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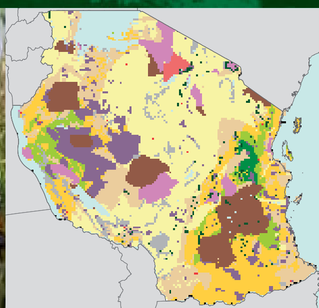
Bioenergy and Food Security

The BEFS Analysis for Tanzania



Sunflower Biodiesel, Water, and Household Food Security

ENVIRONMENT AND NATURAL RESOURCES MANAGEMENT WORKING PAPER

ENVIRONMENT CLIMATE CHANGE [ENERGY] MONITORING AND ASSESSMENT

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ENVIRONMENT AND NATURAL RESOURCES MANAGEMENT WORKING PAPER

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Bioenergy and Food Security

The BEFS Analysis for Tanzania

Sunflower Biodiesel, Water, and Household Food Security

Edited by Elizabeth Beall

BEFS
Bioenergy and Food Security Projects

Bioenergy and Food Security Project
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FOREWORD

Bioenergy development in Tanzania has brought together the energy and agriculture sectors in an unprecedented way. This has created new dynamics and could place pressure on the agricultural sector, which is currently dominated by smallholder production with low yields. The danger is that bioenergy development could bypass the poor, favouring instead, large-scale producers that are able to respond quickly to this new source of demand. The question is whether bioenergy can be a catalyst for improved agricultural productivity in Tanzania.

The BEFS project implemented the BEFS Analytical Framework in Tanzania in 2009 and 2010. The results of the analysis, which addresses multiple dimensions involved in bioenergy development ranging from - the physical and technical to the socio-economic -were published in May 2010 (Bioenergy and Food Security – The BEFS analysis for Tanzania, Environment and Natural Resources Working Paper No. 35, Rome). Although comprehensive, the BEFS analysis for Tanzania carried out could not cover all pertinent issues at that time. Subsequently, the Government identified three areas of interest for further analysis: (i) production costs for biodiesel from sunflower, (ii) water resource analysis in the Wami Basin, and (iii) household level food security and vulnerability analysis following the release of a full household level dataset.

Understanding the specific challenges and opportunities for bioenergy development in Tanzania is crucial to ensure integrated policy formulation that meets the dual objectives of food and energy security.

Alexander Müller
Assistant Director-General
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FAO

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Our appreciation also goes to FAO colleagues who were instrumental in supporting the execution of the analysis both in Tanzania and at FAO Headquarters, including Sharon Darcy, Alessandro Flammini, Aisja Frenken, Yasmeen Khwaja and Laura Perugini.

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EXECUTIVE SUMMARY

INTRODUCTION

There has been substantial debate regarding the potential of bioenergy as an alternative to fossil fuels, and the potential positive and negative impacts on rural development, food security, and the environment. The food price spikes of 2008 created concern about the conflict between bioenergy development and food security due to the potential competition for scarce resources such as land, water, and agricultural inputs, in the context of growing challenges such as climate change. However, it is important to remember that agricultural systems have always produced both food and non-food commodities; for example animal feed and food from maize, or cosmetic oil and edible oil from oil palm, and will respond to changing patterns in demand over time. Growing demand for food, population pressure on land use, and the growing impacts of climate change will create additional challenges for land and resource management. The focus then should be on how bioenergy can be produced in combination with food and other products to enhance both food and energy security.

Much of the debate about biofuels has focused on the potential negative impact of higher food prices on consumers in developing countries. Less attention has been paid to the role that bioenergy can play as a new source of demand and thus as a potential stimulus for an increase in the supply of commodities that can be used for both energy and food. The recent food and economic crises have reminded many governments of the very essential role that agriculture plays in supporting the food security and livelihood needs of the poor, and the need for a new agricultural *revolution* to regenerate the sector in a *sustainable* way. Agriculture can be a key driver of economic growth and poverty reduction for the 75% of the world's poorest people who rely on agriculture for their livelihoods (OECD, 2006). Bioenergy has the potential to serve as a win-win opportunity for energy and food security by stimulating much needed investment in agriculture and rural infrastructure, if certain safeguards and analysis are in place to structure investment in a sustainable, integrated way.

TANZANIAN POLICY CONTEXT

Agriculture is the slowest growing sector in the Tanzanian economy and could benefit from new investments as a result of interest in bioenergy (Maltsoglou and Khwaja, 2010 pg. 26). Over 75% of Tanzania's population is also employed in the agricultural sector, and thus could benefit from increased income/employment opportunities, improved rural infrastructure, and increased access to energy (Maltsoglou and Khwaja 2010). Therefore, investment in this sector could potentially provide poverty reduction and food security benefits if targeted in a way that integrates energy and agriculture policy priorities.

At the same time, growth in agriculture will require investment in irrigation, since one of the key limitations to current growth is that only 1.6% of cultivated land in Tanzania is irrigated (Maltsoglou and Khwaja 2010). Any agricultural growth strategy will need to include how to build capacity and organization among small farmers in order to ensure inclusion and maximization of benefits for rural development and food security. This will require significant capacity building in terms of good agricultural practices. Meeting these goals is a key priority outlined in many Tanzanian policies, e.g. the Agricultural Sector Development Strategy (2001); the National Strategy for Growth and Reduction of Poverty (2005); and most recently the Comprehensive Africa Agriculture Development Program (CAADP) framework (2010). However, there is a lack of integration and coordination with energy policy and energy sector goals. Bioenergy provides an opportunity to integrate the goals of both sectors (i.e. agriculture and energy) and potentially provide a win-win scenario.

Tanzania has participated in and adopted the CAADP framework to help reduce duplication and increase synergies in targeted activities to promote agricultural growth. The framework includes four pillars, 1) extending the area under sustainable land management; 2) improving rural infrastructure and trade related capacities for market access; 3) increasing food supply and reducing hunger; 4) agricultural research, technology dissemination and adoption. By adopting the CAADP, Tanzania is eligible for new multi-donor funds and regional technical assistance. The Tanzanian investment plan under CAADP includes improvement of rural infrastructure, irrigation, agro-processing and value addition, capacity building, smallholder financing, and a focus on public private partnerships. Bioenergy could serve to meet the goals outlined within the four pillars of the CAADP framework, through access to new investment finance and diversified markets. In order to ensure that bioenergy contributes to and enhances the goals and planning under the CAADP framework, it is important that the Ministry of Energy and energy stakeholders are involved in this process.

FAO'S ROLE

To date, the rush to promote bioenergy as an alternative to fossil fuels has often occurred in the absence of a proper understanding of the full costs and benefits associated with bioenergy development and of how to target investments in a way that minimizes the costs and maximize the benefits for the most vulnerable. Over the last few years, FAO has established a number of initiatives that provide information and analysis on the implications of bioenergy development. These initiatives aim to support countries in ensuring that bioenergy development is sustainable (both environmentally and socio-economically) and targeted to enhance food security.

FAO has developed the **Bioenergy and Food Security (BEFS)**[1] approach to support

1 Further information on the BEFS project can be found at http://www.fao.org/bioenergy/foodsecurity/befs/en/

and guide policy-makers by showing them how, based on sound information, the development of a bioenergy sector could drive agriculture growth and poverty reduction while fostering food security. Building on the BEFS approach, FAO has also developed, through the **Bioenergy and Food Security Criteria and Indicators (BEFSCI)**[2] project, a set of criteria, indicators, good practices and policy options to inform and support countries in preventing and managing the risks posed by bioenergy, in addition to monitoring and responding to the impacts of bioenergy production on food security.

THE BIOENERGY AND FOOD SECURITY (BEFS) APPROACH OF FAO – A RISK MANAGEMENT APPROACH TO BIOENERGY DEVELOPMENT

In order to assist governments in developing a broader understanding of the issues at stake, the potential for bioenergy development, the conditions needed to develop the sector sustainably and ultimately how to manage the risks and maximize the benefits identified, the Bioenergy and Food Security (BEFS) project developed the BEFS approach. The BEFS approach has three core elements: inter-ministerial dialogue and coordination, sound analysis of the potential for bioenergy and the impacts of the sector, and capacity building both at the technical and the policy level. A range of multidisciplinary issues are addressed in the approach to provide analysis of the relationship between bioenergy and food security in a specific country context. The BEFS approach illustrates the need for bioenergy planning to be integrated across sectors. Just as the technical experts need to work together in order to understand the technical links across analytical tools and data analysis, policy makers need to work across sectors, ministries and involve numerous stakeholders. The multidisciplinary, cross-ministerial discussion prompted by BEFS is based on information derived from technical analyses with the goal of assisting countries in deciding the direction for policy and development priorities. A key element of the BEFS approach is the BEFS Analytical Framework (BEFS AF), which is supported by a variety of analytical tools (the BEFS Tool Box). While there are a number of issues that surround bioenergy, the focus in the BEFS AF is on the linkages between bioenergy and food security and how to develop a sustainable bioenergy sector that fosters food security and supports the country's development priorities and policies.

The BEFS Analytical Framework has been applied in three countries, including Tanzania, from 2008 to 2010. In each country, the BEFS AF was adapted to address the specific priorities and concerns of the country, and to reflect the stage of bioenergy development. The BEFS analysis in Tanzania originally included the following elements:

- *Biomass Potential:* Based on the list of potential bioenergy crops provided by the government, this component assessed the suitability for the production of the selected crops based on agro-ecological zoning. The analysis includes the identification of specific suitable areas including location and acreage, the subsequent production that could be achieved in these areas.The crops analyzed were sugar cane, sweet sorghum, and cassava for ethanol production; and palm oil and sunflower for

2 Further information on the BEFSCI project can be found at http://www.fao.org/bioenergy/foodsecurity/befsci/en/

biodiesel. The results of this analysis illustrated high land suitability for sunflower and cassava production, especially when applying conservation agriculture practices. The approach here was applied to bioenergy crops but can be used generally for any agriculture production for sustainable land use planning.

- *Biofuel Chain Production Costs:* This analysis included an assessment of the production costs of various bioenergy pathways, with an emphasis on production pathways where smallholders are considered an integral part of the value chain. The production costs of four potential feedstocks were assessed: jatropha, cassava, sugarcane (juice and molasses) and oil palm. The analysis includes an assessment of the technology in the country (local technical capacity, knowledge base and manufacturing capacity) and then defined a set of suitable pathways and country based scenarios that include industrial set up, plant scale, and feedstock origin. The results of the analysis indicate that existing technology capacity in Tanzania is weak and new investment is required to build capacity. The analysis also indicates that cassava based ethanol from smallholders could be competitively produced. This would require investment in productivity and formation of small scale cassava producer associations. Ethanol from sugar cane and biodiesel from jatropha could also be viable under a few of the scenarios analysed. However, the production costs of jatropha are based on uncertain yield projections, since jatropha is still unproven in Tanzania.
- *Economy wide effects:* This section assessed the potential impact of bioenergy production on economic growth, agriculture sector growth, poverty, and labour considering a range of feedstock origins, scales of production and intensification versus extensification. The analysis indicated that overall, bioenergy would lead to economic growth, new employment opportunities, and would not have a negative impact on food security, leading to welfare gains throughout. Sugar cane production could have a higher impact on the economic growth rate while cassava would achieve more poverty reduction.
- *Household-level food security:* Maize and cassava are the two main food staples in Tanzania. Whether or not bioenergy is developed domestically, the prices of these two food staples have been rising due to a variety of global factors, including growing international bioenergy demand. Increasing food prices impact households and can cause food security problems as the capacity of households to buy food diminishes. Households can be both producers and consumers of food, therefore to understand the actual effects of increasing food prices the net positions of households needs to first be understood, i.e. whether the household is a net buyer or a net consumer of the food stuff considered. At the time of the BEFS analysis, a full country level data set was not available so the potential implications of high food prices were illustrated with the use of a partial dataset available for the Ruvuma and Kilimanjaro regions. The analysis in these two regions illustrated that the poorest households in Ruvuma were found to benefit from price increases in maize and rice,

but were impacted negatively by price increases in cassava. The poorest households in Kilimanjaro are indifferent to price changes in cassava but are more vulnerable to price increases in maize and rice.

Based on the conclusions reached in the first BEFS Tanzania analysis (hereafter referred to as "BEFS Tanzania I"), there was interest from the government to:

- Estimate the production costs of sunflower due to the high suitability shown in the biomass potential analysis and the high reliance in the country on diesel fuel both at the local and national levels;
- Assess water availability and management issues related to bioenergy development; and
- Analyse the household level food security with a full country dataset to identify which segments of the population are vulnerable to price changes and what safeguard measures might be required.

KEY FINDINGS OF BEFS TANZANIA II

- *Production Costs of Sunflower:* The land suitability analysis under BEFS Tanzania I showed a high suitability for sunflower. In addition, adequate processing technology was found to be available and affordable in Tanzania. However, according to the production cost analysis conducted under BEFS Tanzania II, sunflower is currently not a viable feedstock for biodiesel production. This is primarily due to the combination of high feedstock production costs and current diesel and edible oil prices, which make biodiesel from sunflower uncompetitive. However, the analysis has also shown that sunflower production for the edible oil market, with power generation from sunflower husks (both for the plant and for the local grid) could be viable. This illustrates how diversifying production, by planting crops with diverse markets (food, fuel, feed) and using all available co-products can provide a more stable income for rural communities and improve energy access.
- *Water Availability Associated with Bioenergy Development:* The Wami River Basin is one of the areas in Tanzania considered to have high potential for irrigated agriculture. Land concessions for biofuel development are also being considered and approved in the basin. The analysis indicates that even in the absence of bioenergy development, water resources are stressed in the Wami River Basin. The analysis also illustrates how the Water Evaluation and Planning system can be useful in water resource management and planning.
- *Household food security:* The analysis is based on the National Panel Survey of Tanzania for 2008/2009, a country representative dataset and investigates the impacts of increasing maize and cassava prices, the two main food crops. The analysis indicates that the urban poor and rural female headed households are the most vulnerable to increases in the price of maize. Poor households in rural areas, poor land owners in rural areas and male headed households in rural areas can benefit from the price increases. Overall, households are not particularly vulnerable

to cassava price changes. The rural poor that own land and are male headed, slightly benefit from cassava price increases. It is recommended that fluctuations in the prices of the key food staples, and most importantly in the price of maize, should be closely monitored.

RECOMMENDATIONS

The results of the analysis included herein and that of the BEFS Tanzania I analysis, highlight key areas where the government of Tanzania could integrate energy and agriculture goals to enhance energy and food security jointly. The following recommendations are a result of the work undertaken in the country.

- **Prioritize crop production with diversified markets, and bioenergy technologies that enhance local access to energy while providing income generating opportunities:** Crops that can serve both energy and food markets provide investors, growers, and local communities involved in the supply chain with diversified market opportunities, and thus are associated with lower risk and more stable income. As the sunflower analysis has illustrated, growers could benefit from high edible oil prices, while processors could potentially reduce costs by powering facilities from sunflower husks or other biomass residues. Integrating energy and food production can contribute to energy security, food security, and poverty reduction goals.
- **Prioritize smallholder involvement/inclusion schemes:** With over 85% of arable land owned by smallholders, there is significant potential for smallholder inclusion in new investment schemes. However, Tanzania does not currently have strong farmer organizations and there is substantial capacity building and institutional strengthening required to enhance smallholders' ability to participate in new investment schemes and to increase productivity. CAADP includes a target of 6% growth in agricultural productivity but does not specify what strategies should be put in place to meet this target. In order to achieve poverty reduction goals, the potential strategies should be smallholder inclusive
- **Prioritize capacity building on good agricultural practices:** Capacity building efforts and extension services should include training and education on agriculture practices to maintain soil fertility, decrease run-off, and reduce pressure on water resources. By improving soil fertility and water utilization, yields could increase significantly, even before considering enhanced fertilizer inputs.
- **Improve water resource management through enhanced data collection and implementation of integrated planning:** Given Tanzania's largely smallholder based agricultural economy, expansion of irrigation capacity could significantly improve productivity. However, in many areas demand from agricultural expansion, including bioenergy investment, will exceed current and projected supply. Improving data collection and availability will help to inform water resource management strategies. At the same time, greater coordination among various sectors (agriculture, energy, industry, etc.) is required in order to address competing

priorities for scarce water resources.

- **Develop social safety nets for urban landless poor and female rural headed households to ensure food security is maintained in the case of increasing food prices:** The two most vulnerable groups to food price increases may still experience food insecurity or welfare loss even with enhanced investment in agriculture and rural development. Specific measures targeted at these most vulnerable groups will help to ensure food security.

It is important that the debate moves forward from the past few years' focus on food versus fuel and energy security versus food security. Bioenergy development can be, and should be, complimentary to food security especially when investment can benefit local energy and food markets. The focus on bioenergy over the last few years has often been on liquid biofuels for export versus local food production, whereas there are many opportunities for local bioenergy production and for food production for both local and export markets (ie. sunflower, sugarcane, oil palm, etc.). Each country needs to determine what type of bioenergy, where it should be grown, and with whom and for whom; in order to address the country specific challenges of food and energy security. The information and awareness generated through the BEFS analysis seeks to contribute to answering these questions and providing the basis for informed sustainable development.

CHAPTER 1

TECHNICAL AND ECONOMIC ANALYSIS FOR BIOFUEL PRODUCTION FROM SUNFLOWER

Oscar Kibazohi[a], Luis Eduardo Rincon Perez[b], Erika Felix[c] and Carlos Ariel Cardona Alzate[b]

1. INTRODUCTION

A number of crops can be used for both food and bioenergy production such as sunflower. Under some circumstances, the potential exists to develop bioenergy systems that allow for synergies between food and energy production. Integrated food and energy systems (IFES) could produce food crops while simultaneously addressing energy needs (Bogdanski et. al, 2010). The land suitability assessment conducted during the first phase of the Bioenergy and Food Security (BEFS) project, identified sunflower as one of the crops with high agroclimatic and soil suitability in Tanzania (FAO, 2010).

Sunflower is one of the major oilseeds produced in Tanzania, accounting for 36 percent of national oilseed production (RDLC, 2008). According to the Ministry of Agriculture, Food Security and Cooperative (MAFSC), in past years the estimated annual production has been around 350,000 tonnes of sunflower oilseeds corresponding to about 90,000 tonnes of oil per year (Ministry of industry, Trade and Market, 2009 and RDLC, 2008). Sunflower is mostly grown by small-scale farmers throughout the country; therefore development of the sunflower sector has a great potential for improving livelihoods and the welfare of poor households in Tanzania (Colombia University, 2010).

A number of sunflower value chain studies in different regions of the country have indicated that the production volumes are relatively low compared to the potential (Gabagami and George, 2010; Business Care Services Limited and Center for Sustainable Development Initiatives, 2012; Match Maker Associated Ltd, 2009 and 2010). Under prevailing farming practices, the national average yield per ha is relatively low at around 0.3 tonne from a yield potential of as high as 2 to 3 tonnes per ha (FAO, 2010; Gabagami and George, 2010; Match Maker Associated Ltd, 2009 and 2010). The factors affecting sunflower productivity include poor agronomic practices, affordability of improved seed varieties, lack of access to inputs including fertilizer, manure, disease and pest control chemicals, and adequate machinery, limited or no access to extension services, an unreliable market and low prices for seed among others (Business Care Services Limited and Center for Sustainable Development Initiatives, 2012). As such, sunflower is an untapped sector with significant potential and its relatively poor productivity is a strong argument for the government to find a range of measures to boost this sector and to support rural development in general.

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The bioenergy sector can be one new economic activity that can bring much needed investment to raise sunflower productivity for the benefits of food security while also meeting energy needs. The objective of this study is to assess if bioenergy produced from sunflower can be cost competitive with the participation of smallholders as feedstock providers. The report is organized into four sections. The first section provides a general overview on edible oil and the energy situation in Tanzania. The second section covers the approach and methodological aspects. The third section discusses the results and the last section presents the conclusions and recommendations.

2. NATIONAL CONSUMPTION OF EDIBLE OIL AND FOSSIL FUEL

According to the Rural Livelihood Development Company (RLDC) report (2008), the production of oilseeds in Tanzania is mainly focused on ground nuts (40 percent), sunflower (36 percent), sesame (15 percent), cotton (8 percent), and palm oil (1 percent). Although there has been a significant increase in domestic edible oil production, Tanzania continues to be a net importer of edible oil. In recent years, edible oil imports for crude palm oil and other crude vegetable oils have been around 140,000 to 170,000 tonnes annually (*Table 1*). Edible oil imports have become the second largest import expenditure in the country as a result of higher prices of palm oil (Business Care Services Limited & Centre for Sustainable Development Initiatives, 2012).

Table 1

Imports of edible vegetable oil (tonne per year)

Year	2006	2007	2008	2009	2010	2011
Crude soybean oil	639	17,302	12,002	7,966	17,127	14,389
Crude palm oil	165,374	3,000	48,654	126,151	125,851	146,473
Crude sunflower seed and safflower oil	6,500	1,825	90	4,247	4,308	3,920
Total	172,515	22,129	60,747	138,365	147,288	164,784

Source: Tanzania Revenue Authority

Demand for vegetable oil is growing with the rate of population growth. Based on FAO's recommended minimum annual per capita consumption of 5 kg of vegetable oil, Tanzania's national requirements for edible oil are estimated to be round 185,000 tonnes per year[1]. Sunflower oil is the preferred cooking oil by many Tanzanians; however the domestic supply chain has not yet matched the existing demand. The main barriers for the development of the sunflower sector are its low productivity and the informal market arrangements that make it difficult to compete on price with cheaper imported edible oils. For example, in the Iringa region, the price of imported oil is competitive against locally produced oil despite the additional transportation cost for moving the product almost 500 km inland (Business Care Services Limited & Centre for Sustainable Development Initiatives, 2012).

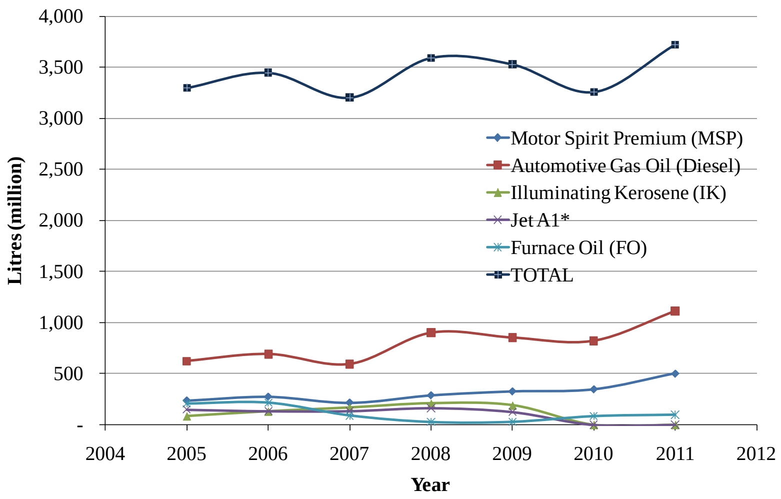
1 There are no reliable figures available and it is likely that the actual national demand is much higher.

The potential for domestically produced sunflower to meet national edible oil demand is significant given the evenly distributed agroclimatic and soil suitability across the country. The results from the BEFS Analysis Phase I indicated that sustainable intensification through the use of conservation agricultural practices combined with higher inputs for example, can produce more than 100 million tonnes of sunflower seed corresponding to roughly 35 million tonnes[2] of vegetable oil (FAO, 2010). Note that this rough estimate is significantly higher than the national quantities needed to supply the domestic edible oil demand.

Tanzania is also a net importer of fossil fuels. Petroleum-based fuels are the largest import expenditure in the country. The petroleum import bill is estimated at US$ 160 million per year, accounting for 30 percent of the country's foreign currency earnings and constitutes about 8 percent of total national imports (REEP, 2012). Tanzania currently imports more than 1.1 billion litres of diesel annually with demand growing. Over the past 10 years, the quantity of imported diesel has almost doubled from 623 million litres in 2005 to 1.1 billion in 2011 as shown in Figure 1 and Annex 1.

Figure 1

Imported fuels, Tanzania



Although national diesel consumption is driven primarily by the transport sector, diesel is also widely used in off–grid diesel power factories, particularly in rural areas (Ahlborg&Hammar, 2010). Tanzania has very low rural electrification rates, only about 2 percent of the rural population have access to electricity (DIFID et. al, 2010). Off-grid power generation is seen as a viable option to increase energy access in the country. However, the high cost of diesel can make this prohibitive and unaffordable for rural communities. The use of biofuel in off-grid diesel systems, if cultivated locally and sustainably, can potentially provide electricity at lower running costs. Moreover, additional sources of income for small farmers would be generated if the required oilseeds

2 This is a rough estimate based on a 35% oil content per tonne of sunflower seed and does not account for potential efficiencies in extraction and processing.

are produced on a small share of the available agricultural land or through intercropping. Beyond using biofuels in a diesel engine to produce electricity, biofuels can also be used directly to power agroprocessing machines.

At the national level, domestically produced biofuels could offset oil imports, thereby 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 feedstock.

Tanzania has the potential to become a top producer of sunflower oil, and meet its national edible oil demand while producing excess vegetable oil for export or for production of bioenergy. In this context, sunflower production can enhance both national food and energy security through reduced fossil fuel and edible oil imports. In considering this alternative, the government of Tanzania will have to carefully balance the food security and energy security concerns by ensuring that production of both food and bioenergy is done through the sustainable use of land, water, and farming resources and with the participation of small-scale farmers.

3. METHODOLOGICAL APPROACH

The analysis aims to establish production cost profiles for biodiesel derived from sunflower seeds. This paper analyses production costs of straight vegetable oil (SVO) and biodiesel from sunflower. A stylized description of the sunflower bioenergy production chain is presented in Figure 2. The production cost analysis follows the logic of the production chain. It first defines the origin of the feedstock (outgrowers or outgrowers and estate schemes[3]), identifies the type of bioenergy processing technology employed and establishes the scale of production. Within the analysis scenarios are identified to determine how much fuel is to be produced, how much feedstock or raw material is needed and who supplies the material.

In this study, it is assumed that there is an agreement between the small farmers and the biofuel processor and no middleman is part of the transaction. Therefore, the analysis starts by establishing the current market price per tonne of raw material, in this case sunflower seed. The information was obtained from secondary information from sunflower oil producers and the national value chain analysis that indicated a price of around 307 US$ per tonne at the factory gate (Mizuno and Mhede, 2012)[45]. This information was the basis to determine the potential price paid by processers to outgrowers. The cost for vegetable oil expression and degumming and the costs for transformation of the oil to biodiesel were computed based on the selected biofuel processing technologies and scale of production.

3 Outgrowers refer to smallholder farmers. Estate are commercial level agricultural producers. Outgrower schemes involve a production set up where a portion of feedstock or raw material is supplied by smallholders and the reminder by the large-scale commercial production.

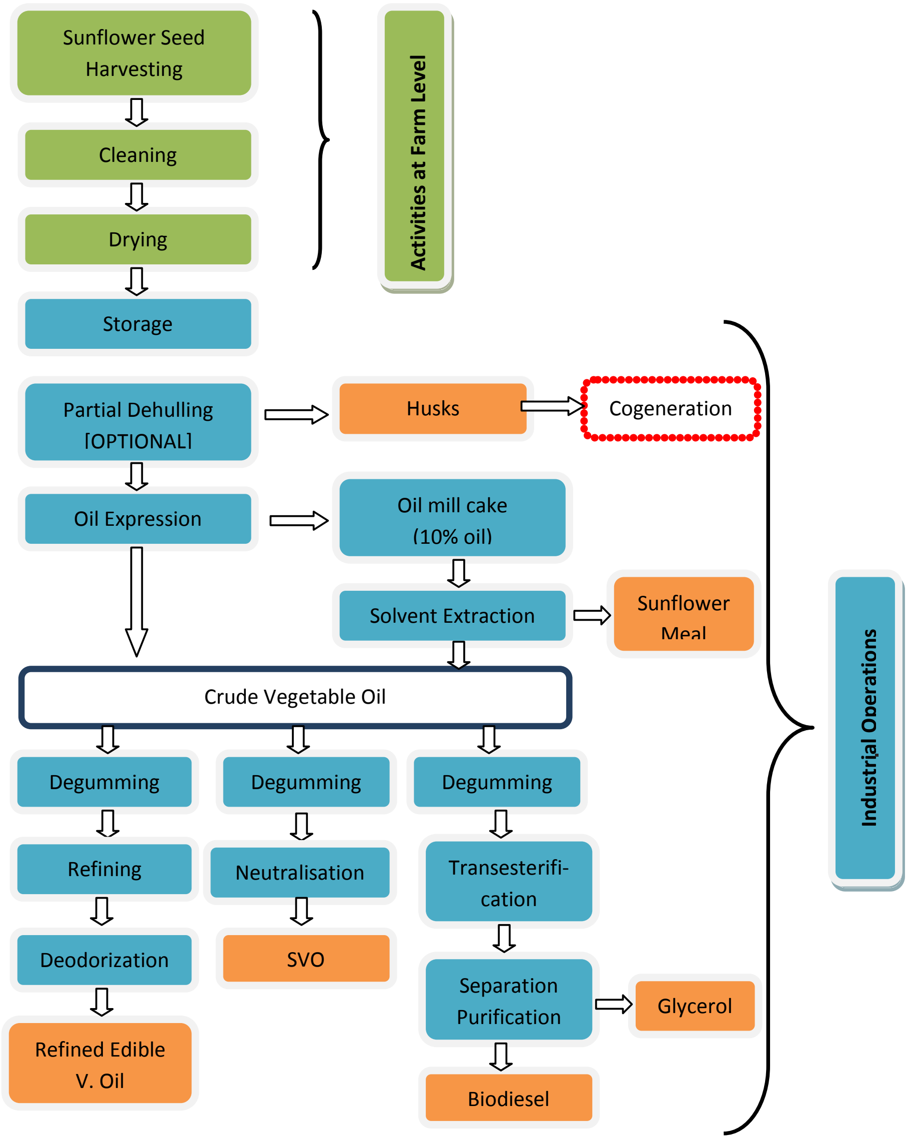
4 The term factory and processing facility is used interchangeably. Both imply the technology conversion of the sunflower seed to the desired biofuel.

5 Information provided by Ringo Iringo Company who indicated that a price of 30,000 Tanzanian Shillings per bag of sunflower seed delivered at factory gate is paid to smallholders. The bag weight is assumed to be on average 65 kg. Exchange rate is 1US$ to 1500 Tanzanian Shillings. This was also reported as potential price paid in Dodoma. http://www.repoa.or.tz/documents/S1B.pdf

Revenue generated from the production and sale or use of by-products, namely sunflower meal for animal feed, glycerol from biodiesel processing, and electricity cogeneration from husks, is also considered.

Figure 2

Stylized flow diagramme for the production of refined edible oil, SVO and biodiesel from Sunflower



3.1 TECHNOLOGY CONSIDERATION

There are various options for utilizing vegetable oils in diesel internal combustion engines (Nowatzki et al, 2007). Two primary options are straight vegetable oil (SVO) where the vegetable oil is used directly, and biodiesel, where vegetable oil undergoes chemical transformation (transesterification). SVO will burn in a diesel engine but only if its viscosity (the thickness of a liquid) is brought down to a level similar to petro-diesel. In order to address this problem, modifications to the engine or fuel system are required, for example by adding a heating mechanism to the fuel line or tank. Alternatively, a second option is to convert the SVO into biodiesel. Biodiesel does not require engine modifications. This report analyses the feasibility of both SVO and biodiesel production at small-scale facilities, and biodiesel production at large-scale facilities.

When SVO is used directly, the quality of the oil is crucial. Apart from other physical properties such as viscosity, gums in vegetable oils must be removed to avoid caking in the engine. Sunflower oil contains high amounts of gums (phospholipids), ranging from 0.5 percent when produced by cold expression to 1.2 percent when produced by solvent extraction. For SVO produced from sunflower, the amount of gums (Phospholipids) must be reduced so that the phosphorus content, a component of the phospholipids, is below 0.0015 percent. The technology proposed for sunflower oil production is cold expression for small-scale operations and solvent extraction for large-scale operations. Degumming is performed by heating the oil with water and acids. Another quality parameter of the SVO is the free fatty acids that may cause engine corrosion. The free fatty acids must be neutralized and removed from the oil during preparation of the SVO (Diligent, 2006).

Biodiesel production entails breaking down the large oil molecules by transesterification reaction into relatively smaller ones (biodiesel) that have lower viscosity, and are more similar to petroleum diesel (Nowatzki et al, 2007). In conventional processes, transesterification is achieved by reacting alcohol (usually methanol or ethanol) with acid in the presence of a catalyst, usually mineral acid or alkali of sodium or potassium. The alkali catalysed process is usually faster and preferred to the acid catalysed process. The reaction produces biodiesel and glycerol that settle, forming two different layers that can be separated by decanting or centrifugation. The biodiesel portion is then heated to remove excess alcohol, washed with water to remove traces of glycerol and dried by heating to produce pure biodiesel. Alternatively, after transesterification, a water free purification process can be used where crude biodiesel is passed through a column of special adsorbent material which immobilises glycerol and alcohol to produce pure biodiesel (Diligent, 2006)

Both SVO and biodiesel production technologies described above are first generation biofuel technologies, which are simple and accessible in Tanzania. Engineers graduating from local universities can manage the implementation and maintenance of the technologies after short-term training. However, some equipment for biodiesel production will have to be imported and the chemical supply chain must be strengthened to ensure smooth availability of chemicals.

3.2 SCALE OF OPERATIONS

The selection of the biofuel factory scale is based on potential production schemes given the conditions in Tanzania. One consideration for defining the scale is that the increased cost from the transportation of feedstock may outweigh economies of scale for larger-scale factories. This is particularly relevant for Tanzania given the limited transportation infrastructure in rural areas and the high transport costs in the country. Hauling feedstock for long distances can become prohibitive for small-scale farmers and too costly for biofuel processors. Estimates suggest that feedstock transportation of less than 50 km is preferable to guarantee cost competitiveness (Ashworth, 2004). Possible transportation barriers and feedstock production potential were considered in defining the scales of processing facilities that could be feasible. The proposed scales of production are 1) a facility producing 500,000 litres of SVO; 2) a 22 million litre factory producing biodiesel; and a 44 million litre integrated edible oil-biodiesel factory.

3.3 SCENARIOS

Four different scenarios were developed based on country specific data and to reflect the potential suitable options of biofuel production in the country. The scenarios are summarized in *Table 2*.

Scenario 1 consists of small-scale straight vegetable oil production. The feedstock originates from outgrowers and the factory capacity is about 500,000 litres per year. Vegetable oil production is a less intensive operation than biodiesel production. It limits the need for additional staff and for additional chemicals and can be a more suitable option for rural areas in Tanzania. The aim of scenario 1 is to assess if SVO can be a competitive alternative to displace local consumption of diesel in off-site power generators.

Scenario 2 consists of small-scale biodiesel production. The feedstock originates from outgrowers and the factory capacity is about 500,000 litres per year. The smallholders bring their seeds to the factory. The biodiesel can be used directly in modified diesel engines to run diesel generators, on farm machinery and in trucks in rural areas. It can also be used to supply local needs such as meeting biofuel blending mandates.

In scenarios 1 and 2, the price paid at the factory gate to the outgrower per tonne of sunflower seed is assumed to be 307 US$ based on current average national sunflower prices of 20 US$ paid per bag and assuming 65 kg per bag. A major problem with the sunflower sector in the country is the fact that the price is paid by volume instead of by weight, which results in farmers often not being compensated adequately. Establishing collection points and equipping them with weighing scales will make the process more transparent and ensure fairer transactions. The collection points may be owned and managed by farmer groups or the buyer or a combination of both.

Scenario 3 examines medium-scale production of biodiesel. The factory capacity is about 20 million litres per year. In this case, 40 percent of the feedstock originates from outgrowers and the other 60 percent is produced by the estate. The objective of this scenario is to assess if biodiesel can be produced competitively with the participation of smallholders, to supply feedstock to help meet a given national biodiesel blending mandate.

Scenario 4 is similar to scenario 4 but it combines both the production of edible oil and biodiesel in one factory. Sunflower oil, due to its lower cholesterol level, is considered one of the best edible vegetable oils, and currently demands a much higher price than the price that would be received for processing into biodiesel. Therefore, the objective is to assess if a processing facility with the capability of producing both edible and biodiesel is a competitive option for Tanzania.

Table 2

Biofuel production scenarios simulated in this study

Scenario	Origin of Feedstock	Biofuel Processing	By Products
1	100 percent from outgrowers	500,000 litres per year of straight vegetable oil Price paid to outgrowers for feedstock is 307 US$ per tonne at factory gate. Extraction by mechanical press.	Sunflower meal
2	100 percent from outgrowers	500,000 litres per year of biodiesel Price paid to outgrowers for feedstock is 307 US$ per tonne at factory gate. Batch reactor, extraction by mechanical press, 50 percent methanol recovery, sodium hydroxide catalyst, vacuum distillation, sedimentation and washing.	Sunflower meal low quality glycerol
3	40 percent from outgrowers 60 percent from Estate	22 million litres per year of biodiesel Raw material cost at factory is 212 US$ per tonne at factory gate. This is based on a combination of 307 US$ per tonne price paid to outgrower, and estimated 150 US$ per tonne cost for estate feedstock production. Batch reactor, solvent extraction with hexane, 50 percent methanol recovery, sodium hydroxide catalyst, vacuum distillation, sedimentation and washing.	Sunflower meal, co-generation, low quality glycerol
4	40 percent from outgrowers 60 percent from Estate	Integrated facility 44 million litres per year, 50 percent both biodiesel and edible oil Raw material cost at factory is 212 US$ per tonne at factory gate. This is based on a combination of 307 US$ per tonne price paid to outgrower and estimated 150 US$ per tonne cost for estate feedstock production. Batch reactor, solvent extraction with hexane, 50 percent methanol recovery, sodium hydroxide catalyst, vacuum distillation, sedimentation and washing.	Sunflower meal, co-generation, low quality glycerol

The estimated cost of the raw material at factory for *scenarios 3 and 4* is estimated to be 212 US$ per tonne. This is calculated using a combination of the 307 US$ per tonne price paid to the outgrowers and an estimated US$ 150 per tonne for estate production[6]. All scenarios will generate co-products that can be an additional stream of revenue if sold into the market. Three co-products are considered in the scenarios, glycerol, sunflower meal for animal feed, and potential surplus of bio-electricity. The potential sale price for these co-products are based on national data. The sale price for sunflower meal is estimated to

6 The production costs were estimated based on the sunflower production experience by Ephata Ministry in Sumbawanga. Personal communications from Oscar Kibazhoi with the Ministry.

be around 57 US$ per tonne[7] (Business Care Services Limited, 2012). The potential sale price for glycerol is 200 US$ per tonne.[8] The potential price for surplus electricity from co-generation considered in the analysis is 26.5USc/kWh (University of Cape Town, 2010).

4. RESULTS AND DISCUSSION

Based on the scenarios analysed and assuming a fixed market price for sunflower feedstock, the results indicate that the cost of oil-based biofuels in Tanzania ranges from 1.07 to as much as 1.30 US$ per litre depending on the end product, the co-product market, the type of processing technology employed, and the scale of production. In scenario 1, the estimated production cost for straight vegetable oil for the smaller scale facility with mechanical oil extraction is 1.07 US$ per litre. In scenario 2, the production of biodiesel for a small-scale facility with mechanical oil extraction is 1.30 US$ per litre. The production cost for a medium-scale facility with solvent extraction is 1.23 US$ per litre in scenario 4. In scenario 3, the co-production of both edible and biodiesel in a medium factory facility results in an estimated production cost of biodiesel of about 1.09 US$ per litre (*Table 3*).

Table 3

Production cost for Biodiesel and SVO

Scenario	Biofuel	Cost of production (US$ per litre)
Scenario 1	SVO	1.07
Scenario 2	Biodiesel	1.30
Scenario 3	Biodiesel	1.23
Scenario 4	Biodiesel	1.09

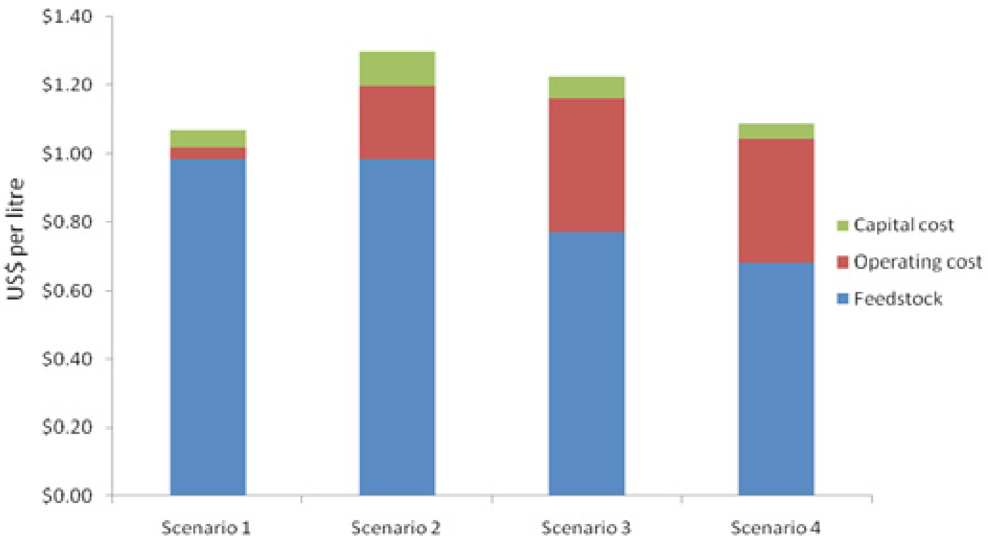
In reviewing the cost of production, as shown in Figure 3, it quickly becomes apparent that the feedstock contributes the largest percentage of the cost to all scenarios. In scenarios 3 and 4, the portion of the feedstock cost is greatly reduced as a result of the scale of production being 45 times larger than scenarios 1 and 2. This is mainly due to vertical integration and the selection of a more efficient processing technology. In both scenarios 3 and 4, it is assumed that 60 percent of the feedstock comes from estate production while the remaining 40 percent from outgrowers. Increasing vertical integration reduces the feedstock cost by 95 US$ per tonne when compared to 100 percent feedstock supplied by outgrowers in scenarios 1 and 2. Secondly, in scenarios 3 and 4, oil extraction is performed by chemical solvent extraction rather than mechanical processing. Solvent extraction is a more efficient method with typically only about 1.2 percent residual oil left in the meal compared to 7.2 percent for mechanical operations (Hammond, et. al, 2005).

7 Prices range from Tsh 70 to 100 per kg. The price was calculated assuming an average of Tsh 85 per kg and Tsh 1500 per 1 US$.
8 The price of glycerol in the global market ranges from $450 to $1000 per tonne. In this case it was set at $200 per tonne due to poor quality of glycerol from biodiesel production.

In the case of the capital and operating costs for similar scales of production for SVO and biodiesel, in scenarios 1 and 2 respectively, the production costs are significantly less for SVO. This is mainly attributed to the additional cost of about 0.23 US$ per litre for machinery and chemical inputs (i.e. methanol and catalysts) needed for the transesterification in the biodiesel process in scenario 2. Comparing production costs of biodiesel production between scenario 2 and scenario 3, the cost is about 7 US$ cents per litre lower for Scenario 3. This is in part attributed to the economies of scale. In Scenario 3 and 4, both produce the same quantity of biodiesel but the cost of production of biodiesel in scenario 3 is about 13 cents higher per litre. The key difference between these two scenarios is that in scenario 4 the facility produces both biodiesel and edible oil. This diversification makes biodiesel production more cost effective.

Figure 3

Estimated cost of Biofuel Production for all Scenarios[9]



WHAT DOES THIS MEAN FOR TANZANIA?

A key question is the potential indicative prices for SVO and biodiesel and how these may compare with diesel prices. The Energy and Water Utilities Regulatory Authority (EWURA) in Tanzania regulates prices on petroleum products. Under the EWURA Act, Cap. 414 and Section 31 of the Petroleum Act, No 4 of 2008, EWURA is authorized to establish rates and charges to determine petroleum pricing. The Agency uses a petroleum pricing formula and amends it as necessary[10]. According to their July 2012 publication, the average price of diesel is about 1.43 US$, with the price rising in areas beyond the ports.

9 For Scenario 4 which is an integrated 40 million litre plant producing 50% edible oil and 50% biodiesel. The portion attributed to the cost of producing biodiesel is based on the mass balance of the two products, where edible oil represents 52% and biodiesel 48%.
10 For more information refer to http://www.ewura.com/pdf/public%20notices/petroleum/notice-pricing%20formula-final%20version.pdf

For example in Kigoma it is about 1.51 US$ per litre. From a basic comparison on a litre by litre basis, the estimated costs of production for all scenarios are lower than the diesel market price. However, this comparison is not appropriate as SVO and biodiesel have about 5 and 8 percent less energy than diesel, respectively (Bettis, et. al 1983 and NREL, 2009). The price of diesel also includes additional regulatory and fiscal fees. Tanzania currently has no biofuel policy and therefore taxation is not yet established. Considering that taxes on conventional fuel are a significant source of revenue collection for Tanzania, it could be assumed that the same level of taxation is to be implemented for biofuels.

According to EWURA's computational formula for indicative prices for petroleum products, taxes are estimated at around 0.35 US$ per litre of diesel (EWURA, 2008). EWURA's indicative prices also stipulate an estimated profit margin for fuel dealers of about 0.09 US$ per litre. Potential indicative diesel-equivalent prices for SVO and biodiesel are estimated using their production costs as a base, taking account of the energy basis and adding the regulatory and fiscal fees. The diesel-equivalent indicative prices for SVO and biodiesel are computed for each of the scenarios and are assessed against current diesel prices at the pump. The results for each scenario are discussed below.

Scenario 1

The cost for producing SVO in a small-scale decentralized facility assuming a price of 307 US$ per tonne for sunflower feedstock from outgrowers is estimated to be about 1.07 US$ per litre. On a volume basis, the cost of producing 1 litre of SVO cost is 25 percent less than the current price of 1 litre of diesel. If the authorized profit margin and estimated transport cost stipulated by EWURA for petroleum fuels are included, then the price of SVO could be 1.17 US$ per litre. Considering an energy reduction of 5 percent for SVO compared to diesel fuel (Bettis et al, 1982), then the equivalent price in energy-basis for one litre of SVO is 1.23 US$. If the same taxes that are applied to diesel are added to SVO, the price of 1 litre of SVO is 1.57 US$. This potential indicative SVO price per litre in Tanzania is 9 percent higher than the average retail price of diesel[11].

However, the production process also generates about 1 158 tonnes of sunflower meal that can be sold for animal feed. The sunflower meal price in Tanzania is estimated to be 57 US$ per tonne (Business Care Services Limited, 2012). The sale of sunflower meal can be an additional source of revenue estimated at about 0.12 US$ per litre of oil[12]. This additional revenue can improve the competitiveness of the production system. The SVO market price applying full taxation is 1.45 US$ per litre, which is slightly higher than current diesel prices. In this case, the additional revenue is not sufficient to compete with the national average diesel market prices. However, in rural areas like Kigoma where the pump price of diesel is higher i.e. 1.51 US$ per litre, the SVO could be competitive.

If the SVO market price is established at the energy equivalent without any taxation,

11 See Annex 3 for more detailed calculations.

12 The sale of co-products is treated as credits. This is based on the assumption that the sale of this co-product avoids cost for waste disposal. In this case, the sale price or revenue is considered a proxy for the reduction in the production cost deriving from waste disposal. Note that in the text the term revenue is meant to indicate a credit.

then the potential indicative price will be about 1.10 US$ per litre, which will make it a viable alternative particularly in rural areas (*Table 4*). It is noteworthy to mention that the government has recently reduced the excise duty for kerosene. Kerosene is the prime source of energy for lighting and the second most common source for cooking after charcoal (Maliti, E. and Mnenwa. 2011). One of the aims of this measure is to reduce the environmentally harmful use of charcoal and firewood (Diligent, 2006). Considering SVO as a potential alternative for energy in off-grid rural communities, the government may want to consider similar tax relief for SVO.

Scenario 2

The cost for producing biodiesel in a small-scale decentralized facility is estimated to be about 1.30 US$ per litre. Adding the authorized profit margin of about 0.09 US$, the transport cost of 0.01 US$ and 0.35 US$ per litre tax as stipulated by EWURA for petroleum fuels, and considering the 8 percent less energy in biodiesel, the indicative price for one litre of biodiesel is then 1.86 US$. This is 30 percent higher than the average retail price of diesel. Accounting for credits from co-products namely sunflower meal and glycerol generates around 0.12 and 0.02 US$ per litre, respectively. By considering this additional revenue, the competitiveness of the production system can improve to a potential indicative price of about 1.71 US$ per litre, but the revenue is still not sufficient to make biodiesel competitive with the diesel market prices.

Table 4

Potential indicative market prices for SVO and Biodiesel using the production cost for each scenario as a base and adding current petroleum fees

Assumptions	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Without Co-products				
Option A: Indicative prices all included	$1.57	$1.86	$1.78	$1.63
Option B: Indicative prices no tax	$1.23	$1.51	$1.43	$1.28
With Co-products				
Option C: Indicative prices all included	$1.45	$1.71	$1.68	$1.28
Option D: Indicative prices no tax	$1.10	$1.36	$1.33	$1.11

Scenario 3

This scenario simulates the production of 22 million litres of biodiesel per year using solvent extraction and feedstock supply from estate and outgrowers at 60:40 ratio. The cost of producing one litre of biodiesel under these conditions is estimated at 1.23 US$. Once the profit margin, transport and tax are added and the energy basis is taken into account, a potential indicative diesel-equivalent price is 1.78 US$. This is 24 percent higher than the average retail price of diesel. Accounting revenue from co-products namely sunflower meal and glycerol generates a potential indicative price of about 1.68 US$ per litre. This improves the competitiveness of the production system but the revenue is still not sufficient to make diesel competitive with the diesel market prices. If taxes were to be discontinued, the indicative price for this scenario is the same as current diesel prices, 1.43 US$ per litre (*Table 4*). In this scenario, co-generation of heat and electricity was also assessed. The volume of seed husks available for combustion could only supply about half of the energy requirements of the factory. The results indicated that this does not make a difference on the production costs. The cost of the co-generation equipment could not justify the benefits of the co-generation.

Scenario 4

Combining the production of both edible oil and biodiesel in a 44 million litre per year facility, producing 50 percent biodiesel indicates that the cost of production for one litre of biodiesel is 1.09 US$. The advantage is the capability of producing two marketable products rather than a single one, which reduces the risk of potential market fluctuations. A potential indicative market price of 1.63 US$ diesel-equivalent[13] is estimated. This is still 20 cents higher than the current diesel market price. This scenario like scenario 3 includes co-generation of heat and power. In this case there are sufficient residual husks to meet the energy requirements of the facility and to actually generate a surplus. Taking into consideration the savings from electricity and the revenue from co-products, namely sunflower meal, glycerol, and co-generation, a potential indicative diesel-equivalent price is 1.11 US$ per litre. The credits from co-products improves the competitiveness of the production system.

Biodiesel is used primarily as a fuel additive and is seldom used in 100 percent form. Therefore, to more adequately analyse the competitiveness of biodiesel from sunflower, the price of various blends at the pump should be assessed. Since at present there is no blending mandate for biodiesel in Tanzania, a 10 percent blending target is assumed. Table 4 illustrates the added cost to the retail price of fuel when biodiesel is blended with diesel at 10 percent rate. For example, considering the indicative price for biodiesel without any taxes and co-products of 1.11 US$ per litre (*Table 4, Scenario 4, Option D*) and the 10 percent blended fuel price at the pump, this could be reduced by as much as 4 cents per litre (*Table 5, Line 2*). On the other hand, considering an indicative price for biodiesel with taxes and without co-products of 1.86 US$ per litre (*Table 4, scenario 2, Option A*), then the retail price for a 10 percent blending mandate increases from 3 to as much as 6 cents per litre (Table 5, line 7). The take home message is that the added cost to the retail price for a 10 percent blend is relatively small.

13 Diesel-equivalent includes EWURA's stipulation for profit margin, transport and tax and the energy-basis equivalent.

Table 5

Added cost to retail price of Diesel Fuel when blended with 10 percent Biodiesel

Scenario	Option	Biodiesel Cost per liter	Retail price of Diesel per Liter		
		100 percent	$1.35	$1.45	$1.55
4	D	$1.11	-$0.02	-$0.03	-$0.04
4	C	$1.16	-$0.02	-$0.03	-$0.04
3	D	$1.33	$0.00	-$0.01	-$0.02
2	B	$1.51	$0.03	$0.02	-$0.02
3	C	$1.68	$0.03	$0.02	$0.01
2	C	$1.71	$0.03	$0.02	$0.01
2	A	$1.86	$0.05	$0.04	$0.03

CHALLENGES AND OPPORTUNITIES

What are the feedstock supply issues? It is difficult to establish exact data about the economics of sunflower production in Tanzania due to the variations in cost in different locations (Gabagami and George, 2010). Moreover, the sunflower seed market in Tanzania is not well-developed and there are vast price fluctuations. Prices between harvest and off-harvest seasons can vary as much as 400 percent, not taking into account annual fluctuations and unreliable producer-middlemen connections (Matchmaker, 2009). This affects food security in two ways, first from higher prices of edible oil to consumers; and secondly by hindering a consistent stream of income for small farmers who grow sunflower. Likewise, the continuous fluctuation of raw material cost is a significant factor in the viability of oil processors, be they for edible oil or biofuel. As indicated previously, the feedstock price is the principal contributor to the overall biofuel production cost and can therefore have a significant impact on the viability of the sector. In this analysis a price at factory gate of 307 US$ per tonne for sunflower seeds[14] is assumed. However, if this price were to increase, then the production cost for SVO and biodiesel may not be able to compete with prices of diesel. If Tanzania decides to pursue SVO and biodiesel from sunflower, significant efforts will be required to ensure reliable supply and reasonable market prices for both farmers and processors.

Can outgrowers (smallholders) profit from selling their seeds to at 307 US$ per tonne? Using data from a number of sunflower value chain studies (Gabagami and George, 2010; Business Care Services Limited and Center for Sustainable Development Initiatives, 2012; Match Maker Associated Ltd, 2009 and 2010), profiles of probable current sunflower

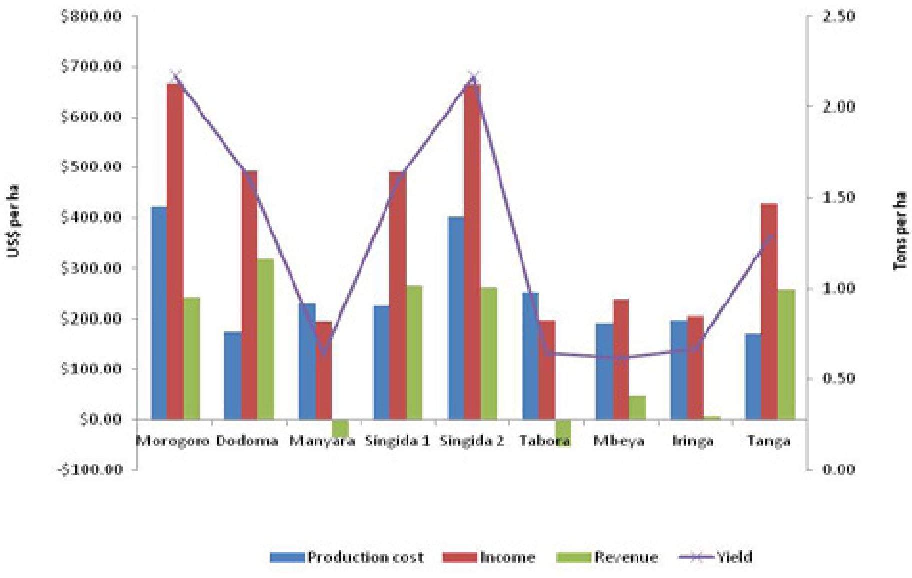
14 The estimated national price for a bag of sunflower is 30,000tsh. This is about 20 US$ per bag and the bag weight is assumed to be 65 kg per bag.

seed production conditions for outgrowers in terms of production cost and yields[15] are complied (Annex 4). Secondary data come from different areas of the country and capture more or less the peculiarity of the production systems in each of the regions. These are used to assess if the biofuel sector can promote income generation from selling the sunflower at this reference price. A number of assumptions, detailed in Annex 4, were made; therefore the results should only be seen as indicative and are only used to demonstrate potential tendencies.

In *figure 4*, production systems in Morogoro, Dodoma and Singida apply chemicals and manure in their production systems or use improved seed leading to higher yields. Therefore, under our price assumption these farmers can profit from selling their seeds to the biofuel industry. Farmers with lower productivity in Mbeya and Iringa will be able to make a small profit. For farmers in Manyara and Tabora the returns are negative. This confirms that as in any other agricultural commodity, for farmers to capitalize on sunflower, they will need to improve productivity. Gabagambi and George (2010) indicated that in the case of Tabora (Igunga) there was only one buyer, without appreciable competition, paying a significantly low price for seeds. The biofuel sector can be one alternative market which could increase demand and bring much needed investment into areas like Tabora to trigger improvements in productivity and improve conditions for smallholders.

Figure 4

Potential revenue for outgrowers from selling sunflower seeds to biofuel market at price of 307 US$ per tonne



Sources: Gabagami and George, 2010; Business Care Services Limited and Center for Sustainable Development Initiatives, 2012; Match Maker Associated Ltd, 2009 and 2010.

15 Note that certain assumptions on yields were made to get the values in US$/tonne as most of the value chains provided the cost in per ha basis. The yields were based on characteristics indicated in the same reports, for example Gabagami and George,(2010) indicated under traditional farming practices and use of local seeds that the yield is in the range of 0.64 tonnes per ha, With the use of improved seeds and good agronomic practices this can increase to 1.6 tonnes per ha, and if chemical inputs are used the yield can be as high as 2.1 tonnes per ha, see Annex 4 for more details.

Findings from a BEFSCI (FAO, 2011) study on Smallholders in Global Bioenergy chains indicate that a number of actions can be taken to improve conditions for smallholders. Actions include establishing a minimum structure for group formation and management of farmers; government incentives to producers who incorporate smallholders into their value chain; processors and smallholders working together to achieve long-term sustainability of the business and that the business model should be tailored to local conditions and specific challenges.

There is already significant ongoing work on improving the sunflower market that can be directly applicable to the development of the biofuel sector, as an alternative market for sunflower. The Rural Livelihood Investment Company (RLDC) in Tanzania, for example, is working with sunflower farmers in Morogoro, Dodoma, Manyara, Singida, Tabora and Shinyanga. The RLDC 2009-2011 pilot on contract farming has helped establish long-term collaborations between processors and local government authorities on the provision of extension services to producers. The results so far have shown that about 13,500 producer households have been directly linked to partner processors and are receiving better prices, and that production per acre has increased by 67 percent.

What would happen to the cost of biofuel production if the price of sunflower seeds were higher than US$ 307 per tonne? The biofuel sector is no different than other industrial sectors, in that the raw material is a substantial contributor to the cost of production and it is therefore important to assess how an upward price fluctuation may affect the viability of the sector. Assuming a price increase to 550 US$[16] per tonne (Columbia University 2010), the estimated production cost for SVO and biodiesel will increase by as much as 64 percent. For example, for scenario 1 the production cost for 1 litre of SVO will increase to 1.85 US$ from 1.07 US$. This production cost is about 22 per cent higher than the indicative price of diesel at the pump in Tanzania (EWURA, 2012).

While the increment in feedstock price can improve the viability of the sunflower production for small farmers, it significantly decreases the viability of the biofuel industry. Establishing adequate business models that work for smallholder and biofuel processors is essential to maximize benefits for both. If Tanzania decides to consider the use of sunflower for biofuel, further sensibility analysis on feedstock prices and biofuel production cost can help better understand a potential middle point whereby both outgrowers and processors can benefit.

It is important to recognize that the edible market could be a more attractive option. For the past five years, world sunflower seed prices have increased from $500 to $1200 per tonne and started decreasing again in 2011. In Tanzania, the retail price for unrefined sunflower oil is 1.5 times the pump price of diesel, and that of refined sunflower oil is more than 2.5 times the pump price of diesel. This analysis simulated the production of 40,709 tonnes (about 44 million litres) of refined sunflower oil. The production cost per

16 The highest prices reached 55 000 TSH in 2010. The price per tonne is calculated assuming 1500 TSH per US$ and 15 bags per tonne.

1 litre is estimated between 0.94 to 1 US$. Considering this production cost and the current market sale price of 3.5 US$ for one litre of sunflower refined edible oil, this outlet market provides a larger potential profit margin than biodiesel. As such, sunflower oil is likely to find its market in the food chain, rather than the fuel chain.

Is small-scale production of SVO a competitive alternative to displace local consumption of diesel in off-site power generators? Locally produced straight vegetable oil (SVO) can be a substitute for fossil diesel to improve energy access, reduce vulnerability to external fuel markets and to strengthen the local agricultural value chain. Technologically, affordable diesel generators can be easily modified with SVO technology to reach a capacity of 5-20 kW. Untreated, straight vegetable oil can be used as fuel to substitute for diesel. According to some studies, a complete engine overhaul can be carried out by local mechanics for US$ 200, making maintenance and upkeep affordable (Diligent, 2006). An added benefit is that the entire value chain process from production to end use remains in local areas.

According to a study on sunflower SVO power generation, the village of Laela A in Sumbawanga in Tanzania consumes an average of 52,920 litres of diesel per year to run about 104 micro-generators to generate about 78,851 kWh[17] (Hoffman et.al, 2012). Considering the market price for diesel in Sumbawanga, the closest urban centre is 1.48 US$ per litre[18], this will mean that the village is likely to spend more than 78,322 US$ per year to run the generators (EWURA, 2012). Sunflower is cultivated in Laela A. The total cultivated area is difficult to quantify as many of the farmers practice intercropping but it is assumed to be around 1,700 hectares (Rordorf, 2011). As of today, the village already produces about 1,040 tonnes of sunflower seed[19] and according to Rordorf (2011) 75 percent of these sunflower seeds are sold to traders for processing elsewhere and the remaining 25 percent is used for local cooking.

There is a significant potential to improve the productivity of sunflower. The average yield per acre of sunflower is a conservative 0.63 tonnes per hectare. Some of the better off households in the village who have access to capital for agricultural inputs are able to attain yields approximately 1.01 tonnes per ha (Rordorf, 2011). Moreover, farmers themselves recognize that those who employed good practices have better yields compared to traditional methods. Therefore, improving farming practices together with using better seed varieties can help increase the yield to 1.6 tonnes per ha. Once external inputs such as chemical or manure are used, the yield can be as high as 2.1 tonnes per ha (Gabagambi and George, 2010).

What will happen if the sunflower productivity in Laela A is increased to 1.6 tonnes per ha? The village will be able to produce about 2,730 tonnes of sunflower. If 25 percent is subtracted to meet local cooking needs, then this indicates that about 2,000 tonnes can be available for production of SVO for energy use. This quantity is enough to establish

17 According to the author the village consumes about 147 litres diesel per day and one litre of biodiesel produces 1.49 kWh.

18 Note that the diesel price in Laela may be much higher due to additional transportation cost to bring the fuel to the village.

19 This was calculated based on 1700 ha sunflower at yield 0.61 tonnes per ha.

a small-scale SVO factory facility as the one previously described in this analysis. The SVO production will be more than enough to meet the demand to run the current mini-generators in the village. The surplus can then be used to provide fuel for power in the village or given that Laela A has no current access to the electric grid, it can be used to support a local mini-grid. However, for this scheme to be successful, stability in the physical supply of sunflower needs to be established.

A key recommendation is the need to put in place an effective agricultural extension programme to help small farmers improve their productivity. Establishing a biofuel sector can be accomplished through public-private partnerships. This approach will allow small farmers to improve productivity while at the same time the private enterprise can secure feedstock supply (RDLC, 2011). Since the proposed factory includes storage for sunflower seeds, this can help ensure the year round supply of feedstock. As for prices, a local value chain with reasonable prices for both outgrowers and processors will need to be established. In the context of the Laela A village, developing the SVO sector can help increase income generation for smallholders by avoiding the middleman transaction costs and the costs associated with transportation outside of the village. The development of the SVO sector can have a spillover effect by also improving productivity for other food and non-food crops in the village. Energy access can be improved as the grid is not running near the village and is not expected to be extended to Laela A in the near future (Rordorf, 2011).

5. CONCLUSIONS

From the analysis conducted herein, it can be concluded that:

- The production costs estimated are lower than the current diesel market price. However, potential indicative market prices for SVO and biodiesel, once energy differences and regulatory and fiscal requirements are accounted for, are higher than the current indicative price for diesel in the country.
- Small-scale SVO production as illustrated in scenario 1 could be feasible under some circumstances. As such, SVO could provide an alternative option to supply local energy needs and add value to local sunflower value chains. The development of local SVO production should be accompanied by improvements in productivity to avoid displacing edible uses. This requires increases in land productivity through the application of improved agronomy practices. A key recommendation is to put in place an effective agricultural extension programme to help small farmers improve their productivity. Outgrower schemes between smallholder farmers and SVO processors could help increase income generation for smallholders by avoiding the middleman transaction costs and costs associated with transportation outside of the village. Local straight vegetable oil (SVO) chains can be a substitute for fossil diesel to improve energy access, reduce vulnerability to external fuel markets and strengthen the local agricultural value chain.
- A small-scale biodiesel factory as illustrated in scenario 2 is not competitive with diesel due to the high per unit production costs. The added degree of processing

costs from the use of chemicals, caustic soda and methanol, together with the scale of production, make it a less competitive option. Additionally, the procurement of these chemicals, particularly in rural areas may prove difficult.

- In Scenario 3 the economies of scale, better processing efficiencies and procurement of feedstock from outgrower schemes help improve the viability of biodiesel. However, the potential indicative diesel-equivalent is still 24 percent higher than the average retail price of diesel. If the regulatory and fiscal fees are relaxed then the indicative price is the same as the current diesel price.
- Scenario 4 shows the most promising results for biodiesel production. Particularly, if the revenue from co-products are considered, the additional revenue helps to improve the competitiveness of the production scenario. Moreover, in this scenario the co-production of edible oil and biodiesel provides the flexibility to switch production from one product to other to respond to market fluctuations. This flexibility is particularly relevant in cases where shortages in domestic edible oil may arise.
- Biodiesel is used primarily as a fuel additive and is seldom used in 100 percent form. The added cost to the retail price for a 10 percent blend is relatively small. Furthermore, at higher diesel prices and lower price of biodiesel the blending can even reduce the fuel retail price.
- If Tanzania decides to pursue sunflower based SVO and biodiesel as an alternative market to maximize productivity increases in the sunflower sector, then a reliable supply and reasonable market prices for both farmer producers and processors need to be established. The government may also need to decide whether to apply all current petroleum fuel taxes to biofuel or whether to forgo partially or completely this requirement for SVO and biodiesel to help them compete with diesel. This will be particularly interesting for SVO.
- Feedstock cost is critical for biodiesel to be cost competitive, given current diesel fuel prices. Anything beyond 300 US$ per tonne will increase the production cost of SVO and biodiesel substantially. SVO and biodiesel will not be able to compete with diesel prices and the national edible oil market.
- A potential factor to consider when assessing the competitiveness of SVO and biodiesel is the possible revenue from sales of co-products namely sunflower meal for animal feed, glycerol and co-generated electricity. In some cases the sale of co-products can improve competitiveness with diesel, but in some cases it is still insufficient.
- Despite potential sunflower biofuel profitability, the food market offers better sale prices to farmers, so for the time being, sunflower is not likely to be a viable option for liquid biofuel production, regardless of the production scenario.
- The husks from sunflower oil processing can be used for bioenergy to provide power to the processing facility and potentially additional energy for local use. As mentioned, the viability of this will depend on the scale of production. As indicated in the results for a 20 million litre facility, the cost of the co-generation equipment at this scale does not justify the benefits of the co-generation.

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DEFINITIONS

Straight Vegetable Oil (Pure Factory Oil): Oil obtained from oil holding seeds (rapeseed, sunflower, jatropha, etc) by pressing and filtering, no other process steps

Biodiesel: Vegetable oil which is chemically modified (esterification). Methanol or ethanol is added to the oil to form biodiesel and glycerol. After the reaction is complete, glycerol is separated from the biodiesel. The biodiesel is then purified to specifications.

ANNEX 1 TANZANIA FUEL IMPORT

Tanzania Fuel Import Data (Million litres)

PRODUCT	2005	2006	2007	2008	2009	2010	2011
Motor Spirit Premium (MSP)	234.02	271.46	212.90	285.44	324.24	344.75	500.00
Automotive Gas Oil (Diesel)	623.15	690.95	592.69	900.62	852.50	821.43	1,113.36
Illuminating Kerosene (IK)	84.93	131.17	167.44	208.72	189.92	0.17	0.21
Jet A1*	147.68	133.44	134.31	163.28	125.45	0.13	0.14
Furnace Oil (FO)	205.25	214.03	90.08	26.41	28.09	83.30	97.42
TOTAL	3,300.03	3,447.05	3,204.42	3,592.48	3,529.20	3,259.79	3,722.13

ANNEX 2

ESTIMATION OF PRODUCTION COST PER SCENARIO

SCENARIO 1

Output Parameters	Quantity
Production Biodiesel (L/YEAR)	499000
Production Meal (Tonne/YEAR)	1024
Feedstock	
• Oil content, %	35
• residual oil in sunflower meal, %	7
net oil extraction, %	28
• shrinkages, %	1
net canola meal yield, %	64
• kg per tonne sunflower	1000
• kg oil per tonne sunflower	280
• Density, kg per litre	0.906
litres per tonne	309
Plant capacity litre	499000
• oil required per litre	0.99088
• liters per tonne of sunflower	309
• Tonnes of sunflower required	1600
• Tonnes of sunflower meal	1024
• Cost of sunflower tonne	307
Cost feedstock	$491,168.10
Operating cost	
Calculations to determine requirements	
• total oil	1600
• days per year	320
• tonnes per day	5.00
• hours	8
• tonnes per hour	0.62
Electricity for crushing	
• tonnes per day	5.00
• HP per tonne	8.5
• HP to Kw	0.75
• electric rate kWh	0.08

• days per year	320
• hours	8
Total	$6,527.58
Water	
• Litre, requirements 1:1 and assuming 50% recycled	249,500
• Price of water per cubic metre	$0.63
• Cubic metres of water, 1000 litre per cubic metre	250
Total	$157.19
Maintenance	
• 2.5% of the capital cost	$667
Total	$667
Miscellaneous	$1,067
Taxes 5% local on capital cost	$1,334.83
Land rental	$3,000.00
Operating interest @5% on 1/2 operating cost	
• subtotal operating	$12,596.48
• half	$6,298.24
Total Interest	$314.91
Capital cost	
Buildings	
• Plant	$10,000.00
• silos	$75,000.00
• subtotal	$85,000.00
• piping and pumps 10% of equipment	$4,725.80
Equipment	
• Oil press	$16,452.00
• filter	$5,000.00
• storage tank	$25,806.00
Total	$47,258.00
Depreciation @ 15% capital interest rate	
• 10 years depreciation	$26,696.56
Total Annual Capitalization	$26,696.56
Labour 3 employees	$3,780
Total annual cost:	$534,712.80
$US per litre without co-product	**$1.07**
Sunflower Meal = (57 US$/tonne)*(tonnes of sunflower) meal)/liters of biodiesel	$0.12
Cost per liter with co-product	**$0.95**

SCENARIO 2

Output Parameters	Quantity
Production Biodiesel (L/YEAR)	499000
Production Glycerol (Tonne/YEAR)	47
Production Meal (Tonne/YEAR)	1024
Feedstock	
• Oil content, %	35
• residual oil in sunflower meal, %	7
net oil extraction, %	28
• shrinkages, %	1
net canola meal yield, %	64
• kg per tonne sunflower	1000
• kg oil per tonne sunflower	280
• Density, kg per litre	0.906
litres per tonne	309
Plant capacity litre	499000
• oil required per litre	0.99088
• liters per tonne of sunflower	309
• Tonnes of sunflower required	1600
• Tonnes of sunflower meal	1024
• Tonnes of glycerol	47
• Cost of sunflower tonne	307
Cost feedstock	$491,168.10
Methanol	
• total biodiesel	499000
• oil required per litre of biodiesel	0.99088
• density sunflower	0.906
• percentage required	0.22
• methanol recovery 25%	0.75
• kg per tonne	1000
• price methanol tonne	650
Total	$48,045
Catalyst	
• total biodiesel	499000
• oil required per litre of biodiesel	0.99088
• density sunflower	0.906
• kg per tonne	1000
• kg NaOH per tonne	130

• kg per tonne	1000
• catalyst US$ per tonne	550
Total	$32,030
Operating cost	
Calculations to determine requirements	
• total oil	1600
• days per year	320
• tonnes per day	5.00
• hours	8
• tonnes per hour	0.62
Electricity for crushing	
• tonnes per day	5.00
• HP per tonne	8.5
• HP to Kw	0.75
• electric rate kWh	0.08
• days per year	320
• hours	8
Subtotal	$6,527.58
Electricity for processing	
• Total biodiesel	499000
• kWh per litre	0.066
• electric rate kWh	0.08
Subtotal	$2,634.72
• Total electricity cost	$9,162.30
Water	
• Litre, requirements 1:1.5 and assuming 25% recylced	561,375
• Price of water per cubic metre	$0.63
• Cubic metres of water, 1000 litre per cubic metre	561
Total	$353.67
Maintenance	
Capital cost of equipment	$51,160.00
• 2.5% of cost	51160
Total	$1,279.00
Miscellaneous	3500
Taxes 5% local on capital cost	$2,558.00
Land rental	$3,000.00
Operating interest @5% on 1/2 operating cost	
• subtotal operating	$16,864.58
• half	$8,432.29
Total Interest	$421.61

Capital cost	
Buildings	
• Plant	$10,000.00
• silos	$75,000.00
• subtotal	$85,000.00
• piping and pumps 10% of buildings	$8,500.00
Equipment	
• Oil press	$16,452.00
• filter	$5,000.00
• storage tank	$25,806.00
• Biodiesel Modular unit price 10% delivery and 25% duty tax	$119,000.00
Total	$166,258.00
Depreciation @ 15% capital interest rate	
• 10 years depreciation	$51,160.00
Total Annual Capitalization	$51,160.00
Labour 4 employees	6000
Total annual cost:	$648,677
$US per litre without co-product	**$1.30**
Sunflower Meal = (57 US$/tonne)*(tonnes of sunflower) meal)/liters of biodiesel	$0.12
Glycerol = (200 $US per tonne)* (Tonnes of glycerol)/L of biodiesel	$0.02
Cost per liter with co-product	**$1.16**

SCENARIO 3

Output Parameters	Quantity	
Production Biodiesel (L/YEAR)	21,255,029.5	
Production Glycerol (Tonne/YEAR)	2,397.9	
Production Meal (Tonne/YEAR)	24,320.8	
Input	**USD/Year**	**USD per Litre**
Feedstock Cost	$ 16,432,260.00	$0.77
Inputs cost	$ 4,634,740.00	$0.22
Total utilities Cost	$ 1,202,720	$0.06
Operating Labor	$ 31,894	$0.002
Maintenance	$ 256,406	$0.01
Operating Charges	$ 7,974	$0.0004
Plant Overhead	$ 144,150	$0.01
General and Administrative Cost	$ 1,959,760	$0.09
Subtotal	$ 24,669,904	$1.16
Total Project Capital Cost	$ 1,383,430	$0.07
Total Production cost	***$ 26,053,334***	***$1.23***
Credit co-products		
Sunflower meal = (57 US$/tonne) *(tonnes of sunflower) meal)/L of biodiesel	-$ 1,386,287	-$0.07
Glycerol = (200 $US per tonne)* (Tonnes of glycerol)/L of biodiesel	-$ 479,572	-$0.02
Total (production cost - credit from co-products)	***$ 24,187,475***	
Unitary Cost (USD/L)		***$1.14***

SCENARIO 4

Output Parameters	Quantity	
Production of Edible oil (Tonne/YEAR)	20,354.71	
Production Biodiesel (L/YEAR)	21,255,030	
Production Glycerol (Tonne/YEAR)	2,397.9	
Production Meal (Tonne/YEAR)	48,648.12	
Production Co-generatated Electricity (kW)	39.53	
Input	**USD/Year**	**USD/Litre**
Feedstock Cost	$ 30,169,877	$1.42
Inputs cost	$ 8,509,453	$0.40
Total utilities Cost	$ 2,950,340	$0.14
Operating Labor	$ 40,538	$0.002
Maintenance	$ 465,695	$0.02

Operating Charges	$ 10,134	$0.0005
Plant Overhead	$ 253,116	$0.01
Capital Cost	$ 2,056,340	$0.10
General and Administrative Cost	$ 3,878,060	$0.18
Total	$ 48,333,551	$2.27
Total biodiesel production cost	***$ 23,191,621***	***$1.09***
Credit from co-products		
Credit Meal	-$ 2,772,943	-$0.13
Credit Glycerol	-$ 479,572	-$0.02
Credit Electricity (26.5 cents per kwh* kwh)/L	-$ 83,804	-$0.004
Total (production cost - credit from co-products)	***$ 19,855,303***	
Unitary Cost (USD/L) with co-products		***$ 0.93***

Note 100% of the credits go to biofuel production in order to establish the minimum base production cost for one liter of biodiesel and in order to facilitate the competitivenss assessment. However, allocation of credits may need to be distributed among the two main products for more precise analysis.

KEY ASSUMPTIONS IN THE SCENARIOS:

Feedstock:

It is assumed that there is an agreement between the smallholders and processors. The price of sunflower seeds for outgrowers is estimated at 307 US$ per tonne. The smallholders bring the seed to the factory and they are paid. These figures were estimated based on information provided by Ringo Iringo Company that indicates a price paid to small farmers at the factory gate of 30,000 Tanzanian Shillings per bag of sunflower seed delivered at the factory. The bag weight is assumed to be on average 65 kg. The exchange rate is 1US$ to 1500 Tanzanian Shillings. This was also reported as the potential price paid in Dodoma. http://www.repoa.or.tz/documents/S1B.pdf

The price of sunflower seeds from estate is the estimate cost of production which was assumed to be 150 US$ per tonne. These figures are estimated based on production costs provided by Ephata and include transportation costs to the mill.

The biofuel processing:

- *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.
    - *For scenarios 1 and 2,* the capital costs were estimated based on literature for approximate cost of equipment and duty taxes of 25 percent.

      The storage silos for 1600 tonnes of seed for Scenario 1 and 2 were assumed to cost $US40 per tonne plus duty tax and were based on the following FAO study: http://www.fao.org/docrep/T1838E/T1838E1c.htm#Costs of bulk storage

      The calculations for both scenarios were estimated based on Guidelines: Biodiesel Production Costs from small scale facilities generated by Manitoba, Canada available at: http://www.gov.mb.ca/agriculture/financial/farm/pdf/copcanoladiodieselcosts2011.pdf

- *For scenarios 3 and 4,* the capital costs were based on global average equipment prices incorporated in the commercial simulator Aspen Plus. The capital cost is 15 percent.

- *The operating costs* for all scenarios were obtained from national statistics data and used to calculate the production cost in the manual calculations and in the simulations. 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 755 US$ per tonne for methanol, 500 US$ per tonne for sodium hydroxide and for hexane 480 USD/tonne. http://www.icis.com/chemicals/channel-info-chemicals-a-z/; http://www.dewittworld.com/portal/Default.aspx?ProductID=114; http://www.scribd.com/doc/96797102/Chemical-Trade-Intelligence-Report-Prices-2
  - Price of energy from EWURA (http://www.ewura.com/fuelprices.html)
    - electricity was a monthly fee of US$9.49 plus 0.08 US$ per kwh
    - water ranged between 0.44 to 0.69 US$ per cubic metre depending on the level of water requirements in each scenario
    - sewage was 0.13US$ per cubic meter
    - Gasoline was US$1.53 per liter and biodiesel US$1.45 per litre
  - Taxes: local taxes were estimated at 5 percent and corporate tax was estimated at 30 percent
  - Labour costs were estimated at and based on http://www.ilo.org/wcmsp5/groups/public/---ed_dialogue/---sector/documents/publication/wcms_160786.pdf

Labour	**per month TSH**	**per month US$**
Engineers	410000	$273.33
Technicians	120000	$80.00
Foremen	150000	$100.00
Skilled labourers	84000	$56.00
Casual/unskilled	60000	$40.00

ANNEX 3

COMPUTATION OF INDICATIVE DIESEL-EQUIVALENT PRICES FOR SVO & BIODIESEL

SCENARIO 1 - SVO SMALL-SCALE

Calculating or Price Build Up for potential indicative Prices for 1 liter of Biodiesel	
Factors to build the indicative price for Biodiesel	**US$ per litre**
Authorized profit margin for fossil fuel by EWURA	$0.09
Taxes to Fossil fuels	$0.35
Transportation fuel to market as calculated by EWURA	$0.01
Biodiesel without co-products	
Authorized profit margin plus transport with co-product	$1.17
Energy-basis 5% less to compare diesel, without co-product	$1.23
Energy-basis 5% less to compare diesel, without co-product and with taxes	$1.57
Indicative price market for 100%	**$1.57**
Biodiesel with co-products	
Authorized profit margin plus transport with co-product	$1.05
Energy-basis 5% less to compare diesel, with co- product	$1.10
Energy-basis 5% less to compare diesel, with co-product and with taxes	$1.45
Indicative price market for 100%	**$1.45**

Calculating indicative price for diesel blended with 10% SVO	
Blending of 10% SVO	**US$ per litre**
Indicative Price Diesel at pump, National average	$1.43
*Indicative price Biodiesel without co-product @pump	$1.52
*Indicative price Biodiesel with co-product @ pump	$1.40
WITH TAXES	
10% blended at Pump	**$1.44**
10% blended at pump with co-product	**$1.43**
WITHOUT TAXES	
10% blended at Pump without taxes without co-product	**$1.40**
10% blended at Pump without taxes with co-product	**$1.39**

**Note that here it is assume that in blended liter the energy difference for blendings may be negligible as per NREL report, therefore here we use volume basis not energy basis.*

SCENARIO 2 - BIODIESEL SMALL-SCALE

Calculating or Price Build Up for potential indicative Prices for 1 liter of Biodiesel	
Factors to build the indicative price for Biodiesel	**US$ per litre**
Authorized profit margin for fossil fuel by EWURA	$0.09
Taxes to Fossil fuels	$0.35
Transportation fuel to market as calculated by EWURA	$0.01
Biodiesel without co-products	
Authorized profit margin plus transport with co-product	$1.40
Energy-basis 8% less to compare diesel, without co-product	1.51
Energy-basis 8% less to compare diesel, without co-product and with taxes	$1.86
Indicative price at pump if 100%	**$1.86**
Biodiesel with co-products	
Authorized profit margin plus transport with co-product	$1.26
Energy-basis 8% less to compare diesel, with co- product	$1.36
Energy-basis 8% less to compare diesel, with co-product and with taxes	$1.71
Indicative price at pump if 100%	**$1.71**

Calculating indicative price for diesel blended with 10% SVO	
Blending of 10% SVO	**US$ per litre**
Indicative Price Diesel at pump, National average	$1.43
*Indicative price Biodiesel without co-product @pump	$1.74
*Indicative price Biodiesel with co-product @ pump	$1.61
WITH TAXES	
10% blended at Pump	**$1.46**
10% blended at pump with co-product	**$1.45**
WITHOUT TAXES	
10% blended at Pump without taxes without co-product	**$1.43**
10% blended at Pump without taxes with co-product	**$1.41**

**Note that here it is assume that in blended liter the energy difference for blendings may be negligible as per NREL report, therefore here we use volume basis not energy basis.*

SCENARIO 3 - BIODIESEL MEDIUM-SCALE

Calculating or Price Build Up for potential indicative Prices for 1 liter of Biodiesel	
Factors to build the indicative price for Biodiesel	**US$ per litre**
Authorized profit margin for fossil fuel by EWURA	$0.09
Taxes to Fossil fuels	$0.35
Transportation fuel to market as calculated by EWURA	$0.01
Biodiesel without co-products	
Authorized profit margin plus transport with co-product	$1.32
Energy-basis 8% less to compare diesel, without co-product	1.43
Energy-basis 8% less to compare diesel, without co-product and with taxes	$1.78
Indicative price at pump if 100%	**$1.78**
Biodiesel with co-products	
Authorized profit margin plus transport with co-product	$1.23
Energy-basis 8% less to compare diesel, with co- product	$1.33
Energy-basis 8% less to compare diesel, with co-product and with taxes	$1.68
Indicative price at pump if 100%	**$1.68**

Calculating indicative price for diesel blended with 10% SVO	
Blending of 10% SVO	**US$ per litre**
Indicative Price Diesel at pump, National average	$1.43
*Indicative price Biodiesel without co-product @pump	$1.67
*Indicative price Biodiesel with co-product @pump	$1.58
WITH TAXES	
10% blended at Pump	**$1.45**
10% blended at pump with co-product	**$1.45**
WITHOUT TAXES	
10% blended at pump without taxes without co-product	**$1.42**
10% blended at Pump without taxes with co-product	**$1.41**

**Note that here it is assume that in blended liter the energy difference for blendings may be negligible as per NREL report, therefore here we use volume basis not energy basis.*

SCENARIO 4 - BIODIESEL MEDIUM-SCALE, INTEGRATED BIODIESEL AND EDIBLE OIL PRODUCTION

Calculating or Price Build Up for potential indicative Prices for 1 liter of Biodiesel	
Factors to build the indicative price for Biodiesel	**US$ per litre**
Authorized profit margin for fossil fuel by EWURA	$0.09
Taxes to Fossil fuels	$0.35
Transportation fuel to market as calculated by EWURA	$0.01
Biodiesel without co-products	
Authorized profit margin plus transport with co-product	$1.19
Energy-basis 8% less to compare diesel, without co-product	1.28
Energy-basis 8% less to compare diesel, without co-product and with taxes	$1.63
Indicative price at pump if 100%	**$1.63**
Biodiesel with co-products	
Authorized profit margin plus transport with co-product	$1.03
Energy-basis 8% less to compare diesel, with co- product	$1.11
Energy-basis 8% less to compare diesel, with co-product and with taxes	$1.46
Indicative price at pump if 100%	**$1.46**

Calculating indicative price for diesel blended with 10% SVO	
Blending of 10% SVO	**US$ per litre**
Indicative Price Diesel at pump, National average	$1.43
*Indicative price Biodiesel without co-product @pump	$1.53
*Indicative price Biodiesel with co-product @pump	$1.38
WITH TAXES	
10% blended at Pump	**$1.44**
10% blended at pump with co-product	**$1.42**
WITHOUT TAXES	
10% blended at Pump without taxes without co-product	**$1.41**
10% blended at Pump without taxes with co-product	**$1.39**

**Note that here it is assume that in blended liter the energy difference for blendings may be negligible as per NREL report, therefore here we use volume basis not energy basis.*

ANNEX 4

COMPUTATION OF PRODUCTION PER TONNE OF SUNFLOWER FOR SMALLHOLDER IN DIFFERENT REGIONS IN TANZANIA

Cost item	Central area based on RLDC Sunflower								Southern
	Morogoro	Dodoma	Manyara	Singida 1	Singida 2	Tabora	Mbeya	Iringa	Tanga
FARM OPERATIONS									
Renting Land	$16.46	$16.46	$24.69	$45.27	$37.04	$49.38	$32.92	$24.69	$0.00
Clearning	$90.53	$28.81	$39.51	$16.46	$16.46	$37.04	$0.00	$11.79	$32.92
Tillage	$61.73	$32.92	$19.75	$37.04	$37.04	$16.46	$0.00	$23.32	$32.92
Sowing	$26.34	$8.23	$13.17	$8.23	$16.46	$4.53	$0.00	$10.42	$9.88
1st weeding	$37.86	$24.69	$37.04	$41.15	$28.81	$37.04	$0.00	$24.14	$19.75
2nd weeding	$37.86	$13.17	$13.17	$0.00	$16.46	$0.00	$0.00	$0.00	$0.00
Bird Scaring	$65.84	$0.00	$16.46	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Harvesting	$53.50	$20.58	$9.88	$28.81	$17.28	$26.34	$0.00	$16.19	$13.17
Transport from farm	$24.69	$17.28	$46.09	$15.64	$18.11	$18.93	$0.00	$8.34	$26.34
pulling	$0.00	$8.23	$6.58	$12.35	$20.58	$32.92	$0.00	$0.00	$26.34
winnowing	$0.00	$0.00	$3.29	$5.76	$4.12	$19.75	$0.00	$8.51	$0.00
Storage	$0.00	$0.00	$0.00	$8.11	$5.51	$7.93	$0.00	$8.15	$0.00
other	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$7.68	$0.00
Subtotal Operations	$414.81	$170.37	$229.63	$218.81	$217.86	$250.32	$148.15	$143.23	$161.32
INPUTS									
Seeds	$0.00	$3.33	$1.65	$6.58	$11.85	$1.32	$0.00	$20.58	$8.23
Manure	$0.00	$0.00	$0.00	$0.00	$172.84	$0.00	$0.00	$0.00	$0.00
Chemicals	$8.23	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$34.65	$0.00
Subtotal inputs	$8.23	$3.33	$1.65	$6.58	$184.69	$1.32	$11.52	$55.22	$8.23
TOTAL COST per Ha	**$423.05**	**$173.70**	**$231.28**	**$225.39**	**$402.55**	**$251.64**	**$192.59**	**$198.45**	**$169.55**
Revenue per ha	$666.19	$492.72	$196.48	$491.20	$665.17	$197.09	$239.17	$204.77	$427.98
Gross margins per ha	**$243.14**	**$319.01**	**-$34.80**	**$265.81**	**$262.62**	**-$54.55**	**$46.57**	**$6.32**	**$258.44**
Yield tons per ha	2.17	1.60	0.64	1.60	2.17	0.64	0.62	0.67	1.28
Cost per ton	**$194.95**	**$108.23**	**$361.37**	**$140.87**	**$185.79**	**$391.97**	**$313.16**	**$225.14**	**$132.05**

Sources: Morogor, Dodoma, Manyara, Singida 1, Singida 2 and Tabora from Gabagambi and George (2010). Mbeya and Iringa from Match maker (2010). Tanga from Match maker (2009).

The original data was presented in a per acre basis. In order to estimate the per tonne cost, the following assumptions were made:

1. If external inputs such as manure or chemicals were used the yield was estimated to be 2.17 tonnes per ha based on observations from Gabagambi and George (2010).
2. If seed cost was higher than 5000 TSH then it was assumed that the seeds were an improved variety and the yield assumed to be around 1.60 tonnes per ha based on observations from Gabagambi and George (2010).
3. In the cases of Mbeya, Iringa andTanga the values were estimated from the price per bag paid and amount of bags sold. The weight of the bag of sunflower seeds was assumed to be 60 kg.

CHAPTER 2

WATER EVALUATION AND PLANNING IN THE WAMI RIVER BASIN: APPLICATION OF THE WEAP MODEL

Deogratias M.M. Mulungu[a] and Cayo Leonidas Ramos Taipe[b]

1. SUMMARY

In an attempt to improve agricultural productivity in developing countries, increasing attention and initiatives aimed at expanding irrigation to supplement rainfed agriculture are being pursued (Mwandosya, 2008). Tanzania, for instance, is planning to increase irrigated land from the current 290,000 hectares to 1 million hectares in the short to medium term (Mwandosya, 2008). The Wami River Basin is one of the areas in Tanzania considered to have high potential for irrigated agriculture. Land concessions for biofuel development are also being considered or approved in the basin. This includes large-scale sugarcane plantations for sugar and biofuel production, and sorghum for brewery and biofuel production. There are serious concerns regarding growing agricultural water demand and supply availability in the Wami basin.

With the goal of supporting water resource management in the Wami River Basin, this study aims to illustrate the need to consider water availability when planning an expansion of agricultural production to produce energy crops. It highlights the potential competition between food and energy crop production, with other demands such as households and ecological requirements. The evaluations and impact assessment modelling has been prepared through applying the Water Evaluation and Planning (WEAP) model. As inputs to the WEAP model, climatic, hydrological, biophysical, and management data were collected from different sources and archives.

The water demand estimation and analysis was conducted on the five major users: agriculture, domestic (urban and rural), livestock, industrial and the environment. The study developed three water use scenarios for the period 2013–2045 in the Wami River Basin as: (1) Reference scenario, which evaluates what is likely to occur if past trends continue (34,015.2ha); (2) Biofuel expansion scenario (91,732.2ha); (3) Population growth and biofuel and agriculture expansion scenario (1292.07 Hm3). The model simulation results showed that there **will be unmet demand in all sectors, and that the Wami River Basin will not be able to support agricultural or bioenergy expansion, unless integrated water management measures are implemented**.

2. INTRODUCTION

The Tanzanian economy is mainly dependent on agriculture, which contributes about 45 percent of the gross domestic product (GDP) and about 30 percent of export earnings while employing over 80 percent of the nation's workforce (Maltsoglou and Khwaja

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2010). Annually some 5.1 million hectares are cultivated, of which 85 percent is for food crops. Although agriculture is the leading sector of the economy, only 6.3 million ha out of 43 million ha suitable for agriculture are under agricultural production (Madulu, 2005). Studies undertaken for the National Irrigation Master Plan in 2002 have shown that the total irrigation potential of the country is about 29.4 million hectares with different suitability levels.

The Wami River Basin (WRB) is among the areas of Tanzania that have a high potential for irrigated agriculture. The main crops grown include sugarcane, paddy (rice), cassava, coconut, maize, sweet potatoes, fruits, vegetables and legumes. Agriculture remains primarily small-scale except for the large-scale sugar estates. There is significant expansion of farming in many parts of the basin and in Tanzania as a whole, which includes large-scale sugarcane plantations for sugar and biofuel production. To a large extent, the expansion also reflects the increasing population pressure in the basin. Smallholder farmers expand farms because they need to increase incomes and to be able to support their families and ensure food security. Therefore, at a local level, expansion of agriculture is a direct impact of increasing population in the basin (Madulu, 2005).

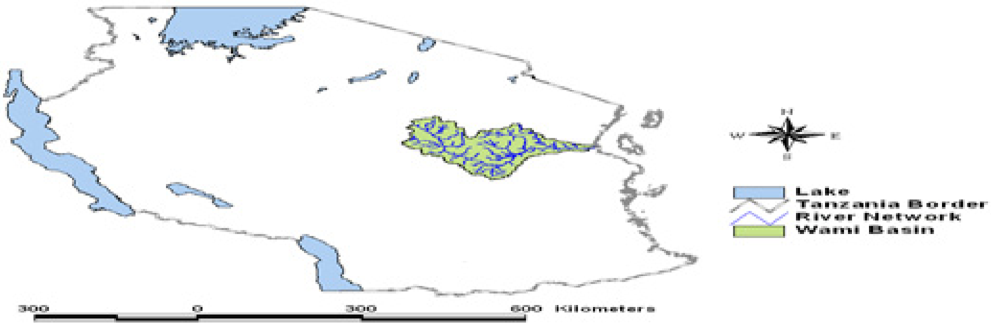
There is growing interest in bioenergy production in the Wami River Basin with two sugarcane projects already in operation – EcoEnergy Africa and the Mtibwa Sugar estate; and plans for the development of a sorghum plantation – Serengeti Breweries. Worldwide, sorghum has recently attracted attention as an option for ethanol production. This crop produces sugar in a way similar to sugarcane. Also, the seeds can be used for feed/food or alternatively for biofuel production (WWF, 2008). To date, there has been very little scientific analysis done regarding the potential impacts of these investments on water availability in the basin as a whole. Therefore, the study evaluates the water availability and impacts of current and planned bioenergy related activities on water availability in the Wami River Basin, Tanzania.

3. DESCRIPTION OF THE BASIN

The Wami Ruvu River Basin (WRRB) is one of the nine basins of Tanzania and it includes two major rivers, the Wami and Ruvu, with an approximate drainage area of 43,000 km^2 (Fig. 1) and 17,700 km^2 respectively. According to a 2002 census, the WRB is home to 1.8 million people in 12 districts: Kondoa, Dodoma-urban, Bahi, Chamwino, Kongwa and Mpwapwa (in Dodoma region); Kiteto and Simanjiro (in Manyara region); Mvomero and Kilosa (in Morogoro region); Handeni and Kilindi (in Tanga region), and Bagamoyo (in Coast region) (IUCN, 2010). The basin also comprises one of the world's most important hotspots of biological diversity: the Eastern Arc Mountains and coastal forests (WRBWO, 2008).

Figure 1

The Wami River Sub-basin within Tanzania



The Wami River, near Mandera gauging site 1G2 (Figs. 2), has a catchment area of 36,400 km^2 and a mean annual runoff of 54 mm. About 60 to 70 percent of flow at Mandera originates from a small part of the catchment on the slopes of Nguru, Ukaguru and Rubeho mountains where rainfall is high. The Wami may be divided into four hydrological areas as follows: the Kinyasungwe that drains the dry north and east of Dodoma, the Ukaguru, Rubeho and Nguru mountain ranges, the northern semi-desert area in the Masai steppe and the lower Wami (URT, 2006). Others have divided the Wami basin into six hydrologic zones based on the main river tributaries: Kinyasungwe, Mkondoa, Mkata, Diwale, Lukigura and Wami (IUCN, 2010). The main Wami zone, which includes the Wami River and its tributaries, the Tami and Kisangata rivers, are mostly perennial systems (IUCN, 2010). The Wami Basin is important for water supply for different uses: domestic, commercial, industrial, irrigation, livestock, fishing, National Parks (Saadani and Mikumi), Eastern Arc Mountains (Nguu, Nguru and Ukaguru Mts.) forests with different biodiversity and in large business cities such as Dodoma and Morogoro.

Sub-catchments are formed in each of the nine river drainage basins in Tanzania for water management. In these sub-catchments, catchment committees are formed, which manage water from upstream to downstream and issue water permits. In this case, community Water User Associations (WUAs) are the most important actors in water resource management in the river basins. The members of the WUAs are represented in catchment water committees. The availability of water is a prerequisite for the issuing of water permits. However, there are challenges in relation to tools and quantification of water availability in the basins for the water resources management. This study seeks to contribute to building capacity by applying the WEAP system to analyse current and future water demands in the Wami River Basin.

3.1 HYDROLOGICAL SYSTEM

The Wami watershed with its hydrological zones and representative hydrological stations is shown in Fig. 2. The watershed was delineated from the global 90 m DEM for Africa. Table 3 shows the average seasonal rainfall for the 10 sub-basins where data was available from WRBWO.

Figure 2

Hydrological zones of the Wami River Basin

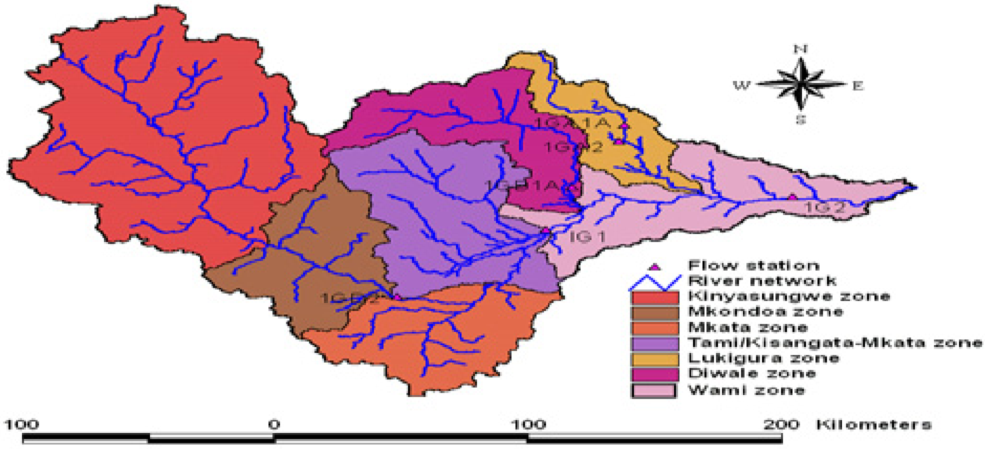


Table 1

Available river flow data from flow gauging stations in the Wami basin

No.	Station	River	Records	% missing
1	1GB1A	Diwale	31/10/1964 - 31/12/1990	**3.85** (1/1/1965 - 31/12/1990)
2	1G1	Wami	14/11/1953 - 31/12/1990	**16.52** (1/1/1954 - 31/12/1990)
3	1GA1A	Lukigura	15/10/1964 - 29/2/1988	**8.82** (1/1/1965 - 31/12/1987)
4	1GA2	Mziha	16/10/1964 - 1/8/1990	**23.25** (1/1/1965 - 31/12/1990)
5	1G2	Wami	9/6/1954 - 15/12/1990	**10.91** (1/1/1954 - 31/12/1990)
6	1GD2	Mkondoa	31/3/1952 - 29/12/1988	**16.91** (1/1/1952 - 31/12/1988)

The intra-annual rainfall variation in the basin has dry periods (low rainfall amounts) from June to October and wet periods (high rainfall amounts) from November to January (*Vuli* rains) and from March to May (*Masika* rains). Other than in Zone 1, the highest peak amount of rainfall occurs in April while the lowest peak of rainfall occurs around July–August (Figs. 3&4).

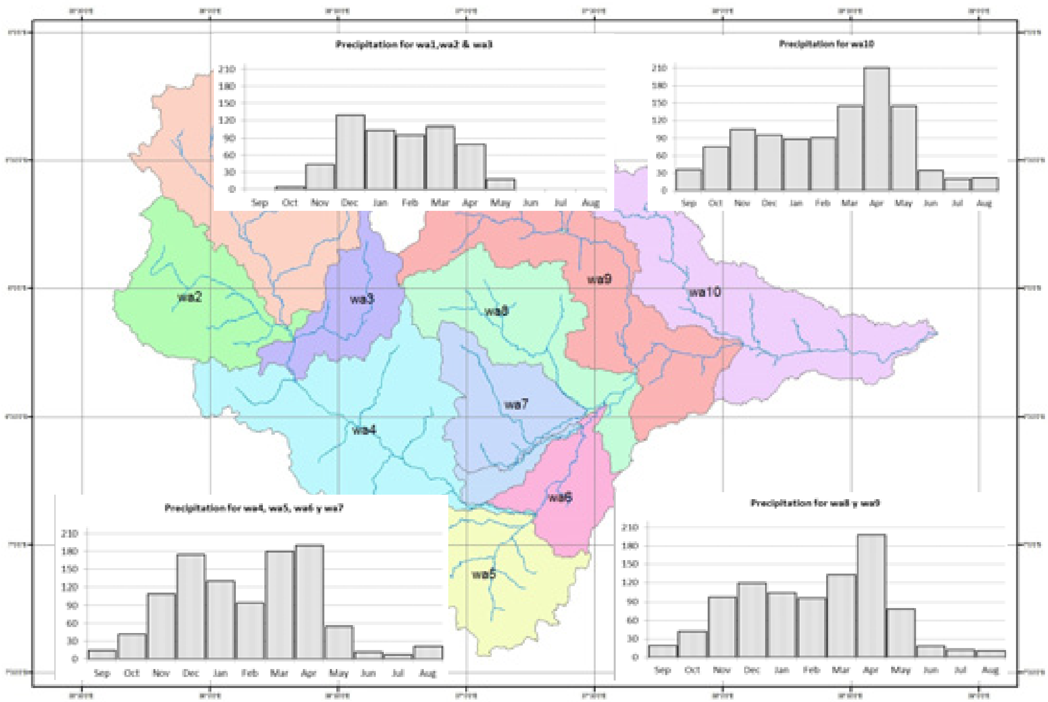
Table 2

Precipitation Data by Sub-Basin

Month	Precipitation			
	ZONE 1 (WA1,WA2 & WA3)	ZONE 2 (WA4, WA5, WA6 & WA7)	ZONE 3 (WA8 & WA9)	ZONE 4 (WA10)
Sep	0	15	20	36
Oct	5	42	43	75
Nov	45	110	98	105
Dec	130	175	119	95
Jan	105	130	105	88
Feb	96	95	97	90
Mar	110	180	133	145
Apr	80	190	198	210
May	18	55	79	145
Jun	0	12	19	35
Jul	0	8	13	20
Aug	0	22	11	22
Annual	589	1034	935	1066

Figure 3

Wami River Basin Season Average Rainfall by Sub-Basin



Source: Hydrology component of EFE study, Wami river Sub-basin – Tanzania, 2007 Literature review (rainfall variation chapter)

Figure 4

Climate and hydrological stations

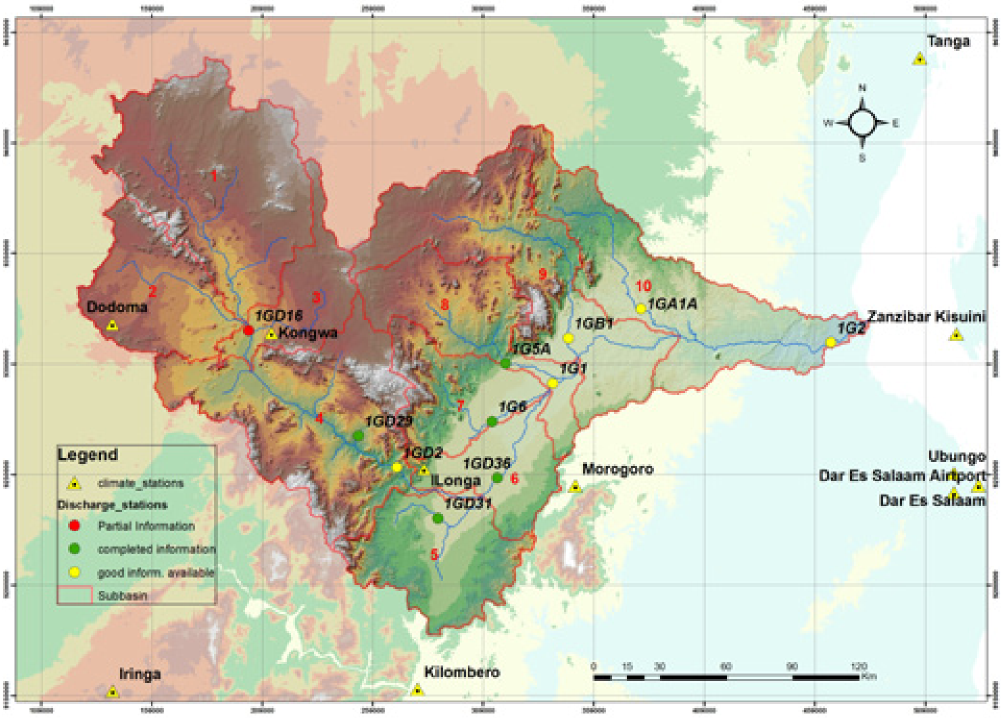


Table 3

Hydrological Stations in the Wami River Basin

No.	Station Code	River	Location	Gauge Range	Last Data Received	Status
1	1G1	Wami	Dakawa	0-10m	December 2006	Operational-rehab in Sep 2006
3	1G2	Wami	Mandera	0-5m	August 2003	Operational-rehab in Dec 2006
4	1G5A	Tami	Msowero	0-5m	July 2007	Operational-rehab in Oct 2006
5	1G6	Kisangata	Mvumi	0-6m	March 2007	Operational-rehab in Oct 2006
7	1GA1A	Lukigura	Kimamba Rd.Br	0-5m	May 1987	Operational-rehab in Sep 2006
8	1GA2	Mziha	Mziha (Kimamba)	0-4m	July 2007	Operational-rehab in Sep 2006
9	1GB1A	Diwale	Ngomeni		July 2007	Operational-rehab in Oct 2006
12	1GD35	Myombo	Kivungu	0-6m	April 1963	Operational-rehab in Oct 2006
14	1GD16	Kinyasungwe	Kongwa/ Dodoma	0-5m	July 2003	Operational-
16	1GD2	Mkondoa	Kilosa	0-6m	March 1991	Operational-rehab in Oct 2006
18	1GD29	Mkondoa	Mbarahwe	0-5m	August 1980	Non-Operational-
20	1GD31	Mdukwe	Mdukwe	0-4m	June 2003	Non-Operational-
23	1GD36	Mkata	Mkata	0	June 2007	Operational-rehab in Oct 2006

The main hydrological stations are illustrated in Figure 4, and of those only five have sufficient and complete data – 1G2, 1G1, 1GD2, 1GB1, 1GA2, and 1GA1A, with statistics presented in Table 1. The stations 1GD29, 1GD31, 1G6 and 1G5A only have partial information for generally only a few years (Fig. 4). Station 1GD16 has very sparse data, with information about every five years and it is not possible to extrapolate or estimate the data as there are no other stations with the same characteristics that can be correlated.

4. ESTIMATION OF WATER SUPPLY

The monthly average water availability for the reference period of 1954–1987 is presented in the Table below.

Table 4

Average volume in the rivers of each sub-basin Mm³

Sub-basin	River	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
WA-1	R_Wami 0 \ Headflow	0.9	10.1	5.7	3.7	1.6	1.6	0.4	0.0	0.0	0.0	0.0	0.0	24.0
WA-2	R_Litle Kinyasungwe 0 \ Headflow	0.4	4.6	2.6	1.7	0.7	0.7	0.2	0.0	0.0	0.0	0.0	0.0	10.9
WA-3	R_Masena 0 \ Headflow	0.3	3.0	1.7	1.1	0.5	0.5	0.1	0.0	0.0	0.0	0.0	0.0	7.2
WA-4	R_Wami 18 \ Reach	45.0	26.7	40.0	50.3	42.0	26.1	23.6	21.0	19.6	18.1	22.7	36.6	371.6
WA-5	R_Mikata 0 \ Headflow	13.1	9.4	12.2	25.6	23.5	9.6	5.9	4.5	3.9	3.2	3.9	8.5	123.4
WA-6	R_Wami 34 \ Reach	133.7	89.1	121.7	227.9	204.4	90.6	61.5	49.0	43.3	37.3	46.3	93.3	1198.2
WA-7	R_Kisangata 0 \ Headflow	12.1	9.8	10.8	26.3	24.6	10.7	6.0	4.5	4.2	4.7	5.4	11.7	130.8
WA-8	R_Tami 0 \ Headflow	10.7	7.9	10.3	25.9	21.0	7.6	4.4	3.8	2.8	2.8	4.7	8.8	110.9
	R_Diwale 0 \ Headflow	22.7	20.3	27.1	57.6	56.0	26.3	16.5	13.5	12.2	12.5	16.7	22.9	304.3
WA-9	R_Wami 52 \ Reach	148.8	99.0	134.5	272.4	242.6	101.9	65.5	51.0	44.1	38.8	50.0	106.8	1355.3
	R_Lukigura 0 \ Headflow	7.2	7.2	6.7	19.8	13.9	5.3	3.5	2.9	3.0	4.0	5.2	8.7	87.5
WA-10	R_Wami 60 \ Reach	172.2	119.7	161.4	343.6	306.5	128.2	80.7	62.5	53.6	48.9	65.5	132.3	1675.3

Table 5

Average flow of the rivers of each sub-basin m³/s

Sub-basin	River	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
wa-1	R_Wami 0 \ Headflow	0.32	4.18	2.12	1.43	0.61	0.63	0.14	0.00	0.00	0.00	0.00	0.00	0.79
wa-2	R_Litle Kinyasungwe 0 \ Headflow	0.15	1.91	0.97	0.65	0.28	0.29	0.06	0.00	0.00	0.00	0.00	0.00	0.36
wa-3	R_Masena 0 \ Headflow	0.10	1.25	0.63	0.43	0.18	0.19	0.04	0.00	0.00	0.00	0.00	0.00	0.23
wa-4	R_Wami 18 \ Reach	16.80	11.02	14.93	19.41	15.67	10.06	8.81	7.84	7.55	6.75	8.75	13.65	11.77
wa-5	R_Mikata 0 \ Headflow	4.90	3.90	4.54	9.89	8.76	3.72	2.19	1.67	1.51	1.21	1.49	3.19	3.91
wa-6	R_Wami 34 \ Reach	49.93	36.85	45.44	87.92	76.31	34.97	22.97	18.28	16.72	13.93	17.87	34.82	38.00
wa-7	R_Kisangata 0 \ Headflow	4.50	4.04	4.05	10.17	9.18	4.12	2.26	1.66	1.62	1.76	2.07	4.36	4.15
wa-8	R_Tami 0 \ Headflow	4.01	3.27	3.85	10.00	7.85	2.95	1.64	1.42	1.09	1.03	1.83	3.29	3.52
	R_Diwale 0 \ Headflow	8.47	8.38	10.12	22.21	20.91	10.15	6.16	5.06	4.70	4.66	6.43	8.57	9.65
wa-9	R_Wami 52 \ Reach	55.55	40.91	50.23	105.08	90.57	39.32	24.46	19.05	17.03	14.47	19.28	39.88	42.98
	R_Lukigura 0 \ Headflow	2.70	2.97	2.49	7.65	5.21	2.06	1.29	1.10	1.16	1.49	2.02	3.25	2.78
wa-10	R_Wami 60 \ Reach	64.31	49.49	60.26	132.58	114.44	49.47	30.13	23.35	20.68	18.24	25.28	49.41	53.14

5. ESTIMATION OF WATER DEMAND

The Wami basin includes a range of water demand areas, following in order of magnitude of volume consumed – 1) agriculture; 2) population/households (rural and urban); 3) livestock; and 4) industrial.

5.1 POPULATION DEMAND (HOUSEHOLDS)

The water demand, from the rural and urban population, changes over time at a rate of change equal to the population growth rate (1.7 percent) reported by the National Bureau of Statistics of the Ministry of Planning, Economy and Development(Table 6). According to a recent study by EFA, the consumption of water per person is approximately 150 litres/person/day in urban areas and 80 litres/person/day in rural areas.

Table 6

Population growth rate (2003–2025)

Region	Basin	Growth Rate
Pwani	No influence	The projections show that population growth rate will decrease slightly from 2.1 percent in 2003 (with a population of 903,816) to 2.0 percent in 2025 (with a population of 1,450,857).
Morogoro	WA1 - WA10	The projections show that population growth rate will decrease from 2.3 percent in 2003 (with a population of 1,794,815) to 1.7 percent in 2025 (with a population of 2,818,784).
Manyara	No influence	The projections show that population growth rate will increase from 3.9 percent in 2003 (with a population of 1,075,022) to 4.2 percent in 2025 (with a population of 2,483,873).
Tanga	WA10	The projections show that population growth rate will decrease from 2.2 percent in 2003 (with a population of 1,672,581) to 1.9 percent in 2025 (with a population of 2,639,366).

Source: Regional and District projections, Tanga, National Bureau of Statistics Ministry of Planning, Economy, and Empowerment, volume XII

Table 7

Population by districts within the basin, following census data 2002

Sub-basin	Population		
	Urban	Rural	Total
P_Kibaya	130,870	430,870	561,740
P_Dodoma	264,813	208,990	473,803
P_Kongwa	69,664	208,991	278,655
P_Mpwapwa	80,987	161,974	242,961
P_Kimamba	153,224	308,882	462,106
P_Morogoro	81,602	237,502	319,104
P_Dumila	153,224	306,448	459,672
P_Dakawa	107,350	214,700	322,050
P_Mvomero	78,680	314,718	393,398
P_Kilindi	181,503	289,859	471,362
Total	1,301,917	2,682,934	3,984,851

Urban population demand is approximately 52.37 Hm^3 at the start of the simulation (1954) and grows to 91.34 Mm^3 in the final simulated year (1987). The rural population demand grows from 58.27 Mm^3 (1954) to 101.63 Mm^3 (1987).

Table 8

Water demand (Mm³) - Rural population

	2012	2045
RuralWA1	2.51	4.37
RuralWA2	1.22	2.12
RuralWA3	1.22	2.12
RuralWA4	4.71	8.21
RuralWA5	8.98	15.67
RuralWA6	6.91	12.05
RuralWA7	8.91	15.54
RuralWA8	6.24	10.89
RuralWA9	9.15	15.96
RuralWA10	8.43	14.70
Sum	58.27	101.63

Table 9

Water demand (Mm³) - Urban population

	2012	2045
P_Dakawa	5.88	10.25
P_Dodoma	2.17	3.79
P_Dumila	8.39	14.63
P_Kibaya	2.87	5.00
P_Kilindi	9.94	17.33
P_Kimamba	8.39	14.63
P_Kongwa	1.53	2.66
P_Morogoro	4.47	7.79
P_Mpwapwa	4.43	7.73
P_Mvomero	4.31	7.51
Sum	52.37	91.34

5.2 LIVESTOCK DEMAND

There are large groups of pastoralists who migrated into the basin in the 1960s due to the availability of pasture and reliable water. They settled with their livestock as observed in Kambala and Mindu Tulieni villages in Mvomero and Bagamoyo districts respectively. The principal livestock keepers in the Wami River Basin are the Maasai pastoralists. Their traditional grazing lands in Arusha and Manyara regions have been significantly affected by population pressure; the Maasai pastoralists have continued to migrate southwards to many other areas including Kilombero, Usangu and the Wami Basin for grazing purposes (Madulu, 2005). As a result, the Wami river basin has a high population of livestock grazing. According to the 1995 census, the density is approximately 3-122 heads per square kilometre in the Dodoma and Morogoro districts. According to the study "Wami Basin Situation Analysis", the average density is 65.49 heads per square kilometre which implies that the average density has not changed much since the 1995 census.

Table 10

Population by district, from census 2002

Sub-basin	Population	
	Unit	Quantity
WA1	heads	215,435
WA2	heads	104,495
WA3	heads	104,496
WA4	heads	171,974
WA5	heads	154,441
WA6	heads	153,224
WA7	heads	153,224
WA8	heads	429,400
WA9	heads	629,436
WA10	heads	579,718
Total		2,695,843

Table 11

Livestock Demand by Sub-basin

Sub-basin	2012	2045
LivestockWA1	0.78	0.99
LivestockWA2	0.38	0.48
LivestockWA3	0.38	0.48
LivestockWA4	3.13	3.93
LivestockWA5	2.81	3.53
LivestockWA6	2.78	3.51
LivestockWA7	2.78	3.51
LivestockWA9	11.44	14.40
LivestockWA8	7.80	9.82
LivestockWA10	10.54	13.26
Sum	42.82	53.91

5.3 INDUSTRIAL DEMAND

Industrial demand in the Wami Basin is only on a very small scale and has very little impact on water resources in the basin. The only important industrial user is Eco Energy, using 1.923 Mm^3 each month for the industrial processing of sugarcane to ethanol.

User	Volume (Mm^3)	Flow (m^3/s)	Use
Ecoenergy	1.927	0.06	Industrial

5.4 ECOLOGICAL FLOWS

The ecological flows of the river are defined as the minimum quantity that provides for biological life in each of the rivers.

Table 12

Ecological flows at the river points

Month	Ecological flow by river (m^3/s)				
	Kinyasungwe at Kongwa	Mkondoa at Kilosa	Wami at Matipwili	Wami at Mtibwa	Wami at Mandera
Oct	0	4.2	6.6	10	13.3
Nov	0	4.3	6.6	10	14
Dec	1.1	6.7	14.7	24.2	27.3
Jan	1.1	9.2	22.8	31.4	32.8
Feb	1.1	11.6	30.9	24.6	24.6
Mar	1.1	14	39	27.5	52.4
Apr	1.1	14	39	67	65
May	0.4	14	39	67	65
Jun	0	5.7	28.2	26.3	37.5
Jul	0	4.3	17.4	13.2	20.8
Aug	0	4.3	6.6	10	14
Sep	0	4.3	6.6	10	14

Source: The Wami River Initial Environmental Flow Assessment, Final Report. Wami River Sub-basin, Tanzania, Sarmett, J. and others, 2008

5.5 CROP AGRICULTURAL DEMAND

The distribution of water for crop production by sub-basin is determined based on the cultivated area, the type of crop, and the period of planting and harvesting. The requirements vary by location, time period (e.g. WS-wet season and DS-dry season), and the water requirements of the crop. The primary agricultural water demand in the Wami Basin is from the cultivation of rice, sugarcane and to a lesser extent vegetables (Table 9).

Table 13

Agricultural Demand Total, Mm^3

Sub-basin	Rice	Sugarcane	Vegetable	Total
WA1 WS	0.00	0.00	0.00	0.00
WA2 WS	0.00	0.00	0.00	0.00
WA3 WS	0.00	0.00	0.00	0.00
WA4 WS	4.35	0.00	1.82	4.35
WA5 WS	43.36	0.21	0.15	43.36
WA6 WS	57.43	0.00	0.00	57.43
WA6 DS	77.71	0.00	0.00	77.71
WA7 WS	15.40	0.00	0.10	15.40
WA8 WS	32.44	111.50	0.00	32.44
WA9 WS	8.17	0.00	0.00	8.17
WA9 DS	7.51	0.00	0.00	7.51
WA10 WS	6.63	0.00	0.00	6.63
WA10 DS	2.00	0.00	0.00	2.00
Total Demand Mm^3	**255.00**	**111.72**	**2.07**	**368.79**
Total Area (Ha)	12859.20	19970.00	1186.00	34015.20

5.6 FUTURE AGRICULTURAL DEMAND

The future agricultural demand considered here looks at the scenario of bioenergy crop expansion based on increasing demand from the planned sugarcane and sorghum projects currently being pursued. The average monthly demand for each crop is shown below in Table 14.

Table 14

Summary of Future Agricultural Demand, Mm³

Sub-basin	Rice	Sugarcane	Vegetable	Total
WA1 WS	0.00	0.00	0.00	0
WA2 WS	0.00	0.00	0.00	0
WA3 WS	0.00	0.00	0.00	0
WA4 WS	15.12		1.82	16.94
WA5 WS	94.21	1.67	0.76	96.64
WA6 WS	108.18		0.00	108.18
WA6 DS	128.00		0.00	128
WA7 WS	85.40		0.26	85.66
WA8 WS	49.92	132.11	0.00	182.03
WA9 WS	166.26		0.00	166.26
WA9 DS	125.94		0.00	125.94
WA10 WS	1.45		0.00	1.45
WA10 DS	15.36		0.00	15.36
Total	**789.85**	**133.78**	**2.84**	**926.47**
Total Area (Ha)	42329.9	48562.2	1788.00	92680.1
Sugarcane for ethanol				
EcoernergyAfrica		102.78		
Mtibwa_w8		124.30		
Mtibwa_w9		104.64		
Outgrower		33.89		
Total Demand		**365.60**		**1292.07**

The EcoEnergy Africa project (formerly SEKAB BioEnergy Tanzania Ltd.) has the objective of developing sugarcane plantations in Rufiji, Kilwa and Bagamoyo districts. The company has selected Razaba farm in Bagamoyo district as the first pilot site covering around 30,000 hectares located within WRB (WWF, 2008). The company has leased agricultural land from prisons in Bagamoyo in order to start seed cane multiplication on 200 ha in preparation for planting on the Razaba farm in mid 2008 (WWF, 2008). The water required for the seed cane farm is pumped from Ruvu River while the sugarcane plantation at Razaba Ranch farm will draw water from the Wami River. This is a concern since sugarcane requires a significant amount of water and much of the water flowing in the Wami River needs to satisfy ecological requirements such as the Saadan National Park and the discharge of water and sediments to the Indian Ocean.

In the Wami Basin, there is also a plan to commission 14,000 ha for a sorghum plantation in Kilosa area for the Serengeti breweries. This plantation will be purely rainfed and with 6,000 ha planted in the first year. The sorghum plantation will add to the water demands in the WRB and could reduce river flows and affect downstream water users.

6. THE WATER EVALUATION AND PLANNING SYSTEM (WEAP)

The process of hydrologic modelling of supply and demand in the Wami River Basin for the period of 2013–2045 was conducted using the Water Evaluation and Planning System (WEAP21).

WEAP was developed by the Stockholm Environmental Institute (SEI) to address water management issues associated with resource allocation. The WEAP model can be applied to both municipal and agricultural systems and can address a wide range of issues including sectoral demand analyses, water conservation, water rights and allocation priorities, streamflow simulation, reservoir operation, ecosystem requirements and project cost-benefit analyses (SEI 2001). The model has two primary functions (Yates et al. 2004):

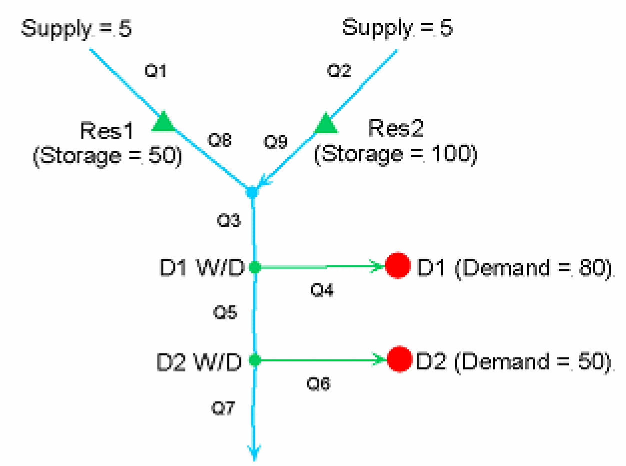
- Simulation of natural hydrological processes (e.g. evapotranspiration, runoff and infiltration) to enable assessment of the availability of water within a catchment.
- Simulation of anthropogenic activities superimposed on the natural system to influence water resources and their allocation (i.e. consumptive and non-consumptive water demands) to enable evaluation of the impact of human water use.

To allow simulation of water allocation, the elements that comprise the water demand-supply system and their spatial relationship are characterized for the catchment under consideration. The system is represented in terms of its various water sources (e.g. surface water, groundwater, and desalinization and water reuse elements), withdrawal, transmission, reservoirs, and wastewater treatment facilities, and water demands (i.e. user-defined sectors but typically comprising industry, mines, irrigation, domestic supply, etc.). The data structure and level of detail can be customized (e.g. by combining demand sites) to correspond to the requirements of a particular analysis and constraints imposed by limited data. A graphical interface facilitates visualization of the physical features of the system and their layout within the catchment.

The WEAP model essentially performs a mass balance of flow sequentially down a river system, making allowance for abstractions and inflows. To simulate the system, the river is divided into reaches. The reach boundaries are determined by points in the river where there is a change in flow as a consequence of the confluence with a tributary, or an abstraction or return flow, or where there is a dam or a flow gauging structure. Typically, the WEAP model is applied by configuring the system to simulate a recent "baseline" year, for which the water availability and demands can be confidently determined. The model is then used to simulate alternative scenarios (i.e. plausible futures based on "what if" propositions) to assess the impact of different development and management options. The model optimizes water use in the catchment using an iterative Linear Programming algorithm, whose objective is to maximize the water delivered to demand sites, according to a set of user-defined priorities. All demand sites are assigned a priority between 1 and 99, where 1 is the highest priority and 99 the lowest. When water is limited, the algorithm is formulated to progressively restrict water allocation to those demand sites given the lowest priority.

Figure 5

Water Balance in WEAP



Source: WEAP manual

6.1 HYDROLOGIC MODELLING

The study area was limited to the Wami River Basin with an approximate area of 43,900 km^2. This was achieved by setting the boundary function of the model, selecting Tanzania from the list of countries and then adding an already delineated catchment into the programme.

The WEAP model was calibrated using observed flow data from two gauging stations located on the Wami River (1G1 and 1GD2) for the period from 1954–1987. This involved altering the demand priorities and changing assumptions about historic demand patterns. This was done to improve the fit between simulated and observed flows. Due to limited spatial hydrological data availability, the headwater flows were determined by area ratio method with reference to the gauged flows' water yields. For the Kinyasungwe sub-basin, the flow at IGD2 was used and for the Diwale and Dakawa sub-basins, the flow at 1G1 was used.

6.2 WEAP DATA REQUIREMENTS

Data required for this study was:

- Existing water use data
- Streamflow gauged records (their location, their period and drainage area)
- Historic monthly flow records for gauged and ungauged catchment for the time horizon of analysis

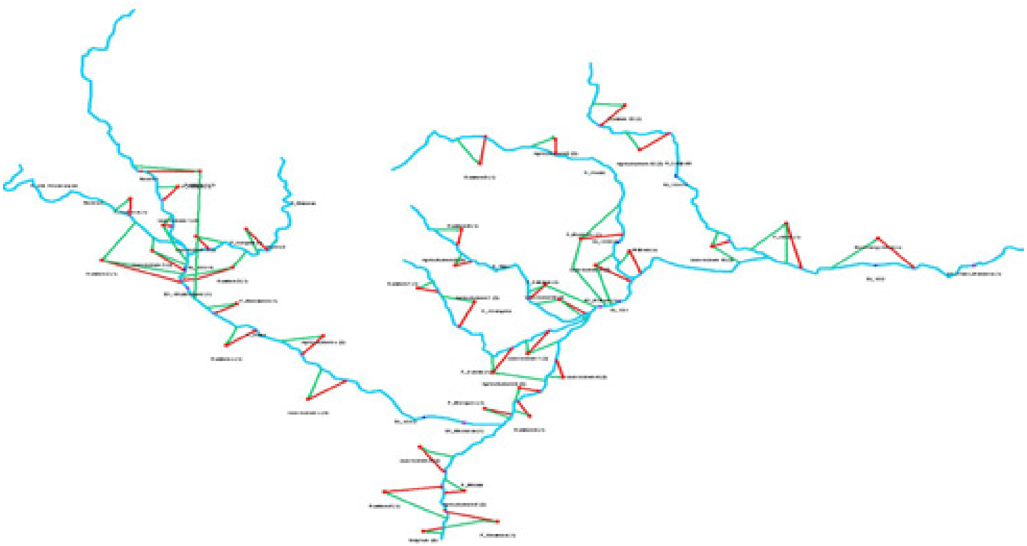
- Permitted surface water withdrawals in the study region
- Permitted discharges, the holders of the permit and the origin of the discharge water in order to associate it with the distribution system as return flow
- The full network of the river system
- A map of the study region
- Activity levels for urban areas, cities and industries (amount of water required)

6.3 WEAP MODEL SET-UP

The SETUP module of WEAP is where the supply and demand features of the water resource system are defined and the system configured. The demand sites modelled by WEAP are shown in Fig. 10 with the numbers in bracket showing the water allocation priorities.

Figure 6

The WEAP schematic: demand sites and water allocation priorities



These are sets of distribution points within a defined area or that share a particular withdrawal supply point. Distribution systems may include cities, irrigation areas, counties and individual surface or underground withdrawal points. All the major water users within a sub-basin were treated as separate demand sites in this study. Industrial abstraction was modelled as a demand site for WA10 sub-basin.

Linking demand and supply is conducted in order to create a system network of linked demand sites to water sources. In the Wami River basin, all demand sites were linked to either the river or its tributaries as they were assumed to be the only water source in the catchment[20].

For each demand site withdrawals are ranked by priority. For each source of supply,

20 Groundwater supply was not considered in this study due to limited time and data.

the supply site assigned a higher priority will always be used to supply water when enough water is available from the source, but if the water is not enough, then the next supply site will be considered. This only works when the water supplied from the river is not enough to fulfil all the water requirements. If the supply of water is low, demand sites with the highest allocation priorities will be met first. In WEAP, priorities for demand sites within the basin were determined as shown in Table 15 based on the priorities established by the Ministry of Water. The priorities of water allocation were established during calibration and were adjusted to give the best fit between observed and simulated flows.

Table 15
Water allocation priorities set in WEAP model

Demand site	Water allocation priority
Environmental Flows	1
Urban	2
Rural	3
Livestock	4
Agriculture	5
Industrial	6

7. RESULTS AND DISCUSSION

The scenarios presented in this study illustrate alternatives where you can compare the ability of the system (Wami basin) to satisfy demands in each scenario to a reasonable degree of confidence. Following the current and future development trends in the Wami Basin and the potential impact of bioenergy, the following three scenarios where analysed:

- Scenario 1: Reference or actual situation
- Scenario 2: Future situation with population growth and sugarcane ethanol production
- Scenario 3: Future situation with population growth, sugarcane ethanol production, and increase in local agriculture

7.1 ANALYSIS OF THE SUSTAINABILITY OF WATER SUPPLY AND DEMAND

Table 16

Principal Parameters

Period	Historic trend	Future
Population growth (Growth=1.7%)	3,984,851	6,625,097
Demand per capita (l/day/ person)	155	155
Expansion Irrigated Crop (ha)	34015.2	92680.1
Demand for irrigation (Mm3)	368.79	1292.07
Rice (ha)	12859.2	42329.9
Sugarcane (ha)	19970.0	48562.2
Vegetable (ha)	1186.0	1788.0
Livestock (Growth=0.7%)	2,695,843	3,393,650

The following assumptions were used in the analysis of all scenarios:

- The water supply for population (rural and urban) for sub-basins WA1, WA2, WA3 is understood to have an alternate source of supply such as groundwater, so only 20 percent of population demand is applied to the Wami.
- For the livestock demand under the same sub-basins (WA1, WA2, and WA3), it is assumed that because there is scarce supply of water in these areas, cattle herds are moved to other areas, even outside this basin area. Therefore, only 15-20 percent of demand is charged to the Wami. For all scenarios it is assumed that in times of water shortage, cattle can be moved to other areas in the near vicinity.
- For all other sub-basins, it was considered that the settlement of the population is not fully centralized and therefore can get water from both the Wami River and other tributaries as it is necessary, shown in the case of sub-basin WA7 (population around Dumila).

7.2 SCENARIO 1: REFERENCE

This scenario took into account the current characteristics of water supply and demand in the basin and the current use capacity. Considering a current demand of 34,015.2 ha of area cultivated, 460.22 Mm^3 is required. The objective of a reference scenario is to help people understand the real situation and what likely could occur if current trends continue. Reference scenarios can also be useful for identifying areas where knowledge is weak in analysing likely trends and where more information needs to be collected. They can be useful for designing contingency plans where there is a lot of risk and uncertainty. The basic model built reflects the reference scenario, which replicates the current situation.

The results of the analysis of Scenario 1 showed **there is not sufficient supply to meet all the current demands, particularly in agriculture. The deficit is high, considering that the average coverage is only 37 percent and the necessary level for agriculture must be above 75 percent, and for populations over 90 percent.**

- Coverage of agricultural demand: The main sub-basins with deficits are WA8 and WA5
- Coverage of urban population demand: The main populations with shortages are Dodoma, Kibaya, Kimamba and Kongwa
- Coverage of rural population demand: The only sub-basin with shortages is WA10
- Coverage of livestock demand: The main sub-basin with shortages is WA3

7.3 SCENARIO 2:

The second scenario considers the demand for the future taking into account population growth and the incorporation of new areas of cultivation for sugarcane for ethanol (34901 ha) and a total cultivated area 91,732.2 ha. The demand in this scenario is 1278.55 Mm^3 in total, distributed in 8010.84 Mm^3 for rice, 473.85 Mm^3 for sugarcane and 2.86 Mm^3 for vegetables. No increase is included in general for agriculture for this scenario.

The results of the analysis of Scenario 2 showed **there is not sufficient water supply to meet all the current demands. The deficit is high and the average coverage is 32.7 percent, with an increase of approximately 40 percent in average demand**

- Coverage of agricultural demand: Compared with Scenario 1, persistence of coverage becomes an even greater issue once bioenergy crop expansion is added in this scenario
- Coverage of urban population demand: This is the area most affected under this scenario, where the same areas with shortages in Scenario 1 now experience shortages reaching almost 50 percent
- Coverage of rural population demand: This group only experiences a small reduction which is not significant as the coverage remains high
- Coverage of livestock demand: In this scenario, sub-basin WA3 is affected but only marginally

7.4 SCENARIO 3:

This scenario takes into account the future demand, plus an increase in the cultivated area for agriculture generally (1292.07 Mm^3), of which 365.60 Mm^3 are for sugarcane ethanol.

The results of the analysis of Scenario 3 showed **there is not sufficient supply to meet all the current demands. The deficit is high and the average coverage is 18 percent of volume or 40 percent of the projected areas**

- Coverage of agricultural demand**:** This sector is highly affected in this scenario, and only the sub-basins of WA3 and WA7 have decent coverage; the rest have serious shortages, particularly in the new areas of cultivation.
- Coverage of urban population demand: The populations most affected in this

scenario are Dodoma, Kibaya and Kongwa with approximately only 50 percent of the demand covered in these areas.

- Coverage of rural population demand: In this scenario the populations with reduced coverage are in sub-basins WA10 and WA5, with around 90 percent coverage, which is the lower limit for populations.
- Coverage of livestock demand: The coverage of the demand for livestock is similar to Scenario 2 with a lowering in all sub-basins except WA3 where the decrease is 5 percent less.

Table 17

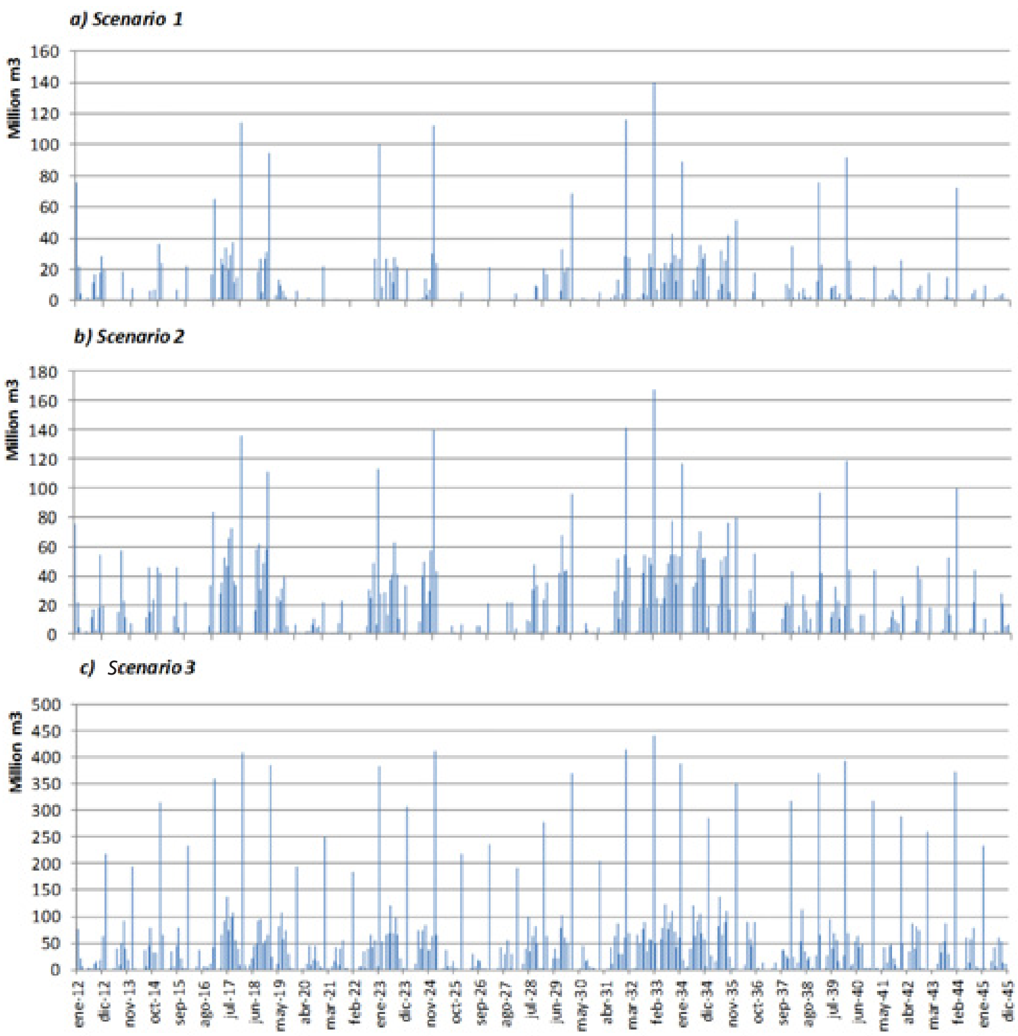
Confidence Indicators

	Scenario 1	**Scenario 2**	**Scenario 3**
Deficit Mm^3	257	277	332
Reliability	37.0%	32.1%	18.6%
Average Vulnerability Mm^3/month	13.21	24.27	62.17
Maxium Vulnerability Hm^3	140.36	167.70	440.35
Average Resilience (month)	4.8	5.8	7.2
Maximum Resilience (month)	11.0	11.0	24.0
Accumulated Deficit Mm^3	3395.60	6723.98	20638.90
Maximum Deficit Mm^3	140.36	167.70	440.35

As illustrated in Table 17. above, demand cannot be fully met in any of the scenarios analysed. The reliability is low in all scenarios (18.6% - 37%). The vulnerability is high, and the resilience is also high because 5–7 months are required to recover from periods of deficit.

Figure 7

Deficits in each scenario



8. CONCLUSIONS

The WEAP model was successfully established in the Wami River Basin. Rainfall data was used in the determination of sub-basin yields and hence for the spatialization of water flows. Three gauging stations at 1GD2, 1G1 and 1G2 were used to calibrate the model. The coefficients of determination (R^2) were 87%, 71% and 91% respectively and the model efficiency criteria (Nash Sutcliffe) were 99%, 54% and 84% respectively. However, given the timeframe for the analysis, the dispersion of data, and the gaps in data availability, several assumptions were made during the model calibration. This included areas with very low water availability; the water demand has been reduced from these sub-basins because of down or up-river movement of livestock to basins where there is greater water availability.

The results from the developed scenarios showed unmet water demands in the basin.

The unmet demand in the basin during the reference scenario is 178.46 Mm3, experienced mostly by the agriculture sector. The results of this study illustrate the growing urgency of water resource management in the Wami Basin, and the implications that the expansion of biofuel crops may have on in the basin. Thus far the policy dialogue in Tanzania has focused largely on land availability. However agriculture needs both land and water. This study aims to illustrate the importance of water resource consideration in policymaking around bioenergy production. The Ministry of Water has initiated a water sector reform programme that stresses comprehensive river basin management based on *integrated water resource management* (IWRM) principles, user involvement in management, cost recovery and sustainable resource use. However, it is important that this program is also integrated with the Ministry of Agriculture's programme for irrigation expansion to ensure that future irrigation expansion is adequately reflected in the IWRM plans for each basin. The Ministry of Energy is leading the biofuel policy development in Tanzania in close coordination with other Ministries. It will be important that the Ministry of Water is also part of this discourse in order to ensure that IWRM plans consider potential biofuel crop expansion in each of the basins where it is feasible and/or there is growing interest.

The increased demand for water could lead to higher risk of water shortages, reduced river flows and groundwater recharge, reduced blue water and reduced quality in the Wami River due to industrial effluent (untreated) pollutants, and reduced quality water discharged into the Indian Ocean Estuary.

9. RECOMMENDATIONS

- The Ministry of Water needs to participate in the bioenergy policy process in order to ensure that water resource management is considered
- Further clarity around the process and procedures for water concessions and prioritization needs to be developed at the local and national level
- Increase and improve systematic collection and maintenance of water, climate, and soil data
- Consider the possibility of regulating the flow of the river through reservoirs, where environmental conditions allow
- Incorporate water resource management technologies and strategies (e.g. rainwater harvesting) for both the agricultural and household sectors

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CHAPTER 3

HOUSEHOLD LEVEL IMPACTS OF INCREASING KEY FOOD STAPLES PRICES

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1. INTRODUCTION

Global food security concerns have been heightened by recent events in world commodity markets. The demand for agricultural feedstocks for biofuels has been the largest source of new demand for agricultural production in decades, and has been a contributing factor to the increase in agricultural commodity prices in recent years. The precise contribution of biofuels to the recent rise in commodity and food prices has been the subject of considerable debate, but its effect is difficult to disentangle from other contributing factors, such as rising food demand in emerging economies, declining stocks, exchange rate movements and trade restrictions. Estimates of the impact of biofuels vary, given differences in methods, commodities, and time periods covered[21] but most studies agree that biofuels have affected the international price for maize and vegetable oils.

The debate has mostly focused on the consumer side of higher food prices ignoring the fact that higher food prices can be beneficial to producers and can stimulate supply response. This analysis aims to explore the impact of increasing food prices in more detail, understand whether the poor in Tanzania are net producers or consumers of the key food staples, and identify which segments of the population are vulnerable to these price changes.

New bioenergy demand has contributed to the rise in the price of maize. Maize and cassava are the two most important food staples in Tanzania. The previous analysis carried out in Tanzania (FAO, 2010) illustrated how the domestic price of maize follows similar trends to the international price of maize and how the price of cassava follows the domestic price of maize. Thus, if the international price of maize increases this will eventually be followed by an increase in the domestic price of maize and cassava. What is unclear is whether these price increases are detrimental or beneficial. The analysis included herein first addresses the country level impacts and assesses the country's net trade position. Countries that are net importers lose from the price increase, while countries that are net exporters can gain, but the results are still very aggregated. Differences exist at the household level, especially if they are urban households versus rural households. Urban households will generally be net consumers of food while rural households can be net

21 Most studies have found that biofuels have accounted for about a third of the increase in the prices of maize and vegetable oils in recent years, with smaller effects for other commodities.

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producers of food. Net consumers will be hurt by the price increase while net producers can gain. Female-headed households and landless households also tend to be more vulnerable to price volatility. These household characteristics are used to further classify households and define vulnerable groups.

Within this context, it is understandable why many are concerned about biofuel implications for food security in developing countries. Nonetheless, what remains key is new investment in agriculture and enabling a supply response to increasing food prices. The agricultural system has the capacity to produce more to meet both food and other demands. Without new investment and increased agricultural productivity, producing biofuels could redirect the already inadequate crop production towards the energy sector. Thus, biofuel investment should be targeted and used to drive agricultural sector growth, and economic growth more generally.

2. HOUSEHOLD AND COUNTRY LEVEL IMPACTS OF INCREASING FOOD PRICES: METHODOLOGICAL BACKGROUND

In order to assess the household and country level impacts of increasing food prices, the main food staples are identified at country level. Main food staples are determined based on per capita calorie contribution.

The analysis included herein begins by looking at the country level effects of price increases of key food staple and then at the household level impacts. 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 of the main food staples. 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.

After having identified the crops that are most vulnerable to price changes in the country is, we turn to the household level analysis to identify the most vulnerable segments of the population.

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, sell it and consume it. An urban household may not produce it but only purchase it.

Due to the potential dual nature of households, it is necessary to understand the net positions of households, namely whether households are net producers or net consumers. 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 would hurt the household. The overall household impact is determined by the effect of the price change on the 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 described by Minot and Goletti (1999) and adapted as discussed in Dawe and Maltsoglou (2009). The impacts are short term and are based on a 10 percent price increase on the producer side. Further details on the assumptions and the methodology are contained in Annex 1.

3. MAIN STAPLE CROPS IN TANZANIA AND COUNTRY LEVEL IMPACTS

The list of food security crops selected for the analysis is based on their caloric contribution to the diet of Tanzanian households. Based on the 2009 values, total calorie intake per capita was 2,035 calories per person per day. As shown in Table 1, the most important food crops in Tanzania are maize, cassava and rice, whereby maize contributes 33.8 percent to total calorie intake, cassava accounts for 13.8, and rice for 9 percent. The top ten food stuffs listed contribute more than 80 percent of total calorie intake. Noticeably, no meat or fish products are among the top ten food stuffs.

Table 1
Ranking of main crop commodities

Ranking	Commodity	Amount of calories	Calorie Share
1	Maize	688	34
2	Cassava	280	14
3	Rice (Milled Equivalent)	182	9
4	Wheat	97	5
5	Sugar (Raw Equivalent)	87	4
6	Sorghum	85	4
7	Sweet Potatoes	65	3
8	Beans	60	3
9	Beverages, Fermented	53	2,6
10	Palm Oil	51	2,5
Subtotal share for selected items		1,648	81
Total Calories per capita		2,035	

Source: FAOSTAT 2012, data from 2009

As maize, cassava and rice are the most important food stuffs, the following analysis will focus on these commodities.

In the case of the two main food security crops, maize and cassava, the net trade position is different. As shown in Table 2, Tanzania produced 3,659,000 mt of maize in 2009, while importing 66,000 mt and exporting 87,076 mt. Based on recent years, Tanzania does not generally trade large amounts of maize and fluctuates from being a slight net exporter to being a slight net importer. In 2009, Tanzania was a slight net exporter of maize, and therefore at the aggregate level the country could benefit from price increases.

Table 2
Trade data by commodity

Commodity	Production ('000 tons)	Imports ('000 tons)	Exports ('000 tons)	Net-importer[1] (percent)	Net-exporter[2] (percent)
Maize	3,659	6.6	87	-	2
Cassava	5,199	0	0	-	-
Rice	2,013	69	23	2	-

[1] Calculated as (Imports-Exports)/Production, [2] Calculated as (Exports-Imports)/Production
Source: FAOSTAT 2012, data from 2009

Cassava, on the other hand, is a non-tradable commodity and production in 2009 was 5,199,000 mt in 2009 (see Table 2). A previous analysis [22] has illustrated that as maize and cassava can be substitutes, the price of cassava tends to follow maize price movements. Nonetheless, as cassava is not traded, Tanzania at the aggregate level would not be susceptible to price changes, but this might vary at the household level.

With respect to rice, Tanzania is a slight net importer of rice. In 2009 Tanzania produced 2,012,775 mt of rice, imported 69,186 tonnes and exported 23,177 tonnes. Therefore at the aggregate level, increases in the price of rice would negatively impact the country.

4. HOUSEHOLD LEVEL DATA AND CHARACTERISTICS

The household level analysis is based on the National Panel Survey 2008-2009 for Tanzania[23]. The dataset is country representative and covers 3,280 households and 26 regions of the country. Sample size and breakdown are illustrated in Table 3.

Table 3
Geographical distribution of surveyed households

Area	Subarea	Households (Number)	Share (percent)
Total Mainland		2800	85.4
	Dar es Salaam	560	17.1
	Other urban areas	416	12.7
	Rural areas	1824	55.6
Total Zanzibar		480	14.6
	Urban areas	240	7.3
	Rural areas	240	7.3
Total Tanzania			3280

Source: NPS 2008/2009

22 If world prices increase and domestic maize prices do also, then a higher price for maize shifts in the cassava supply curve (farmers switch from cassava to maize) and shifts out the cassava demand curve (consumers switch from maize to cassava). Both of these shifts in cassava supply and demand lead to higher prices, which could hurt poor consumers. Details on the interconnection of cassava and maize prices have been discussed in Chapter 8 of FAO (2010). Please also see details in Annex 2.

23 The sample size analyzed in this paper was slightly reduced due to some reporting errors found on expenditure shares. The final sample size for the analysis was 2,958.

The focus of the household level analysis is to understand which households are most vulnerable to increases in price changes. For this reason households are divided into quintiles, and by urban and rural location. The division in quintiles allows to distinguish between poor and wealthy households. The bottom quintile represents the poorest segment of the population (hereafter referred to as 'Poor') while the top quintile represents the richest part of the population (hereafter referred to as 'Wealthy').

Table 4

Household characteristics by welfare level

Household characteristic	Poor	Medium poor	Medium	Medium wealthy	Wealthy	Total
Household size (members)	6.5	5.8	5.6	4.8	3.8	5.4
Age of the household head (years)	48	48	48	47	42	46
Male-headed household (percent)	75	73	75	74	76	75
Number of years of education of household head (years)	5.8	5.9	6.5	7.3	9.1	7.2

Source: NPS 2008/2009

Some of the general household qualifiers include household size, age, gender and education. Household size is characterized by the number of members within the household, age is the age of the household head, gender is the gender of the household head and education is the number of years of education of the household head. Based on the NPS 2008/2009, the average household size in Tanzania is 5.4 members (see Table 4). Average household size does decrease with increased family welfare, a pattern which is very common in developing countries. The difference between the size of the poorest and richest households is approximately 2.7 members. On the other hand, the age of the household head and the share of male-headed households do not particularly differ among different welfare groups. The average age of the household head is 46 years old and 75 percent of households are male-headed, meaning that 25 percent of households in Tanzania are female-headed. The number of years of education of the household head shows a strong relation with welfare. On average, household heads receive 7.2 years of education. Household heads in poor households receive 5.8 years of education while wealthier household heads receive 9.1 years of education.

An additional important characteristic is whether households own land and the average land area possessed[24]. Adding the distinction between urban and rural households allows capturing some of the differences between urban households that are generally net buyers of food and rural households that can be net sellers of food. Table 5 illustrates average land area per household and the share of landless per welfare group and location.

24 Tables in Annex 2 contain the number of households per household group.

Table 5
Descriptive statistics by welfare level and location

Household characteristic	Poor	Medium poor	Medium	Medium wealthy	Wealthy	Total
Rural households						
Land area (ha)	1.8	1.8	1.6	1.8	1.5	1.7
Share of landless households per household group (percent)	11	10	11	16	26	13
Urban households						
Land area (ha)	1.4	1.2	1.0	1.2	1.7	1.3
Share of landless households per household group (percent)	57	60	64	75	88	65

Source: NPS 2008/2009

Average land area in rural areas is 1.7 ha and is similar across welfare segments as the average plot ranges between 1.5 and 1.8 hectares in rural areas (see Table 5). Most households in rural areas own land, where on average 13 percent of rural households are landless. The share of landless households is fairly constant for poor to medium welfare households. The share of landowners declines in wealthier quintiles where 74 percent of households own land, illustrating how wealthier households are diversifying income activities.

Urban dwellers on average own smaller plots of land with an average area of 1.3 hectares compared to 1.7 hectares in rural areas. The plot area across welfare segments remains pretty constant even in the case of urban households, ranging from 1.4 ha for the poorer households to 1.7 for the wealthier households. The majority of urban dwellers do not hold any land, with the share of landless households increasing with the expenditure quintile. Urban households are mostly involved in other forms of income generation.

Poorer households are generally found to spend a larger share of their money on food, illustrated in Table 6. On average, households in Tanzania spend more than 50 percent of their income on food. In the case of the poorest segment of the population, the share spent on food increases to 64 percent and is reduced to 40 percent for the wealthier segment of the population.

Table 6
Food budget shares

	Poor	Medium poor	Medium	Medium wealthy	Wealthy	Total
Food budget share	64	56	52	46	40	53

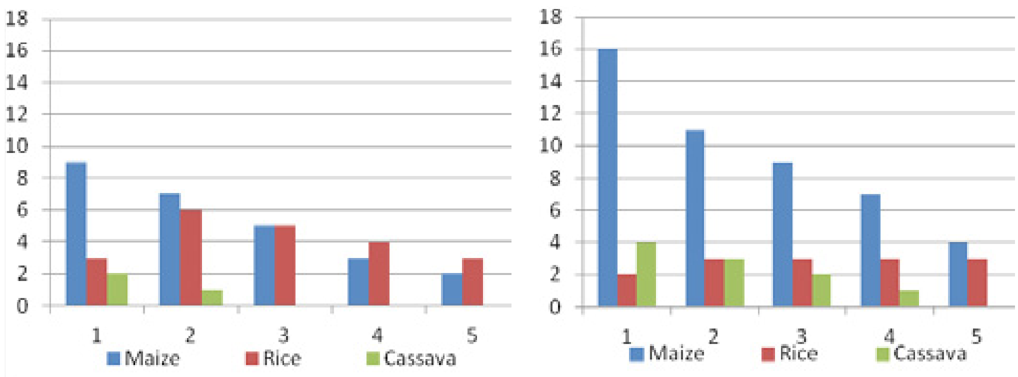
Source: Calculations by the authors based on NPS 2008/2009

Differences between urban and rural dwellers include not only the amount of money spent to buy food but also the shares allocated among the three main food crops (see Figure 1). In both urban and rural areas, the share of money spent to buy maize decreases with the welfare of the household. This again is in line with the theory that, as households become wealthier and the overall income levels increase, less money in proportion is spent on food and therefore on staples as consumption is further diversified. Rural households spend more on maize whereby the share of money spent to buy maize is almost double the amount spent in urban areas. Cassava is mostly consumed in rural areas and by the poorest households living in urban areas. The expenditure share on rice is relatively constant for rural households, while it mostly decreases for urban households.

Differences among urban and rural households arise when looking at the number of producers and the number of consumers for the three main crops included in this analysis.

Figure 1

Household food budget share, by urban and rural areas



Source: Calculations by the authors based on NPS 2008/2009

As expected, the number of producers - whether we look at maize, cassava or rice - is higher in rural areas (see Table 7). The reason for this is that most farmers reside in rural areas while the majority of urban dwellers are engaged in other income generating activities. A large share of rural households produce maize, namely 63 percent. Rice and cassava are, on the other hand, produced by a lower percentage of rural dwellers. Both in the urban and rural areas, similar shares of households are maize consumers, 83 and 84 percent respectively. Cassava is mostly consumed in rural areas, while rice is consumed more in urban areas.

Table 7

Number of households producing and consuming maize, cassava and rice

Crops	Urban areas				Rural areas			
	Number of producers	Share of urban household (percent)	Number of consumers	Share of urban households (percent)	Number of producers	Share of rural households (percent)	Number of consumers	Share of rural households (percent)
Maize	181	16	981	84	1141	63	1500	83
Cassava	2	1	432	37	145	8	914	51
Rice	48	4	950	82	337	19	854	48

Source: Calculations by the authors based on NPS 2008/2009

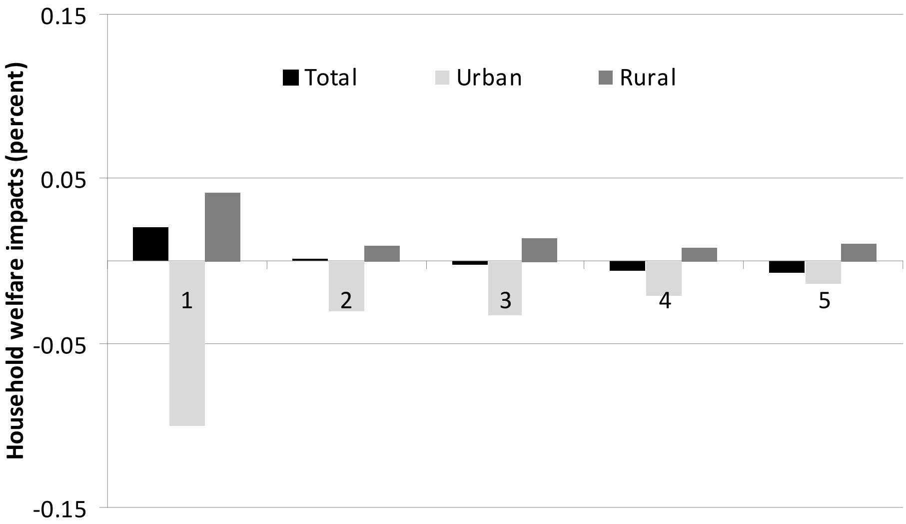
4.1 HOUSEHOLD WELFARE IMPACTS OF MAIZE PRICE CHANGES

At the aggregate level, household welfare impacts are minimal and slightly positive for the poorer quintile of the population (see Figure 2). This means that overall, poor households are net producers of maize and can benefit from a price increase in the price of maize. In the case of a 10 percent price change, households would increase their income by 0.02 percent. Minimal impacts are found for the other quintiles with impacts becoming slightly negative toward the richer quintile of the population.

When comparing urban and rural households, impacts vary more widely and the diversity of income patterns becomes more apparent. Poor urban households that mainly consume maize but do not produce it, i.e. are mostly net consumers of maize, are impacted by the maize price increase. A 10 percent price increase results in a 0.10 percent decrease in household welfare. This group of households are the most negatively impacted by the price increase.

Figure 2

Household welfare impacts by location of a 10 percent maize price increase



Source: Calculations by the authors based on NPS 2008/2009

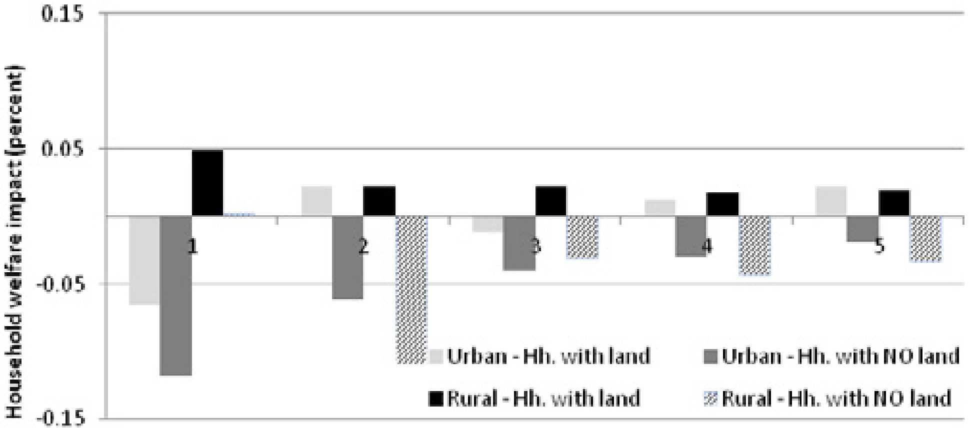
On the other hand, rural households have the potential to benefit from the price increase. Rural households on average produce more maize than they consume and benefit from the price increase whereby a 10 percent price increase results in a welfare gain of 0.04 percent.

We further distinguish household groups by land ownership and gender[25], two key household characteristics. In the case of land ownership, urban households lose from the price increase, with households with no land becoming even worse off (see Figure 3).

25 The spread of households by group can be found in Annex 3.

Figure 3

Household welfare impacts by land ownership and location of a 10 percent maize price increase



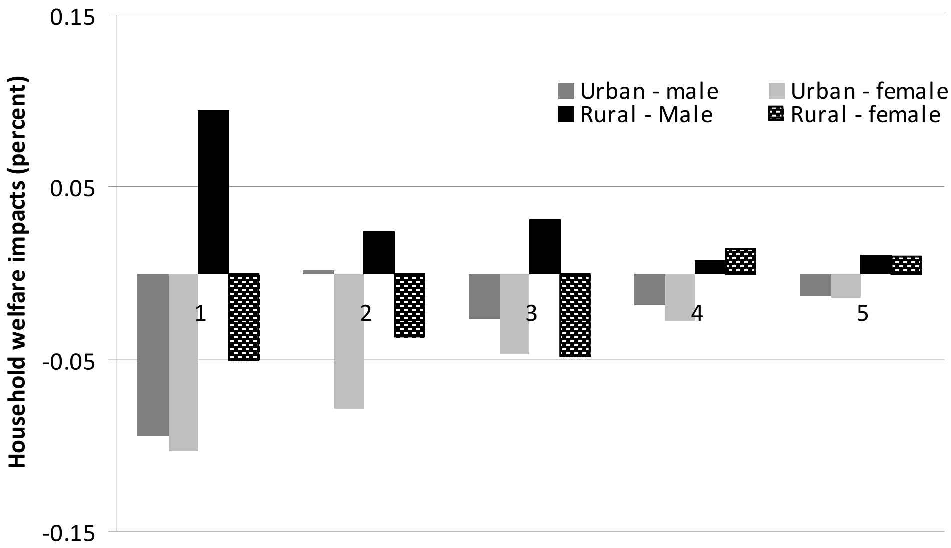
Source: Calculations by the authors based on NPS 2008/2009

Urban households with land lose 0.06 percent of their income while households with no land reduce their income by 0.13 percent. In the case of rural households, households that own land gain from the price increase while impacts for households with no land are insignificant. In the case of the second income quintile, the impact of owning land is even more apparent. Households that own land benefit from the price increase, be it in urban or rural areas. Households with no land lose from the price increase.

We distinguish households by the gender of the household head (see Figure 4). In the case of urban households, the impact of an increase in the price of maize is similar both in the case of male and female-headed households. The implication of the gender of the household head is more apparent in rural areas. Male-headed households benefit from the price increase. A 10 percent increase in the price of maize results in a welfare gain of 0.10 percent. On the other hand, female-headed households lose from the price gain, with a welfare loss of approximately 0.05 percent. On average, we find that male-headed households in rural areas are net producers of maize and therefore benefit from the increase in the price of maize. Female-headed households are net consumers on average and therefore lose from the price increase. This is related to men producing larger volumes of maize and generally being the landowners.

Figure 4

Household welfare impacts by gender and location of a 10 percent maize price increase



Source: Calculations by the authors based on NPS 2008/2009

Households vulnerable to an increase in the price of maize

The urban poor and rural female-headed households are the most vulnerable to a maize price increase. Poor households in rural areas, poor landowners in rural areas and male-headed households in rural areas can benefit from the price increase. The gender of the household head seems to have a more severe impact on households in rural areas compared to land ownership. However, this would require further research and more specific analysis.

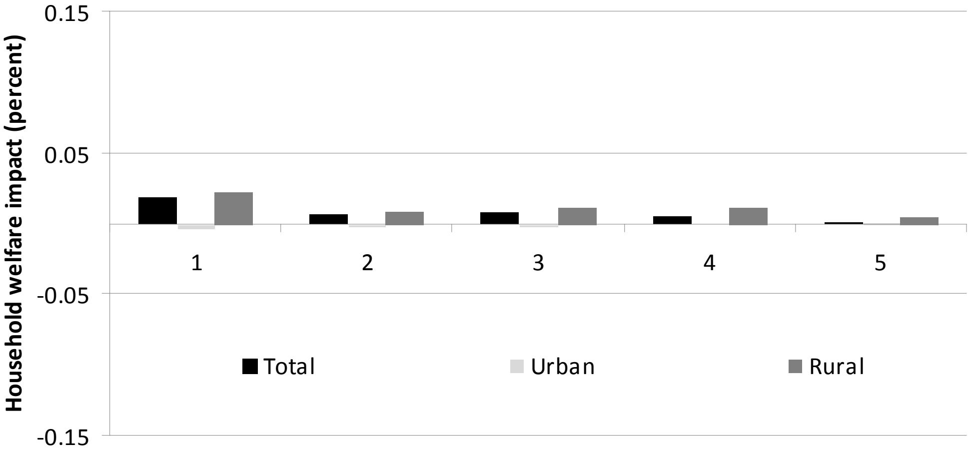
4.2 HOUSEHOLD WELFARE IMPACTS FOR CASSAVA PRICE CHANGES

Overall, household level impacts of cassava price changes are minimal (see Figure 5). At the country level, a slightly positive impact is found for the poorest segment of the population and more specifically the rural poor. All other segments are minimally positively impacted.

When further distinguishing urban and rural households by land ownership, we find that urban households are minimally negatively impacted in both cases (see Figure 6). For the rural poor, land ownership does increase the positive impact of the price increase. Rural landowners are net producers of cassava on average and the 10 percent price increase results in a 0.03 percent increase in household welfare.

Figure 5

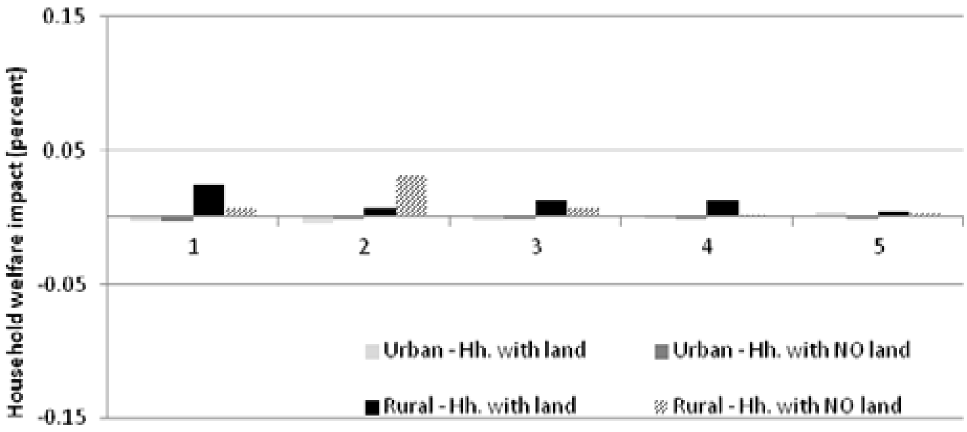
Household welfare impacts by location of a 10 percent cassava price increase



Source: Calculations by the authors based on NPS 2008/2009

Figure 6

Household welfare impacts by land ownership and location of a 10 percent cassava price increase

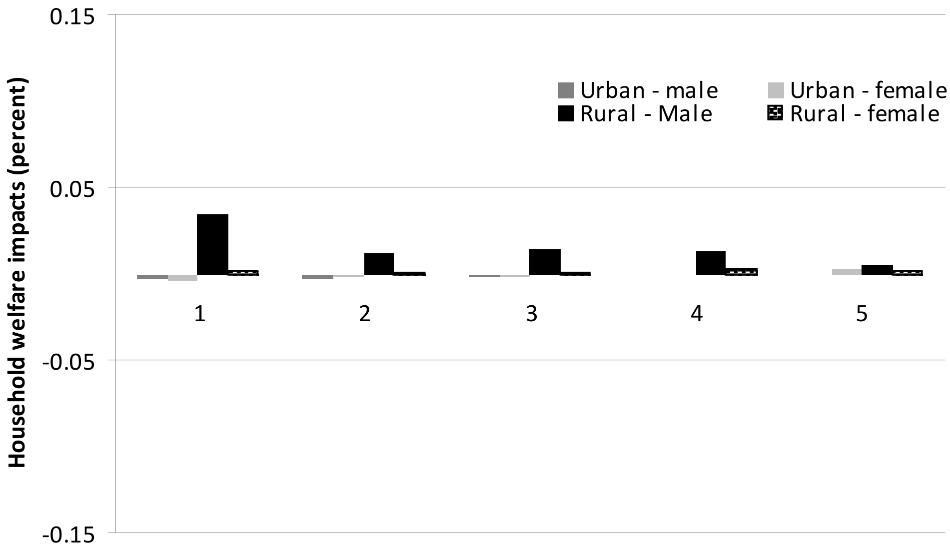


Source: Calculations by the authors based on NPS 2008/2009

The gender of the household head is an important factor for rural households (see Figure 7). Male-headed households benefit, compared to other households, from the cassava price increase. A 10 percent price change results in a 0.04 percent welfare increase for rural male-headed households, compared to a close to zero welfare increase for female-headed households.

Figure 7

Household welfare impacts by gender and location of a 10 percent cassava price increase



Source: Calculations by the authors based on NPS 2008/2009

Households vulnerable to an increase in the price of cassava

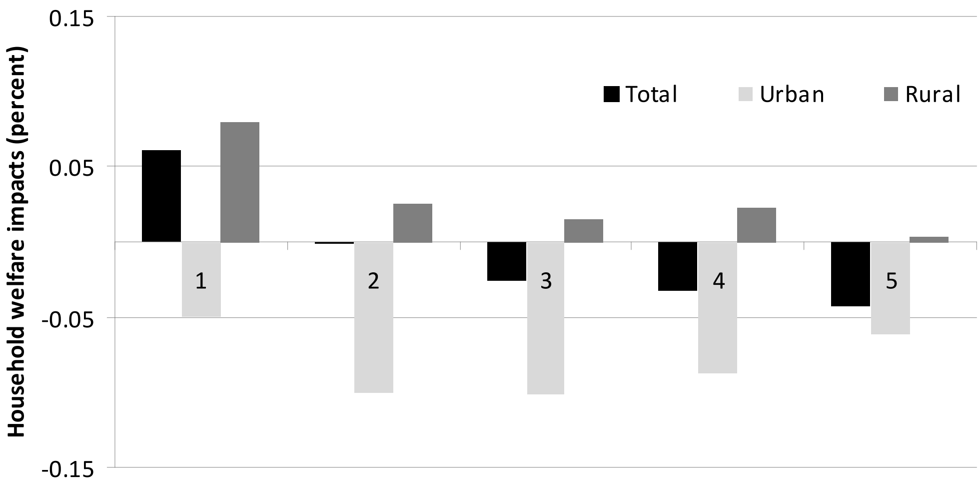
Overall there are minimal impacts on household welfare due to cassava price increases. In the case of the rural poor that own land and rural male-headed households, impacts are minimally beneficial when the price of cassava increases.

4.3 HOUSEHOLD WELFARE IMPACTS OF RICE PRICE CHANGES

At the national level, poor households benefit from a 10 percent increase in the price of rice (see Figure 8). When distinguishing between the urban poor and the rural poor, the impacts vary. Poor urban households lose from the price increase, as net consumers of rice.

Figure 8

Household welfare impacts by location of a 10 percent rice price increase



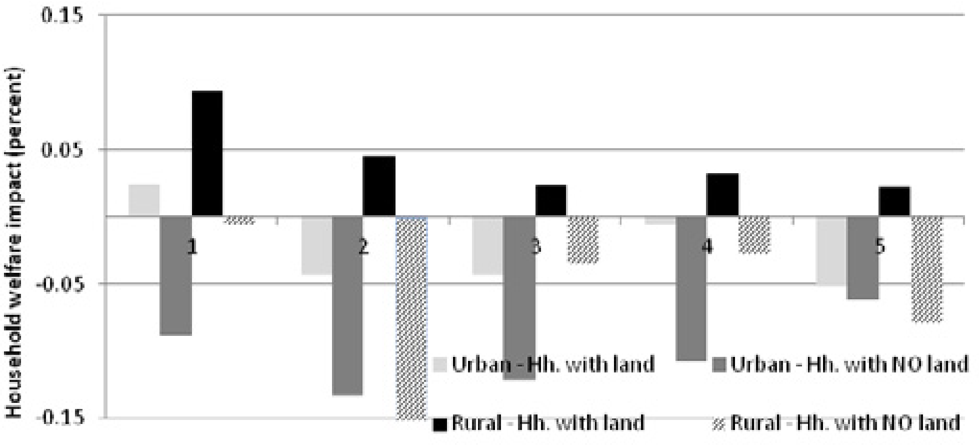
Source: Calculations by the authors based on NPS 2008/2009

The negative impact of a 10 percent rice price increase results in a 0.05 percent loss in household welfare. The rural poor, on the other hand, benefit from the price increase as overall they are net producers of rice. A 10 percent price increase results in 0.08 percent welfare gain for the rural poor. The price increase has no significant impact on the second quintile of the population, while the third, fourth and fifth quintiles, the wealthier segments of the population, lose from the price increase.

In the case of rice, land ownership is a much more important factor than the gender of the household head (see Figure 9).

Figure 9

Household welfare impacts by land ownership and location of a 10 percent rice price increase



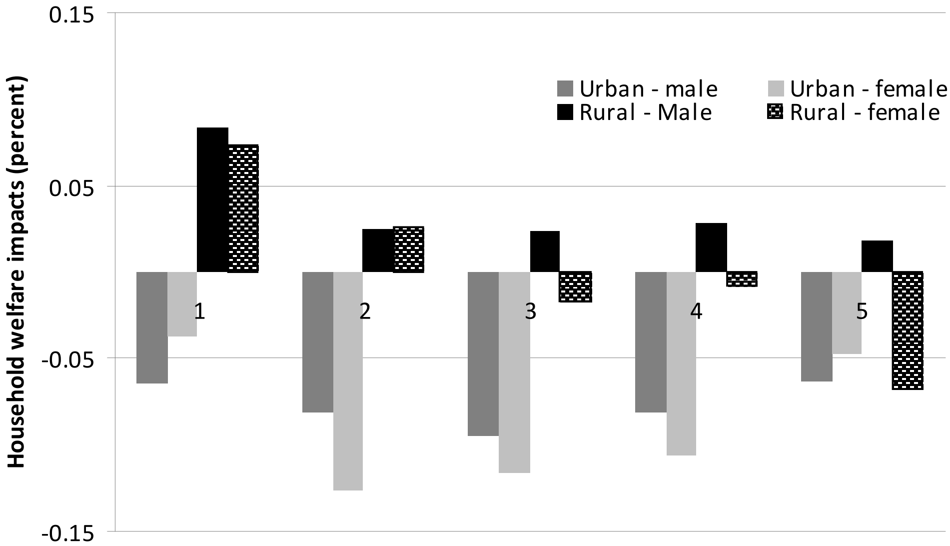
Source: Calculations by the authors based on NPS 2008/2009

Urban households gain from the price increase, even if marginally, when they are landowners but lose when they do not own land. Similarly, rural households' welfare increases by close to 0.10 percent from the price increase when they own land but there is no impact for the rural households that do not own land. Thus, in the case of rice, land ownership for the poor households is a key determinant to whether households are net producers of rice and can benefit from the price increase.

The gender of the household head in both urban and rural areas changes the magnitude of the household impacts only slightly (see Figure 10). Households in urban areas lose from the price increase in both cases, i.e. both when the household head is a male and when the head is a female. On the other hand, rural households benefit from the price increase, both when headed by a male or by a female. Male-headed households benefit slightly more from the price increase.

Figure 10

Household welfare impacts by gender and location of a 10 percent rice price increase



Source: Calculations by the authors based on NPS 2008/2009

Households vulnerable to an increase in the price of rice

Urban households that do not own land, both female and male-headed, lose from the price increase. Urban households that own land and rural households in general gain from an increase in the price of rice.

4.4 RECENT PRICE CHANGES IN KEY FOOD STAPLES

The household level impacts presented in the previous section are for an assumed price change of 10 percent. Table 10 illustrates recent price movements in Tanzania for maize and rice. No recent data is available for cassava.

In 2009 the price of maize increased by 63 percent in real terms. In 2010 the price of maize increased by 19 percent, while in 2011 the price of maize fell by 20 percent in real terms. Considering the price increase in 2010, the household level impacts would have been twice the impacts presented. In the case of a 20 percent reduction, the impacts would be reversed compared to the impacts previously presented.

Table 8

Real producer price changes for maize and rice

Year	Real price change (percent)		
	Maize	Rice	Cassava
2003/2008	44		42
2007/2008	63	50	N/A
2008/2009	19	24	N/A
2009/2010	-20	-10	N/A
2007/2010	55	67	N/A

Source: Calculations by the author, raw data collected from the Ministry of Trade and Industry

Considering cumulative price changes, the overall maize price change between 2007 and 2010 was 55 percent. This would mean that the household level impacts would be five times the impacts illustrated and that the vulnerable households would be five times worse off. On the other hand, the household that can benefit would benefit 5 times more.

5. CONCLUSIONS

World food prices have been increasing with world bioenergy production contributing, among other factors, to the increased demand. At the household level this can be positive for net food producers but negative for net food consumers. The analysis aims to shed some light on which segments of the population may lose from increases in the prices of key food staples and which segments may gain. In the case of Tanzania the key food staples are, in order of caloric importance, maize, cassava and rice. The analysis uses the country representative dataset from the first round of the National Panel Survey of Tanzania for 2008/2009.

The analysis shows that the urban poor and rural female-headed households are the most vulnerable to increases in the price of maize. Poor households in rural areas, poor landowners in rural areas and male-headed households in rural areas can benefit from the price increase. The gender of the household head seems to have a more severe impact on households in rural areas compared to land ownership, but will require further research and more specific analysis. Urban households that do not own land, both female and male-headed, lose from the price increase. Urban households that own land and rural households generally gain from an increase in the price of rice. Overall, households do not seem very vulnerable to cassava price changes. The rural poor that own land and are male-headed, greatly benefit from cassava price increases.

Fluctuations in the prices of the key food staples, and most importantly in the price of maize, should be closely monitored.

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ANNEX 1

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 full technical details the reader is referred to the complete BEFS Analytical Framework FAO (2010) 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). All references are in Dawe and Maltsoglou (2009).

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:

$$\frac{\Delta w_i^1}{x_{0i}} = \%P_p \cdot PR_i - \%P_c \cdot CR_i \tag{1}$$

where $\frac{\Delta w_i^1}{x_{0i}}$ 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 initial 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)

Assumptions made on the producer and consumer price changes have proven to be

* For a detailed discussion on this summary appendix, the reader is referred to Dawe and Maltsoglou (2009).

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 greater 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).

$$\%P_p = \left(\frac{P_c}{P_p}\right) \cdot \%P_c \tag{2}$$

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).

$$P_C/P_F = CE/PV \tag{3}$$

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).

$$P_C/P_F = CE'/PV \tag{4}$$

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 (see Fao 2010). Again, a more detailed discussion on processing is presented in Dawe and Maltsoglou (2009).

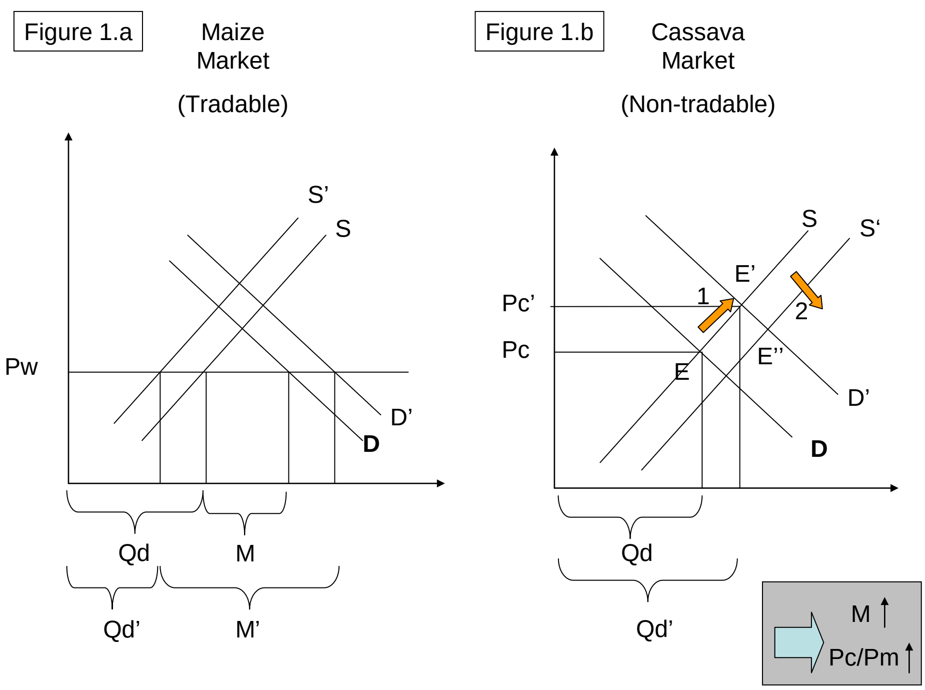
ANNEX 2

MAIZE AND CASSAVA MARKET INTERLINKAGES

What if the Government of Tanzania were to use cassava for ethanol production?

In the case of the maize market and the cassava market , maize is a tradable[26] good for which a world price exists and an open economy set-up is considered. On the other hand, 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 p_c to p_c'. Consequently, farmers respond to the price signal and increase production, reaching a new equilibrium in E' (arrow 1 in Figure A.2).



26 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, P^w. Domestic demand and supply are described by D and S. In the initial equilibrium, domestic supply will be equivalent to Q_d+M, where Q_d 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. As a result, the maize supply curve will shift inwards from S to S', and the maize demand curve outwards, from D to D'[27]. The inward shift in the maize supply curve will reduce the domestic production of maize to Q_d' 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, (p_c/p_m), and, more importantly, an increase in maize imports.

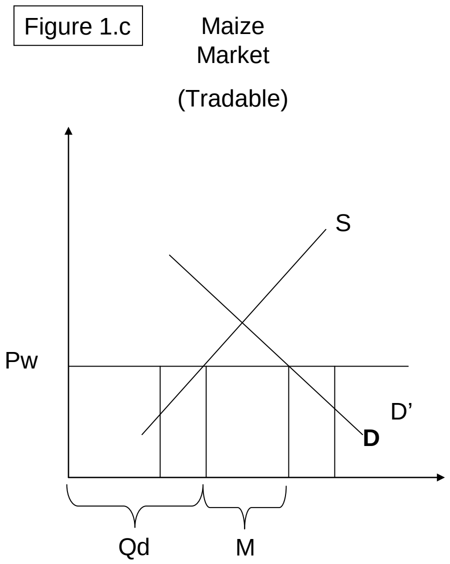
In order to avoid an increase in maize imports, it will be crucial to ensure that the supply curve of cassava shifts out from S to S', as shown in Figure 1a, arrow 2. This will only be possible if adequate investments in agriculture R&D, infrastructure, land expansion (or changes in policies) are implemented 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 p_c.

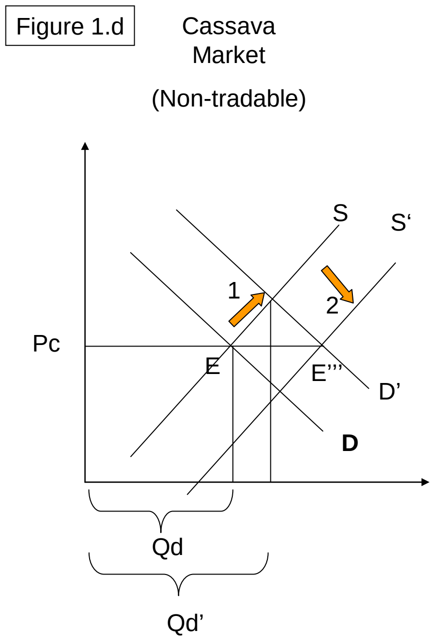
A key policy recommendation therefore will be to ensure that adequate investments and or policies are put in place to foster an environment that will allow the outward shift of the cassava supply curve that will ultimately bring the cassava price level back to its original level, or even lower.

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.

27 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.

ANNEX 3 ADDITIONAL TABLES

Table A1

Share of urban and rural households with and without land

Region	Share (Percent)					Total
	Poor	Medium poor	Medium	Medium wealthy	Wealthy	
Urban with land (percent)	1	1	2	2	2	8
Urban with no land (percent)	1	2	3	7	18	31
Total (percent)	1	3	5	10	20	39
Rural with land (percent)	13	13	12	9	5	53
Rural with no land (percent)	2	1	1	2	2	8
Total (percent)	14	15	14	11	7	61

Source: NPS 2008/2009

Table A2

Share of urban and rural households by gender

Region	Share (Percent)					Total
	Poor	Medium poor	Medium	Medium wealthy	Wealthy	
Urban female-headed (percent)	1	1	1	3	5	11
Urban male-headed (percent)	1	2	3	7	15	29
Total (percent)	1	3	5	10	20	39
Rural female-headed (percent)	3	4	3	3	2	15
Rural male-headed (percent)	11	11	11	8	5	46
Total (percent)	14	15	14	11	7	61

Source: NPS 2008/2009

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There has been substantial debate regarding the potential of bioenergy as an alternative to fossil fuels, and the potential positive and negative impacts on rural development, food security, and the environment. Growing demand for food, population pressure on land use, and the growing impacts of climate change will create additional challenges for land and resource management. The focus then should be on how bioenergy can be produced in combination with food and other products to enhance both food and energy security. In this context, FAO, with generous funding from the German Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) established the Bioenergy and Food Security (BEFS) Approach, to contribute analytical and policy guidance on how the development of a bioenergy sector could drive agriculture growth and poverty reduction, while fostering food security. The multidisciplinary, cross-ministerial discussion prompted by BEFS is based on information derived from technical analyses with the goal of assisting countries in deciding the direction for policy and development priorities.

The analysis included herein builds on the analysis published as a result of the first BEFS Tanzania project and specifically includes three components – 1) Production cost analysis of biodiesel from sunflower; 2) Water availability and management issues in the Wami River Basin; and 3) Household level food security using a country representative dataset. The results of the analysis highlight key areas where the government of Tanzania could integrate energy and agriculture goals to enhance energy and food security jointly.




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