Technical Background Document – Biofuels in Burkina Faso

Crop Intensification and the potential of biofuels in Burkina Faso

An Appendix to the study “Climate, Land, Energy and Water (CLEW) interlinkages in Burkina Faso”

Part 1: Options for Agricultural Intensification
Part 2: Biofuel Potential in Burkina Faso

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Part 1: Options for Agricultural Intensification in Burkina Faso

Increasing crop yields can be achieved by a number of measures as improved mechanization, fertilizer input, improved harvesting as well as irrigation and water management. The necessary energy input these measures for different crops varies greatly and strongly depends on climate conditions, soil type and existing farming practice. Our research suggests that a substantial increase of energy input would be required to increase yields in Burkina Faso. Nevertheless according to our results based on the IIASA Agro Ecological Zoning (AEZ)\(^1\) model such input increases will result in substantial yield gains for several crops. The figures below illustrate potential yield increases for increased energy input values for Maize and Sorghum, two of the main staple crops in Burkina Faso. According to the AEZ model the yields for both crops could be doubled or even tripled by increasing energy input to intermediate levels\(^2\). The dotted lines in Figure A1 show the desired yield development if food security in the country is to be maintained without agricultural land expansion, taking into account projected population growth in Burkina Faso. The figure shows that according to AEZ these yield increases can be achieved if agricultural input is increased from currently predominantly low input levels (dark green area) to intermediate input levels (medium green area).


\(^2\) Intermediate Input levels are defined by IIASA as market oriented agricultural forms with some mechanization and a functioning market system as applied in a developing countries and countries in transition.
Intensifying per hectare crop production will become important as current population growth rates make increased agricultural production necessary. Under current yields (using low agricultural input) the necessary agricultural land to support the growing population will grow to 16 million ha in 2050. When an intermediate agricultural input level is assumed this figure drops to approximately 8 million ha in 2050, freeing up that additional land resources for additional income generating agriculture or nature conservation.

Figure A1: Yield Potentials for Maize and Sorghum under different input levels (mainly increased energy, water and labor input resulting in agricultural intensification) according to the IIASA AEZ models. Dotted lines presenting yield increases needed to maintain current levels of per capita food production.
Part 2: Biofuel Potential in Burkina Faso

Introduction
Burkina Faso has a substantial area of marginal land currently not used for agricultural food production. As shown in Appendix 1, a moderate yield increase in the existing agricultural areas would stop a further substantial need for agricultural land expansion and could potentially free space for biofuel crops.

In Burkina Faso, 3 different potential biofuel crops have been identified: Sugarcane for ethanol production (with limited potential in the south of the country), the use of cotton seed for biodiesel production (potentially interesting through the existing cotton industry) and production of jatropha (due to its relatively low water and soil quality requirements). The following paragraphs will give an overview on their potential as well as an estimation of their impact on land and water resources. Jatropha will be analyzed in more detail to highlight the advantages of an integrated “CLEW” perspective on development issues such as biofuels.

An Overview of Potential Biofuel Sources

Sugar Cane
The suitable area for sugarcane is limited to a relatively small area in the south of the country, due to climatic reasons and water availability. The national sugar company (SN SOSUCO) has approximately 5,000 ha that could be used for this purpose; this would yield in a theoretical potential of 20,000 m³ of ethanol each year\(^3\), which would equal approximately 424,000GJ or 10 ktoe\(^4\) - less than 2% of fossil fuel imports (539 ktoe) in 2009. The expansion of area devoted to sugar cane is difficult and would require extensive irrigation – the overall future potential for sugarcane as energy crop is therefore almost exclusively limited to existing cultivated areas.

Cotton Seed
Cotton is the single most important cash crop in the country and its production is constantly increasing. The cotton plant does not only provide the cotton lint which is used in the textile industry but also has nutritious (or energetic) value in the form of seeds. Harvesting 100kg of seed cotton produces approximately 30-45kg of fibre (accounting for approximately 85% of the

\(^3\) ECOWAS – Sustainable Bioenergy Development in UEMOA Member Countries, 2008 (Source: http://vi.unctad.org/digital-library/annexd////?act=show&doc_name=403-umoabioenergy, accessed 07.06.2012)

\(^4\) Energy content of ethanol: 21.2 MJ / liter ethanol
commercial value of the harvest) and approximately 55-65kg of cottonseeds (which contain 9-12kg of pure vegetable oil).\(^5\)

![Production of Seed Cotton](image)

**Figure A2:** Cotton production (tons) and yield (hectogram per hectare (Hg/ha)) in Burkina Faso (Source: FAO)

The production of cotton has grown from around 200,000 tons in the early 1990s to reach a peak of 760,000 tons in 2006. In 2010 production was 530,000tons. Assuming average extraction rates this translates into approximately 47,700 tons – 63,600 tons of vegetable oil.

This amount of vegetable oil (already produced today) would provide a substantial amount of energy towards the Burkina Faso Energy System. However, cottonseed oil (used as oil or margarine) provides one of the main sources of fat and oil supply and has several food applications in Burkina Faso and in many other West and Central African countries. According to FAO statistics, it can be considered that only 3% to 5% of the African cottonseed oil production has effectively been exported over the 2000-2005 period, indicating that the local usage of the oil within the food sector is of great importance and therefore a complete use as an energy source should be disregarded.\(^6\)


Still, there are on-going projects to produce cotton oil with SN SOSUCO. From the government side there is increasing interest to pursue this potential energy source to produce local biodiesel\(^7\) as this option might prove economically beneficial when compared with fossil fuel imports and taking into account the additional food imports required.

**Jatropha**

Jatropha Curcas is a shrub that is fairly common in West African countries. Jatropha seeds and fruits are non-edible, and the plant is typically used as a protective hedge or to delimit agricultural lots. Jatropha seeds can be used to produce oil, soap, medicines, and candles. Jatropha is relatively easy to cultivate in marginal and semi-arid areas; it has the capacity to develop on poor soils. It is particularly drought- and pest-resistant, and can produce seeds containing up to 40% oil. The plant develops very rapidly and can begin to produce seeds in less than one year, but does not reach full productivity until three to five years, depending on the climate and nature of the soil. The plant's longevity is 30 to 40 years, and it requires little maintenance. Two harvests per year are possible.

When the seeds are crushed and processed, the resulting oil can be used in a standard diesel engine, while the residue can be used in biomass electricity plants. Alternatively, the seed cake can also be used as fertilizer.

Though Jatropha can exist with little water, production yields have been shown to be higher with water and fertilizer added. Additionally, despite its abundance, none of the Jatropha species have been properly domesticated and, as a result, its productivity is highly variable. Further, the long-term impact of its large-scale use on soil quality and the environment is unknown. Previously, Jatropha was sometimes presented as a wonder crop, but G. Fischer et al. (2009)\(^9\) warn: “Despite considerable investment and projects being undertaken in many countries, reliable scientific data on the agronomy of Jatropha are not available.” Concern is growing that plant yields in a number of countries were Jatropha was introduced as a source of biofuel are not satisfactory and have been greatly overestimated in previous literature.

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### Basic Characteristics of Jatropha cultivation

<table>
<thead>
<tr>
<th>Soil</th>
<th>Water</th>
<th>Nutrients</th>
<th>Climate</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undemanding,</td>
<td>Can be cultivated under</td>
<td>Low-fertility sites and alkaline soils</td>
<td>Tropical and subtropical but</td>
<td>Could potentially be grown on marginal land which is unsuitable for food</td>
</tr>
<tr>
<td>does not</td>
<td>irrigation and rain-fed</td>
<td>possible, but better yields with</td>
<td>also arid and semi-arid climates</td>
<td>crops</td>
</tr>
<tr>
<td>require tillage</td>
<td>conditions</td>
<td>fertilizer</td>
<td></td>
<td>2 harvests per year possible</td>
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<td></td>
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<td>Yield determination of wild seeds largely unknown</td>
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<tr>
<td></td>
<td></td>
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<td>Labor intensive</td>
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*Table A1: Basic characteristics of Jatropha as a biofuel crop (Source: ECOWAS – Sustainable Bioenergy Development in UEMOA Member Countries, 2008)*

### Assessing the Potential Yield of Jatropha

Out of the three selected crops, Jatropha appears as the most interesting option due to its modest soil requirements, allowing it to be grown on land that is marginal or unsuitable for other agricultural uses. This responds well to Burkina Faso’s extensive land resources and generally poor agricultural conditions. To date, the potential for planting Jatropha in the ECOWAS region has not been fully estimated, but Burkina Faso has been one of the countries with the highest interest in Jatropha.

In the following analysis Geographical Information Systems (GIS) and the AEZ Land Use Models are combined, using existing data on water availability and soil quality and its nutrient content as input data. The Jatropha yields based on both rain-fed and irrigated conditions are then derived from the AEZ model. Jatropha yields are estimated conservatively for marginal lands with lower soil quality which are currently not used for agricultural production. The yields on these lands are generally lower than on agricultural land, but ensure a realistic biofuel output if competition with food crops is to be avoided.

A first investigation has shown that there are substantial differences in expected yields and production within Burkina Faso – especially under rain-fed conditions. The left graph of Figure A3 gives an overview of the best growing areas for Jatropha under rain-fed conditions – it can be seen that under these circumstances only areas in the South of the country, receiving the most rainfall, are suitable. The clear boundary visible in this illustration represents the “rainfall threshold isohyet” for Jatropha – north of the boundary no large scale Jatropha cultivation is possible in these areas as the annual rainfall is too small to support cultivation without any
irrigation or water management. Irrigation can significantly increase the area where Jatropha could potentially be grown, as shown in the right graph of Figure A3.

![Figure A3: Expected Jatropha yields in Burkina Faso under rain fed and irrigated conditions](image)

Maximum oil seed yields under both rain-fed and irrigated conditions on these marginal areas are found to be in the order of only up to a maximum of 1.4 tons per hectare. Some regions in the very North are entirely unsuitable for growing Jatropha, even when irrigation is applied. The analysis undertaken with the AEZ model used only marginal land not currently used for agriculture – therefore yield estimations can be assumed to be very conservative. Some form of mechanization and land preparation will increase yields, for simplicity reasons and illustrative purposes we will assume a potential yield of 2 t/ha for the following calculation.

Assuming a yields of 2 t/ha a production of approximately 810 liter of vegetable oil will be possible per hectare. If Jatropha was grown on 1% of Burkina Faso’s total agricultural area (currently 5.9 million ha), this would yield an approximate production of 47.8 million liters (or 41,200 tons) of biodiesel. This amount represents approximately 8% of the countries fossil fuel imports in 2009.

Using more intensive agriculture could increase Jatropha yields substantially with an upper limit under best conditions of approximately 5 t/ha. This would however increase agricultural competition for most suitable soils and require a high level of mechanization and fertilizer application and as well higher irrigation requirements.

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10 Standard conversion factor for the production of vegetable oil from Jatropha seeds is approximately 35% taking into account a density of biofuel from Jatropha of 0.85g/cm³ (http://www.bioenergy.org.nz/documents/liquidbiofuels/Pilot_Plant_for_Biodiesel-leaflet1.pdf).

11 Burkina Statistics office

Water Demand for Jatropha
The AEZ model enables the calculation of the overall irrigation demand for Jatropha cultivation. Starting from available climatic data (such as temperature and rainfall) as well as soil and land characteristics (such as dominant soils types) the AEZ model can develop so called crop water deficit values for a large number of different crops. We used the model to calculate the water deficit for Jatropha cultivation in Burkina Faso as well as the associated expected yields. Climate and resulting rainfall data are combined with soil data to calculate yield reduction factors. These reduction factors provide an indication of how “water stressed” an area is, and allows calculating the crop water deficit required to achieve an optimal harvest. Figure A4 shows the crop water deficit for Jatropha in Burkina Faso.

Due to the uneven geographical distribution of rainfall, water demand for Jatropha cultivation varies considerably over the country. In the South, which receives most of the rain, only modest amounts of additional water (300 mm) are required to gain an optimal water balance for Jatropha (limiting the amount of extra yield through irrigation). The North on the other hand is extremely dry, with regions requiring up to approximately 1,000 mm of water per year to achieve appropriate Jatropha yields. Some areas are entirely unsuitable for Jatropha cultivation, independent on the level of irrigation applied. This is due to soil constraints and the extremely high temperature in those regions.

The Energy Balance of Jatropha
An irrigation need of 300 mm (or 1,000 mm) per ha can be translated into a volume of 3,000 m³ (or 10,000 m³). Providing this volume from surface water or gravitational irrigation is obviously
the most economical method. Nevertheless, surface irrigation is scarce in Burkina Faso due to the ever increasing pressure on providing domestic water demands. On the other hand, a recent study\(^\text{13}\) has shown that Africa in general has a large untapped resource potential of 978 km\(^3\) of groundwater at different depths. Estimated groundwater tables in Burkina Faso are characterized by very moderate depths, judging from an average well length of 50 m. It was therefore assumed that irrigation needs would be met by pumping groundwater from a depth of 40 m.

While the irrigation demand in the South is modest, it is worth mentioning that it compares unfavorably with typical aquifer recharge rates in Burkina Faso of 40 – 80 mm/y. While these are average values, they give a good indication that if widespread groundwater pumping to support irrigation on the order of 300 mm/y were to occur, there would be a potential overdraft associated with decreasing groundwater levels. Potentially this issue could be reduced if the plantations were not concentrated in one area and if only limited crop land was used. Therefore, for the purpose of this study it was assumed that Jatropha would only be grown on marginal land corresponding to 1 % of all agricultural land.

Meeting the irrigation need can potentially be very energy intensive. Further, while only a modest fertilizer application of 50 kg of nitrogen per hectare was assumed, this also has significant implications on the energy balance – as has the processing of the oil seeds in order to generate biodiesel. As indicated above, under conservative assumptions most suitable marginal areas will produce yields of approximately 2 tons of oil seeds per hectare. This will enable a total production of 1,600 TJ of biodiesel (based on an energy content of 39.6 MJ / kg Jatropha oil).

140 TJ would be required to meet the associated yearly irrigation requirements of 3,000 m\(^3\). The following graph (A5) compares the three main energy inputs for the biodiesel production with the biodiesel output\(^\text{15}\). It is simplified in the sense that it only focuses on the tree main energy inputs, i.e., fertilizers, irrigation requirements and methanol (for processing purposes) and does not take other potentially useful by-products like the seed cake of the Jatropha plant into account.

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\(^{13}\) A M MacDonald et al 2012 Environ. Res. Lett. 7 024009 doi:10.1088/1748-9326/7/2/024009

While the overall energy balance is clearly positive, a quick economic assessment focusing solely on the electricity bill suggests that under current prices, the use of biodiesel alone without its by-products might not justify growing Jatropha. Based on a current electricity price of 35 cent/kWh, USD 14 million would be required for pumping. This corresponds to 0.28 $/liter and leaves only a small amount for growing and processing the crop, especially if fuel taxes would need to be added onto the final biofuel price.

So while it is perfectly possible to grow Jatropha on marginal land, the economics do not look favorable based on our simple assessment. It seems that more suitable land, at least with higher rainfall, would need to be identified for this activity to make sense.

The graphic below shows that taking into account interlinkages between land use, water and energy can help identify potentially suitable or unsuitable areas for biofuel (and any other crop production).

The results of this analysis can be in turn being fed back into GIS systems and be used to produce maps highlighting water shortages in relation to potential biofuel production areas. Figure A6 below gives a presentation of such a map for Burkina Faso taking into account Jatropha yields but also water requirements to estimate most favorable plantation location, if groundwater irrigation would be used to supply the crop with the water required. The areas marked “unsuitable” in this map represent all areas that would need amounts of groundwater irrigation which would be prohibitively high compared with yields of biofuel produced. The map is based on average energy requirements for irrigation and compares these requirements with the energy production from the Jatropha plants grown in the specific location. Within this map only areas with a definite requirement for irrigation have been assumed (leaving out the south with its potential for rain fed Jatropha). It becomes easily visible that the areas suitable for
groundwater irrigated Jatropha are extensively reduced when compared with the total available land area.

Figure A6: Map representation of Jatropha plantation areas in Burkina Faso with irrigation demand – colors represent the suitability of the location based on an energy balance taking into account water consumption (to be met by irrigation).

**Conclusion**
Within this technical supplementary paper we wanted to demonstrate the interrelation of biofuel use and its impact and dependence on available land and water resources. These resources do have a significant impact on the overall energy balance of the final bio-fuel-energy-product. GIS methodologies and techniques can help bringing together land, water and energy data for informed decision making offering the option to visualize interconnection on a geographical scale.