Assessing sustainable biofuel potential in Sub-Saharan Africa

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WWF South Africa

Based on research conducted by Dr Günther Fisher and Dr Sylvia Tramberend (IIASA) and funded by the Boeing Foundation
INTRODUCTION
Aircraft fuel burn from international aviation, including potential replacement of jet fuel with alternative fuels (ICAO, 2016)

- Potential demand for biojet by 2040: 400 Mt (= approx 490 billion l)
- Current global biofuel production: 133 billion l
Context

• Africa, and particularly sub-Saharan Africa, is seen as one of the major expansion areas for the production of biofuel feedstock.

• The sustainability of large scale biofuel supply depends on available resources for the production of biomass feedstock in the context of future demand for food, water resources and the need to safeguard natural environments.

• The importance of taking a system view of biomass for energy development.
Study aim

To estimate current and future technical potentials for biofuels in sub-Saharan Africa in accordance with the principles of the Roundtable on Sustainable Biomaterials (RSB) for the following categories of biofuel feedstock:

1. Land-based energy crops

2. Crop residues

1. TO ESTIMATE THE POTENTIAL FROM LAND-BASED ENERGY CROPS, WE MUST:
   1. Estimate the amount of land that is available for feedstock production
   2. Pick the crop that would deliver the highest energy yield while complying with RSB criteria

2. TO ESTIMATE THE POTENTIAL FROM CROP RESIDUES, WE MUST:
   1. Determine the amount of residues
   2. Determine the proportion of residue that can be sustainably extracted from the field
METHODOLOGY
Land resources & agro-ecological zoning

- FAO and IIASA have developed a spatial analysis system that enables rational land-use planning on the basis of an inventory of land resources and evaluation of biophysical limitations and production potentials of land.

- The AEZ methodology follows an environmental approach; it provides a standardized framework for analyzing synergies and trade-offs of alternative uses of agro-resources (land, water, technology) for producing food and energy, while preserving environmental quality.

- GAEZ spatial databases provide:
  - Spatial distribution of current land use/cover in Sub-Saharan Africa consistent with FAO cropland statistics and remotely sensed data.
  - Inventory of protected areas & areas of high value for the environment and biodiversity
  - Climate of 5 arcminute resolution of current (1981-2010) and projections for future (2011-2090) conditions
  - Soil attributes and terrain/slope conditions
  - Land productivity assessment for food crops and biofuel feedstocks
The RSB Principles

1. Legality
2. Planning, monitoring & Continuous Improvement
3. Greenhouse Gas Emissions
4. Human & Labour Rights
5. Rural and Social Development
6. Local Food Security
7. Conservation
8. Soil
9. Water
10. Air Quality
11. Use of Technology, Inputs & Management of Waste
12. Land Rights
Greenhouse Gas Emissions

Local Food Security

Conservation

Soil

Water

Reserve cropland for food production & sufficient grazing land for ruminant livestock

Biofuels must deliver min 60% GHG saving after all LC + dLUC emissions are considered

No deforestation for biofuel feedstock production

Exclude slopes, do not extract residues above a sustainable rate

No irrigated biofuel feedstock production, exclusion of strategic water source areas

Air Quality

Use of Technology, Inputs & Management of Waste

Land Rights

The RSB Principles

1. Legality

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6. Reserve cropland for food production & sufficient grazing land for ruminant livestock

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10. Air Quality

11. Use of Technology, Inputs & Management of Waste

12. Land Rights

@RSB_ORG
Exclusion layers: cropland, grazing land, forest, environment
Biofuel feedstock selection

1st generation biofuel production chains

• Solaris
• Jatropha
• Oil palm
• Soybean
• Camelina

1st generation biofuel production chains

• Sugarcane
• Maize (grain + stover)
• Sweet sorghum
• Cassava
• Triticale

2nd generation biofuel production chains

• Miscanthus
• Crop residues

‘UMBRELLA CROP’

• Selects the best biofuel feedstock in terms of biofuel energy output and thereby defines an upper technical potential.
Development scenarios until 2050

CONSISTENT WITH IPCC

• Shared Socio-economic Pathways (SSP) for:
  – population and GDP projections
  – food demand, food production and trade
  – cropland use and irrigation demand for food production together with
• Representative Concentration Pathways (RCP) for climate change projections
• Both are input to the assessment framework of the IIASA World Food System (WFS) and GAEZ models

<table>
<thead>
<tr>
<th>SCENARIO</th>
<th>SOCIO-ECONOMIC DEVELOPMENT NARRATIVE</th>
<th>CORRESPONDING EMISSION PATHWAYS &amp; CLIMATE CHANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC1 – SUSTAINABILITY</td>
<td>Sustainability (SSP1)</td>
<td>RCP 2.6</td>
</tr>
<tr>
<td>SC2 – MIDDLE</td>
<td>Middle of the Road (SSP2)</td>
<td>RCP 6.0</td>
</tr>
</tbody>
</table>
RESULTS

current technical potential
Estimation of current REMAIN land

<table>
<thead>
<tr>
<th>LAND EXTENTS (MIO KM2)</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL LAND</td>
<td>24.27</td>
</tr>
</tbody>
</table>

**NO-GO AREAS**

- Exclusion layer FOOD – Cropland for food: -2.35 MIO KM²
- Exclusion layer FOREST: -6.90 MIO KM²
- Exclusion layer ENVIRONMENT + Grazing: -3.89 MIO KM²
- Exclusion SPARSELY VEGETATED and BARE LAND: -5.62 MIO KM²

**LAND CONSIDERED FOR BIOFUEL FEEDSTOCK PRODUCTION**: 5.5 MIO KM²

[Diagram showing 23% of TOTAL LAND]
Intensity and spatial distribution of REMAIN land (%), and number of annual growing period days, in 2010

Only a relatively small fraction of REMAIN land can support economically viable energy crops production because of differences in prevailing agro-climatic, soil and terrain conditions.

- Very suitable (VS) (prime) or suitable (S) (good) for specific energy crop production (60–100% of potential yield)

- Moderately suitable (MS) land (40–60% of potential yields); often not economically viable for commercial production, but may become so with high agricultural commodity prices.
Adding the GHG restrictions

- Biofuels must deliver min 60% GHG saving after all LC + dLUC emissions are considered
- dLUC: soil carbon & above and below ground biomass
- Indirect land-use change
- Allocation of GHG burden to multi-product crops
## Land area in South Africa that would support production of energy crops for RSB-compliant biofuel

<table>
<thead>
<tr>
<th>Category</th>
<th>Area</th>
<th>Percentage</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA total land area</td>
<td>1 222 587 km²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total REMAIN land</td>
<td>493 264 km² (40% of total)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prime and good REMAIN land for production of energy crops</td>
<td>37 349 km² (3% of total)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GHG criteria compliant prime and good REMAIN land</td>
<td>6 153 mio km² (0.5%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderately suitable GHG compliant REMAIN land</td>
<td>11 261 km² (0.9%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Current technical potential for “umbrella crops” with max energy yield and min 60% GHG saving (in PJ)**

### Very Suitable And Suitable Land

<table>
<thead>
<tr>
<th>Region</th>
<th>Sugarcane</th>
<th>Oilpalm</th>
<th>Miscanthus</th>
<th>Jatropha</th>
<th>Solaris</th>
<th>Sweet Sorghum</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>EASTERN AFRICA</td>
<td>253</td>
<td>38</td>
<td>1 188</td>
<td>84</td>
<td></td>
<td></td>
<td>1 564</td>
</tr>
<tr>
<td>CENTRAL AFRICA</td>
<td>513</td>
<td>898</td>
<td>959</td>
<td>882</td>
<td></td>
<td></td>
<td>3 342</td>
</tr>
<tr>
<td>SOUTHERN AFRICA</td>
<td>0.20</td>
<td></td>
<td>584</td>
<td>33</td>
<td>1</td>
<td></td>
<td>617</td>
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<tr>
<td>SUDANO-SAHELIAN A.</td>
<td>26</td>
<td></td>
<td>291</td>
<td>36</td>
<td></td>
<td></td>
<td>353</td>
</tr>
<tr>
<td>GULF OF GUINEA</td>
<td>115</td>
<td>297</td>
<td>594</td>
<td>183</td>
<td></td>
<td></td>
<td>1 188</td>
</tr>
<tr>
<td><strong>GRAND TOTAL</strong></td>
<td><strong>907</strong></td>
<td><strong>1 294</strong></td>
<td><strong>3 645</strong></td>
<td><strong>1 217</strong></td>
<td><strong>1</strong></td>
<td><strong>1</strong></td>
<td><strong>7 064</strong></td>
</tr>
</tbody>
</table>

Source: WDPA, PPF, GLWD, IBAT, Mining-Guidelines and own analysis
Current technical potential for “umbrella crops” with max energy yield and min 60% GHG saving (in PJ)

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<th>Sweet Sorghum</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>EASTERN AFRICA</td>
<td>301</td>
<td>47</td>
<td>2 644</td>
<td>11</td>
<td></td>
<td></td>
<td>3 003</td>
</tr>
<tr>
<td>CENTRAL AFRICA</td>
<td>898</td>
<td>1 293</td>
<td>4 923</td>
<td>126</td>
<td></td>
<td></td>
<td>7 499</td>
</tr>
<tr>
<td>SOUTHERN AFRICA</td>
<td>0.20</td>
<td></td>
<td>1 293</td>
<td>3</td>
<td>1</td>
<td></td>
<td>1 297</td>
</tr>
<tr>
<td>SUDANO-SAHelian A.</td>
<td>27.00</td>
<td></td>
<td>1 058</td>
<td>30</td>
<td></td>
<td></td>
<td>792</td>
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<tr>
<td>GULF OF GUINEA</td>
<td>167</td>
<td>437</td>
<td>1 990</td>
<td>2</td>
<td></td>
<td></td>
<td>2 596</td>
</tr>
<tr>
<td><strong>GRAND TOTAL</strong></td>
<td><strong>1 394</strong></td>
<td><strong>2</strong></td>
<td><strong>11 908</strong></td>
<td><strong>184</strong></td>
<td><strong>1</strong></td>
<td></td>
<td><strong>15 510</strong></td>
</tr>
</tbody>
</table>

Source: WDPA, PPF, GLWD, IBAT, Mining-Guidelines and own analysis
Best RSB-compliant bioethanol feedstocks on REMAIN land (current)

Best RSB-compliant biodiesel feedstocks on REMAIN land (current)
RESULTS
future technical potential
Changes in future availability of REMAIN land

Source: WDPA, PPF, GLWD, IBAT, Mining-Guidelines and own analysis
Future (2050) technical potential for “umbrella crops” with max energy yield and min 60% GHG saving (SC1)

<table>
<thead>
<tr>
<th>Region</th>
<th>Sugarcane</th>
<th>Oil palm</th>
<th>Miscanthus</th>
<th>Jatropha</th>
<th>Solaris</th>
<th>Sweet Sorghum</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>EASTERN AFRICA</td>
<td>113</td>
<td>80</td>
<td>639</td>
<td>39</td>
<td></td>
<td></td>
<td>872</td>
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<tr>
<td>CENTRAL AFRICA</td>
<td>98</td>
<td>646</td>
<td>514</td>
<td>838</td>
<td>3</td>
<td></td>
<td>2099</td>
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<tr>
<td>SOUTHERN AFRICA</td>
<td>0.60</td>
<td></td>
<td>273</td>
<td>21</td>
<td>27</td>
<td>8</td>
<td>329</td>
</tr>
<tr>
<td>SUDANO-SAHELIAN A.</td>
<td>1</td>
<td></td>
<td>227</td>
<td>24</td>
<td></td>
<td>10</td>
<td>262</td>
</tr>
<tr>
<td>GULF OF GUINEA</td>
<td>9</td>
<td>76</td>
<td>236</td>
<td>80</td>
<td></td>
<td></td>
<td>400</td>
</tr>
<tr>
<td>GRAND TOTAL</td>
<td><strong>222</strong></td>
<td><strong>801</strong></td>
<td><strong>1 890</strong></td>
<td><strong>1 001</strong></td>
<td><strong>30</strong></td>
<td><strong>18</strong></td>
<td><strong>3 962</strong></td>
</tr>
</tbody>
</table>

Source: WDPA, PPF, GLWD, IBAT, Mining-Guidelines and own analysis
### Future Potential Relative to Current Potential (VS+S)

<table>
<thead>
<tr>
<th>Region</th>
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<th>Jatropha</th>
<th>Solaris</th>
<th>Sweet Sorghum</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>EASTERN AFRICA</td>
<td>-55%</td>
<td>111%</td>
<td>-46%</td>
<td>-54%</td>
<td></td>
<td></td>
<td>-44%</td>
</tr>
<tr>
<td>CENTRAL AFRICA</td>
<td>-81%</td>
<td>-28%</td>
<td>-46%</td>
<td>-5%</td>
<td>300%</td>
<td></td>
<td>-37%</td>
</tr>
<tr>
<td>SOUTHERN AFRICA</td>
<td>200%</td>
<td>-53%</td>
<td></td>
<td></td>
<td></td>
<td>2 600%</td>
<td>-47%</td>
</tr>
<tr>
<td>SUDANO-SAHELIAN A.</td>
<td>-96%</td>
<td>-22%</td>
<td>-33%</td>
<td></td>
<td></td>
<td>1000%</td>
<td>-26%</td>
</tr>
<tr>
<td>GULF OF GUINEA</td>
<td>-92%</td>
<td>-74%</td>
<td>-60%</td>
<td>-56%</td>
<td></td>
<td></td>
<td>-66%</td>
</tr>
<tr>
<td>GRAND TOTAL</td>
<td>-76%</td>
<td>-38%</td>
<td>-48%</td>
<td>-18%</td>
<td>2 900%</td>
<td>1800%</td>
<td>-44%</td>
</tr>
</tbody>
</table>

**Source:** WDPA, PPF, GLWD, IBAT, Mining-Guidelines and own analysis
Technical potential from energy crops relative to global bio jet fuel demand

**POSSIBLE DEMAND BY GLOBAL INTERNATIONAL AVIATION IN 2050 AS PROPOSED IN THE ICAO VISION FOR ALTERNATIVE FUELS**

<table>
<thead>
<tr>
<th>Description</th>
<th>Potential (Mt/a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSA technical potential by 2050 from VS + S land</td>
<td>93</td>
</tr>
<tr>
<td>% global demand that could be met by biofuel from feedstock grown on VS + S land</td>
<td>~30%</td>
</tr>
<tr>
<td>SSA technical potential by 2050 from VS + S + MS land</td>
<td>260</td>
</tr>
<tr>
<td>% global demand that could be met by biofuel from feedstock grown on VS + S + MS land</td>
<td>~90%</td>
</tr>
</tbody>
</table>
### Technical potential relative to aviation fuel demand: South Africa

<table>
<thead>
<tr>
<th>DEMAND</th>
<th>SA TOTAL CURRENT</th>
<th>SA TOTAL 2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel demand - mio l</td>
<td>2 600</td>
<td>6 896</td>
</tr>
<tr>
<td>Fuel demand – PJ</td>
<td>97</td>
<td>258</td>
</tr>
</tbody>
</table>

% that could be satisfied by all energy crops in SA ***

- 80 - 180%
- 60 - 115%

*biofuel

**assumed 3% annual growth for jet fuel demand

***from VS+S+MS land in SC1 (lower bound) and SC2 (upper bound) scenarios
MAIN MESSAGES
Key insights from the modelling work

• Even the strictest environmental sustainability criteria allow for a meaningful technical potential for biofuels in SSA.

• The potential for all crops increases substantially if we include “moderately” suitable areas (where 40% - 60% of the maximum potential yield is achieved), but the economic attractiveness of farming in such areas demands higher commodity prices or higher subsidies.

• Opportunities for annual feedstock crops are not on virgin land; if dLUC is involved, they mostly cannot meet the GHG criteria. Rather focus on abandoned agricultural land, inter/rotation cropping or marginal land.

• Perennial crops, with soil carbon stock change factors > 1 and considerable carbon stocks in vegetation, can very often meet the strict GHG criteria, so have a wider range of options in terms of planting areas.
Key insights from the modelling work

• Caveats:
  o Significant investment in climate change adaptation are urgently needed, to avoid a sharp reduction in crop yields that is otherwise expected for most crops and across all regions. (Exceptions: potential for solaris and sweet sorghum expected to increase over time
  o Miscanthus is showing by far the largest theoretical potential in SSA, however, no experience with mischantus in the region-> agricultural trials and full risk assessment (invasiveness!) are needed before this potential can be exploited.
  o Technical potential vs economic potential.

• Case for local value chains towards domestic fuel mix (how do we support this?).
OTHER INITIATIVES IN THE REGION
Further Boeing funding (2019-2021) secured to:

In South Africa
- Assess the potential for alternative production routes in South Africa & their socio-economic benefits
- Create a specific guidance for new feedstocks (i.e. alien invasive plants)

In Ethiopia
- Develop a roadmap for the SAF sector in Ethiopia
- Supply chains support – working with individual sectors (agricultural, waste management, manufacturing) to build capacity, developing tools and protocols, regional indicators

In Brazil
- Replicate resource assessment
- Assess the additional positive social and environmental benefits of key feedstocks (macauba, carinata, etc.) as well as the potential of integrated production systems (crops-livestock-forestry) to provide feedstock for SAF production
First of its kind in Africa.

Aims to prove the feasibility of waste-based sustainable bio jet fuel production and consumption in South Africa with the view to replicating elements of the project in other African countries.

It will enable 25 MSMEs to be meaningfully involved in the development of a new value chain in South Africa – the production of SAF.

It will adhere to global sustainability standards that have been chosen by the aviation industry for the development of a biofuel sector that promotes food security, biodiversity, and water, land and labour rights.

Ultimately, the project will address the need for a reduction in GHG emitted by aviation, while better capacitating micro, small and medium enterprises to promote and adopt sustainable consumption practices and seize green economy opportunities.