CSPR Briefing

Pros and Cons of International Biofuel Production

An overview of research and policy reports 2008

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Centre for Climate Science and Policy Research

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1. Aim and Key Message

This briefing from the Centre for Climate Science and Policy Research presents a summary of research and policy reports on positive and negative aspects of liquid biofuels. It covers three areas: economic and energy security, rural development and agricultural production and environmental challenges. It will also shortly depict the cases of Brazilian ethanol as a model of processing agricultural crops to liquid fuels for transport, and finally cover the future bioenergy production potential in Sub-Saharan Africa (SSA). The purpose of this briefing is to provide an overview of present discussions and to present arguments from a variety of organisations and scholars. As a service to a reader, the briefing contains an extensive reference list for further studies.

The reports and research covered in this briefing are quite disparate. Nevertheless, ten significant conclusions can be observed:

- Biofuels cannot solely substitute oil in meeting the expected future energy demand in transportation.
- Development of next-generation biofuels can ease the food vs. fuel competition since they can be processed from other sources of biomass than the major food crops.
- Countries in tropical regions are more suited for biomass production. However, we lack sufficient research on future stresses compounded due to climate change and economic globalisation.
- International trade rules, particularly governing agricultural commodities, as well as development of standards and certifications will play a significant role in shaping global, as well as local conditions of future biofuel production. Thus, the outcomes of trade agreement and policies will impinge on development goals and livelihood security in developing countries.
- An important factor for developing countries will be whether biofuels will be considered as an agricultural or non-agricultural good by WTO. If they are classified as agricultural commodities they can be eligible for special measures such as subsidies for environmental reasons. But this may also be used to uphold agricultural subsidies in industrialised countries.
- Liquid biofuel production can be beneficial for developing countries in tropical regions. Present research indicates that rural communities in SSA may benefit if they hold control over the local or regional production conditions.
- Taking into account *present* conditions, food security of several SSA countries could be under strain caused by increased biofuel production.
- Depending on production conditions, SSA countries can stand to gain in the *future*. However, we lack comprehensive research on the conditions for a sustainable development of biofuel production which will benefit development aspirations.
- Although economies of scale is one factor to consider, sustainable development in SSA can benefit from small-scale production since this type of agriculture can put less stress on environment, in contrast to large-scale production projects.
- The production of liquid biofuels in SSA should be directed to meet other important needs in addition to transports (in contrast to the Brazilian example) like heating, cooking and electricity generation.

2. Introduction

The current global debate on biofuels has become a strongly polarized and generalized issue. The discussion is generalized not only due to the strong polarization of the topic (good vs. bad opinions), but also because most research and reports highlight problematic of biofuel production mainly in two countries: the USA and Brazil. There is much less scientific body regarding the current production of liquid fuels from biomass in other regions, such as Africa and Asia. In result, for example critical remarks regarding ethanol production in the US (maize) are sometimes understood and interpreted as a criticism of biofuel production in general, regardless the type of crop and agricultural region.

The main focus of the current bioenergy discussion is placed on different aspects and controversies surrounding production of *first-generation liquid* biofuels for road-transportation use. Despite the fact that production of crop-based fuels is not a new idea, the significant increase of worldwide interest in the first-generation biofuels has been recently triggered by rising oil prices, climate change mitigation efforts and availability of biomass feedstock that could have a potential to meet a relevant share of future energy demands in transportation. Furthermore, the heated debate on those biofuels has been currently driven by escalating global food crisis and rising environmental concerns, such as deforestation in tropical countries. The so called *next-generation liquid* biofuels are less discussed, at least with much less heat and polarity, because they are still in the phase of development and are not commercially viable, but it does not mean their future potential should be disregarded.

3. Liquid biofuels for transport

Development of biofuel production

Biofuels were almost nonexistent in the global energy market until 1970s oil crises that forced countries to find alternatives to imported oil. Among nations motivated to seek fuel substitutes were the US and particularly Brazil. By now, the US and Brazil have become the biggest biofuel producers and they currently dominate in the world ethanol production (IEA, 2004; Steenblik, 2007; WorldWatch Institute, 2006; WorldWatch Institute, 2007). Since 1970s global ethanol production has been expanding steadily, but between 2001 and 2006 it noted a two-fold increase (see Figure 1). World biodiesel production was launched later and started from a lower level than ethanol but expanded nearly six-fold during the same period of time (see Figure 2).[1]

Figure 1. World ethanol production (*2007 estimated)

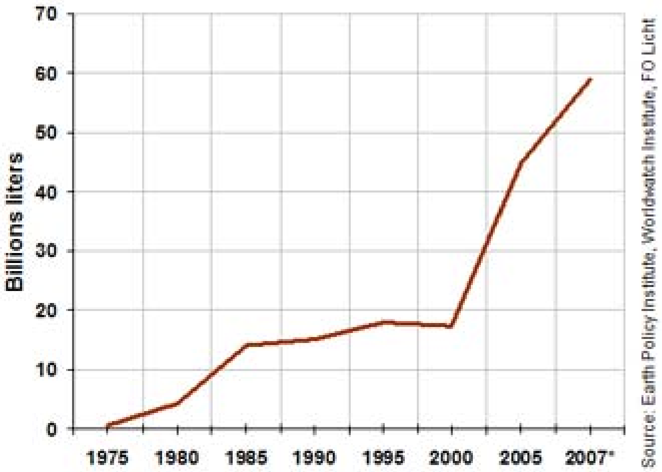
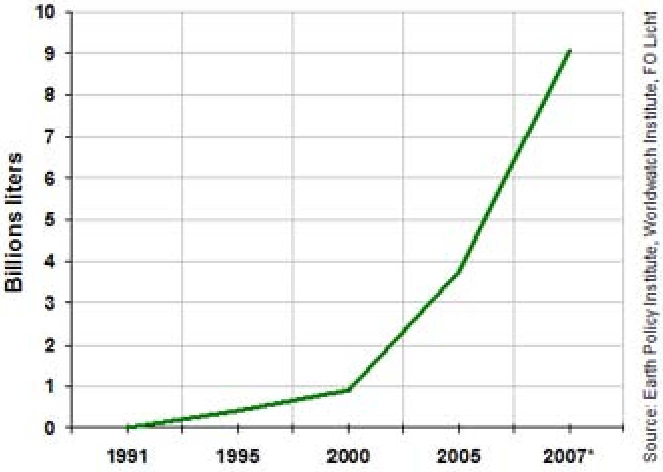


Figure 2. World biodiesel production (*2007 estimated)



Currently, modern biofuels are most widely used for transport (IEA, 2007). There are two types of liquid fuels produced from agricultural crops: pure ethanol (appr. 95%), ethanol

[1] In global terms, ethanol production jumped by 13% between 2004 and 2005 and world biodiesel production capacity doubled during the same period of time (Steenblik, 2007).

blended with gasoline, and biodiesel blended with conventional diesel. At present, global biofuel use in transportation accounts for a very small fraction of the whole gasoline and diesel consumption.

Types of feedstocks for biofuel production

First-generation fuel ethanol can be processed from sugar crops[2] and from starch crops[3]. First-generation biodiesel can be produced from oilseed crops[4], as well as from other potential crops and tree-based seeds with oil sources[5]. Maize is the highest-yielding feedstock used for ethanol production (RFA, 2005), whereas sugar cane is considered to have the greatest potential in processing it into fuel ethanol (Macedo, 2005; Moreira, 2004). Rapeseed is regarded as one of the most productive oilseed crops that can be grown in temperate regions (and is a primary feedstock for biodiesel production in Europe), but its ability to displace conventional fuel is also limited due to land use constraints, while soybeans is characterized by low yields that need to have more room to expand (Oil World, 2005; Sutton et al, 2005). Oilseeds grown in tropical regions have greater potential to use land more efficiently. However, there is a strong concern that expanding plantations of oilseed trees could cause environmental damages in wild ecosystems and tropical forests (BiofuelWatch, 2007; Leahy, 2007; Pearce, 2005).

Although in development stage, requiring more expensive process and not commercially available, next-generation liquid biofuels could be produced from: forestry and crops residues[6], fall grasses and municipal wastes (WorldWatch Institute, 2007).

Regions suitable for biofuel production

Currently, tropical regions are considered to be better suited for ethanol and biodiesel production to meet biofuel demand for transportation in developed countries, due to favourable climatic conditions, high yields, availability of cheap land and low costs of labour (IEA, 2004; Mathews, 2006; Mathews, 2007; WorldWatch Institute, 2007; Gilbertson et al, 2008; Biopact, 2006). However, proponents of concentrating biofuel production in developing nations rarely take under consideration future climate change impacts on weather patterns in those regions (IPCC, 2007a). Water availability for biofuel production in regions of the South is also an issue that lacks serious attention when biofuel strategy is considered.[7]

4. Potentials of biofuels

Currently, biofuels are marketed as a solution to:

- increasing national as well as international economic and energy security
- rural development and agricultural production
- environmental problems

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[2] Sugar crops: sugar cane, sugar beets, sweet sorghum;
[3] Starch crops: maize, wheat, cassava, sorghum grain;
[4] Oilseedcrops: reapeseed, soybeans, palm, jatropha;
[5] Other potential crops and tree-based seeds with oil sources: sunflower, cottonseed, mustard seed, peanut, coconut, castor oil, waste vegetable oil;
[6] Forestry and crops residues: woody undergrowth, industrial and urban woody residues, corn stover and wheat residues, sugar cane residues;
[7] Various biofuel feedstocks require different amount of water and fertilizers for cultivation (UN Energy, 2007, p. 6). For different water requirements in production of crops for biofuels see e.g.: Pimentel and Patzek, 2005; Sheehan et al, 1998; Gehua et al, 2005. For research that lacks climate and water considerations see e.g..: IEA, 2004; Mathews, 2006; Mathews, 2007.

These objectives can work together, but also impede on each other depending on policy choices. In the following section, we will give an overview over the ongoing biofuel discussions on pros and cons in these three areas.

Biofuels for economic and energy security

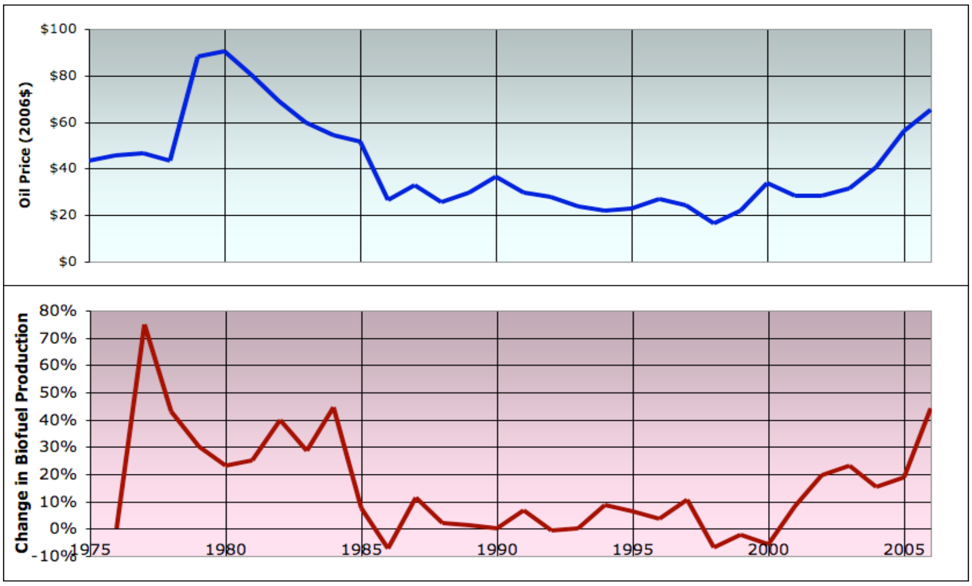
Potential positive effects

Current escalation of crude oil prices (Flood, 2008; Blas and Flood 2008) and steady growth in energy consumption, particularly in developing nations (EIA, 2007a), have heightened interest and investment in bioenergy globally. In result, liquid fuels produced from agricultural crops have been labelled as a substitute or addition to petroleum-based fuels in transportation (IEA 1994; IEA 2004; Childs and Bradley, 2006; Steenblik, 2007; WorldWatch Institute, 2007). According to proponents it will contribute to diversify energy resources, bring much broader group of countries into the fuel business, and thus lower pressure on the oil market, as well as reduce oil dependency, particularly in oil-importing developing nations (Hodes et al, 2004; WorldWatch Institute, 2006).

Potentially problematic issues

Liquid fuels processed from biomass can compete with petroleum on the fuel market only if oil prices stay high (Benjamin, 2008; Canuto, 2007). Otherwise biofuels loose a competitive advantage over petroleum and their production stops growing (see Figure 3), due to their high production costs and still undeveloped infrastructure juxtaposed with oil's domination on the energy market and on consumer habits. In order to make biofuels more competitive with conventional fuel and lower their price at the pump, governments in developed countries provide a strong support for bioenergy incentives in form of policies on tariffs and other trade regulations as well as subsidies (Steenblik, 2007).

Figure 3. Annual percentage change in biofuel production, 1975-2006 (bottom), with oil prices (top)[8]



Source: Staniford, S. (2008), "Fermenting the Food Supply." *The Oil Drum*, January 7, 2008 http://www.theoildrum.com/node/2431

[8] Notice that a peak percentage change of biofuel production after 1975 was influenced by the 1973 OPEC oil embargo. Biofuel production was almost non-existent on the energy market before the 1970s, but the oil crisis triggered a strong interest in alternative liquid fuels produced from biomass.

At present, liquid fuels processed from biomass are less energy efficient than conventional fuel. A litre of ethanol consists about two-thirds as much energy as a litre of gasoline, whereas biodiesel contains 88-95% as much energy as diesel fuel (WorldWatch Institute, 2007). Another significant inconvenience concerning the current biofuel production potential is that it takes energy to produce bioenergy. The overall energy performance of crop-based fuels together with their production processes can be measured by estimating energy balance[9] or energy efficiency[10].

Sustainable development conditions

Calculations and results vary among researchers, depending on how the processing of biomass to liquid fuel is assessed, what factors and stages of production are included, as well as what synergies can be made with other energy production, for instance, biogas, etc. (Farell et al, 2006; Pimentel and Patzek, 2005, WorldWatch Institute, 2006; WorldWatch Institute, 2007).
In order to successively substitute the current oil used in transportation with alternative fuel processed from agricultural feedstocks, there is a need for a large-scale biofuel production that would be implemented globally, particularly including developing countries. However, according to the WorldWatch Institute, in the long-term scenario biofuels cannot meet increasing global energy demand for transport (2007).

Strong concerns regarding the future role of first-generation biofuels as a reliable source of energy include among others:

- global population growth (UNPD, 2006) and increasing world urbanization trends (UNPD, 2007),
- rising energy consumption, particularly in rapidly industrializing nations as China (EIA, 2007a; Liu, 2008; US DOE and EIA, 2005),
- growing human demand for food and changing diet patterns (Steinfeld, Gerber et al, 2006; Amarasinghe, Shah and Singh, 2007),
- climate change uncertainties and risks (such as rising temperature, droughts, floods, fires) and global warming impacts on regional weather patterns (IPCC, 2007a),
- shrinking global resources of water, fertilizers, etc. (Abelson, 1999; Bradsher and Martin, 2008; Barlow, 2008; Chesher, 2008; Klare, 2002; Klare, 2008; Philpott, 2008);

The future prospect of liquid fuels produced from first-generation feedstocks and their long-term potential seems to have some serious limitations, especially when assessed in terms of growing global energy demand for transportation. Therefore, such biofuels could be treated only as an addition to oil, severely constrained by natural conditions in meeting the expected demand for energy in transport, until the next-generation biofuels or other solutions to energy security would become commercially available.

Biofuels for rural development and agricultural production

Potential positive effects

Biofuel advocates claim that liquid fuels produced from first-generation biomass could transform the agricultural sector in a positive way. For instance, Joseph Schmidhuber, a

[9] Energy balance is the ratio of energy contained in the final biofuel product to the energy used by human effort to produce it (WorldWatch Institute, 2007, Chapter 10)
[10] Energy efficiency is the ratio of energy in the biofuel to the amount of energy input that includes all fossil and biomass inputs and other renewable energy inputs (WorldWatch Institute, 2007, Chapter 10)

Senior Economist with FAO's Agricultural Development and Economics Division, argues that properly managed biofuel production "could promote something akin to an agricultural *renaissance* in some developing countries where biofuels can be produced profitably." (FAO, 2007a). Processing fuel from crops could provide jobs, increase farm incomes and strengthen rural economies, whereas higher prices for biofuel feedstocks could have a potential to yield increasing profits in agricultural areas (IEA, 2004; WorldWatch Institute, 2006; WorldWatch Institute, 2007). According to FAO, bioenergy could not only provide cleaner energy services to meet Millennium Development Goals that, among others, require eradicating extreme poverty and hunger, but it might also be able to contribute to diversification of forestry and agricultural activities, improving access to energy, particularly in the poor rural areas of developing countries (FAO, 2005a).

An increased market for biofuels is also seen as a solution to eliminate or reduce agricultural subsidies in developed countries. Instead of sending under-priced crops abroad (dumping), industrialized nations, could process them into liquid fuels for transportation (IEA, 1994). Meanwhile, biofuel production has been serving as a tool to reduce food surpluses in developed countries because their industrialized and heavily subsidized agricultures produce too much, thus the bioenergy strategy is implemented in order to maintain the same level of production and utilize excesses when needed (Steenblik, 2007).

Potentially problematic issues

Lately, biofuels have been pointed out by some observers as one of the factors driving world food prices up (Brown, 2003; Brown, 2008, OECD/FAO, 2007). In the food vs. fuel competition (Runge and Senauer, 2007), first-generation biofuels are framed as a key element in displacing crop production, changing land-use patterns in agriculture and influencing global food prices, especially in the case when food and energy have become increasingly intertwined in the global market (OECD/FAO, 2007; Thoenes, 2007, Morton et al, 2006). According to the FAO Committee on World Food Security, "biofuels could reduce food availability and inflate food prices", but "the impacts will vary depending on the evolution of market forces, technological developments and policy choices at both the national and international level." (FAO, 2007b:15) Moreover, even if there is enough global land to maintain food security and expand production of biofuels, as some observers maintain (Mathews, 2006; Mathews, 2007; Sachs, 2007), climate change uncertainties and weather related risks in form of droughts, fires and floods (IPCC, 2007a), as well as various crop diseases (Mackenzie, 2007; Pearce, 2007) have to be seriously taken under consideration in bioenergy strategy implementation, particularly in developing countries that are least vulnerable to global warming impacts.

Introduction of a large-scale biofuel production involves changes in agricultural practices that could result either in reduction of employment opportunities as a result of mechanization, or exploitation of farm workers (Patel, 2008; Phillips, 2007; BiofuelWatch, 2007). Whereas small-scale schemes developed by rural communities might bring energy and profit for local livelihoods, a large-scale production could result in industry concentration and consolidation, pre-empting small farmers and depriving them from benefits (Gehua et al, 2005, Kaltner et al, 2005; Morris, 2006).

Given the sustainable development challenges to liquid fuels produced from biomass, the future shape of global biofuel market with different standards and certification rules can have a profound impact on the state of food security in years to come (Gilbertson et al, 2008, WorldWatch Institute, 2007). Initiatives are being developed by, for instance, the Nordic environmental labelling system Nordiska Svanen (www.svanen.nu).

Sustainable development conditions

In the long-term perspective, production of biofuels – especially if introduced on a large-scale to meet a growing energy demand for transport - requires serious improvements in agriculture efficiency, mostly in developing countries. Such strategy could lead to negative environmental and socioeconomic impacts on rural communities. Large plantations of feedstocks, that require high quantities of water for irrigation, could divert fresh water resources from essentially important food production (Dias De Oliveira, Vaughan and Rykiel Jr, 2005; Kojima and Johnson, 2005; Postel, 2006). Implication of industrial crop monocultures for liquid fuel might result in loss of genetic and biological diversity, also due to the increasing use of genetically modified (GM) crops. Extensive use of fertilizers and pesticide for cultivation of some feedstocks might cause soil and water contamination (WorldWatch Institute, 2007, Box 12.2)

In order to maximize benefits from biofuels in rural development there is a need to involve farmers in the production, processing and use of fuels from agricultural crops. Biofuels could bring socioeconomic benefits to rural areas only if agriculture is restructured in such a way that it will empower farmers enabling them to own the value-added chain of bioenergy production (WorldWatch Institute, 2006) (see Chapter 6).

At present, lack of purchasing power is a major reason for the state of food insecurity in the world. Increased revenues from biofuel production can potentially raise the level of incomes in a country. If these incomes are distributed also to benefit the urban poor, biofuel production in certain poorer countries can counteract the threat to food security caused by rising food prices (FAO, 2005a). The shape of future biofuel production and the structure of global biofuel market are particularly dependent on decisions made under the WTO Doha Round negotiations that will determine whether fuels processed from biomass are agricultural or non-agricultural goods[11] (Murphy, 2007). If they are classified as agricultural commodities they can be eligible for special measures such as subsidies for environmental reasons. But this may also be used to uphold agricultural subsidies in industrialised countries. Even as a non-agricultural commodity, biofuels may be classified as an environmental good and thus subject for special measures (Hjerpe and Linnér, forthcoming).

Biofuels as a solution to environmental problems

Potential positive effects

Liquid fuels produced from agricultural crops are widely framed as a solution to such environmental problems as local air pollution and especially a global issue of climate change. Using biofuels in transport could improve air quality in urban areas (McCormick et al, 2006; Hulsey and Coleman, 2006)[12]. Liquid fuels produced from biomass are also able to reduce CO_2 emissions and, thus, help mitigate global warming, since combustion of such fuels releases carbon that was earlier sequestered from the atmosphere by growing crops (IEA, 1994; IEA, 2004)[13].

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[11] "An introduction to trade and environment in the WTO", http://www.wto.org/english/tratop_e/envir_e/envt_intro_e.htm

[12] However, reduction of air pollution from transportation by using ethanol and biodiesel blends could reduce emissions from major pollutants, but such blends could also result in emissions of NO_x (contributing to ozone depletion) and other health-risky pollutants (Westerholm et al, 2008).

[13] In its latest report, International Panel on Climate Change (IPCC) mentions biofuels as a key mitigation technology that is currently commercially available, and biofuel blending as one of the policy options to be environmentally effective (IPCC, 2007b). These and other remarks made on biofuels in the report were called into question by five senior scientists that contested IPCC advices (Pimentel et al, 2007).

Potentially problematic issues

Carbon-neutrality of biofuels is a controversial issue, because production of ethanol and biodiesel requires land-use changes for agricultural cultivation and energy inputs for processing. These two activities, that are prerequisites of the first-generation biofuel production, could become a substantial source of GHG emissions, undermining climate change mitigation efforts (Sachs, 2007; BiofuelWatch, 2007). Similarly to the case of measuring biofuel energy performance, calculations of GHG emissions reductions achieved by biofuels vary among researchers. According to IEA, ethanol and biodiesel provide significant reductions in GHG emissions compared to gasoline and diesel on a "well-to-wheel" basis[14] (2004), whereas Fargione et al argue that land clearing for production of crop-based biofuels could lead to a "biofuel carbon debt", what researchers call the amount of carbon dioxide released during the first 50 years of converting native habitats to croplands[15] (Fargione et al, 2008).

Sustainable development conditions

In the long-term perspective and if not properly managed, particularly large-scale biofuel production from agricultural crops could cause various environmental problems, such as:

- diversification of water resources (Dias De Oliveira, Vaughan and Rykiel Jr, 2005; Kojima and Johnson, 2005; Postel, 2006), water contamination and aquifer depletion (McLeod, 1994; Simpson et al, 2008),
- soil depletion, soil fertility loss and soil erosion caused by monoculture plantations (Brown, 1997; Wood, Sebastian and Sherr, 2000; Kindall and Pimentel, 1994),
- deforestation (burning and razing forests for plantations of feedstocks), destruction of rich ecosystems and loss of biodiversity (Butler, 2008; Laurance, 2008; Morton et al, 2006; Righelato and Spracklen, 2007),
- emissions of CO_2 and other pollutants that can contribute to global warming, due to land-use changes for agricultural cultivation, deforestation, or processing of biomass to liquid fuels (Hill et al, 2006; Crutzen et al, 2007; Fargione et al, 2008; Searchinger et al, 2008);

5. The case of Brazilian ethanol

In the bioenergy debate, Brazilian ethanol is presented as a model case for an efficient, profitable and sustainable biofuel production that could be successfully implemented in other countries, particularly in developing regions (IEA, 2004, Mathews, 2007; Kaltner et al, 2005; WorldWatch Institute, 2007). This is also a strategy pursued by Brazil itself. On one hand, Brazilian government directs strong promotion of biofuels towards industrialized nations, labelling ethanol as an alternative to petroleum. Brazil is currently the biggest exporter of ethanol, successively selling its sugar cane-based fuel despite high trade tariffs imposed by developed countries (Hennigan, 2008). On the other hand, Brazilian politicians channel a strong support (also financial) for the South-South cooperation in the field of bioenergy production development schemes, particularly in Sub-Saharan Africa (Biopact, 2007).

Brazilian ethanol is put forward as a strategy that could have the potential to reduce energy dependency, particularly in developing countries. However, in debate on biofuels it is rarely mentioned that Brazil has the second largest proven oil reserves in South America,

[14] "Well-to-wheels" is a specific type of life-cycle assessment (LCA) that calculates efficiency of fuels in transport.

[15] For example, land clearing for palm biodiesel production in peatland rainforest of Malaysia and Indonesia would result in a biofuel debt repayment time of ~423 years, whereas land clearing for sugar cane ethanol production in Brazilian Cerrado grassland ~17 years (Fargione et al, 2008).

holding an estimated 11.7 billion barrels in 2007 - a result of Brazilian government's long-term goal of increasing domestic oil production (EIA, 2007b). Brazilian use of fossil fuels is rapidly growing (Román, 2007). Moreover, in 2007 and 2008 Brazilian state-owned oil company Petrobras announced major new oil discoveries: the Tupi oil field with estimated 5-8 billion barrels and similarly huge Jupiter oil field (Barrionuevo, 2007; Duffy, 2008). It is also important to emphasize that ethanol fuel produced in Brazil is primarily utilized in the transportation sector. This is possible mostly thanks to the so called flexible-fuel technology that car manufactures introduced in Brazil in 1990s. Currently the flexible-fuel vehicle (FFV) market strongly stimulates consumption of ethanol in the country (Lemos, 2007). On the other hand, Brazil is highly dependent on hydroelectric power and in 2001 the whole country experienced a serious energy crisis caused by the worst drought in 70 years (EIA, 2002).
Therefore, when considering the model of Brazilian ethanol production, it is important to take under scrutiny what type of energy dependency could be possible to reduce by introducing biofuel strategy in a given country, how stable this energy source could be, as well as what scale of production would be needed to meet a particular energy demand, especially in cases when liquid biofuels are planned to be processed only for urban transportation or export to developed nations, and not for other (domestic) uses, e.g.: heating, electricity generation, agricultural production (e.g. fuel for machines).[16]

6. Potential of biofuel production in Sub-Saharan Africa

Figure 5. Sub-Saharan Africa

According to IEA, Africa accounts for the world's largest share of biomass in total energy consumption, with firewood for about 65% of biomass use, and charcoal about 3% (IEA, 2004; IEA 2007). Nevertheless, liquid fuels from biomass are currently processed on a marginal level and there is lack of sufficient experience in the field. Of African countries, Kenya, Malawi and Zimbabwe have the longest experience in producing ethanol for transportation, but achieved different outcomes and results in the fuel development (WorldWatch Institute, 2007). In 2004, the continent's total ethanol production was dominated by South Africa, accounting for around 70% of fuel production mostly utilized in industrial and pharmaceutical markets (IEA, 2004). At present, there is a growing interest in developing biofuel schemes in Africa, particularly in the Sub-Saharan (SSA) part of the continent (see Figure 5).

Nevertheless, potential, risks and obstacles of biofuel production in Africa are less discussed and documented.[17] The option to concentrate crop-based fuel production in the South is not only channelled from developed countries seeking to import cheaper ethanol and biodiesel for growing transportation needs, but it is also put forward by African countries that try to find ways to reduce their energy (oil) dependency. Ethanol projects are under way in Mozambique, Nigeria and Sudan, whereas implementation of biofuel blending policies takes place in Ethiopia, Nigeria and Uganda (Brough, 2008). Among African countries looking to

[16] A traditional form of acquiring energy from biomass for cooking has been already practiced by nearly 2,5 billion people, but some 1,6 billion do not have access to electricity at all, what makes a serious constraint to socioeconomic development (Modi et al, 2006).
[17] For example, the joint UNDP/World Bank report on potential of biofuels for transport in developing countries does not discuss Africa at all, and focuses mainly on Brazil and Asian countries (Kojima and Johnson, 2005). Whereas some researches, such as Mathews (Mathews, 2006; Mathews, 2007), treat Africa more as a part of the uniform group of developing countries, rather than a unique continent with different regional characteristics, including: climate, land, water, urbanization, etc.

establish, develop or extend production of liquid fuels from biomass, are: Benin, Ghana, Ethiopia, Kenya, Malawi and Zimbabwe (F.O. Licht, 2005).

Current estimates and assumptions regarding the biofuel potential in Africa are mostly based on the continent's vast land-mass that is available for food-crops cultivation, and on suitable weather conditions, usually marginalized to the single fact that some African tropical countries have favourable climate and plenty of sun. Low cost of land and labour is also a factor mentioned as an advantage for Africa to produce cheap biofuels.

Unfortunately, there is lack of a broader and more thorough analysis (particularly carried out on a regional/local level) that would also include such important factors as e.g.: availability of water (including irrigation), fertilizers and pesticides; weather-related risks, wildfires and climate change uncertainties; infrastructure, economic situation, domestic policies and international trade rules. These and other factors are important especially when considering a long-term, large-scale production oriented for export to meet biofuel demand in the industrialized world.

According to an extensive research on global bioenergy potentials to 2050, SSA is one of the regions with the highest potential for bioenergy production. Authors of the study state that potential of SSA and other highly promising regions comes from "the large area suitable for cropland, large areas of pasture land presently used and the present low productive and inefficient production systems." (Smeets, Faaij and Lewandowski, 2004:2-3). However, FAO report indicates that SSA has less arable land and vast pasture lands, but between 1980 and 2003 the region experienced expansion of crop area by 22% and this trend in the region's agriculture is currently accelerating (Steinfeld, Gerber et al, 2006).

Figure 6.
Extent of forest resources

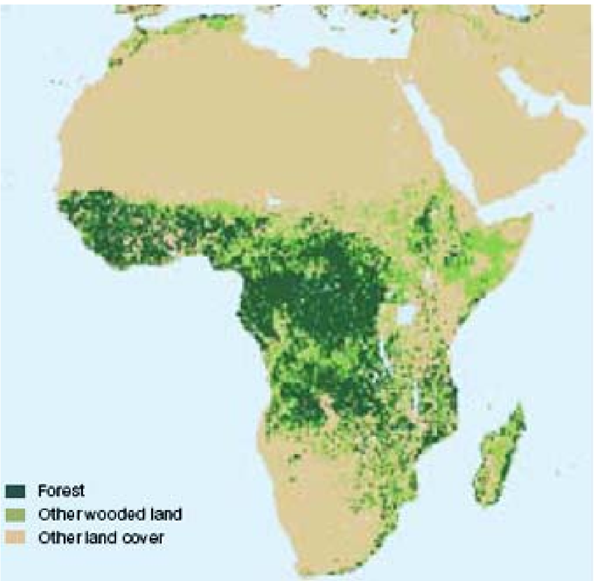
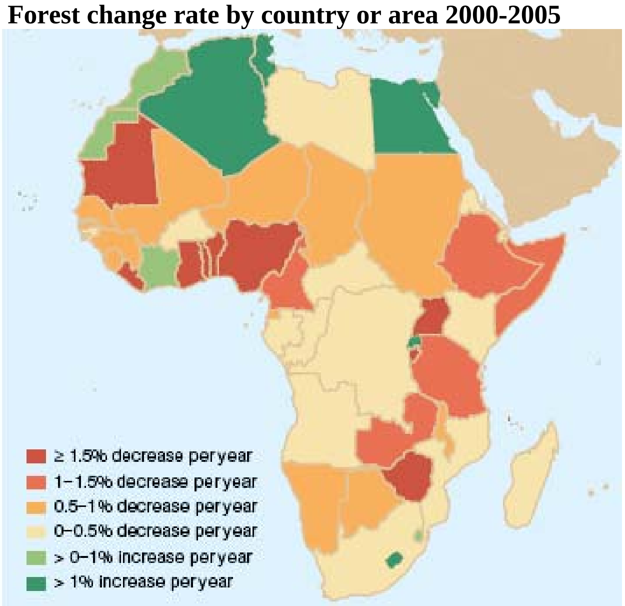


Figure 7.
Forest change rate by country or area 2000-2005



Source: FAO (2007), *State of the World's Forests 2007*.

Moreover, between 2000 and 2005 Africa lost 4 million hectares of forest annually (see Figure 6 and 7), mostly due to conversion of forest lands to agricultural production (FAO, 2005b). Additionally, Africa is often called a "fire continent"[18], because it experiences higher occurrence and frequency of vegetation fires than any other continent. Most fires are caused

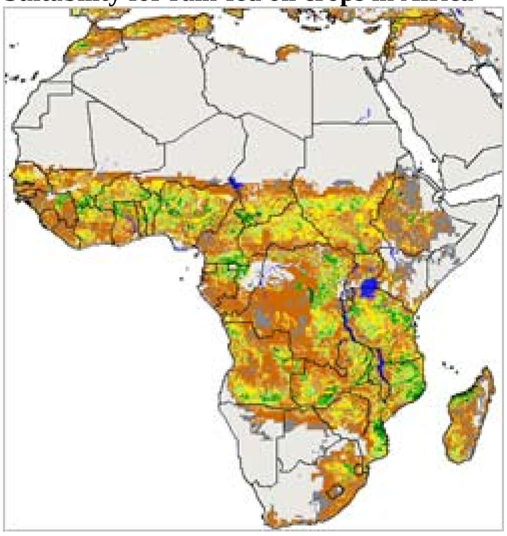
[18] See: 2005 Fire Patterns Across Africa, http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=17016

by burning for agriculture, particularly by widely used slash-and-burn method, for clearing agricultural sites or removing agricultural residues[19] (Held, 2006).

It is sometimes suggested that in Africa biofuels could be grown on marginal or degraded lands, in order to reduce replacement of food production in areas with higher soil quality. However, in Africa such lands are often habited, utilized and provide a basis for different social activities and functions to rural poor who are dependent on ecosystem services of common pool resources for their subsistence (Gilbertson et al, 2008). A recent study by FAO shows that converting such lands into large-scale plantations for biofuel production could particularly marginalize women (Rossi and Lambrou, 2008). Currently, the classification of land as degraded in Africa has become a sensitive issue in the current debate on criteria for sustainable bioenergy production, for example in the new EU bioenergy directive.

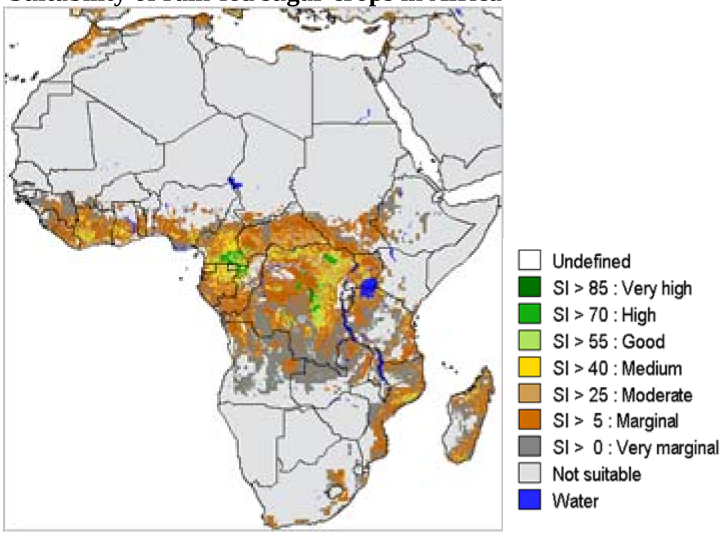
Furthermore, the study on global bioenergy potentials by Smeets, Faaij and Lewandowski does not calculate climate change impacts on agriculture in SSA estimating biofuel potential in the region (2004), whereas according to FAO, the "impact of climate change on food security will be higher in those countries with low economic growth potential that currently have high malnourishment levels (…) Some of the severest impacts seem likely to be found in the currently food-insecure areas of sub-Saharan Africa, which are the least able to adapt to climate change or to compensate for it through increased food imports." (FAO, 2005c:3).

Figure 8.
Suitability for rain-fed oil crops in Africa



Source: FAO Terrastat

Figure 9.
Suitability of rain-fed sugar crops in Africa



Source: FAO Terrastat

The significance of global warming and changing weather patterns in the region is discussed in a recent document published by IIASA (Shah et al., 2008).[20] It concludes that due to impacts of climate change "about 98% of cultivated land in Sub-Saharan Africa, with its predominantly rain-fed agriculture, faces an exceptionally daunting situation" (see Figure 8 and 9 for suitability of rain-fed oil and sugar crops in Africa).[21] For many SSA countries agricultural production is the basis of their economies, accounting for over 30% of total GDP

[19] In case of agricultural residues, next-generation biofuel technology could become one of the options for processing such residues to liquid fuel for transportation.
[20] International Institute for Applied Systems Analysis (IIASA), http://www.iiasa.ac.at/
[21] It is important to note that some feedstocks for biofuel production do not necessarily require large amounts of water for cultivation, e.g. jatropha regarded by some as one of the best candidate for biodiesel processing, because the plant does not need much water or fertilizers and can be grown on any type of soil. However, its impact on environment and biodiversity has not been properly studied (Walter, 2007). Therefore, particularly a large-scale replacement of food crops with (likely invasive) energy crops has to be seriously reconsidered.

and over half of export earnings, and for "the livelihood of approximately 85% of the undernourished population depends on rain-fed agriculture and agriculture-based rural activities." (Shah et al., 2008:1-2)[22].

The latest report issued by IAASTD[23] on agriculture in SSA states that production of first-generation biofuels in SSA might put pressure on forests and marginal lands. The document also suggest that the use of agricultural feedstocks for fuel requires a major debate centred on whether displacing biomass will remove land from production of food crops and/or will result in increased prices of staple commodities, such as maize. According to IAASTD, next-generation biofuels (see Footnote 19) may have greater potential for SSA (IAASTD, 2008).

Long-term, large-scale production of biofuels oriented on export to meet energy demand in transportation of industrialized nations could put a strong pressure on socioeconomic and environmental issues in Africa (UN DESA, 2007; UN Energy, 2007). Such form of production would rely on extensive energy crop cultivation, intensive mechanization and use of fertilizers, and is likely to involve a presence of large corporations in the chain of production. This could lead to large land-use changes, deforestation and land clearing, displacement and contamination of water, and eventually food scarcity, whereas concentration and domination of only few agro-industries (likely foreign companies) in a domestic market could leave small farmers without many harvesting options and substantial benefits. There is also a strong concern that Africa could become, again, an exporter of raw materials in form of feedstocks for biofuel production, instead of processing biomass to liquid fuel locally.

Therefore, some researchers point to small-scale production of biofuels oriented on domestic or regional market as a more promising strategy that could lead to development of rural communities in Africa. Currently SSA has enough of cropland to grow food, as well as energy crops that could be utilized not only in transportation sector for domestic purposes, but also in more essential needs of the region, such as: heating, cooking and electricity generation (Djurfeldt, Holmén and Jirström, 2005).

Small-scale bioenergy option could trigger implementation of more efficient agriculture on already cultivated land in SSA, producing rural goods in ways that both mitigate and adapt to climate change, especially if farmers would invest their incomes in production schemes that are better prepared for impacts of global warming (Toulmin and Huq, 2006). The choice of feedstock for processing to biofuels (how particular energy crops fit local crop rotation regarding weather conditions and peak level of seasonal work, etc.) and involvement of small-scale farmers in creation of biofuel markets for local and regional needs are key elements in establishing effective small-scale bioenergy schemes in SSA. The strategy also requires improvements in production efficiency, development of infrastructure, construction of storing houses and processing plants, as well as creation of local and regional markets. Agricultural investments, technology transfer and policy options play a crucial role in developing a successful small-scale production of biofuels that could benefit rural areas in Africa (UN DESA, 2007). However, there is a need for more research in the area, particularly on regional and local level. It is especially relevant in a current situation when available data on Africa's natural resources is unsatisfactory[24]. There are many important issues that have to be taken under consideration in future implementation of biofuel production in Sub-Saharan Africa, including:

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[22] For more on current climate vulnerability in Africa and future climate scenarios for the continent, see Chapter 9 of the IPCC Fourth Assessment Report on Climate Change 2007: Impacts, Adaptation and Vulnerability (IPCC, 2007a).

[23] International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD), http://www.agassessment.org/

[24] Among other issues that lack sufficient data on Africa's natural resources, e.g. forest inventories and hence its change is very poor.

- food security in the region and replacement of food crops (as well as feed crops for animal production) with energy crops
- impacts of climate change and changing weather patterns
- type of feedstock and type of land for cultivation
- scale and orientation of production process
- land ownership[25]
- water limitations
- institutional capacity and policy support
- technology transfer and local technology production
- development of domestic markets
- the closing of the WTO Doha Development Round and other international trade agreements.

[25] See: Nyari, 2008, Toulmin, 2005.

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