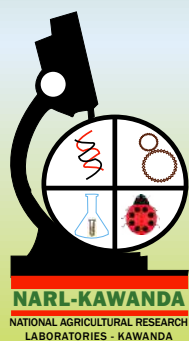




THE REPUBLIC OF UGANDA

The Potential of Bio-fuel in Uganda

An Assesment of Land Resources for Bio-fuel Feedstock Suitability



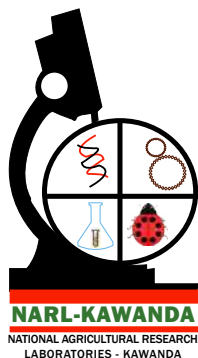


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The Potential of Bio-fuel in Uganda

An Assessment of Land Resources for Bio-fuel Feedstock Suitability

January 2010



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Cover page photographs: Jatropha in Uganda; Maize at Kawanda, Uganda; Cane at Kakira Sugar Works, Jinja Uganda; and a 4-year old palm tree at Bwendero, Kalangala Uganda.

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Foreword

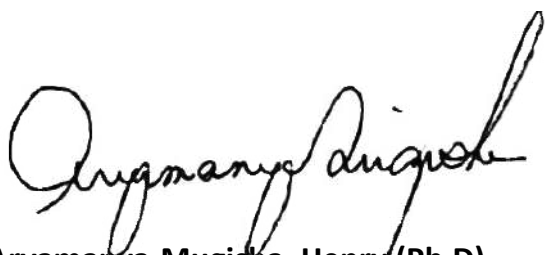
Bio-fuel production is rooting in Uganda amidst problems of malnutrition and looming food insecurity, and environmental degradation. Meanwhile, controversy surrounds the sustainability of bio-fuels as source of bio-fuel in Uganda with proponents and opponents having convincing reasons. There is concern that bio-fuel feedstock production is likely to aggravate food insecurity and environmental degradation. It is also apparent that bio-fuels can provide clean transportation fuel while contributing to rural poverty alleviation.

Given the above circumstances, adequate studies are required to determine the amount of feedstock or energy the agricultural and forestry sector can sustainably provide, the adequacy of land resources of Uganda to produce the quantity of biomass needed to meet demands for food, feed, fiber and also to provide energy.

This study was conducted under the framework of the **National Environment Information Network** with a major objective of assessing the suitability of land resources for bio-fuel production and identifying relevant policy options that seek to integrate bio-fuel feedstock production into the land use planning process.

Focusing on Jatropha, Sugarcane, Oil palm and Maize as bio-fuel feedstocks this report presents the suitability of land resources for bio-fuel feedstock and implications for food availability, rural poverty alleviation and environmental degradation. Areas of research focus and policy review options are highlighted.

I hope that the stakeholders spearheading the sustainable promotion of bio-fuel production in Uganda, those opposed to the introduction of bio-fuels, and policy makers will find this report resourceful during all decision making processes.



Aryamanya-Mugisha, Henry (Ph.D)

EXECUTIVE DIRECTOR

NATIONAL ENVIRONMENT MANAGEMENT AUTHORITY (NEMA)

Summary

Bio-fuel production is rooting in Uganda amidst problems of malnutrition and looming food insecurity (Uganda government, 2002b; Bahiigwa, 1999). Worldwide, there is concern that food should not be used for energy since competition for resources between bio-fuel feedstocks and food crop production is inevitable. Controversy surrounds the sustainability of bio-fuels as source of bio-fuel in Uganda with proponents and opponents having convincing reasons.

Given the above circumstances, adequate studies are required to determine the amount of feedstock or energy the agricultural and forestry sector can sustainably provide, the adequacy of land resources of Uganda to produce the quantity of biomass needed to meet demands for food, feed, and fiber and to provide energy.

This study was conducted under the framework of the **National Environment Information Network** with a major objective of assessing the land resources suitable for production of bio-fuels and identifying relevant policy options that seek to integrate bio-fuel feedstock production into the land use planning process.

Assemblage of spatial data consisting of atmospheric temperature, digital elevation model, mean annual rainfall, soil productivity, gazetted areas and wetlands resulted into land resource suitability maps for the production of various bio-fuel feedstocks. Potential land-use conflict visualization was conducted to determine how much land is available for the production of bio-fuel feedstocks. Integration of commodity prices gives insight on the potential contribution of bio-fuels to household poverty alleviation and overall rural development.

The agro-ecological settings favor the growing of *Jatropha Curcas*, sugarcane and oil palm which are important bio-fuel feedstocks. Most of the arable land area can be grown with *Jatropha Curcas*, followed by sugarcane and then oil palm. Producing feedstocks from varied geographical regions allows a combination of feedstocks to be allocated to respective ecological niches thereby enabling exploitation of environments that uniquely support a given feedstock. This supports the hypothesis that a combination of feedstocks is considered to be more efficient and sustainable.

Bio-fuels can bring many benefits for Uganda by providing access to clean energy services. Sugarcane, given its energy balance advantage, is likely to be beneficial if promoted as bio-fuel feedstock as this is likely to increase sugarcane prices to the benefit of the small scale farmer. High farm gate prices, dual provision of food and ethanol makes maize a promising feedstock after sugarcane. Production of ethanol from maize grain is likely to increase grain prices which in turn will increase maize grain output.

About 2.2% of arable land is available for *Jatropha* production at a marginal level as soils in these areas are poor and not preferred for food crop cultivation. These marginal environments are likely to be associated with low un profitable *Jatropha* seed yields.

The None palatability, low yields and current meager price are likely to limit *Jatropha Curcas* promotion in Uganda where food security is priority over none staple crops. The low yields also make it the greatest competitor for land.

Promotion of bio-fuel industry is likely to increase pressure on the gazetted areas and wetlands with consequent potential loss of bio-diversity. Sixty percent of the arable land area good for crop production is equally good for *Jatropha Curcas* production; 50% is equally good for sugarcane and 30% for Oil palm. *Jatropha Curcas* and food crop cultivation have the highest potential of encroaching on gazetted areas including forests. Oil Palm cultivation has the lowest encroachment potential.

In view of the impressive product prices, large scale commercial estates are likely to benefit commercial plantation investors at the expense of the small scale outgrower farmer as the current farm gate prices offered by the firms are meager and cannot support a farm household of 5.

The potential competition for resources between bio-fuel feedstocks and food crops, and consequent increased food insecurity, calls for the need to develop synergistic inter sectoral policies to guide sustainable development of bio-fuels in Uganda. Lack of appropriate policy support to small-scale bio-fuel development at the local level may slow down the progress of the bio-fuel programs.

In view of increased land demand for investing in bio-fuels, there is need to invest in improved land administration systems to deal with conflicting claims likely to emerge under bio-fuels expansion. Also there is need to ensure that changes and production practices associated with bio-fuel production are sustainable.

Promotion of bio-fuel feedstock will include doing project feasibility studies at regional, district or sub-county levels; scales that require detailed information and data. This requires updating the current reconnaissance soil and related ecological information as part of the strategy to promote bio-fuel establishment in Uganda.

List of Acronyms

AS	Animal Sanctuary
BLP	Below Poverty Line
CFR	Central Forest Reserve
CO ₂	Carbon dioxide
DJMs	Defence Joint Military Pay Systems
EIN	Environment Information Network
FAO	Food And Agricultural Organization
FFB	Fresh Fruit Branches
GHG	Green House Gases
GR	Game Reserve
GTZ	German Technical Cooperation
ha	Hectares
HA	Hunting Area
kg	Kilogram
LFR	Local Forest Reserve
LUT	Look Up Table
m	Meters
masl	Meter Above Sea Level
mm	Mille meters
NEMA	National Environment Management Authority
NARO	National Agricultural Research Organisation
NARL	National Agricultural Research Laboratories, Kawanda
PMA	Plan For Modernization of Agriculture
SCOUL	Sugar Cooperation Of Uganda
sh	Shilling
SRTM	Shuttle Radar Topography Mission
UBOS	Uganda Bureau of Statistics
USA	United States Of America
USCTA	Uganda Sugarcane Technologist's Association
VEDCO	Volunteer Efforts for Development Concerns

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Chapter 1

Introduction

General overview on Bio-fuel in the world

Bio-fuels are defined as combustible fuels produced from biomass and they are generally in the form of alcohols, esters, ethers, and other chemicals. Governments around the world support bio-fuels production because of concerns about climate change and a possible reduction in availability of imported traditional oil. It is believed that bio-fuels can be used as gasoline and in this way it can be a way of contributing towards carbon emissions reduction by some governments. In addition, bio-fuels contribute towards job creation and keeps money within the country. Examples of countries that produce bio-fuels are the United States, France, United Kingdom, Brazil and Spain. Europe's bio-fuels are mostly made from sugar beets, wheat, and barley. Brazil is the largest producer of sugar cane and it is used to make ethanol for powering cars, lorries and buses instead of petrol. Other countries are making fuel from soya bean, sugar beat, corn and palm oil. Below are estimated yields of bio-fuel from various crops.

- Sugar beet in France yields 714 gallons per acre.
- Sugar cane in Brazil yields 662 gallons per acre.
- Corn in the USA yields 354 gallons per acre, or roughly half the beet and cane yields.
- Oil palm plantations yield 508 gallons per acre.
- Coconut oil yields 230 gallons per acre.
- Rapeseed yields 102 gallons per acre.
- Soya beans are grown primarily for their protein content and yield only 56 gallons per acre.

African countries in the forefront of promoting bio-fuels include several South African countries and Sudan. In 2009, Sudan's largest sugar company inaugurated the ethanol plant which aims to produce 65 million litres a year of the bio-fuel. Its first 5 million litres of ethanol were exported to the European Union; at an initial price of around 450 euros a cubic metre (Opheera McDoom, 2009).

Jatropha Curcas is a potential multipurpose bio-fuel feedstock being promoted mostly in developing countries especially Asia and Africa where growing *Jatropha Curcas* is viewed as an opportunity to rehabilitate degraded landscapes while improving on rural livelihoods. India is in advanced stages of promoting *Jatropha Curcas* to meet fuel demands.

Although biofuels are promoted as environmentally friendly sources of energy that address problems of climate change as well as a boon to farmers, skeptics argue

that biofuel production will threaten food supplies for the poor while producing few environmental benefits (Harrington and Hobbs, 2009).

Recent research has shown that more bio-fuels mean more land-use change and more annual emissions of GHGs. For example, if Brazil wants to produce more fuel made from sugarcane it will need to increase the amount of land which is used to grow sugarcane (Green Peace, 2008). The risk is that parts of the Amazon basin will be used to grow sugar cane and this will pose a new threat to plant and animal diversity. However, Xavier (2007) indicates that sugarcane production is not a threat to land availability for food production in Brazil.

By using a worldwide agricultural model to estimate emissions from land-use change, it was found that corn-based ethanol, instead of producing a 20% savings, nearly doubles greenhouse emissions over 30 years and increases greenhouse gases for 167 years. Bio-fuels from switch grass, if grown on USA corn lands, increase emissions by 50%. This result raises concerns about large bio-fuel mandates and highlights the value of using waste products (Timothy Searchinger et al, 2008).

Therefore, the use of biomass for fuel must not compromise the ability of developing countries to secure food for their people, nor should it prevent achieving environmental priorities such as protecting forests and other important ecosystems (EuropaBio Fact Sheet, 2008).

Issues relating to bio-fuel

The issues related to bio-fuel production and use are linked to the agricultural sector because agricultural resources like soils, rainfall, temperature, labour and capital are required in the same measure to support the bio-fuel enterprises. These include: the “food versus fuel” debate, carbon emission levels, sustainable bio-fuel production, deforestation and soil erosion, impact on water resources, human rights issues, poverty reduction potential, ethanol prices, energy balance and efficiency, and centralized versus decentralised production models.

Food security

Food versus fuel is about the risk of diverting farmland or crops for ethanol production to the detriment of the food supply. The debate is internationally controversial, with good-and-valid arguments on all sides of this ongoing debate. There is disagreement about how significant this is what is causing it, what the impact is, and what can or should be done about it. A balance must therefore be sought. Growing crops for biofuel is good for developing countries like Uganda where improving farm income through increased produce prices is a challenge. Food security might be increased through employment and increased incomes for poor farmers generated through biofuel production. Small scale sugarcane production has been linked to decreased farm household food security, and encroachment on forest and wetlands in Uganda (Isabirye, 2005).

Environmental impacts

Deforestation and biodiversity

Large-scale deforestation of mature trees (which help remove CO₂ through photosynthesis— much better than does sugarcane or most other bio-fuel feedstock crops do) contributes to un-sustainable global warming atmospheric green house gas levels, loss of habitat, and a reduction of valuable biodiversity (both on land and in oceans). Demand for Bio-fuel has led to clearing land for oil palm plantations. In Sumatra and Borneo, over 4 million hectares of forest have been converted to palm farms and tens of millions more hectares are scheduled for clearance in Malaysia and Indonesia. Similar trends are observed in Uganda where the needs for self sufficiency in sugar and vegetable oil have fuelled forest conversion to sugarcane and oil palm fields amidst protests by environmental activists (Olupot et al 2007; Gerald, 2010)

Loss of biodiversity

Decrease in biodiversity is a natural fall out of Bio-fuel crop production as is exemplified by experiences with Palm oil and Soy, where large forested areas have been cleared for energy crops. In Uganda, forests have been directly or indirectly encroached on due to the establishment and expansion of agricultural enterprises like Oil palm and sugarcane. This development is greatly protested by environment activists. Critics argue that expansion of farming for bio-fuel production causes unacceptable loss of biodiversity for a much less significant decrease in fossil fuel consumption. Besides, large energy crop farms resort to monoculture cropping, thus replacing valuable biodiversity. Resolutions to these issues are being sought through crop mixing, rotation schemes, and scaling down the magnitude of cultivation.

Energy efficiency and energy balance of Bio-fuel

Production of Bio-fuel from raw materials requires energy (for farming, transport and conversion to final product, as well as the production or application of fertilizers, pesticides, herbicides, and fungicides). This has environmental consequences. The energy balance of a Bio-fuel varies by feedstock and according to the assumptions used. Biodiesel made from sunflowers may produce only 0.46 times the input rate of fuel energy. Biodiesel made from soybeans may produce 3.2 times the input rate of fossil fuels. This compares to 0.805 for gasoline and 0.843 for diesel made from petroleum.

Studies show that it takes more than a gallon of fossil fuel to make one gallon of ethanol — 29% more. This is because it takes enormous amounts of fossil-fuel energy to grow corn (using fertilizer and irrigation), to transport the crops and then to turn that corn into ethanol. However, studies show that Bio-fuel save around 50% of the CO₂ emissions of the equivalent fossil fuels. This can be increased to 80-90% GHG emissions savings if second generation processes or reduced fertilizer growing regimes are used. Further, GHG savings can be achieved by using by-products to provide heat, such as using bagasse to power ethanol production from sugarcane.

Pollution

Aldehydes

Formaldehyde, Acetaldehyde and other Aldehydes are produced when alcohols are oxidized. When only a 10% mixture of ethanol is added to gasoline, (as is common in American E10 gasohol and elsewhere) aldehyde emissions increase by 40%. Some study results are conflicting on this fact however, and lowering the sulfur content of Bio-fuel mixes lowers the acetaldehyde levels. Burning biodiesel also emits aldehydes and other potentially hazardous aromatic compounds which are not regulated in emissions laws. Many aldehydes are toxic to living cells. Formaldehyde irreversibly cross-links protein amino acids, which produces the hard flesh of embalmed bodies. At high concentrations in an enclosed space, formaldehyde can be a significant respiratory irritant causing nose bleeds, respiratory distress, lung disease, and persistent headaches. Acetaldehyde, which is produced in the body by alcohol drinkers and found in the mouths of smokers and those with poor oral hygiene, is carcinogenic and mutagenic. Atmospheric Formaldehyde was 160% higher in Brazil, and Acetaldehyde was 260% higher.

Rural Economic Development

Bioenergy production can provide an increased economic vitality and quality of life for the farmers and communities involved. In the USA farm gate prices for commodity crops as well as feedstocks increased with increased fuel prices (Erbach and Wilhelm, 2009). Low biomass production and crop yields of feedstocks like *Jatropha Curcas*, are reasons why large areas are required for the production of bio-fuels. This means that biomass production and gathering of the biomass feedstock will be distributed and will provide jobs and incomes for rural residents. On-farm and local community preprocessing adds value to the biomass feedstock thereby creating jobs and enhanced rural community vitality.



A local palm farmer at Bwendero, Kalangala District.

Chapter 2

Energy use and Policy in Uganda

Bio-fuel in Uganda

Over 90% of the population in Uganda still relies on biomass as the main source of energy for cooking (NEMA, 2008). This has resulted in the continuous clearing of the country's forests and woodlands. To date, twenty eight districts have lost their forest ecosystem and nineteen have forest cover less than 1% (NEMA, 2008). The loss of these fragile ecosystems not only has serious implications on Uganda's biodiversity, but also compromises the ability of the majority of the poor in the country to cope with the changing environment, especially in the face of climate change.

With the discovery of abundant fossil fuel reserves coupled with promotion of investments and research in bio-fuels, Uganda is on its way to fuel self-reliance. Motivated by the need to cut down on the 70 million litres of fossil fuel consumption per month, there are indications that government proposes to oblige local oil companies to blend fossil oil with bio-ethanol (Bio-fuel international). A blend of up to 20% bio-fuel is proposed in the Uganda renewable energy policy (Uganda Government, 2007). According to Da Silva, the proposed blend is rather ambitious as government would need a bio-fuel industry with a capacity to produce 176 million litres per year. Borrowing a leaf from Brazil, he suggests starting with a lower less strenuous blend of 2% that can be increased over time. Ethiopia began with a blend of 5% ethanol (Sorbara, 2007).

Bio-fuel feedstocks currently grown to improve income and food security in Uganda include maize, sugarcane and oil palm. *Jatropha Curcas* is used as boundary marks, live fence and support for vanilla plant. However, there is growing interest, mostly by the private sector, to promote *Jatropha Curcas* as bio-fuel feedstock for various reasons. According to Guloba et al. (2008), the Madhvani group of companies has finalized plans to start a *Jatropha Curcas* project in Busoga to manufacture insecticides, oil etc. The projected demand for the bio-fuel currently stands at 100 million litres and is expected to grow to 187 million litres in 2012 and 220 million litres in 2022 (Mwanda). Current fossil fuel imports of 70 million litres a month puts bio-fuel requirement at 176 million litres per year with a 20% blend (Da Silva,).

According to Namubiru (2008), Energy Agriculture Uganda in Mukono, VEDCO Uganda in Luweero and Royal Van Zanten are purchasing *Jatropha Curcas* seeds. In 2007 a kilo of dry *Jatropha Curcas* seeds was bought at sh 150 (\$ 0.08). The current price is sh 300 (\$ 0.16) per kilo. Preliminary estimates indicate an annual earning of sh 900,000 (\$468) from an acre of land. This translates to sh 2,223,940 (\$1157) per ha. *Jatropha Curcas* production is being promoted in the districts of Mukono and Moyo.

Currently, small scale factories are producing their own biodiesel from *Jatropha Curcas* to run generators, while the sugar processing firm is blending petroleum with Bio-fuel that it produces from the sugarcane by-products (The East African Dec. 2010).

According to Seppuya (2009) arrangements are in place to establish a plant with a capacity to crash 1000 tons of *Jatropha Curcas* seeds per day producing 60,000 litres of bio diesel oil per day. 2000 acres have been secured in Karamoja region.

The government energy policy advocates for increased research and use of modern renewable energy sources which it expects to increase from the current four per cent to 61 per cent of the total energy consumption by 2017.

Research to support the bio-fuel industry in Uganda is already underway.

The National Forestry Authority (NFA) has been monitoring the agronomic performance of *Jatropha Curcas* experiments since September 2009. (The East African Dec. 2010). In another related development, there are indications that Uganda may be producing bio-ethanol from non-food crops within a year. The National Crop Resources Research Institute is using a wide range of cellulosic feedstock such as elephant grass, cassava and wood to extract ethanol.

Bio-fuel feedstock in Uganda

Oil Palm

Successful growing of oil palm requires suitable growing conditions and the technical know-how. The optimum conditions for growing oil palm are given below:

- An evenly distributed annual rainfall exceeding 1800 mm or at least 150 mm each month.
- Monthly mean minimum temperature above 18°C.
- Monthly mean maximum temperature of 28 to 34°C.
- Sunshine period of 5-7 hours per day or solar radiation of around 350 cal per cm² per day.
- Fertile soils of at least 1 metre in depth with high clay content.

If the above conditions are met, the oil palm can yield above 30 metric tons of fresh fruit bunches (FFB) per hectare per year.

There are two species of Palm oil. The *Elaeis guineensis* originates from West Africa, in Angola and Gambia, while the American Oil Palm *Elaeis guineensis* originates from the tropical Central and South America. The generic name is derived from the Greek for oil, *elaion*, while the species name refers to its country of origin. Mature trees are single-stemmed, and grow to 20 m tall. The leaves are pinnate, and reach between 3-5 m long. The palm fruit is reddish, about the size of a large plum and grows in large bunches. Each fruit contains a single seed (the palm kernel) surrounded by a soft oily pulp.

Oil is extracted from both the pulp of the fruit (palm oil, edible oil) and the kernel (palm kernel oil, used mainly for soap manufacture). For every 100 Kilograms of fruit bunches, typically 22 Kilograms of palm oil and 1.6 Kilograms of palm kernel oil can be extracted. The high oil yield of oil palm trees (as high as 7,250 litres per hectare per year) has made it a common cooking ingredient in South-east Asia and the tropical belt of Africa. Oil palm is the foremost producer of vegetable oil per unit land area, and on a worldwide basis, is second to soybean in oil production. Palm oil is now one of the world's most widely consumed edible oils. In Uganda, oil palm is grown in the districts

of Kalangala and Bundibugyo. It is one of the crops being developed and promoted under the Vegetable Oil Development Programme as an alternative source of vegetable oil. It is anticipated that areas with average annual rainfall of 1400 mm or a minimum of 1200 mm could support oil palm production with estimated fresh fruit bunch yields of 12 to 17 tons/ha/year provided the soils are well drained and can supply adequate levels of organic matter, major plant nutrients such as Nitrogen, phosphorus, potassium, calcium, and magnesium.

These areas are estimated to cover:

- Kalangala district and the land within a radius of 20 km of the Northern shore of Lake Victoria comprising the districts of Mpigi, Mukono, Jinja, and Iganga.
- The districts of Bundibugyo, Masindi, Hoima, Kibale and Kabarole.

How much oil palm is growing in Uganda

In 1910, the Dura variety of palm oil was introduced in Uganda from the Democratic Republic of the Congo. It was planted in the Bwamba area of Bundibugyo district from where it spread to other parts of Uganda. In the mid 1930's a formal introduction was made at the Entebbe Botanical gardens. In 1962 the Tenera Hybrid materials from the Nigerian Institute was planted at Kituza (25 trees), Kabarole and Bundibugyo. The average yields for these introductions at the age of 13 years were 11.8 kg/bunch, 7.9 kg of fresh fruits per bunch, 2.5kg of kernels per bunch. This compared with fresh fruit bunch weights of 8.4, 8.1, and 0.7 kg of kernels per bunch from the hybrids at La Me in Ivory Coast. In 1972 -pre-germinated seeds of 8 tenera improved hybrids from Lamé, Ivory Coast were planted in 4 trial sites: Kituza coffee research station in Mukono, Nakabango in Jinja, Bubukwanga in Bundibugyo and on Bugala Island in Kalangala. In 1990 - more comprehensive yield results from Kituza showed that fresh fruit bunch yields of 14 to 17 metric tons/ha/year at the age of 11 years were obtained without any soil amendments (Wetala and Kibirige – Sebunya, 1990).

The major oil palm plantations amounting to about 6000 ha of the tenera hybrids are now grown in Kalangala district consisting of nucleus plantation and small holders. The dura variety of oil palm grows wild in several areas of Uganda notably in Bundibugyo, at 750-1000 metres above sea level. An estimated 500,000 litres of palm oil are produced each year in Bundibugyo alone with an estimated 5,000 households cultivating 10-50 palms each. Other districts with scattered trees are Mukono, Kabarole and Jinja districts.

Sugarcane

Consumption of sugar in Uganda is estimated to be 9 kg per head per annum with a predicted per capita consumption per annum expected to increase by 1 % over the next 15 years (USCTA, 2001). Sugarcane is an important income earner to households in the neighborhood of the estate commonly referred to as out-growers. Twenty km is the critical distance beyond which cultivation of sugar cane at high input level ceases to be beneficial. Intermediate sugar cane LUT is marginally suitable at 20km and ceases to be beyond 20km. Low input sugarcane cultivation is not economically suitable beyond 25km.

Uganda has three main sugarcane growing companies namely Sugar Corporation of Uganda (SCOUL), Kakira Sugar Works and Kinyara Sugar Works. Sugar is the main product from these industries and today 250,000 tones of sugar are consumed by the

population of 30 million. However, as predictions show that our population might double by 2030, then the country will require about 500,000 tones of sugar for its population. The area for sugarcane growing has also been increasing over the years. For example in Kinyara it can be seen in the Figure 1 below that the area for commercial plantation has increased from 1960 to 1998. It is expected to expand even further as more out grower farmers are taking on the growing of this crop. Sugar Corporation of Uganda (SCOUL) in the central region covers an area of 10,000 hectares and Kakira Sugar works in the eastern region covers an area of 9531 hectares.

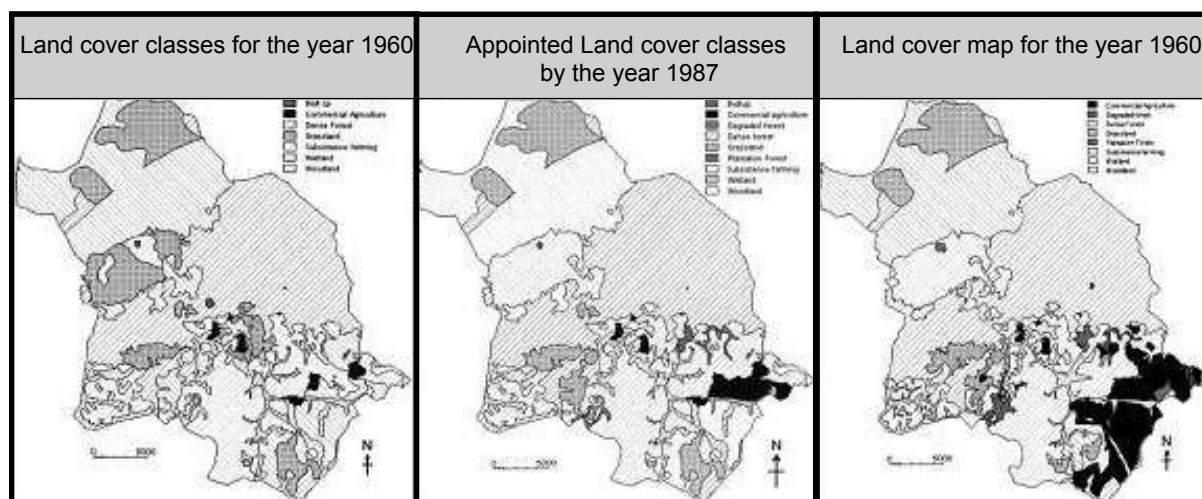


Figure 1: Areas of sugar cane growing in 1960, 1987 and 1998 in Kinyara areas.

SCOUL has a distillery for industrial alcohol and this happens to be the only industry in the country.

Jatropha Curcas

Jatropha Curcas is an excellent bio-fuel crop which has many other advantages namely: medicinal, pesticidal, none palatable to livestock. Ecologically, *Jatropha Curcas* is promoted as an easy to manage hardy perennial crop that can grow in arid conditions (even deserts), poor shallow and stony soils, and does not require irrigation or suffer in droughts. Therefore unlike the common bio-fuel crops of today (corn and sugar), they are very easy to cultivate even on poor land in Africa providing great social and economic benefits for that region (Energy Agriculture Uganda Ltd). However, it is increasingly reported that *Jatropha Curcas*, like other agricultural crops, requires good soils, enough water, fertilizers and agronomic practices to realize economical yields (KnowGenix, 2008). *Jatropha Curcas* is fast growing and begins yielding oil in the second year and for the next forty to fifty years. Optimal yields are obtained from the sixth year when spaced at 2 m intervals. Around 2500 plants can be cultivated per hectare with possibilities of harvesting 6 – 10 metric tons per hectare with up to 12 tons/hectare in dry lands under irrigated conditions (Bulk Agro, India Pvt. Ltd.)

Jatropha Curcas requires rainfall of 600-2000mm per year. Among all the oil bearing crops, *Jatropha Curcas* has emerged as the focal point for the bio-fuel industry with rapid Research and Development investments flowing into its cultivation, processing and conversion into biodiesel. With growing emphasis on the sustainability of the bio-fuels value chain from feedstock to consumer, there have been pressures on regulators and governments to set in place sustainable models for *Jatropha Curcas* cultivation

and use as a bio-fuel feedstock (KnowGenix, 2008).

There are three key issues concerning *Jatropha Curcas*:

- Plant agronomy demands, production complexities and ways to resolve them
- Business models suitable for small land holders
- Environmental and social benefits.

Ensuring sustainability standards for *Jatropha Curcas* projects, particularly in developing economies involve a detailed assessment of economic, ecological and social dimensions at the planning and pre-project stages. Though heralded as the most preferred non food crop, *Jatropha Curcas* is yet to deliver on its promises.

In Uganda *Jatropha Curcas* grows as a wild plant. It is used as live fence and as a stake for vanilla crop. It is common in the North, Eastern and Central regions of Uganda. It is being promoted, mostly by private firms, for the following reasons among others:

A source of clean fuel for transportation and domestic use, greatly reducing on the cost of oil imports while contributing to rural poverty reductions. It is a medicinal plant with anti-cancer properties. It is a hardy crop that can thrive in harsh environments and can be used to control soil erosion in marginal areas and intercropped well with soybean among other crops. Many farmers know how to grow it, as it has been used traditionally as a live hedge and livestock fence/kraal. Its establishment does not require heavy investment in machinery.

Maize

Maize can grow in most parts of Uganda and maize growing is done at all levels with over 90% production is by smallholders, of which about 60% of the annual maize output is consumed on the farm. A negligible part of the production is processed into maize-based foods and beverages. Its production is expanding to places that were not traditionally maize growing partly because of increased consumption due to declining production of cassava and bananas- key staples in the country (Kikafunda-Twine et al., 2001). Low maize grain prices, among others, are key factors limiting maize production in Uganda. As a strategy to boost production and improve on farmer's income, government plans to buy off surpluses and add value to the grain by exporting maize flour (Sunday Vision, February 9, 2010).

As the promotion of bio-fuel use in Uganda picks up, the use of maize as feedstock for ethanol production is likely to be a boon as this will increase maize prices and therefore production.

Elsewhere in Africa, maize is being promoted as feedstock amidst an overall fear that the increased use of maize based ethanol feedstock will cause a price increase; putting maize beyond the reach of Sub-Saharan Africa's poor. In South Africa, the ability to produce surplus stocks of maize is the key determinant of the inclusion of maize as feedstock for ethanol production (Nieuwoudt, 2010).

Bio-fuel Policy in Uganda

Bio-fuel production is rooting in Uganda amidst problems of malnutrition and looming food insecurity (Uganda government, 2002b; Bahiigwa, 1999). In view of the competition for resources between bio-fuel feedstock and food crops, there is need of synergistic inter sectoral polices to guide the sustainable development of bio-fuels in Uganda. Lack of appropriate policy support to small-scale feedstock development at the local level may slow down the progress of the bio-fuel programs.

Although bio-fuels are not mentioned as possible renewable and alternatives to fossil fuel consumption in Uganda, elements emphasizing the use of environmentally friendly alternative sources of energy and technologies are mentioned in the energy policy (Uganda Government, 2002). Specifically, the policy emphasizes the need to integrate the elements of environmental sustainability into all energy initiatives. The policy emphasizes the use of alternative energy sources to save forests. The role of the energy sector in economic development is also emphasized wherein the sector is seen as a potential contributor to the Poverty Eradication Action Plan strategy. At the time of policy formulation, bio-fuels were not foreseen as potential alternative sources of energy. This explains the reason why the policy does not cater for land-use conflict and food availability in view of the likely competition for resources between agriculture and the energy sector.

Promotion of bio-fuel feedstock calls for the need to harmonize policies related to food and nutrition security. The overall objective of the food and nutrition policy is to promote the nutritional status of all the people of Uganda through multi-sectoral and co-ordinated interventions that focus on food security, improved nutrition and increased incomes. Bio-fuel feedstock or expansions of perennial crops like sugarcane are not seen as a threat to food availability. Links to the energy policy are not indicated. However, plans to support the land planning services at the national, district, and farm level to promote optimum land use are indicated. The food policy implementation strategy is multi-dimensional but short of the Ministries of energy and mineral development, and that of the Environment, lands and water development.

Apparently, there is need to assess the suitability of land resources for the production of various bio-fuel feedstocks, potential areas of land use conflict over land resources as a basis for synergistic reviewing of the energy and food policies and identification of areas of research to support bio-fuel production industry. Therefore, this assessment seeks to identify the areas that are best suited for development of the bio-fuels industry, while minimizing potential impacts on the environment and risks to food security.

Objectives of this study

The objective of this study is:

1. To display, identify and provide information on the potential of bio-fuels in Uganda.
2. To provide spatial information on areas suitable for bio-fuels and not including protected areas and other fragile ecosystems.

Chapter 3

Methodology

Background to the methodology

Datasets used in the analysis include minimum and maximum temperatures, mean annual rainfall, digital elevation model, gazetted areas, wetlands, soil productivity and administrative layers.

Uganda's climate can be related to its equatorial situation, elevation, the major air currents and the occurrence of large masses of water within a continental land mass. Mean annual temperatures can be correlated with altitude (Langdale-Brown et al. 1964).

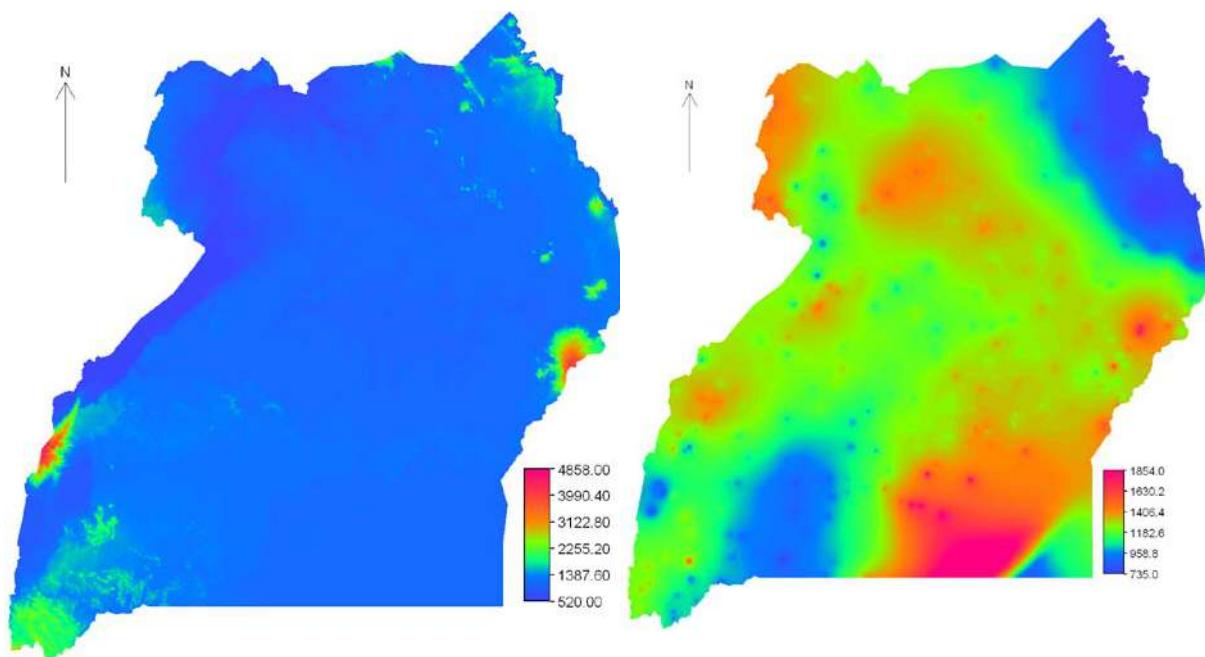


Figure 2: i) Digital elevation model (m.a.s.l) and ii) Mean annual rainfall

Source: Global Land Cover Facility, 2009 Shuttle Radar Topographic Mission, (<http://glcf.umiacs.umd.edu/data/srtm/index.shtml>) August 2009

The pattern of rainfall over the whole country relates to differences in altitude in relation to the air currents and the location of the great lakes. The South-east monsoons, bearing moisture from the Indian Ocean, are responsible for the main seasonal rainfalls while dry conditions occur when the north-east winds prevail. A comparison of the map of mean annual rainfall in Uganda with a contour map shows how altitude and exposure to the moisture-bearing winds affects the annual rainfall.

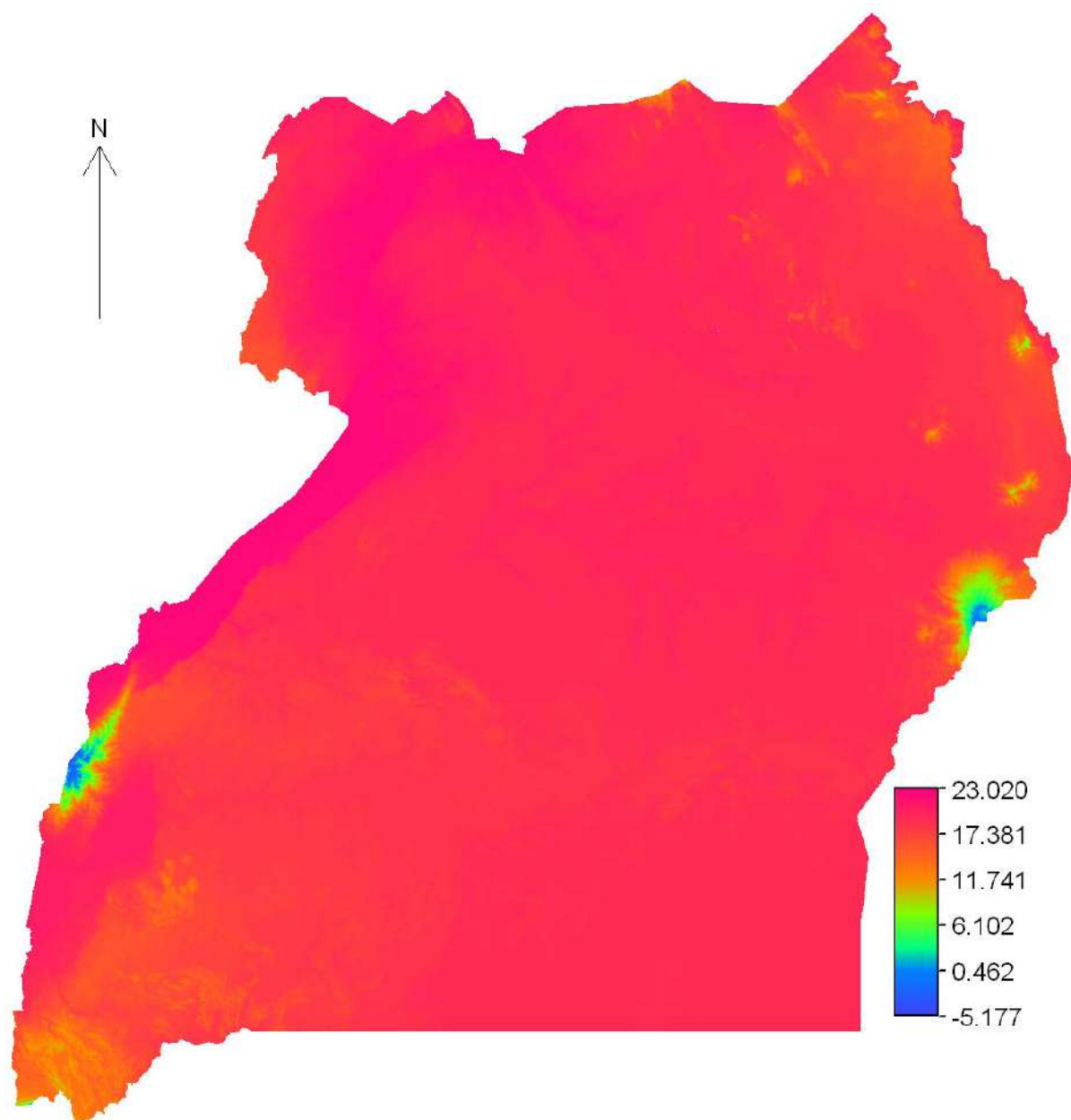
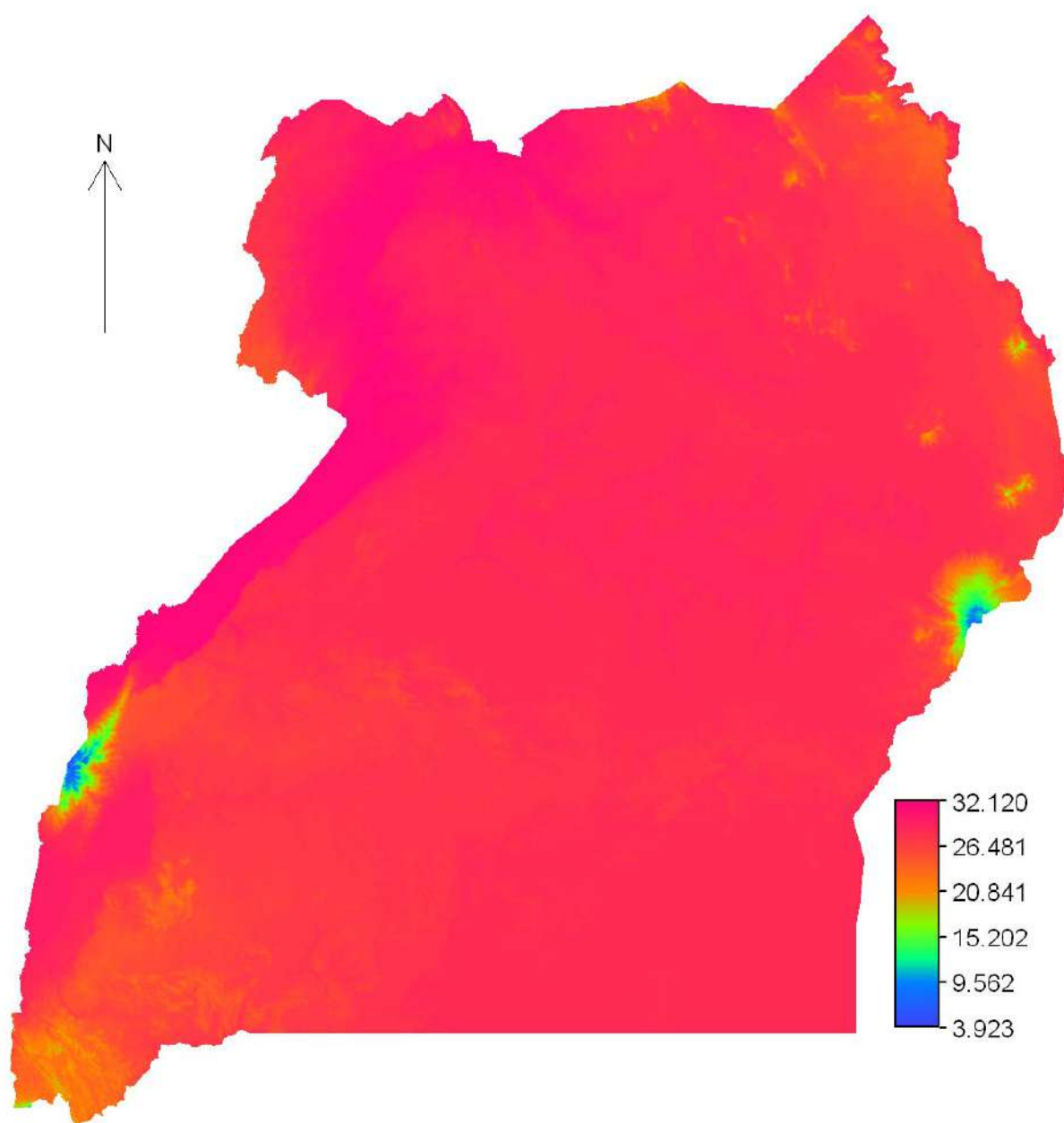


Figure 3: i) Minimum (above-left) and ii) Maximum (right) Temperatures

Source: Meteorological Department, 1961 Climate data, Meteorological Department, Entebbe Uganda

The main vegetation zones are more easily related to climate than to soil. However, there is a considerable range of vegetation within each of the main zones, and it can be observed that an appreciable percentage of the vegetation is azonal. This is a measure of the effects of topographic and soils factors.

Climate is the more important factor on the broad geographical scale and this has its applications in regional agricultural planning; but when one considers the growth of plants, the development of communities or individual farm planning it is necessary to assess the environment as a whole, paying due regard to the soils.



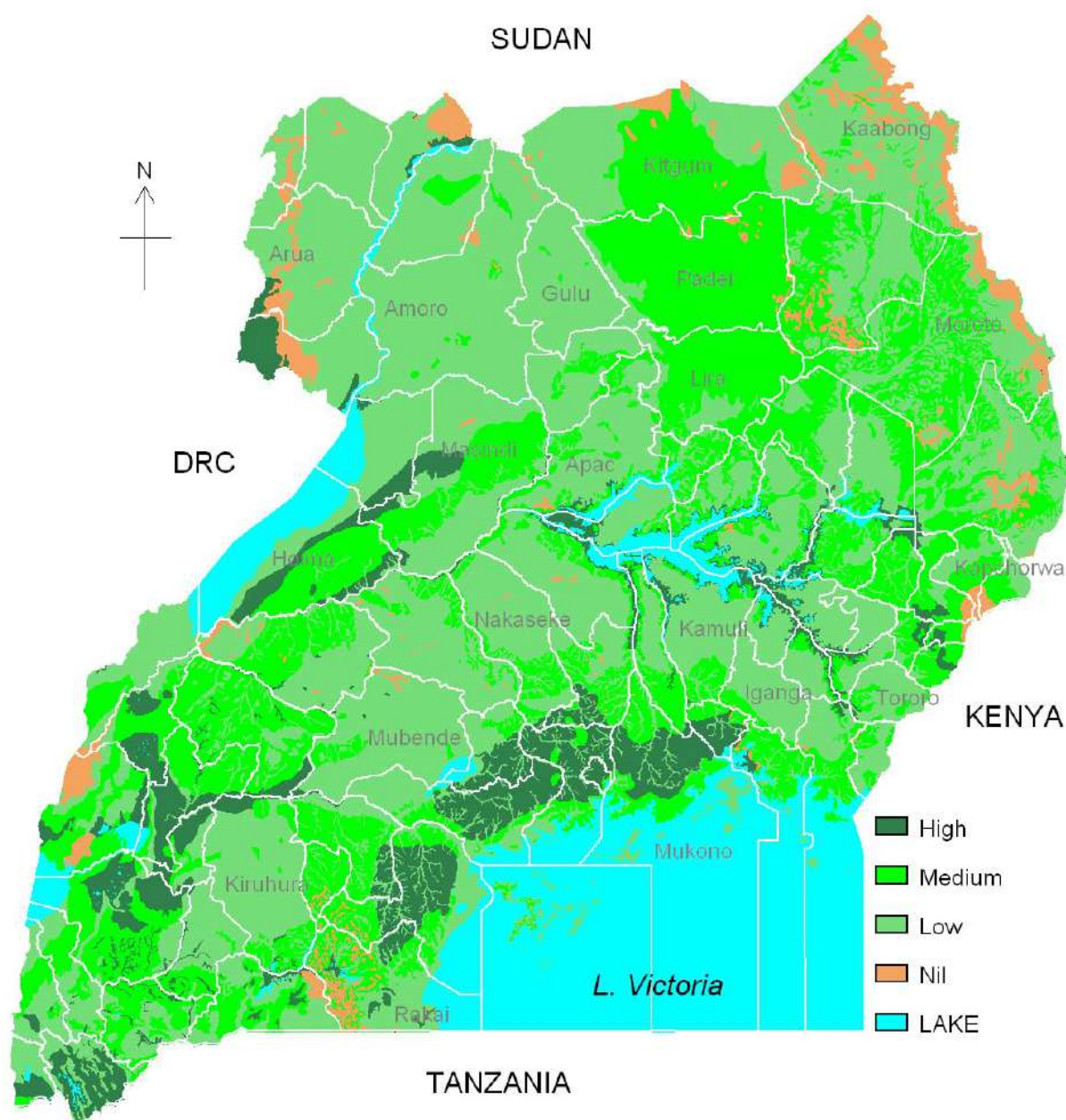


Figure 4: Soil productivity ratings

Source: Chenery, 1960. Introduction to the soils of the Uganda Protectorate, Memoirs of the Research Division, Series1 - Soils, Number 1, Department of Agriculture, Kawanda Research Station, Uganda.

Therefore the agricultural productivity rating/grading (Chenery, 1960) is used to assess crop suitability in addition to temperature and rainfall. Agricultural productivity rating refers to the ability of the soils to produce the crops without amendments such as manures, fertilizers or irrigation and drainage but with the use of techniques of good husbandry.

The productivity ratings reflect the overall quality of soils for agricultural production as indicated.

The productivity ratings of High, Medium, Low and Nil correspond to highly suitable, suitable, marginal and not suitable respectively have been used in the suitability assessment. They cover 9, 55, 32, and 4 percent of the arable land in Uganda respectively. The arable land area is 20,595,034 ha.

Guiding principles and assumptions

Food security, the need to protect important ecosystems like Wetlands, Forests and game reserves has guided the analysis in this study. Maize is used as proxy for food since it is increasingly becoming a staple that is grown widely in Uganda. Therefore analyses involving maize are good indications of the impact of bio-fuels on resource availability and eventual effect on food availability.

Food availability is given priority not only to government but to the farmers as well. This understanding has also guided data analysis in this study.

Derivation of climate parameters

The SRTM DEM (Fig. 1i) with a resolution of 90 meters was used to derive the minimum and maximum temperature. The mean annual rainfall derived from rainfall point data (Meteorology Department, 1961) was used to assess crop production limitations due to atmospheric temperatures.

Classification of the rainfall map using the rainfall boundaries in Table 1 resulted in a partial rainfall suitability map.

Table 1: Rainfall requirement and degree of limitation of bio-fuel feed stock

Crop		Highly Suitable	Suitable	Marginal	Not Suitable
	Limitation	85	60	40	25
<i>Jatropha Curcas</i>		> 1380	1380 - 800	800 - 600	< 300
Maize		> 1000	1000 – 800	800 – 600	< 600
Oil Palm		> 2000	1700 – 1450	1450 – 1250	< 1250
Sugarcane		> 2510	2510 – 2160	2160 – 1800	< 1080
Limitation = expected yield as percentage of optimum yields; Sys et. al. (1993)					

Elevation also has an important effect on rainfall. However, while rainfall increases with altitude over limited areas, the pattern of rainfall over the whole country is related to differences in altitude in relation to the air currents and the location of the great lakes.

Minimum and Maximum temperature determination

Data on maximum and minimum temperatures that covers the whole country is limited. Temperatures were therefore derived using the relationship between altitude and temperatures as elaborated below.

The minimum and maximum temperatures were derived from the digital elevation model (Fig. 1i) using the following temperature equation (Kansas Flyer 2005):

$$T = T_1 + a(h - h_1)$$

Where:

T = temperature we want to find

T¹ = starting temperature of the atmospheric region or layer

- a = the rate of temperature change in the given region
h = altitude (height)
 h_1 = base height of the atmospheric region or layer

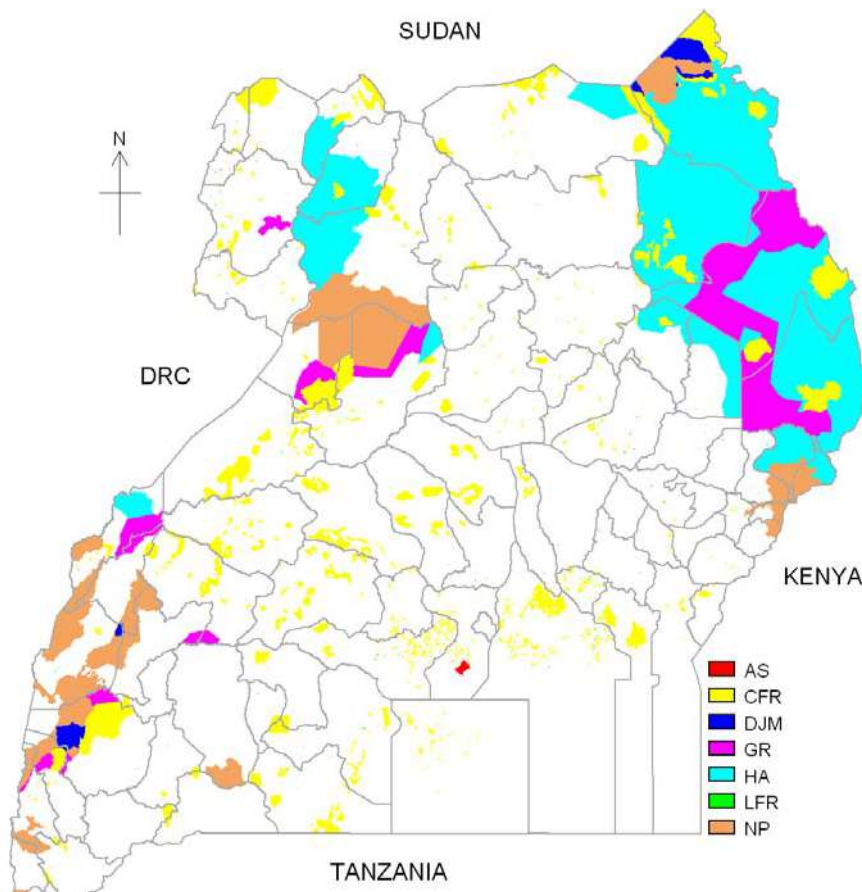
Results were validated using the temperature data in the Atlas of Uganda.

Table 2 shows that unlike the maximum temperatures, minimum temperatures are within the range that affects crop growth in Uganda. Minimum temperatures were therefore used in the suitability study.

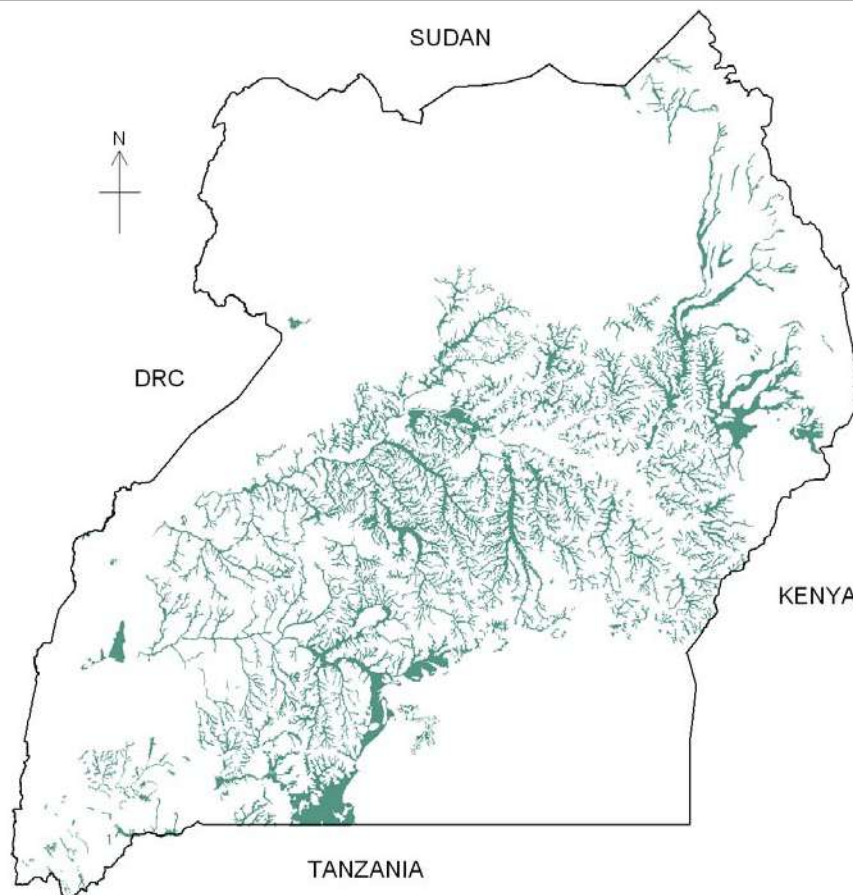
Classification of the temperature map using the boundaries in Table 2 resulted in partial temperature suitability maps.

Table 2: Temperature requirements and degree of limitation of bio-fuel feedstocks

Crop		Highly Suitable	Suitable	Marginal	Not Suitable
	Limitation	85	60	40	25
<i>Jatropha Curcas</i>	Min	20	28	35	>35
					< 2
Maize	Max	26	32	35	> 40
	Min	22	18	16	< 14
Oil Palm	Max	29	27	24	< 22
	Min	20	18	16	< 14
Sugarcane	Max	30	32	34	> 35
	Min	26	24	20	< 16
Limitation = expected yield as percentage of optimum yields; Sys et. al. (1993)					



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Figure 5: i) Gazetted areas (Forest and Wildlife) and ii) Wetlands

Source: Gazetted areas: Department of Lands and Surveys, 1962 Atlas of Uganda, Entebbe, Uganda
Wetlands: Chenery, 1960

Gazetted areas, covering about 5,340,981 ha, are protected areas covering the forest and wildlife sectors. They indicate areas with high bio-diversity that can lead to bio-diversity loss once interfered with. Animal sanctuaries (AS), hunting areas (HA), Game reserves (GR), and National parks are linked to the wildlife areas. Forested areas include Central forest reserves (CFR), LFR and DJMs. Gazetted areas are extensive in Karamoja, southwest and Northwest Uganda.

Wetlands, covering about 2,493,945 ha, are natural resources with high environmental benefits in Uganda. They are best left intact and that is the reason they have not been considered in the analysis on bio-fuels.

Data analysis

The overall suitability assessment involved the use of the partial suitability maps of temperature, rainfall and soil productivity ratings. An overlay of the three maps gave suitability ratings for each of the bio-fuel feedstock. Subtraction of gazetted areas, wetlands and water bodies produced final suitability maps and tables presented in the results. Steep areas have not been excluded since they are associated with highlands which are densely populated areas. It is hoped that soil conservation practices will be practiced where such areas are considered for production of bio-fuel feedstock. Urban areas, though expanding, are negligible and have been considered in the calculations.

The suitability of the land resource quality for the specific bio-fuel feedstock was based on sets of values which indicate how well each feedstock requirement is satisfied by each land quality say: mean annual rainfall, minimum and maximum temperatures and soil productivity. The four suitability classes (rating), assessed in terms of reduced yields, and were defined according to FAO (1983). See Table 1 and 2. Indicative economic assessments included the use of gross sales for the raw material (farm gate) and the bio-fuel e.g. ethanol or biodiesel.

Potential land-use conflict visualization also gives an indication of land available for the production of bio-fuel feedstocks. Conflict visualization for food versus feedstock was done by an overlay of maize suitability maps with each of the feedstocks. Land-use conflict with gazetted areas was assessed by overlaying gazetted area maps with suitability maps of each of the feed stock.

Chapter 4

Results

1. Suitability of bio-fuel feedstocks

Oil Palm and Sugarcane suitability

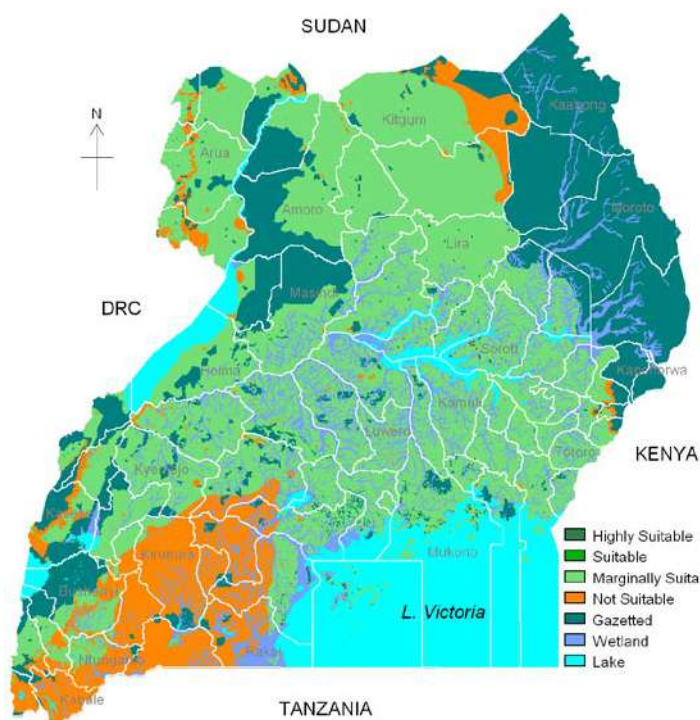
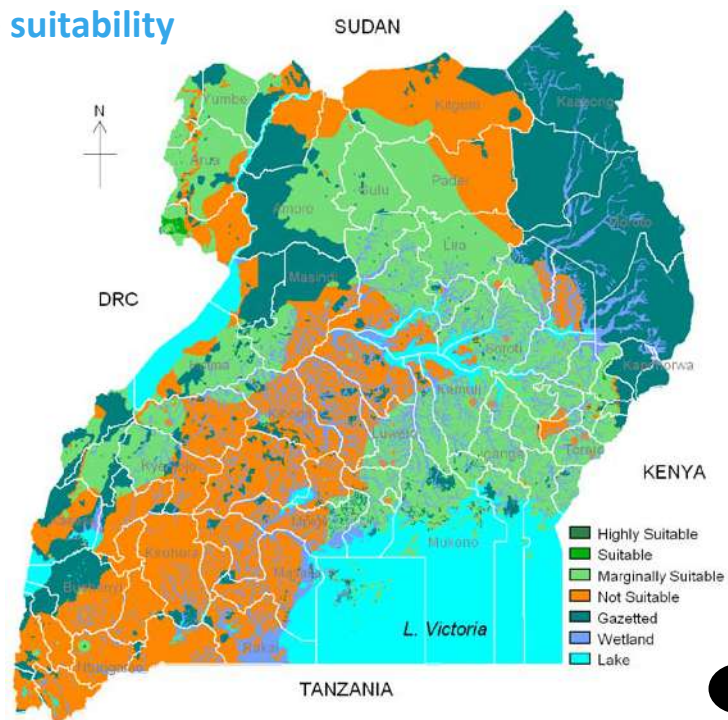


Figure 6: i) Oil Palm and ii) Sugar cane suitability ratings

The suitability of oil palm and sugarcane with related production estimates are shown in Table 3.

Atmospheric temperatures, especially the minimum temperatures and rainfall are important ecological factors controlling the extent of Oil palm cultivation in Uganda. Oil palm grows marginally in 29.4% of the arable areas with 32.5% of the areas considered unsuitable. Only 0.2% of the arable area is suitable with yield expectations of 60% of the optimum yields.

Table 3 Oil palm and sugarcane suitability and related yield estimates

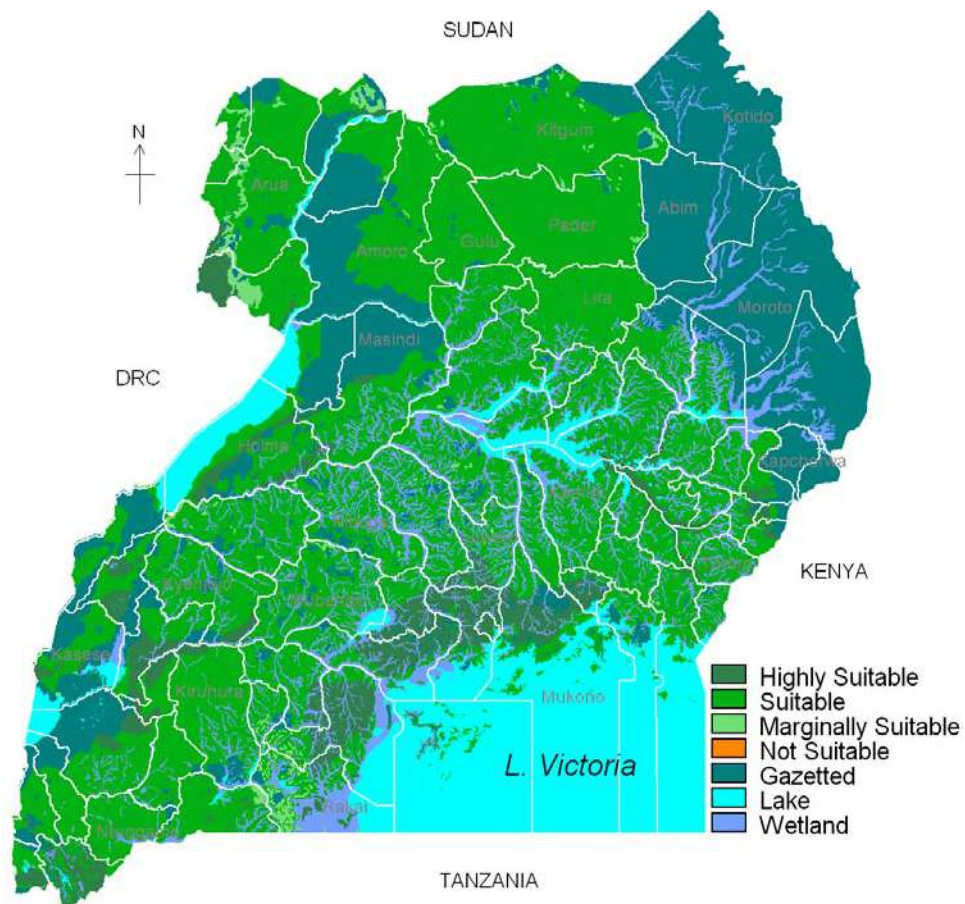
Suitability	Oil Palm Area Ha	Production (ton)	Sugarcane Area Ha	Production (ton)
Suitable	36299	6534		
Marginally Suitable	6045022	725403	10212757	908935330
Not Suitable	6690133	501760	2558698	60769069
Optimum yields: oil palm = 30 ton/ha (Wetala per comm.);sugarcane = 89 ton/ha (Isabirye, 2005) Suitable = 60%, Marginally suitable = 40%, not suitable = 25% of optimum yield Current sugarcane production = 2,350,000 tones from 35,000 ha (FAO Statistics Division 2010)				

Rainfall amount is the main ecological factor controlling the extent of sugarcane production in Uganda. However, the average optimum yields (89 ton/ha) realized without fertilizer application are comparable to those in Brazil (85 ton/ha) where sugarcane is heavily commercialized (Xavier 2007). Because of the limited rainfall (Table 1), sugarcane thrives marginally in Uganda, covering 49.6% of the arable land area. 12.4% of the area is not suitable for sugarcane production.

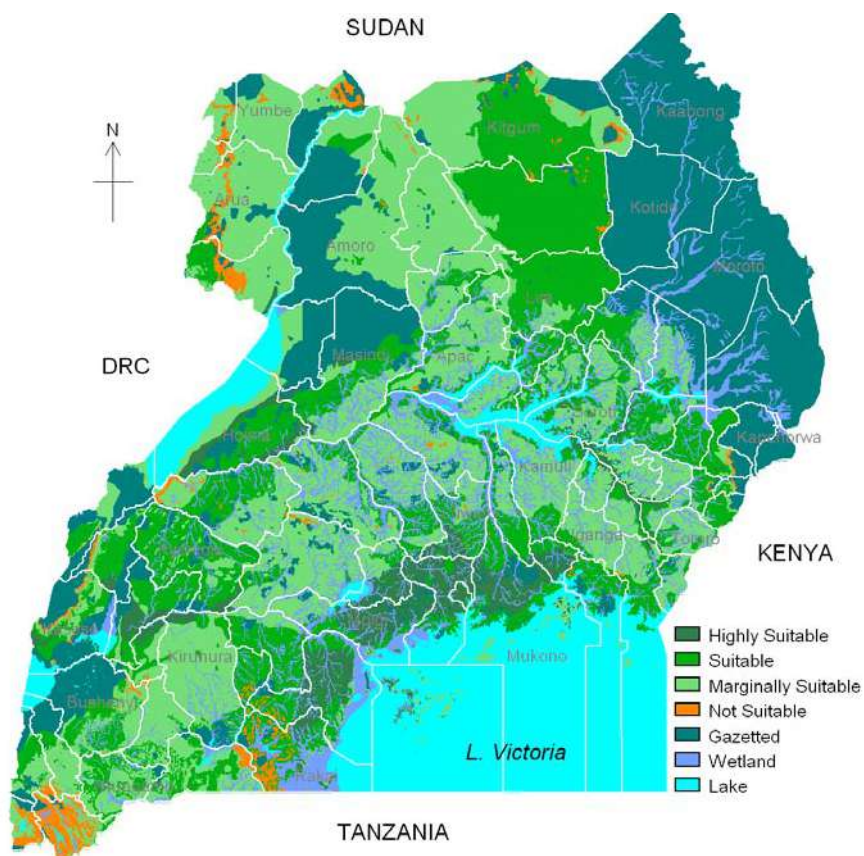


Oil palm produce in Kalangala District.

Jatropha Curcas and maize suitability



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ii

Figure 7: i) *Jatropha Curcas* and ii) Maize suitability ratings

The suitability of *Jatropha Curcas* and maize are shown in Table 4.

The ecological setting is suitable for *Jatropha Curcas* cultivation, covering 54% of the arable land area with estimated 60% of the optimum yields. Highly suitable areas cover 6.8% of the arable land area while only 1.3% is considered marginal. Areas classified as unsuitable are negligible.

Table 4: *Jatropha Curcas* and Maize suitability and related yield estimates

Suitability	Jatropha Curcas		Maize	
	Area Ha	Production (ton)	Area Ha	Production (ton)
Highly Suitable	1390675	9456592	979518	9991086
Suitable	11104946	53303742	4884408	35167738
Marginally Suitable	275713	882282	6456839	30992828
Not Suitable	119	237	450689	1352067
Optimum yields: Jatropha = 8 ton (Parsons, 2005); Maize = 6 ton / ha (Isabirye, 2005)				
Suitable = 60%, Marginally suitable = 40%, not suitable = 25% of optimum yield				
Current maize production = 1,266,000 tones from 862,000 ha (FAO Statistics Division 2010)				

Maize is widely grown in Uganda. It performs marginally in 31.4% of the arable land area while 23.7% of the arable land area is suitable with an expected yield of 60% of the optimum yield. Highly suitable areas cover 4.8% while the 2.2% is considered unsuitable.



A maize garden at Kawanda, Uganda.

2. Potential Land-use Conflict visualization and land availability for Bio-fuels

Sugarcane versus food crop and gazetted areas

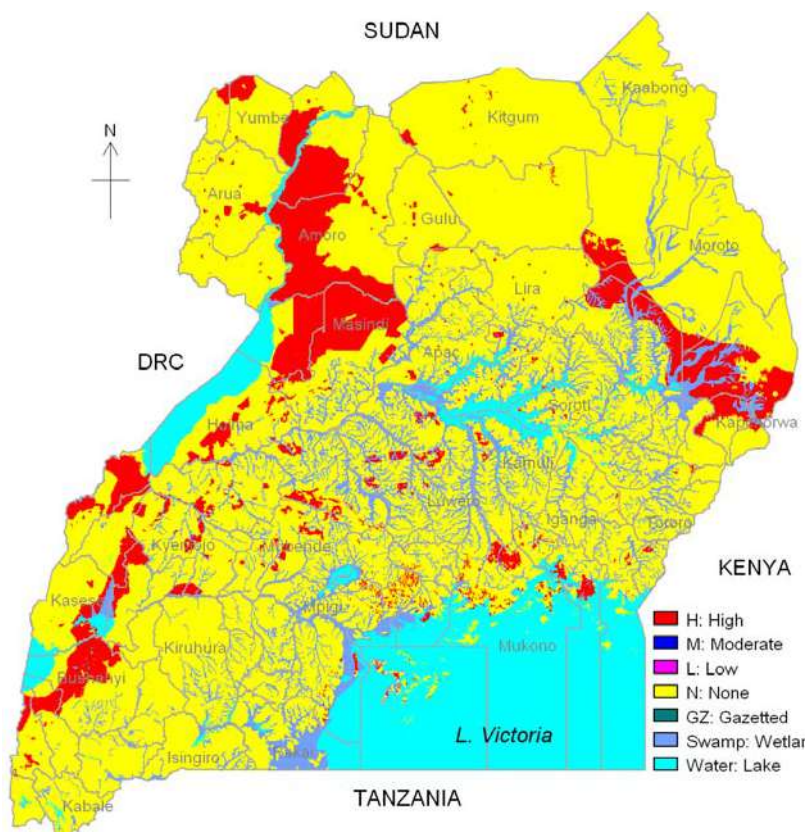
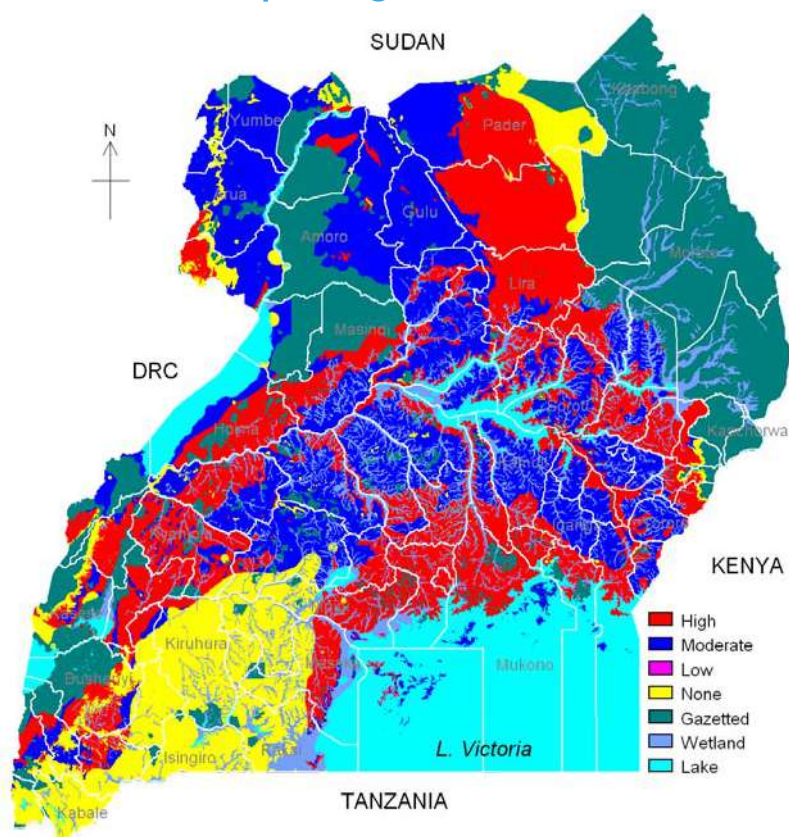


Figure 8: Areas of potential land-use conflict between sugarcane and; i) Maize, ii) Gazetted areas

Potential land-use conflict is high between sugarcane and maize (food crops) as both have similar ecological requirements (Figure 7).

In Figure 7, 49.6% of arable land can be grown with both sugarcane and food crops. Figure 7 ii), shows 14% of the land where sugarcane has potential conflict with gazetted areas of which 4.3% has potential conflict with forest reserves.

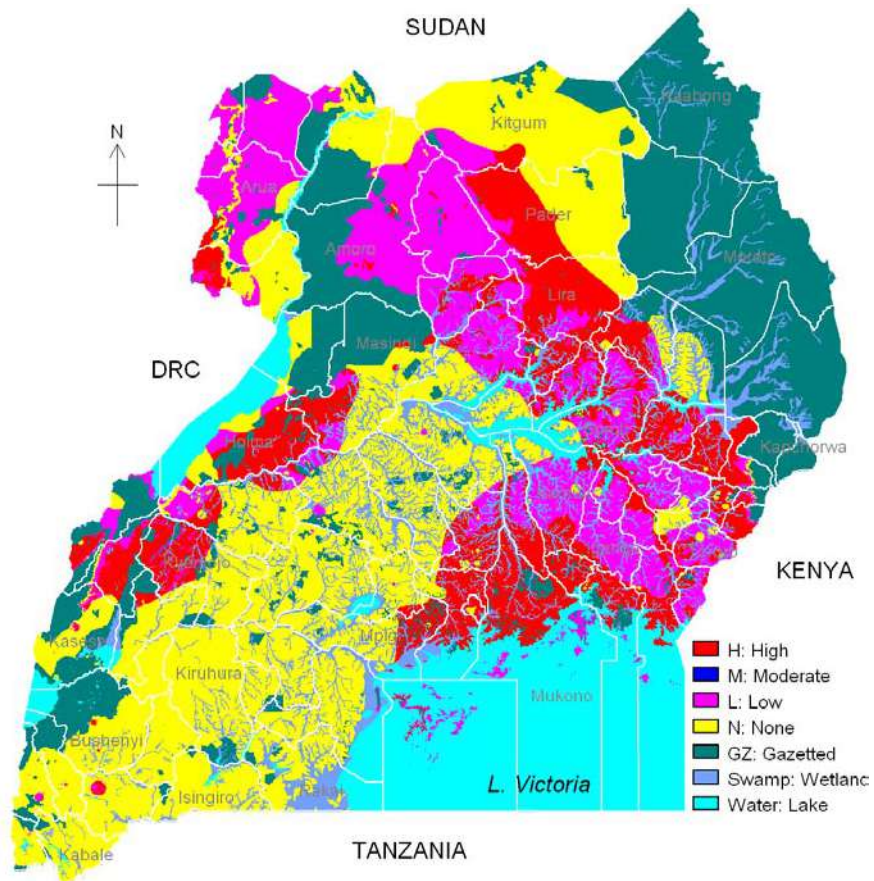
Table 5: Available land for sugarcane cultivation and related potential production and sales estimates

	Production Bio-ethanol			Sales Bio-ethanol	
	Area Ha	Farm (Ton)	(Litres)	Farm	(Litres)
Marginally Suitable	10212757	908935373	75,441,635,959	19087642833	226324907877
Bio-ethanol = 83 litres/ton of sugarcane (Xavier, 2007); Sugarcane = \$21/ton; Bio-ethanol = \$ 3 /liter (the Africa report.com) Current sugarcane production = 2,350,000 tones from 35,000 ha (FAO Statistics Division 2010)					

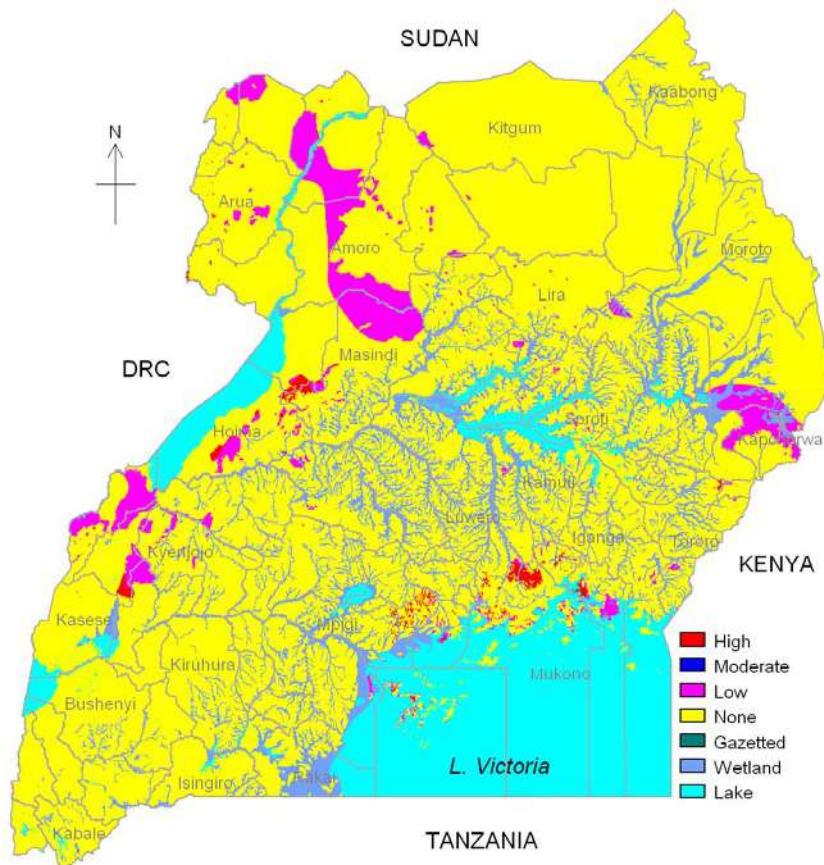


A section of the sugar plantation for Sugar Corporation of Uganda, Lugazi.

Oil Palm versus food crop and gazetted areas



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Figure 9: Areas of potential land-use conflict between Oil palm and; i) Maize, ii) Gazetted areas

The areas that are not suitable for food crop production are also not suitable for oil palm production. 32.5% of arable land is not suitable for oil palm; 2.2% is not suitable for both maize and oil palm; 29.5% of arable land that can be grown to oil palm is highly competitive since the same extent is also suitable for food crop productivity. Forested areas are highly competitive for oil palm production as the ecological requirements are similar for both forests and oil palm.

Table 6: Available land for oil palm cultivation and related potential production and sales estimates

Suitability	Production			Sales	
	Area ha	Farm (ton)	Processed	Farm	Processed
Suitable	36299	272243	54448500	43558800	87117600
Marginally Suitable	6045022	45337665	9067533000	7254026400	14508052800
Not Suitable	6690133	50175998	10035199500	8028159600	16056319200
Totals	12771454	95785905	19157181000	15325744800	30651489600

Crude oil = 20% of yield; oil palm fruit = \$160/ton; Crude oil = \$ 1.6/litre;
 Suitable = 60%, Marginally suitable = 40%, not suitable = 25% of optimum yield

The area of 6.4% is of potential conflict between food crops and gazetted areas; of which 2.1% is in conflict with forest areas.



A palm tree at Bwendero, Kalangala District.

Jatropha Curcas versus food crop and gazetted areas

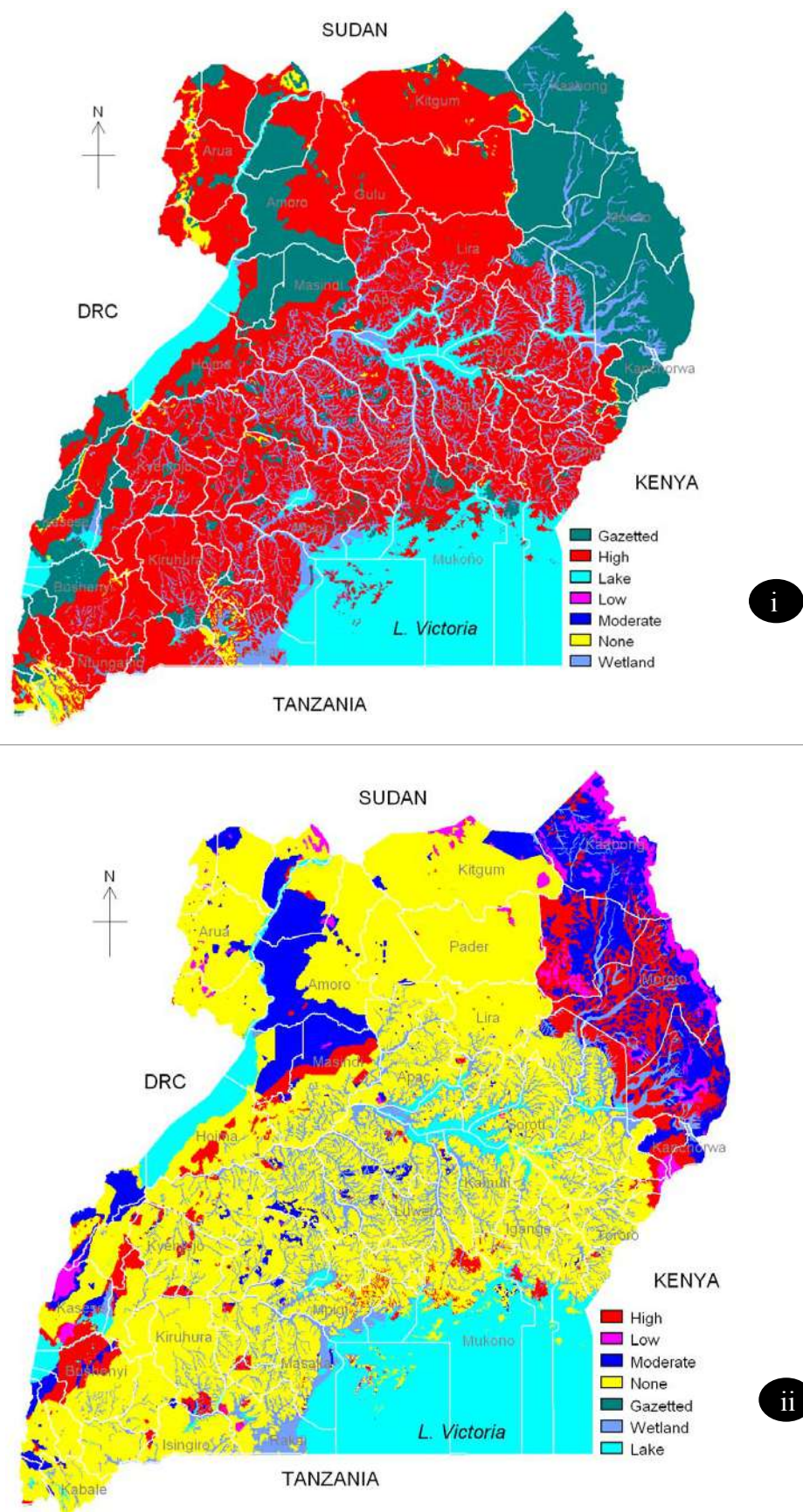


Figure 10: Areas of potential land-use conflict between *Jatropha Curcas* and; i) Maize, ii) Gazetted areas

Areas of highly suitable, suitable and marginally suitable for maize production are considered to have a high crop production potential and therefore not suitable for *Jatropha Curcas* from the food security point of view. It is only areas that are not suitable for Maize that can be considered for *Jatropha Curcas* production. The total area under this category is 450688 ha covering 2.2 % of the arable land area. The corresponding total *Jatropha Curcas* production and sales at Farm gate and processed prices are indicated below.

Table 7: Available land for *Jatropha Curcas* cultivation and related potential production and sales estimates

Suitability rating	Production			Sales	
	Ha	Seed (Ton)	Crude oil	Seeds	Crude Oil
Highly Suitable	75,261	511774.8	102354960	81883968	204,709,920
Suitable	103,318	495926.4	99185280	79348224	198,370,560
Marginally Suitable	272,109	870748.8	174149760	139319808	348,299,520
Not Suitable	0.9	1.8	360	288	720
Total	450,689	1,878,452	375,690,360	300,552,288	751,380,720
Crude oil = 25% of yield; Jatropha seed = \$160/ton; Crude oil = \$ 2 / liter; Suitable = 60%, Marginally suitable = 40%, not suitable = 25% of optimum yield					

Areas of no conflict with gazetted areas are shown in Figure 9 ii.

Figure 9 ii) shows 29.5% potential area of conflict between *Jatropha* and gazetted areas of which 6.6% is forest reserves. Areas of nil Agricultural productivity (274,562 ha) are also marginal for *Jatropha Curcas* even if the rainfall and temperatures are suitable for *Jatropha*. The soils are shallow and stony; these cover 1.1%; *Jatropha Curcas* yield estimates are expected to be 25% of the optimal yield (8 tons) which is equivalent to 551,426 ton of *Jatropha*; equivalent to a total annual sales of \$ 1,041,092,288 (\$ 1 billion) see article on *Jatropha in Africa* (Parsons, 2005).



Jatropha Curca in Uganda.

Source: www.pr.wurnl.



Jatropha Curca fruit.

Chapter 5

Discussions

Results are discussed according to the bio-fuel feedstock, paying special attention to implication on food availability, land availability, and the potential to contribute to household poverty alleviation.

It is important to note that bio-fuel production requires a complex interplay of socio-economic and agro-ecological factors that are unique for each region or country. This makes it rather challenging to transfer or share experiences on bio-fuel production across borders. However, since Uganda is new in the bio-fuel industry, experiences from other countries will serve the purpose of enriching the discussion. This is especially true for *Jatropha Curcas*, which is likely to be grown at plantation scales compared to the current use as a live fence, boundary mark or support for vanilla.

Physical productivity comparison

Table 8: Feedstock productivity, sales and potential land-use conflict comparison of various feedstocks

Feedstock	Production/year*		Gross sales \$			Conflict		
	Feedstock ton	Billion litres	Sales Oil/per Farm ethanol capita* /ha/year			Food Gazetted Forest %		
<i>Jatropha Curcas</i>	63.6 m	12.7	797	1993	0.8	60.0	29.5	6.6
Sugarcane	908.9 m	75.4	1869	22161	1.6	50.0	14.0	4.3
Oil Palm	73.2 m	14.6	1926	3852	1.0	30.0	6.4	2.1
Maize	76.2 m	27.2	3276	6620	1.7	-	27.8	6.3
<i>Jatropha Curcas</i> seed and Oil Palm = \$160/ton ; Sugarcane = \$21/ton; Maize = \$ 265/ton; Projected population of 33 m in 2009 is used; Estimations for 'Not Suitable' categories are not included								

Sugarcane bio-fuel productivity is more than twice that of maize and about five times that of oil palm and *Jatropha Curcas*. *Jatropha Curcas* has the lowest bio-fuel productivity per hectare. At the farm level, maize has the highest farm gate gross sales with a potential to contribute to house hold farm income compared to *Jatropha Curcas*, sugarcane and oil palm as depicted by gross sales per hectare in Table 8, *Jatropha Curcas* contributes the least. Processed products have higher gross sales compared to the raw materials.

Jatropha Curcas

Sixty percent of the arable land area good for crop production is equally good for *Jatropha Curcas* production; 50% is equally good for sugarcane and 30% for Oil palm. *Jatropha Curcas* and food crop cultivation has the highest potential of encroaching on gazetted areas including forests. Oil Palm cultivation has the lowest encroachment potential.

The Low *Jatropha* seed yield is a disadvantage in that more land will be required to supply the same unit of energy obtained from sugarcane, maize and oil palm. High yielding bio-fuels are preferable as they are less likely to compete over land (Pesckett et al., 2007).

Jatropha Curcas, given its various advantages, is being promoted as a promising bio-fuel feedstock partly because it is already being used as live fence, vanilla stake and boundary marks in Uganda.

Results here indicate that *Jatropha Curcas* can thrive in the Ugandan agro-ecological setting with about 60% of the arable land area suited to its cultivation. This makes *Jatropha Curcas* a potentially aggressive competitor of arable land meant for crop cultivation. Increasing pressure from commerce to optimise yield per hectare have also tended to force food production off the best land to make way for *Jatropha*. Land for *Jatropha* cultivation needs to be evaluated against food or other productive uses of land (Xavier, 2008). It is observed in Mozambique that *Jatropha* is likely to compete for labor as it matures during labor peak periods (Lerner and Schubert, 2009). This potential aggressiveness is also observed in relation to competition with gazetted areas including forests.

Jatropha Curcas gross sales per person per day is less than one dollar; an indication that the cultivation of *Jatropha Curcas* is less likely to contribute to alleviation of household poverty. However, reports from else where show that *Jatropha Curcas* can be profitable. In Mukono, an area of high agricultural productivity, earnings of up to \$1157 per hectare have been reported (Namubiru, 2008). The assessment of *Jatropha* economics in Mozambique shows that *Jatropha* compares favorably with day labourers' earnings (Lerner and Schubert, 2009). Comparisons to indicators of household expenditure are not mentioned.

Current *Jatropha Curcas* seed sales estimates are based on the price firms are paying to farmers that result into gross sales of less than a dollar per capita; a value below the poverty line. The sales per hectare are just above \$ 755- the amount required to support a household of 5 with maize flour to provide the energy requirements per year in Uganda (Isabirye, 2005). *Jatropha Curcas* may be more beneficial for farm households where its products can be used for lighting, running engines, soap making and medicine. Similar directions are echoed by Xavier (2008), who advocates for small scale *Jatropha* production as the best way of improving rural livelihoods.

In Uganda, farmers give priority to food crops that double as cash crops. Non-food crops can be grown only if the earnings can significantly outweigh those of traditional crops in meeting household income. Therefore, unlike sugarcane and oil palm, more effort may be required to involve farmers in *Jatropha* projects.

Apparently, *Jatropha Curcas* is likely to be beneficial to large plantation firms that can process *Jatropha Curcas* into various products. This, however, is likely to be detrimental as it does fuel encroachment on gazetted areas and pose a threat to availability of food in households.

It should therefore be introduced into the farming systems in a way that cannot significantly change the existing farming system. *Jatropha Curcas* is already being used as live fence, stakes for vanilla and boundary marks. This makes *Jatropha Curcas* a side income earner in addition to the main farm enterprises. This is observed by Nyapendi (2008) who indicates that a farmer can earn up to \$250 (sh427, 500) annually from 1 km hedge of *Jatropha Curcas*.

Sugarcane

The sugarcane industry has made Brazil the world's largest producer and consumer of sugarcane ethanol as a transportation fuel (Xavier, 2007). In Uganda, sugarcane has impressive yields even when it is thriving in a marginal environment. However, Table 5 shows that the current production is far below the potential production indicated by FAOStat (2010). It is also evident that there is possibility of increasing production through expansion of land area under sugarcane. As a biofuel feedstock, it has a high favorable energetic balance with impressive gross sales that are likely to improve farm income through associated increase in sugarcane farm gate prices. Therefore, promoting sugarcane as a feedstock for ethanol is likely to improve rural livelihood and also minimize on forest encroachment since energy output per unit land area is very high for sugarcane compared to *Jatropha Curcas* and oil palm.

In Brazil for example the production of sugar cane for ethanol only uses 1% of the available land and the recent increase in sugar cane production for bio-fuels is not large enough to explain the displacement of small farmers or soy production into deforested zones (Xavier, 2007).

However, when grown for sugar, sugarcane has a high potential to compete for land and being a threat to both food availability and encroachment on gazetted areas including forests. This threat is already felt with the current need to meet national sugar demands through expansion of land under sugarcane. The per capita gross sales are impressive but not for a small scale farmer. Studies done in Mayuge and Rakai districts show that sugarcane is profitable when grown on large commercial plantations (Isabirye, 2005). The "impressive" price has lured small scale farmers into allocation of their entire farm to sugarcane cultivation. This has fueled encroachment on wetlands, forests and use of shallow stony marginal hills. It has also fueled food insecurity where the number of farm households having a meal a day has increased. Isabirye (2005) observed that net proceeds from one hectare cannot sustain a household. On the other hand, maize produced from 0.63 ha can sustain a household nutritionally; however considering the annual household expenditure (760.8 \$; UBOS, 2001) for Mayuge, about three hectares of land are required at low input level to support a household

Maize

Maize, considered as a bio-fuel feedstock, performs better than *Jatropha Curcas* and oil palm and outperforms all when sold as grain. Maize is grown as a food crop with limited value addition. It is used as material for manufacturing some alcoholic drinks

on a limited scale. Its potential as bio-fuel feedstock is indicated in Table 8 where its energy potential is roughly half that of sugarcane. The switching of maize from food and feed to ethanol production is associated with increased maize prices and therefore income for the farmers in the USA. Realizing the potential of maize as a feedstock in Uganda requires a concerted effort that will translate PMA strategies of improved crop productivity into household food and feed requirements with huge surpluses to support ethanol production. This can be achieved through the use of high yielding improved varieties and expansion of land under maize cultivation. The current production (Table 4) is far below the potential production. This will greatly improve grain prices and marketability to the benefit of the rural farmer.

Oil palm

Large scale oil palm plantations are a new introduction not more than 6 years in Uganda. Introduced under the plan to modernize agriculture and eradicate poverty, oil palm has faced resistance from the environmentalists as forests had to be cleared to establish the plantations, first on Ssese Islands in Lake Victoria. Though oil palm scores lowest as a threat to encroachment on gazetted areas and food availability, the few favorable sites are those grown with forest most of which are gazetted as reserves. With land scarcity and complex land tenure systems, most of the land (forest reserves) had to be offered by the government. At farm level and with gross sales per capita of \$ 1.0, oil palm is a promising enterprise that could contribute to poverty alleviation and household cooking oil requirements. It is said that 3 oil palm plants can make a household self sustaining in cooking oil.



A large scale oil palm plantation.

Chapter 6

Conclusions and recommendations

Conclusion

The agro-ecological settings favor the growing of *Jatropha Curcas*, sugarcane, maize and oil palm which are important bio-fuel feedstocks. Most of the arable land area can be used for growing *Jatropha Curcas*, followed by maize, sugarcane and then oil palm. Producing feedstocks from varied geographical regions allows a combination of feedstocks to be allocated to respective ecological niches thereby enabling exploitation of environments that uniquely support a given feedstock. This supports the hypothesis that a combination of feedstocks is considered to be more efficient and sustainable.

Bio-fuels can bring many benefits for Uganda by providing access to clean energy services while improving rural livelihoods. Sugarcane, given its energy balance advantage, is likely to be beneficial if promoted as bio-fuel feedstock, this is likely to increase sugarcane prices to the benefit of the small scale farmer. High farm gate prices, dual provision of food and ethanol makes maize a promising feedstock after sugarcane. Production of ethanol from maize grain is likely to increase grain prices which in turn will increase maize grain output thereby ensuring food security and surpluses for ethanol and feed production.

About 2.2% of arable land is available for *Jatropha* production at a marginal level as soils in these areas are poor and not preferred for food crop cultivation. These marginal environments are likely to be associated with low unprofitable *Jatropha* seed yields. None palatability, low yields and current meager seed prices are likely to limit *Jatropha Curcas* promotion in Uganda where food security is priority over none staple crops. The low yields also make it the greatest competitor for land.

Promotion of bio-fuel industry is likely to increase pressure on the gazetted areas and wetlands with consequent potential loss of bio-diversity increased demand for water. Sixty percent of the arable land area good for crop production is equally good for *Jatropha Curcas* production; 50% is equally good for sugarcane and 30% for Oil palm. *Jatropha Curcas* and food crop cultivation have the highest potential of encroaching on gazetted areas including forests. Oil Palm cultivation has the lowest encroachment potential.

In view of the impressive product prices, large scale commercial estates are likely to benefit commercial plantation investors at the expense of the small scale outgrower farmer as the current farm gate prices offered by the firms are meager and cannot support a farm household of 5.

Uganda is already faced with the challenge of malnutrition and looming food insecurity. Promoting bio-fuels and satisfying their requirements is an additional challenge likely to aggravate the state of malnutrition and food insecurity in Uganda.

Recommendations

In view of the likely competition for resources between bio-fuel feedstocks and food crops, and consequent increased food insecurity, there is need of developing synergistic inter sectoral policies to guide sustainable development of bio-fuels in Uganda. Lack of appropriate policy support to small-scale bio-fuel development at the local level may slow down the progress of the bio-fuel programs.

Bio-fuel feedstock, especially *Jatropha Curcas*, is being promoted without facts pertinent to their performance under Ugandan conditions. Experience in other countries is useful to guide research on bio-fuels but not to inform decisions on policy review in relation to bio-fuels in Uganda. Research is required to validate promotional statements like:

- It (*Jatropha Curcas*) does not compete with food production directly; it is not edible and grows in areas unsuitable for food production. It intercroops well with food crops
- *Jatropha Curcas* grows on rocky land and lasts for about 40 years;
- *Jatropha Curcas* is drought resistant; and relatively easy to grow and manage;
- A mature *Jatropha Curcas* tree may produce significant amounts of oil and other useful by-products like seed cake
- It (*Jatropha Curcas*) is more affordable than other alternative energies as it does not require new machinery (cars, generators etc. will run on *Jatropha Curcas*), as opposed to other alternative sources of energy (sun, wind, water)
- Many farmers know how to grow it (*Jatropha Curcas*), as it has been used traditionally as a live hedge and livestock fence/kraal.

Non-Forest Areas, availability of wasteland, secure ownership, rural poverty ratio, Below Poverty Line (BPL) census and agro-climatic conditions suitable for *Jatropha Curcas* cultivation, energy and food policies synergizing with the needs of the land, and carrying capacity of the land are criteria that should be used in a feasibility study to inform energy-food-poverty policy reviews in relation to promoting *Jatropha Curcas* and other bio-fuel feedstock establishment in Uganda.

In view of increased land demand for investing in bio-fuels, there is need to invest in improved land administration systems to deal with conflicting claims emerging under bio-fuels expansion. There is need to ensure that changes and production practices associated with bio-fuel production are sustainable. To minimize competition over land, and therefore food insecurity and encroachment on protected areas, it is advisable to grow sugarcane and maize that have higher yields with higher energy output compared to oil palm and *Jatropha*.

Experience in Brazil and the USA shows that heavy subsidies were key factors to the success of the bio-fuel industry; otherwise bio-fuels simply would not be cost-competitive with gasoline. The Ugandan Government must therefore arrange to have a long-term subsidy plan for the bio-fuel industry before embarking on campaigns to

establish the bio-fuel industry. It took Brazil about 20 years to have a break-through on oil self-sufficiency using ethanol (Xavier, 2007).

As the Government plans to promote the use of bio-fuels, bio-fuels should not be seen as a replacement of oil imports. It is evident that the bio-fuel program becomes un-economical when world petroleum prices fall. Fallback mechanisms must be planned to protect farmers and industrialists against such unfavorable economic changes.

Promotion of bio-fuel feedstock will include doing project feasibility studies at regional, district or sub-county levels; scales that require detailed information and data. In Uganda, soil information and data is available at reconnaissance scales not detailed enough to support implementation of bio-fuel projects. Therefore, updating the available soils and related ecological data must be part of the strategy to promote bio-fuel establishment in Uganda.



Cane grown as an economic factor at Kakira Sugar Works, Jinja Uganda.

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