POTENTIAL FOR BIOFUEL FEEDSTOCK IN KENYA

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Abstract

Biofuels have gained significant importance in the past decade as the world struggles to addresses the problem of the ever increasing fossil fuels prices and global warming. As the world energy demand continues to grow in line with economic development and population growth, the increase in the price of fossil fuels will put more pressure on the net importers. First generation liquid biofuels which include biodiesel, ethanol and straight vegetable oil (SVO) have been particularly promoted in many developed and developing countries which want to diversify their domestic energy supply, reduce dependency on highly volatile fossil fuel prices, enhance access to energy in rural areas, promote rural development and to reduce carbon emissions.

The principal energy supply sources in Kenya are biomass 68 %, Petroleum 22 %, electricity 9 % and coal at less than 1%. The energy scene thus exhibits a predominant reliance on dwindling biomass energy resource to meet energy needs especially for the rural households and a heavy dependence on imported petroleum to meet the modern economic sector needs. Investment in liquid biofuels for the transport sector can alleviate this situation leading to saving foreign currency reserves, rural development and reduction of green house gases (GHG) emissions from fossil fuels.

This study was done to assess the potential for supply of biofuel feedstock for bioethanol and biodiesel production for domestic consumption and export. To achieve this, key feedstocks were indentified and their environmental suitability, production and yields were analysed. Gross margin as a tool was used to make economic analysis of the production of the feedstocks and compared to that of the most prominent food and cash crops. A review of the national biofuel strategies, policies and regulations currently adopted in Kenya was also done. Since the success of the liquid biofuels sector will also depend on their quality and safety, a report on certification schemes and standards that apply to biofuels or their feedstocks in the country was compiled.

The study established that for bioethanol production, sweet sorghum has the largest suitable area it can do well at 185,822km^2 or 30.6% of the country's surface area after the protected areas, wildlife conflict areas, animal movement paths and slopes greater than 45% are zoned out. This is followed by cassava and sugarcane at 66,092km^2 (11.2%) and 12,591 km^2 (2.2%) respectively. For biodiesel feedstocks, most of their agronomic Conditions are not well understood but are derived from places where they are found growing freely in the wild.Based on the derived agronomic conditions, castor has the largest suitable area at 159,115 km^2 or 28% of the country's surface area when protected areas, wildlife conflict areas, animal movement paths and slopes greater than 45% are zoned out. It is closely followed by jatropha at 149,302km^2 or 26.2%.

In terms of gross margins, sweet sorghum has the highest gross margin at KSh. 71,808 followed by sugarcane at KSh. 37,746 and cassava at KSh. 20,240 per hectare for bioethanol feedstocks. For biodiesel feedstocks, sunlflower has the highest gross margin at KSh, 2,921 per hectare while the commonly promoted feedstocks; jatropha and croton, have KSh. -4,423 and KSh. 143 respectively. It was also established that when all the planned ethanol production facilities are established, the country will have the capacity to supply all the bioethanol required to implement the proposed E10 blending program.

It is hoped that this study will play a significant role in guiding the policy makers in making important decisions to drive the biofuels sector forward and small scale farmers before they comit their land and resources to biofuels investment.

Key words: *Bioethanol, Biodiesel, biofuel feedstocks, gross margins, Kenya*

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Acronyms

ACFC	Agro Chemical and Food Corp
ASALs	Arid and Semi Arid Lands
CBD	Convention on Biological Diversity
CBK	Central Bank of Kenya
CDM	Clean Development Mechanisms
COMESA	Common Market for Eastern and Southern Africa
DEG	Deutsche Investitions und Entwicklungsgesellschaft GmbH
EIAL	Environmental Impact Assessment License
EMCA	Environmental Management and Coordination Act 1999
EU	European Union
EPZA	Export processing Zone Authority
FAO	Food and Agriculture Organisation of United Nations
GAF	Green Africa Foundation
GDP	Gross Domestic Product
GHG	Green House Gases
GIS	Geographical Information Systems
GoK	Government of Kenya
GTZ	German office for Technical cooperation (currently GIZ)
Ha.	Hectares
HSHC	Help Self Help Centre
IEA	International Energy Agency
ICRAF	International Centre for Research in Agro-forestry
JSP	Jatropha Support Program
KARI	Kenya Agricultural Research Institute
KCFC	Kenya Chemical and Food Corp
KEBS	Kenya bureau of standards

KESREF	Kenya Sugar Research Foundation
Kg	Kilograms
KIRDI	Kenya Industrial Research and Development Institute
KNBS	Kenya National Bureau of Statistics
KPC	Kenya Pipeline Company
KPLC	Kenya Power and Lighting Company
KM^2	Square Kilometers
KSh.	Kenya Shillings
MoA	Ministry of Agriculture
MoE	Ministry of Energy
NGOs	Non Governmental Organisations
NPV	Net Present Value
OECD	Organisation for Economic Co-operation and Development
PIESCES	Policy Innovation Systems for Clean Energy Security
SVO	Straight Vegetable Oil
USA	United States of America
UNFCCC	United Nations Framework Convention on Climate Change

1. Introduction

Biofuels have gained significant importance in the past decade as the world struggles to addresses the problem of the ever increasing fossil fuels prices and global warming. As the world energy demand continues to grow in line with economic development and population growth, the price of fossil fuels increases putting more pressure on the net importers. First generation liquid biofuels which include biodiesel, ethanol and straight vegetable oil (SVO) have been particularly promoted in many developed and developing countries which want to diversify their domestic energy supply, reduce dependency on highly volatile fossil fuel prices, enhance access to energy in rural areas, promote rural development and to reduce carbon emissions.

At present, first generation liquid biofuels which comprise of ethanol obtained from sugar and starch crops and biodiesel produced through transesterification of oil extracted from oil crops like oil palm and rape seed are the only commercially produced biofuels for the transport market. Second generation biofuels which include lignocellulosic ethanol and biodiesel from microalgae are an advanced stage of research and are expected to play a major role in transport energy provision in future (IEA, 2009).

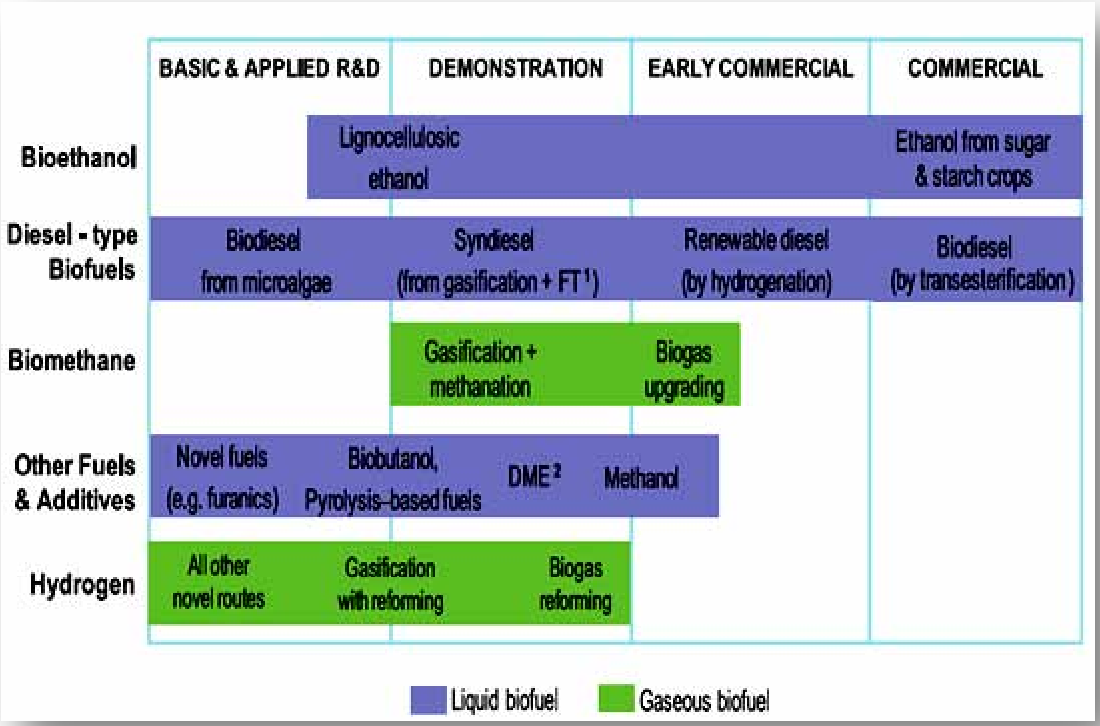

Fig. 1: Development status of the main technologies to produce biofuels for transport from biomass

Source: E4tech, 2009.

First generation biofuels have the potential to play a major role in transport energy supply in many developing countries currently incurring huge fiscal burdens from imported fossil fuels. This is because, the technology to produce them already exists and is easily adapted to suit existing local conditions (IEA, 2009). These countries have vast land parcels currently underutilised, most of it considered marginal where many biofuels feedstocks can flourish. Prevalence of adequate labour (though mostly unskilled) in many of these rural areas means that the sector is guaranteed of receiving maximum support from these impoverished poor who have few or no income generating opportunities. However, such an initiative has to be carefully pursued to ensure environmental protection and conflict with indigenous communities since most of this perceived underutilised marginal land has a fragile ecosystem and is in most cases a source of pasture for the nomad communities.

1.1. International biofuel status

Biofuel production and demand has increased continuously worldwide over the last years mostly as a result of support from respective governments especially in the developed counties. The sector is expected to experience continued growth until 2020, with most of it in USA and European Union which have mandated large increase in biofuel consumption (Mitchell, 2011). IEA (2009) reported that in the year 2009, global biofuels production reached 83 billion liters contributing 1.5% of transport fuels. The EU has mandated that 10% of all transport fuels should come from biofuels by the year 2020. This will mean that by 2020 the total biofuels demand will be thrice the 15 billion liters of what was consumed in 2009 in the transport sector. The USA has mandated that 136 billion liters of biofuels should be consumed by 2022, almost triple the 45 billion liters consumed in 2009.The greatest consumption of biofuels in the USA is in the form of Ethanol and the mandate for biodiesel is 3.8 billion liters.

While the mandate for biodiesel in EU is expected to be met locally, the mandate for ethanol is expected to benefit many African countries due to many trade concessions that allow them duty-free access. In 2008, emerging and developing countries accounted for 40% of the global biofuels production, with Brazil, China and Thailand being the highest producers outside the OECD countries (IEA, 2009). Brazil is currently the largest developing country producer, having heavily promoted the production and use of ethanol since the 1970's.

In Africa, Malawi has been producing ethanol since the 1970s, but at a much smaller scale and currently several other African countries are producing it mostly for industrial purposes rather than fuel, most of it from sugarcane (Mitchell, 2011). Kenya was however an exception having started production in 1977 and adopted ethanol blending in 1984. This was however abandoned in 1995 after the liberalization of the industry mostly due to unsustainable commercial arrangements as well as inadequate policy framework (MOE, 2010).

During the past few years, many foreign countries have seen great opportunities in some Sub-Saharan Africa countries, such as Tanzania and Zambia, to acquire land to invest in large-scale agrofuels plantations. These were generally aimed at export (ABN 2007) and not for local consumption, which is ironical bearing in mind most of these countries are net importers of fossil fuels. Total ethanol production in Africa amounted to less than 500 million liters in 2006 with South Africa being the largest producer.

Ethanol production has the highest potential from sugarcane in Africa since cane growing is already taking place and the existing production technology is easily adapted to African conditions. In many countries, smallholder outgrowers are easily integrated into the system through subcontracting ensuring they receive high quality inputs, technical field support, and an assured market. African ethanol exporters also have preferential access to the USA, but due to lower tariffs this is not expected to be their preferred target market.

Mitchell (2011) points out that large-scale biodiesel production for export is less attractive for African producers because production costs are expected to be higher than for Southeast

Asian producers and tariff advantages to the EU or USA markets are low hence do not offset the higher production costs. However with prices of fuel in sub-Saharan African countries about double those in the most competitive markets, and landlocked countries facing even higher prices, demand for transport fuels is projected to grow by more than 5.0 percent per year in sub-Saharan African countries during 2005–2020 which is expected to provide opportunities for domestic use (Mitchell 2011).

Already, there are countries in tropical Africa with major development projects for Jatropha biodiesel production. These include; Mali, Burkina Faso, Ghana, Tanzania, Malawi, Zambia and Madagascar. Most of the Jatropha is grown as mono-crop in plantations, mixed cropping with other food crops and as hedges. The total length of Jatropha hedges in Tropical Africa is estimated at 75,000 km, yielding potentially 60,000 t of seeds per year (Wiskerke, 2008).

IEA (2010b) states that to achieve the ambitious bioenergy potential targets especially in Africa, government policies, and industrial efforts need to be directed at increasing biomass yield levels and modernizing agriculture to ensure increased food production in a continent faced with food insecurity. This can be achieved by technology development, and by the diffusion of best sustainable agricultural practices. To this end several African countries have adopted pro-biofuel strategies that also promote food security. These include Malawi, Mali, Mauritius, Senegal, South Africa, Zambia and Zimbabwe (FAO, 2007). However some moves have been controversial especially when foreign investors have acquired large tracks of land to invest in biofuel crops. A good example is in Madagascar where Daewoo logistics of South Korea acquired 1.3M ha to farm maize and palm oil and in Tanzania where foreign countries grow sugarcane for ethanol production in their own countries (PIECES, 2009).

1.2. National liquid biofuel status

Bioethanol

Bioethanol is an alcohol based fuel produced by fermentation of sugars in the presence of yeast to produce alcohol and carbon dioxide. It uses naturally occurring feedstocks like sugarcane, cassava, wheat, maize and sorghum. Most of these feedstocks are grown in Kenya but ethanol production has only been done from sugar molasses so far. Since ethanol is currently not used as a fuel, all the ethanol produced is for industrial purposes like solvents, alcoholic beverages and pharmaceutical industry (MOE, 2009).

There are two main types of ethanol that are used as fuel; hydrous and anhydrous. Hydrous alcohol contains 4% water and can only be used in vehicles that are specifically designed for it. Anhydrous alcohol has almost no water and can be blended with gasoline and used in ordinary vehicles. Blends ranging from 10% ethanol and 90% gasoline (referred to as E10) to 85% ethanol and 15% gasoline have been used in various parts of the world (MOE/GTZ, 2008).

Ethanol production for fuel in Kenya can be traced back to 1977 with the construction of the Kenya Chemical and Food Corp (KCFC) which was aimed at producing ethanol for blending, but this did not start until 1983 (MOE, 2010). The blend was a substitute for premium gasoline (93 0ctane) with a volume composition of 65% super petrol, 10% alcohol and 25% ordinary or regular petrol. The programme which was experimental in Nairobi region included incentives such as Government tax relief, free provision and maintenance of ethanol storage, handling and blending facility to the oil marketers, priority access to molasses as raw material and restricted production of industrial and potable alcohol. In 1983, another power alcohol plant, Agro Chemical and Food Corp (ACFC) was constructed to support the national blending programme. Blending was however was abandoned in 1995 after the liberalization of the industry mostly due to unsustainable commercial arrangement as well as inadequate policy framework (MOE, 2010). The handling, pricing and operational logistics made the bioethanol fuel venture commercially unattractive to both the biethanol producers and the petroleum marketers leading to its collapse.

Currently, the government is trying to revive the ethanol blending programme. This was expressed in a gazette notice no.12900 of November 24, 2009 which gave the blending guidelines and set the roll out on March 1st 2010 but later postponed it to September 1st, 2010. The notice stated that, *"With effect from March 1 2010, all motor gasoline loaded from the petroleum storage and loading depots…, for sale in Kenya, shall be blended with power alcohol to make gasohol"* Blending was expected to start at Kenya Pipeline Company (KPC)'s depots in Kisumu, Eldoret and Nakuru because they are close to the sugar belt. However, the programme has not yet started to date and KPC, the agency that was charged with blending the fuel at its storage reservoirs is yet to identify the suppliers of the ethanol and complete fixing the facilities where blending is to be done (Business Daily, 2011).

Biodiesel

Biodiesel is a vegetable oil or animal fat-based diesel fuel consisting of long-chain alkyl esters made by chemically reacting with an alcohol in a process called transesterification. It can be derived from a variety of oil bearing plans like castor, croton, jatropha, sunflower and coconut (MOE/GTZ, 2008). It contains between 88% and 95% as much energy as diesel but has advantage over diesel in that it improves the lubricity to the diesel and raises the cetane value, thereby making the fuel economy of both generally comparable. It also has a higher oxygen content which aids in the completion of fuel combustion hence reducing particulate air pollutants, carbon monoxide and hydrocarbons (MOE, 2010).

Biodiesel can be blended with traditional diesel fuel or burned in its pure form in ordinary compression ignition engines. The blends can range from 1% biodiesel and 99% diesel (B1) to 25% biodiesel and 75% diesel (B25). However the most common blends are B5 and B20. A research on biofuels done in Kenya commissioned by GTZ and Ministry of Energy recommended a B2 blend as the most feasible and sustainable (MOE/GTZ, 2008).

Compared to bioethanol, the biodiesel sector in Kenya is at its infant stage. Promotion of biodiesel has been mainly by NGO's and the private sector which had indentified growth of feedstocks as a major income generation for the people living in marginal areas. Most of these organizations like Vanilla Jatropha Development Foundation and Green Africa Foundation promoted Jatropha to farmers mostly in the arid and semi-arid areas due to the believe that it could perform well under harsh conditions and required minimum inputs and care. The seeds being inedible also ensured that the problem of competition with food does not arise (MOE/GTZ, 2008). Though the most promoted feedstock has been jatropha, others like croton and castor have been given consideration (MOE, 2010).

The growth of the sector has of late raised a lot of controversies with the farmers abandoning Jatropha due to poor yields and lack of market for the produce. Many people have raised concern over how the crop was promoted without proper research on its agronomical requirements and seed germplasm. Lack of processing infrastructure and a policy and legal framework only made the situation worse since the farmers who harvested the seeds did not have the technical capacity to process them to oil and there was no established market (MOE/GTZ, 2008, GTZ, 2009a).

The government, which was seen as a late entrant in the scene, has been actively involved in trying to salvage the situation. This has been through commissioning of a study together with GTZ in 2008 titled *"A Roadmap for Biofuels in Kenya; Opportunities and Obstacles"*, facilitating drafting of the biofuel policy, biodiesel strategy and bioethanol strategy in the last three years. Biodiesel Association of Kenya comprising of major stakeholders, like NGO's and research institutions in which the government is represented by its ministry officials was also formed in 2008 to promote and coordinate all activities related to biodiesel.

1.3. Purpose of study

The aim of this study is to ***assess the potential supply of biofuel feedstock for bioethanol and biodiesel production for domestic consumption and export in Kenya.*** To achieve this, key feedstocks were indentified, the land in use for their production and their yields analysed.

Gross margin as a tool was used to make economic analysis of the production of the feedstocks and compared to that of the most prominent food and cash crops. The production methods used, the scale and type of production methods adopted was also considered. A review of the national biofuel strategies, policies and regulations currently adopted in Kenya was done. Since the success of the liquid biofuels sector will also depend on their quality and safety, a report on certification schemes and any standards that apply to biofuels or their feedstocks was compiled. It is expected that the biofuels will displace fossil fuels in the transport industry hence a review of the national liquid transport fuels market was done to estimate to amount of fuel consumed and the price development over 10 years.

This report is divided in to nine chapters. Following the introductory chapter one, chapter two deals with methodology and challenges. Chapter three reviews the country background, chapter four analyses the potential for producing biofuels feedstocks, and chapter five presents economic analyses of producing main biofuels feedstocks and competing crops. National legislations governing biofuels and important certification standards are vital for the development of the biofuels sector and these are covered in chapters six and seven. Chapter eight explores the national transport fuels while chapter nine outlines main conclusions based on the study and gives recommendations to move the biofuels sector forward.

2. Methodology and challenges

The major part of this study was conducted through literature review. Published reports, archival data and internet resources were extensively reviewed. Among the reports that were heavily referred are: *A Roadmap to Biofuels in Kenya; Opportunities and Obstacles, (MOE/GTZ, 2008), Environmental Suitability and Agro-environmental Zoning of Kenya for Biofuel Production (Muok et al, 2010)* and *Jatropha; A reality* check (GTZ, 2009). Semi-structured interviews with stakeholders and key informants in the biofuels sector were conducted to get a deeper insight about the sector as well as validate the data from the secondary sources.

A three days site visit to Spectre International Limited, Mumias Sugar Company and Kenya Sugar Research Foundation (KESREF) yielded important information on the sugarcane and sugar production in the country. This visit was also accompanied with a visit to three sugarcane farmers who gave a detailed account on their sugarcane farming and the challenges they face.

The main constraint faced during the study was time limit. This limited the geographical coverage of the interviews as well as the number of stakeholders that could be interviewed.

2.1.1. Gross margin calculation

Gross margin calculations as a tool is used mostly by farmers to help in choosing between different farming systems. It was selected to help evaluate the competitiveness of growing specific biofuels feedstocks and compared to growing other food and cash crops. A gross margin of a crop is the difference between the gross income earned by the crop and the variable or direct costs associated with it (Abbott and Makeham, 1979). The wages of permanent workers and depreciation of machinery is normally left out when calculating the gross margins.

Gross margin = Gross income - Variable costs
Where:

Gross income is obtained by multiplying the gross output (yields) by the “farm-gate” price received for the product.

Variable costs are the costs directly linked to the crop or farm method. The more of a crop a farmer grows the more of these costs he will incur. They include; cost of seeds, spray, ploughing, fertilizer, harvesting, packing marketing, storage etc.

It is important to note that the gross margins should not be negative for any farming enterprise if the farmer is to make profits. Abbott and Makeham (1979) argues that, for semi-subsistence farmers, food security might be more important than gross margins, but if one or two crops have very high gross margin, then it is advisable to grow them and buy food from the returns. During the research, the cash flows were estimated using the current market prices of commodities. For perennial crops, an investment period of 10 years was considered and analyzed and resulting cash flows discounted at 14% interest rate which was the rate in the country at the time of writing this report (CBK, 2011). The 10 years net present value (NPV) was then divided by 10 to get the annual NPV equivalent which was taken to be the annual gross margin.

3. Country background

3.1. Socio-economic status

Kenya has a total land area of 569,250 km^2 and an estimated population of 39 million inhabitants (2009 Population Census). Nairobi and its suburbs, the central highlands and the shores of Lake Victoria have the highest population density of more than 600 people per square kilometer (Harding and Devisscher, 2009). The country has a GDP per capita (PPP) of US$1,600 and about 50% of the population lives below the poverty line. The economically active population (Comprising of all persons aged 15 and above who supply labor for the production of goods and services during a specified time reference period) is projected to increase from 17,825 (80.9%) in 2008 to 24,821 (81%) in 2020.

Although Kenya's economic performance has exceeded that of most other African nations, its benefits have been seriously diluted by several factors. Some of these are: poor governance and corruption, increasing economic inequality and environmental deterioration partly caused by high surging population and erratic weather patterns (KIPPRA, 2010). The country's key economic sectors include agriculture, tourism, livestock/pastoralism, horticulture, fisheries, and forest products. In 2009, the agricultural sector contributed 22% to the country's GDP, industrial sector contributed 16% and the services industries 62% (CIA, 2011)

The largest population lives in rural areas with the concentration largely dependent on the climatic and soil conditions. Highly productive agricultural areas in the central, Rift valley and Western provinces and major urban centers such as Nairobi, Mombasa and Eldoret have a high population density.

Table 1: Country profile: Kenya

Source: Ndegwa, 2010

Area (KM^2)	580,367
Population	39,802,015
GDP per capita (PPP)- 2009 estimate (US$)	1,600
Contribution of agriculture to GDP (%)	22
Population employed in agricultural sector (%)	75
Population below poverty line-2008 estimate (%)	50
Main exports	Coffee, tea, pyrethrum, horticultural products, fish.

3.2. Energy status

The Kenyan government considers the energy sector a key enabler to achieving vision 2030 a development blue print that aims to transform Kenya into a newly industrializing, middle-income country providing a high quality life to all its citizens by the year 2030 (MOE, 2010). Electricity and petroleum receives the highest government attention even though wood fuels are the most consumed fuels in Kenya (Ndegwa, 2010). This is because petroleum and electricity are the most dominating fuels in the commercial sector hence are seen as the driver to industrialization. Other major energy consumption sectors apart from commercial sector, are transport, manufacturing and residential sectors.

The principal end energy supply sources in Kenya are biomass 68 %, Petroleum 22 %, electricity 9 % and coal at less than 1% (GOK, 2008). The energy scene thus exhibits a predominant reliance on dwindling biomass energy resource to meet energy needs especially for the rural households and a heavy dependence on imported petroleum to meet the modern economic sector needs. In the electricity sub-sector, hydropower accounts for 57 % followed by fossil- based thermal generation which accounts for 33 % and geothermal 10 %. The other forms of renewable energy, including wind, solar, biogas and micro hydro account for less than 1% (NEMA, 2007)

Over 90% of rural households use firewood for cooking and heating while 80% of urban households depend on charcoal as a primary source of fuel for cooking (ESDA, 2005). In 2006, biomass demand was estimated at 38.1 million tonnes against a sustainable supply of 15.4 million tons creating a demand-supply deficit of 60 % (NEMA, 2007). The demand is estimated to be growing at 2.7 % per year while sustainable supply was growing at a slower 0.6 % per year (GOK, 2002).

Electricity remains far beyond the poor majority as the cost remains high at US$0.15 per KWh (Ogweno, Opanga and Obara, 2009). The access to electricity in the country stands at 83% of the population, but only a low 18% of the people are connected to the grid (GOK, 2008). Connection is lowest in the rural areas where it stands at 4% while in the urban areas it stands at 51%. Solar energy, which has gained a lot of importance in the rural areas to charge mobile phones and power electronics like radios and televisions, has been increasing quite fast. Currently, solar photovoltaic (PVs) provide 4 MW of off -grid electricity, mainly to small household rural-based consumers. Communities especially in the central region of the country are also engaged in micro-hydro power production where the resource is available (KIPPRA, 2010).

3.3. Agricultural status

Land in Kenya is considered a basic commodity that supports life and is very treasured. As much as 85% of the country landmass is classified as marginal land and about 15% of land has medium to high potential. Population pressure has led to encroachment of the arid and semi arid lands (ASALs) which have a fragile ecosystem a fact that may lead to further degradation (NEMA, 2007).

The country has climatic and ecological extremes, with altitudes varying from sea level to over 5,000m in the highlands with most of the country having a tropical climate. It is hot and humid at the coast, temperate inland and very dry in the north and northeast parts of the country (NEMA, 2009). The average annual rainfall at the coast is 1200mm and the average daily temperature ranges from 27°C - 31°C. Nairobi, the capital city, has an altitude of 1,661m and has a temperature range of 14°C - 25°C. Eldoret sitting in the Rift Valley at an altitude of 3,085m, has a temperature ranging from 10°C to 24°C. Lodwar, also in the Rift Valley but near the northern-most extremity is at an altitude of 506m above sea level, with a temperature range of 24°C - 35°C (KIPPRA, 2010).

There are two rainy seasons; the long rains occurring from April to June and short rains from October to December. The hottest period is from February to March and coldest in July to August. The majority of the country receives less than adequate rainfall to support rain-fed crop cultivation. Over two thirds of the country receives less than 500mm of rainfall per year and 79% has less then 700mm annually (KIPPRA, 2010). 11% of the country receives more than 1000mm per year. The mean annual rainfall shows a wide spatial variation, ranging from about 200mm in the driest areas in north-western and eastern parts of Kenya to the wetter areas with rainfall of 1200-2000 mm in areas bordering Lake Victoria and Central Highlands east of the Rift Valley. As a result, the Central Highlands, parts of Rift Valley, the Lake Victoria region and the coastal area boast the most intensive agriculture and greatest concentration of people. Pastoral farming dominates the remaining drier regions of Kenya. The mean annual rainfall ranges from less than 250mm in semiarid and arid areas to more than 2,000mm in high potential areas.

The country has seven main Agro-ecological zones. Zones I to III have Humid to sub-humid climate and have the highest agricultural potential. Rain-fed agriculture, intensive livestock farming and forestry are the main activities carried out here (NEMA, 2004). Zones IV and V are sub-humid to semi-arid and have limited agricultural potential with only drought resistant crops doing well. Ranching has the highest potential in this area. Zones VI and VII are arid and only extensive pastoralism is practiced.

Table 2: Kenya’s Agro-ecological zone and agriculture potential

Source: NEMA, 2004

Agro-ecological Zone	Potential land Use	Area (000 Ha.)	% of land
I-III	**Medium to high:** Agriculture, livestock (intensive), forestry	860	15
IV-V	**Marginal to medium:** Agriculture (drought resistant crops) livestock (ranching)	11,500	20
VI-VII	**Marginal:** livestock (extensive pastoralism)	37,400	65
Total		57,500	100

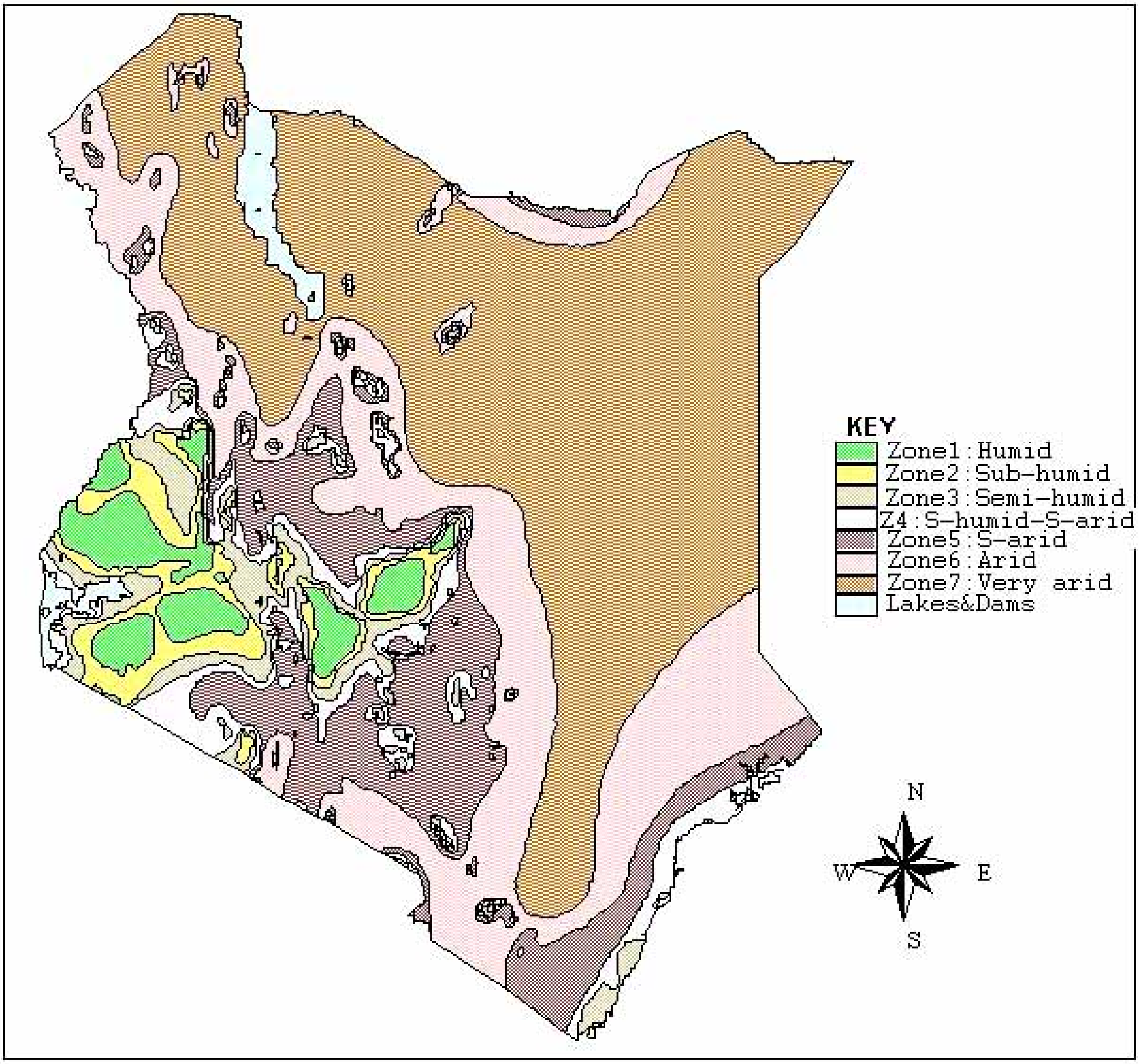

Fig. 2: Agro-ecological zones of Kenya

Source: http://www.fas.usda.gov

Agriculture is the leading sector of the national economy, employing about 75% percent of the population and accounting for 22% of the country's GDP and 60% foreign exchange earnings (CIA, 2011). Out of 9.4 million ha of potentially cultivable land, only 2.8 million hectares are devoted to agriculture (GOK, 2007). Even though certain areas endure arid and semi-arid conditions, most cropping systems are rain fed, and irrigation development remains quite limited. 80% of the farmers practice subsistence farming mainly producing maize, beans, sorghum, millet, onions, peas and other traditional crops for self consumption (MOA, 2009). The main cash crops grown are coffee, tea, sisal, cotton, pyrethrum, rice, sugarcane and horticultural products meant for export market like flowers, green beans and other vegetables (MOA, 2010).

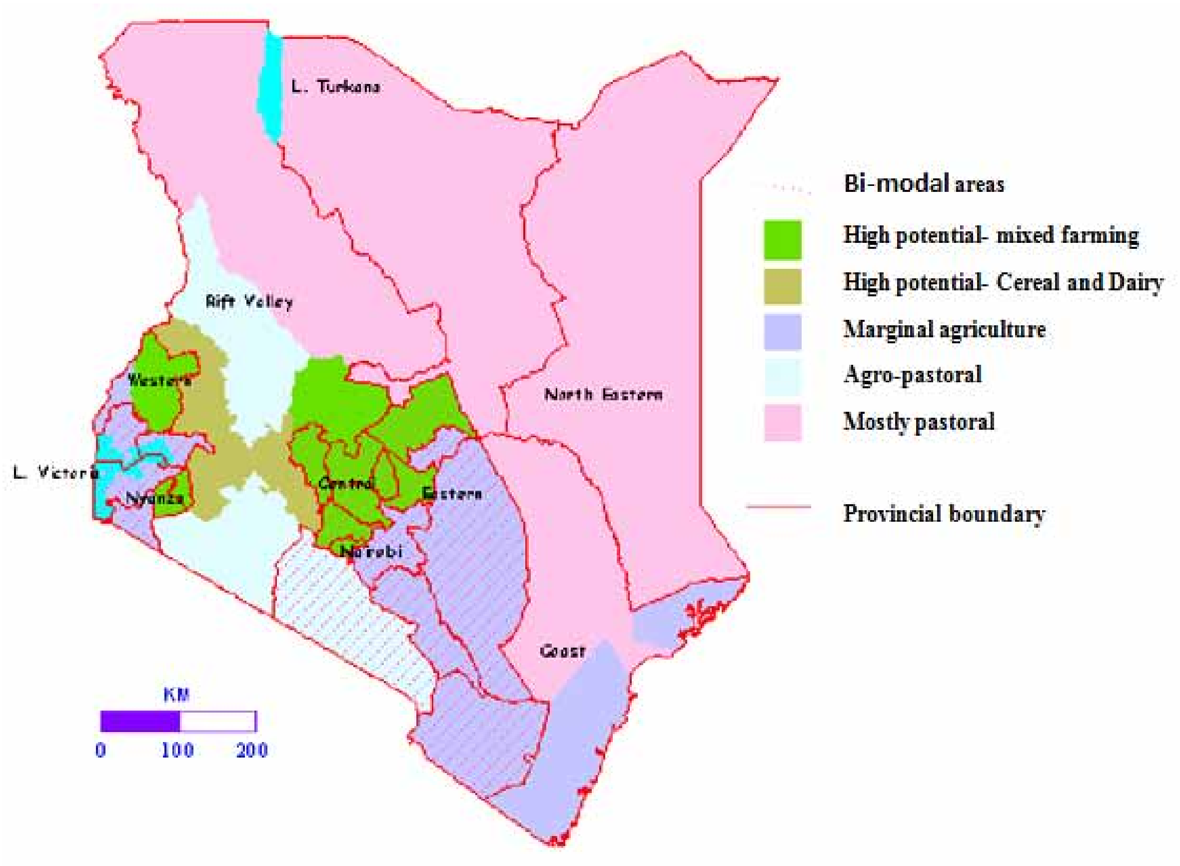

Fig. 3: Kenya's production/livelihood systems

Source: http://www.fas.usda.gov

4. Potential supply of biofuel feedstock for domestic consumption and export

There are several crops currently grown in Kenya that can serve as feedstocks for either bioethanol or biodiesel. For the purpose of this report, only the major feedstocks, and specifically those that can be sustainably produced without resulting to food crises in Kenyan conditions have been considered. The feedstocks analyzed for bioethanol are; sugar cane, sweet sorghum and cassava, while those analysed for biodiesel are; jatropha, castor, croton and sunflower.

4.1. Biodiesel feedstocks

4.1.1. Jatropha*(Jatropha curcas)*

Jatropha is a multi-purpose, shrubby, tree belonging to the *Euphorbiaceae* family. It is native to Mexico or Central America, but now thrives in many parts of the tropics and sub-tropics in sub-Saharan Africa and Asia. It has a multiple uses as a biofuel source (as straight vegetable oil, or biodiesel after transesterification) while the seedcake after pressing to remove the oil can be directly used as fuel or as fertilizer. It can also be used as traditional medicine as a laxative, emetic, for cough treatment, and healing wounds (Crothers, 1998; Heller, 1996, Thomas, 1989). It can also be used to produce a dye which is used to give tan and brown shades, and for making ink. The bark yields about 37% tannin. The plant has also been used in vanilla farms to support vanilla in some parts of Kenya and Tanzania, while other farmers have planted it as a live fence or for soil erosion control. It did not gain much importance in Kenya until 2005-2006 when some NGO's started promoting it as a biofuel feedstock mostly in the arid and semi-arid parts of Kenya.

Fig. 4: *Jatropha curcas* at various stages of development in Kibwezi, Kenya.

Source: Author

The plant can reach a height of three to five meters under normal conditions, and as much as eight to ten under favourable conditions. It can bear seeds of variable size and oil content for up to 40 – 50 years. Once established, the plant can endure drought as it stores nutrients and water in its stem. The seeds usually contain between 27-40% oil. During its early promotion phase, it was claimed that it had a wide adaptability to diverse climatic zones and soil types, short gestation period, easy multiplication, drought tolerance, not competing with food production, and pest and disease resistance. However, these claims have been proved wrong with time as more farmers adopted the crop, a factor that has led to frustrations and even abandonment of the crop all together (GTZ, 2009a).

The oil extracted from the seed can be used directly as straight vegetable oil (SVO) in adapted diesel engines to power local grain mills, oil presses, water pumps and small electricity generating plants. In Tanzania, trials of using it in specially made lamps and stoves have proved that it can be used to displace kerosene in areas not supplied with electricity (Wiskerke, 2008). This makes it a particularly attractive investment in remote areas.

In the transport industry, the oil can be used to power modified diesel engines by using a dual-tank system so that the engine can be started with conventional diesel. Furthermore the oil can also be blended with diesel and used in diesel engines. A blend of up to 25% can run the engine without any modifications. Finally, Jatropha oil can be converted to biodiesel by the chemical process of transesterification. In this process, Jatropha oil is mixed with methanol and caustic soda. However, such a process is rather capital intensive and can only be realized on a larger scale (van Eijck 2007).

Agronomy

Table 3: Agronomic parameters for Jatropha

Source: Muok et al. 2010

Agronomic parameters	Overall range	Optimal range
Annual temp (^oC)	12-32	19.3-27.2
Annual rainfall (mm)	480-2380	1000-2000
Soil pH	6-7	6.5
Altitude	0-1650	-
Climate	Warm and humid climate	
Soil	Well drained loamy sand and sandy loam soils	

It is important to note that because Jatropha has not been fully domesticated hence its agronomic conditions are not scientifically proven but have only been derived from the where the crop has been found growing naturally. The plantation is normally established by raising seedlings in a nursery. It is reported that plants propagated by seed have a longer lifespan of 50 years while those propagated by cuttings have a shorter lifespan of only 15years (Nyamai and Omuodo, 2007, Githunguri et al., 2008). The yields from plants propagated by cuttings are also said to be lower and the mortality rate higher. To maximize seed production, proper pruning is necessary especially the terminal bud to ensure the shrub adds more branches and has minimal vertical growth (Mshanga, 2007). Fertilizer should be applied annually to sustain optimal seed yield. In the first five years, the shrubs can easily be intercropped with crops like beans and other legumes. Seed yields are only expected in year 3-4 and will reach a maximum in year 8-10 (Mshanga, 2007, GTZ, 2009a).

Agricultural potential and suitability in kenya

In Kenya, Jatropha is mainly grown in Kitui, Namanga, Kajiado, Malindi, Nyanza, Nakuru, Marakwet, Naivasha, in the coastal regions and in Meru. In the past few years a lot of research on Jatropha has been done in Kenya to understand its agronomic factors and evaluate its performance in a bid to separate fact from fiction surrounding its hype. As a result, sizeable information is currently available, but due to the young age of the plantations in Kenya, there is still minimum data on productivity. Several organizations spearheaded by Kenya Agricultural Research Institute (KARI) are currently conducting research on the best practices as far as cultivation of Jatropha is concerned.

A recent research on environmental suitability commissioned by UNEP and Policy Innovation Systems for Clean Energy Security (PISCES) (Muok et al, 2010), mapped the area potentially suitable for Jatropha farming in Kenya based on the derived agronomic parameters. Based on the mapping, the area available for jatropha cultivation after zoning off protected zones, wetlands, slopes greater than 45% and wildlife conflict areas is approximately 149,302 km2 or 26.2% of the total Kenya surface area. However, some of this lies within the cultivated land, either for food or cash crops. The result showed that some areas in Western Kenya and the Coastal strip are highly suitable, while the whole of eastern Kenya is moderately suitable for jatropha farming.

Table 4: Jatropha suitability

Source: Muok, et al, 2010

Suitability and Zonation	Suitability area (KM^2)	% of Kenya land surface area
General suitability	221,937	39.0
Suitable outside protected area	177,700	31.2
Suitable within food crops areas	58,184	10.2
Suitable within cash crops areas	3,835	0.7
Suitable outside food and cash crops areas	115,340	20.3
Suitable within cultivated areas	62,017	10.9
Suitable within non-cultivated areas	115,340	20.3
Suitable outside wildlife conflict areas	153,811	27.0
Suitable outside wetlands	153,651	27.0
Suitable outside animal movements paths (3KM)	149,302	26.2

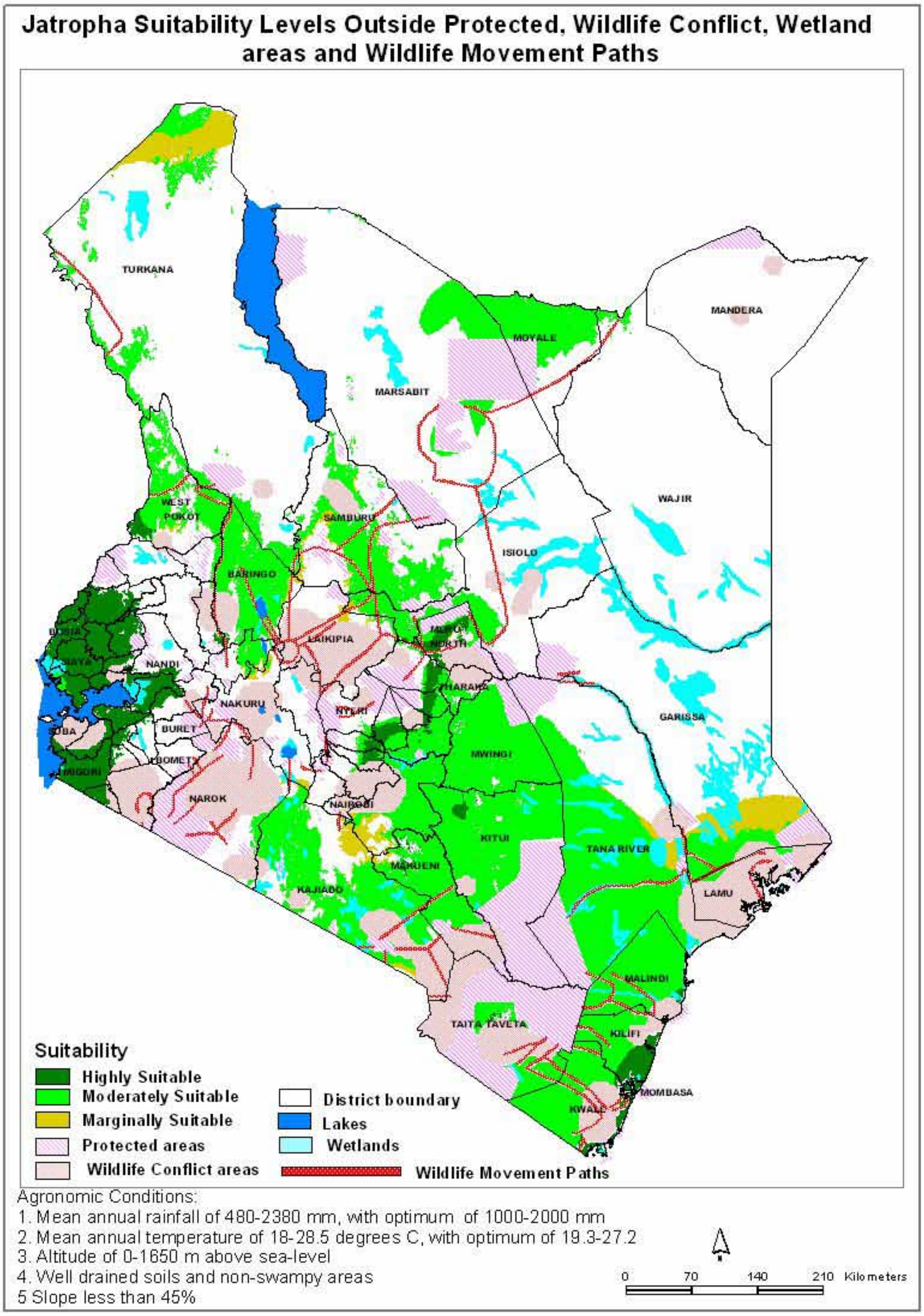

Fig. 5: Jatropha suitability levels

Source: ICRAF, GIS Unit

Current status

Jatropha activities in Kenya currently consist of small-scale production involving NGOs and private companies working with outgrowers and/or small demonstration/trial efforts. Most farmers have planted jatropha in parcels of land that range from half acre to 5 acres as a mono-crop or intercrop with various crops such as maize, beans and other legumes and often with banana and vanillas. Others have established it for a long time as a live fence or hedge, to prevent animals from straying into their farmlands and destroying crops (GTZ, 2009a). A few foreign companies have in the past attempted to negotiate with the authority to develop Jatropha curcas plantations for biodiesel production on semi-arid land owned by the government or large private ranches (GTZ 2009). The latest involves Bedford Biofuels, a foreign based company that plans to invest about US$ 3.6 million to develop an estimated area of 64,000 hectares into jatropha plantation in the Tana Delta (Bedford biofuels, 2010), whose proposed plan is under the extensive review process in response to concerns raised by conservationists..

Other notable developments include the setting up of Jatropha Support Programme (JSP) in 2008 to research on different aspects of jatropha in Kenya, Uganda and Tanzania supported by DEG (Deutsche Investitions –und Entwicklungsgesellschaft GmbH). The programme is a Public Private Partnership between nine companies in Eastern Africa and the German Government through DEG. Under the programme, field trials were established to help gain practical understanding of the commercial viability of jatropha as a first generation biodiesel fuel stock in Eastern Africa (JSP, 2011). The Ministry of Energy (MOE) also reported that it has started demonstrations plots in all its energy centres to research and educate farmers on Jatropha farming (MOE, 2011).

In terms of biofuel production, there is currently no commercial processing hence no market for the harvested seeds. Several initiatives are however reported in the country to rectify this situation. The MOE is in the process of helping Jatropha farmers in Makueni procure equipment for oil extraction to be used as SVO. In Mpeketoni, Jatropha farmers supported by Norwegian Church Aid, Green Africa Foundation (GAF) and ESDA are in the process of acquiring a Kenya Power and Lighting Company (KPLC) diesel electricity generator which they can use SVO from their produce to generate electricity and feed it into the grid (MOE, 2011). Kenya Industrial Research and Development Institute (KIRDI) has also done extensive research on transesterification and is currently concentrating on design of locally made equipment that interested local investors can use to process the oil. However, no commercial transesterification of jatropha oil was reported in Kenya by the time this research was done (KIRDI, 2011). The MOE is also contemplating setting up oil presses in all its energy centres, procure seeds from the farmers and use the oil to generate electricity for their own use and at the same time pass the skills to the farmers (MOE, 2011).

4.1.2. Castor *(Ricinus communis)*

Castor is a perennial shrub from the *Euphorbiaceae* family with green, reddish to purple stems and finger-like leaves that likely originated in Abyssinia, or modern day Ethiopia. In the wild, Castor can reach up to 9 meters, but cultivated varieties generally grow to between 1-4 meters (MOE/GTZ, 2008). Perennial varieties of castor are relatively drought tolerant because of their deep tap roots which can extract water from the sub-soil.

The plant is indigenous to East Africa but is considered invasive in other parts of the world. It can be grown as an annual or perennial depending on the variety. It is generally easy to cultivate with minimum care and inputs but yields increase with more intensive management. It is suitable for manual harvesting as well as mechanization on a large scale. *Castor* does best on fertile, well-drained soil, and therefore it may compete with food production on arable land (MOE/GTZ, 2008).

Fig. 6: Castor plant (left) and fruits (right) in Central province, Kenya.

Source: Author

Traditionally, castor oil was used to cure hides and for cosmetic purposes. Because it contains ricinoleic acid, castor can be used in many industrial products e.g. hydraulic fluids, jet engine lubricants, plastics, synthetic textiles, soap and paint. The cellulose from the stem is used for make cardboard and paper products.

The seed contain 40-50% oil which can be extracted by crushing in a conventional oil press. The oil can be used in diesel engines but its viscosity needs to be adjusted because it is too high (Muok, et al, 2010). Castor oil can also be used to lubricate moving parts in machinery. Due to its many other industrial uses, castor oil fetches a much higher price than most other biodiesel oils hence experts argue that is better left for industrial use than as a biofuel (KIRDI, 211).

Agronomy

Table 5: Castor agronomic factors

Source: Muok, et al, 2010

Agronomic parameters	Overall range	Optimal range
Annual temp (^oC)	15-39	20-30
Annual rainfall (mm)	400-2000	750-1000
Altitude	0-2000	300-1800
Climate	Warm and humid climate	
Soil	Well drained soils friable, sandy loams	
Maturity	5-6 months	

Castor seeds are normally propagated by direct sowing about 6 to 8 cm deep in rows 0.9 -1.2 meters and spaced 0.2-0.6 meters in between rows. Seeds should be treated with fungicide before planting to avoid root rot and alterneria blight especially in cold areas and high soil moisture content (MOE/GTZ, 2008). The plant is highly susceptible to pests, so fortnight spraying is recommended from flowering to harvesting (GTZ, 2009a) and it also requires two weedings, one before planting and one during mid growth. The crop is normally intercropped with other crops like maize, beans, potatoes, sorghum and bananas.

Agricultural potential and suitability

Castor is one of the most widely spread biofuels crops in terms of suitability in Kenya. Its natural distribution range spreads from Western, Rift Valley, Central, Eastern to Coastal region covering an area of 240,494km2 or 42.2% of the country (Muok et al 2010). However when protected areas, wildlife conflict areas, animal movement paths and slopes greater than 45% are zoned out, the land available for castor cultivation reduces to 159,115km2 or 28.0% of the total Kenya surface area.

Castor offers less competition to cash crops production in terms of the area but its highly suitable areas are scattered in agriculturally marginal to medium potential areas which could offer completion to food crops like maize and beans (Muok et al, 2010).

Table 6: Castor suitability

Source: Muok et al, 2010

Suitability and Zonation	Suitability area (KM^2)	% of Kenya land surface area
General suitability	240,494	42.2
Suitable outside protected area	192,303	33.8
Suitable within food crops areas	65,324	11.5
Suitable within cash crops areas	5,377	0.9
Suitable outside food and cash crops areas	121,236	21.3
Suitable within cultivated areas	70,854	12.4
Suitable within non-cultivated areas	121,236	21.3
Suitable outside wildlife conflict areas	166.047	29.2
Suitable outside wetlands	163,603	28.7
Suitable outside animal movements paths (3KM)	159.115	28.0

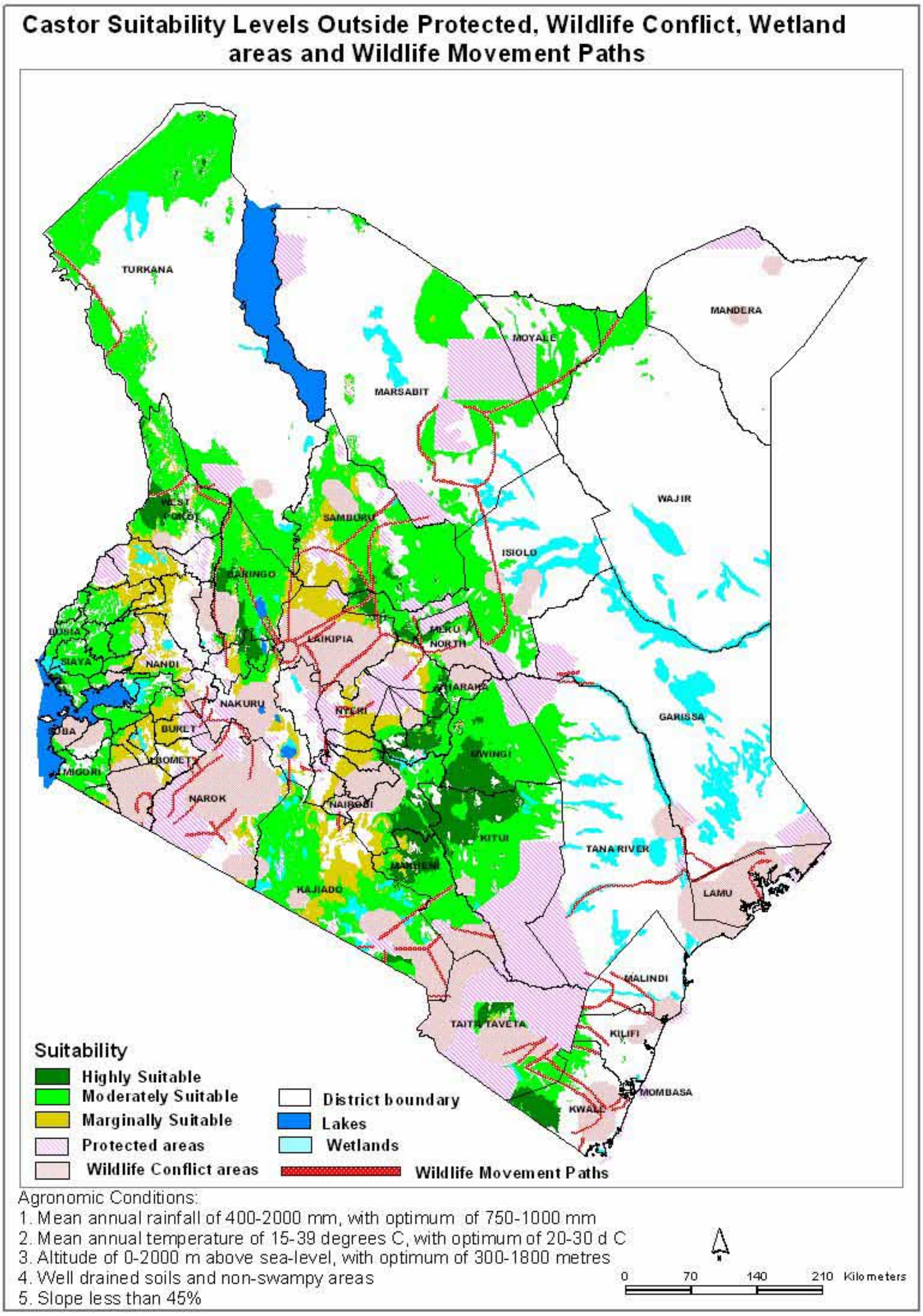

Fig. 7: Castor suitability levels

Source: ICRAF GIS Unit

Current status

Commercial castor farming is nonexistent in Kenya though there are reports of castor farming in the country for many years. In 1970's and 1980's, there was widespread interest in castor growing due to promotion by the government but this failed due to lack of market (GTZ, 2009a). Currently, castor can be seen growing in the wild like weed but there are some people who grow it for soil erosion control or for oil extraction to make home-made lotions. Kenya Agricultural Research Institute has developed about 4 local hybrid varieties but they are not yet bulked for distribution to farmers for planting.

There is a huge market for castor oil both locally and internationally but Kenya has not been able to tap into this market. In 2006, Kenya imported 428 tons of castor oil for industrial purposes due to lack of processed oil locally (GTZ, 2009a). However, experts from Kenya Industrial Research and Development Institute (KIRDI) feel that with the high value of castor oil for industrial processes, it would be better if the crop is not promoted for biodiesel production but rather for industrial purposes which would fetch more for the farmers.

4.1.3. Croton (*Croton megalocarpus*)

Croton is a hardy, fast-growing deciduous tree with distinctive layering of branches, growing into a straight stem of between 6-36 meters. The tree is indigenous to East Africa where it has been widely grown in its mountainous regions. It is believed that the centre of its endemism is the Aberdare Mountains of Kenya (Muok et al, 2010). It has a dark grey or pale brown, rough, and longitudinally cracking bark with a strong pepper-like spicy odour. It has variable, long, oval-shaped leaves and grey, woody, ovoid fruits measuring about 2- 4 by 1.5-3 centimetres in size (GTZ, 2009A). Each fruit contains three flattened, greyish-brown seeds.

Fig. 8: Croton seedlings (left) and a fruiting croton tree (Right)

Source: Author

Croton starts to seed after four years and produces up to 25kg of seed per tree. The seeds have 30% of highly unsaturated oils suitable for biodiesel. The seedcake cake is a highly rich with protein and is commonly used as poultry feed (Muok et al, 2010). The tree can grow up to 50 years from planting after which it can be felled and used for furniture making, firewood or charcoal. The tree has also been extensively grown as wind-break or boundary markers in many rural areas (MOE/GTZ, 2008).

Agronomy

Table 7: Croton agronomic parameters

Source: Muok et al 2010, GTZ, 2009a

Agronomic parameters	Overall range	Optimal range
Annual temp (^oC)	11-26	16-22
Annual rainfall (mm)	800-1900	1000-1400
Altitude	1200-2450	1200-1600
Soil	Light deep and well drained soils.	

Croton performs best in agro-ecological zones with bimodal rainfall with cool, humid temperatures. The tree is best propagated through direct sowing but vegetative propagation is also possible by grafting or cuttings. The seeds are extracted by cracking the shell drying them to 5-9% moisture content. Normally, the seeds germinate within 35-45 days, with an expected germination rate of 95% for mature and healthy seed lots (GTZ, 2009a). Flowering starts at the end of April and May producing mature seeds in October through December or January through February depending on the agro-ecological zone. The trees can be intercropped with other crops such as maize, beans and potatoes. Intercropping croton with maize and legumes such as been is recommended. Because it has deep tap roots it offers limited competition to other crops and the long tap roots help access sufficient soil nutrients making them available to crops through litter fall (Muok et al, 2010).

Agricultural potential and suitability

Croton is widely grown in diverse ecological zones ranging from Kakamega, Nairobi, Nyeri to Taita and is mostly cultivated near homesteads, in croplands water courses or in swamps (GTZ, 2009a). However, its natural distribution range is mainly in Central and Western Kenya. Based on the environmental suitability the total suitable area is 62,773km2 which is about 11% of the total Kenya surface area. This reduces to 35,254km2 or 6.2% when protected areas, wildlife conflict areas, wetland areas, important bird areas, slopes more than 45% and animal movement paths area zoned out (Muok et al, 2010).

The crop if wholly adopted as a plantation monocrop could offer competition to cash crops because in Central region and part of Western region (e.g. Kisii, Bomet, Kericho), the areas suitable for its production lies within the same range as cash crops such as coffee and tea. The entire land suitable for croton growing also lies within areas classified as arable land whether cultivated or uncultivated (Muok et al, 2010).

Table 8: Croton suitability and zonation

Source: Muok et al, 2010

Suitability and Zonation	**Suitability area (KM^2)**	**% of Kenya land surface area**
General suitability	62,773	11.0
Suitable outside protected area	46,266	8.1
Suitable within food crops areas	32,842	5.8
Suitable within cash crops areas	4,415	0.8
Suitable outside food and cash crops areas	8,654	1.5
Suitable within cultivated areas	37,611	6.6
Suitable within non-cultivated areas	8,654	1.5
Suitable outside wildlife conflict areas	35,950	6.3
Suitable outside wetlands	35,734	6.3
Suitable outside animal movements paths (3KM)	35,254	6.2

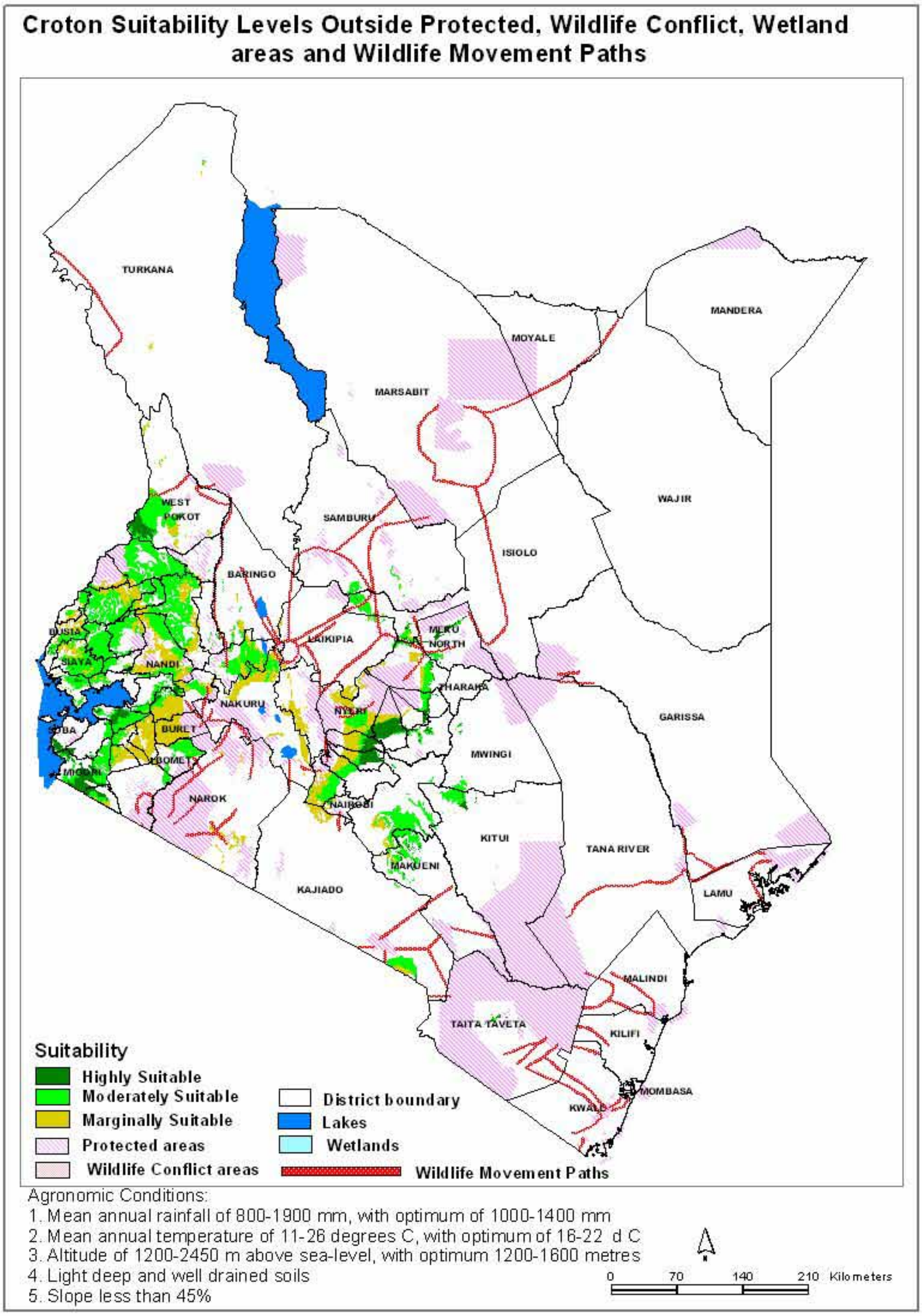

Fig. 9: Croton suitability levels

Source: ICRAF GIS Unit

Current status

Croton in Kenya is not grown as a biodiesel crop. Most people grow it for shade, firewood and construction materials although no formal tress census has been done to ascertain the actual number. There are no croton plantations, with many farmers having a few trees spread across their farms while others plant in along the boundaries (MOE/GTZ, 2009). As such, it is difficult to establish a processing plant for biodiesel due to scattered feedstock making transportation expensive. KEFRI and KARI have been doing research on croton for some years with the aim of popularizing it as a multi-purpose crop but if it is to be commercially exploited for biodiesel production, more farmers concentrated at one area need to adopt the crop to raise enough feedstock.

In 2008 during the fuel crises, an NGO in Kieni area in Central province called the Help Self Help Centre (HSHC) was reported to be buying croton seeds from farmers who collect them from neighbourhoods and forest for making biodiesel. The project according to the project officers is still ongoing and they buy the seeds at 7 shillings per kilogram. The centre has a capacity of 800 liters of biodiesel per day but produces 400 liters of biodiesel per day due to shortage of feedstock. The fuel was mostly sold to motorists in Kieni. The project was supported by Solarix Netherlands and Kenya School Project (USA) among others.

4.1.4. Sunflower (*Helianthus annus*)

Sunflower is an annual plant that originated from Central America that possesses a large inflorescence (flowering head). It got its name from its huge fiery blooms, whose shape and image is often used to depict the sun (Wikipedia). It has a rough, hairy stem, broad, coarsely toothed, rough leaves and circular heads of flowers. The heads consist of 1,000-2,000 individual flowers joined together by a receptacle base. A mature crop grows to 0.6 m to 4.5m high depending on the variety and the flowers are about 30cm in diameter with yellow petals forming an outer ring (Muok et al, 2010).

Sunflower is widely adapted and one of the major edible oil crops grown in Kenya. It is was introduced in Kenya as an edible oil crop and is up to date regarded as a high value cash crop (Okoko N. E. K. et al 2008). Sunflower has deep tap roots, that enables them extract water from the subsoil hence tend to be drought tolerant (Acland, 1971).

Sunflower is mostly used for edible oil extraction while the seedcake is used in animal feed formulations. Since the oil has good drying properties that do not affect colour, it is used to make some paints and vanishes for the niche market. The seeds can also be eaten as a snack (Muok et al 2010).

Agronomy

Table 9: Sunflower agronomic parameters

Source: Muok et al, (2010), GTZ, (2009a)

Agronomic parameters	**Overall range**	**Optimal range**
Annual temp (^{o}C)	20-28	-
Annual rainfall (mm)	500-1200	-
Altitude	0-2600	-
Soil	Well drained loam soils	
Maturity period	5-10 months	

Sunflower is propagated by direct sowing and this should be done during the rains to ensure maximum yields (Drumnet, 2010). The crop does well in well drained loam soils where annual rainfall ranges between 500 and 1200 mm. The time for planting sunflower should allow for enough rain at flowering so that the crop can mature during a dry spell (Muok et al, 2010). Inter-row spacing is recommended at 75cm while intra-row spacing is recommended at 30cm. The crop should be weeded at regular intervals until it is 90cm high. Thereafter the weeds are suppressed by shading. Soil should be drawn up around the stems during weeding to avoid lodging. Sunflower can be intercropped with legumes which provide good groundcover. It responds well to fertilizer but is not demanding for nutrients as cereal crops (IDRC, 1998)

KARI has done breeding of sunflower and has come up with different varieties that suit different agro-ecological zones. These include early to late maturing varieties that take 100 to 140 days to reach maturity after planting that were developed at the KARI Njoro Station (Mathu *et al*, 2007). Drumnet, an organization that works in conjunction with Bidco Oil refineries introduced a new Sunflower variety Pannar 7369 in Nyanza and through trials established that the variety grew to 6 feet in height with heads between 9- 12 inches in diameter. In addition, the crop yielded an average of 550 Kg per acre as compared to 150-200 kg for other varieties that the farmers planted (Drumnet, 2010).

Agricultural potential and suitability

Sunflower is a crop that has been found to do well in agro-ecological zones with high to medium rainfall and deep loamy soils in Kenya. These include the Coast province, parts of Eastern, Nyanza, Western and Central provinces.

Based on the environmental suitability the suitable areas for growing sunflower is 140,003 km^2 or 24.6% of the country. When the protected areas, wildlife conflict areas, wetland areas, important bird areas, slopes more than 45% and animal movement paths are removed, the total area suitable for sunflower farming is 86,414km2 or 15.2% of the total Kenya surface. Except for parts of coast, upper eastern around Mt. Kenya and small pockets of western regions, sunflower does not compete significantly competing with cash crop farming but all the suitable areas lie within arable land, both cultivated and uncultivated (Muok et al, 2010).

Table 10: Sunflower suitability

Source: Muok et al, 2010

Suitability and Zonation	**Suitability area (KM^2)**	**% of Kenya land surface area**
General suitability	140,003	24.6
Suitable outside protected area	104,574	18.4
Suitable within food crops areas	43,246	7.6
Suitable within cash crops areas	1,950	0.3
Suitable outside food and cash crops areas	63,462	11.1
Suitable within cultivated areas	45,231	7.9

Suitable within non-cultivated areas	63,462	11.1
Suitable outside wildlife conflict areas	90,289	15.9
Suitable outside wetlands	88,986	15.6
Suitable outside animal movements paths (3KM)	86,414	15.2

Current status

Sunflower farming in Kenya is concentrated in Western and Eastern provinces. In 2003, over 3,300 ha were under sunflower in Nyanza and almost 2,500 hectares in Western province. Currently more people have adopted sunflower farming in Nyanza and Central due to its promotion by Bidco oil refineries which partnered with other organizations in its efforts to increase its edible oil raw material resource base (EPZA, 2005).

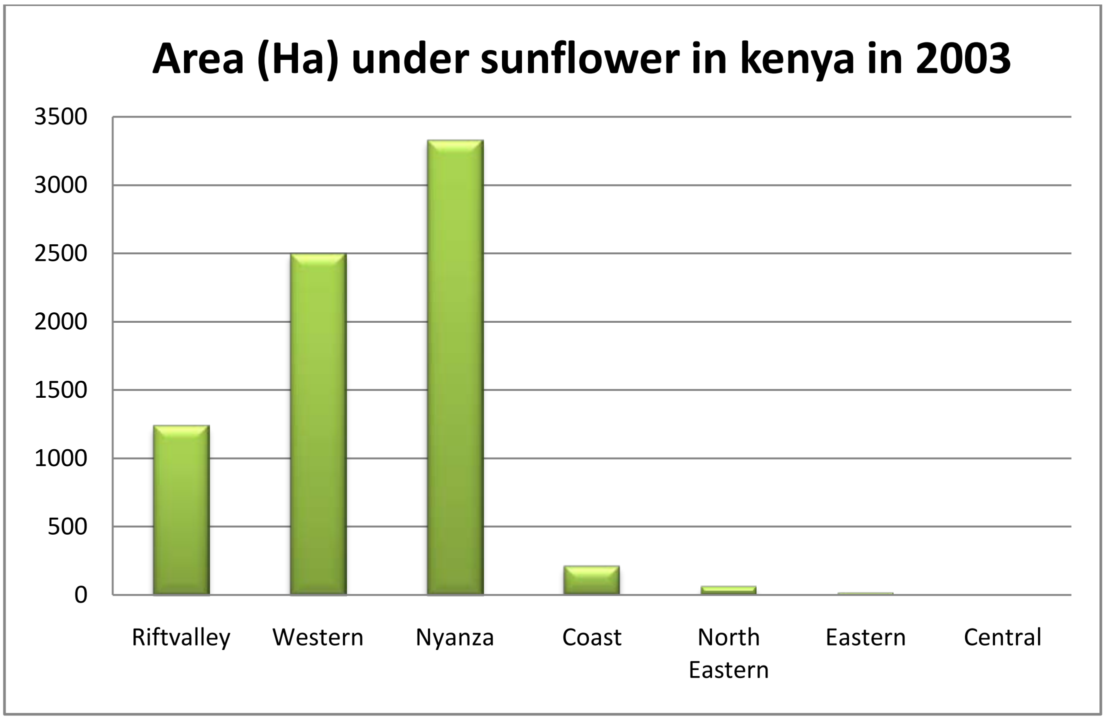

Fig. 10: Area in Kenya under sunflower cultivation in 2003

Source: EPZA, 2005b

In 2009, Ministry of Agriculture reported that 108 tons of sunflower seeds were produced in the country while only 200 kg were imported (MAO, 2010). Most of these were absorbed by edible oil processing firms like Bidco oil refineries which make sunflower oil. However most of the sunflower is produced by small scale farmers and in almost all case intercropped with other crops which are considered as the main crops. The low yields due to poor varieties that yield only 150-200 kg per acre is the main reason farmers have not fully accepted the crop, though the varieties promoted by organizations are high yielding (IDRC, 1998, Drumnet, 2010)

Sunflower oil has been put across as one of the crops with a huge potential for biodiesel production in Kenya but due to its wide uses and high cost, the likelihood of it being used to make biodiesel is marginal. Currently, a litre of sunflower cooking oil retails at about Ksh 200 compared to Ksh 90 for a liter of diesel.

4.2. Bioethanol feedstocks

4.2.1. Sweet sorghum *(Sorghum bicolor (L) Moench)*

Sweet sorghum is a plant that can be traced back to Egypt. The plant grows to around 0.6 to 5 m tall and the stem has sweet and juicy pith (Muok et al, 2010). It was introduced in Kenya mainly for its grain which is used as food but its sweet juice from the stalk can be used for ethanol production. Sweet sorghum is drought resistant and has a short maturity period that can allow for 2-3 harvests a year. It is a C_4 plant characterized by a high biomass sugar-yielding and photosynthetic efficiency (MOE/GTZ, 2008).

Sorghum is mainly grown in the lower potential districts in Kenya where it plays a key role in ensuring food security. The grains are used to make cereals, snacks, bread and porridge (fermented and unfermented) while the stalks can be used as animal fodder and in the manufacture of paper and wallboards (Muok et al, 2010). Ethanol from sweet sorghum has superior quality, lower sulphur content, high octane rating and is automobile friendly (up to 25% blending). Bagasse obtained after juice extraction has higher biological value as it is rich in micronutrients making it suitable as organic manure and can also be used as feed or for power cogeneration.

When grown for bioethanol production, the first crop is usually left to grow to maturity and the grain harvested for food. This is positive in that it ensures food security eliminating then competition between food and biofuels. The potential grain yield is about 10-15 bags per hectare (MOE, 2010). Thereafter the ratoon crops can be harvested twice or thrice a year for the stalks which are crushed to remove the juice for fermentation.

Agronomy

Table 11: Sorghum agronomic parameters

Source: Muok et al, 2010

Agronomic parameters	**Overall range**	**Optimal range**
Annual temp (^oC)	17-40	22-35
Annual rainfall (mm)	350-2380	400-600
Altitude	0-2500	-
Soil	Pellic vertisols	
Maturity period	4 months	

The crop is best propagated through the seeds. The seed is cultivated in rows spaced 50-60cm apart with hill to hill spacing of 12-15cm (Rao et al, 2008). Weeds in sorghum can be controlled through chemical sprays (pre-emergence herbicides are applied at most one day after sowing) and mechanically until the crop is 35-40 days old. The crop is affected by major pests at different stages of growth and they include cutworms, armyworms, wireworms and seed beetles. In areas where the humidity and rainfall are high sweet sorghum suffers from foliar diseases such as leaf blight and dwarf mosaic (Rao et al, 2008).

Fig. 11: A Sweet sorghum trial plot.

Source: ICRISAT

The crop matures after 4 months and this can be established when a black spot appears on the grain at the lower end. The grain can be harvested either manually or using a combine harvester. The sweet sorghum stalks can be harvested for juice when its brix reaches 16-18% (Muok et al, 2010).

Agricultural potential and suitability

In Kenya, sorghum is an important cereal in the medium and low altitude areas. O'Neill and Kamau (1990) estimated that 52% of sorghum in Kenya is grown in Nyanza and 23% in Western province. It is an important food crop around Lake Victoria region, an area where maize does relatively poor or fails due to erratic rainfall, pests and diseases (Wanyama, Njue & Kidula, 1995).

According to Muok et al (2010), sweet sorghum has the widest suitability area from western, central, eastern and coastal regions of Kenya estimated at 263,965km^2 or 46.4% of the total Kenya surface area. However, the suitable area reduces to 185,822km^2 or 32.6% of the total Kenya surface area when the protected areas, wildlife conflict areas, wetlands and animal movement paths are zoned off.

Table 12: Sweet sorghum suitability and zonation

Source: Muok et al 2010

Suitability and Zonation	**Suitability area (KM^2)**	**% of Kenya land surface area**
General suitability	263,965	46.4
Suitable outside protected area	206,574	36.3
Suitable within food crops areas	53,204	9.3
Suitable within cash crops areas	4,029	0.7
Suitable outside food and cash crops areas	149,260	26.2
Suitable within cultivated areas	57,332	10.1
Suitable within non-cultivated areas	149,260	26.2
Suitable outside wildlife conflict areas	182,758	32.1
Suitable outside wetlands	179,260	31.5
Suitable outside animal movements paths (3KM)	174,446	30.6

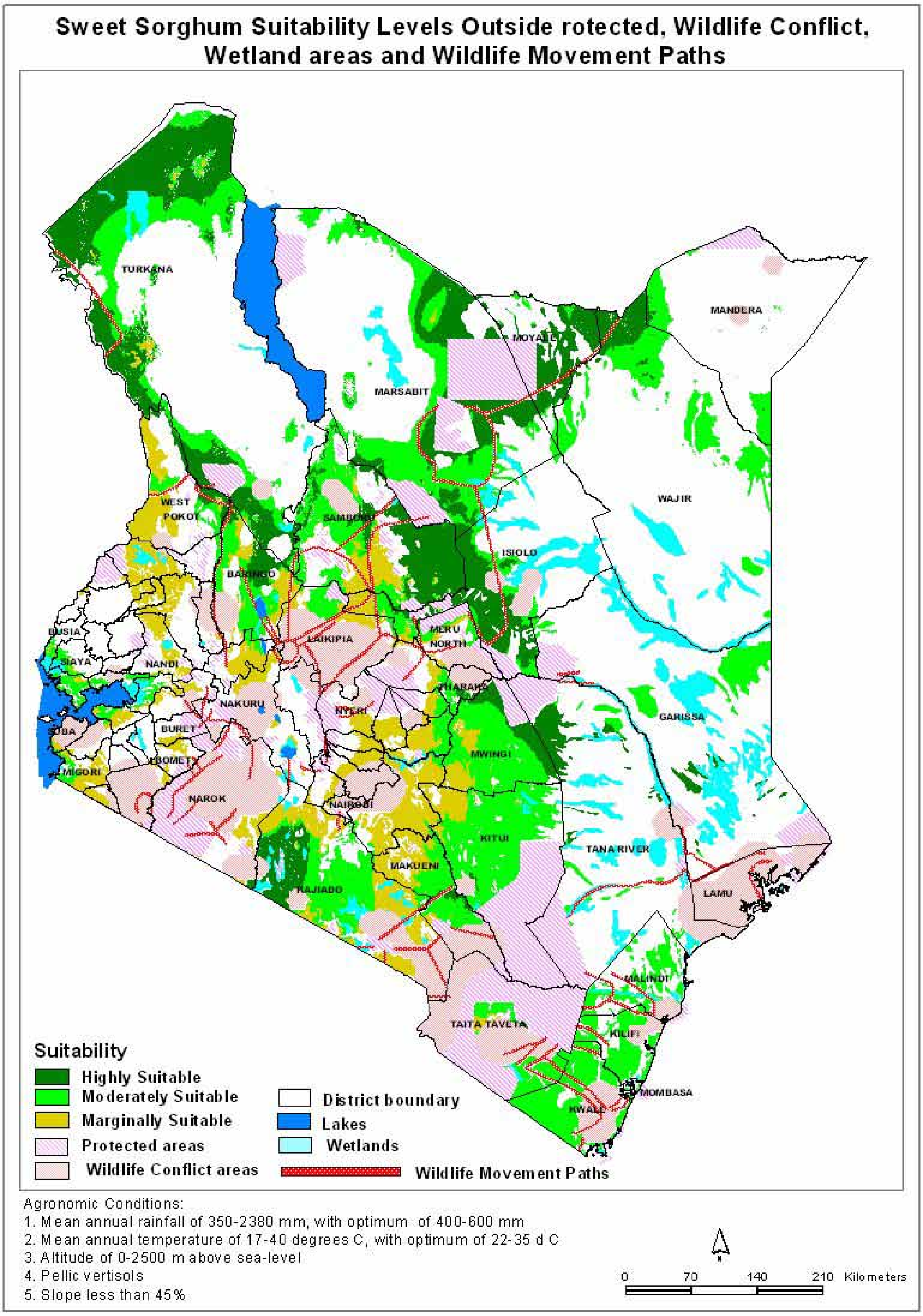

Fig. 12: Sweet sorghum suitability levels

Source: ICRAF GIS Unit

Current status

Production of sorghum in Kenya has been declining over the years both in yields per hectare and total productivity. However, production increased by a dramatic 75% from 54.26 million tons in 2008 to 94.955 million tons in 2009. There was also a slight improvement on the yield per hectare to 621kg but this was still lower though when compared with the 14.0 bags/ha recorded in 2005 (MOA, 2010). The area under the crop also registered an increased acreage to achieve 173,172 ha in 2009 due to being promoted as a drought resistant and hence a primary poverty eradication vehicle in marginal areas.

Table 13: National sorghum production 2005-2009

Source: MOA, 2010

Year	2005	2006	2007	2008	2009
Area under sorghum (Ha)	122,368	163,865	155,550	104,041	173,172
Production (90kg bags/ha)	1,668,081	1,457,503	1,63,391	602,910	1,055,051
Yields (Kg/Ha)	1260	810	819	522	621
National consumption (90kg bags)	1,425,000	1,510,000	1,551,525	366,667	900,000

A study done in 2008 showed that sweet sorghum is by far the best raw material, as far as cost of raw material is concerned, for bioethenal production in Kenya. This is also supported by the vast amount of land suitable for its cultivation and the short crop rotation period compared to sugarcane (MOE/GTZ, 2008). It however has some disadvantages of low sugar content and additional processing costs compared to molasses, which is currently the main raw material.

Current developments where most sugar companies are contemplating starting ethanol production will mean there will be a huge shortage for molasses for the established ethanol manufacturing plants that rely on molasses from these firms. This will force them to diversify in terms of raw materials they use and sweet sorghum has been one alternative that has been floated (MOE/GTZ, 2010, MOE, 2009). Already, Specter international has imported sorghum seeds from India and has been doing seed bulking to distribute to farmers when they start the ethanol production from sweet sorghum.

East African Breweries has joined in the process of sorghum promotion as they prepare to launch cheaper beer brands made of sorghum instead of barley which has to be imported. In 2010, East African Breweries distributed certified gaddam sorghum (This is a unique sorghum variety that is approved for beer manufacturing) seeds to over 10,000 farmers in Eastern Province (The East African, 17^{th} of May, 2010).

4.2.2. Sugar cane (*Saccharum spp)*

Sugarcane is a tall grass-like perennial crop that has stems referred to as canes and stores its carbohydrates in the form of sugar. It grows in tropics and provides half of the world's sugar. In Kenya, it is mainly grown on fairly flat regions in the Western, Nyanza and Coast Provinces (EPZA, 2005a). Sugarcane is one of the most important crops in Kenya alongside tea, coffee, horticultural crops and maize. It directly supports 200,000 small-scale farmers who supply over 88% of the cane milled by the sugar companies (Muok et al, 2010). The sugar sub-sector directly or indirectly supports about 6 million Kenyans and sugarcane farming provides direct employment to over 500,000 workers (Kenya Sugar Board, 2009). It also generates about Ksh. 12 billion annually while domestic production of sugar saves the country in excess of KES 20 billion in foreign exchange annually playing a major economic role (KESREF, 2009).

Sugarcane is used for sugar manufacture, jaggery manufacture and power/industrial alcohol manufacture. For the residues, bagasse is used in cogeneration to generate process heat and electricity while molasses is used for power/ alcohol manufacture and biogas (MOE/GTZ, 2008).

Agronomy

Table 14: Agronomic parameters for sugarcane

Source: Muok et al 2010

Agronomic parameters	**Overall range**	**Optimal range**
Annual temp (^{o}C)	12-38	20-30
Annual rainfall (mm)	1000-1800	1200-1800
Altitude	0-1500	-
Soil	Loam to clay soil	
Maturity	18-24 months (12-16 months in the Coastal area)	

Sugarcane is mostly propagated using cuttings. Each cutting must contain at least one bud and the cuttings are mostly hand-planted (Muok et al, 2010). Once planted, a stand can be harvested several times since after each harvest, the cane sends up new stalks, called ratoons but yields decrease with successive harvests. For this reason, only three harvests are recommended in Kenya. A sugarcane plantation takes between 18 and 24 months to mature in the western and Nyanza provinces while varieties planted in the Coastal region take between 12 and 16 months (KESREF, 2009, MOE/GTZ, 2008).

Harvesting can be done either by hand and mechanically but the earlier is practiced in Kenya. During harvesting, the field is first set on fire to burn dry leaves, and kills any lurking venomous snakes, without harming the stalks and roots. Harvesters then cut the cane just above ground-level using cane knives.


Fig. 13: Newly burned sugarcane ready for harvesting (Left) and newly harvested cane in Kibos

Source: Author

Sugarcane ratoon crop can be intercropped with legumes like beans in the initial months and multipurpose trees can also be planted in contour hedgegrows in non-mechanized areas (MOE/GTZ, 2008).

Agricultural potential and suitability

Sugarcane farming in Kenya is concentrated in Western, Nyanza and Coastal areas. Some parts of Eastern province have a suitable environment for cane production but this is not been commercially exploited (Muok et al, 2010). Most of the cane in Western and Nyanza Provinces is rain-fed and takes 18 to 24 months to mature but in the Coastal region where the altitude is lower, it takes between 12 and 16 months. On average, a hectare of cane plantation yields between 70 and 85 tons of cane in the Western and Nyanza provinces while in the Coastal region it averages around 100 tons. There is also a huge potential for irrigation in the Tana Delta which can raise the production to over 150 tons per hectare (KESREF, 2011).

About 17,332 km^2 which is equivalent to 3% of the surface area of Kenya is suitable for cane production but after zoning off wetlands, protected zones, wildlife conflict areas and slopes greater than 45%, this reduces to 12,591 km^2 (Muok et al, 2010).

Table 15: Sugarcane suitability in Kenya

Source: Muok, et al, 2010

Suitability and Zonation	**Suitability area (KM^2)**	**% of Kenya land surface area**
General suitability	17,332	3.0
Suitable outside protected area	15,916	2.8
Suitable within food crops areas	12,912	2.3
Suitable within cash crops areas	1,545	0.3
Suitable outside food and cash crops areas	1,458	0.3
Suitable within cultivated areas	14,457	2.5
Suitable within non-cultivated areas	1,458	0.3

Suitable outside wildlife conflict areas	13,052	2.3
Suitable outside wetlands	12,728	2.2
Suitable outside animal movements paths (3KM)	12,591	2.2

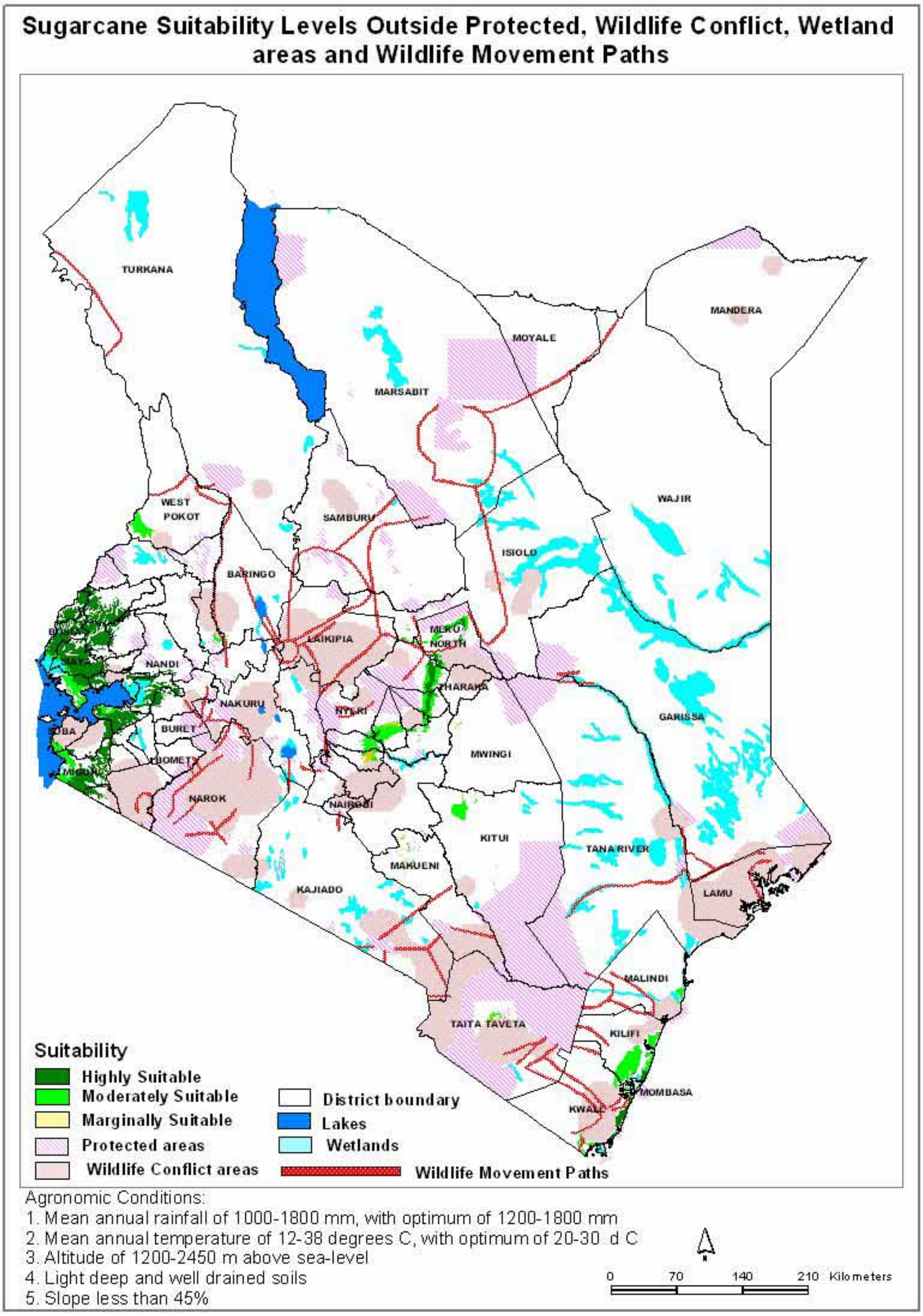

Fig. 14: Sugarcane suitability zonation in Kenya

Source: ICRAF GIS Unit

Current status

The sugar industry in Kenya has struggled for many years for various reasons, such as lack of accountability and transparency in the sector, poor management, excessive taxation and delayed payments to farmers to name a few (KESREF, 2009). Sugar production technology in most factories is old and inefficient making sugar production to be among the highes in the continent (MOA, 2010). However, the sector has impressively recovered in the last decade due to major government reforms and increase in acreage under cane (KSB, 2010)

Table 16: Sugar production 2005-2009

Source: Kenya Sugar Board

Year	**2005**	**2006**	**2007**	**2008**	**2009**
Area under cane (Ha)	144,765	144,730	158,568	169,421	154,298
Cane production (Tons)	4,800,820	4,932,839	5,204,214	5,176,670	5,610,702
Yields (Tons/Ha)	84.9	90.3	87.9	95.0	85.3
Sugar production (Tons)	488,997	475,670	520,404	517,667	548,208
National consumption (Tons)	695,622	718,396	741,190	751,523	605,358

In 2009, the area under cane was 154,298 hectares of which 88% is owned by smallholders and the rest nucleus estates. A study commission by MOE and GTZ in 2008 estimated that a tone of sugarcane can yield 0.1 tons of sugar and the molasses from sugar processing 10 liters of ethanol (MOE/GTZ, 2008) or 70 liters of ethanol if all the cane juice was used for the purpose of ethanol production. Using the same parameters, we can say that in 2009, Kenya had a capacity to produce 56 million liters of ethanol from molasses or 372.75 billion liters of ethanol in case all the cane juice is used for ethanol production.

Fig. 15: Molasses storage tank (Right) and Molasses transportation tank in Mumias sugar

Source: Author

There are currently 9 operational sugar mill in Kenya with a total crushing capacity of 26,276 tons of sugarcane per day, the latest one being Butali Sugar company that started operations in January 2011 .

Table 17: Current sugar mills in Kenya and their crushing capacities

Source: KESREF

Sugar company	**Rated Capacity (T/day)**	**Actual Crushing capacity (T/day)**	**Remarks**
Mumias	8,880	8,048	
West Kenya	2,496	2,417	
Nzoia	3,000	3,147	
Sonysugar	3,240	2,666	
Kibos	1,800	1,484	
Chemelil	3,360	2,805	
Muhoroni	2,400	2,152	
SOIN	300	267	
Butali sugar mills	800	-	Started operations in January 2011
Total	26,276	-	

There are four sugar companies expected to be build in the next three years, two of them in the coastal region, one in Transmara and one in Nyanza with a capacity of 15,800 tons per day. These would raise the total capacity of sugar crushing in the country to a whooping 42,076 tons of cane per day.

Table 18: Upcoming sugar companies in Kenya

Source: KESREF

Sugar company	**Locality**	**Expected capacity (T/D)**	**Remarks**
International	Kwale	3,500	Expandable to 5,000 T/D
Transmara Sugar	Transmara	800	

Sukari	Ndhiwa	1,500	Expandable to 2,500 T/D
TARDA	Tana River	10,000	
Total		15,800	

Ethanol production is currently done by two companies only namely; Agro-Chemical and Food Company Limited and Specter International Limited. Between them they have a capacity of producing 125,000 liters of ethanol per day but produce only 57,400 liters per day (MOE/GTZ, 2008). The capacity is expected to increase with Mumias Sugar Company currently building an ethanol plant with a capacity of 80,000 liters per day. Kwale international is also planning 30,000 liters per day ethanol plant while most of the new plants are planning to build ethanol plants of various capacities (Daily Nation Newspaper, January 11, 2011). As such, the ethanol industry in Kenya is expected to grow rapidly in the next one decade.

Table 19: Ethanol production and planned capacity

Source: MOE/GTZ 2009, KESREF

Ethanol plant	Current production (L/D)	Current and Planned production capacity (L/D)
Agro-Chemical	27,400	60,000
Specter International	30,000	65,000
Mumias	-	80,000
Kwale International	-	30,000
Total	**57,400**	**235,000**

In 2003 Kenya sought COMESA intervention of safeguard mechanism to protect its sugar industry from threats by cheap imported sugar form other COMESA countries by limiting imports from COMESA to 200,000 tons per year. This later increased to 220,000 tons per year. The Safeguards were to expire in March 2008 but Kenya were extended to 2012. As a part of the sector reform, the government is planning to privatize all the sugar factories and which will have to be more innovative and efficient to survive the fierce competition. AS such, it is projected that all of them will venture in to ethanol production and cogeneration to increase their product range hence revenues. This is expected to further increase the ethanol production capacity in the country.

Fig. 16: Mumias Sugar Company entrance (left) and ongoing excavation at the proposed site for ethanol plant (right)

Source: Author

4.2.3. Cassava *(Manihot esculenta Crantz)*

Cassava is a perennial woody shrub with up to 32% starch content extensively cultivated in tropical and subtropical countries. It is widely grown in East Africa especially in semi-arid areas due to its drought tolerant characteristic to ensure food security. It has industrial uses in the manufacture of animal feeds and starch. Starch from cassava is used as a raw material in food, textile, paper, adhesives and pharmaceutical industries (IITA, 1990)

In the coastal lowlands of Kenya, cassava is a staple food while in western and Nyanza provinces, it is the second most important staple crop after maize (Muok et al, 2010). Cultivation is mainly by small holder poor households for subsistence. The highest production is realized in Nyanza and Western provinces which produce 60% followed by Coast Province (30%) and Eastern province (10%). Major constrains of cassava production include pests and diseases, poor agronomic practices, low yielding varieties, high cyanide levels, lack of clean planting materials and long maturity periods (C3P, 2011). One ton of cassava can yield between 160-180 liters of hydrous bioethanol making it a very good crop for biofuels production.

Agronomy

Table 20: Cassava agronomic parameters

Source: Muok et al, 2010

Agronomic parameters	Overall range	Optimal range
Annual temp (^oC)	16-30	-
Annual rainfall (mm)	580-1500	-
Altitude	0-1500	-
Soil	Free drained rock free soils of medium fertility	
Maturity	6-9 months	

Cassava is propagated vegetatively by use of stem cuttings which must have a node. They are planted at 45° or laid flat in a hole about 7.5-10 cm deep and spacing of 0.9m by 1.5m for a pure stand (Muok, et al, 2010). Planting is done on ridges which makes harvesting easier. Fertilization is rarely necessary and it requires minimal maintenance (C3P, 2011). The crop takes 12 – 24 months to mature. In the Coast province the crop yields 5-10 t/ha compared to the 32 t/ha potential. The crop can be intercropped with other food crops like beans legumes and other but this has not been scientifically tested (Muok et al, 2010).

Agricultural potential and suitability

Under natural conditions cassava can be grown across the southern half of Kenya. Its drought tolerance means that it can survive even during the dry season where soil moisture is low but humidity is high and performs far much better than any other major food and cash crop in soils Western, Coastal and the semi-arid regions of Eastern of Kenya have the highest production (MOE/GTZ, 2009).

According to Muok et al (2010), a total of 103,044km^2 or 18.1% of the total Kenya surface area is suitable for cassava production. However, when the protected areas, wildlife conflict areas, wetlands, slopes more than 45% and animal movement paths area zoned out, the total land available for growing cassava is 66,092km^2 or 11.6% of the total Kenya surface area

Table 21: Suitability zonation for cassava

Source: Muok et al, 2010

Suitability and Zonation	Suitability area (KM^2)	% of Kenya land surface area
General suitability	103,044	18.1
Suitable outside protected area	81,312	14.3
Suitable within food crops areas	38,629	6.8
Suitable within cash crops areas	2,141	0.4
Suitable outside food and cash crops areas	38,754	6.8
Suitable within cultivated areas	40,762	7.2
Suitable within non-cultivated areas	38,754	6.8
Suitable outside wildlife conflict areas	67,139	11.8
Suitable outside wetlands	66,092	11.6
Suitable outside animal movements paths (3KM)	63,953	11.2

Current status

Cassava has been mostly farmed in Kenya for domestic food consumption. Industrial processing is at its infant stages with most of it done in micro processing plants (Mbwika and Kamau, 2002). The main processed products are cassava chips, dried chips, flour and starch. Cassava crisps are slowly gaining popularity in most parts of Kenya. Cassava is also used as a base in canned foods, ice cream, biscuits, confectionary and pharmaceuticals (Muok et al, 2010).

Cassava production has increased continuously from 566,400 in 2005 to 911,074 tons with the area under the crop also increasing from 68,320 to 70,426 ha in the duration. The yields per hectare have also been increasing with the average yields standing at 12.9 from up from 8.0 in 2005. This has been attributed to research on better yielding and drought and pest resistant varieties spearheaded by Kenya Agricultural Research Institute (KARI).

Table 22: Cassava production 2005-2009

Source: MOA, 2010

Year	**2005**	**2006**	**2007**	**2008**	**2009**

Area under (Ha)	68,320	68,502	53,610	54,673	70,426
Production (Tons)	566,400	656,633	397,705	750,964	911,074
Yields (Tons/Ha)	8.0	9.6	8.7	13.7	12.9

4.3. Other potential feedstocks

Several other feedstocks have been put across as suitable for biofuels production in Kenya. The table below shows a list of the other feedstocks that have either not been fully adopted by farmers or their oil is currently used for much more profitable purposes.

Table 23: Other potential feedstocks

Source: Authors compilation

Feedstock	Biofuel	Current status	Remarks
Coconut palm	biodiesel	Mostly farmed in the coastal region.	At current price of Ksh. 300 per liter for coconut cooking oil, biodiesel cannot compete with it.
cotton	biodiesel	Grown by small-scale farmers in Western, Nyanza, Central, Rift Valley, Eastern and Coast Provinces.	Cotton oil processing is non-existence in Kenya while the amount of seeds can not support a biodiesel industry
Oil palm	Biodiesel	Grown in Western Kenya	No current commercial use other than soap manufacture. Limited acreage.
Rapeseed (Canola)	Biodiesel	Grown by wheat farmers in Rift valley for soil protection and pilot projects for biodiesel in Central Province.	No commercial processing and quantity is low to warrant biodiesel investment.

5. Economics of biofuel feedstocks production and competing crops

5.1. Gross margins of different feedstocks and competing crops

The cost of feedstock production largely determines the final cost of biofuels hence the viability of biofuels industry and its capacity to compete with fossil fuels. It is reported that the cost of feedstock in accounts for about 65-78% of overall production expense depending on the size of the facility (Pruszko, 2006).

It is therefore imperative that before a company or country embarks on producing biofuel from a particular feedstock, economic analysis is done to ascertain the profitability and sustainably of the venture. For this reason, gross margins for the feedstocks covered above were done and this was compared with maize and beans the most common food crops grown. From the suitability mapping done by ICRAF, GIS unit, it was clear that biofuels feedstocks are best produced in agro-ecological zones IV to VII, which have medium to marginal agricultural use. This would eliminate potential competition with traditional food and cash crops and is also in line with the government's objective of increasing agricultural productivity in marginal and waste lands. As such, the gross margins were based on the productivity of feedstocks and food crops in these agro-ecological zones. Even though the main cash crops in Kenya are coffee and tea, the gross margins of the feedstocks were not compared with these cash crops since the perform well in agroecological zones I to III which should not be targeted for biofuel feedstocks production. The cash crops that are prominent in agro-ecological zones IV-VII are sugarcane and cotton. Sugarcane is already covered in this report as source for bioethanol while cotton is mentioned as potential source of biodiesel.

The data used in this study was compiled from various sources, to include; the Ministry of Agriculture publications (*Farm Management Handbook of Kenya* (2005), the Economic Review on Agriculture (MOA, 2009 and 2010)), commissioned research papers (*Jatropha; a reality check* (GTZ, 2009a), *Assessment of Costs of Maize Production, Marketing and Processing in Kenya: A Maize Meal Value Chain Analysis* (KARI, 2009) *and Participatory sunflower production, technology dissemination and value addition in Southwest Kenya* (Okoko N. E. K. et al, 2008) among others. Interviews with key informants from KARI, KESREF, HSHC, MOE, MOA, ICRISAT, Bidco Oil Refineries, Specter International and Mumias Sugar Company supplied important data on productivity and market prices for different crops. Interview with farmers in Mumias yielded data on cost of production of sugarcane and income, based on the payment by Mumias Sugar Company.

The cost of labour was found to vary between KSh 150 to KSh 250 per man-day from high income areas in central province to impoverished areas in Eastern province. A standard Ksh. 200 was applied throughout this study. Other costs taken into consideration are farm inputs (Seedlings, fertilizer, equipment and pesticides) which were based on the recommended quantities at the prevailing market rates. The yields are based on the reported yields from rain-fed cultivation, which is the most common practice in Kenya, from the agro-ecological zones under consideration. For castor, jatropha and croton there are is not accurate data on productivity and market and this study relied on data estimated by GTZ (GTZ, 2009a) during a research on jatropha and also on small scale producers and processors experiences in the country.

Sweet sorghum has not been grown in Kenya as a biofuel feedstock therefore its data was estimated from research findings by ICRISAT and Jomo Kenyatta University of Agriculture and Technology, two institutions that have been doing extensive research on the crop as a biofuel feedstock. The yields were for sweet sorghum was also considered to be that of both seeds and stalk since the maturity of the seeds coincides with the optimal harvesting time for stalks for ethanol production.

It is possible to harvest most of the seasonal crops like maize, beans, sweet sorghum, sunflower and cotton twice a year, but this is dependent on rainfall availability which is quite erratic in the agro-ecological zones under consideration. For the purpose of this study, the seasonal gross margins of beans, sweet sorghum and sunflower were multiplied by two since it was reported the possibility of harvesting twice a year is quite high compared to maize and cassava which were considered to be annual crops.

For the perennial crops like sugarcane, jatropha and croton, a 10 year investment period was considered, the cash flows calculated, NPV for the period calculated and divided by ten to find the annual NPV equivalent which was taken to be the annual gross margin.

In all the cases, the gross margins were discounted at 14% interest rate, which was the prevailing rate at the time of the study according to Central Bank of Kenya (CBK). All the results of the analysis are presented in the appendices of this report.

From the analysis, sweet sorghum has the highest gross margin seconded by sugarcane. This confirms the results of study commissioned by MOE and GTZ (MOE/GTZ, 2008) that concluded that sweet sorghum is the most suitable feedstock for bioethanol production, both in terms of suitability and profitability. It is more profitable than the competing cash crops (both sugarcane and cotton) and food crops (maize and beans). It also does not pose the problem of food security since as stated earlier, since every harvest of feedstock comes with harvest of sorghum seeds which boosts food security.

Table 24: Gross margins of selected crops in Kenya

Source: Author's calculation

Crop	**Gross margin (KSh/ Ha.)**	**Remarks**
Jatropha	-4,423.25	Negative gross margin due to lower productivity and high cost of inputs.
Croton	143.97	Minimal positive gross margin due to low price of seeds.
Castor	-551.49	Negative gross margin as a biodiesel feedstock
Sugarcane	37,746.75	Positive gross margin but productivity is still too low at 70 tons per hectare.
Sweet sorghum	71,808	Has the best returns as a bioethanol feedstock and also improves food security
Sunflower	2,921.6	Has a positive gross margin but is mostly used as a source of edible oil providing completion for food.
Cassava	20,240	Has a positive gross margin but is a source of livelihood for the resident of the arid and semi-arid areas

Maize	3,784	Positive gross margin
Beans	18,304	Positive gross margin
cotton	-14,912.48	Cotton farmers have been making losses due to the volatile nature of the international market.

Jatropha is not profitable as a feedstock, mainly due to its low income and low productivity and high cost of inputs. This is in line with GTZ study of 2009 (GTZ, 2009a) which also concluded that in Kenya, jatropha cultivation is not profitable for Kenyan farmers unless it is planted as a fence or hedge, in which case it requires minimum attention. The same study concluded that croton as a feedstock is not profitable unless it is planted as a fence, or for wood supply. During the time of that study, HSCS, the only organization currently buying croton seeds for small-scale biodiesel production, was paying farmers KSh. 5 per kg of seeds but the orgainisation has since then increased the figure to KSh 6 which now sees a farmer realize minimal profit.

Castor as a biodiesel feedstock is not profitable due to the low rates that would have to be paid for the final product to be able to compete with fossil diesel. As mentioned earlier, KIRDI had come up with the argument that castor oil is much too valuable for other industrial uses and since Kenya is a net importer of the oil, its farming should be promoted not as a biodiesel feedstock, but for industrial utilization and this might fetch farmers higher returns.

Cassava has been used in some countries as a feedstock for bioethanol production and its gross margin at over KSh. 20,000 per hectare support the investment in Kenya. However, such an initiative needs to be carefully evaluated since the crop is seen as a source of livelihood for the poor in the arid and semi-arid areas of the country.

Sugarcane has been used for ethanol production in Kenya mainly from molasses and the positive gross margins at almost KSh. 38,000 per hectare support its continued use.

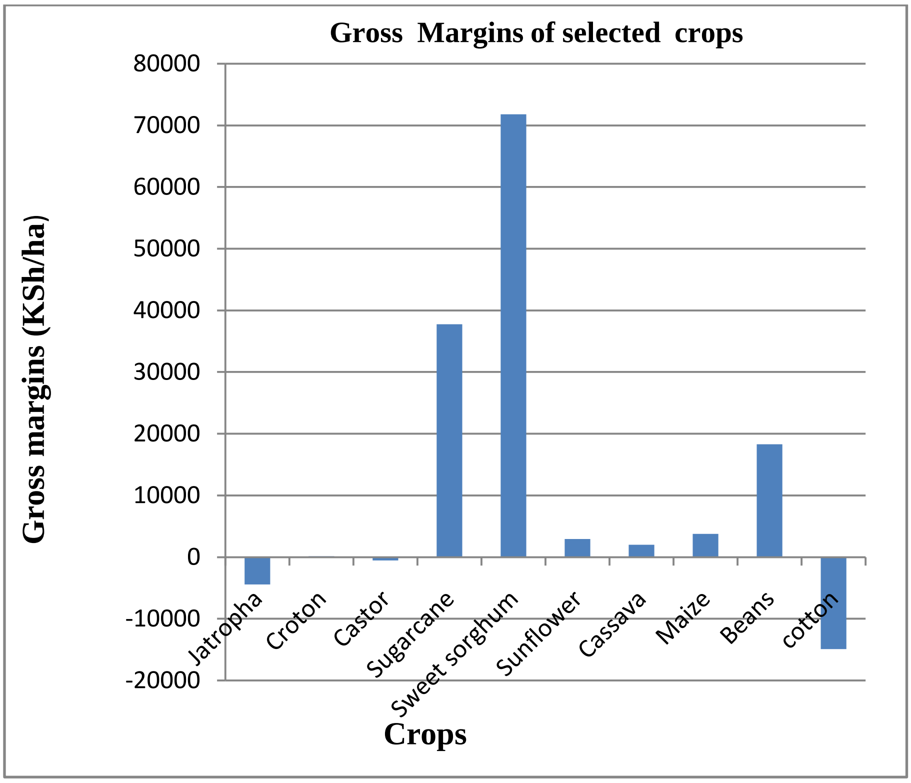

Fig. 17: Gross margins of selected crops

Source: Author

5.2. The way forward

The biofuel sector in Kenya has a huge potential with bioethanol expected to play a bigger role that biodiesel. The gross margins clearly show that the country is better off promoting sweet sorghum for bioethanol production, not only because it is more profitable, but also because it enhances food security. Sugarcane is expected to play a major role in bioethanol supply, and with COMESA safeguards (see previous chapter) nearing expiry, production of ethanol will give the sugar industries a chance to diversify and increase their revenues hence becoming more economically sound.

In 2009, Kenya consumed a total of 0.46 million tons or 633 million liters of petrol (KNBS, 2010) of which 10% or 63.3 million liters will have to be displaced by ethanol when blending directive comes into effect. According to ICRISAT, a ton of sweet sorghum stalks can produces about 40 liters of ethanol, while a hectare of land produces about 35 tons of stalks (Mgonja 2011). This in translates to 1,400 liters of ethanol per hectare of sweet sorghum. If Kenya purposes to supply all the ethanol for blending from sweet sorghum, about 45,000 hectares of sweet sorghum would be required and this in turn would yield 66,000 tons of sorghum for consumption.

For sugarcane, if the current trend continues of producing ethanol from molasses, one ton of sugarcane produces 0.1 tons of molasses which in turn produces 10 liters of ethanol. With one hectare of sugarcane plantation yielding about 70 tons of cane, this translates to 700 litres of ethanol. A total of about 90,000 hectares would therefore be required to produce ethanol from molasses to cover E10 blend. Kenya is currently producing 57,400 liters on ethanol per day which if production takes place every day of the year would only amount to 21 million liters. This is only a third of the national E10 blending program requirement. However, with the planned and current capacity projected to rise to 235,000 liters per day in the future (see previous chapter) which would translate to 86 million liters if production takes place every day, Kenya will have the capacity to cater for all her biethanol requirements.

Table 25: Land requirement to meet the E10 demand from sweet sorghum and sugarcane

Source: Author's estimation

Crop	**Yield (T/ha)**	**Bioethanol yield (L/ton)**	**Bioethanol yield (L/ hectare)**	**Land requirement to meet E10 blending (63.3 million liters) in ha**
Sweet sorghum	35	40	1,400	45,000
Sugarcane	70	10 (molasses)	700	90,000

In 2009, Kenya consumed 1.46 million tons or 1.72 billion litters of diesel. With a B2 blending (later to be rolled out to B5) as recommended in a study commissioned by MOE and GTZ (MOE/GTZ, 2008) about 35 million liters of biodiesel would be required. However, with the main biodiesel crops promoted being croton and jatropha whose productivity is quite low and their cultivation not fully understood, it is difficult to estimate the requirements in terms of land or processing capacity.

Based on rough estimates by GTZ, a tonne of jatropha seeds produces 336 liters of biodiesel. At an average yield of 2.5 tons of seeds per hectare for rain fed cultivation (MOE/GTZ, 2008), over 102 thousand hectares of land would be required for a B2 blending and about 260 thousand hectares for a B5 blend. From the same study, croton has similar biodiesel yields per ton and seed yields per hectare which translates to approximately the same land requirement. This is a sobering reality the government will have to take into consideration before plunging into B2 and later rolling it out to B5 blending because it can lead to either massive competition with other land uses to satisfy demand or collapse due to lack of feedstock.

6. National biofuel strategies, policies and regulations

6.1. Existing national policies and legislations impacting on the biofuels sector

Policy interventions and strategies greatly shape the biofuels sector in any country by setting objectives that help in improving energy access, ensure security of supply of affordable energy and achieve efficiency and conservation (FAO/GBEP, 2007). Several countries especially in the European Union have implemented policies that have seen their biofuels sector flourish and play an important role in the country development. For the biofuel sector to flourish in Kenya, the right legal and policy framework needs to be in place. This section makes an analysis of the existing and draft policies and legislations that impact on the biofuels sector in Kenya.

Sessional Paper No. 4 was the first major energy framework policy which developed specific sectoral or sub-sectoral energy policies aimed at encouraging wider adoption of renewable energy technologies in Kenya. The Policy recognizes the potential for production of biofuel from locally grown crops, and in order to utilize biodiesel, observes that a system for production, distribution and use will need to be put in place (KIPPRA, 2010). The policy recognizes the need to set aside land for the production of energy crops, formulate strategies to optimize land use and to harmonize the existing land use policy with the energy policy (GoK, 2004). It also calls for resources to be mobilized for research and development that will facilitate introduction of biofuels as a motor fuel blend in the medium term.

The Energy Act 2006 which became operational in July 2007 mandates the government to pursue and facilitate the production of biofuels. It does not give much detail on how this is to be achieved but it mandates the government to adopt a biofuels policy to promote biofuels activities in the country (Muok et al, 2008). However this has not happened to date but the policy has been drafted awaiting adoption. The Energy Act is also unclear whether it is permissible to produce, sell or use biofuels in the absence of clear standards from the Kenya Bureau of Standards (MOE/GTZ, 2008). The Energy Act also directs that KEBS determines fuel quality and blending standards for biofuels.

The Environmental Management and Coordination Act 1999 (EMCA) and the Environmental (Impact Assessment and Audit) Regulation 2003 ("Regulations") provides a framework for coordinated management of environment and development matters. This framework provides instruments and tools for assessing proposed development activities to ensure they are economically viable, socially acceptable and environmentally sound. The EMCA requires that KEBS conduct an environmental impact assessment (EIA) analyzing the environmental impact of any biofuels standards it proposes. It also requires that EIA be performed by National Environmental Management Authority (NEMA) for any biofuels project, program or policy that may have an impact on the environment. An Environmental Impact Assessment License (EIAL) is then issued before the project can be started.

Research has shown that most of the land considered Arid and Semi-Arid is suitable for biofuels feedstock production. However, the policy on Arid and Semi Arid Lands (ASALs) indicates that this opportunity for investment not been utilized (GoK, 2005). Biofuels production initiatives can be mainstreamed in the ASALs with a view to achieving the objectives of the strategy of increasing agricultural investments in the area and the economic wellbeing of the people.

The Agriculture Act (Cap 318) provides for the conservation of soil and its fertility, and the development of agricultural land in accordance with accepted practices of good land management and good husbandry. The Strategy for Revitalizing Agriculture 2004-2014 focuses on agriculture as a key sector for growth and employment, and discusses in detail the need for increased support to agro-processing industries in rural areas and improved linkages between producers, suppliers, processors and market. It also recognizes the importance of new and emerging crops including biofuel feedstocks. The country's vision 2030 aims at industrializing the agricultural sector through enhanced agro-processing and value addition to crops.

Government Lands Act (Cap 280), the Registration of Titles Act (Cap 281), the Land Titles Act (Cap 282), Registered Land Act (Cap 300), Trust Land Act (Cap 288), the Indian Transfer of Property Act and the Sectional Properties Act, all deal with issues concerning land tenure which is an important component of adopting biofuels in Kenya. They give directives on the terms and conditions under which rights to land and land-based resources are acquired, held, used, disposed and transferred or transmitted to another party.

The Forest Act 2005 provides for the conservation of Kenya's forest resources and their rational utilization for the socio-economic development of the country. Section 8 of the act requires all indigenous forests and woodlands to be managed on a sustainable basis for the conservation of water, soil and biodiversity, river bank and shoreline protection, and the sustainable production of wood and non-wood products. This act cannot be ignored especially where the feedstock is from woody biomass like jatropha and croton.

The most recent developments in terms of legislations related to biofuels include drafting of both the biodiesel *(Strategy for Developing the Bio-Diesel Industry in Kenya; 2008-2012)* and biodiesel *(Bioethanol Strategy 2009-2012)* strategies and drafting of the biofuels policy *(Proposed National Biofuel Policy, 2010).* These pieces of legislation are supposed to promote biofuels production and use as well as act as a legal framework within which the sector will operate. The drafting has been facilitated by the Ministry of Energy by calling together all the stakeholders and line ministries to give their input. However, all remain drafts but the stakeholders and the public as a whole hope that they will be adopted soon to help move the sector forward.

6.2. Regional and international commitments impacting on biofuels.

Kenya is a member of international community and has entered into several international agreements which would impact on any biofuels investment. Regionally, Kenya is a member of Common Market for Eastern and Southern Africa (COMESA) a regional economic block of 19 countries that requires free movement of goods and services between the member countries. Under COMESA all the member states are supposed to abolish all non-tariff barriers to trade amongst themselves and establish a common external tariff. The member states are also supposed to adopt common standards, measurements systems and quality assurance practices in respect of goods produced and traded within the Common Market.

Internationally, Kenya is a signatory to the UNFCCC and has ratified the Kyoto Protocol which was adopted in 1997 and came into force in 2005. However, it is not obliged to reduce its greenhouse gas emissions but use of biofuels would contribute to the goals of this convention. The Kyoto Protocol allows for several mechanisms, such as emissions trading and the Clean Development Mechanisms (CDM), to allow industrialized countries meet their reduction targets by either purchasing emission reduction credits from elsewhere within the industrialized world, or through projects that reduce emissions in developing countries. Biofuels projects in Kenya would benefit from such mechanisms.

The Convention on Biological Diversity (CBD) establishes a global legally binding framework for the conservation of biodiversity, the sustainable use of its components, and the fair and equitable sharing of benefits arising out of utilization of genetic resources. Any biofuels project needs to abide by its requirements of conservation of various species of native plants, animals and variety of ecosystems in the project area. Kenya has also ratified the convention on wetlands of International Importance (the Ramsar convention) where the parties are required to promote wise use of wetlands in their territories and to take measures for their conservation by establishing nature reserves in wetlands. Any investments in biofuels feedstocks production in such areas need to be in conformity with the provisions of this convention.

7. Certification schemes and standards for biofuels or their feedstock

Biofuels are relatively new fuels in most countries and Kenya is no exception, rendering them more uncertain regarding their performance than conventional gasoline and diesel. To safeguard against these uncertainties, many countries have drafted standards giving the minimum specifications that the biofuels must meet, while those who don't have, have adopted from other countries like USA and Germany which are already far much ahead in this field (IEA, 2009). The minimum test requirements for Biodiesel blend extenders are specified in ASTM D6751 in USA and EN 14214 within Europe. On top of the quality standards, the Energy act 2006 explicitly directs that; "a *person engaged in petroleum business shall comply with the relevant Kenya Standard and in the absence of such standard, any other standard approved by the Commission from time to time on environment, health and safety in consultation with the relevant authorities and in conformity with the relevant statutes touching on environment, health and safety standards*". It is therefore imperative that anybody engaged in biofuels would also be subject to these directives to ensure safety to the people and the environment.

7.1. Existing biofuels standards

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7.1.1. Draft biodiesel standards

Though biodiesel is yet to be commercialised in Kenya, the government and stakeholders anticipates this occurrence in the future. In this regard, Kenya bureau of standards (KEBS), the body mandated to design standards in Kenya, together with the Ministry of Energy and other stakeholders in the energy sector drafted biodiesel standards that are contained in article KS 2227:2010 of KEBS. These standards, though still in draft form, give the minimum requirements that biodiesel should meet before being availed into the market in terms of chemical composition, physical properties and safety parameters as shown in the table below.

Table 26: Physical and chemical composition of biodiesel

Source: KEBS, 2010

Property	Requirement	Test method
Sulphated ash content	0.02	ISO 3987
Alkaline content		
Free glycerol content % mass fraction, max	0.02	EN 14105, 14106
Copper stripe corrosion (3 h at 50 ^{0}C) rating, max	Class 1	ISO 2160
Methanol and ethanol content	0.2	EN 14110
Acidic number mg KOH/g, max	0.5	EN 14104
Total glycerol content % mass fraction	0.25	EN 14105
Phosphorous content mg/kg, max	10	EM14107
Carbon residue on 10 % distillation residue)	0.3	ISO 10370
Ester content (% mass fraction, min)	96.5	EN14103
Distillation temperature		
Flash point 0C, min	120	ISO 3104
Total contamination mg/kg, max	24	EN 12662
Sulphur content mg/kg, max	10	ISO 20846, ISO 0884
Cold climate operability	6	EN 116
Cetane number, min	51	ISO 5165
Oxidation stability at 110 ^{0}C, h, min	6	EN14112
Mono, di, tri, acylglycerides	0.8, 0.2, 0.2 respectively	EN 14105

Density at 20^0C,kg/m^3	860-900	ISO 3675,ISO 12185
Kinetic viscosity at 40^0C ,kg/m^3	3.5-5.0	ISO 3104
Water content and sediment %mass fraction	0.05	ISO 12937
iodine number g of iodine/100g of FAME	140	EN 14111
Linoleic acid content	12	EN 14103
Polyunsaturated methyl ester	1	

7.1.2. Bioethanol standards

The bioethanol draft KS 382:1982 was prepared by the fuel technical committee on petroleum products. It was distributed on the 4th February 2010 for public review in preparation for revision. The table below shows the requirements for bioethanol standards that are yet to be revised.

Table 25: Physical and chemical composition of bioethanol

Source: KEBS, 1990

Property	Requirement
Colour	colourless
Apperance	Clear
Density at 15 ^{0} C ,max	0.7961
Sulphate content	
Total Sulphur content by mass, max	0.2
copper content 3 h at 50 ^{0} C	Class 1
iron content	
sodium content	
Electrolyte conductivity	
Ethanol content % by vol at 15 ^{0} C, min	99.5
Acidity as acetic acid % by mass, max	0,006
Phosphorous content	
Ph	
Gum/ residue evaporation	0.005
Chloride content	
Water content % by volume, max	0.5

8. National liquid transport fuels market

8.1. Major transport fuels consumed in Kenya

The transport sector which includes land, water and air transport is the largest consumer of petroleum fuels accounting for about 70% of petroleum fuel consumption in the country. Diesel (Automotive gas oil) is the leading petroleum product consumed in the country because it is a dual purpose fuel consumed by transport and agriculture. It had a six fold rise between 2003 and 2008 (KIPPRA, 2010). On the other hand, petrol (motor spirit) which is mostly used in the transport of passengers and goods has not had remarkable growth due to the high efficiency of the vehicles entering the domestic market, in spite of the rise in numbers (KNBS, 2010). Illuminating kerosene is the fuel of choice for many rural and infromal urban settelemnts in Kenya which don’t have acces to electricity. Its consumption has reamined almost constant over the years despite increase in population owing to the rolling out of rural electrifcation program which has seen many rural areas get connected to the electric grid and adoption of solar for lighting.

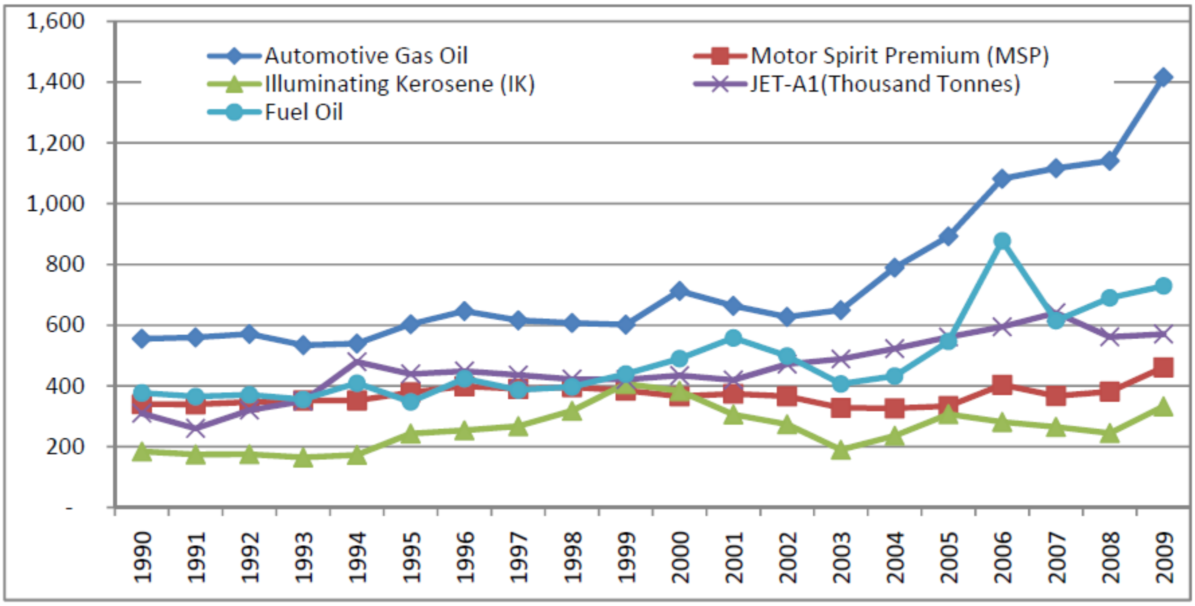

Fig. 18: Consumption of selected petroleum products (000s tons)

Source: KIPPRA, 2010

In 2009, over 3.61 million tons of petroleum fuels were consumed in the country with about 57% of it being sold at retail pump outlets and for road transport. Of this total, 1.46 million tons was diesel and 0.46 million tons motor spirit (KNBS, 2010). This is the amount of fuel that is targeted for blending with liquid biofuels. With the recommended E10 blending, 46,000 tons of bioethanol would be required per annum. A study done by commissioned by MOE and GTZ (GTZ/MOE, 2010) recommended a 2% blend of biodiesel with 98% of diesel as a starting point for Kenya's biodiesel blending program. This would require about 29,200 tons of biodiesel per annum. Another potential use of biodiesel is illumination, displacing kerosene. Displacing a quarter of the illuminating kerosene used in 2009 would require about 83,200 tons of biodiesel which is even more than that for blending.

Table 27: Selected petroleum fuels consumption in Kenya from 2005-2009

Source: KNBS, 2010

Fuel type	**Consumption in '000 tons**				
	2005	**2006**	**2007**	**2008**	**2009**
Motor spirit	333.7	358.2	367.1	381.3	461.7
Illuminating kerosene	307.0	279.2	265.2	244.7	332.8
Light Diesel	892.4	1,035.6	1,116.5	1,141.1	1,416.1

8.2. Prices evolution of fuels consumed in Kenya

Table 28: Evolution of selected fuel prices in Kenya

Source: GTZ, 2009b and KNBS, 2010b

Year	**1991**	**1993**	**1995**	**1998**	**2000**	**2002**	**2004**	**2006**	**2008**	**2010**
Motor spirit price (US cents/L)	53	40	56	70	71	70	92	112	120	109*
Diesel price (US cents /L)	37	33	43	54	60	56	76	98	114	96*

*July 2010 prices

Fuel prices have been progressively increasing over the years from 53 US cents/liter and 37 US cents/liter for petrol and diesel respectively in 1991 to a high of 120 US Cents/liter and 114 US Cents /liter in 2008. In 2009 there was a sharp decline in prices of petroleum products as a result of world financial crisis and the international fall in demand for crude oil (KNBS, 2010a). The upward trend however continued in 2010 with economic recovery and the Kenyan government felt that the oil marketers were exploiting the public.

In 2010, the government legislated *The Energy (Petroleum Pricing) Regulations 2010* which set out to regulate the maximum wholesale and retail prices in accordance with the following formulae:

(a) Wholesale Prices

For super petrol, regular petrol, kerosene or automotive diesel;

$P_w = C_u (1 + L_p + L_d) + K(1 + L_d) + m_w$

Where:

P_w = the maximum wholesale price for super petrol, regular petrol, kerosene or automotive diesel;

C_u = the weighted average cost in shillings per litre ex the Kenya Petroleum Refineries Limited (KPRL) and ex Kipevu Oil Storage Facility (KOSF);

K = the transportation cost from Mombasa to the nearest wholesale depot, which is made up of x percent of pipeline tariff (K_{pt}) and (100 - x) percent of road bridging cost (K_{rd}).

L_p = the allowed losses in the pipeline;

L_d = the allowed losses in the depot;

m_w = the allowed oil marketing company's gross wholesale margin.

(b) Retail Pump Prices for super petrol, regular petrol, kerosene or automotive diesel;

$P_r = P_w + m_r + z$

Where,

P_r = the maximum retail pump price of super petrol, regular petrol, kerosene or automotive diesel applicable, in shillings per litre;

m_r = the allowed maximum retail gross margin;

z = the delivery rate from the nearest wholesale depot to a retail dispensing site in shillings per litre.

Under these rules, those found selling petroleum products above the maximum levels are liable to a fine of one million shillings or the withdrawal of their operating license or both. The maximum prices are determined every 15th day of the month and come into force until the 14th day of the following month.

8.3. Fossil fuels displacement targets

Many countries in the world have set biofuels mandates in order to support their biofuels sector and also to meet green house gases emissions target for those required to do so under the Kyoto protocol. In Kenya, all automotive spirit should be blended with 10% bioethanol which would end up displacing 10% of the petrol consumed in the country. This has however not been implemented, though it has already been gazette, but according to the Ministry of Energy will come into force around March 2011. When this legislation comes to force, going by the 2009 automotive oil consumption figures, the demand bioethanol would stand at 46,000 tons required per annum.

For Biodiesel, no mandates have been legislated to date though the D*raft Biodiesel Licensing Regulations, 2009*, and the *Draft Strategy for developing the Bio-Diesel Industry in Kenya, 2008-2012* (MOE, 2008) set the mandate at B5 (5% biodiesel and 95% diesel) by the year 2012. However, a previous research commissioned by MOE and GTZ had recommended a B2 Mandate (MOE, GTZ, 2008) in commensurate with the available capacity for Kenya to produce all the biodiesel locally.

9. Conclusions and recommendations

This study sought to ascertain the national potential of producing enough biofuel feedstock for both local consumption and export in Kenya. To this end the following conclusions can be made:

Bioethanol

- In terms of suitability, sweet sorghum is the most suitable bioethanol feedstock at 185,822km^2 of the country surface area. This is followed by cassava and sugarcane at 66,092km^2 and 12,591 km^2 respectively.
- Production of bioethanol from sweet sorghum enhances food security because with every harvest of sweet sorghum stalks for ethanol production sorghum seeds for human consumption are produced.
- Production of bioethanol from sweet sorghum is the most profitable with a gross margin of over KSh.71 thousand shillings per hectare.
- Based on the 2009 petrol consumption levels, Kenya would require 46,000 tons or 63.3 million liters of bioethanol to implement the E10 blending program and this would require about 45,000 hectares of sweet sorghum plantation. If all the bioethanol is to be produced from sugar molasses, then this would require about 90,000 hectares of sugarcane plantation.
- The technology to produce bioethanol already exists in the country, the program have started in early 1980's. Already, two companies are producing ethanol and others are planning to commence operations in the next few years.
- Kenya currently produces 57,400 liters of ethanol per day which would translate to about 21 million litters per annum. This would cover about a third of the amount required to implement the E10 blending program. However, the planned and current capacity totals 235,000 liters of ethanol per day which translates to about 81 million liters per annum. This is more than the amount required for the E10 program hence will leave some for export.
- Kenya has had bioethanol standards which were formulated for the blending program in early 1980's. However, these have been revised to reflect the current regional and international requirements where necessary but they are still in draft format.
- There exists national and international legislations and commitments to govern production of bioethanol feedstocks and fuel in order to ensure safety to the environment and consumers.

Biodiesel

- Based on environmental suitability, castor has the largest suitable area in Kenya at 159,115 km^2 and is closely followed by jatropha at 149,302km^2. However, since both crops have not been fully domesticated and little data exists on their cultivation and management in Kenya, this information is based on estimation and in reference to where the crops have been found growing freely in the wild.

- There is no commercial production of any biodiesel feedstock in Kenya for biofuel purposes.
- Considering the current productivity levels of the feedstocks under review, only sunflower has significant positive returns while croton has marginal returns. Jatropha and castor have negative gross margins making them unsuitable for cultivation as biofuels feedstock. However, sunflower is an edible oil crop and diverting it to biodiesel production would lead to a serious food problem.
- Castor oil, though it can be used to make biodiesel has many other industrial uses that would fetch farmers much more revenue hence should not be promoted as a biofuel crop.
- There is no established commercial biodiesel production in the country, with only one known self help group buying croton seeds from farmers who collect them from the neighbourhoods and the forest.
- The technology to make biodiesel is there in Kenya with KIRDI having done extensive research in the field but there are no local equipment producers hence everything has to be imported.
- A national B2 blending program which was recommended in the *bioofuels Roadmap* (MOE/GTZ, 2008), requires 35 million liters (based on national 2009 diesel consumption) of biodiesel, which at the current productivity of jatropha and croton, would require 102 thousand hectares of land for plantation establishment. If the B2 program is rolled out later as suggested, it would require about 260 thousand hectares of land.
- Biodiesel standards have been drafted by KEBS in readiness for the anticipated blending program.
- There exists national and international legislations and commitments to govern production of biodiesel feedstocks and fuel in order to ensure safety to the environment and consumers.

Recommendations

Based on this study, the following recommendations can be made to ensure a sustainable biofuel sector in Kenya in terms of production and consumption:

- The country does not currently have the capacity in terms of ethanol production to support an E10 blending program but this will change in the near future and therefore this initiative should be pursued in line with capacity expansion.
- More research should be done on sweet sorghum as a biofuels feedstock due to its duo benefit of enhancing food security and economic benefits to the farmers.
- Incorporating food based crops like cassava and sunflower in biofuels production could negatively impact on food security in the country, therefore should be discouraged.
- More research should be done to develop better biodiesel feedstocks varieties especially jatropha and croton and improve their productivity if the crops are to make significant contribution in biofuels supply and economic development for the farmers.

- The biofuels policy needs to be adopted so as to give the sector a legal framework within which to operate.
- Small scale pilot biodiesel production units needs to be established in the rural areas already having biodiesel feedstocks to act as a demonstration sites to the rural communities and also a market for their produce which currently has no market.
- Use of biodiesel in rural areas not connected to the grid to generate power for water pumping, lightning and for use by SME's like posho mills should be encouraged to promote rural development.
- Biofuels produced should be for local consumption and not export unless there is surplus since there is a big local market.

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Appendices

Gross margin calculation for one hectare of sorghum in Kenya				
Spacing: 30 cm between forrows				
Item	**Units**	**Quantity**	**Unit price (Ksh)**	**Total (per ha)**
Yields:				
Seeds	Kg	2000	17	**34000**
Stalks	tons	35	1000	**35000**
Total income (A)				**69000**
Variable costs				
Inputs				
Seeds	kg	10	20	200
Equipment (hoes, machete)	no.			2000
DAP fertilizer for planting	50kg bags	2	2500	5000
CAN fertilzer for topdressing	50kg bags	2	2500	5000
Pesticides (Thiodan)	L	2	500	1000
Pesticides (Furadine)	kg	2	1200	2400
Sub-total				**12200**
Labour (Ksh/ha)				
Land preparation	man days	15	200	3000
Furrowing	man days	10	200	2000
Planting	man days	10	200	2000
Fertilization	man days	5	200	1000
Pest control	man days	5	200	1000
Weeding	man days	15	200	3000
Harvesting	man days	10	200	2000
Threshing, winowing and packing	man days	10	200	2000
Sub-total				**16000**
Total variable costs (B)				**28200**
Gross margin (per season)				***40800***
Gross margin (per annum- 2 seasons)				***81600***
NPV (at 14% at interest rate)				***71808***

Gross margin calculation for 1 ha of castor *(Ricinus communis*) in Kenya										
Spacing: 1mX1.5m . Population = 6666										
Years	1	2	3	4	5	6	7	8	9	10
Yields (Kg/ha)	1002.5	1002.5	1002.5	1002.5	1002.5	1002.5	1002.5	1002.5	1002.5	1002.5
Icome @ Ksh 20/kg (A)	20050	20050	20050	20050	20050	20050	20050	20050	20050	20050
Variable costs										
Inputs										
Seeds (10 kg @ksh 200/kg)	2000	0	0	0	0	2000	0	0	0	0
Equipment (Shovels, hoes, sprayer, buckets, etc). 10% replacement cost of worn-out equipment every other year	4900	490	490	490	490	490	490	490	490	490
Manure (0.5kg/tree @Ksh 1.1/kg)	3666.3	3666.3	3666.3	3666.3	3666.3	3666.3	3666.3	3666.3	3666.3	3666.3
Pest/diseases control (0.25 g/tree @ Ksh 2000/ kg)	3333	3333	3333	3333	3333	3333	3333	3333	3333	3333
DAP fertilizer for planting (2, 50kg bag @ 3500	7000	0	0	0	0	7500	0	0	0	
Sub-total	**20899.3**	**7489.3**	**7489.3**	**7489.3**	**7489.3**	**16989.3**	**7489.3**	**7489.3**	**7489.3**	**7489.3**
Labour (Ksh/ha)										
Land preparation (20 man days @ Ksh 200)	4000	0	0	0	0	4000	0	0	0	0
Planting (10 man days (year 1 and 6)@ksh.200)	2000	0	0	0	0	2000	0	0	0	0
Fertilization (5 mandays/year @ Ksh 200)	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Pest/diseases control (5 man days/year @ Ksh 200)	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Weeding (20 man days/year @ Ksh 200)	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
Harvesting (15 man days/year @ Ksh 200)	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
Sub-total	**15000**	**9000**	**9000**	**9000**	**9000**	**15000**	**9000**	**9000**	**9000**	**9000**
Total variable costs (B)	35899.3	16489.3	16489.3	16489.3	16489.3	31989.3	16489.3	16489.3	16489.3	16489.3
Cash flows (A-B)	**-15849.3**	**3560.7**	**3560.7**	**3560.7**	**3560.7**	**-11939.3**	**3560.7**	**3560.7**	**3560.7**	**3560.7**
discount rate 14%	0.88	0.77	0.67	0.59	0.52	0.46	0.40	0.35	0.31	0.27
Discounted cash flows	-13902.9	2739.84	2403.37	2108.22	1849.32	-5439.38	1422.99	1248.24	1094.94	960.48
NPV	**-5514.88**									
IRR	**-12%**									
NPV annual equivalent	**-551.49**									

Gross margin calculation for 1 ha of Jatropha in Kenya										
Spacing: 2.5mX2.5m . Population = 1600										
Years	1	2	3	4	5	6	7	8	9	10
Yields (Kg/ha)	8	138	189	309	526	646	766	905	905	905
Icome @ Ksh 15/kg (A)	120	2070	2835	4635	7890	9690	11490	13575	13575	13575
Variable costs										
Inputs (KSh/Ha)										
Seeds (3 kg @ksh 775/kg)	2325	0	0	0	0	0	0	0	0	0
Equipment (Shoevels, hoes, sprayer,buckets,etc). 10% replacement cost of wornout equipment every other year	2500	250	250	250	250	250	250	250	250	250
Manure (1.2kg/tree @Ksh 1.1/kg)	2112	2112	2112	2112	2112	2112	2112	2112	2112	2112
Pest/diseses control (3 kg furadine @ Ksh 1200/ kg)	3600	3600	3600	3600	3600	3600	3600	3600	3600	3600
Sub-total	**10537**	**5962**	**5962**	**5962**	**5962**	**5962**	**5962**	**5962**	**5962**	**5962**
Labour (Ksh/ha)										
Land preparation (ox)@ ksh. 3000/ha	3000	0	0	0	0	0	0	0	0	0
Planting (6 mandays @ksh.250)	1500	0	0	0	0	1500	0	0	0	0
Fertilization (5 mandays/year @ Ksh 250)	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250
Pest/diseses control (4 man days/year @ Ksh 250)	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Weeding (12 man days/year @ Ksh 250)	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
Harvesting @ ksh.250/man day	500	1000	1500	2000	2500	2500	2500	2500	2500	2500
Sub-total	**10250**	**6250**	**6750**	**7250**	**7750**	**9250**	**7750**	**7750**	**7750**	**7750**
Total variable costs (B)	20787	12212	12712	13212	13712	15212	13712	13712	13712	13712
Cash flows (A-B)	**-20667**	**-10142**	**-9877**	**-8577**	**-5822**	**-5522**	**-2222**	**-137**	**-137**	**-137**
discount rate 14%	0.88	0.77	0.67	0.59	0.52	0.46	0.40	0.35	0.31	0.27
Discounted cash flows	-18128.9	-7803.94	-6666.69	-5078.27	-3023.76	-2515,75	-887.994	-48.0266	-42.1286	-36.9549
NPV	**-44232.5**									
IRR	**N/A**									
NPV annual equivalent	**-4423.25**									

Gross margin calculation for 1 ha of croton in Kenya										
Spacing: 5m X 5m. Population = 400										
Years	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Yields (Kg/ha)	0	600	1200	2400	4000	5600	7200	8400	9200	10000
Icome @ Ksh 6/kg (A)	0	3600	7200	14400	24000	33600	43200	50400	55200	60000
Variable costs										
Inputs (KSh/Ha)										
Seedlings (500 @ksh 25/seedling)	12500	0	0	0	0	0	0	0	0	0
Equipment (Shovels, hoes, sprayer, buckets ,etc). 10% replacement cost of worn-out equipment every other year	4900	490	490	490	490	490	490	490	490	490
Manure (2.5kg/tree @Ksh 1.1/kg)	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
Pest/diseases control (3 g/tree @Ksh 2000/ kg)	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400
DAP fertilizer for planting (2, 50kg bag @ 3500)	7000	0	0	0	0	0	0	0	0	
Sub-total	**27900**	**3990**	**3990**	**3990**	**3990**	**3990**	**3990**	**3990**	**3990**	**3990**
Labour (Ksh/ha)										
Land preparation (20 man days @ ksh 200)	4000	0	0	0	0	0	0	0	0	0
Planting (20mandays @ksh.200)	4000	0	0	0	0	0	0	0	0	0
Fertilization (5 mandays/year @ Ksh 200)	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Pest/diseases control (twice, 5man days/year @ Ksh 200)	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Pruning (12 man days @ Ksh. 200)	2400	2400	2400	2400	0	0	0	0	0	0
Weeding (20 man days/year @ Ksh 200 first four years)	4000	4000	4000	4000	0	0	0	0	0	0
Harvesting @ Ksh 200/ man day	0	1000	2000	3000	6000	8000	10000	12000	14000	16000
Sub-total	**17400**	**10400**	**11400**	**12400**	**9000**	**11000**	**13000**	**15000**	**17000**	**19000**
Total variable costs (B)	45300	14390	15390	16390	12990	14990	16990	18990	20990	22990
Cash flows (A-B)	**-45300**	**-10790**	**-8190**	**-1990**	**11010**	**18610**	**26210**	**31410**	**34210**	**37010**
discount rate 14%	0.88	0.77	0.67	0.59	0.52	0.46	0.40	0.35	0.31	0.27
Discounted cash flows	-39736.8	-8302.55	-5528.02	-1178,24	5718.249	8478.466	10474.49	11011.06	10519.85	9983.22
NPV	**1439.68**									
IRR	**0%**									
NPV annual equivalent	**143.97**									

Gross margin calculation for one hectare of cotton in Kenya				
Item	**Units**	**Quantity**	**Unit price (Ksh)**	**Total (per ha)**
Yields	kg	572	32	**18304**
Variable costs				
Inputs				
Cotton Seed	kg	5	50	250
Equipment (hoes, machete)				2000
DAP fertilizer for planting	50kg bags	2	2500	5000
CAN fertilzer for topdressing	50kg bags	2	2500	5000
Pesticides				10000
Sub-total				**22250**
Labour (Ksh/ha)				
Land preparation	man days	15	200	3000
Planting	man days	10	200	2000
Fertilization	man days	5	200	1000
Pest control	man days	10	200	2000
Weeding	man days	15	200	3000
Harvesting	man days	10	200	2000
Sub-total				**13000**
Total variable costs (B)				**35250**
Gross margin				***-16946***
NPV (at 14%)				***-14912.48***

Gross margin calculation for one hectare of maize in Kenya				
Spacing: 75cm by 30 cm. Population 17,777				
Item	**Units**	**Quantity**	**Unit price (Ksh)**	**Total (per ha)**
Yields (A)	90kg bags	17	1800	**30600**
Variable costs				
Inputs				
Seeds	kg	40	20	800
Equipment (hoes, machete)	no.			2000
DAP fertilizer for planting	50kg bags	2	2500	5000
CAN fertilzer for topdressing	50kg bags	2	2500	5000
Storage dust	50 gm bags	2	250	500
Sub-total				**13300**
Labour (Ksh/ha)				
Land preparation	man days	15	200	3000
Planting	man days	10	200	2000
Fertilization	man days	5	200	1000
Weeding	man days	15	200	3000
Harvesting	man days	10	200	2000
Threshing, winowing and packing	man days	10	200	2000
Sub-total				**13000**
Total variable costs (B)				**26300**
Gross margin				***4300***
NPV (at 14%)				***3784***

Gross margin calculation for one hectare of beans in Kenya				
Spacing: 75cm by 30 cm. Population: 59,259				
Item	**Units**	**Quantity**	**Unit price (Ksh)**	**Total (per ha)**
Income (A)	90kg bags	8	4800	**38400**
Variable costs				
Inputs				
Seeds	kg	25	100	2500
Equipment (hoes, machete)	no.			2000
DAP fertilizer for planting	50kg bags	2	2500	5000
CAN fertilzer for topdressing	50kg bags	2	2500	5000
Storage dust	50 gm bags	2	250	500
Sub-total				**15000**
Labour (Ksh/ha)				
Land preparation	man days	15	200	3000
Planting	man days	10	200	2000
Fertilization	man days	5	200	1000
Weeding	man days	15	200	3000
Harvesting	man days	10	200	2000
Threshing, winowing and packing	man days	10	200	2000
Sub-total				**13000**
Total variable costs (B)				**28000**
Seasonal Gross margin				***10400***
Annual gross margin				***20800***
NPV (at 14%)				***18304***

Gross margin calculation for one hectare of cassava in Kenya				
Item	**Units**	**Quantity**	**Unit price (Ksh)**	**Total (per ha)**
Yields	tons	10	8000	**80000**
Variable costs(A)				
Inputs				
Cuttings	no.	10000	1	10000
Equipment (hoes, machete)				8000
DAP fertilizer for planting	50kg bags	2	2500	5000
CAN fertilzer for topdressing	50kg bags	2	2500	5000
Sub-total				**28000**
Labour (Ksh/ha)				
Land preparation	man days	20	200	4000
Planting	man days	20	200	4000
Fertilization	man days	5	200	1000
Weeding	man days	20	200	4000
Earthing up	man days	20	200	4000
Harvesting	man days	40	200	8000
Bagging and transport	man days	20	200	4000
Sub-total				**29000**
Total variable costs (B)				**57000**
Gross margin				***23000***
NPV (at 14%)				***20240***

Gross margin calculation for one hectare of sunflower in Kenya				
Item	**Units**	**Quantity**	**Unit price (Ksh)**	**Total (per ha)**
Icome (A)	kg	2000	15	**30000**
Variable costs				
Inputs				
Seeds	kg	2	170	340
Equipment (hoes, machete)	no.			2000
DAP fertilizer for planting	50kg bags	2	2500	5000
CAN fertilzer for topdressing	50kg bags	2	2500	5000
Sub-total				**12340**
Labour (Ksh/ha)				
Land preparation	man days	15	200	3000
Planting	man days	10	200	2000
Fertilization	man days	5	200	1000
Weeding	man days	15	200	3000
Bird watching	man days	30	100	3000
Harvesting	man days	10	200	2000
Threshing, winnowing and packing	man days	10	200	2000
Sub-total				**16000**
Total variable costs (B)				**28340**
Seasonal Gross margin (A-B)				***1660***
Annual Gross margin				***3320***
NPV (at 14% interest rate)				***2921.6***