Spatial assessment of optimum growing areas for potential biofuel feedstock (soybean) in South Africa

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OVERVIEW

- INTRODUCTION
- LITERATURE REVIEW
- AIMS AND OBJECTIVES
- METHODOLOGY
- RESULTS AND DISCUSSION
Soybean as a Biofuel Feedstock

- Soybean production in SA ranges from 450,000 to 500,000 t an\(^{-1}\)
- Average yield of 2.5 to 3 t/ha under dry-land conditions
- Second largest source of vegetable oil in SA after sunflower
- By-product of biodiesel processing is animal feed which is currently imported
- Reduce the cost of high quality protein animal feed in SA
  - Coega IDZ biodiesel: 288 million L an\(^{-1}\) from 1,300,000 t soybean
Soybean Production by Province

Figure 2: Soybean Production by province 2010

- Mpumalanga: 42%
- Free State: 27%
- Kwazulu-Natal: 13%
- Limpopo: 9%
- Eastern Cape: 0%
- Northern Cape: 0%
- North-West: 5%
- Gauteng: 4%

Source: Statistics and Economic Analysis
## Soybean Production by District

**Major production areas in South Africa**

<table>
<thead>
<tr>
<th>Province</th>
<th>District</th>
<th>Towns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mpumalanga</td>
<td>Gert Sibande</td>
<td>Morgenzon, Volkrust, Piet Retief, Perdekop</td>
</tr>
<tr>
<td></td>
<td>Nkangala</td>
<td>Ermelo</td>
</tr>
<tr>
<td></td>
<td>Mankaligwa</td>
<td>Secunda</td>
</tr>
<tr>
<td>Free State</td>
<td>Thabo Mofutsanyane</td>
<td>Bethlehem, Warden</td>
</tr>
<tr>
<td></td>
<td>Fezile Dabi</td>
<td>Villiers, Vrede</td>
</tr>
<tr>
<td>Kwa-Zulu Natal</td>
<td>Umgungundlovu</td>
<td>Greytown</td>
</tr>
<tr>
<td></td>
<td>Amajuba</td>
<td>Normandien</td>
</tr>
<tr>
<td></td>
<td>Zululand</td>
<td>Pongola, Vryheid</td>
</tr>
<tr>
<td></td>
<td>UMzinyathi</td>
<td>Dundee</td>
</tr>
<tr>
<td></td>
<td>eThekweni</td>
<td>Winterton, Bergville</td>
</tr>
<tr>
<td>Limpopo</td>
<td>Waterberg</td>
<td>Koedoeskop, Naboomspruit</td>
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<tr>
<td></td>
<td>Sekhuhkune</td>
<td>Groblersdal, Marble Hall</td>
</tr>
<tr>
<td>North West</td>
<td>Ngaka Modiri Malema</td>
<td>Mafikeng, Delareyville, Lichtenberg, Zeerust</td>
</tr>
<tr>
<td></td>
<td>Dr. Kenneth Kaunda</td>
<td>Potchefstroom</td>
</tr>
<tr>
<td></td>
<td>Bojanala</td>
<td>Venterdsdorp, Klerksdorp</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rustenburg, Moretele, Koster, Brits</td>
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<td>Gauteng</td>
<td>Metswediing</td>
<td>Bapsfontein, Bronkorspruit</td>
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<tr>
<td></td>
<td>Sedibeng</td>
<td>Heidelberg/Nigel</td>
</tr>
</tbody>
</table>

Source: DAFF, 2010
Expansion of Soybean Production: Concerns...

1. Land Use and Food Security
   - Competition between food vs. fuel
   - Possible increase in food prices

2. Environmental impacts
   - If not well planned, bioenergy development has the potential to:
     - Destroy biodiversity
     - Deplete/pollute water resources
Case Study

- Scoping study (Jewitt et al., 2009)
  - Aim of study
    - Map potential growing areas and
    - Estimate water use of biofuel feedstocks
  - Only considered climatic mapping factors
  - Soil parameters & disease risk were not considered
  - Further work is therefore necessary to refine the potential growing areas
CLIMATIC OPTIMUM GROWTH AREAS FOR SOYBEAN
(Glycine max)

Source: Jewitt et al. (2009)
Aim and Objectives

Aim

- To map areas suitable for soybean (Scoping study)
- To improve the approach used in previous mapping studies

Objectives

(a) To undertake detailed literature review for biofuel feedstocks
(b) To account for climatic factors affecting feedstock production
(c) To account for edaphic factors affecting feedstock production
(d) To account for biotic factors affecting feedstock production
Methodology 1: Literature Review

- **Update the factors limiting feedstock growth:**
  - Rainfall
    - Seasonal rainfall
  - Temperature
    - Monthly average and monthly maximum
  - Relative humidity
    - Potential for disease occurrence (e.g. soybean rust)
  - Soils and topography
    - Soil depth and slope
## Optimum Growth Criteria

<table>
<thead>
<tr>
<th>Source</th>
<th>Annual rainfall (mm)</th>
<th>Seasonal rainfall (mm)</th>
<th>$T_{\text{ave}}$ ($^\circ$C)</th>
<th>Frost Tolerance</th>
<th>RH$_{\text{ave}}$ (%)</th>
<th>Slope (%)</th>
<th>Soil Depth (mm)</th>
<th>pH</th>
<th>Soil Texture</th>
<th>Rank</th>
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</thead>
<tbody>
<tr>
<td>Jewitt et al. (2009) recommended</td>
<td>550-700</td>
<td>20-30</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Smith (1994)</td>
<td>&gt; 700</td>
<td>450-700</td>
<td>18-35 Sub</td>
<td></td>
<td>600-1300</td>
<td></td>
<td>No very Sandy/ poorly drained</td>
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<tr>
<td>Smith (1998)</td>
<td>&gt; 700</td>
<td>550-700</td>
<td></td>
<td></td>
<td>600-1200</td>
<td></td>
<td>Medium</td>
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<tr>
<td>Smith (2006)</td>
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<td></td>
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<td></td>
<td></td>
<td>600-1200</td>
<td></td>
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<tr>
<td>FAO (2006)</td>
<td>600-1500 Opt</td>
<td>20-33 Opt</td>
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<td></td>
<td>5.5-6.5 Opt</td>
<td></td>
<td>Medium, organic</td>
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<tr>
<td>Schoeman and Walt (2006)</td>
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<tr>
<td>Schulze &amp; Maharaj (2006)</td>
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<td>Jan &gt; 18</td>
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<td></td>
<td></td>
<td>0-20</td>
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<td>INR (2004), Kassam (2012)</td>
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<td>Ebrahim (2007), Singels (2013)</td>
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<td>Jan &gt; 18</td>
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<td>DAFF (2010)</td>
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<td></td>
<td></td>
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<tr>
<td>DAFF (2010)-At planting</td>
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<td>15-18</td>
<td></td>
<td></td>
<td>&gt; 5.2 Sub</td>
<td></td>
<td></td>
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<tr>
<td>Bassam, 2010</td>
<td>500-750</td>
<td>24-25 Opt</td>
<td></td>
<td></td>
<td>6-6.5</td>
<td></td>
<td>300-400</td>
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<td>loamy</td>
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</tbody>
</table>
Methodology 2: Mapping

1. Rain Data
2. Temp Data
3. RH Data
4. Slope Data
5. SD Data

- Re-class and assign influence importance
- Multiply by Corresponding Weights
- Weighted Rain
- Weighted Temp
- Weighted RH
- Weighted Slope
- Weighted SD

- Summation of the weighted maps
- Mask the land use
- Overall Suitability Map

Source: After Koikai, 2008
Methodology 3: Rainfall

- Growth season: November to March
- Accumulated seasonal rainfall total
- Classified seasonal rainfall into optimum and sub-optimum classes (Reclassify)

<table>
<thead>
<tr>
<th>Suit classes</th>
<th>No</th>
<th>Abs</th>
<th>Sub</th>
<th>Opt</th>
<th>Sub</th>
<th>Abs</th>
<th>No</th>
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<td>Nov-Mar</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>1</td>
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<tr>
<td></td>
<td>0.450</td>
<td>450-550</td>
<td>550-700</td>
<td>700-900</td>
<td>900-1000</td>
<td>1000-1100</td>
<td>&gt;1100</td>
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</tbody>
</table>
Methodology 3: Rainfall

- Rainfall distribution according to crop coefficients
  - Apportioned per month based on $K_{cm}$
    - FAO, 2013 Local
    - 0.3 - 0.4 0.72 Initial stage (20 to 25 days)
    - 0.7 - 0.8 0.72 Development stage (25 to 35 days)
    - 1.0 - 1.2 1.00 Mid-season stage (45 to 65 days)
    - 0.7 - 0.8 1.03 Late-season stage (20 to 30 days)
    - 0.4 - 0.5 0.84 At harvest

- Monthly rainfall distribution classes (700 - 900 mm):
  - Month 1 70 - 90
  - Month 2 135 - 170
  - Month 3 165 - 210
  - Month 4 195 - 250
  - Month 5 135 - 180
Methodology 4: Temp & Humidity

• Monthly means of daily average temperature (°C) (Reclassify)
  • At germination
  • Rest of the growing season

<table>
<thead>
<tr>
<th>Suit classes</th>
<th>No</th>
<th>Abs</th>
<th>Sub</th>
<th>Opt</th>
<th>Sub</th>
<th>Abs</th>
<th>No</th>
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<tr>
<td>Nov</td>
<td>0-10</td>
<td>10-13</td>
<td>13-15</td>
<td>15-18</td>
<td>18-25</td>
<td>25-33</td>
<td>33-100</td>
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<tr>
<td>Dec-Mar</td>
<td>0-10</td>
<td>10-18</td>
<td>18-23</td>
<td>23-27</td>
<td>27-30</td>
<td>30-33</td>
<td>33-100</td>
</tr>
</tbody>
</table>

• Daily average relative humidity (%)
  • 0-60 Low disease risk Suitability=3
  • 60-75 Medium disease risk Suitability=2
  • 75-80 High disease risk Suitability=1
  • >80 Very high disease risk Suitability=0
Methodology 5: Depth & Slope

- **Soil depth (mm) (Reclassify)**
  - < 200  Unsuitable  Suitability=0
  - 200-300  Absolute  Suitability=1
  - 300-500  Sub-optimum  Suitability=2
  - > 500  Optimum  Suitability=3

- **Slope (%) (Reclassify)**
  - < 4  Optimum  Suitability=3
  - 4-8  Sub-optimum  Suitability=2
  - 8-10  Absolute  Suitability=1
  - > 10  Unsuitable  Suitability=0
Methodology 6: Weightings

- Assigned influence of importance
  - Monthly rainfall 4 (Odindo, 2013)
  - Monthly temperature 2
  - Monthly relative humidity 1
  - Soil depth 1
  - Slope 2

  Total 10

- Weighting varied per month
  - e.g. Monthly relative humidity weightings
    - Month 1 0.1
    - Month 2 0.1
    - Month 3 0.2
    - Month 4 0.3
    - Month 5 0.3
## Criteria and Ranking

<table>
<thead>
<tr>
<th>Criteria Values</th>
<th>Unsuitable</th>
<th>Low Suitability</th>
<th>Medium Suitability</th>
<th>High Suitability</th>
<th>Medium Suitability</th>
<th>Low Suitability</th>
<th>Unsuitable</th>
<th>Assigned Influence Importance</th>
<th>Decimal Weight</th>
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<td>Reclass Values</td>
<td>0</td>
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<tr>
<td>MR01 (mm)</td>
<td>0-45</td>
<td>45-55</td>
<td>55-70</td>
<td>70-90</td>
<td>90-100</td>
<td>100-110</td>
<td>&gt;110</td>
<td>0.4</td>
<td>0.04</td>
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<td>MR02 (mm)</td>
<td>0-85</td>
<td>85-105</td>
<td>105-135</td>
<td>135-170</td>
<td>170-200</td>
<td>200-220</td>
<td>&gt;220</td>
<td>0.9</td>
<td>0.09</td>
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<tr>
<td>MR03 (mm)</td>
<td>0-105</td>
<td>105-130</td>
<td>130-165</td>
<td>165-210</td>
<td>210-250</td>
<td>250-270</td>
<td>&gt;270</td>
<td>1.3</td>
<td>0.13</td>
</tr>
<tr>
<td>MR04 (mm)</td>
<td>0-125</td>
<td>125-150</td>
<td>150-195</td>
<td>195-250</td>
<td>250-290</td>
<td>290-320</td>
<td>&gt;320</td>
<td>0.9</td>
<td>0.09</td>
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<tr>
<td>MR05 (mm)</td>
<td>0-90</td>
<td>90-110</td>
<td>110-135</td>
<td>135-180</td>
<td>180-210</td>
<td>210-230</td>
<td>&gt;230</td>
<td>0.5</td>
<td>0.05</td>
</tr>
<tr>
<td>Month1 Temp (°C)</td>
<td>0-10</td>
<td>10-13</td>
<td>13-15</td>
<td>15-18</td>
<td>18-25</td>
<td>25-33</td>
<td>&gt;33</td>
<td>0.5</td>
<td>0.05</td>
</tr>
<tr>
<td>Month2 Temp (°C)</td>
<td>0-10</td>
<td>10-18</td>
<td>18-23</td>
<td>23-27</td>
<td>27-30</td>
<td>30-33</td>
<td>&gt;33</td>
<td>0.2</td>
<td>0.02</td>
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<tr>
<td>Month3 Temp (°C)</td>
<td>0-10</td>
<td>10-18</td>
<td>18-23</td>
<td>23-27</td>
<td>27-30</td>
<td>30-33</td>
<td>&gt;33</td>
<td>0.3</td>
<td>0.03</td>
</tr>
<tr>
<td>Month4 Temp (°C)</td>
<td>0-10</td>
<td>10-18</td>
<td>18-23</td>
<td>23-27</td>
<td>27-30</td>
<td>30-33</td>
<td>&gt;33</td>
<td>0.5</td>
<td>0.05</td>
</tr>
<tr>
<td>Month5 Temp (°C)</td>
<td>0-10</td>
<td>10-18</td>
<td>18-23</td>
<td>23-27</td>
<td>27-30</td>
<td>30-33</td>
<td>&gt;33</td>
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<tr>
<td>Month1 RH (%)</td>
<td>100-80</td>
<td>80-75</td>
<td>75-60</td>
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<td>Month2 RH (%)</td>
<td>100-80</td>
<td>80-75</td>
<td>75-60</td>
<td>60-0</td>
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<tr>
<td>Month3 RH (%)</td>
<td>100-80</td>
<td>80-75</td>
<td>75-60</td>
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<td>0.2</td>
<td>0.02</td>
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<tr>
<td>Month4 RH (%)</td>
<td>100-80</td>
<td>80-75</td>
<td>75-60</td>
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<td>60-0</td>
<td></td>
<td>0.3</td>
<td>0.03</td>
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<tr>
<td>Month5 RH (%)</td>
<td>100-80</td>
<td>80-75</td>
<td>75-60</td>
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<td>60-0</td>
<td>60-0</td>
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<td>0.3</td>
<td>0.03</td>
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<tr>
<td>Soil Depth (mm)</td>
<td>0-200</td>
<td>200-300</td>
<td>300-500</td>
<td>500-1200</td>
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<td>Slope (%)</td>
<td>100-10</td>
<td>10-8</td>
<td>8-4</td>
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<td>Total</td>
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</tbody>
</table>
South African Atlas of Climatology and Agrohydrology

(Schulze et al., 2007; 2008)
**Raster calculator**

Rain Weight = ((Reclass_rfl_1 * 0.04) + (Reclass_rfl_2 * 0.09) + (Reclass_rfl_3 * 0.13) + Reclass_rfl_4 * 0.09) + (Reclass_rfl_5 * 0.08)

S = Rfl weight + Tmp weight + RH weight + Slpe weight + Soild weight  (minute* minute)
Potential Soybean Production Areas (Based on FAO crop coefficients)
Potential Soybean Production Areas (Based on Local crop coefficients)
Discussion

• Greatest potential identified in
  – KwaZulu-Natal
  – Limpopo
  – Mpumalanga
  – Free State (FS)

• Least Potential
  – Gauteng
  – Eastern Cape (Why build the processing plant near Port Elizabeth?)