Biofuels in Africa

An assessment of risks and benefits for African wetlands

Commissioned by Wetlands International

May 2008

AIDEnvironment

WETLANDS INTERNATIONAL

Biofuels in Africa

An assessment of risks and benefits for African wetlands

Sven Sielhorst

Jan Willem Molenaar

Don Offermans

Commissioned by Wetlands International

May 2008

AIDE nvironment

Donker Curtiusstraat 7-523
1051 JL AMSTERDAM
Tel. +31 (0)20 6868111
Fax +31 (0)20 6866251
Email info@aidenvironment.org
Website www.aidenvironment.org

Wetlands International

Droevendaalsesteeg 3
6708 PB Wageningen
The Netherlands
Tel. +31 (0)317 486774
Fax. +31 (0)317 486770
Email: post@wetlands.org
Website: www.wetlands.org

A1763

CONTENTS

Executive Summary

Wetlands are a vital link in the African water cycle. They are a source of life for both people and nature. Although African wetlands cover only about 4% of its total land mass, they store more than half the world's liquid fresh water storage. Many people depend directly on the wetlands. The fertile soils, the availability of fresh water and fish stocks provide the basis for their livelihood. African wetlands also host a broad array of species and play an essential role for migratory birds in Europe and Asia. Despite their importance, inland and coastal wetlands are being lost faster than any other ecosystem. Large-scale irrigation, drainage and pollution increasingly take their toll.

The growing global attention for biofuels could increase the pressure on the African wetlands. So far, Africa has remained at the sideline of the production of biofuel feedstocks, but is more and more regarded as the 'global power house'. Africa has a favorable climate, affordable labor and abundant land resources. This raises the question of how the development of biofuels will affect African wetland areas and the people living there.

The – medium term – demand for African biofuels is uncertain. International trade in biofuels is limited and if European and American trade and agricultural policies remain unchanged, international trade is not expected to grow significantly. If, however, international trade increases, it is likely that Brazil will take most of the ethanol market; Brazil out competes Africa in terms of cost price and production volume. Nevertheless, many African countries have intentions to step into biofuels – either for export or for import substitution.

If these intentions become reality, African wetlands could be seriously at risk. Of all biocrops, sugarcane poses the most direct threat. It requires large amounts of water and is therefore often grown in wetlands, leading to wetland conversion and degradation. Palm oil can be grown in wetlands too, although the soils provide less favorable conditions. Conversion of tropical forest in upstream areas for palm oil cultivation, can lead to sedimentation of wetlands. Effluent discharge of oil palm mills can seriously harm the aquatic environment. Other crops like cassava, sweet sorghum, maize and jatropha grow on drier soils, but require irrigation to become commercially attractive. Large-scale irrigation can seriously deplete water resources that feed into wetlands. Biofuel expansion also poses serious risks for indigenous people. If production takes place in highly populated areas, local communities may lose their land or access to water, leading to land conflicts and jeopardizing local self-sufficiency.

The production of biofuel can however also stimulate economic development in and around wetland areas. Planting, maintenance and harvesting will probably be done manually and this form of employment can be quite substantial. The processing of crops requires higher skilled personnel and adds more value to the local community. African farmers can produce biofuel crops themselves and supply them to ethanol plants or palm oil mills.

The land requirements for producing biofuels in Africa are marginal in relation to the available land. In which areas production will take place depends largely on the type of crops, production intended for import substitution or for export, on available infrastructure and population density. It is very likely that wetlands will be in focus for production expansion. The African wetlands and the people depending on them are vulnerable. Careful management of biofuel feedstock expansion is essential. Several conditions, such as effective land use planning, comprehensive biofuel policies, accountability mechanisms for producers, raising awareness, and sound agricultural management practices can help to mitigate the risks and promote the benefits.

1. Introduction

1.1. African wetlands: cradles of life

Wetlands are a vital link in the African water cycle. They are a source of life for both people and nature. Although African wetlands cover only about 4% of its total landmass, they store more than half the world's liquid freshwater. Especially in Africa, many people depend directly on wetlands for their livelihood because of their fertile soils, availability of fresh water and fish stocks. African wetlands host a broad array of species and play an essential role for migratory birds from Europe and Asia.

Wetlands are areas on which water covers the soil or where water is present at or near the surface of that soil. Water can also be present within the root zone, all year or just during various periods of the year."[1] They include coasts, estuaries, floodplains, swamps/marshes and shallow lakes. Wetlands provide services of great value to society. They control floods, protect coastal zones and they host a great diversity of species. They have a great cultural and economical importance to indigenous communities.[2] Figure 1 displays the various types of wetlands in Africa.

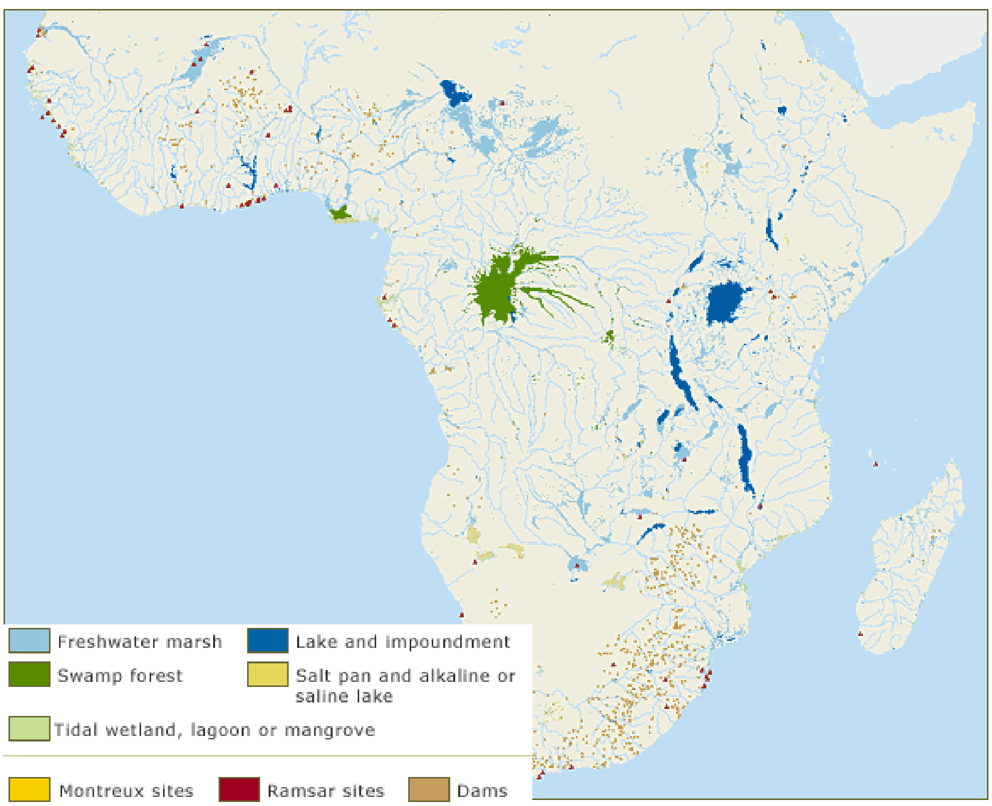

Figure 1: Wetlands in Africa (World Resources Institute - PAGE, 2000)

[1] www.wetlands.org
[2] www.wetlands.org

Despite their importance, inland and coastal wetlands are being lost faster than any other ecosystem. Large-scale irrigation, drainage and pollution increasingly take their toll. Poor people living in wetland areas are especially affected, as their resource base is disappearing.

To counter this trend, governments and non-governmental organizations established the Ramsar Convention for the protection of wetlands. One hundred and seventy Ramsar sites have been recognized in Sub-Saharan Africa, with a total surface of over 70 million hectares[3] (see Figure 2). The total surface of African wetlands is estimated at 168 million hectares.

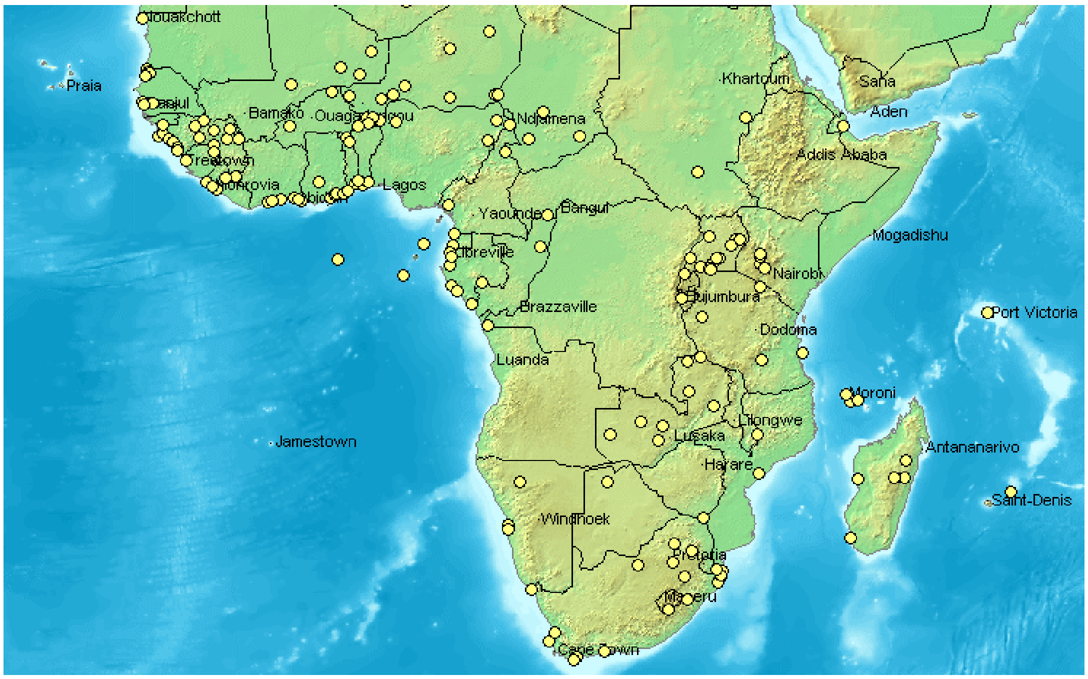

Figure 2: Ramsar sites in Sub-Saharan Africa (Source: www.wetlands.org)

1.2. Quick scan questions

The recent surge of interest in biofuels is increasing the pressure on global land availability[4]. Europe, North America and Latin America have experienced serious growth in the production of biofuel feedstock. Africa has so far remained at the sideline of this development, but the continent is increasingly viewed as the global powerhouse for biofuel feedstock production due to its supposed supply of 'excess' land[5].

[3] Ramsar (2008)
[4] Bergsma et al. (2006)
[5] e.g. Smeets et al (2004)

This raises the question of how the development of biofuels will impact on African wetland areas and the people that live there. This quick scan aims to improve our insight into this development by providing answers to the following questions:

1. What is likely to be the demand for African grown biofuels?
2. Which biofuels are likely to be ‘winners’ in the African context?
3. Which areas in Africa are likely to become expansion areas for biofuels?
4. What is the likely nature and magnitude of the impacts of biofuel expansion in Africa?

1.3. Scope of the quick scan

The scope of this quick scan is limited to the most likely future feedstocks, their impacts on wetlands and their people and general expansion areas.

Feedstocks under consideration include all scalable cultivated biomass sources for the production of transport fuels (biodiesel and ethanol), industrial heat and electricity. A more detailed explanation follows in Chapter 2. Traditional use of wood or charcoal for cooking is left out of the assessment. Although this represents the bulk of biomass used in local energy, it is subject to well-known dynamics which are different than those of a bio-energy commodity.

The quick scan will focus on both direct effects and indirect effects of biofuel production. Direct effects are those that happen on or near a specific production location of the feedstock and can be directly attributed to this location. Examples of this include erosion, water use and employment. Indirect effects of biofuel production cannot be attributed to one specific producer. They become prevalent at an aggregated level. Examples are increased food prices (due to increased demand for agricultural produce) and increased conversion of natural areas (due to increased land pressure).

Both environmental and social effects of biofuel production on wetlands and the communities that depend on them will be assessed and attention will be given to negative as well as positive effects.

The geographical focus will be on Sub-Saharan Africa, as this coincides with Wetland International’s *Wetlands and Poverty Reduction Project*.

We focus on likely biofuel developments in the medium term, i.e. 2020 – 2030. This timeframe is sufficiently short to diminish some of the uncertainties that hamper a reliable assessment, while being sufficiently long to recognize possible trends. Most government policies directed at stimulating biofuels have a comparable timeframe.

1.4. Approach of the quick scan

This quick scan is based on existing literature on biofuels and data regarding the growth conditions of the main feedstocks.

1. Expected demand of the feedstocks selected in this study has been based on two sets of assumptions. The import substitution scenario assumes that 10% of African domestic fuel consumption will be derived from biofuels in 2020. The export market scenario

assumes that 5% of US and EU transport fuel consumption will be supplied by African biofuels (see section 2.4).

2. The question of which feedstock will most likely be used to produce biofuels is answered through qualitative analysis. Elements determining the likelihood of a crop becoming a large-scale biofuel feedstock are:

- Production costs
- Energy yield per hectare
- Familiarity with cultivation and production methods
- Adaptability to natural conditions
- Storage potential

3. The expected expansion areas were identified through qualitative analysis using the following indicators:

- Natural environment (soil, water and temperature)
- Labor availability
- Availability of land and water
- Infrastructure and logistics (roads, railways and ports)

4. The potential impacts of the various biofuel feedstocks were determined on the basis of available literature and figures regarding agricultural input and output from various databases.

How much is a hectare?

The term hectare is regularly used in this report to indicate production potentials, water requirement of crops, et cetera. But how much is a hectare?

- One hectare is about one-and-a-half soccer field, 100 x 100 meters
- A thousand hectares is the size of Melilla the smallest Spanish enclave in Africa.
- A 100,000 hectares is the size of São Tomé and Príncipe
- One million hectares is slightly less than the size of The Gambia
- Ten million hectares is slightly less than the size of Liberia
- The total size of Africa is 30,368 million hectares

2. Demand for African biofuels

2.1. What is bio-energy?

Biomass is a major source of energy in Sub-Saharan Africa. It is used in the form of fuel wood, charcoal and residues for cooking, heating and for small industries.[6] Demand for fuel wood is large, surpassing even total world demand for round wood[7], and is expected to grow by 47% by 2020.[8]

This quick scan does not focus on the traditional use of biomass for energy, but on modern bio-energy. This is defined as the conversion and use of biomass at higher efficiency into more versatile energy carriers – electricity, liquid or gaseous fuels and process heat.[9] Figure 3 shows the main conversion routes, i.e. the technological ways in which biomass can become heat, electricity or engine fuel. There are basically four types of biomass:

- Lignocellulosic: woody biomass (cellulose)
- Sugars and starches: crops containing sugars and starches
- Oils and fats: vegetable oils and animal fat
- Wet biomass: e.g. sewage waste, dung, industrial wastes

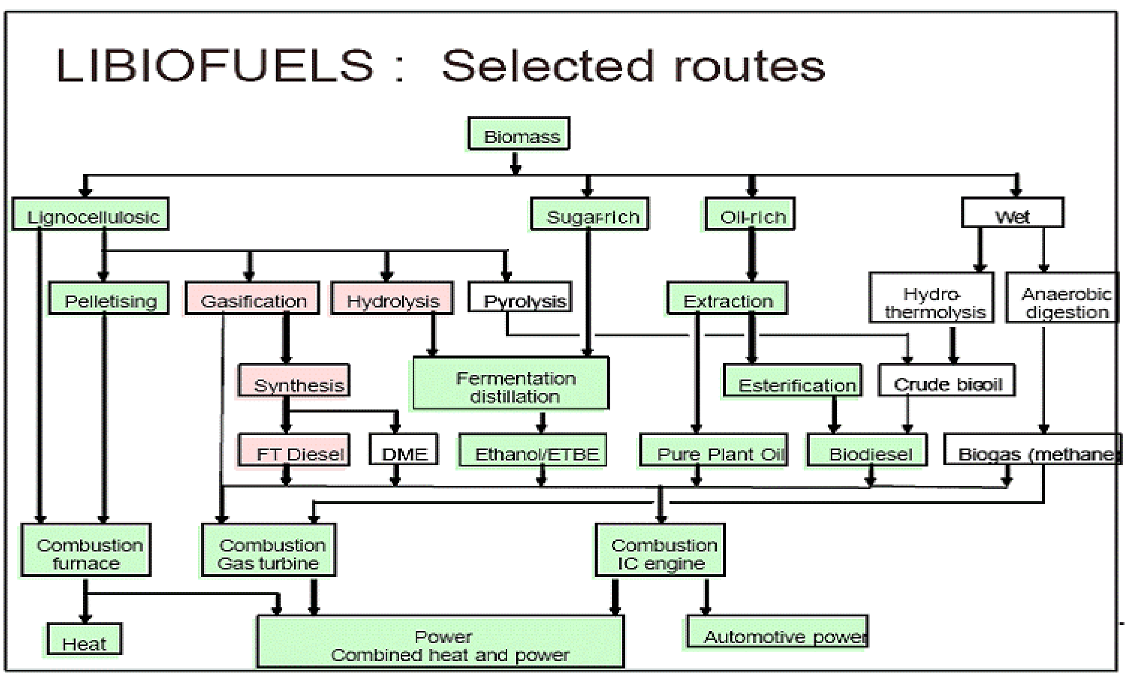

Figure 3: Conversion routes for bio-energy (Source: De Rijck, 2006)

---

[6] Johnson, F.X. and E. Matsika (2006)
[7] Heinimö et al (2007)
[8] Smeets et al (2004)
[9] Kartha et al (2005)

Figure 3 shows that all types of biomass can be turned into any desired kind of energy carrier using various techniques. Currently, three conversion routes are applied on a large-scale:

1. Lignocellulosic biomass (wood chips or wood pellets) > Combustion > Heat and electricity

2. Sugars (mainly sugarcane and sugar beet) or starches (mainly maize) > Fermentation > Ethanol

3. Vegetable oils (mainly rapeseed, sunflower, palm and soy oil) > Esterification > Biodiesel

Ethanol and biodiesel are mainly used as transport biofuels. Ethanol is a substitute for gasoline, and biodiesel can substitute diesel. A litre of ethanol has an energy content of some 75% compared to gasoline; a litre of biodiesel contains 85% of a litre of conventional diesel. Ethanol is the most important biofuel in terms of volume, accounting for over 85% of globally produced biofuels.

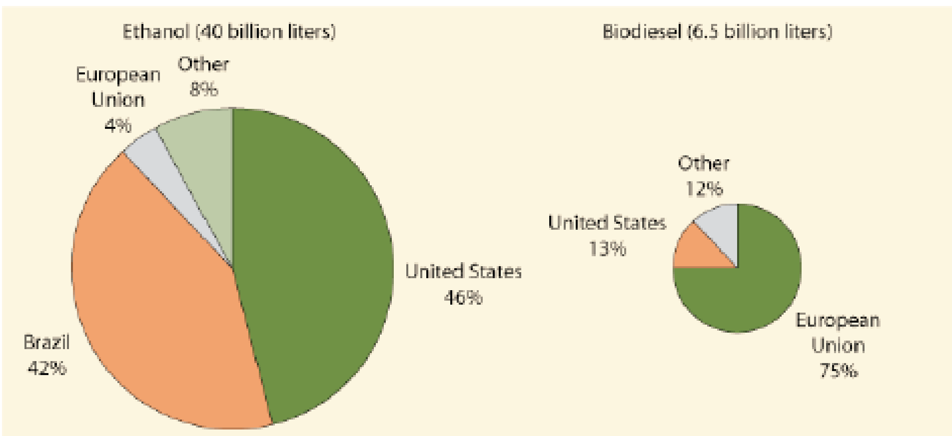

Figure 4: Origin and production volumes of ethanol and biodiesel (source: World Bank, 2008)

Being derived directly from sugars, starches or vegetable oils, ethanol and biodiesel are often referred to as *first generation biofuels*. Scientists around the world are currently developing *second generation biofuels*, liquids made of lignocellulosic material. These fuels could offer more environmental benefits as they can be derived from agricultural waste and waste wood and do not compete with the human food chain for inputs. However, it is unlikely that second generation biofuels will become competitive with first generation by 2020 due to a much higher cost price. It is therefore expected that they will become only widely available after 2020.[10] Therefore, this quick scan does not take into account possible demand for second generation biofuels.

[10] De Santi et al (2008)

2.2. Bio-energy crops mainly used for transport fuel

Bio-energy crops are crops that are especially cultivated to serve as a feedstock for bio-energy. They are at the heart of this quick scan as their potential impact is much bigger than that of vegetable by-products or waste flows of other products. But not all bio-energy carriers are made of energy crops.

About one percent of global electricity production is fuelled by biomass. This is particularly the case in countries with a substantial forestry sector, such as Sweden, Finland and Austria. The availability of saw dust and forest residues makes biomass a competitive energy source.[11] Canada, Baltic countries, Sweden and Finland are also major exporters of wood pellets made from forest residues. Very few bio-energy crops are grown especially for conversion into electricity or heat. The reason is that the cost difference between bio-energy crops and conventional coal is too high. Governments do not generally feel urged to subsidize this difference. Energy security is one of the main drivers of stimulation policies regarding bio-energy. Consequently, biomass-derived electricity and heat is not seen as a priority in contrast to transport biofuels. Changing from coal to biomass hardly contributes to greater energy security as coal is abundantly available all around the world. This will certainly remain the case up to 2020 and it is therefore deemed unlikely that large-scale demand for African biofuel crops will come from the heat and electricity sector. We will therefore not focus on woody crops such as Eucalyptus and Myscanthus, which would be the most appropriate feedstock for electricity and heat bio-energy due to their rapid growth. Palm oil stearine, a product derived from the oil palm which was used in the Netherlands before its price-hike made it economically unfeasible, could become an electricity feedstock again. There is no way to determine the actual magnitude of the demand this would induce, as it totally depends on the extent of government stimulation. Effects of oil palm cultivation will however be treated in following chapters, as it is also a potential feedstock for biodiesel.

With transport biofuels, things are the other way around. Liquid biofuels can currently only be made from energy crops. Making them from waste-flows (i.e. second generation) is still in its early pilot stage. Governments around the world are encouraging the conversion of the use of fossil fuels into biofuels, because liquid fossil fuels are increasingly scarce and come from a limited number of countries, some of which are considered politically unstable. Many governments have set in motion policies aimed at increasing biofuel use in the medium run (by around 2020), so we can expect demand for biofuel crops to rise substantially over the next years. Crops for transport biofuels are therefore the real focus of attention of this quick scan. In the African context six crops seem to have large-scale potential: sugarcane, sweet sorghum, maize and cassava for ethanol and oil palm and jatropha for biodiesel. We will go deeper into this in Chapter 3.

2.3. Uncertainties concerning demand for African biofuels

The production and use of modern bio-energy is currently limited. Electricity and heat are produced where residues are available on site. Liquid biofuels are produced and used on a small scale and export is still almost non-existent. This is in sharp contrast with the technical production potential of many African countries. Biomass in tropical and sub-tropical countries is five times as productive as in non-tropical climates in terms of photosynthetic efficiency and there seems to be an abundant supply of affordable land and labour. Feedstock represents 80%

[11] Heinimö et al (2007)

of the production costs for biofuels[12], so Africa could have a substantial competitive edge as a biofuel producer. Accordingly, Africa is often mentioned as a future power house for the production of energy crops and biofuels. So far, an unattractive investment climate and poor infrastructure have hampered such development.[13] Potential profit margins are not sufficiently high to justify the risks of political instability and inconsistent policy behaviour by some African governments. This may change as the EU, US and Chinese markets demand more biofuels or once African countries embark on a policy of import substitution of fossil liquid fuels.

Determining future demand for African grown biofuels is however a complex undertaking. It is highly dependent on policy factors and market circumstances. The main uncertainties are:

- Magnitude and enforcement of biofuel policies
- Trade and agricultural policies
- Competitiveness of African biofuel production

2.3.1. Biofuels policies

Governments around the world have developed biofuel policies in an attempt to:

1. increase energy security
2. increase rural development
3. decrease CO2 emissions

The United States, Brazil and the European Union are among the countries with the most ambitious biofuel targets, followed by Japan, China and a host of other countries. Most African governments have so far refrained from ambitious biofuel policies, although they are increasingly paying attention to this opportunity.

The United States is already the largest producer of biofuels in the world. The US car market is dominated by gasoline-powered motors and therefore the main policy focus is on ethanol. The US has set a production target at 132.6 billion litres of ethanol in 2017. This will mainly be produced from domestically grown maize.[14] Imports are expected to remain limited, despite trade treaties being made with Brazil for the import of sugarcane-ethanol.

Brazil used to be the world's biggest producer and consumer of biofuels until the US took over its position. Still, it produces around 21 billion litres of ethanol a year of which over 90% is consumed domestically. Sugarcane-based ethanol production has been stimulated by various policies since the 1970. The current policy sets a 20% mandatory biofuel target. This is easily met as ethanol accounts for 48% of transport fuel consumption. With the current high oil prices, sugarcane-based ethanol from Brazil is cheaper than regular petrol. Many Brazilians drive flexfuel cars, allowing them to switch from gasoline to ethanol depending on the price and availability.[15]

The European Union has set ambitious biofuel targets: 10% of its transport fuels should be derived from biomass in 2020[16]. It is especially ambitious, because the actual EU achievement

[12] WWI (2007)
[13] Johnson and Matsika (2006)
[14] Eickhout et al (2008)
[15] WWI (2007)
[16] EC (2008)

does not exceed a few percent so far. The assumption that 10% of the European transport consumption is to be provided by biofuels in 2020 will require a biofuel production of 22.9 billion liters of biodiesel and 29.2 billion liters of ethanol.[17]

China is also promoting biofuels. Its domestic production target for 2020 is between 6 billion and 16 billion litres of ethanol and 12 billion litres of biodiesel. Domestic production of ethanol, mainly from sweet sorghum and cassava, is deemed sufficient until 2020. For biodiesel, a domestic production shortage of 7 billion litres is foreseen in 2020.[18] This will have to be imported, most probably in the form of vegetable oil.

The International Energy Agency expects African domestic demand for biofuels to be about 3.5 Mtoe in 2030 (i.e. about 2 billion litres).[19] Few African countries have biofuel policies. Malawi is the only country besides Brazil that has been blending ethanol continuously on a national basis for more than twenty years. South Africa, Sub-Saharan Africa's most developed economy, and Nigeria are also stimulating biofuels. Most countries are still studying the opportunities of biofuels.[20]

Figure 5 shows expected world market share of biofuel consumption in 2030, assuming limited biofuel policy. This is a prediction by the IEA, that deviates from the official targets that various countries have defined.

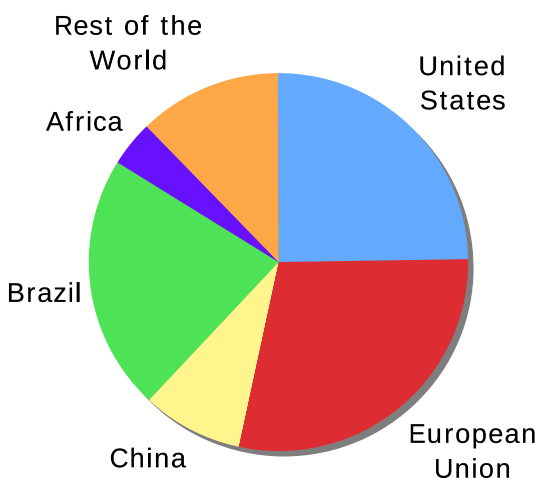

Figure 5: Expected share of global biofuel consumption in 2030 for main consumer markets (Source: IEA, 2006)

[17] Eickhout et al (2008)
[18] WWI (2007)
[19] IEA (2006)
[20] Johnson and Rosillo-Calle (2007)

2.3.2. Trade and agricultural policies

Only ten percent of ethanol produced is traded internationally. Trade in biodiesel is also limited, despite the competitive advantage of (sub)-tropical production countries. Figure 6 presents the differences in cost price per litre gasoline equivalent for ethanol from Brazil, US and EU. Ethanol is already produced in some African countries at lower cost prices varying from USD 0.25 to USD 0.60 per litre [21], so there seems to be a large potential for export growth. The IEA nevertheless believes that the bulk of biofuels consumed in each region will continue to be produced indigenously, as a result of protective farm and trade policies.

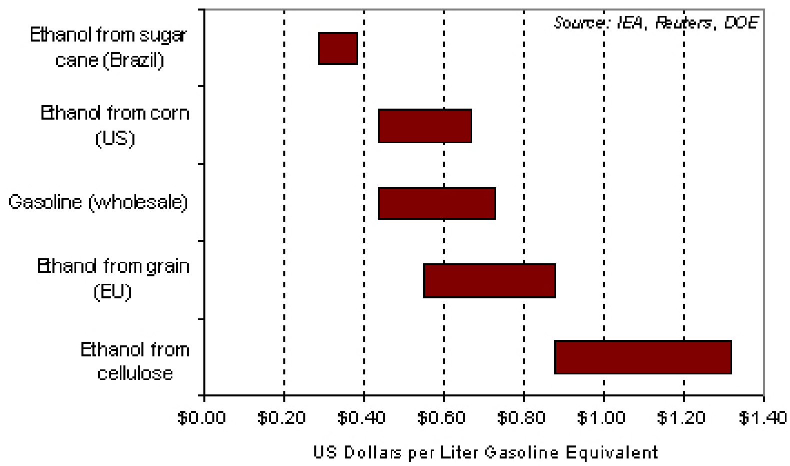

Figure 6: Cost price per liter gasoline equivalent in USD (Source: WWI 2006)

Imports into the major consumer markets of the United States and the European Union are currently restricted by import barriers, by financial support to US and EU farmers and by non-tariff barriers. US and EU fuel standards regulating the chemical composition of fuel especially pose barriers.[22]

Liberalization of agricultural policies would substantially increase global biofuels production as well as shift part of biofuel production from the US and EU to (sub-) tropical countries. The International Energy Agency expects that biofuels will constitute 4% of world road-transport fuel in 2030 under current conditions. If trade barriers were to be lowered, this share would increase to 7%.[23] Simulation shows that more than 50% of biofuel consumption in the EU would come from regions with more favourable production conditions.[24]

Apart from national and international policies, the donor community can also play an important role for the biofuel sector in Sub-Saharan Africa. Multilateral and bilateral donors can boost the start of biofuel cultivation by sharing costs and risks of initial phases of development. In recent years the attention of multilateral and bilateral donors for biofuel production has increased rapidly. For example, the World Bank and the Dutch government already invest in feasibility studies, production pilots and processing units.

[21] Johnson and Matsika (2006)
[22] Johnson and Matsika.(2006)
[23] IEA (2006)
[24] Eickhout et al (2008)

2.3.3. Competitiveness of African biofuel production

Due to preferential access to the EU market, small amounts of ethanol are shipped from African countries (Congo, Swaziland, and Zimbabwe) to Europe.[25] Besides this, African biofuels are generally not yet competitive on the world market. Production costs are between 0.25 USD and 0.60 USD per litre for sugarcane-ethanol in Zimbabwe and Malawi. Brazilian cost price ranges from 0.19 USD to 0.25 USD. Johnson and Matsika[26] recommend the following measures for making African sugarcane-ethanol viable:

- Increase scale of production, as factories are currently too small to achieve competitive cost price
- Improve and expand distribution and transportation infrastructure
- Create reasonably assured market, e.g. through long-term contacts, in order to attract investments

While Brazilian production capacity is growing dramatically[27], investments in processing capacity and infrastructure in Africa are still low. For ethanol the gap between Africa and Brazil is widening and Brazil has enough land available for further production growth. Figure 7 shows four scenarios for biofuel production. In every scenario, Brazil and virtually all other regions in the world (except for Oceania and Latin America other than Brazil) produce more biofuels than Africa.

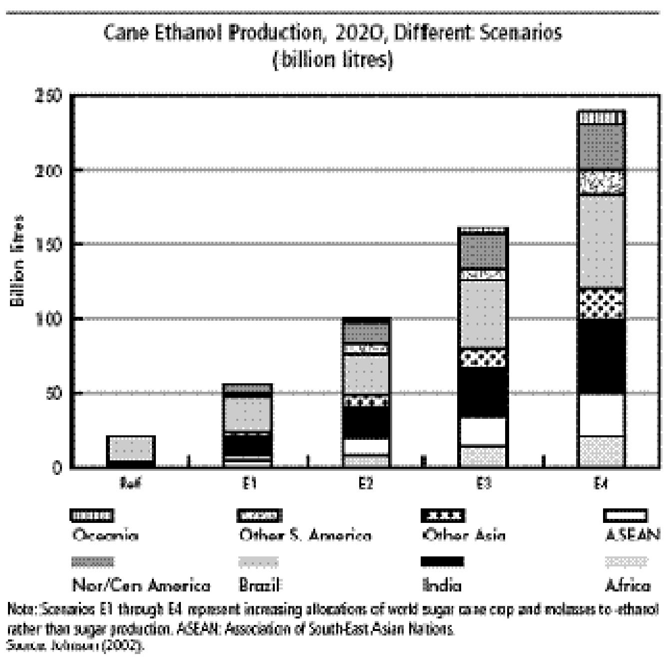

Figure 7: Predicted sugarcane-ethanol production in various regions in 2020 (Source: Fulton et al, 2004).

---

[25] WWI (2007)

[26] (2006)

[27] In 2008 expected growth is between 15 and 19% alone - boerderij.nl

The picture is less clear for biodiesel. Over 80% of biodiesel is made of rapeseed, a crop that grows in the temperate climates of Europe and North America. Soy oil-based biodiesel is increasing in soy producing countries, but other than that tropical crops have not been utilized for biodiesel production until now. Oil crops that would suit the African conditions are mainly oil palm and jatropha. If vegetable oil prices remain as high as they are today or given the availability of sufficient subsidies, oil palm and jatropha could become viable energy crops in Africa.

Country	Ethanol demand in millions of liters in 2020	Biodiesel demand in millions of liters in 2020
Angola	82	177
Benin	89	26
Botswana	78	49
Burkina Faso	21	16
Burundi	8	5
Cameroon	77	74
Cape Verde	2	11
Central African Republic	6	5
Chad	2	5
Comoros	2	3
Congo (Brazzaville)	16	27
Congo (Kinshasa)	28	47
Cote d'Ivoire (IvoryCoast)	30	95
Djibouti	5	18
Equatorial Guinea	2	6
Eritrea	3	21
Ethiopia	35	134
Gabon	12	46
Gambia, The	10	9
Ghana	168	167
Guinea	22	15
Guinea-Bissau	5	6
Kenya	94	180
Lesotho	6	4
Liberia	10	9
Madagascar	42	78
Malawi	26	26
Mali	18	16
Mauritania	76	8
Mauritius	24	60
Mozambique	25	77
Namibia	86	80
Niger	14	28
Nigeria	1.754	403
Reunion	38	47
Rwanda	10	18
Saint Helena	0	0
Sao Tome and Principe	2	4
Senegal	29	109
Seychelles	4	35
Sierra Leone	6	23
Somalia	12	14
South Africa	2.279	1.243
Sudan	133	304
Swaziland	19	13
Tanzania	52	116
Togo	56	39
Uganda	46	40
Zambia	43	51
Zimbabwe	59	59
Africa	5.667	4.044

2.4. Two scenarios for African biofuel growth

The uncertainties highlighted in the previous section make it very difficult to predict demand for African biofuels and hence biofuel production in 2020. In an attempt to increase our insight in the magnitude and possible implications of increasing demand for African biofuels, we have developed two scenarios of limited complexity. They are the *import substitution scenario* and the *export driven scenario.* We will refer to these scenarios in Chapters 4 and 5 about the potential impact of biofuels growth.

2.4.1. Import Substitution Scenario

This scenario is based on the assumption that all African countries have substituted 10% of their domestic gasoline and diesel with ethanol and biodiesel respectively. This percentage is chosen as other countries have a comparable ambition level. It is unlikely that many African countries will actually achieve this level of substitution, because it would require considerable investments that have not yet been made. For a few countries, however, this scenario could become a reality if governments develop and implement policies and if business responds to the government incentives.

In section 2.3 we explained that African governments have so far not made much effort to stimulate biofuel use, e.g. by imposing mandatory targets in 2020, hence this import substitution scenario seems unlikely. Furthermore market conditions are poor in many African countries. It therefore seems unlikely that demand for biofuels will increase to 10% in most countries. On the other hand, for some countries the 10% could be a realistic production level as they can be reached by operating just a handful of factories and plantations.
Tanzania could serve as an example. Fifty-two million liters of ethanol would require about 10,000 hectares of sugarcane and one ethanol plant. Ten thousand hectares amounts to 0.02% of Tanzania's agricultural area, of which 90% is currently not used according to FAO[28]. According to WWI[29], sugarcane ethanol from Tanzania would be competitive with gasoline at

[28] In Johnson and Matsika (2006)
[29] (2007)

current prices. We will come back to land requirements and other impacts in Chapter 4, but this example is to illustrate that for many countries substitution to biofuels seems at least technically feasible in the foreseeable future.

Domestically grown biofuels may become an attractive substitute for imported fossil fuels for many African countries. A 2004 IEA study found that a 10 USD increase in oil prices meant 1.5% lower GDP for oil importing African countries.[30] In 2000, Sub-Saharan African countries spent 14% of their income on oil imports. Terms of trade have worsened since as oil prices have more than doubled. Table 1 depicts the oil imports as a percentage of total imports and the number of countries that fall into the different categories, e.g. 10 African countries spend between 15 and 20% of their imports on oil.

Category (in %)	*Num. of countries*
Less than 5	5
[5 - 10[	14
[10 - 15[	16
[15 - 20[	10
[20 - 25[	1
More than 25%	1

Table 1: Oil Imports as a Percentage of Total Imports (Source: ADB 2006)

A rough calculation using figures from the US Department of Energy[31], leads to the prediction that under the import substitution scenario Sub-Saharan Africa will have an ethanol demand of 5.6 billion liters and a biodiesel demand of 4 billion liters in 2020 (see Table on previous page).

We assumed that the proportion between gasoline and biodiesel remains constant and that annual growth in transport fuel use would be 2.2% for each country[32].

Under this assumption, the bulk of biofuel demand will be concentrated in South Africa and Nigeria. These countries are the biggest African consumers of fossil transport fuels at the moment. Although it does not seem logical for Nigeria to embark on biofuel expansion, as it is an oil-rich country, it is taking serious steps in that direction. This is motivated by employment creation and by the fact that biofuels may be able to compete with refined oil products, many of which Nigeria has to import due to its limited oil processing facilities.

2.4.2. Export driven scenario

In this scenario we assume that 5 % of EU and US ethanol and biodiesel consumption is covered by African biofuels in 2020. This would lead to an ethanol demand of 6.6 billion liters for the US and 1.45 billion liters for the EU. The US would also be the largest biodiesel importer of the two, requiring 1.6 billion liters while the EU would use 1.1 billion liters.

[30] IEA (2004)

[31] Figures from International Energy Annual 2005, Energy Information Administrations, USDOE extrapolated based on figures from World Energy Outlook 2007, International Energy Agency.

[32] Please refer to Annex A for calculations

This scenario does not seem very likely, but some African countries may become serious exporters to the EU and US consumer markets. As energy security is the main driver for EU and US biofuel policies, it is unlikely that they want to become too dependent on relatively unstable production countries in Africa. Moreover, African biofuels are not likely to compete with those from Brazil. In any case, judging by current international trade in biofuels it seems that the US and EU aim to be self sufficient and will refrain from letting foreign farmers profit from biofuels policies at the expense of their own agricultural sector.

Using scenarios: developing insight in magnitude of impacts

The scenarios have been formulated to provide a reference for the type and magnitude of potential impacts of biofuel expansion in Africa. They should not be seen as predictions. It is unlikely that they will unfold completely, but some African countries may substitute 10% of their fossil fuel use with biofuels. Also: demand from the US and the EU will increase and will need to be serviced to a degree by foreign markets. The latter is probably limited however and therefore African biofuel exports are not expected to rocket. Some countries in Africa will however certainly try to take advantage of this and start growing biofuel crops on a large-scale.

2.5. Conclusions

Global demand for liquid biofuels is increasing rapidly. High oil prices and biofuel policies make fuels from energy crops a viable alternative to fossil fuels. Ethanol and biodiesel are mostly produced in the consumer markets and international trade in biofuels is limited. If EU and US trade and agricultural policies remain unchanged, which is likely given their ambitions regarding energy self-reliance, international trade is not expected to grow dramatically. In that case, African exports to these markets would remain limited as well.

If, however, international trade in ethanol and biodiesel would increase, it is likely that Brazil will take most of the ethanol market. Brazil has embarked on a massive expansion of sugarcane plantations and processing capacity and has by far the lowest cost price of ethanol in the world.

An enlarged export market for biodiesel would present market opportunities to more countries besides Brazil. Some African countries could venture into palm oil and jatropha and seize a share of the market.

Biofuel production in Africa is still marginal and large-scale export is non-existent. Investments in crop production, processing facilities and infrastructure are still largely absent. Nevertheless, more and more foreign investors turn an eye on Africa for it has excellent natural conditions, affordable labour and abundant land to produce biofuels. They are however often hesitant to invest due to the high risk profile of many African countries.

Biofuel production to substitute for imported fossil fuels could benefit Africa, especially with rising oil prices. Not many African governments have actual biofuel policies yet, although several are currently considering them. Apart from South Africa and Nigeria, partial import substitution in African countries would not lead to a surge in demand for ethanol or biodiesel from African countries.

3. Biofuel crops in Africa

3.1. Introduction

So far there are few commercial, large scale biofuel crops. Global ethanol production is dominated by Brazilian sugarcane and United States maize, while about 90% of global biodiesel production is based on rapeseed.

For Africa, we have selected six biofuel crops to be the focus of this quick scan. The selected ethanol crops are:

- Sugarcane
- Maize
- Sweet sorghum
- Cassava

The selected biodiesel crops are:

- Oil palm
- Jatropha

All six are deemed technically and economically feasible in various parts of Africa. This feasibility has been determined through qualitative analysis based on:

- Natural conditions: required soil types, rainfall and other natural conditions differ between biofuel crops
- Agricultural experience: although many crops have the potential to become a biofuel crop, we have focused on those crops with which there is already considerable cultivation experience. These are the crops that are most likely to be produced in a rational fashion in the short and medium term (up to 2020)
- Scalability: Biofuel crop production requires a substantial scale for competitive production. This makes the question “is there potential for up scaling and how quickly can we do it?” relevant.
- Energy production per hectare: 80% of the cost price of biofuels is determined by the costs of biofuel crop. These costs are mostly determined by the costs of land and labor. High-energy productivity per hectare means less costs for land and efficient planting and harvesting.
- Process ability: although all plants can theoretically be used for biofuel production, some have better characteristics for processing than others.

This chapter will give a basic background on the most important biofuel crops. Chapter 4 will go deeper into their potential environmental and socio-economic impacts. Chapter 5 involves an analysis about land requirements for the various crops.

3.2. Ethanol crops

This section gives an overview of four ethanol crops that have a high potential for Africa. Virtually all ethanol for transport fuel is currently made from Brazilian sugarcane or US maize. These crops are part of existing large scale production systems that were initially developed for food and feed production. They are also located in the vicinity of large gasoline consumer markets. It was therefore relatively straightforward to expand into biofuels. Sugarcane and maize are also potential feedstock for African ethanol, as the crops are already cultivated in many countries. Maize is mostly a smallholder crop and given the current conditions not competitive and as an ethanol feedstock. Sugarcane is mostly produced on large-scale estates and would be more suitable as a feedstock.

Other crops with a high potential to become a feedstock for ethanol do not have such a head start. Cassava is cultivated on a relatively large scale as an export feedstock in some countries outside Africa, but in Africa it is mostly an important smallholder crop. Sweet sorghum is a popular smallholder crop in Africa as a source of food and silage. Both sorghum and cassava can have considerable energy yield per hectare, but are not commonly used as biofuel feedstock yet.

3.2.1. Feedstock sugarcane

Sugarcane is a perennial grass that grows in tropical and subtropical areas up to 1600 meters above sea level[33]. Figure 7 shows the areas that would be suitable for sugarcane cultivation in Africa. Sugarcane is currently the highest yielding crop in terms of energy per hectare. The Brazilian ethanol yield per hectare amounts to 5,800 liters[34]. Africa has a much lower sugarcane yield of some 4,000 liters of ethanol per hectare.

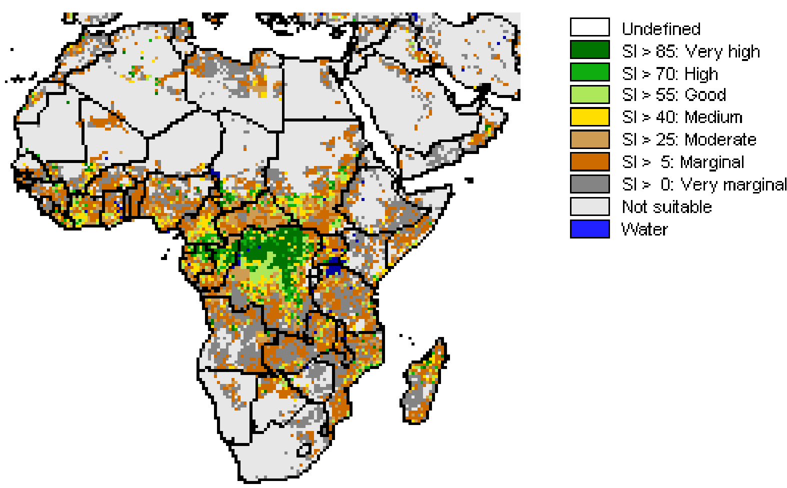

Figure 8: Suitability for rain-fed and irrigated sugarcane (source: IIASA/FAI (2002))

[33] FOA Ecocrop
[34] Fresco (2006)

What is ‘suitable land’?

In the index of figures 8 to 12, the suitability index SI represents the portion of the grid-cell with attainable yields. Very suitable are areas with 85% or more of the maximum technically potential yield. Similarly, the figures indicate areas which have high (>70%), good (>55%), medium (>40%), moderate (>25%) and marginal (5%) or very marginal (>05) suitability.

The suitability has been determined by the Food and Agricultural Organization, based on rainfall, soil characteristics, irrigation possibilities, altitude and other natural conditions.

Sugarcane is mostly produced in large-scale plantations. About 10 – 20% of sugarcane in Sub-Saharan Africa is produced by smallholders or outgrowers with plots ranging from one to ten hectares.[35] Thirty-seven countries in Sub-Saharan Africa produced sugarcane in 2006. South Africa accounted for 27% of production. Other large producers (by African standards) are Sudan, Kenya, Swaziland, Zimbabwe and Mauritius.[36]

To become ethanol, sugarcane needs to be processed within forty-eight hours after harvesting, otherwise, energy yields start to decrease significantly. Sugarcane is also a voluminous crop increasing transport costs. For these reasons, sugarcane should be produced in the vicinity of the ethanol plant. The optimal scale for a competitive sugarcane-ethanol plant is between one and two million tones of raw cane per year.[37] With current average African yields, this would require a sugarcane production area of about 17,500 hectares. This corresponds with an ethanol production of seventy million liters.

A sugar mill that is used for crushing the raw sugarcane stalks produces considerable volumes of a pulp rest product called *bagasse*. This bagasse is often used in combustion furnaces in the plant to produce heat. In Brazil, it is increasingly fired in a Combined Heat and Power Plant, where heat and electricity are generated simultaneously. The electricity can then be supplied to the grid. This does not yet happen in Africa, but in Mauritius bagasse is co-fired with coal to produce electricity.[38] This leads to an increase in electricity production without additional greenhouse gas emissions.

3.2.2. Feedstock maize

Maize is an annual crop that grows almost everywhere, although it often needs irrigation.[39] Figure 9 shows suitable areas for rain-fed maize production. Maize has a much lower yield than any of the other ethanol crops mentioned in this report. This is because only the seeds of the plant can be used. Using first generation technology, the stalk cannot be converted into ethanol. A hectare of maize can nevertheless still yield 3,000 liters of ethanol per hectare[40], but this is under highly favorable circumstances. In Africa, where maize yields are only between 15 and 25% of optimum yields, ethanol yield is more likely to be some 700 liters per hectare. A seventy million liter ethanol plant would require a cultivated area of 100.000 hectares. This is substantially more than for any of the other crops.

[35] Johnson and Rosillo-Calle (2007)
[36] FAOSTAT, http://faostat.fao.org
[37] Johnson and Rossilo-Calle (2007)
[38] Id.
[39] CIAT/FAO
[40] Fresco (2006)

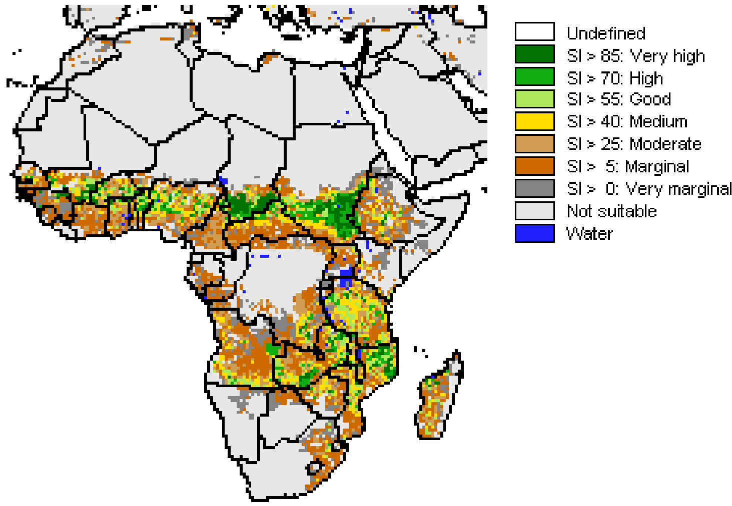

Figure 9: Suitability for rain-fed maize cultivation (source: IIASA/FAI (2002))

An advantage of maize over the other ethanol feedstock is that it is far less perishable and that it can be transported over longer distances at reasonable costs. Therefore, a maize-fed ethanol plant can rely on a much more decentralized area of supply and it is easier to include smallholders into the logistical processes required.

According to FAO, about 25 million hectares are used for maize cultivation in Sub-Saharan Africa. This corresponds with roughly half the size of Madagascar. The biggest producers are South Africa, Nigeria, Ethiopia, Kenya and Tanzania. It seems that there are no operational maize-fed ethanol plants in Sub-Saharan Africa, but the construction of various plants is foreseen in South Africa.[41]

3.2.3. Feedstock sweet sorghum

Sweet sorghum belongs to the same family of grasses as sugarcane and maize. It grows well in drier areas in tropical, subtropical and temperate regions up to 2.500 meters altitude[42]. In tropical areas it is possible to have two harvests a year, as the crop takes only three to four months to mature. The grains of sweet sorghum are traditionally used as a human food crop, while its stalks make excellent fodder.

[41] REEEP (2007)
[42] FAO Ecocrop

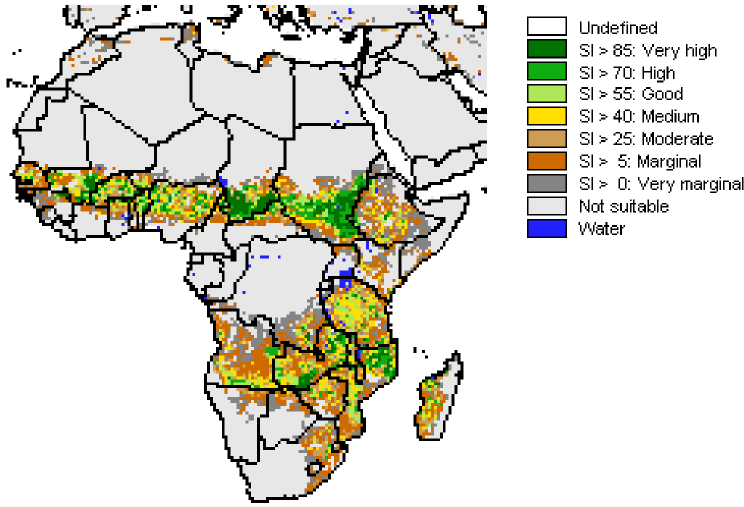

Figure 10: Suitability for rain-fed sorghum cultivation (source: IIASA/FAI (2002))

Sweet sorghum is increasingly used as a feedstock for ethanol. It is particularly attractive as the stalks have high sugar content and can be used to produce alcohol in the way that sugarcane is used. A hectare of sweet sorghum can produce between 3,000 and 6,000 liters of ethanol, provided there are two harvests a year. Irrigation is required in that case. Scientists are even developing sorghum varieties with a higher amount of sugar-rich juice in their stalks[43], which would make sorghum an even more promising crop than sugarcane in terms of energy yield, especially in drier areas.

Sorghum stalks should be processed within one or two days after harvest and have considerable volume. This means that production should be concentrated around a mill, as with sugarcane. A few sorghum-fed ethanol plants are operational in the US, the Philippines and India, but not yet in Africa.

Around 25 million hectares are under sorghum cultivation in Africa, comparable to maize. However, a large part of this surface is cultivated with grain sorghum, a variety less apt for bioethanol production. Nigeria is the biggest sorghum producer in Sub-Sahara Africa counting for 39% of total production. Sudan is second with 21%.[44] Ethiopia and Burkina Faso are also large producers. In all countries, sorghum is mainly a smallholder crop.

Nigeria is entering into large-scale sweet sorghum production for biofuel production. A project by Nigerian National Petroleum Corp. is planning to expand the current 10.000 hectare to a size that could produce 1.5 million liters per day, thereby servicing 5% of Nigerian petrol demand. The company only uses the stalks; grains are sold in the food market.[45]

---

[43] Chege (2007)
[44] FAOSTAT
[45] www.ae-africa.com/read_article.php?NID=149

3.2.4. **Feedstock Cassava**

Cassava is a perennial woody shrub that grows in tropical climates up to 1.000 meters altitude. Its roots can be dug up between six and twenty-four months after planting and are rich in starch. The crop is mainly used as a staple for poor farmers around the world, but is also exported as animal feed. The crop is resilient to poor environmental conditions, such as low rainfall.[46] Figure 11 shows areas that are suitable for cassava production.

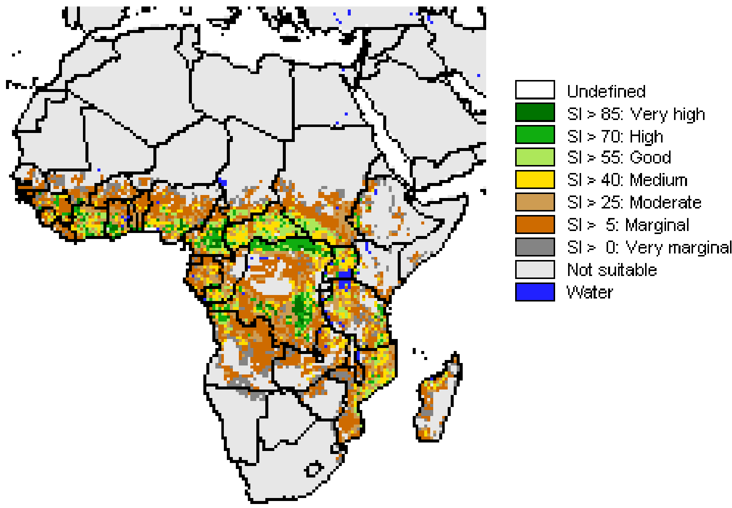

Figure 11: Suitability for rain-fed cassava cultivation (source: IIASA/FAI (2002))

As a biofuel crop, cassava has the advantage that the root can remain in the ground for months without deterioration, allowing for carefully planned and continuous harvest schemes. Once it is harvested, cassava needs to be processed within two to three days.[47] This means that cassava can be grown at considerable distance from the ethanol plant. The roots are not as voluminous as sugarcane or sorghum stalks and cassava is therefore also easier and cheaper to transport. A hectare of cassava can produce up to 5.400 liter of ethanol. Based on the current average cassava production in Africa, ethanol production would be around 1.750 liters per hectare. This is because the bulk of the African production is done at very low efficiency by small family farmers. It is mostly intercropped with other food crops. Farmers hardly use fertilizers and pesticides to stimulate production, as they cannot afford them.[48] If the crop is given more attention, yields could double or triple in Africa.[49]

Cassava is already used for ethanol production in Nigeria in small processing units with capacities varying from 50 to 2000 liters a day.[50] Nigeria aims to produce cassava ethanol worth over USD150 million every year, once it establishes a suitable infrastructure. This includes construction of 15 ethanol plants with assistance from Brazil.[51] In various countries worldwide, researchers are currently trying to improve cassava starch technology.

---

[46] FAO Ecocrop
[47] Clay (2004)
[48] Id.
[49] FAO website
[50] NNPC (2007)
[51] Chege K. (2007)

In Nigeria, Africa's largest producer of cassava (37% of total production), some large-scale cassava plantations exist. Nigeria is followed by the Democratic Republic of Congo, Mozambique, Ghana and Angola.

3.3. Biodiesel crops

Biodiesel can be made from a broad spectrum of crops, e.g. oil palm, jatropha, soybean, coconut, rapeseed, groundnuts, sesame, castor and sunflower. For Africa, we chose to focus on two crops that have potential to be up scaled in the near future:

- Oil palm, because of its extremely high energy yield per hectare
- Jatropha, because this crop is at the center of biofuel attention in Africa

Neither oil palm nor jatropha are important biodiesel crops yet, in comparison with rapeseed, which grows in temperate climates. While oil palm is a well-known crop, growing mainly in Indonesia and Malaysia, jatropha is not. Still it is on everybody's lips. It is said to grow under poor environmental conditions and it is not edible for people or animals so it does not make up part of the food chain.

This section describes some basic characteristics of the crops as biofuel feedstock and Chapter 4 goes into the sustainability claims and risks that surround them.

3.3.1. Feedstock oil palm

Oil palm is by far the most productive source of vegetable oil in the world. The tree has a production cycle of 25 to 35 years and starts to produce fruits after only three to five years. It grows in humid tropical areas up to 700 meters altitude. Figure 12 shows suitable production areas in Africa. Contrary to most other biofuels, this area is limited to Central Africa and parts of the West African coast.

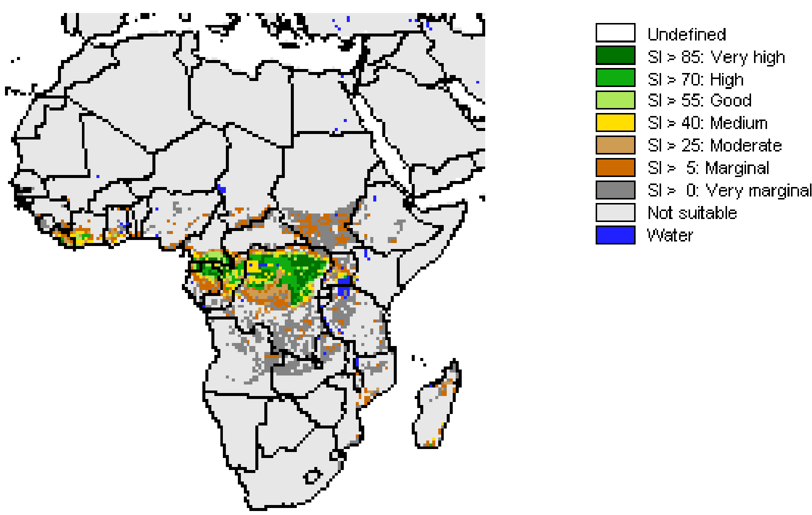

Figure 12: Suitability for rain-fed oil palm cultivation (source: IIASA/FAI (2002))

Oil palm can give a higher energy yield per hectare than any other oil crop. In Malaysia, a hectare can produce nearly 6,000 liters of biodiesel in well managed plantations. African plantations generally have a much lower productivity, averaging less than half this level of production.[52]

Once the fruit of the oil palm is harvested, it should be pressed in a palm oil mill within twenty-four hours to prevent deterioration. As a consequence, oil palm plantations need to be located close to the mills. In Indonesia and Malaysia, the minimum supply area of a mill is 4,000 ha. Smaller mills needing only 400 hectares have also been developed.[53] Due to the necessity of pressing and the high investment cost, oil palm is predominantly produced in plantations or by outgrower systems that heavily depend on them. Once the fruit has been pressed the resulting palm oil can be stored for long periods and can be processed into biodiesel anywhere in the world.

Although twenty-one African countries grow oil palm, its world market share is negligible. Nigeria is the largest producer with a market share of 3%; Ivory Coast and Democratic Republic of Congo follow, both having a market share of around 0.5%.[54] No palm-oil based biodiesel is produced in Africa.

3.3.2. Feedstock jatropha

Jatropha Curcas is a perennial plant with a lifecycle of thirty to fifty years. It can grow in tropical, sub-tropical and semi-arid regions at altitudes of up to 500 meters. It takes three to five years before jatropha produces yields, but after that harvesting is possible every six to twelve months.[55]

Jatropha is drought resistant and can grow in areas where annual rainfall is as low as 300 mm and on poor soils. However, at poor soils and low rainfall, the production of seeds is limited. Rainfall patterns of 1,200 mm and the use of fertilizers on poor soils are more appropriate.[56] With sufficient water and nutrients, two harvests a year are possible. Jatropha is said to be resistant to diseases and pests, but in humid conditions this is not always the case.[57]

Cultivation of the plant started only recently, as it had little relevance to human or animal consumption until the development of biofuels. Jatropha seeds have a high oil content, but they are poisonous to people and animals. Estimates of the productivity of jatropha vary greatly and are based on a limited number of actual field experiences. Generally, pure plant oil yield varies between 400 liters and 2.200 liters per hectare.

The jatropha seeds have to be harvested manually and can be stored for months after drying. They can later be pressed anywhere in the world. The fact that the seeds can be stored makes it an interesting smallholder crop. Seeds can be collected from a large area according to a fixed logistical plan.

[52] Mielke (2007)
[53] Clay (2004)
[54] Mielke (2007)
[55] ECDO (2006)
[56] UNEP et al. (2007)
[57] Jongschaap et al. (2007)

Various projects concerning jatropha cultivation have failed as a result of generating insufficient revenues or meeting farmer resistance to be dependent on one processing plant. Despite these failures, new investments in jatropha plantations are being made around the world.[58] In Ghana, Mali, Tanzania and Mozambique some jatropha plantations exist and pilot projects to produce biofuels from jatropha are being implemented.[59] In Mali a project to generate electricity from jatropha has recently started.[60] Another project in Mali aims at setting up several biodiesel plants with a combined capacity of 55,000 liters per year. They should be supplied through an extensive network of smallholders.[61] In South Africa, different biodiesel plants are under construction that should be supplied with jatropha seeds. Large-scale plantations have been set up within South Africa to provide some of the supply to these plants, with the rest to be imported from neighboring countries.[62] In Ethiopia, the government is trying to attract foreign investments in the biofuel sector. Officially 196,000 hectares of land have been granted for jatropha cultivation, but if one counts land under negotiation, the total increases to 1.15 million hectares.[63]

3.4. Summarizing feedstock characteristics

The following two tables summarize the key characteristics of the feedstocks discussed:

Optimal growing conditions	Ethanol/Oil Yields (l/ha)	Preferential rainfall (mm/year)	Sensitivity to water supply	Fertilizer use	Pesticide use
Ethanol					
Sugarcane	4.000 – 8.000	1.500 – 2.500	High	High	Medium
Maize	700 – 3.000	700 – 1500	High	Medium	High
Sweet sorghum	3.000 – 6.000	400 – 650	Low to medium	Medium	High
Cassava	1.750 – 5.400	1.000 – 1.500	Low to medium	Low/ medium	Medium
Biodiesel					
Palm Oil	2.500 – 6.000	1.800 – 5.000	High	Low	Low
Jatropha	400 – 2.200	600 – 1.200	Low to medium	Low	Low

Table 2: Summarizing yields and necessary inputs of biofuel feedstock[64]

[58] Euler & Gorriz (2004) & Grain (2007)
[59] www.jatropha.de
[60] www.malibiocarburant.com
[61] www.fact-fuels.org/en/FACT_Projects/Mali
[62] EVD (2007)
[63] Grain (2007)
[64] Sources: FAOSTAT, Mielke (2007), FAO&AGL (2002), Clay (2004), FAO/IFAD (2001), FAO Ecocrop, Jongschaap et al. (2007), UNEP et al. (2007)

	Maximum time between harvesting and processing	Required economical scale for competitive biofuel production (Ha)	Mechanization potential	Smallholder potential/ outgrower scheme potential
Ethanol				
Sugarcane	2 days	17.500	Medium	Low
Maize	1 year	N.A.	High	High
Sweet sorghum	1-2 days	15.000	High	Medium
Cassava	2-3 days	15.000	Low	Medium
Biodiesel				
Palm Oil	2 days	400 - 4.000	Low	Low
Jatropha	Several months	400 – 1.000	Low	High

Table 3: Conditions for producing competitive biofuels

4. Potential effects of biofuel production on wetlands and their people

4.1. Introduction

This chapter discusses the potential effects of biofuel production on wetlands and the people depending on these wetlands. The following framework shows the most likely impacts and effects of biofuel production on wetlands.

Biofuel production:	**Activities linked to production:**	**Effects:**	**Impacts:**
- Sugarcane - Maize - Sweet sorghum - Cassava - Palm oil - Jatropha	- Conversion of wetlands - Upstream deforestation - Irrigation - Use of fertilizers and pesticides - Discharge of effluents - Construction of infrastructure	*Environmental effects on wetlands:* - Reduced wetland areas and their functions - Increased risk of flooding - Declining water quantity - Declining water quality (by nutrient/effluent loading and sedimentation) and increased risk of eutrophication. *Socio-economic effects for people depending on wetlands:* - Increased land pressure and conflicts - Decreasing food production - Increased rural employment, improved accessibility and market access - Improved access to energy	- Declining biodiversity - Declining livelihood alternatives from wetlands (income and food) - Livelihood and income changes - Reduced future options (tourism, water storage, etc.) - Health

Figure 13: Framework of, likely environmental and socio-economic effects and impacts of biofuel production on wetlands

When the production areas for biofuels expand in a certain region in Africa, different activities related to this production can affect the state of the wetlands in those regions. For example, the use of fertilizers on a production site of maize can cause nutrient to leach into nearby rivers. The increased level of nutrients in the river can lead to declining water quality by the absorption of oxygen in the water (eutrophication). This can kill most aquatic life, such as fish. The declining fish population will have severe impacts on people who depend on fisheries for their food and income. The diminishing water quality can also affect people's health and the overall biodiversity in wetland ecosystems. These effects and impacts can be felt all over the downstream wetland ecosystems of the specific production site.

The probability and magnitude of the different environmental and socio-economic effects vary greatly according to many different factors such as environmental and ecological circumstances, crop, scale of production, agricultural and processing techniques. This makes it difficult to quantify the impact of biofuel production on wetlands. Still, based on the crop characteristics in the previous chapter it is possible to distinguish per crop whether or not a certain effect is likely to take place. The following table gives an overview of whether some production related activities that can have positive and negative effects on wetlands are likely to occur.

Activities linked to biofuel production	Wetland conversion	Irrigation	Fertilizer and pesticide use[65]
Ethanol			
Sugarcane	High	High	High
Maize	Low	Medium to high	High
Sweet sorghum	Low	Medium	High
Cassava	Low	Low	Medium
Biodiesel			
Palm Oil	High	Low	Low
Jatropha	Low	Medium	Medium

Table 4: Likeliness of biofuel production related activities

The next sections discuss the most likely environmental and socio-economic effects of biofuel production on wetlands.

4.2. Environmental effects of biofuel production on wetlands

Direct effects can be attributed to a specific plantation or plantation area in a wetland itself or outside the wetland. Three of the most serious environmental effects of biofuel crop cultivation will be discussed in further detail:

- Reduced wetland areas and their functions
- Declining water quantity
- Declining water quality and increased risk of eutrophication

All three can lead to biodiversity loss and ecosystem damage. All three can have an impact on people living in the wetland areas. The exact nature and magnitude of these effects depends on the biofuel crop characteristics and the agricultural practices applied.

[65] Without Integrated Pest Management and Integrated Soil Fertility Management

4.2.1. Less space for natural habitat, fisheries, livestock and agriculture

Wetlands provide good natural conditions for many agricultural crops. There is an abundance of water and soil fertility is often high. As a consequence, natural wetlands are under threat of conversion to agricultural areas.

Sugarcane flourishes best in tropical wetland areas. It requires large amounts of water almost year-round. Sugarcane can only be produced when large plantation close to a mill can be developed. Often this is only possible outside current agricultural areas where land rights will frustrate the establishment of large plantations. Both factors make conversion of natural wetlands attractive. Sugarcane is perhaps the single most important crop responsible for the conversion of tropical ecosystems.[66] Reports from Tanzania, Uganda[67] and Kenya[68] show that African wetlands are currently under threat of large-scale sugarcane expansion. In Kenya, a plan has been launched to develop 20.000 ha of the 130.000 ha Tana River Delta into sugarcane to feed a planned ethanol plant. In Tanzania, plans exist to plant 400.000 hectares of sugarcane for ethanol in the Wami Basin, one of the country's major wetlands. The project will inevitably displace local small-scale rice farmers.[69]

Oil palm can also grow in wetland areas and often replaces tropical rainforest. But the environmental impacts can go further than deforestation. This crop also needs to be grown in large areas and close to a mill to be economically viable. Rainforests and wetlands are often the remaining areas where the natural conditions are suitable for this crop and where plantations of thousands of hectares can be developed without problems with land rights. When planted on peat swamp areas, the drainage systems to maintain water levels on plantation sites can severely change the hydrology outside the plantation systems.[70] In Africa, such peat swamp forests exist in Nigeria, the Democratic Republic of Congo and Ivory Coast. Deforestation also leads to the emission of greenhouse gasses, because essentially all above ground natural vegetation is released into the atmosphere. Overall, the clearing and planting of peat soils contributes disproportionately to carbon emissions.[71]

4.2.2. Declining water quantity

The effect of the feedstock production on the quantity of water for wetlands depends mainly on the water requirement of the feedstock related to the relative scarcity of water in a specific water basin.

All crops need water to grow, but in many places rain conditions are not sufficient to produce maximum yields. Therefore, irrigation is often applied. Water is either withdrawn from for instance wetlands like lakes or marshes directly, or from the rivers feeding into these. Research at the International Water Management Institute (IWMI) in Sri Lanka has shown that, to produce one liter of biofuel between 1.000 and 4.000 liters of water is evaporated, depending on the type

[66] Clay (2004)
[67] ABN (2007)
[68] Guardian
[69] Grain (2007)
[70] ProForest (2003)
[71] Wetlands International (2007)

of feedstock and conversion techniques used.[72] When large areas of crops are irrigated, the supply of freshwater can therefore be structurally reduced. For example, in Zambia, Zimbabwe and Mozambique, 60% of total water supply in the Zambezi river basin is used for sugarcane production.[73] The construction of irrigation related infrastructure such as dams and dikes can further deregulate the hydrological cycles that are vital to wetlands.

Water requirements differ from crop to crop. Of all ethanol feedstock, sugarcane requires the largest amounts of water. Table 5 shows the water requirements of three ethanol crops.

Crop	Crop duration	Water requirement (1000 liter/ha)	Ethanol yield (l/ha)	Water requirement water in liters per liter ethanol
Sugarcane	12 months	36.000	8.925	4.000
Maize	4 months	8.000	3.216	2.500
Sweet sorghum	4 months	4.000	3.160	1.300

Table 5: Water requirements of main bioethanol crops (Source: Dar, 2007)

The above figures show that one liter of ethanol sugarcane demands 3 times more water than one liter of sweet sorghum. Other research has shown that sugarcane in Brazil evaporates around 2.200 liters for every liter of ethanol. In this water-rich region, the demand is easily met by abundant rainfall. In more arid countries, irrigation must make up the shortfall. In India, for example, a liter of sugarcane ethanol requires 3.500 liters of irrigation water.[74] In Africa, irrigation is needed in most countries, as rainfall is either not sufficient or sufficiently continuous.

Maize demands less water than sugarcane and can be grown in drier areas. Maize is drought tolerant up to five weeks, but thereafter it is very susceptible. As a consequence, maize is often irrigated.[75] When irrigated, water loss mainly occurs through evaporation during application.

Sweet sorghum requires less water than maize and is more drought tolerant. If sweet sorghum is to compete with sugarcane as a feedstock, two harvests a year will be necessary. In most regions, this will require irrigation.

Cassava is hardly irrigated at all and grown mainly in areas where it has sufficient rainfall. Therefore the impact of cassava culture on the water availability is expected to be limited.

Oil palm is a perennial tree with a long life cycle. Although its water requirements are high, the tree is rarely irrigated, as it grows only in the humid tropics where there is enough rainfall.

Jatropha is drought tolerant but its productivity in drier areas responds well to irrigation.[76] This makes irrigation schemes an economically viable option in areas where access to irrigation water is affordable. This can be expected to be the case near wetland areas, where water is abundant. This extraction can lead to drying out of wetland areas.

[72] De Fraiture (2007)
[73] Harrison & Guttenstein (2005)
[74] De Fraiture (2007)
[75] CIAT/FAO
[76] www.jatrophabiodiesel.org

Tanzania: Wami Basin
According to Tanzania Investment Centre a Swedish company is looking for 400.000hectares of land for sugarcane production. One area identified so far is the Wami Basin, a vast area in the alluvial flood and delta plain of the Wami River and its distributaries as it enters the Indian Ocean. This area has good access to water, and is currently used for rice production. Should the proposed plantation go ahead, then about a thousand small scale rice farmers could be evicted and wildlife be endangered.

Source: (1) AGROfuels in Africa –The impacts on land, food and forests Case Studies from Benin, Tanzania, Uganda and Zambia, African Biodiversity Network, July 2007 / Grain (2007)

Although palm oil does require large amounts of water, its impact on the water availability of wetlands is limited as it is grown in areas with abundant rainfall. For sugarcane, maize, sweet sorghum and jatropha irrigation can be economically viable in areas where rainfall is insufficient or irregular. In those regions, production is likely to be concentrated along riversides, lakes or other types of wetlands. The impact of such irrigated cultivation on the quantity of water can be enormous, as the example of sugarcane production in the Zambezi river basin shows. When grown in drier regions, large scale irrigated sweet sorghum, maize and jatropha can also have an important impact on the scarce available water resources and thus on wetlands in those areas. The wetlands in Senegal, upper Niger, Lake Chad and Nile basins and the drier parts of Southern Africa are particularly sensitive to water withdrawal. Meanwhile some countries in these regions have no other option than to irrigate when they want to turn to large-scale biofuel production.

Apart from cultivation, the demand for water in processing units is high as well. Ethanol production in particular demands considerable amounts of water for boiling the feedstock and for other processes.

4.2.3. Declining water quality

Water quality can be negatively impacted by biofuel crop production in two ways: sedimentation and eutrophication. Sedimentation of wetlands can be caused by erosion on biofuel production sites upstream of rivers that feed into the area. Eutrophication can be a result of two things. First, of nutrient leaching caused by inappropriate fertilizers. Second, of the release of wastewater or effluent from the ethanol plant or the oil palm mill. Eutrophication leads to the absorption of oxygen in the water, killing aquatic life. Both negative impacts can be seriously reduced or even avoided with good management practices, but this requires farming skills and investments that smallholders often lack. A focus on short term profitability and a credit crunch that is typical for starting plantations can lead to negligence of the issue of soil and water deterioration.

Sugarcane cultivation has a tremendous impact on soils as they are laid bare to be planted with cane, causing the soil to dry out and lose fertility. The continuous removal of cane from the fields gradually reduces fertility and forces an increasing use of fertilizers. Exposed top soils are easily washed away and nutrient runoff from sugarcane cultivation has led to nutrient loading and eutrophication of freshwater and marine systems.[77]

[77] Clay (2004)

Sorghum is also one of the most chemically dependent of all agricultural crops. Many types of fertilizers and pesticides are used in sorghum production. Without proper use of fertilizers or manure, soil fertility can however decline significantly over the years. Effluent from sorghum silage has a very high biochemical oxygen demand and in surface water it can kill many freshwater organisms. Sweet sorghum also has a high potential for soil erosion.[78]

The fertility demands for maize are relatively high and should be maintained continuously. Maize is also subject to many diseases and has to compete with weeds, making the use of pesticides and herbicides necessary. The monoculture of maize provides little soil cover, which increases the risks on soil erosion and nutrient leaching.[79]

The soil impact of cassava production is expected to be limited when it continues to be grown by smallholders using little to no fertilizers and pesticides. When it is grown on a large-scale, the use of fertilizers, pesticides and herbicides might become an economically interesting option, increasing the risks on nutrient leaching and pollution of nearby streams. Cassava does not produce enough vegetation to cover the soil well. This can result in considerable soil erosion during the life time of the plant.[80]

Benin

Plans for the development of an agrofuel industry in Benin have the strong backing of government, and make up a key part of the government's Agricultural Revival Programme for economic development.

Various industrial groups from Malaysia and South Africa have made visits to Benin to assess the opportunities to grow biofuels. They have proposed the conversion of 300.000-400.000 hectares in the wetlands of the Southern Part of Benin, for production of palm oil.

Source: AGROfuels in Africa –The impacts on land, food and forests Case Studies from Benin. African Biodiversity Network, July 2007

With oil palm, the biggest risk of erosion is during land clearance, disturbing stream-flow and increasing sediment loads in rivers and streams. Soil erosion is five to seven times greater during clearance, while sediment loads in rivers increase by a factor of four.[81] Although some of these impacts are temporary, the pressure on river and coastal ecosystems remains significant.[82] In terms of eutrophication, the discharge of palm oil mill effluent is important. If this is not well stored, it can pollute waterways having significant negative effects on aquatic life downriver.[83]

The cultivation of jatropha can actually contribute positively to the soil fertility of marginal soils, by bringing nutrients from deeper layers to the top soil.[84] The use of fertilizers, pesticides and water probably remains limited if it is not produced on an industrial scale. However, jatropha

[78] Clay (2004)
[79] Clay (2004)
[80] Clay (2004)
[81] Henson (2004)
[82] Wakker (2004)
[83] Wakker (2004)
[84] Jongschaap et al (2007)

extracts considerable amounts of nitrogen from the soil. So, when grown in high concentration, it would need fertilizer and there would be a considerable risk of nutrient leaching.

4.3. Socio-economic effects of biofuel production on people that depend on wetlands

Millions of African people depend on wetlands for their livelihood They depend on the availability of fresh and clean water for domestic use and irrigation, using the areas for seasonal grazing or agricultural lands or for fishing. The rise of biofuels may be both an opportunity and a threat to them. Biofuel development could increase economic growth, but everything comes at a cost. Whether local communities stand to win depends on the distribution of benefits and costs. We hear both positive stories, for example from Mali[85] and Tanzania[86]. We also hear negative stories coming from other countries.[87] Some African NGOs even propose a moratorium on African biofuels, because they fear African communities may bear the cost, while others get to benefit.[88] This fear is not far-fetched in countries that have relatively weak institutional structures for protecting their citizens.

In this quick scan we look at positive and negative effects that may stem from biofuel expansion in or near African wetlands. We identified three main effects:

- Increased land pressure and conflicts
- Decreasing food production
- Increased rural employment, improved accessibility and market access

Biofuel crop production can have a negative impact on the land availability for local communities in wetlands. Crops that are highly appropriate for monoculture cultivation in particular (sugarcane, oil palm, sweet sorghum, maize), may breach communities' land use rights. Land-use rights are often not formalized, but contain the customary rights to use community land for cattle ranging, firewood collection, fishing and shifting cultivation. Community land thus provides an essential resource for millions of Africans and private use of it is bound to lead to land rights conflicts. Obviously, this is more likely to happen where land resources are scare, i.e. in areas with high population density. As was explained in the previous chapter, this is an incentive for feedstock producers to develop plantations in more sparsely populated areas.

Land right conflicts can still occur in sparsely populated areas, where people are often even more reliant on community land. But a secondary effect can further increase land pressure in case of plantation development in such areas. Most crops require a considerable amount of manual labour. As this is not prevalent in areas with low population densities, labour migration is triggered. The newcomers will increase pressure on available communal natural resources such as land, water and firewood. This often leads to friction or even conflict between the original inhabitants and the migrant labourers.

---

[85] www.malibiocarburant.com
[86] www.diligent.nl/
[87] ABN (2007); Gaia Foundation.
[88] http://www.gaiafoundation.org/documents/Africaagrofuelmoratorium.pdf

Ivory Coast - Tanoé Swamps Forest
The Tanoé Swamps Forest covers approximately 6.000 hectares between the Ehy Lagoon (to the West) and the Tanoé River (to the South and the East) and is the only relatively large forest block remaining in the South-eastern corner of Côte-d'Ivoire. This High Conservation Value Forest, representing a precious asset for the promotion of sustainable development in the region, is currently under an alarming threat posed by PALMCI, a palm oil company which has started the replacement of the whole Ehy forest by a palm oil plantation without any study of environmental impact, and ignoring the disagreement of numerous local peoples.

Source: Manifesto for the Conservation of the Tanoé Swamps Forest, a poorly known High Conservation Value Forest in south-eastern Côte-d'Ivoire
http://www.manifeste-fmt.org/fichier/manifesto.pdf

4.3.1. Food safety

Food safety for communities in wetland areas may be jeopardized as a result of feedstock production. Although the indirect effects of biofuel production on food safety (see 4.2) are probably more serious in general, localized impacts of large-scale biofuel feedstock production can also be serious. Little research has been performed on this topic, but various effects can be foreseen. First, local food production can be displaced by production of biofuel crops if local farmers loose their land, either by selling or being expropriated, or if they switch to biofuel crop production themselves. This disrupts the local food market, necessitating imports and probably resulting in higher local food prices. Second, local food production can be affected by decreased availability of water (see 4.2.2), which is already a limiting factor for agriculture in large parts of Africa[89]. Third, food produced on community land can become less available if this is used for biofuel crop production. In wetlands in particular, fisheries may be affected. Eutrophication, sedimentation (4.2.3) and water drainage can lead to lower fish stocks. Fish being a major part of many wetland communities' diet, the impact of this can be considerable.

4.3.2. Increased rural employment, improved accessibility and market access

While increasing biofuel feedstock production in Africa entails risks for people in wetlands and their environment, it can also bring economic benefits. We have already pointed out that biofuel production can improve the trade balance of African countries, by substitution of oil imports and stimulation of export. Import substitution makes countries less dependable on the volatile and increasingly stressed oil markets, thereby providing a more stable macro-economic business environment.

Besides these macro-economic benefits, the production of biofuel crops would lead to the creation of rural employment. The magnitude of this effect depends largely on two factors: the type of feedstock that is produced and the production methods.

[89] IEA (2006)

Table 6 shows the number of jobs created per 100 hectares in Brazil for various crops. Although labor productivity is much higher in Brazil, it gives a sense of required labor input. In general, biofuels have a lower labor input than food crops, which is necessary in order to remain competitive. As corn and sugarcane production are highly mechanized in Brazil, figures for Africa would probably look slightly different. Jatropha is more comparable to castor beans, a related species of oil producing seeds.

Activity	Number of jobs	Activity	Number of jobs
Cattle for meat	0.24	Orange	16
Eucalyptus	1	Castor Bean	24
Soy	2	Potato	29
Corn	8	Manioc	38
Sugarcane	10	Coffee	49
Bean	11	Onion	52
Rice	16	Tomato	245

Table 6: Number of jobs created per 100 hectares in Brazil for various crops. (Source: Bebb et al, 2008)

The employment benefits depend strongly on the degree of mechanization of their cultivation and harvesting. A high degree of mechanization leads to low labor inputs. The biofuel crops under consideration in this report differ in terms of mechanization potential. Maize, sugarcane and sweet sorghum are crops that are produced in a highly mechanized way outside Africa. This is not yet common in Africa and in many places not very likely, first, because labor input is still cheap in Africa and, second, because mechanization requires the availability of qualified labor. Also, maintenance of machinery is a challenge in Africa as there is a lack of spare parts and service agents. Oil palm can never be fully mechanized, as the harvest of fresh fruit bunches requires precision work. The mechanization rate of cassava production is also likely to remain limited. Although it is imaginable that jatropha planting and harvesting can be mechanized, this will only happen in the long term. As this crop has only been cultivated commercially for a few years, no mechanical equipment has yet been developed. Its development would require serious investments, as harvesting is precision work.

Economic benefits also depend on the type of production system used. We differentiate between:

- Monoculture cropping
- Organized small producers
- Monoculture with outgrower schemes

Monoculture cropping is possible for all crops under consideration and almost necessary for sugarcane, oil palm and sweet sorghum. This is explained by the fact that these are perishable voluminous crops, which therefore have to be produced near a mill or an ethanol plant. These mills and plants require large inputs in order to achieve sufficient economies of scale. Monocultures generally have lower labor input than small scale farming. The labor input is provided by employees who get a fixed salary per day or, more often, get paid according to their harvest. Monoculture farming is often associated with poor labor conditions, particularly if it concerns low-skilled migrant workers.

Small producers can be organized to produce biofuel crops on a large scale. They can form cooperatives or their individual supply can be organized by a biofuel producer. The latter are often referred to as *outgrower schemes*. Small farmers can integrate biofuel crop production with their regular production as a cash crop. Depending on the nature of the deal between the farmer (or cooperative) and the client, this can be either more or less beneficial to farmers than becoming a day laboror on a plantation. Often, the client would supply farmers with seeds, fertilizers and agronomic advice, as farmers cannot make these investments themselves. After harvest, they are often supposed to pay back those investments to their client. The examples of this production system common for certain crops in Africa, most notably cocoa and cotton, prove that it is not automatically good for farmers, as there is often a strong dependence of the farmer on their client. However, it is one of the few ways that African farmers can grow crops for cash and the system can be organized in ways that are beneficial to the farmer. The farmer then remains more independent than the day laborer in the monoculture system and is less likely to be exploited. If the farmer eliminates his production, the biofuel plant risks becoming short of supply, resulting in increasing production costs. Maize and jatropha are the biofuel crops that are most suitable for smallholder production. The seeds that form the input for biofuel production can be stored for considerable times after harvesting, allowing a systemized collection over longer period and thus continuous inputs for the biofuel plant.

Monoculture with outgrower schemes is an intermediate way of producing biofuel crops. In this system, a plant’s basic feedstock load is supplied by a large scale plantation in order to create security of supply. Additionally, farmers or cooperatives can supply the plant with feedstock through outgrower schemes. In this case, the relationship between the processing plant and the farmers is more skewed, as the plant has assured its basic production load. There is a risk that this results in dependence and sub-optimal benefits for the farmer. All biofuel crops can basically be produced through this production system; the more perishable the crop, the bigger the dependence of the farmer on the mill or ethanol plant.

4.4. Effects of global bio-energy production on food security

While the production of biofuel crops in Africa does generally not compete with food crops directly, the rise of biofuels does have an effect on African food security. This effect is mostly indirect.

The United States and the European Union previously used land only for food production, often leading to overproduction. Excess production of grains (corn, wheat) was exported to many food-importing countries in Africa at rock bottom prices. This kept food affordable, but drove African farmers out of business as they were not able to compete with heavily subsidized grains.

Now, the US and EU are allocating considerable parts of their agricultural area to the production of biofuels. The excess capacity of grains has disappeared, seriously driving up commodity prices. Imports are becoming unaffordable to the African population and their domestic production capacity is insufficient to increase production in the short term. While the rising food prices benefit the African farmers, the increasing urban population suffers from decreased access to food.

For vegetable oils the story is somewhat more complicated. Ninety percent of biodiesel-production is based on rapeseed oil. The resulting decreased availability of this vegetable oil has increased demand for a highly efficient alternative: palm oil. This has spurred the production of oil palm worldwide.

The trends above show that Africa may suffer from the biofuel boom, even if no biofuel crops are grown large scale in the continent. The indirect effects, as they are often referred to, should be tackled at high policy level and it is impossible to manage them through certification.[90]

Issue: Tana River Delta in Kenya

In Kenya plans have been developed to transform a part of the Tana River Delta into sugarcane plantations. The Delta, covering 130,000 hectares in total, is one of Kenya's largest and most important freshwater wetlands. It is a vast patchwork of habitats including savannah, forests, beaches, lakes, mangrove swamps and the Tana River itself. Local people live by the seasons, adapting to the regular floods that keep the area fertile through the year. The proposed plans comprise the transformation of 20.000 hectares of the Tana River Delta into irrigated sugarcane together with the construction of sugar and ethanol plants. According to the RSPB at least one third of the Tana's waters will be diverted. The effects would be soil erosion, sedimentation and pollution, leaving people and wildlife competing for the clean water and remaining productive land.

Source: www.rspb.org.uk, February 2008

[90] Bebb et al (2008)

5. Assesment of likely expansion areas for biofuel production in or near African wetlands

5.1. Potential biofuel expansion areas in Africa

In this section, we try to determine which areas are likely to see expanding biofuel crop production. Although there are many factors contributing to such development, we have identified three factors that can give an indication:

- Magnitude and nature of biofuel demand
- Population density (available labour force)
- Available infrastructure

The most important factor has already been treated in section 3.3: natural growth conditions. The maps in figures five to seven show a remarkable division between crops. Palm oil and sugarcane are most productive in the humid tropics of the Congo Basin and the coastal regions of West Africa. Sorghum, cassava, maize and jatropha flourish better in the dryer tropics and subtropics. Despite natural growth conditions being as they are, the actual production centers for these biofuel crops are often located elsewhere. For example: South Africa is Africa's largest sugarcane producer as is Nigeria for palm oil, although the natural condition for this range from marginal to moderate at best. This is because irrigation, fertilization and agricultural techniques make it possible to profitably grow crops in areas that are less suitable in terms of natural conditions. It turns out that population density, market demand and infrastructure may be better indicators of crop production areas.

5.1.1. Magnitude and nature of biofuel crop demand – land requirement

We sketched two scenarios in Chapter 2 for demand levels in 2020. Although it is uncertain if they will be realized, they can serve as a proxy for estimating how many hectares would be needed to grow biofuel crops. These estimates are based on average crop yields in Africa and general energy conversion rates.

<u>Import substitution scenario</u>

The import substitution scenario assumes that all Sub-Saharan African countries substitute 10% of their 2020 demand for fossil transport fuels for biofuels. With current yields, this would require an agricultural area of between 3 million and 11 million hectares. This corresponds to the size of Lesotho and Malawi respectively, two fairly small African nations. The large difference in land requirement can be explained by the types of feedstock that are used. This becomes apparent from Table 7.[91] Ethanol demand of over 5.6 billion liters would require 'only' 1.4 million hectares if the ethanol is made of sugarcane, but over 8.5 million hectares if maize serves as a feedstock.

[91] For overview of all African countries, please refer to Annex A.

Country	Ethanol demand in millions of liters in 2020	Required area for 100% sugarcane in 1000 ha	Required area for 100% maize in 1000 ha	Required area for 100% sweet sorghum in 1000 ha	Required area for 100% cassava in 1000 ha	Available agricultural land in 1000 ha (FAO)	Required area for 100% sugarcane ethanol in % of total available agricultural area
Nigeria	1.754	440	2.633	510	994	n.a.	
South Africa	2.279	571	3.421	662	1.292	83.900	2,7
Tanzania	52	13	78	15	29	48.900	0,1
Sub Sahara Africa	***5.667***	***1.420***	***8.509***	***1.647***	***3.213***	n.a.	

Table 7: Land requirements for ethanol under import substitution scenario

Nigeria and South Africa will become the major markets for biofuels in this scenario. It is probable that these countries can produce serious quantities of biofuels themselves and the previous chapter mentioned that they are preparing to step up production. According to the FAO figures, there is enough agricultural land available that is currently not used. If total South African ethanol production was supplied by domestic sugarcane, it would require 2.7% of South Africa's available agricultural area. We defined this as agricultural area minus cultivated area. In FAO's definition, this would be equal to temporary and permanent pastures. FAO notes that the figures do not provide any indication of the suitability of the land for particular purposes. This is important, as water and soil quality could prove to be more serious constraints than the available quantity of land. Anyway, in the case of South Africa, FAO says that 82% of the total land area is classified as agricultural and 12.9% is cultivated.[92]

It is likely that countries north of South Africa will also supply the South African market. Due to the availability of affordable land and labor and the well-developed overland logistical ties with South Africa, Mozambique and Zimbabwe in particular could become large exporters.

For countries with large land banks and a relatively small population, such as Tanzania, the production of biofuels would require only a minor investment in terms of land. Again, it should be kept in mind that the quality of available land resources may prove to be a larger constraint. Pastures are also often used by local communities and nomadic people for cattle breeding or part of a slash and burn way of cultivation. Due to poor land use planning, this information is often unavailable. This makes the figures above look more positive than they will be in reality, but the potential nevertheless remains present.

Table 8[93] gives the figures for the required acreage for biodiesel crops under the import substitution scenario. The same observations about land availability regarding ethanol are valid for biodiesel. The difference that should be kept in mind is that the most attractive biofuel crop in terms of energy per hectare, oil palm, can only grow in large quantities in a limited number of countries.

[92] Johnson and Matsika (2006)

[93] For overview of all African countries, please refer to Annex B.

Country	Biodiesel demand in millions of liters in 2020	Required area for 100% oil palm in 1000 ha	Required area for 100% jatropha in 1000 ha	Available agricultural land in 1000 ha (FAO)	Required area for 100% oil palm biodiesel in % of total available agricultural area
Nigeria	403	166	269	n.a.	
South Africa	1.243	511	829	83.900	1,5
Tanzania	116	48	77	48.900	0,2
Africa	***4.044***	***1.663***	***2.696***	n.a.	

Table 8: Land requirements for biodiesel under import substitution scenario

Figure 14 shows the required increase in production areas for biofuel crops in relation to the current production area. If all ethanol is to be made of maize, this would result in a 25% increase in maize acreage. Sugarcane area would have to double and palm oil would also grow by 25%.

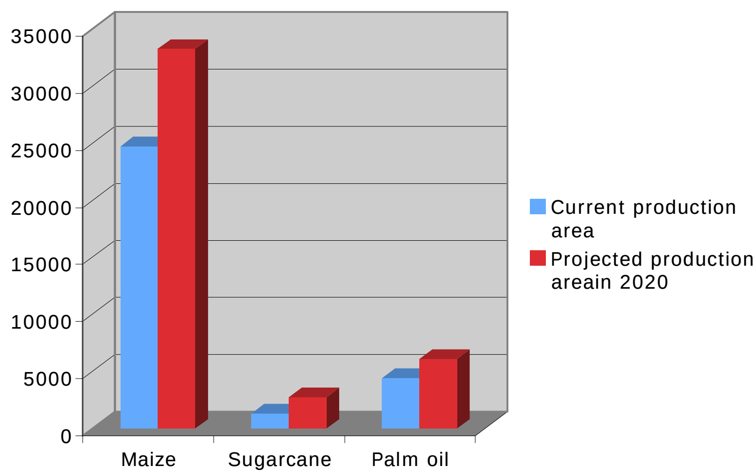

Figure 14: Current and projected production areas in 1.000 hectares under import substitution scenario, assuming all ethanol and biodiesel are produced from one crop only.

For the export driven scenario, assuming that 5% of US and EU biofuels will be supplied by Africa, the land requirements would range between 3 million and 14 million hectares. Tables 9 and 10 show US and EU land requirements for ethanol and biodiesel.

Demand	Ethanol demand in millions of liters in 2020	Required area for 100% sugarcane in 1000 ha	Required area for 100% maize in 1000 ha
United States	6.600	1.654	9.910
European Union	1.450	363	2.177
Total	8.050	2.018	12.087

Table 9: Land requirements for ethanol under export driven scenario

Demand	Biodiesel demand in millions of liters in 2020	Required area for 100% oil palm in 1000 ha	Required area for 100% jatropha in 1000 ha
United States	1.650	678	1.100
European Union	1.100	498	733
Total	2.750	1.176	1.833

Table 10: Land requirements for biodiesel under export driven scenario

The bulk of demand would come from the US in this scenario. Since the US is mainly a gasoline market, rather than a biodiesel market, ethanol crops would dominate export production. This is also the biofuel with the largest variety in yields. If all ethanol were to be produced from maize, the area under maize cultivation would grow by 50% (see Figure 14). For sugarcane, the increase would even be bigger (more than double), but in terms of total hectares, this would have a less severe effect.

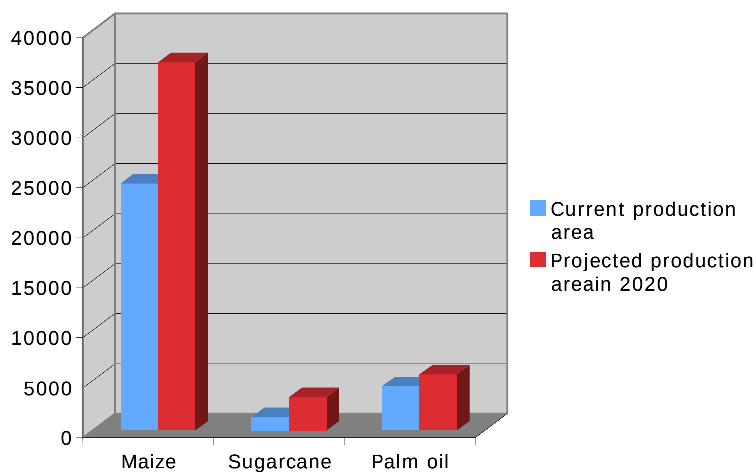

Figure 14: Current and projected production areas in 1.000 hectares under export driven scenario, assuming all ethanol and biodiesel are produced from one crop only.

It is important to realize that all projected land requirements above have been based on current average yields in Africa. For all crops, African productivity per hectare is below world average levels (Table 11). With improvements in agricultural techniques, productivity increase would lead to a decrease in land requirement. This is particularly valid for maize and palm oil. It is likely that biofuels will at least partially be cultivated in large-scale farms, which means higher productivity and thus lower land requirements than projected in Tables 7 to10.

Source	Productivity Sub Sahara Africa as % of average global productivity
Ethanol	
sugar cane	90%
cassave	78%
sweet sorghum	67%
maize	35%
Biodiesel	
oil palm	57%
jatropha	n.a.

Table 11: Productivity of Sub-Saharan Africa biofuel crop production compared to world average (Source: FAOSTAT; Mielke (2007) for oil palm).

5.1.2. Population density

Population density, as an indicator for biofuel production, gives conflicting results. On the one hand, a high population density is favorable. It means that there will be high demand for biofuels, which is particularly important in case of import substitution. It also increases the availability of labour, which is relevant as most biofuel crops are labour intensive. Although many crops can be harvested mechanically, this is unlikely in the African context: there is a lack of qualified labour and spare parts for mechanical production, while manual labour is cheap.

On the other hand, high population densities mean low availability of agricultural land. Most African people produce their own food to a large extent and therefore use at least one or two hectares per family. Finding a concentrated piece of land of 4.000 – 17.500 hectares that is necessary to facilitate an oil palm mill or an ethanol plant will be difficult in populated areas. Where this happens, it will often result in land use conflicts. Land use conflicts often result in sabotage of plantations through intentional burning by local communities that are deprived of their land.[94] Starting large scale production of biofuel crops in densely populated areas is therefore deemed too risky by plantation developers. Instead, they are more likely to move into less populated areas, often with a high natural value. Recent plans for conversion of the Mabira Forest in Uganda[95] and the Tana wetlands in Kenya[96] confirm this trend. Seasonal labour will flow into the area for harvesting and other activities. This trend is seen in oil palm plantation development in Indonesia as well. This risk is smaller for jatropha and corn, which can be produced in a more decentralized manner, particularly if smallholders are involved.

Figure 15 shows the population density of Sub-Saharan Africa. Based on the logic outlined above, it would be improbable that biofuel expansion would expand greatly along West Africa, the Ethiopian Highlands, the area around Lake Victoria and the East of South Africa. Still, relatively unpopulated areas within these regions may be at risk. Land conflicts stemming from biofuel crop production are reported from Benin[97] and Ghana[98]. The rest of Africa would be attractive from this point of view, given that areas are suitable for crop cultivation.

[94] Sefawa (1982)
[95] ABN (2007)
[96] Guardian (2008)
[97] ABN (2007)
[98] Gaia Foundation

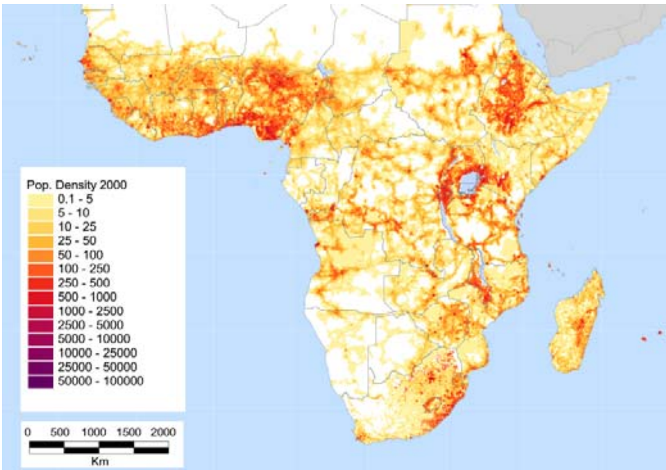

Figure 15: Population density in Sub-Saharan Africa (Source: UNEP/CIESIN 2004)

5.1.3. Infrastructure

A sufficient infrastructure is essential for transporting the feedstock to the processing plant (be it a mill or an ethanol plant) and from there to consumer markets. Johnson and Matsika[99] note that lacking infrastructure is one of the most important constraints for biofuel expansion in Africa. Still, some African areas are better positioned than others

If biofuels would be mainly produced for the domestic markets, infrastructure requirements would mostly consist of roads and railways. Figure 16 shows the African railroad network and Figure 12 depicts the African road network. If the export market is to be supplied, deep sea ports allowing for 50,000 MT ships would be required in order to keep transport costs at competitive levels. Given the size of these vessels, biofuels would probably have to be delivered in the harbor by train.

Most countries in Africa have a harbor, road and railway networks. They are concentrated in populous areas and are generally interesting from a logistical point of view. Even more popular would be more sparsely populated countries that still have a well-developed infrastructure. The East African coast springs out as an example. It has various railways leading up to deep sea ports, while having a relatively high availability of underutilized agricultural land. Mozambique in particular is well positioned due to its vicinity to Africa's largest consumer market of South Africa.

The Congo basin, a potentially attractive, sparsely populated production area from a productivity point of view (oil palm, sugarcane) has poor infrastructure, making it less likely that this area will be used for large scale production before 2020. Infrastructure requires enormous investments and major biofuel crop production countries such as Brazil and Indonesia are more likely to attract such investments.

[99] 2006

Figure 16: African railroads (Source: Exploring Africa[100])

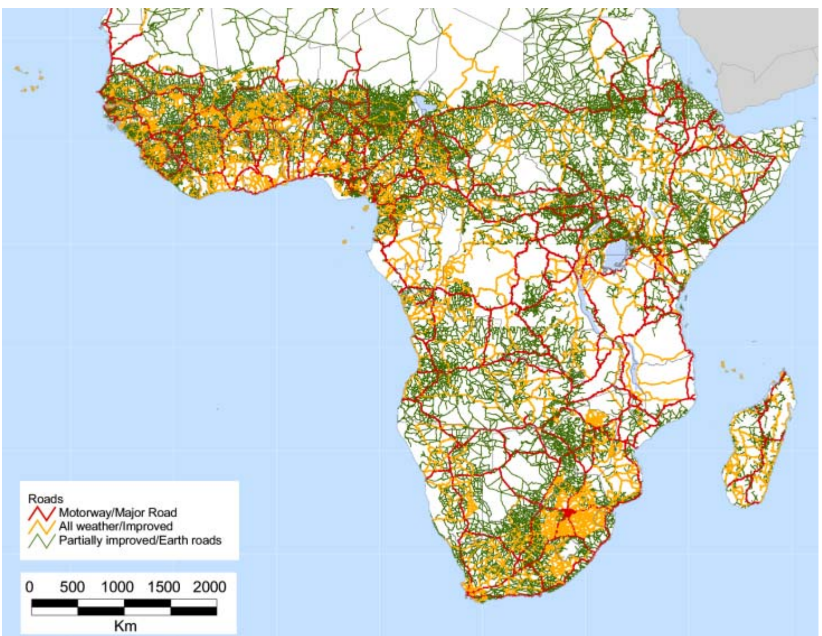

Figure 17: African road network (UNEP/CIESIN, 2004))

[100] Published on http://exploringafrica.matrix.msu.edu

5.1.4. Summary: expansion of biofuel production in or near African wetlands

It is difficult to predict the probability and magnitude of the effects of potential biofuel production on African wetlands in quantitative terms. The total area needed to satisfy the demand presented by the import substitution and/or export scenarios is rather small compared to the available land. However, on a local scale they can pose a threat to wetlands. Based on the data presented in this assessment several potential risk zones can be identified.

The most eminent risks for African wetlands seem to be the expansion of the most productive ethanol and biodiesel crops, sugarcane and palm oil. Both crops need to be cultivated in large plantation areas, close to a processing unit due to their perishability. For such plantation schemes large production areas are needed. It is expected that production will expand progressively towards less populated and remote areas. Wetlands and rainforests in those areas can be at risk in several ways. First, they can be converted into farm land. Secondly, the quality of the wetlands can decrease due to sedimentation (due to deforestation and erosion) and eutrophication (due to nutrient leaching and effluent release). Thirdly, as both sugarcane and oil palm are labour intensive cops, the influx of migration workers will increase the pressure on the resources of those wetlands close to the production sites. Fourthly, irrigation schemes and their related infrastructure can disturb and decrease the influx of fresh water into wetlands.
The most likely regions where such development could occur are the coastal regions of East and South Africa. In Kenya and Tanzania, wetlands are already under threat by proposed sugarcane production schemes. The humid zones of Central and West Africa are also potential locations for palm oil production and sugarcane. Sugarcane can also be cultivated in drier regions, but its water requirements require production sites close to rivers, lakes and other wetland types to enable irrigation.

Sugarcane and palm oil as feedstock for biofuel production are not the only threats to African wetlands. Other, less productive crops such as maize, sweet sorghum and jatropha, are viable alternatives in arid and semi-arid regions. Again, in those regions large scale production schemes are likely to be situated close to rivers, lakes and other water sources, in order to achieve a competitive productivity level. Irrigation can be economically beneficial to maize, sweet sorghum and jatropha cultivation. Although the quantity of water used for crops is less than for sugarcane production, the effects can be considerable as fresh water is a scarcer resource in those areas. The wetlands particularly sensible to water extraction are those lying in the Senegal, Upper Niger, Lake Chad, and Upper Nile basins, and the drier regions of Southern Africa.

6. Overall conclusion

Wetlands like lakes, rivers, marshes and coastal zones are the most productive areas for people and biodiversity around the world. Wetlands also belong to the fastest disappearing ecosystems in the world. Maintaining healthy wetlands is crucial for the provision of fresh water purification and storage. In Africa in particular, many people depend directly on wetlands. The fertile soils, availability of fresh water and fish stocks provide the basis for their livelihood. African wetlands also host a broad array of species and play and essential role for migratory birds from Europe and Asia.

6.1. Background

Increasing global attention for biofuels can increase pressure on African wetlands. Africa has some competitive advantages for producing biofuel crops. These advantages may be used to produce for export markets and to substitute oil imports, which make up a substantial part of most African trade balances. Africa has a favorable climate for highly productive crops, affordable labor and many people perceive Africa to have abundant land resources. This potential largely remains to be unlocked, as investments in infrastructure and processing capacity are limited. Investors prefer to focus on politically stable countries in Latin America with experience in biofuels, most notably Brazil. Nevertheless, various African countries have intentions to step into biofuels.

6.2. Risks

If these intentions become reality, African wetlands will be at serious risk of conversion and degradation. Sugarcane poses the most direct threat. It requires large amounts of water and is therefore often grown in wetlands, replacing areas of natural value or food production. Palm oil can be grown in wetlands too, although the soils provide less favorable conditions. Still, the peat land in the Congo Basin may be an economically viable expansion area.

Other biofuel crops, like cassava, sweet sorghum, maize and jatropha grow on drier soils, but their production often requires irrigation to be commercially attractive. Large-scale irrigation can seriously deplete water resources that feed into wetlands. Water quality can also be negatively affected if topsoil, fertilizers and pesticide residues pollute waterways. These risks can be mitigated through application of good agricultural management. Discharge of effluents from ethanol production or oil palm mills can seriously diminish aquatic life.

Wetlands of high natural value and indigenous people are particularly at risk as a result of biofuel expansion. The commercial processing installations for turning crops into biofuels require substantial crop production areas, ranging from a few hundred hectares for jatropha and oil palm to several thousands hectares for sugarcane, cassava, sweet sorghum and maize. These production areas should be concentrated in order to keep harvesting and road transport costs to the plant low. This is most relevant for highly perishable crops like sugarcane, oil palm, cassava and sweet sorghum. If biofuel crop production takes place in highly populated areas, the implication of this land requirement will be that local people and communities may lose their access to land or water, jeopardizing food security. This often leads to serious and even violent land and water conflicts. Biofuel investors generally aim to minimize these conflicts and are therefore inclined to move into less populated areas, which are often of high natural value. Land right conflicts can arise here too: indigenous people often populate these areas, but biofuel investors find it easier to cope with this situation. The magnitude of the problem is smaller due to the size of communities and the weak law enforcement and low media exposure that characterizes many of these areas.

6.3. Opportunities

Besides bringing risks, biofuel production can also be an opportunity for economic development in and around wetland areas. Planting, maintenance and harvesting will probably be done manually in the African context, thereby providing employment to the local population. This form of employment can be quite substantial and can trigger an influx of migrants that should be carefully managed. Processing of crops requires higher skilled personnel, adding more value to the local economy.

Alternatively, African farmers can produce biofuel crops themselves and supply these to ethanol plants or oil palm mills. Jatropha and maize are particularly suitable for this, since they are less perishable, making collection more feasible.

6.4. Required land and water resources

The required African land and water resources to supply biofuels markets are still uncertain for several reasons.

The first reason is that future demand for African biofuels is uncertain. Demand from export markets will be determined by the openness of the large EU and US biofuel markets to foreign products. This is currently limited by subsidies and trade policies. Export potential will also be determined by the competitiveness of African biofuel production vis-à-vis the global biofuel powerhouse, Brazil. So far, Brazil out-competes Africa in terms of cost price and production volume. Demand from domestic African markets is dependent on effective biofuel policies. Most African countries are now only starting up these policy cycles.

The second uncertainty for determining land and water requirements is that the biofuel crops under consideration differ widely in terms of productivity and water requirements per hectare.

Sugarcane is currently the most productive crop for ethanol, yielding 6.000 liters from a hectare. However, it also has the highest water requirements amounting to 6.000 liter of water per liter of ethanol. In areas with water scarcity, other crops such as sweet sorghum may be more appropriate. Maize is a highly ineffective crop in terms of both land and water requirements.

Palm oil is the highest yielding biodiesel crop in the world, yielding up to 5.500 liters of biodiesel per hectare. Palm oil does not need irrigation, but has to grow in areas with very high rainfall. For jatropha, figures are less clear as it is a relatively new crop. Productivity is generally considered to be substantially lower than oil palm (>50%). Although the plant does not need irrigation, its productivity increases when it is irrigated.

In general, crop productivity in Africa is behind by global averages. This constitutes a hidden production potential that does not need any expansion in term of acreage.

To give a sense of magnitude of required land for biofuel expansion, we developed two simple scenarios.

The first assumes that 5% of EU and US biofuel consumption in 2020 is supplied by Africa. This would require between 3 and 14 million hectares, depending on the crops used, corresponding to areas the size of Lesotho to Malawi respectively.

The second scenario assumes that African countries substitute 10% of their transport fuel with domestically produced biofuels by 2020. Land requirements would be 3 to 12.5 million in that case.

3 to 14 million hectares is a relatively limited area if compared to figures provided by FAO on available agricultural land; this represents only one or two percent of Africa's available agricultural land. In the longer run, biofuel production can therefore be combined with sufficient food production provided there is careful land-use planning. In the short run, biofuels can jeopardize food security in Africa. Arable land can be used for biofuel crop production instead of food production. Also, cheap food imports from the USA and EU are no longer available because these countries have started using their arable land for biofuels, diminishing their overproduction of food. While this may benefit farmers in many African countries, it takes a toll on the urban population, which is confronted with higher food prices.

6.5. Recommendations

Biofuel production can have positive socio-economic effects on the population of African wetlands, provided that production is carefully managed by governments and companies and monitored by certification schemes and non-governmental organizations. The following conditions help to mitigate risks from biofuel production and promote the benefits:

- Effective land use planning by governments
- Effective biofuels policies by governments
- Effective accountability mechanisms, i.e. sustainability criteria for biofuels
- Adjust biofuel crop to natural conditions present at production location (instead of the other way around)
- Apply good agricultural management practices
- Stimulate awareness raising of impacts of biofuel production on African wetland areas

References

Literature

African Biodiversity network (2007), *Agrofuels in Africa – The impacts on land, food and forests. Case studies from Benin, Tanzania, Uganda and Zambia*.

African Development Bank Group (2006), *High Oil Prices and the African Economy*. Ouagadougou: ADB.

Bebb, A., S. Sielhorst and E. Veen (2008), *Sustainability as a smokescreen: The inadequacy of certifying fuels and feeds*. Brussels: Friends of the Earth Europe.

Bergsma, G. B. Kampman, H. Croezen, M. Sevenster (2006), *Biofuels and their global influence on land availability for agriculture and nature.* Delft: CE Delft.

Chege K. (2007), Biofuels: Africa's new oil?, published on *Science and Development Network,* 5 December, http://www.scidev.net/en/features/biofuel-africas-new-oil.html

Clay, J. (2004), *World Agriculture and the Environment: A Commodity-by-Commodity Guide to Impacts and Practices*, Island Press, Washington

EC (2008), *Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources*. European Commission, COM (2008) 30 final, Brussels, Belgium.

ECDO (2006), *Size does matter: The possibilities of cultivating Jatropha curcas for biofuel production in Cambodia*. Amsterdam: University of Amsterdam.

Eickhout, B., G.J. van den Born, J. Notenboom, M. van Oorschot, J.P.M. Ros, D.P. van Vuuren, H.J. Westhoek (2008), *Local and global consequences of the EU renewable directive for biofuels*. Bilthoven: Milieu- en Natuur Planbureau (MNP).

Euler, H. & Gorriz, D. (2004), *Case Study "Jatropha Curcas*, commissioned by Global Facilitation Unit for Underutilized Species (GFU) & Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, Frankfurt.

EVD (2007), *Market survey South Africa - opportunities for the Dutch clean technology sector*, Dutch Ministry of Economic Affairs

De Fraiture (2007), Biofuels could suck the developing world dry. http://www.scidev.net/en/opinions/biofuel-crops-could-drain-developing-world-dry.html

FAO/IFAD (2001), *Strategic Environmental Assessment: An Assessment of the Impact of Cassava Production and Processing on the Environment and Biodiversity*, Volume 5, Rome

Fresco, L.O. (2006), *Biomass for Food or Fuel: Is there a dilemma?* Singapore: Duisenberg Lezing

Fulton, L. et al (2004), *Biofuels for Transport: An International Perspective*. Paris: International Energy Agency

Grain (2007), Agrofuels special issue, in *Seedling*, July Issue.

Harrison, A. and E. Guttenstein (2005), *WWF's position on reform of the EU sugar regime*, WWF

Heinimö, J., V. Pakarinen, V. Ojanen and T. Kässi (2007), *International bioenergy trade – scenario study on international biomass market in 2020*. Lappeenranta: Lappeenranta University of Technology

International Energy Agency (2004), Analysis of the Impact of High Oil Prices on the Global Economy. Paris: IEA.

International Energy Agency (2006), *World Energy Outlook 2006*. Paris: IEA.

Johnson, F.X. and E. Matsika (2006*), Bio-energy trade and regional development: the case of bio-ethanol in southern Africa*. In: Energy for Sustainable Development, Vol. X No. 1.

Johnson, F.X. and F. Rosillo-Calle (2007), *Biomass, Livelihoods and International Trade: Challenges and opportunities for the EU and Southern Africa*. Stockholm: Stockholm Environmental Institute.

Jongschaap, R.E.E., Corré W.J., Bindraban P.S. & Brandenburg W.A. (2007), *Claims and facts on Jatropha Curcas L.: Global Jatropha Curcas evaluation, breeding and propagation programme,* Wageningen: Plant Research International.

Kartha, S., G. Leach and C. Rajan (2005), Advancing Biofuels for Sustainable Development: Roles for Policymakers and Entrepreneurs. Stockholm: Stockholm Environmental Institute (SEI).

Mielke (2007), *Oil World Annual 2007*, Hamburg

NNPC (2007), *Biofuels Development in Nigeria*, a presentation to the international renewable energy conference, Abuja, October, http://irec-nigeria.com/irecnet/downloads/nnpc_biofuels.ppt

ProForest (2003), *Palm oil, forests and sustainability - Discussion paper for the Round Table on Sustainable Oil Palm*, Oxford

Dar, W.D. (2007), *Sweet sorghum bioethanol technology*, International Crops Research Institute for the SemiArid Tropics (ICRISAT)

Santi, G. De, R. Edwards, S. Szekeres, F. Neuwahl and V. Mathieu (2008), *Biofuels in the European Context: Facts and Uncertainties*. Brussels: European Commission Joint Research Centre.

Smeets, E. A. Faaij and I. Lewandowski (2004), *A quickscan of global bio-energy potential to 2050. An analysis of the regional availability of biomass resources for export in relation to the underlying factors*. Utrecht: Copernicus Institute – Utrecht University.

UNEP, Daimler Chrysler & Ministry of Agriculture Baden Württemberg (2007), *Working paper: Compilations of existing certification schemes, policy measures, ongoing initiatives and crops used for bioenergy*

Wakker E. (2004), *Greasy Palms - The social and ecological impacts of large-scale oil palm plantation development in Southeast Asia,* Aidenvironment in collaboration with Sawit Watch Indonesia and Joanna de Rozario, Friends of the Earth UK, London

Wetlands International (2007), *Factsheet on palm oil, tropical peatlands and climate change,* www.wetlands.org

Worldwatch Institute, German Agencies for Technical Cooperation (GTZ) and Renewable Resources (FNR) (2006) *Biofuels for Transportation: Global Potential and Implications for Sustainable Agriculture and Energy in the 21st Century*. London: EarthScan.

World Bank (2008) *World Development Report 2008: Agriculture for Development.* Washington D.C.: World Bank

World Watch Institute (2007), *Biofuels for transport: global energy potential and implications for sustainable energy and agriculture*. London: Earthscan.

Websites

- http://www.boerderij.nl/1051640/Landbouw/Nieuws/Brazili-voorspelt-recordproductie-ethanol.htm
- FAO Ecocrop, http://ecocrop.fao.org
- IIASA/FAI (2002), Global Agro-ecological Assessment for Agriculture in the 21st Century, on http://www.iiasa.ac.at/Research/LUC/SAEZ/index.html
- CIAT/FAO Grassland species profiles, http://www.fao.org/ag/AGP/AGPC/doc/GBASE
- REEEP (2007), REEEP looks at complexity of producing biofuels in South Africa, posted at www.globalbioenergy.org, 01 May
- Biofuel –news.com 1 www.biofuels-news.com/news/nigeria_firstbio.html, 29 February 2008
- FAO Website http://www.fao.org/docrep/x5032e/x5032E01.htm#The%20plant
- FAO, AGL (2002) www.fao.org/ag/AGL/aglw/cropwater
- www.jatropha.de
- www.jatrophabiodiesel.org
- www.malibiocarburant.com
- www.fact-fuels.org/en/FACT_Projects/Mali
- Gaia Foundation, Biofuel land grabbing in Ghana (2007) http://www.gaiafoundation.org/documents/biofuelsghana.pdf
- Guardian (2008) http://www.guardian.co.uk/environment/2008/apr/06/biofuels.alternativeenergy
- http://exploringafrica.matrix.msu.edu
- FAO Water Database http://www.fao.org/nr/water/cropinfo.html
- http://www.gaiafoundation.org/documents/Africaagrofuelmoratorium.pdf
- www.allafrica.com
- Ramsar (2008) List of Wetlands of International Importance, March 2008 on www.ramsar.org
- www.wetlands.org Website of Wetlands International

Annex A: hectare requirement under Import Substitution Scenario - ethanol

Country	Ethanol demand in millions of liters in 2020	Required area for 100% sugarcane in 1000 ha	Required area for 100% maize in 1000 ha	Required area for 100% sweet sorghum in 1000 ha	Required area for 100% cassava in 1000 ha
Angola	82	21	123	24	47
Benin	89	22	134	26	50
Botswana	78	20	118	23	44
Burkina Faso	21	5	32	6	12
Burundi	8	2	12	2	4
Cameroon	77	19	116	23	44
Cape Verde	2	1	3	1	1
Central African Republic	6	1	9	2	3
Chad	2	1	3	1	1
Comoros	2	0	3	1	1
Congo (Brazzaville)	16	4	24	5	9
Congo (Kinshasa)	28	7	43	8	16
Cote d'Ivoire (IvoryCoast)	30	8	46	9	17
Djibouti	5	1	8	2	3
Equatorial Guinea	2	1	3	1	1
Eritrea	3	1	5	1	2
Ethiopia	35	9	53	10	20
Gabon	12	3	18	4	7
Gambia, The	10	3	15	3	6
Ghana	168	42	252	49	95
Guinea	22	5	32	6	12
Guinea-Bissau	5	1	8	2	3
Kenya	94	23	141	27	53
Lesotho	6	1	9	2	3
Liberia	10	3	15	3	6
Madagascar	42	10	63	12	24
Malawi	26	7	39	8	15
Mali	18	5	27	5	10
Mauritania	76	19	114	22	43
Mauritius	24	6	36	7	14
Mozambique	25	6	38	7	14
Namibia	86	22	129	25	49
Niger	14	3	21	4	8
Nigeria	1754	440	2.633	510	994
Reunion	38	10	58	11	22
Rwanda	10	2	14	3	5
Saint Helena	0	0	0	0	0
Sao Tome and Principe	2	0	2	0	1
Senegal	29	7	44	8	16
Seychelles	4	1	7	1	2
Sierra Leone	6	2	9	2	3
Somalia	12	3	18	3	7
South Africa	2279	571	3.421	662	1.292
Sudan	133	33	199	39	75
Swaziland	19	5	28	5	11
Tanzania	52	13	78	15	29
Togo	56	14	84	16	32
Uganda	46	11	69	13	26
Zambia	43	11	65	12	24
Zimbabwe	59	15	89	17	34
Africa	***5667***	**1.420**	**8.509**	**1.647**	**3.213**

Annex B: hectare requirement under Import Substitution Scenario – biodiesel

Country	Biodiesel demand in millions of liters in 2020	Required area for 100% oil palm in 1000 ha	Required area for 100% jatropha in 1000 ha
Angola	177	73	118
Benin	26	11	17
Botswana	49	20	33
Burkina Faso	16	7	11
Burundi	5	2	3
Cameroon	74	30	49
Cape Verde	11	5	7
Central African Republic	5	2	3
Chad	5	2	3
Comoros	3	1	2
Congo (Brazzaville)	27	11	18
Congo (Kinshasa)	47	19	31
Cote d'Ivoire (IvoryCoast)	95	39	64
Djibouti	18	8	12
Equatorial Guinea	6	2	4
Eritrea	21	9	14
Ethiopia	134	55	89
Gabon	46	19	31
Gambia, The	9	4	6
Ghana	167	69	111
Guinea	15	6	10
Guinea-Bissau	6	3	4
Kenya	180	74	120
Lesotho	4	2	2
Liberia	9	4	6
Madagascar	78	32	52
Malawi	26	11	17
Mali	16	7	11
Mauritania	8	3	5
Mauritius	60	24	40
Mozambique	77	32	51
Namibia	80	33	53
Niger	28	11	19
Nigeria	403	166	269
Reunion	47	19	31
Rwanda	18	7	12
Saint Helena	0	0	0
Sao Tome and Principe	4	2	3
Senegal	109	45	72
Seychelles	35	15	24
Sierra Leone	23	10	16
Somalia	14	6	9
South Africa	1.243	511	829
Sudan	304	125	203
Swaziland	13	5	9
Tanzania	116	48	77
Togo	39	16	26
Uganda	40	16	27
Zambia	51	21	34
Zimbabwe	59	24	40
Africa	***4.044***	***1.663***	***2.696***