the household level analysis for the country as a whole[7]. Nevertheless, in order to show the structure of the analysis and how it is undertaken a partial dataset that contains disaggregated agriculture income data to the level of detail required is used. Policy conclusions at the country level cannot be drawn from this partial dataset.

The partial dataset covers two regions in Tanzania, namely Ruvuma, a poorer region, and Kilimanjaro, a wealthier region. The dataset was collected jointly by REPOA/FAO/WB between 2003 and 2004[8].

8.4.1 THE KILIMANJARO AND RUVUMA DATASET[9] AND RELEVANT HOUSEHOLD CHARACTERISTICS

The survey covered 957 rural households in the Kilimanjaro region and 890 rural household in Ruvuma. It starts by describing key household characteristics across regions and quintiles, focusing on the poorer quintile group.

TABLE 8.5

Household characteristics in Kilimanjaro and Ruvuma

Quintile*	Kilimanjaro			Ruvuma		
	Size (Number)	Education (Years)	Age (Years)	Size (Number)	Education (Years)	Age (Years)
1	4.3	5.3	53.4	3.8	5.1	42.6
2	4.9	5.8	52.4	4.8	5.2	45.4
3	5.3	5.6	55.1	5.3	6.0	43.8
4	5.6	6.1	54.1	5.7	6.6	41.4
5	6.6	7.1	52.5	6.4	7.0	42.7
Total	5.3	6.0	53.5	5.2	6.0	43.2

Source: Ruvuma and Kilimanjaro Dataset (2003-2004)

** Household quintiles calculated based on expenditure*

7 At the time when this analysis was started the HBS 2001 was the latest version available. Currently HBS 2007 is being completed but the format of the survey remains essentially unchanged thus presenting the same data problem for the BEFS analysis.

8 The World Bank is currently collecting a very comprehensive panel data set which will include detailed agriculture income data. BEFS plans to train technical experts in the country so that they can then apply the approach outlined here to the new dataset.

9 These data were collected in the context of a project on "Rural household vulnerability and insurance against commodity risks" financed by the Dutch-Japanese-Swiss Poverty Reduction Strategy Trust Fund and implemented by FAO, the World Bank, and Research in Poverty Alleviation (REPOA) in Tanzania.

As shown in Table 8.5, the average household size is approximately the same in both Kilimanjaro and Ruvuma where on average households are constituted of five family members. Household heads in Kilimanjaro live longer than household heads in Ruvuma. Average education levels are low in both Kilimanjaro and Ruvuma.

Average household expenditures across quintiles and region, reported in Table 6, confirm that households in Ruvuma are poorer than households in Kilimanjaro. In Ruvuma, average yearly household expenditure was 794 thousand shillings, while in Kilimanjaro average household expenditure was 1,091 thousand shillings. Furthermore, in Ruvuma the poorest households spend 289 thousand shillings, approximately one sixth of the richest households. The poorest quintile in Kilimanjaro spends 444 thousand shillings on average, while the richest spend 2 173 thousand shillings.

TABLE 8.6

Average expenditure levels and food expenditure shares in Kilimanjaro and Ruvuma

Quintile	Kilimanjaro		Ruvuma	
	Total Expenditure ('000 Tsch)	Food Share	Total Expenditure ('000 Tsch)	Food Share
1	444	0.76	289	0.71
2	723	0.72	487	0.72
3	927	0.72	660	0.71
4	1195	0.68	901	0.71
5	2173	0.60	1635	0.66
Total	1091	0.69	794	0.70

Source: Ruvuma and Kilimanjaro Dataset (2003-2004).

Households across regions and quintiles spend a large share of their wealth on food, approximately 2/3 for all households. The poorest quintiles in Ruvuma spend 71 percent, while the poorest quintiles in Kilimanjaro spend 76 percent on food.

There is some difference in the crop production patterns across regions. As shown in Table 8.7, the majority of farmers in Kilimanjaro produce maize, bananas and beans[10]. In the Ruvuma region, the majority of rural households are dedicated to maize, cassava, banana and rice in order of importance.

10 Producers are defined as those households that earn some amount from the production and or sale of a specific crop. This includes also household own consumption production.

TABLE 8.7

Producer and consumer numbers by crop in Kilimanjaro and Ruvuma

Producers by crop (Number of households)									
Location			Maize	Cassava	Rice	Sweet Potato	Sugar	Banana	Bean
Kilimanjaro			798	70	14	20	17	728	638
Ruvuma			841	539	281	54	6	319	399
Consumers by item (Number of households)									
Location	Maize Flour	Maize Cob	Maize Grain	Cassava Dry or fresh	Rice	Sweet Potato	Sugar	Banana	Bean
Kilimanjaro	912	31	532	146	646	97	868	862	861
Ruvuma	631	221	65	717	252	49	464	363	618

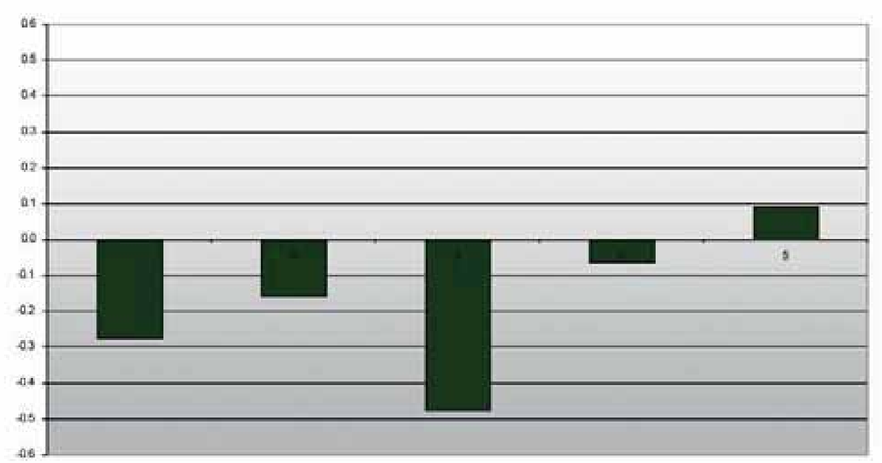
There is also some difference in consumption[11] across regions. Rural households in Kilimanjaro mostly consume maize flour, maize grain, rice, sugar, banana and beans. Comparatively, Ruvuma households consume more cassava and maize cob and less rice and sugar.

8.4.2 IMPACTS OF MAIZE PRICE INCREASE IN KILIMANJARO AND RUVUMA

Most households in the Kilimanjaro region stand to lose from a 10 percent price increase in the price of maize, as shown in Figure 8.4. The poorer households, on average, lose 0.3 percent of their welfare upon this price increase. The middle quintile loses the most from the price increase, while the richer households benefit from the price increase.

Figure 8.4

Welfare impacts in Kilimanjaro for a 10 percent increase in the price of maize

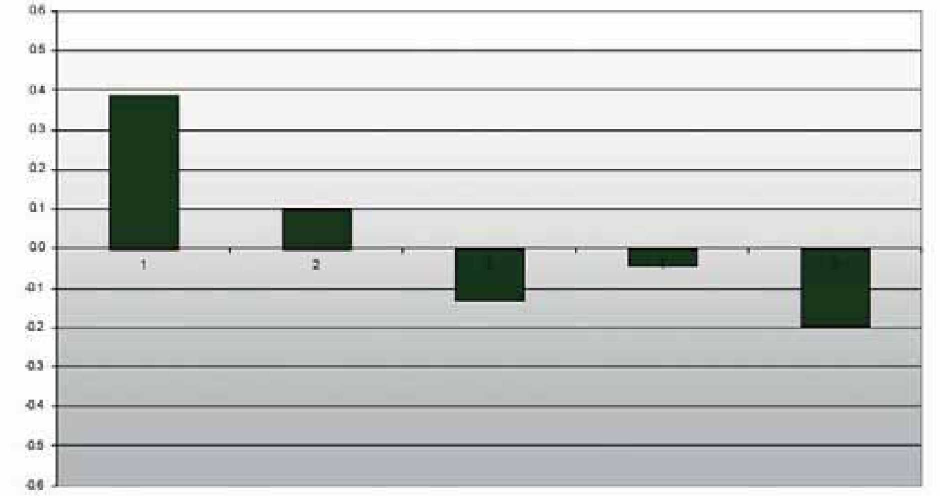


Source: Calculations by the authors.

11 Consumption includes both purchased foods and consumption of own production.

However, as illustrated in Figure 8.5, the poorest households in Ruvuma benefit from a 10 percent price increase in the price of maize indicating that, on balance, poor households in this area grow more maize than they consume. Based on the dataset at hand, the 10 percent price increase would correspond to an approximate 0.4 percent income gain. The second lowest income quintile benefits from the price increase, but by less, approximately 0.1 percent welfare increase. The other quintiles lose from the price increase

Figure 8.5:
Welfare impacts in Ruvuma for a 10 percent increase in the price of maize



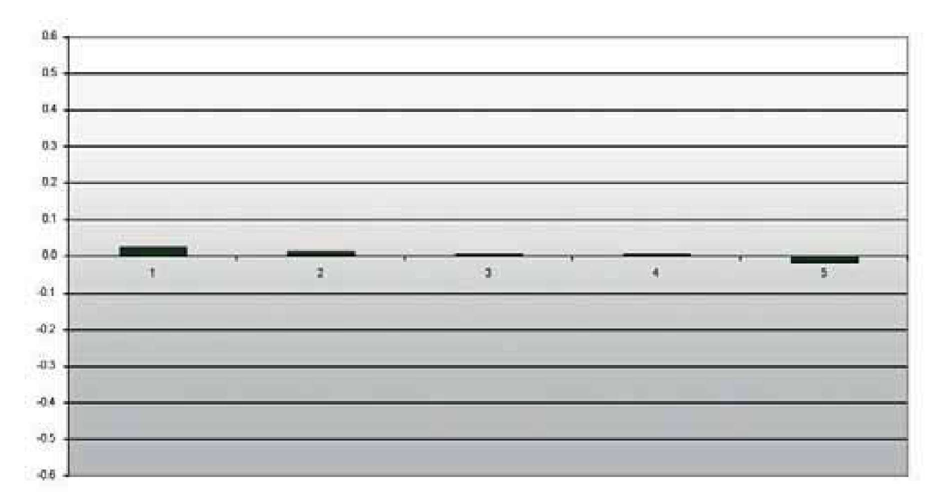
Source: Calculations by the authors.

8.4.3 IMPACTS OF CASSAVA PRICE INCREASE IN KILIMANJARO AND RUVUMA

There is little impact from price increases in the case of Cassava in Kilimanjaro, as shown in Figure 8.6. The 10 percent price increases has a minimal positive impact on all quintiles with the exception of the wealthiest quintile. The quintile that stands to gain the most, even if minimally, is the poorest.

Figure 8.6

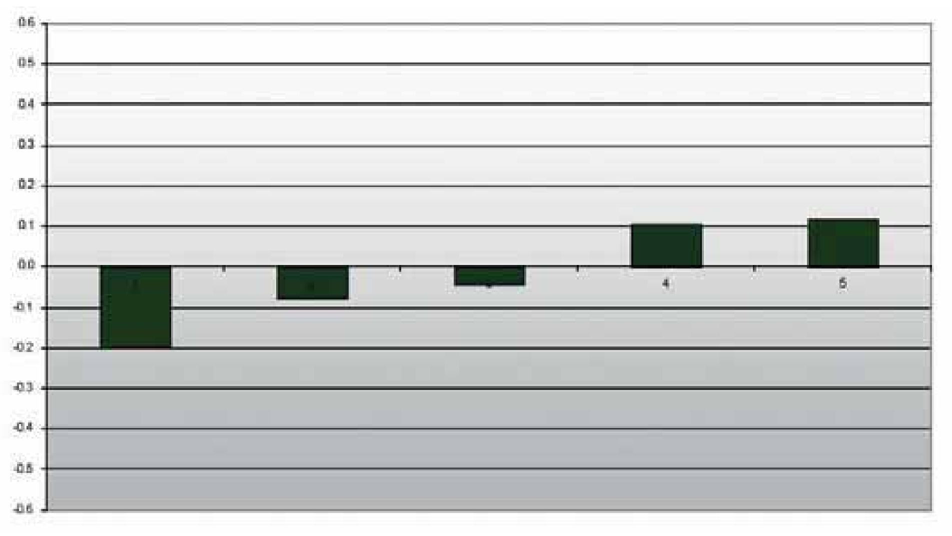
Welfare impacts in Kilimanjaro for a 10 percent increase in the price of cassava



Source: Calculations by the authors.

Figure 8.7:

Welfare impacts in Ruvuma for a 10 percent increase in the price of cassava



Source: Calculations by the authors.

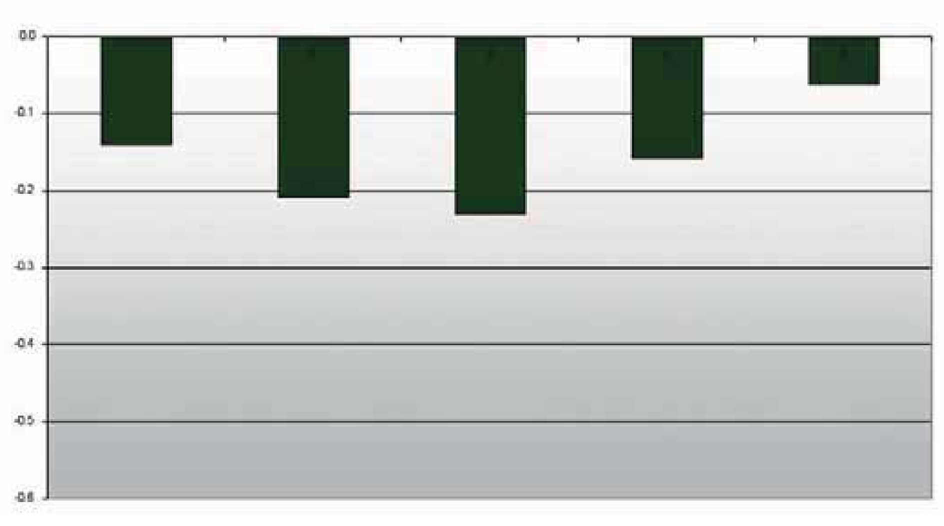
However, as illustrated in Figure 8.7, the poorer households in the Ruvuma region are negatively hit by a 10 percent increase in the price of cassava indicating that poorer households consume more cassava than they produce. The poorest quintile loses 0.2 percent of its welfare based on this price increase. The wealthier quintiles in the region benefit from the price increase. The poorer households in Ruvuma are marginally affected by price changes of sugar, banana and sweet potato.

8.4.4 IMPACTS OF RICE PRICE INCREASE IN KILIMANJARO AND RUVUMA

For the sake of illustration another food staple is included in order to show how the analysis can be extended across the board to all crops. In the case of rice, all households in the Kilimanjaro region are negatively hit by a 10 percent price increase as shown in Figure 8.8.

Figure 8.8

Welfare impacts in Kilimanjaro for a 10 percent price increase in the price of rice



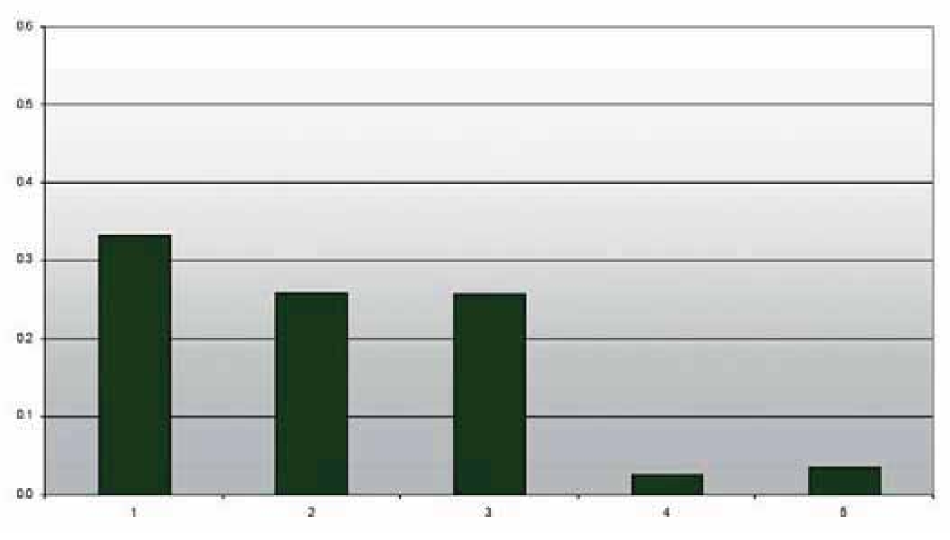
Source: Calculations by the authors.

As illustrated in Figure 8.8, poorer households lose on average a little more than 10 percent of their welfare. Households in the second and third quintile lose approximately 0.2 percent of their welfare. Households in the top quintile are less affected (in percentage terms).

In the case of Ruvuma as reported in Figure 8.9, increases in the price of rice are beneficial to all quintiles in the Ruvuma region. A 10 percent increase in the price of rice, increases the poorest households' welfare by 0.3 percent. The second and third quintiles benefit significantly from the price increase too.

Figure 8.9

Welfare impacts in Ruvuma for a 10 percent increase in the price of rice



Source: Calculations by the authors.

How severe are the welfare impacts?

As discussed in the price sections, the real percentage price changes over the last five years were in the order of fifty percent for both maize and cassava. Consequently households over the longer period have been subject to higher percentage changes compared to the starting discussion of a 10 percent price change. Producer prices could be set to vary at 10%, 20% and then 50%. The resulting impacts would be respectively twice as high for the 20 percent change and five times as high for the 50 percent change. These percentage changes would result in significant impacts on households' welfare.

The shortcoming of the dataset

The results presented here are only for two regions in the country and solely for rural households. Further, taking the example of maize, we find that increases in the price of maize are positive for the Ruvuma poor but negative for poor households in the Kilimanjaro regions. This shows two shortcomings of this partial dataset. On the one hand we are unable to draw conclusions on how prices impact urban households, generally net consumers of food crops. Secondly, since we are unable to run a country level assessment, overall we do not know if an increase in the price of maize could be beneficial for households in Tanzania. For sake of illustration for example, if a country level analysis had been possible and had showed that the maize price increase were positive for the country's welfare, the policymaker would not be concerned with the overall price increase but only with safeguarding livelihoods of particular segments of the population. In the case analyzed here, the vulnerable segment of the population would be the rural poor located in the Kilimanjaro region.

8.5 CONCLUSIONS

Developing a domestic biofuel sector takes time, in fact the establishment of a new industry typically requires a medium- to long-term perspective, but food prices in Tanzania have been changing. Changes in food prices can have a significant impact on households' food security, especially for the most vulnerable segments of the population. In this context, it is important to realize that, while there may have been no significant bioenergy developments within the country to date, international biofuel mandates have been gaining steam. Changes in food prices are a result of international and domestic supply and demand shocks, which include additional biofuel demand. Thus, households, in the short term, can still suffer food security impacts due to domestic price movements caused by biofuel policies being implemented elsewhere. Furthermore, as argued in the chapter, medium-term and long-term food prices may rise also due to domestic biofuel policy decisions unless adequate supply response is stimulated through agriculture investment and research and development.

Consequently, from a policy perspective, it is necessary to understand how the price changes can impact the country as a whole and which price changes could affect the poor segments of the population. If the government decides to pursue the development of the bioenergy sector, there might be some short-term to medium-term trade-offs for some vulnerable segments of the population. In such a case the government might want to implement targeted safety nets for the vulnerable groups.

Although initially a wider range of crops are investigated, the analysis presented focused mainly on maize and cassava, the primary food crops in Tanzania. Price changes that could affect the country were assessed first. Secondly, actual price movements in key food crops over the medium and short term were considered and thirdly the household level welfare impacts, targeting the most vulnerable segments of the population were assessed.

Over recent years, Tanzania has fluctuated from being a slight net importer to net exporter of maize, while cassava is not a traded commodity. Maize and cassava prices have been steadily increasing in the country since 2000. Investigation of the maize and cassava price trends suggest that the maize and cassava markets are interconnected in the medium term, although less so in the short term. Between 2003 and 2008, maize and cassava prices increased approximately by 50 percent in real terms.

In the case of Tanzania, it was not possible to carry out a country representative household level analysis as the Tanzanian household budget survey does not contain detailed agriculture income by crop. Nevertheless, in order to illustrate the steps of the analysis within Module 5 and the type of questions this part of the analysis can answer, a partial dataset was used which was collected from the rural areas of the Ruvuma and Kilimanjaro regions. While this does not permit to draw conclusions at the country level as it is not a country representative dataset of Tanzanian households, it allows the analysis to show which conclusions could potentially be drawn from the household level analysis.

The poorest households in Ruvuma were found to benefit from price increases in maize and rice but are negatively hit by price increases in cassava. The poorer households in Kilimanjaro are indifferent to price changes in cassava but stand to lose from price increases in maize and rice.

Although this dataset offers an example of what the analysis can accomplish it is not possible to draw country level conclusions. For example, it was not possible to assess whether price increases in maize and cassava would benefit the poor in Tanzania overall. A country level dataset would allow the analysis to determine this. There might still be some segments that lose and would potentially need to be assisted, but in view of an overall country level welfare gain.

The underlying problems remain the need to increase food production, address infrastructure needs, and invest in agriculture R&D including human capital development. A key policy recommendation therefore will be to ensure that adequate investments and/ or policies are put in place to foster an environment that will allow an outward shift of the cassava supply curve that will ultimately bring the cassava price back to its original level, or even lower. If this outcome can be achieved due to sufficiently large investments in public goods, then maize imports will not increase, and might even be reduced, even though cassava is being diverted to biofuel production. However, simply using cassava to produce ethanol without simultaneously investing more in public goods will lead to higher prices and increased maize imports.

Finally, in order to ensure appropriate monitoring of the poorer and most vulnerable segments of the population, it will be essential to run the analysis presented on a country representative dataset. Furthermore, accurate cassava price data was problematical to obtain, especially for the years between 2004 and 2006. If Tanzania decides to invest in cassava for ethanol production, it will be key to monitor cassava prices closely.

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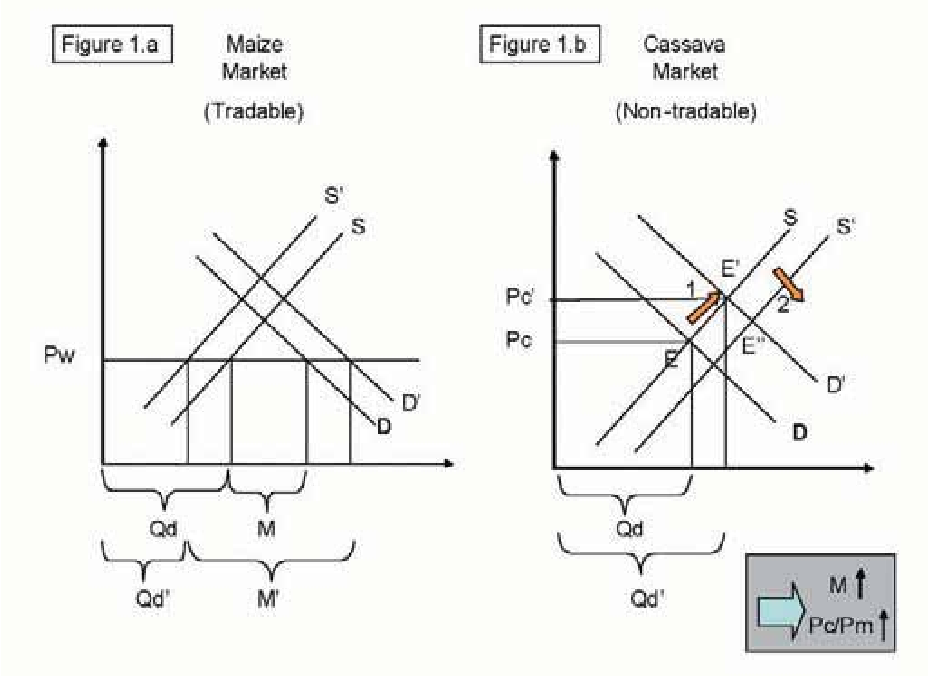
APPENDIX 8 A MAIZE AND CASSAVA MARKET INTERLINKAGES

WHAT IF THE GOVERNMENT OF TANZANIA WERE TO USE CASSAVA FOR ETHANOL PRODUCTION?

In the case of the market of maize and the market of cassava, maize is a tradable[1] good for which a world price exists and an open economy set-up is considered. Cassava is not a tradable commodity so the market behaves as a closed economy in this case.

First, the cassava market: current supply and demand are in equilibrium at E. If Tanzania decided to use cassava for ethanol production this would add demand and would shift the demand curve from D to D' as shown in Figure 1b, raising the price of cassava from pc to pc'. Consequently, farmers respond to the price signal and increase production, reaching a new equilibrium in E' (arrow 1 in Figure A.2).



1 An internationally tradable good is a good which can be traded across countries.

In the case of the maize market, domestic suppliers and consumers face the world price of maize, Pw. Domestic demand and supply are described by D and S. In the initial equilibrium, domestic supply will be equivalent to Qd+M, where Qd is the amount of production supplied by domestic producers and M is the amount imported to meet domestic demand.

Due to the biofuels induced shift in cassava demand and the consequent price increase, maize production and consumption will also respond (Figure 1a). Some farmers (but not all) will shift towards the production of cassava and out of the production of maize, while some consumers (but not all) will reduce cassava consumption and increase maize consumption. Due to this, the maize supply curve will shift inwards from S to S', and the maize demand curve outwards, from D to D'[2]. The inward shift in the maize supply curve will reduce the domestic production of maize to Qd' and increase the amount of imports to M'. Therefore, overall, the decision to use cassava for ethanol production will result in an increase in the relative price of cassava to maize, (pc/pm), and, more importantly, an increase in imports of maize.

In order to avoid an increase in maize imports, it will be crucial to ensure that the supply curve of cassava shifts out from S to S', as shown in Figure 1a, arrow 2. This will only be possible if adequate investments in agriculture R&D, infrastructure, land expansion (or changes in policies) are implemented so that farmers can significantly increase production. Shifting the cassava supply curve out will result in a new equilibrium in the cassava market at E''. Based on the magnitude of the shift, the new price at E'' could be lower or higher than the original level of pc.

A key policy recommendation therefore will be to ensure that adequate investments and or policies are put in place to foster an environment that will allow the outward shift of the cassava supply curve that will ultimately bring the cassava price level back to its original level, or even lower.

If this outcome can be achieved due to sufficiently large investments in public goods, then maize imports will not increase, and might even be reduced, even though cassava is being diverted to biofuel production. However, simply using cassava to produce ethanol without simultaneously investing more in public goods will lead to more maize imports.

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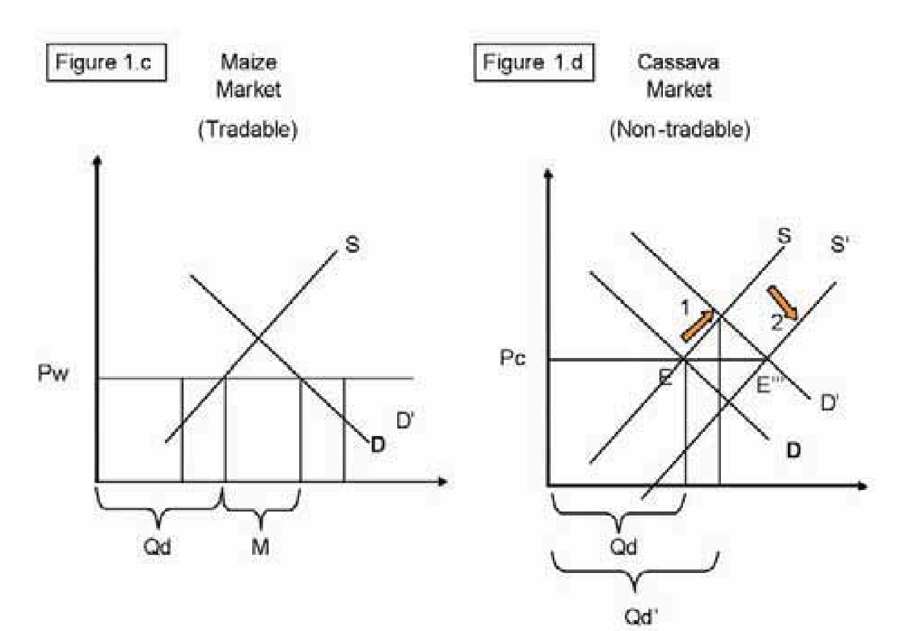
2 The magnitude of the maize price change will be determined by the magnitude of the price change for cassava (which will depend on the size of the target for biofuel production) and by the cross-price elasticities of demand and supply between maize and cassava (which measure how consumers and farmers can shift between the two crops).

WHAT IF "NEW LAND" WERE TO BECOME AVAILABLE?



In the case that new land is available for all of the cassava devoted to biofuel production, the shift in demand would be accompanied by an equivalent shift in supply and there would be no change in the price of cassava (Figure 1c and 1d). In this case, the maize market would not be affected, and there would be no increase in maize imports. The availability of new land, however, would obviously rely on suitable investment to make the new land exploitable. Thus, the importance of investment is again clear. Attention should also be given to any environmental effects of exploiting new land, as well as effects on the land rights of the poor.

APPENDIX 8 B

METHODOLOGICAL BACKGROUND FOR THE ASSESSMENT OF NET HOUSEHOLD WELFARE IMPACTS.

An outline of the procedure used to calculate the net welfare impacts of price changes at the household level is given here. For the full technical details the reader is referred to the complete BEFS Analytical Framework (forthcoming) and Dawe and Maltsoglou (2009).

The methodology was initially set up by Deaton (1989), then followed by a number of empirical applications by other authors including Budd (1993), Barrett and Dorosh (1996), Minot and Goletti (1998, 2000) and, recently, Ivanic and Martin (2008). Here the methodology has been applied as described in Minot and Goletti (2000).

The impact of a price change on household welfare can be decomposed into the impact on the household as a consumer of the goods and the impact on the household as a producer of the goods. The net welfare impact will be the difference between the two. Therefore if the demand and supply side elasticities are set to equal zero, thus ignoring consumer and producer side response to price changes, the short run welfare impact on households is calculated as

$$\frac{\Delta w^1_i}{x_{0i}} = \%P_P \cdot PR - \%P_C \cdot CR_i \qquad (1)$$

where $\frac{\Delta w^1_i}{x_{0i}}$ is the first order approximation of the net welfare impact on producer and consumer households deriving from a price change in commodity i, relative to intial total income x_{0i} (in the analysis income is proxied by expenditure)

$\%P_P$ is the change in producer price for commodity i

PR_i is the producer ratio for commodity i and is defined as the ratio between the value of production of i to total income (or total expenditure)

$\%P_C$ is the change in consumer price for commodity i.

CR_i, is the consumer ratio for commodity i and is defined as the ratio between total expenditure on commodity i and total income (or total expenditure)

1 For a detailed discussion on this summary appendix the reader is referred to Dawe and Maltsoglou (2009).

Assumptions made on the producer and consumer price changes have proven to be crucial in the welfare impact assessment analysis. In the analysis presented here it is assumed that marketing margins are constant in absolute terms. This assumption entails that producer price changes will be larger than consumer price changes in percentage terms and that the percentage producer price change is equal to the percentage consumer price change weighted by the consumer to producer price ratio as shown in (2).

$$\%P_P = \left(\frac{P_C}{P_P} \right) \cdot \%P_C \qquad (2)$$

The consumer and producer price ratio can be calculated using commodity price data, aggregate survey data, macroeconomic data or a mixture of these. In the analysis presented in this paper aggregate survey and macroeconomic data are used to calculate the price ratio. It can be shown that in the case of a self-sufficient commodity the ratio of the consumer to producer price is equal to the total consumer expenditures (CE) divided by the gross production value (PV), (3).

$$PC/PF = CE/PV \qquad (3)$$

If the country is not self-sufficient in the production of the commodity being considered, an adjustment is needed to account for the consumption share of the good that is imported (or the production share that is exported). In this case the calculation is amended as shown in equation (4).

$$PC/PF = CE'/PV \qquad (4)$$

where CE'= CE· (PROD/CONS), PROD is domestic production and CONS is domestic consumption.

In the results presented here a hypothetical price variation of 10 percent on the producer side is used and the consumer price change is evaluated based on the calculations outlined above. Price changes will also be an output of Module 3 and 4 and need to be cross-checked across these modules.

Two additional considerations were included in the analysis. Firstly, it is taken into account that prices for goods important to the poor are usually higher in urban areas. For two households with the same level of income, one in an urban area and one in a rural area, the urban household will effectively be poorer. In order to account for these purchasing power differences, rural expenditures were scaled up by the urban and rural poverty line ratio.

Secondly, based on the selected commodity list, crops produced at the farm level might be very different compared to the commodity actually consumed by the households. Clear examples of this are wheat and maize. Wheat is produced at the farm level, but consumers eat bread, biscuits or purchase wheat flour. Maize is slightly more complex since maize produced on the farm can either be used for human consumption (white maize) or used for feed (yellow maize). All commodities generally have some degree of processing embedded in them which varies according to which commodity is under scrutiny. Based on discussions with experts in FAO, some rules of thumb have been set up for what the processing factors may be and these have been used in this paper (Table B.1). Again, a more detailed discussion on processing is presented in Dawe and Maltsoglou (2009).

TABLE B.1

Subproduct factors used to calculate the net welfare impacts at household level.

Commodities	Subproduct or Description	Share in Value Ratio *
Maize	Chicken	20
	Eggs	20
	Pigs	10
	Flour	60
	Cobb	75
	Grain	75
Cassava	Fresh	50
	Dry	50
Rice		65
Sweet potato		50
Sugar		20
Plantains		50
Beans		65

Source: FAO, 2009

** This is the ratio of the final product to the farm gate product.*

CHAPTER 9

USING BEFS TO INFORM POLICY

Yasmeen Khwaja

9. INTRODUCTION

Energy security has become a critical issue for the twenty-first century. Increased demand for energy from emerging economies such as China and India, the dependence on oil from countries in unstable political regions, the expected shortages of fossil fuels and the need to limit greenhouse gas (GHG) emissions have generated enormous interest in biofuels. For countries like Tanzania, biofuels offer an opportunity to create national sources of energy and the potential to develop new rural employment that could help regenerate the agricultural sector. However, there are valid concerns about the development of fuels from agriculture because of its potential impact on food security and the competition it may create for natural resources. There are a number of issues related to biofuels developments which require careful analysis of the impacts. The Bioenergy and Food Security (BEFS) Project offers a range of tools that can assess whether bioenergy developments can be managed in a way that does not compromise food security and in a way that contributes to wider development and economic growth.

This chapter considers how the BEFS analysis of potential biofuel developments in Tanzania can contribute to the formulation of new policies and regulations for the sector so that the benefits are more equitably distributed. The chapter is structured as follows. Section 9.2 presents an overview of the results from each module. Section 9.3 presents one avenue for biofuel development through the consideration of a pilot scheme. In Section 9.4 some issues emerging from the BEFS analysis are discussed before concluding in Section 9.5.

9.1 HOW BEFS INFORMS POLICY IN TANZANIA

Before deciding on how to realize a bioenergy sector it is important to understand the full range of net impacts of bioenergy pathways on food security issues. The BEFS tools can analyze whether bioenergy is feasible in the first place and if so, how different bioenergy pathways can affect poverty and food security. The BEFS analysis can help inform and shape the direction of policy so that it promotes a sector that contributes to inclusive growth and development.

The BEFS approach

There are a number of conditions that influence bioenergy development at national level. These are:

- the agro-ecological and agro-edaphic conditions and availability of land resources;
- the suitability, productivity and production potential of various biofuel feedstock;
- the technical capabilities needed for the biofuels industry.

These factors determine the *where* and the *how* of setting up an industry. However, any consideration of these factors needs to be accompanied by an analysis of how bioenergy impacts on the agricultural sector, the wider economy and the household. Bioenergy developments have impacts on national food systems which could be positive or negative but require rigorous analysis to determine the precise nature of these effects. Suppose Tanzania chooses a particular pathway for bioenergy development based only on the biophysical and technical feasibility factors because this is the most cost-effective choice. However, that pathway may have wider impacts on food security through adverse changes in prices, income and employment. Thus, knowing what the likely impacts *a priori* are of certain choices may alter the where and the how of bioenergy development. Policy instruments and institutional developments can be constructed in order to adapt to changes or shocks to the food system so that Tanzania's goals on food security and poverty reduction are not compromised.

The diagram below (Figure 9.1) presents the Analytical Framework by BEFS in Tanzania.

Figure 9.1

The BEFS Analytical Framework

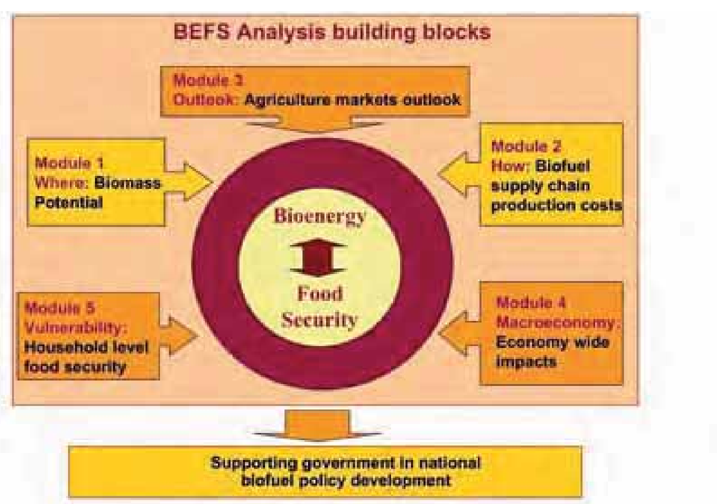


Table 9.1 presents the key information generated by each module in the Tanzanian assessment. It is precisely this information that should regularly feed into the policy process for more informed decision-making as the bioenergy sector evolves. Importantly, the information yielded by any single module needs to be considered against the information yielded by the other modules in order to arrive at a more comprehensive understanding of how decisions at one stage of the decision-making process can have impacts later on. Moreover, it should be noted that while the results presented in this analysis build on recent Tanzanian data, these results are by no means *definitive* or *comprehensive*. Rather, they demonstrate how the BEFS tools can answer a variety of questions by policy-makers concerned with economic development, food security and poverty reduction and the way bioenergy can affect these.

TABLE 9.1

The Tanzania Assessment- Summary analysis and output by Module

Module	Analysis	Information generated
ONE BIOMASS POTENTIAL	Identifies a range of areas where bioenergy crops may be grown by carrying out a land suitability assessment of bioenergy crops under rainfed conditions Based on the AEZ methodology developed by FAO.	#At subregional level identifies the areas that are most suited to production of particular crops #Identifies exclusion areas and potential food production competition areas. #Identifies how this suitability may be enhanced through the application of inputs and/or through improved agricultural management practices. #Calculates potential yield for specific crops and total production based on above #Identifies bioenergy zones that can meet industrial requirements
TWO BIOFUEL SUPPLY CHAIN PRODUCTION COSTS	Assesses the techno-economic feasibility of biofuel production by calculating production cost profiles to determine how the bioenergy industry may be set-up Based on process simulation analysis using Aspen Plus. The program was originally developed by the Massachusetts Institute of Technology for the U.S. Department of Energy to evaluate synthetic fuel technologies. Within Module 2, it was applied to biofuels by the University of Manizales in Colombia.	#Review of feedstock production prices # Assessment of biofuel technology access and human capacity for Tanzania #Identifies current technology status for Tanzania for ethanol and biodiesel based on an in country review # Sets up relevant reality based scenarios building on feedstock origin and industrial configuration #Generates biofuel production costs based on the selected scenarios #Identifies how development of co- and by-products can offset productions costs
THREE AGRICULTURE MARKETS OUTLOOK	Illustrates how the domestic agriculture market will evolve given domestic and international bioenergy policies. Based on the FAO-OECD Cosimo-Aglink Agriculture Outlook.	#Illustrates potential demand for commodities given projected income and population growth and potential supply given yield productivity and relative crop returns #Sets up a number of relevant scenarios including biofuel production #Identifies possible consequences of biofuel production on the agriculture outlook #Illustrates sensitivity of agriculture markets to external shocks including oil prices and international biofuel policies
FOUR ECONOMY WIDE IMPACTS	Examines the economy-wide impacts of bioenergy developments in terms of poverty reduction and economic growth potential under different bioenergy industrial set-ups Based on the dynamic Computable General Equilibrium model developed by IFPRI.	#Building on production costs defined in Module 2, sets up scenarios for the whole economy. #Identifies which biofuel production chains are most effective at stimulating economic growth and targeting poverty. #Identifies implications for other sectors of the economy, including other agriculture sectors #Identifies implications for capital, labour and land..
FIVE HOUSEHOLD LEVEL FOOD SECURITY	Since international and domestic biofuel developments result in crop price increases, determines household level impacts of resulting food price increases to define most vulnerable segments of the populations. Based on household level analysis developed by FAO and IFPRI.	#Identifies most important food crops in Tanzania #Assess vulnerability of country to prices fluctuations of key food crops #Identifies linkages between domestic and international key food prices #Assess which population segments are most vulnerable to major crop price changes

The BEFS tools can be used to analyse further variables. For example, the feasibility of using other crops not considered here or the consideration of alternative industrial configurations that yield different production cost profiles. The real strength of the tools lies in their ability to provide continued analyses to explore the bioenergy-agriculture-food security interface. The starting point for the BEFS analysis is agriculture. In Tanzania as in many other countries agriculture remains an important sector for the livelihoods of the most vulnerable in the population. For governments in the developing world an important question revolves around how best to boost the agricultural sector. An array of options needs to be considered. Bioenergy presents an important potential for agriculture because of the large sums of financial resources it brings from the private sector. Can these resources be managed in a way that harmonises the private interests with the public good? The BEFS analysis considers how a country's natural resources can be managed to promote agricultural growth and boost rural incomes consequently. Tanzania has just begun the process of biofuel developments. By contrast, Peru and Thailand (the other countries analyzed under BEFS) are at a different stage of bioenergy development and the BEFS tools consider different ways of managing the natural resource base by considering issues relating to GHG emissions, water availability, and wood fuels by way of examples.

The information produced by the Tanzanian analysis needs to be considered against the backdrop of prevailing policy on energy, food security poverty, employment and the environment (see Table 9.2). It is important that the BEFS tools are used in alignment with current policy objectives rather than suggest the creation of new initiatives that would strain the public purse. The results of the Tanzanian analysis suggests that there are potentially many gains to be had from bioenergy development but that these gains are likely to be only realized with careful management of the processes that guide bioenergy development.

TABLE 9.2

Summary of the key issues for Tanzania

Area of Policy Focus	Goals
Food Security	Ensure availability, reliability, improved access to markets by farmer
Energy Security	Ensure availability access, reliability, affordability
Poverty reduction	Promote Vision 2025, PRSP targets and MDGs through *income* generation
Environmental conservation	Improved biodiversity, reduced GHG, soil protection, water conservation, reduced deforestation
Social empowerment	Improved livelihoods, participation of Tanzanians in bioenergy industry
Land	Ensure equitable land ownership and tenure arrangements
Agricultural practices	Improve yields, sustainable agriculture
Identify *best* bioenergy crops	To develop bioenergy for energy security, improve agricultural yields of all crops, augment rural incomes for improved food access.

Note: Table summarizes key elements drawn from the country's policies on poverty, food security, agriculture and energy. For a more comprehensive discussion on these please see chapter 3.

9.2 POLICY IMPLICATIONS FROM THE BEFS TANZANIA ANALYSIS: UNDERSTANDING THE RESULTS AGAINST THE POLICY INFRASTRUCTURE IN TANZANIA.

MODULE 1 - *WHAT DO THE RESULTS TELL US? IMPLICATIONS FOR POLICY*

Module 1 derives the land suitability status at the subnational level for a number of crops. For the Government of Tanzania two questions arise in considering the development of the bioenergy sector. First what crop to produce and second where to produce it? The results from Module 1 provide a general picture of which crops do best where, under *rainfed* conditions. However, the analysis also shows that land suitability can increase substantively with a change in agricultural management practices in the medium term and the increased application of inputs over the long term.

Tanzania is rightly anxious that bioenergy developments should not compete with food crops for land use. However, the trade-off between feed and food is often overstated. The real food security issue for Tanzania and indeed for Africa in general, stems from poor yields. Understandably, the Government of Tanzania places a high priority on food self-sufficiency. This is seen as an important buffer against rising global food prices which can feed into Tanzanian food markets even when the crop is not traded internationally. Improving yields of food crops could do much to enhance the food basket of Tanzania using existing land areas. Bioenergy developments would not then compete with lands used for food. Even if a food crop such as cassava is chosen for biofuel production, improved yields would allow both food and bioenergy crop requirements to be met. This of course presupposes supportive investments into new crop varieties, access to and the promotion of conservation agriculture etc. to ensure that potential yields are reached.

The results of Module 1 are able to provide information on total production of a particular crop in the identified suitable areas. Some of these areas will already be under existing agricultural production while other areas may involve development into new lands. An important consideration would be whether it is best to develop bioenergy crop through intensification - using existing areas under crop production and ensuring that yields achieve close to their maximum potential - or developing the sector by expanding into new lands previously unused for any cultivation. The choice depends on whether the bioenergy crop is an existing food crop with the potential to improve yields or whether the bioenergy crop selected would involve displacing already established agricultural cultivation.

A further important aspect in the consideration of where the sector should be located among the available suitable lands relates to infrastructure such as roads, irrigation infrastructures, etc. that are essential to support the associated market be it for food or biofuels. Additionally, for the biofuel industry to be viable requires large contiguous pieces of land in order to ensure that the production requirements of industry can be met in a cost-effective way. Thus, crop choice rests not just with the results of Module 1 but must be considered against the production cost profiles offered in Module 2 which, in this analysis, show that crops producing ethanol have a distinct cost advantage.

An interesting result that arises from the analysis of Module 1 is the comparative advantage of Tanzania in the development of sunflower. Even at the lowest level of inputs where the land is tilled, land suitability is still high. The use of inputs and a move to conservation agriculture dramatically improves the land suitability of sunflower - much more so than for any of the other crops analysed here. This could present an important point of discussion for policy-makers. Many argue that bioenergy developments should promote the use of a food crop because if the energy market fails, the output can serve the food market. Sunflower developments require, in terms of land suitability, the lowest inputs to yield investments.

The results of Module 1 consider land suitability only under rainfed conditions. Sunflower, sweet sorghum and cassava have a clear comparative advantage over some other crops, such as sugar cane and palm oil, where current land suitability is water constrained. Under a programme of irrigation, the land suitability for these crops would be vastly improved under all agricultural practices and for all level of inputs.

Can decisions on changing land use for bioenergy impact positively on food security, energy security, environmental sustainability, poverty reduction, etc.? Module 1 suggests an affirmative answer but this very much depends on the land decisions that are made and how poor farmers are included in the process. Land selection for biofuel production based on the very narrow biophysical criteria offered by Module 1 alongside the cost criteria offered in Module 2 could easily bypass the interests of smallholders. If one aim of bioenergy provision is to enhance food security and reduce poverty, the inclusion of smallholders in the sector will be vital. Module 4 demonstrates that particular bioenergy developments yield particular gains for poverty reduction. Decisions on where to locate must be considered in the light of the results generated by the other modules.

Module 1 provides clear evidence on where and how food crop yields can be potentially improved through the application of new inputs and changes in agricultural practice. This will require public investment whether there is a bioenergy sector or not. Module 1 can be used to ensure that regions important for national food security are not compromised by bioenergy developments. Indeed bioenergy presents an important opportunity to stimulate agricultural growth which will have spillover effects throughout the rural economy.

MODULE 2 - *WHAT DO THE RESULTS TELL US? IMPLICATIONS FOR POLICY*

Module 2 derives the production cost profiles of producing ethanol and biodiesel under diverse industrial configurations based on crop choice, the feedstock provider, the industrial set-up and different technology levels. In essence this is a feasibility study but with one critical difference. The feasibility analysis deliberately includes smallholders within the industrial configurations to analyse whether their involvement can be cost competitive. This contrasts with the kind of feasibility study carried by the private sector where the industrial set-up is large so that economies of scale may be enjoyed and profits enhanced. The analysis conducted under Module 2 is conditional upon the production requirements being met by the bioenergy crops under consideration. This information is generated by Module 1.

Using real data the results suggest that Tanzania has a technology capability of level 2 for ethanol production and level 1 for biodiesel. The technology levels are derived based on the degree to which conventional or more advanced cutting edge technologies are used. For example, level 1 is consistent with the use of proven conventional technologies only. Production cost profiles are also conducted for technology levels 1, 2 and 3 in order to illustrate how technological advancements can impact significantly on production costs. The results suggest that long-term technology will dictate profitability levels and the ability to adapt better to changes in the sector, notably towards second generation bioenergy. Bioenergy development could provide an impetus to invest in scientific programmes at the graduate and vocational levels. The relationship between education, high incomes and the ensuing investment for growth has been well documented.

Results from Module 2 also show, perhaps not surprisingly, that large-scale sugar cane is more profitable than small-scale sugar cane where production costs match world ethanol production costs. Based on profitability criteria only, such a development would exclude poor smallholder farmers. However, profitability levels of small-scale cassava production compete well with those of large-scale sugar cane suggesting that cassava may be an optimal crop choice both on cost and food security criteria. Results derived in Module 4 also suggest that cassava generates higher levels of pro-poor growth than sugar cane-based systems. However, if smallholder yields can be improved, then sugar cane and cassava outgrower schemes produce similar pro-poor outcomes. Once again, the ability of the biofuel sector to include the poor does hinge on the extent to which smallholders can improve yields. Module 2 shows that neither molasses nor jatropha are profitable under the conditions assumed.

Profitability of the bioenergy sector matters to the investor which in Tanzania is likely to be private and external. For the Government of Tanzania the issue is whether the sector can be profitable enough for the private investor and also address the food security and poverty concerns of the country. Results in Module 2 show that cassava production is best for promoting the smallholder. Profitability is maintained under small-scale production but particularly under a mixed smallholder-estate production system. Moreover, this result is based on rainfed cassava yields. Under irrigation cassava yields are likely to increase resulting in lower feedstock costs making the small-scale cassava option even more profitable. Smallholders tend to have restricted access to the kind of credit that would enable them to make the necessary irrigation infrastructure investments. These constraints could be overcome in two ways: through government-backed loans or directly through government investment into irrigation. Block farming appears to overcome some of the investment constraints faced by individual smallholders. Such a system would allow large-scale public investments to be more forthcoming while still benefiting individual smallholders.

Module 2 provides a range of productions cost profiles. The analysis does suggest that while large-scale production costs are low, smallholders can compete under certain conditions. This has important policy implications. Yields and technology are critical variables influencing production costs. Large-scale public investment here can do much to enhance agricultural performance.

The results presented here consider a limited range of cost profiles. Block farming has emerged as a possible way to enhance smallholder competitiveness. The tools in Module 2 could be further used to analyse how production costs under block farming compare with those of estates or mixed systems. In addition, it is also possible to consider production cost profiles using alternative crops and also to assess costs for other forms of bioenergy. The BEFS work in Peru and Thailand consider these other aspects.

MODULE 3 - *WHAT DO THE RESULTS TELL US? IMPLICATIONS FOR POLICY*

Module 3 considers how Tanzania's agricultural markets are expected to evolve over the next several years in the absence of biofuels. The Module considers the potential demand for commodities given projected income and population growth, and potential supply given yield productivity and relative crop returns. Policy-makers and investors can use this information to analyse whether Tanzanian agricultural markets have the capability to develop biofuels without adversely affecting food security.

Even though stakeholders have identified lands within Tanzania to develop biofuel feedstock to produce biofuels and there is potential to export to lucrative markets such as the European Union, biofuel markets are just emerging and there remains a significant risk within these markets. Biofuel viability is very much linked to oil prices and government policies, both of which are subject to volatility. For example, the results of a scenario analysis with lower oil prices would lead to an increase in world crop production, particularly in developed countries, and consequently would lead to lower crop prices. For most commodities Tanzania would need to increase imports to meet domestic consumption. The results illustrate the vulnerability of Tanzanian agricultural markets to movements in oil prices.

It is important to note that the analysis of Module 3 considers the current situation of agriculture and considers what would happen to agricultural markets over time assuming that *nothing* in the sector changes. These results are projections of the current status of agriculture and are thus not definitive forecasts. In reality, we would expect changes such as the adoption of new technology, climate change, trade agreements or economic shocks. These would change the outlook or picture for Tanzania. What this Module demonstrates is the very real need for agriculture to modernize. If the status quo were to be maintained into the future, then the outlook is gloomy as the results demonstrate. Even in the absence of bioenergy, Tanzania must revive its agricultural sector in order to meet its own food needs in the long term.

MODULE 4 - *WHAT DO THE RESULTS TELL US? IMPLICATIONS FOR POLICY*

Module 4 builds on the results of production costs derived in Module 2 and links them into the national economy of Tanzania. In order to strategically target poverty reduction, linking the production costs results to the economy-wide effects can help policy-makers consider the necessary interventions needed to include small-scale outgrowers in the development of the sector and the preferred combination of large-scale estate and the small-scale outgrower scheme.

The bioenergy sector competes for resources (land, labour, inputs and capital). The sector is small at the start but grows with increased investments in the sector. Biofuel scenarios are developed and their impact on poverty reduction analysed. These scenarios differ according to their production technologies and strategies, that is, with feedstock, scale of feedstock production and intensive versus extensive production strategies.

The results show that all biofuel scenarios increase growth and reduce poverty. However, small-scale production options are the most pro-poor with small-scale cassava emerging as a clear winner for promoting growth and reducing poverty. The results also suggest that the best option to meet biofuel feedstock demand is through increasing yields because it does not require new lands or additional labour. While Module 2 showed that cassava feedstock production under mixed systems can be profitable, the results in Module 5 suggest that this is not a desirable option because it would require huge amounts of additional land. Moreover, the gains that derive from increased employment and wages in the biofuel sector would be, in part, offset by falling incomes of poor farmers because of their land loss.

An important result to emerge from the analysis is that displaced land for biofuel is likely to come from export crops rather than food crops. This suggests that the trade-off between food and fuel in Tanzania is unlikely to emerge. The real issue, however, is whether a new biofuel sector can be better than the existing export crop sector at reducing poverty. This is difficult to predict with any certainty. Much depends on the additional investments needed to support biofuels and whether these investments are in line with existing agricultural growth strategies. If not, the costs of investments into biofuels may override the gains in which case maintaining traditional export crop markets may be more feasible.

The results of Module 4 show that economy-wide impacts of biofuel development are positive for growth and poverty reduction. This could provide a strong impetus in developing the Sector. However, the results also suggest that biofuel developments need to be consistent with existing growth/agricultural strategies in order to harness the gains suggested. This requires careful planning on where to locate the industry, what crops to develop as feedstock and a consideration of the opportunity cost of new investments that are not part of existing investment programmes.

MODULE 5 - *WHAT DO THE RESULTS TELL US? IMPLICATIONS FOR POLICY*

The analysis in Module 5 illustrates crop price changes and which households are most vulnerable to these changes. It also considers recent price movements. Maize and cassava price data suggest that the maize and cassava markets are interconnected in the medium term, although less so in the short term. Were Tanzania to divert cassava into ethanol production without an accompanying supply response, maize imports will increase with impacts for food security because world prices will have gone up and cassava prices too would rise.

The analysis in Module 5 has used a partial dataset collected from the rural areas of the Ruvuma and Kilimanjaro regions because a complete country dataset was not available. Whilst conclusions at the country level cannot be inferred by this analysis, the results do illustrate how price rises of different food crops affect regions and households differently. It would be important for Tanzania to derive a national picture to see what the net effects are from crop price increases to be aware of the scale of the problem and in order to instigate appropriate responses in terms of safety nets, etc.

The results show that the poorest households in Ruvuma will benefit from price increases in maize and rice. These households will be negatively hit by price increases in beans and cassava. By contrast, poorer households in Kilimanjaro will lose if the prices of maize, rice or sugar were to increase.

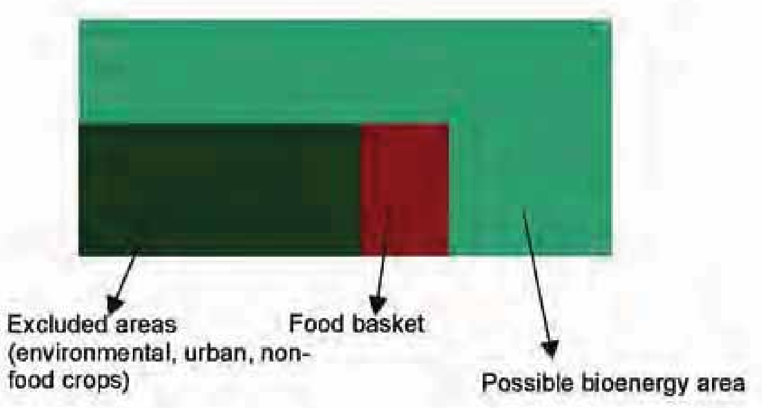
9.3 GETTING THE BIOFUEL PATHWAY RIGHT? WAYS FORWARD

The BEFS Tanzanian analysis demonstrates how smallholders could play a role in producing feedstock for biofuels. To date most of the potential producers of biofuels in Tanzania are large commercial scale farmers. Unless the value chain is strategically controlled and monitored, leaving the biofuel sector to market forces would prove disadvantageous to poor rural farmers and households. Although biofuel offers the potential for income diversification if the sector is poorly managed it may compromise food security for many. Balancing the benefits of bioenergy against the potential costs can be difficult on a national scale. Module 4 suggests that to achieve positive impacts on poverty and growth requires a large-scale biofuel industry. However, the risks of a widespread and large national biofuel programme may be too high at the outset for a poor country such as Tanzania. Developing a pilot scheme in a specific location can limit the risks associated with developing too fast and too large. It allows governments to identify the constructs for an efficient sector in terms of improved yields, training, technology development and other public investments without too much additional strain on the public purse. Moreover, it offers an opportunity to learning-by-doing and apply the knowledge gained from bioenergy into a wider agricultural setting.

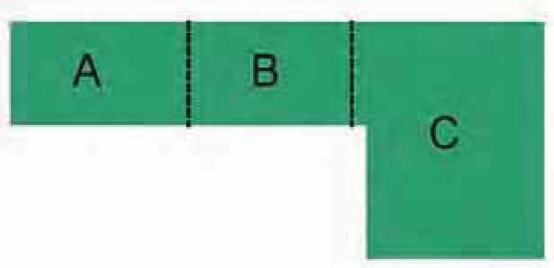
9.4 GETTING THE BIOENERGY SECTOR TO WORK FOR ENERGY SECURITY AND FOOD SECURITY – USING BEFS TO SET UP A PILOT

The Tanzanian analysis provides a basis to identify where and how to implement a pilot scheme while the analytical tools can be used to monitor and evaluate performance. The exercise below illustrates, at a very simple level, an approach to developing a pilot scheme based on the BEFS Analytical Framework.

The coloured box below represents the land mass of any particular country. In this case, the box represents Tanzania and total land mass. Not all land can be used for biofuel production. Some land will be excluded for other uses. In this simple exercise land for food (red) and other excluded areas (green) are *not* considered for biofuel developments. The food baskets are areas identified as being critical for national food production. The excluded areas include areas such as conservation parks, forest protected, mountainous or sloped regions. This leaves the blue areas as potential areas for development.



Of the remaining areas A, B and C available for bioenergy development the BEFS tools can be applied for selection of the pilot scheme.



Stage 1: Assessing biophysical criteria.

- Which crops grow best in each of the available areas, A, B and C (Module 1)
- Can production of bioenergy crops in the suitable areas fulfil the requirements of the industry
- Determine the need for extra investment in each area A, B and C for infrastructure-irrigation, water, roads, etc. (Module 1).

Stage 2: Assessing techno-economic feasibility

- Determine the production cost profile for a range of preferred crops under different technology and production systems (Modules1 and 2).
- Identify public investments and institutional supports for education, technology extension services, etc. (Module 2).

Stage 3: Evaluate biofuel pathways against the BEFS assessment

- Identify viable bioenergy pathways for pilot (Modules 1 and 2).
- Identify the benefits of each pathway using criteria on food security, poverty and growth.
- Identify *one* bioenergy pathway for pilot scheme and implement for a fixed period.

Stage 4: Monitoring household and economy wide impacts

- Implement monitoring and evaluation of pilot to consider effects at national and household levels.
- Monitor effects of national and international blending mandates on agricultural prices.
- Assess profitability of sector given prevailing global oil and agricultural markets (Modules 2 and 3).

Stage 5: Assessing the viability of a national biofuel sector

- Identify possibility and viability of extending the pilot to a national level using BEFS tools.

The pilot presented here is highly simplified and the stages of decision-making described are not intended as a blueprint for setting up a biofuel pilot scheme in Tanzania. The process described here is intended to show how the BEFS tools can inform the decisions involved in creating a new sector. Indeed, individual governments should certainly consider more steps or criteria in the decision-making process to reflect specific concerns. A pilot scheme offers policy-makers the advantage of assessing what policy and social constructs are needed to support progress and to adapt to difficulties created by biofuel developments. This can aid the formation of a bigger national bioenergy sector that is governed by comprehensive policies and regulations. In addition, a pilot offers the opportunity for local, regional and national authorities as well as the public to gain an understanding into how bioenergy developments may be used to enhance agricultural growth.

9.5 KEY ISSUES

There are a number of other issues that emerge from the Tanzanian analysis, not answered by the analytical tools of BEFS, that require policy attention.

- **Land Rights**

The necessity for a clear property rights system is central to the successful integration of biofuel production in the agricultural sector. The Government of Tanzania needs to consider how best to establish a system that is accessible to investors but also to subsistence farmers.

- **The opportunity cost of public investment**

It is important that investments associated with bioenergy are in-line with existing development plans on infrastructure, irrigation, education, etc. If investments are diverted away from valuable programmes on for example, healthcare, the true cost or opportunity cost of bioenergy would be much higher than the financial costs associated with construction. The re-direction of government investment away from important public goods is not be advocated.

- **Labour displacement**

Biofuel production (either domestic or international) may have an effect on labour demand if new land is brought into cultivation or if cropping patterns on currently cultivated land change substantially. Changes in labour demand could affect rural wages. Movements out of export crop production into bioenergy production could increase wages but this may be offset by falling land incomes for farmers as more land is brought under cultivation.

- **Negotiations between the government and private investor and governments**

The BEFS assessment for Tanzania has illustrated that the enormous potential for bioenergy to contribute to growth and poverty reduction. However, this requires careful management of the industry. Much of the interest in biofuel developments has come from private foreign investors. Thus, it is important for the government to continue to ensure that a balance is maintained between the interests of the private sector and the rural populations most likely to be affected by bioenergy developments. There is scope for the Government of Tanzania to consider how best to promote public-private partnerships in order to optimize the gains from the bioenergy sector. Note that the information generated by Module 2 allows governments to negotiate with the private sector for the inclusion of smallholders in the production of biofuels where their costs match those of large scale estates only.

- **Second generation bioenergy**

An important concern for many countries, such as Tanzania, considering developments into first generation bioenergy is whether investments today may obviate future second-generation bioenergy developments. Clearly, the more advanced the technology used for the preparation of first generation fuels the easier the transition to some second generation fuels. However, the strongest argument for promoting advanced technology lies in the strong contribution this makes to enhancing domestic human capital which is essential for long-term growth and development.

A further concern stems from the increasing interest of developed countries to move towards second generation fuels which would render first generation biofuel producers uncompetitive. In spite of the excitement surrounding second generation fuels, their use in developed countries is still some way off. Indeed, for developing countries the threat of competition by second generation fuels is unlikely to be realized in the near future. By the time second generation fuels become operational Tanzania should be in a very different position on the development spectrum and should consider how to respond if necessary.

- **Regional Southern African Development Community biofuel programme**

For sub-Saharan Africa food insecurity is as much a regional as a national concern. Poor food crop yields characterize the performance of the agricultural sector in most countries in the Southern African Development Community (SADC) region. Promoting domestic energy security in the face of future oil price rises have prompted many countries in the region to move towards bioenergy. Since the SADC countries are all involved in trying to ensure food security and also to develop alternative national sources of energy, this suggests an opportunity for more cooperation towards regional food security and regional energy security strategies.

- **Climate Change**

One of the most important links between bioenergy, environment and food security occurs through climate change. In sub-Saharan Africa, how future climate change will affect food insecure households is of growing concern. Although this has not yet been directly covered by BEFS, there is a need to consider how climate change will affect agricultural performance with implications for both food and bioenergy security. Module 1 in the BEFS Analytical Framework implicitly deals with climate change because land suitability is determined as much by agroclimatic conditions as by agro-edaphic conditions.

9.6 CONCLUDING REMARKS

Tanzania has the potential to develop a bioenergy sector. Biofuel developments can be an important catalyst that regenerates the agricultural sector by bringing in new private as well as public investment. There is naturally profound concern that biofuels may compete with food production. High food prices in recent years have strengthened the resolve of the government to promote greater food self-sufficiency. In general, food insecurity in Tanzania has been driven by low food crop yields for some time. Cheap global food prices for many decades until about 2006 meant that agricultural investment was overlooked and diminished as a proportion of GDP with consequences for food production, food security and poverty. Most of Tanzania's poor live in rural areas so investment in agriculture is key to lifting these people out of poverty. Improving crop yields through better inputs, improved land management, increased infrastructures to support production, more research and development and greater investment into human capital are the necessary ingredients of a comprehensive agricultural development package that would raise agricultural productivity levels so it feeds into increased income and growth. These measures would be essential even in the absence of a bioenergy sector. Maintaining the status quo in agriculture is not an option if long-term food needs are to be met. The critical question is whether bioenergy can help bring about the kinds of investments needed for agricultural growth. The BEFS assessment shows that bioenergy could do much for agriculture provided the sector is carefully managed.

The dividends from investing in biofuels can have positive impacts on poverty reduction and growth. This result rests on the assumption that the necessary public investments needed to support biofuel development will be forthcoming so that profits from the sector are more equitably distributed for the benefit of poor rural populations. It is important that the government of Tanzania selects a bioenergy pathway that is consistent with existing plans for energy, poverty reduction and food security to avoid misallocation of public funds. The results show that small-scale cassava production can be an optimal bioenergy pathway in Tanzania. It is recommended that the BEFS Analytical Framework is used further to explore this option.

The BEFS analysis in Tanzania represents the start of a discussion on the viability of biofuels in the country. The analysis should not be seen as comprehensive or definitive. Rather it serves as a starting point for the kind of analysis needed to underpin the realization and implementation of a bioenergy sector. The tools developed under BEFS should be seen as dynamic, whereby data can be updated, crops and analysis components added and recent policy changes or outlooks included. In this way, the BEFS tools can support government decision-making and policy formulation as bioenergy developments evolve over time.

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ENVIRONMENT – CLIMATE CHANGE – BIOENERGY – MONITORING AND ASSESSMENT

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Bioenergy developments are high on many countries' agendas today in an effort to improve energy access, energy security and in the context of concerted efforts towards lowering global green house gas emissions. Over time, however, serious concerns on the food security impacts, social feasibility and sustainability of bioenergy have arisen, especially with first generation bioenergy. In this context FAO, with generous funding from the German Federal Ministry of Food, Agriculture and Consumer Protection (BMELV), set up the Bioenergy and Food Security (BEFS) project to analyze how bioenergy developments could be implemented without hindering food security. Over its term, the BEFS project has been supporting Peru, Tanzania and Thailand in analyzing the competitiveness of the bioenergy sector, potential impacts on food security, growth and poverty. In this effort, BEFS has constructed an Analytical Framework that can assist countries with the development of bioenergy policy and/or clarification of the potential impacts of the bioenergy developments.

The analysis presented in this document is the implementation of the BEFS Analytical Framework in Tanzania. The analysis includes five building blocks on biomass potential, biofuel supply chain production costs, the agriculture markets outlook in Tanzania, economy wide impacts and household level food security. The final aim of this analysis is to support policy in the country and start a continuous process that can inform policy over time. The crucial element in developing a sustainable bioenergy sector in Tanzania lies in the management of the sector. This is discussed though out the analysis and more in depth in

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