5 REGIONS SUITABLE FOR FEEDSTOCK PRODUCTION

The main aim of this chapter is to identify and describe bio-climatic regions suitable for crop/tree systems suitable for biofuel production with reference to, *inter alia*:

- rainfall average and variability,
- surface and underground water resources,
- temperature average and extremes,
- soil properties,
- known pests and diseases, and
- topography.

In order to achieve the objective, a land suitability assessment was completed to identify both high potential (optimum) and low potential (sub-optimum) bio-climatic regions deemed suitable for feedstock cultivation. However, the sub-optimum class was split into two categories, namely moderately suitable and marginally suitable for crop growth.

5.1 Introduction

Feedstock demand can be met by 1) an increase in the area under cultivation, and/or 2) through an increase in feedstock yields. Owing to the high volumes of feedstock required for biofuel production in South Africa (e.g. an additional 600 000 tons of grain sorghum), a large increase in the planted area is required to satisfy the demand (e.g. an additional 215 000 ha of grain sorghum production). Feedstock derived from gains in crop yields and the diversion of feed (not food) crops to biofuel production is insufficient to meet the demand. In other words, the intensification of agricultural production on existing land is deemed insufficient to produce the required volume of feedstock required for biofuel production.

Since an expansion of agricultural production is required, it is important to identify areas where feedstock cultivation can realistically occur. A land suitability assessment is therefore needed to identify areas suitable for the cultivation of biofuel feedstocks. Land suitability assessments require geo-referenced information to characterise and optimise land use by location. These assessments are therefore limited by the availability and quality of the required spatial datasets. In some cases, the necessary data sets are not yet available. In addition, the datasets may need to be acquired from a number of different institutions. This leads to compatibility problems and issues related to spatial scale and resolution. Hence, data quality often determines the scale at which such analyses can be conducted. For example, coarse GIS data (in terms of scale and resolution) is only suitable for national-level assessments.

The theoretical and conceptual basis for the approach is explained in *Volume 2*. The reader is also referred to Khomo (2014) if further detail is required on the derivation of the land suitability maps for sugarcane, grain sorghum and soybean. For additional information on the interim steps used to develop the sugarbeet and canola maps, the reader is referred to *Volume 1*. A brief summary of the approach used is given in this volume, using soybean as the example.

136
5.2  Weighted Site Criteria

5.2.1 Background

Khomo (2014) identified five criteria that were used to assess the suitability of land to grow feedstocks as follows:

- monthly rainfall (as an index of moisture supply),
- monthly means of temperature (index of moisture demand),
- monthly means or relative humidity (index of disease risk),
- soil depth (index of moisture storage), and
- slope (e.g. eliminate areas with steep slopes).

5.2.2 Methodology

The four main steps followed in the land suitability assessment were as follows:

- determination of feedstock growth criteria,
- ranking of suitability criteria,
- weighting of each criterion, and finally
- calculating the suitability score.

5.2.2.1 Feedstock growth criteria

Rainfall, temperature, relative humidity and soil depth thresholds were obtained from a detailed review of available literature which distinguish between optimum (Opt), sub-optimum (Sub) and marginal (Abs) growing conditions as shown in Table 16. It is important to realise that the growth thresholds were derived from a subjective assessment of values gleaned from a literature review. Thus, these estimates are not absolute and should only be used as a definitive guide to where the crop may be grown in South Africa. In general, such estimates may “improve” with time as more data becomes available on each feedstock, especially if it is grown extensively in South Africa.

Table 16  Growth criteria for soybean derived from values published in the literature

<table>
<thead>
<tr>
<th>Variable</th>
<th>Abs Minimum</th>
<th>Sub</th>
<th>Opt Minimum</th>
<th>Opt</th>
<th>Sub</th>
<th>Abs Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seasonal rainfall (mm)</td>
<td>450</td>
<td>550</td>
<td>700</td>
<td>900</td>
<td>1000</td>
<td>1100</td>
</tr>
<tr>
<td>Monthly mean temperature (°C): Nov</td>
<td>10</td>
<td>13</td>
<td>15</td>
<td>18</td>
<td>25</td>
<td>33</td>
</tr>
<tr>
<td>Monthly mean temperature (°C): Dec-Mar</td>
<td>10</td>
<td>18</td>
<td>23</td>
<td>27</td>
<td>30</td>
<td>33</td>
</tr>
<tr>
<td>Monthly mean relative humidity (%)</td>
<td>60</td>
<td>75</td>
<td>80</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil depth (mm)</td>
<td>200</td>
<td>300</td>
<td>500</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5.2.2.2 Ranking of criteria

A ranking was then assigned to each class. Thus, growth conditions are deemed optimal for soybean when accumulated monthly rainfall ranges from 700 to 900 mm over the five-month growing season (Table 17).

5.2.2.3 Weighting of criteria

The five selected criteria were weighted according to their relative importance in determining feedstock survival at a particular location (Table 18). These subjective weightings were based on expert opinion, with rainfall deemed most important to crop survival. These weightings were then normalised to create a decimal weighting.
### Table 17  
Seasonal rainfall thresholds and rankings for each suitability class derived for soybean (Khomo, 2014)

<table>
<thead>
<tr>
<th>Code</th>
<th>Seasonal rainfall range (mm)</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not</td>
<td>&lt; 450</td>
<td>0</td>
</tr>
<tr>
<td>Abs</td>
<td>450 - 550</td>
<td>1</td>
</tr>
<tr>
<td>Sub</td>
<td>550 - 700</td>
<td>2</td>
</tr>
<tr>
<td>Opt</td>
<td>700 - 900</td>
<td>3</td>
</tr>
<tr>
<td>Sub</td>
<td>900 - 1 000</td>
<td>2</td>
</tr>
<tr>
<td>Abs</td>
<td>1 000 - 1 100</td>
<td>1</td>
</tr>
<tr>
<td>Not</td>
<td>&gt; 1 100</td>
<td>0</td>
</tr>
</tbody>
</table>

### Table 18  
Weighting assigned to each suitability criterion (Bertling and Odindo, 2013)

<table>
<thead>
<tr>
<th>Suitability criteria</th>
<th>Relative weighting (%)</th>
<th>Decimal weighting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall</td>
<td>40</td>
<td>0.4</td>
</tr>
<tr>
<td>Temperature</td>
<td>20</td>
<td>0.2</td>
</tr>
<tr>
<td>Relative humidity</td>
<td>10</td>
<td>0.1</td>
</tr>
<tr>
<td>Soil depth</td>
<td>10</td>
<td>0.1</td>
</tr>
<tr>
<td>Slope</td>
<td>20</td>
<td>0.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
<td><strong>1.0</strong></td>
</tr>
</tbody>
</table>

#### 5.2.2.4 Total suitability score

In Table 19, the suitability score is the product of the ranking and the decimal weighting. The five suitability scores were then summed to derive the overall land suitability score. Hence, if a particular site is ideally suited to the optimum growth of a feedstock, it is assigned an overall suitability score of 3.

### Table 19  
Total suitability score obtained when each suitability criteria is ideally ranked

<table>
<thead>
<tr>
<th>Suitability criteria</th>
<th>Ranking</th>
<th>Decimal weighting</th>
<th>Suitability score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall</td>
<td>3</td>
<td>0.4</td>
<td>1.2</td>
</tr>
<tr>
<td>Temperature</td>
<td>3</td>
<td>0.2</td>
<td>0.6</td>
</tr>
<tr>
<td>Relative humidity</td>
<td>3</td>
<td>0.1</td>
<td>0.3</td>
</tr>
<tr>
<td>Soil depth</td>
<td>3</td>
<td>0.1</td>
<td>0.3</td>
</tr>
<tr>
<td>Slope</td>
<td>3</td>
<td>0.2</td>
<td>0.6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3</strong></td>
<td><strong>1.0</strong></td>
<td><strong>3.0</strong></td>
</tr>
</tbody>
</table>

#### 5.2.2.5 Normalised suitability score

The total suitability score ranges from 0 (not suitable) to 3 (optimally suited), which was then normalised. The normalised values were grouped into four classes for mapping purposes as shown in Table 20. For the mapping of sugarbeet, the lower threshold was increased from 0.60 to 0.63, to eliminate unsuitable areas in the Northern Cape Province. Each suitability class was then equated to the land suitability classification proposed in 1976 by the Food and Agriculture Organisation of the United Nations o FAO (c.f. Section 5.3.2.1).
Table 20  Normalised total suitability score used for mapping purposes (Khomo, 2014)

<table>
<thead>
<tr>
<th>Normalised suitability score</th>
<th>Suitability for feedstock cultivation</th>
<th>FAO (1976) classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 - 0.60</td>
<td>Not suitable</td>
<td>N1 or N2</td>
</tr>
<tr>
<td>0.60 - 0.65</td>
<td>Marginally suitable</td>
<td>S3</td>
</tr>
<tr>
<td>0.65 - 0.75</td>
<td>Moderately suitable</td>
<td>S2</td>
</tr>
<tr>
<td>0.75 - 1.00</td>
<td>Highly suitable</td>
<td>S1</td>
</tr>
</tbody>
</table>

5.2.2.6 Rainfall distribution

Monthly crop coefficients ($K_c$) for Baynesfield were used to determine the optimum distribution of monthly rainfall over the growing season. The monthly values were normalised and then multiplied by each of the seasonal rainfall thresholds given in Table 16.

Table 21  Preferred distribution of seasonal rainfall in each month of the growing season for soybean

<table>
<thead>
<tr>
<th>Month</th>
<th>$K_c$ norm</th>
<th>Monthly rainfall thresholds (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Abs</td>
</tr>
<tr>
<td>November</td>
<td>0.72</td>
<td>0.167</td>
</tr>
<tr>
<td>December</td>
<td>0.72</td>
<td>0.167</td>
</tr>
<tr>
<td>January</td>
<td>1.00</td>
<td>0.232</td>
</tr>
<tr>
<td>February</td>
<td>1.03</td>
<td>0.239</td>
</tr>
<tr>
<td>March</td>
<td>0.84</td>
<td>0.195</td>
</tr>
<tr>
<td>Total</td>
<td>4.31</td>
<td>1.000</td>
</tr>
</tbody>
</table>

If February’s rainfall total ranges from 175 to 215 mm, it is considered optimal and is assigned a ranking of 3 (Table 22). Similarly, if February’s rainfall total is in the range 135-175 mm or 215-245 mm, the location is considered sub-optimal for soybean cultivation and assigned a ranking of 2.

Table 22  Ranking of seasonal rainfall in each month of the growing season for soybean

<table>
<thead>
<tr>
<th>Ranking</th>
<th>Monthly rainfall ranges (mm) per suitability class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>November</td>
<td>&lt; 75</td>
</tr>
<tr>
<td>December</td>
<td>&lt; 75</td>
</tr>
<tr>
<td>January</td>
<td>&lt; 105</td>
</tr>
<tr>
<td>February</td>
<td>&lt; 105</td>
</tr>
<tr>
<td>March</td>
<td>&lt; 90</td>
</tr>
<tr>
<td>Seasonal total (mm)</td>
<td>&lt; 450</td>
</tr>
</tbody>
</table>

This approach produces a ranked value for each month in the growing season. The monthly crop coefficient was also used to weight the relative importance of each month’s ranking. Thus, the rainfall suitability score is the ranking multiplied by the decimal weighting, then summed to give a total score for the five-month growing season (Table 23).
Table 23  Maximum rainfall suitability score when each month’s rainfall is ideally suited to soybean cultivation

<table>
<thead>
<tr>
<th>Month</th>
<th>Optimum range (mm)</th>
<th>Rank</th>
<th>$K_c$</th>
<th>Relative weighting</th>
<th>Decimal weighting</th>
<th>Suitability score</th>
</tr>
</thead>
<tbody>
<tr>
<td>November</td>
<td>115-150</td>
<td>3</td>
<td>0.72</td>
<td>0.67</td>
<td>0.067</td>
<td>0.20</td>
</tr>
<tr>
<td>December</td>
<td>115-150</td>
<td>3</td>
<td>0.72</td>
<td>0.67</td>
<td>0.067</td>
<td>0.20</td>
</tr>
<tr>
<td>January</td>
<td>160-210</td>
<td>3</td>
<td>1.00</td>
<td>0.93</td>
<td>0.093</td>
<td>0.28</td>
</tr>
<tr>
<td>February</td>
<td>175-215</td>
<td>3</td>
<td>1.03</td>
<td>0.96</td>
<td>0.096</td>
<td>0.29</td>
</tr>
<tr>
<td>March</td>
<td>135-175</td>
<td>3</td>
<td>0.84</td>
<td>0.78</td>
<td>0.078</td>
<td>0.23</td>
</tr>
<tr>
<td>Total</td>
<td>700-900</td>
<td>4.31</td>
<td>4.00</td>
<td>0.400</td>
<td>1.20</td>
<td></td>
</tr>
</tbody>
</table>

Each monthly rainfall dataset (for November to December) was re-classified to produce five new datasets. For example, if the monthly rainfall in February ranged from 175 to 215 mm, it was re-classified as 3 (i.e. optimum). Each new re-classified rainfall dataset (called Rfl_Rec_xx; where xx = month) was weighted using the normalised crop coefficient, then summed to calculate the rainfall suitability score (Rfl_Sum) using the following expression:

$$Rfl\_Sum = ([Rfl\_Rec\_11] \times 0.067) + ([Rfl\_Rec\_12] \times 0.067) + ([Rfl\_Rec\_01] \times 0.093) + ([Rfl\_Rec\_02] \times 0.096) + ([Rfl\_Rec\_03] \times 0.078)$$

Equation 2

The weighted rainfall map for soybean (Figure 59) shows that soybean cultivation under dryland conditions is best suited to the eastern parts of South Africa, and not the drier western and north-western regions.

Figure 59  Normalised suitability score for seasonal rainfall which ranges from 0 (not suitable) to 0.4 (highly suited) for soybean cultivation, based on FAO crop coefficients (Khomo, 2014)
5.2.2.7 Temperature and relative humidity
This exercise was repeated for the other monthly climate datasets for temperature and relative humidity. The relative temperature weightings assigned to each month (Table 24) indicate soybean is more sensitive to temperature stress early in the season (i.e. November-January). Similarly, the risk of soybean rust outbreak is highest in January and February and declines in March.

Table 24 Relative monthly weighting assigned to each criterion (Khomo, 2014)

<table>
<thead>
<tr>
<th>Month</th>
<th>Decimal weighting</th>
<th>Rainfall</th>
<th>Temperature</th>
<th>Relative humidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>November</td>
<td>0.067</td>
<td>0.050</td>
<td>0.010</td>
<td></td>
</tr>
<tr>
<td>December</td>
<td>0.067</td>
<td>0.050</td>
<td>0.010</td>
<td></td>
</tr>
<tr>
<td>January</td>
<td>0.093</td>
<td>0.050</td>
<td>0.030</td>
<td></td>
</tr>
<tr>
<td>February</td>
<td>0.096</td>
<td>0.030</td>
<td>0.030</td>
<td></td>
</tr>
<tr>
<td>March</td>
<td>0.078</td>
<td>0.020</td>
<td>0.020</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>0.400</td>
<td>0.200</td>
<td>0.100</td>
<td></td>
</tr>
</tbody>
</table>

5.2.2.8 Soil depth
Due to data limitations, only soil depth was evaluated in this study. Table 25 summarises the soil depth suitability classes and rankings (i.e. scores) used for soybean. The depths were gleaned from the literature review undertaken for soybean.

Table 25 Ranking of each suitability class based on soil depth (mm) for soybean

<table>
<thead>
<tr>
<th>Code</th>
<th>Suitability class</th>
<th>Soil depth (mm)</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opt</td>
<td>S1</td>
<td>&gt; 500</td>
<td>3</td>
</tr>
<tr>
<td>Sub</td>
<td>S2</td>
<td>300 - 500</td>
<td>2</td>
</tr>
<tr>
<td>Abs</td>
<td>S3</td>
<td>200 - 300</td>
<td>1</td>
</tr>
<tr>
<td>Not</td>
<td>N1</td>
<td>&lt; 200</td>
<td>0</td>
</tr>
</tbody>
</table>

Soil depth comprises of a single dataset that does not change over the growing season. The final weighting of this dataset is 0.1, i.e. same importance as relative humidity. Figure 60 shows the coarseness of the soil depth data available for Lesotho and Swaziland. Table 26 indicates that for a large portion (~40%) of the country, soil depths are unsuitable for production of annual feedstocks. These areas mainly occur in the western parts of the country (Figure 60).

Table 26 Areas suitable for the cultivation of canola based on soil depth

<table>
<thead>
<tr>
<th>Value</th>
<th>Pixel count</th>
<th>% of total land area</th>
<th>Accum. %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>10 791 910</td>
<td>39.79</td>
<td>39.79</td>
</tr>
<tr>
<td>0.01-0.05</td>
<td>6 090 919</td>
<td>22.46</td>
<td>62.25</td>
</tr>
<tr>
<td>0.05-0.10</td>
<td>10 233 310</td>
<td>37.75</td>
<td>100.00</td>
</tr>
</tbody>
</table>
5.2.2.9 Slope
Steeper areas (> 10% slope) are not suitable for cultivation due to the high risk of soil erosion from increased runoff. Furthermore, steeper slopes are more difficult and costly to cultivate than flat land (Santos et al., 2000). Table 27 summarises the slope suitability classes and rankings used in this study for all feedstocks.

<table>
<thead>
<tr>
<th>Code</th>
<th>Suitability class</th>
<th>Soil slope (%)</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opt</td>
<td>S1</td>
<td>&lt; 10</td>
<td>&lt; 4</td>
</tr>
<tr>
<td>Sub</td>
<td>S2</td>
<td>10 - 15</td>
<td>4 - 8</td>
</tr>
<tr>
<td>Abs</td>
<td>S3</td>
<td>15 - 30</td>
<td>8 - 10</td>
</tr>
<tr>
<td>Not</td>
<td>N2</td>
<td>&gt; 30</td>
<td>&gt; 10</td>
</tr>
</tbody>
</table>

The procedure followed to process slope is similar to that used for soil depth, in that there is only a single dataset (Figure 61). However, the final weighting of this dataset is 0.2, i.e. same influence as temperature.
Figure 61  Slope suitability map for the cultivation of canola

With regard to slope constraints, Table 28 shows that the majority of the country is deemed suitable for cultivation of annul crops. It is interesting to note that 24.5% of the country is considered unsuitable for cultivation, with the majority (60.4%) being relatively flat for crop cultivation.

Table 28  Areas suitable for the cultivation of canola based on slope

<table>
<thead>
<tr>
<th>Value</th>
<th>Pixel count</th>
<th>% of total land area</th>
<th>Accum. %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>5 341 942</td>
<td>20.51</td>
<td>20.51</td>
</tr>
<tr>
<td>0.01-0.05</td>
<td>0</td>
<td>0</td>
<td>20.51</td>
</tr>
<tr>
<td>0.05-0.10</td>
<td>1 041 173</td>
<td>3.99</td>
<td>24.50</td>
</tr>
<tr>
<td>0.10-0.15</td>
<td>3 925 460</td>
<td>15.07</td>
<td>39.57</td>
</tr>
<tr>
<td>0.15-0.20</td>
<td>15 737 103</td>
<td>60.43</td>
<td>100.00</td>
</tr>
</tbody>
</table>

5.3  Elimination of Unsuitable Production Areas

5.3.1  Background

The approach used in this study was further extended by considering the existing land use, which reduced the total arable land available for feedstock cultivation. This is considered important in order to produce land suitability maps which more realistically represent the biofuel feedstock production potential in South Africa. Land use describes how mankind utilises land, e.g. for urban living and agricultural food production. Areas deemed unsuitable for feedstock growth (i.e. “no-go” areas) were eliminated to provide a realistic estimate of the land area available for biofuel feedstock production.
5.3.2 Methodology

5.3.2.1 Land suitability classification

The definition of land suitability, as proposed by the Food and Agriculture Organisation of the United Nations (FAO) "is the fitness of a given type of land for a defined use". According to FAO (1976), land can be classified as suitable (S) or unsuitable (N) for a particular use. Suitable means sustained use is expected to give positive results. Similarly, not suitable means land qualities are considered inappropriate for a particular use.

The degree of suitability is reflected by land suitability classes. The classes are numbered in a sequence where the highest number represents the least suitable and the lowest number represents the most suitable. According to FAO (1976), the relationship between inputs and benefits mainly determines the differences in the degree of suitability. The FAO recommends three suitability classes, with the following denominations:

- Class S1: Highly suitable
- Class S2: Moderately suitable
- Class S3: Marginally suitable

The land can be classified as not suitable based on, for example, environmental considerations (e.g. potential damage to biodiversity), technical considerations (e.g. soil depth and slope) or economic considerations (e.g. revenues). There are normally two classes for not suitable as follows:

- Class N1: Currently not suitable
- Class N2: Permanently not suitable

5.3.2.2 Present land use

The seven land cover classes of the NLC2009 dataset subdivided in two categories, viz. absolute “no-go” areas and functional “no-go” areas. Absolute no-go areas comprise of land covers that are physically unsuitable for feedstock production. According to the FAO classification (see Section 5.3.2.1), such areas are classed as N2 (i.e. permanently not suitable) and include mines, urban areas and water bodies (Table 29).

Functional no-go areas refer to land covers currently not suitable for feedstock cultivation (N1 class) and include, inter alia, forest plantations, orchards (i.e. citrus and avocado) & vineyards (i.e. Cape winelands). It is highly unlikely that these well-established industries would consider a change in land use to biofuel feedstock production.

Table 29 Classification of the 2009 national land cover dataset according to suitability for feedstock cultivation

<table>
<thead>
<tr>
<th>Land cover class</th>
<th>FAO suitability class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water bodies</td>
<td>N2</td>
</tr>
<tr>
<td>Urban built-up</td>
<td>N2</td>
</tr>
<tr>
<td>Mines</td>
<td>N2</td>
</tr>
<tr>
<td>Plantations</td>
<td>N1</td>
</tr>
<tr>
<td>Natural</td>
<td>N1</td>
</tr>
<tr>
<td>Degraded</td>
<td>N1</td>
</tr>
<tr>
<td>Cultivation</td>
<td>N1</td>
</tr>
</tbody>
</table>
Furthermore, in order to cultivate virgin land (i.e. natural vegetation), the land owner must be granted written permission by the Executive Officer (except if approval was granted under Section 4A of the 1972 Forest Act). Virgin soil is defined as land that has not been cultivated in the previous ten years and thus is referred to as "undeveloped" by the Executive Officer (Niemand, 2011). This is in accordance with the Conservation of Agricultural Resources Act (CARA) 43 of 1983. Thus, natural areas were classified as functional “no-go” (i.e. N1) areas.

It is reported in the literature that certain feedstocks may restore the productivity of degraded land. For example, the national biofuels feasibility study (DME, 2006a) suggested two indigenous plums (*Xiemenia Caffra* or sour plum; *Papia Capensis* or jacket plum) that have potential to stabilise degraded land with their strong rooting systems. Based on this suggestion, degraded areas were classified as functional “no-go” (i.e. N1) areas.

Cultivated areas were also classified as functional “no-go” areas since biofuel crops can be produced in rotation with food crops. However, an expansion of agricultural land is preferable for the cultivation of biofuel feedstocks. In terms of food security, existing cultivated areas are better utilised for food production.

5.3.2.3 Protected areas

The updated national land cover did not include boundaries of protected areas. Thus, the approach was again extended to consider this land use. According to the National Environmental Management: Protected Areas (Act 57 of 2003), the declaration of protected areas includes South Africa’s threatened or rare species as well as areas which are vulnerable or ecologically sensitive. SANBI provides a number of useful datasets which describe areas that are protected or endangered. These datasets were used to eliminate areas not suitable for biofuel feedstock cultivation at the national scale.

Only the formerly protected areas (*Figure 2*; c.f. *Section 2.9*) were eliminated in this study. The boundaries of protected areas were reclassified as N2 (i.e. permanently not suitable for biofuels). Hence, all areas that were identified as suitable for feedstock cultivation (S1, S2 or S3), but overlapped with protected areas classified as N2, were excluded (or filtered out) using GIS.

5.3.3 Results

The land suitability map for canola before (*Figure 62*) and after (*Figure 63*) the exclusion of absolute “no-go” areas is illustrated next. The approach provides a more realistic estimate of the land available for feedstock cultivation, especially by eliminating the Kruger National Park and the world heritage site that borders with Lesotho. It is important to note that no land cover or protected areas data exists for Swaziland or Lesotho and thus, these land suitability maps are only applicable to South Africa.
Figure 62  Land suitability map for canola production in South Africa, before the elimination of absolute “no-go” areas

Figure 63  Land suitability map for canola production in South Africa, after the elimination of absolute “no-go” areas
5.4 Land Suitability Assessment

5.4.1 Background

A land suitability assessment identifies the land area suitable for feedstock production and then assesses the feedstock’s potential yield in such areas. A land suitability map can be used to estimate South Africa’s biofuel production potential. According to the German Advisory Council on Global Change (WBGU, 2004), there are five different types of energy resource potential as follows:

- **Theoretical potential**: identifies the physical upper limit of energy available from a certain renewable source (i.e. biomass). This potential does not account for a) land-use restrictions, or b) the efficiency of conversion technologies used.

- **Technical potential**: considers various restrictions related to the land realistically available for energy production. However, the criteria used in identifying potential land are not applied uniformly in the literature and hence this potential is dependent on a wide range of assumptions and conditions.

- **Conversion potential**: derived from the overall efficiency of the respective conversion technology. It is therefore not a strictly defined value, since the efficiency of a particular technology depends on technological advances and usually improves with time.

- **Economic potential**: describes the proportion of technical potential that can be utilised economically. For example, the quantity of biomass that can be exploited economically, taking into account competition from other products and land uses.

- **Sustainable potential**: limits the biofuel production potential based on evaluation of critical ecological and social factors. Sometimes, authors include sustainable criteria in their consideration of technical and/or economic potential. Hence, sustainable potential is not clearly defined and is also dependent on a wide range of assumptions and conditions.

Based on the definitions given above, the land suitability maps produced in this study highlight the country’s technical potential to produce biofuel feedstocks. The approach that was developed is considered unique and innovative. However, the approach does not consider the future land uses needs (i.e. land required to house and feed the growing population, the need to expand current mining activities as well as protecting the country’s rich biodiversity heritage).

5.4.2 Methodology

The overall aim was to map areas suitable for selected feedstocks and to improve the mapping approach used in previous land suitability studies. The methodology developed and implemented in this study is broadly similar to that adopted in four case studies reviewed in presented in Volume 2. To re-cap, a literature review of feedstock growth criteria added to that undertaken in previous studies (e.g. the biofuels scoping study). Spatial rainfall data were classified into different suitability classes according to each feedstock’s crop water
requirements, using the crop coefficient concept. Similarly, spatial temperature was also
categorised into different classes to separate optimum from sub-optimum growing areas.
The rainfall and temperature datasets were then combined and weighted in order to identify
land climatically suited to feedstock production.

The approach then made use of a range of “filters” which were applied to the climatically
suitable areas in order to highlight areas realistically suitable for crop production. For
example, relative humidity was used (as a surrogate variable) to exclude areas with a high
risk of disease incidence, thus minimising the risk of crop failure. Soil depth and slope data
were also used to exclude areas with shallow soils and steep slopes that cannot support
sustainable agriculture. Land use datasets were used to exclude areas that are classified as
built-up, mining and water bodies as well as those areas protected by law for their
biodiversity. It was important to eliminate these so-called “no-go” areas in order to identify
land area realistically available to feedstock production. This approach helped to obtain a
more realistic map of areas that can be planted to biofuel feedstocks. Although the latest
available datasets were utilised, small patches of land may have been ignored (i.e. not
highlighted as suitable) due to the coarseness of input climate data, which cannot account
for microclimate effects.

The approach included relative humidity and soil depth, and is unique in that these two
additional sites factors were not considered in previous GIS mapping studies. However, the
most innovative aspect of this study is the use of crop coefficients to quantify the feedstock’s
optimum distribution of rainfall over the growing season. It is important to note that the
methodology identifies three bio-climatic regions and not two as required by the project’s
Terms of Reference. These regions range from high potential to low potential and are called
highly suitable, moderately suitable and marginally suitable.

5.4.3 Results

5.4.3.1 Sugarcane

The map showing areas suited to dryland sugarcane production is shown in Figure 64. This
map is based on rainfall weightings derived using local crop coefficients \( K_c \) that were
averaged for three sugarcane producing areas. These \( K_c \) values represent ratoon cane and
not planted cane. This map was originally produced by Khomo (2014), but was re-produced
to fix an error discovered in the soil depth data (this also applies to the grain sorghum and
soybean maps presented in the sections that follow).

Figure 64 highlights areas suitable for sugarcane production, which correlates well with
Figure 65. The latter is a simplified map of irrigated vs. dryland sugarcane production areas
obtained from the South African Sugar Association (SASA, 2011). Approximately 68% of
cane is grown within 30 km of the coast line, which extends from northern Pondoland
(Eastern Cape) to the northern KwaZulu-Natal coastal region. Approximately 17% is grown
in higher rainfall regions in KwaZulu-Natal, with the remainder grown in the northern irrigated
areas that comprise the Pongola and Mpumalanga Lowveld regions ( DAFF, 2011b).
Figure 64  Overall suitability map for sugarcane production in South Africa (based on local crop coefficient weightings)

Figure 65  Rainfed (light green) and irrigated (light blue) sugarcane production areas in South Africa (SASA, 2011)
The suitability map shown in Figure 64 highlights the northern coastal region of KwaZulu-Natal as ideally suited to cane production. This region is north of the Amatikulu sugar mill and south of the Umfolozi mill, with the Felixton mill in-between (Figure 65). The suitability map highlights the marginal areas near the Komatipoort mill (north of the Swaziland border in the Mpumalanga lowveld region). Due to the low rainfall conditions in the Mpumalanga lowveld region, sugarcane is produced under irrigated conditions.

The suitability map does not highlight all the irrigated sugarcane areas surrounding the Malelane mill (north west of the Komati mill in Figure 65). Similarly, the suitability map does not show all the irrigated sugarcane areas near the Pongola mill (south of the Swaziland border in Figure 65). The reason for this is Figure 64 highlights areas where sugarcane can be grown under rainfed/dryland conditions (not irrigated). However, the suitability map does not show all the dryland production areas surrounding the Dalton, Noodesberg and Eston mills (in Figure 65) which are situated in the KZN midlands. Although the suitability map shows the Eastern Cape coastal regions as suitable for cane production, only a small fraction of cane is produced in the Eastern Cape Province (just south of the KZN provincial boundary).

Finally, it should be noted that frost-prone areas were not eliminated in this study. Hence, some areas classified as suitable for sugarcane cultivation in higher altitude regions will be at risk of severe frost damage. Such areas should rather be classified as unsuitable and not marginal. For further clarity, the reader is referred to Section 7.4.3 and Section 8.3.3.6 of Volume 1, as well as Section 7.5.2 of Volume 2.

5.4.3.2 Sugarbeet (summer)
The map showing areas suited to sugarbeet production is shown in Figure 66 for a September (summer) planting. The map was produced using rainfall weightings based on crop coefficients obtained at Ukulinga during the 2010/11 season. Based on a summer planting, sugarbeet is better suited to the northern interior of the country, where optimum growing conditions exist. This is due to the seasonal rainfall occurring in these areas, which exceeds the lower threshold of approximately 400 mm per season (September to March) for sugarbeet. Coastal areas associated with higher humidity levels are not suited for sugarbeet production during the summer months. The individual maps that were combined to produce the final version are presented in Volume 1.

5.4.3.3 Sugarbeet (winter)
The map showing areas suited to sugarbeet production is shown in Figure 67 for a June (winter) planting. The map was produced using rainfall weightings based on crop coefficients obtained at Ukulinga during the 2012/13 season. Figure 67 illustrates that very few areas in South Africa can support dryland cultivation of sugarbeet planted in winter. Areas with sufficient rainfall from June to December exist along the Zululand coast, the Knysna coastal region and parts of the Western Cape where winter canola and wheat are currently grown. This finding indicates that supplemental irrigation is required to grow sugarbeet in winter, as is planned for the Cradock region. The individual maps that were combined to produce the final version are presented in Volume 1.
Figure 66 Overall suitability map for sugarbeet production in South Africa (based on crop coefficient weightings derived at Ukulinga from September 2010)

Figure 67 Overall suitability map for sugarbeet production in South Africa (based on crop coefficient weightings derived at Ukulinga from June 2013)
5.4.3.4 Grain sorghum
The map showing areas suited to grain sorghum production is shown in Figure 68. The map was produced using rainfall weightings based on crop coefficients that were averaged from two seasons of data obtained at Ukulinga in 2012/13 and 2013/14. According to Mashabela (2012), grain sorghum can be grown in all of South Africa’s nine Provinces. However, the map does not highlight the Western Cape and Northern Cape Provinces as being suitable for sorghum production. This is due to the low average rainfall received in these regions. According to Mashabela (2012), grain sorghum is mainly produced on a commercial scale in the Free State (51.9%), Mpumalanga (24.3%) and Limpopo (15.3%) Provinces. Finally, the land suitability map does not identify the Free State as the largest producing grain sorghum area in the country.

Figure 68 Overall suitability map for grain sorghum in South Africa (based on crop coefficient weightings derived at Ukulinga from November 2012)

5.4.3.5 Soybean
The overall soybean suitability map is shown in Figure 69 and is based on the approach where the single crop coefficient ($K_c$) was used to weight monthly rainfall totals across the growing season. This map highlights areas optimally (i.e. highly) suited to soybean production, which are mainly situated in the KwaZulu-Natal, Mpumalanga and Limpopo Provinces. Compared to the map produced in the biofuels scoping study (Jewitt et al., 2009a), a relatively large increase in suitable growing areas in the Limpopo and Mpumalanga Provinces is noted in the new map. This result is expected since the scoping study used a smaller seasonal rainfall range of 550 to 700 mm to delineate optimum growth areas, compared to the 700 to 900 range adopted in this study.
Figure 69 Overall suitability map for soybean production in South Africa (based on crop coefficient weightings derived at Baynesfield from October 2012)

The most notable difference in this map is the classification of the eastern Free State as moderately suitable for soybean production. In addition, more than half the areas highlighted in Mpumalanga are considered highly suitable for soybean. This is important considering that in 2010, 42.3% and 26.8% of soybean was produced in Mpumalanga and Free State respectively.

5.4.3.6 Canola (winter)
The map showing areas suited to canola production is shown in Figure 70. The map was produced using rainfall weightings based on crop coefficients obtained from Majnooni-Heris et al. (2012). According to DAFF (2014), the major production area for canola is the Western Cape (98%), with farmers in the North West and Limpopo Provinces slowly expanding canola’s production (2%). According to DAFF (2014), the labour intensive nature of the post harvesting processes often renders the cultivation of canola unviable for many farmers. The land suitability map for canola underwent many iterations to complete, which is further explained in Volume 2. In addition, the individual maps that were combined to produce the final version are also presented in Volume 2.

The finalisation of the canola map was a major challenge due to the lack of information pertaining to this crop. The project resorted to expert opinion (and emailed DAFF, ARC, GRAIN SA and PhytoEnergy) to derive site criteria needed to produce the suitability map. Fouché (2015) states that canola can basically grow anywhere in South Africa since the crop is very drought tolerant. However, the above map does not indicate canola can be grown in the eastern parts of the Free State during winter, where PhytoEnergy plan to cultivate the
crop for biodiesel production. Setting the lower limit of seasonal rainfall for canola was problematic which is explained further in Volume 2.

![Land Suitability Map for Canola](image)

**Figure 70** Overall suitability map for canola production in South Africa (based on crop coefficient weightings derived from Majnooni-Heris et al., 2012)

### 5.5 Summary

The overall aim was to map areas suitable for selected feedstocks and to improve the mapping approach used in previous land suitability studies. The methodology developed and implemented in this study is broadly similar to that adopted in four case studies that were reviewed (refer to Section 7.3 in Volume 2 for additional detail). To re-cap, a literature review of feedstock growth criteria added to that undertaken in previous studies (e.g. the biofuels scoping study). Spatial rainfall data were classified into different suitability classes according to each feedstock’s crop water requirements, using the crop coefficient concept. Similarly, spatial temperature was also categorised into different classes to separate optimum from sub-optimum growing areas. The rainfall, temperature and relative humidity datasets were then combined and weighted in order to identify land climatically suited to feedstock production. This is illustrated in the first tier of Figure 71, where 0.4 (for example) represents that weighing assigned to rainfall (i.e. 40% as given in Table 18 in Section 5.2.2.3).
Figure 71 Decision tree flowchart highlighting various criteria considered when identifying areas suited to sustainable feedstock production
The approach then made use of a range of “filters” which were applied to the climatically suitable areas in order to highlight areas realistically suitable for crop production. For example, soil depth and slope data were used to prioritise areas with deep soils and gentle slopes that can support sustainable agriculture (second tier in Figure 71). Land use datasets were then used to exclude areas (i.e. weighting set to zero) that are classified as built-up, mining and water bodies as well as those areas protected by law for their biodiversity (third tier in Figure 71). It was important to eliminate these so-called absolute “no-go” areas in order to identify land area realistically available to feedstock production. The exclusion of function “no-go” areas was not considered in this study (i.e. the weighting was set to 1 in the fourth tier of Figure 71).

This approach helped to obtain a more realistic map of areas that can be planted to biofuel feedstocks. Although the latest available datasets were utilised, small patches of land may have been ignored (i.e. not highlighted as suitable) due to the coarseness of input climate data, which cannot account for microclimate effects. The approach included relative humidity and soil depth, and is unique in that these two additional sites factors were not considered in previous GIS mapping studies. However, the most innovative aspect of this study is the use of crop coefficients to quantify the feedstock’s optimum distribution of rainfall over the growing season. It is important to note that the methodology identifies three bio-climatic regions and not two as required by the project’s Terms of Reference. These regions range from high potential to low potential and are called highly suitable, moderately suitable and marginally suitable.
6  THE BIOFUELS ASSESSMENT UTILITY

6.1  Introduction

A utility was developed as part of the SFRA project (Jewitt et al., 2009b) to allow users to extract estimates of water use (defined as a reduction in stream flow) for different land uses at the quinary sub-catchment scale. This utility was written in the Microsoft .Net programming language and is packaged on a CD. This utility was modified to accommodate the requirements of this project as well as to disseminate the output from this project that is related to feedstock water use.

6.2  Overview of the Utility

The assessment utility has a user-friendly interface which allows the user to select a particular quinary sub-catchment. It then “zooms” into the area (or sub-catchment) of interest. Next, the user selects the baseline land use, as well as the proposed land use. The utility then displays a daily or monthly time series of simulated runoff (i.e. SIMSQ) generated under 1) baseline conditions and 2) the proposed land use. These two time series can be displayed in both tabular and graphical form, the latter producing a plot which helps to “visualise” the difference in runoff generated by the two land uses. In essence, the utility provides a time series of ACRU model output, whilst performing various calculations “on the fly”.

As noted in Section 3.2.1, feedstock water use is defined as the reduction in stream flow that may result from a land use change from the baseline to a particular feedstock. The simulated stream flow reduction (i.e. \( \text{MAR}_{\text{base}} - \text{MAR}_{\text{crop}} \)) is calculated “on the fly” and is easily exported if necessary. Estimates of stream flow reductions (SFR) can also be viewed as monthly or annual flow duration curves for user-selected time periods. The change in SIMSQ (mm) is plotted against the probability of exceedance, with low flows defined as those falling below the 75th percentile exceedance level. Various statistics can also be calculated (and exported) for the sub-catchment.

In terms of the current SFR legislation, the user would select Acocks Veld Types as the baseline land cover. Hence, stream flow reductions are assessed relative to the runoff generated under “pristine” or natural conditions. However, the utility also allows the user to select any land use as the baseline. This option is useful for the comparison of runoff reductions relative to the actual land use that the feedstock may be replacing. Finally, an updated user guide for the utility is provided in APPENDIX J.

6.3  Improvements Made to Utility

A number of improvements were made to version 1.0 of the biofuels assessment utility. Since then, the utility underwent a major revision to version 2.0. The most significant changes to the utility are briefly described next.
6.3.1 **ACRU BIN files**

For the SFRA project, the output from the *ACRU* model (daily stream flow or *SIMSQ* values) was stored in a structured database. This involved the conversion of *ACRU*’s binary output files for multiple quinaries into a single data “blob”. Although this process simplified the packaging (and retrieval) of information by the SFRA utility, it significantly increased the time required to update the utility’s database. The utility was modified to read an *ACRU* output (i.e. BIN) file directly, in its raw binary (non-ASCII) format. This improvement negated the need to “re-format” *ACRU*’s output, thus significantly reducing the time required to update the utility’s database.

6.3.2 **Exclusion of arid areas**

An MAP threshold of 250 mm was selected as the absolute minimum annual rainfall required for dryland farming. Thus, the total number of quinaries is 5 018, with the whole of basin F excluded. This MAP threshold was derived by superimposing the canola farms with the quinary sub-catchment rainfall map. The canola farms were derived from an aerial census undertaken by the Department of Agriculture (Western Cape) in 2013. The farm-level data were obtained via Mr Andre Roux (Roux, 2015). Some canola farms in the southern Cape region, particularly near Ruens, are located in quinaries where the MAP is below 300 mm (e.g. 289 mm).

6.3.3 **Exclusion using land suitability maps**

Although the *ACRU* model was run at the national scale (i.e. for all 5 838 quinaries) for each feedstock, a particular quinary may not be ideally suited to the growth of certain feedstocks. Hence, the land suitability maps are used to “filter-out” sub-catchments were the feedstock may not be grown successfully (i.e. to produce an economically viable crop yield).

6.3.4 **Default options**

A number of “default” options have been set in the utility for the user’s convenience:  
- The utility initially displays all quinaries exhibiting an MAP ≥ 250 mm.  
- The baseline land use is set to Acocks Veld Types.  
- The *ACRU* output variable is set to simulated stream flow, excluding all upstream contributions (i.e. *SIMSQ*).  
- The hydrological year for all statistics is set from October to September.

When the user selects the sugarcane land suitability map, the following occurs:  
- The quinary sub-catchments not suited to the growth of this feedstock are eliminated.  
- The proposed land use is to sugarcane automatically.  
- The user then selects the quinary of interest and the utility calculates the statistics.

6.3.5 **Inclusion of other variables**

The calculation of statistics was modified to accommodate other *ACRU* output variables where daily values are either aggregated (i.e. summed) into monthly values (e.g. rainfall) or averaged to monthly values (e.g. crop coefficients).
6.3.6 Improved statistics

Another improvement made to the original SFRA utility is the option to calculate statistics with October as the start of the hydrological year (and not January as the start of a calendar year). In the summer rainfall region of South Africa, annual statistics calculated from October to September (and not January to December) are more intuitive from a hydrological viewpoint.

6.3.7 Installation issues

A Microsoft Access database file was originally used by the utility to, *inter alia*, link the quinary number (e.g. 0010) to its name (e.g. A21A1) as well as manage the list of feedstocks for which data are available. This utility required a driver to access the database file, which caused installation problems on certain PCs. This database file was converted to XML format, which negated the need to use the specialised driver to access the database.

6.3.8 *ACRU* output variables

At present, the user is able to display, query and analyse a number of *ACRU* output variables other than stream flow (e.g. *SIMSQ*). These are highlighted in
Table 32 in APPENDIX J. This list of variables can be changed without the need to update and re-package the utility for distribution.

6.3.9 Batch export

The batch export utility which re-written to improve the speed of extracting data from the ACRU binary (.BIN) file and re-formatting it to a more user-friendly comma separated (.CSV) file format. This feature allows the user to extract data for use in another software application and was used by the former Department of Water Affairs. Only the mean statistic is output at present.

6.3.10 Other improvements

Numerous “cosmetic” enhancements were made to the user interface that relate to the formatting of columns and numbers. In addition, the headings (e.g. AET, SIMSQ) and units (e.g. mm, %) that appear in tables and graphs were improved. The mean statistic is highlighted for stream flow reductions expressed as a percentage.

6.4 Dissemination of Data

The filtered (i.e. 5 018 quinaries) binary stream flow database compresses from ≈4.3 Gb to ≈2.5 Gb for each feedstock (average compression of 52.5%), which means it can be packaged on a single-layer DVD for distribution. Hence, each land use is written to a separate DVD or alternatively, all land uses written to a single layer Blu-ray disc.

An open data portal (e.g. SAEON) or web-based mapping utility would simplify access to the data by this project. A data portal would also streamline the dissemination of updated data (in particular .BIN files) and information (i.e. map-based output such as crop yield), as well as the inclusion of additional feedstocks and associated maps. In essence, this approach will facilitate the maintenance of a single database (consisting of data, tables & figures), that would be accessible by end-users via the Internet.

The SAEON (South African Environmental Observation Network) data portal could be used to disseminate the stream flow database required by the utility. Owing to the potential size of the data to be disseminated, SAEON suggested setting up a dedicated server so that data requests would not impact other portal functions.
REFERENCES


BAHIZIRE FB (2007) Effect of Salinity on Germination and Seedling Growth of Canola (*Brassica napus L*). Study leader: Prof. GA Agenbag. Thesis in partial fulfilment of Degree of Master of Agricultural Sciences, University of Stellenbosch, RSA.


DOI:10.1007/BF00010975 
http://link.springer.com/article/10.1007%2FBF00010975

http://www.ijreat.org/Papers%202013/Issue2/IJREATV1I2019.pdf


[http://openaccess.icrisat.org/bitstream/10731/1636/1/AniNutFeedTech%209_1_1-10_2009.pdf](http://openaccess.icrisat.org/bitstream/10731/1636/1/AniNutFeedTech%209_1_1-10_2009.pdf) [Accessed 16 October 2010]


BRANDLING J (2010) Production of ethanol from tropical sugar beet. Unpublished MSc thesis, Faculty of Engineering Sciences (Chemical and Minerals Engineering), North-West University, Potchefstroom, RSA.


[Accessed 03 April 2012]


[Accessed 30 September 2014]


DAFF (2009) Canola. Department of Agriculture, Forestry and Fisheries (DAFF), Pretoria, RSA. Available from:
[Accessed 21 September 2012]

DAFF (2010a) Soya beans: production guideline. [Internet]. Department of Agriculture, Forestry and Fisheries (DAFF), Pretoria, RSA. Available from:
[Accessed 20 September 2012]

DAFF (2010b) Sorghum: production guideline. [Internet]. Department of Agriculture, Forestry and Fisheries, RSA. Available from:
[Accessed 27 September 2012]

DAFF (2010c) Sunflower: production guideline. [Internet]. Department of Agriculture, Forestry and Fisheries (DAFF), Pretoria, RSA. Available from:
[Accessed 20 September 2012]

DAFF (2010d) Canola: production guideline. [Internet]. Department of Agriculture, Forestry and Fisheries (DAFF), Pretoria, RSA. Available from:
[Accessed 20 September 2012]

DAFF (2010e) Grain sorghum market value chain profile. [Internet]. National Department of Agriculture (NDA), Pretoria, RSA. Available from:
[Accessed 16 October 2010]

DAFF (2011a) Soybean market value chain profile 2010/2011. [Internet]. Department of Agriculture, Forestry and Fisheries (DAFF). Pretoria, RSA. Available from:
[Accessed 20 September 2012]

DAFF (2011b) A profile of the South African sugar market value chain. [Internet]. Sector trade performance review (ATPR). Department of Agriculture, Forestry and Fisheries (DAFF). Pretoria, RSA. Available from:
[Accessed 21 September 2012]


[Accessed 17 November 2009]

[Accessed 17 November 2009]

[Accessed 19 March 2012]

[Accessed 25 September 2012]


[Accessed 26 September 2011]

[Accessed 31 March 2013]
DoE (2012b) Regulations regarding the mandatory blending of biofuels with petrol and
diesel. [Internet]. Government Gazette No. 35623, 23 August 2012. Amendment no. R.671
of the Petroleum Products Act of 1977, Pretoria, RSA. 3-7. Available from:
[Accessed 29 August 2012]

DoE (2013) Presentation by Mr Mkhize (Chief Director: Hydrocarbons Policy) to the Portfolio
Committee on Energy regarding an update on the biofuels industrial strategy. 13th August
2013. Available from:
http://slideplayer.com/slide/4730169/
[Accessed 18 January 2014]

[Internet]. Department of Energy (DoE), Pretoria, RSA. Government Gazette, Vol. 583 (No.
37232), Notice 24 of 2014, 15 January 2014. Available from:
[Accessed 20 January 2014]

DOORENBOS J and KASSAM AH (1979) Crop water requirements. FAO Irrigation and
Drainage Paper No. 33. Food and Agricultural Organisation (FAO), Rome, Italy.

DOORENBOS J and PRUITT WO (1983) Yield response to water. FAO Irrigation and
drainage paper, 2nd revised edition.

DRAPCHO CM, NGHIÊM NP and WALKER T (2008) Biofuel feedstocks. [Internet]. In:
0071487492/9780071487498. Available from:
[Accessed 29 September 2013]

9780470751114. DOI:10.1002/9780470751114.

DRDLR (2013) Minister Nkwinti lambasts the lazy. [Internet]. Department of Rural
Development and Land Reform (DRDLR), Pretoria, RSA. Available from:
[Accessed 02 September 2013]

DU PLESSIS J (2008) Sorghum production. [Internet]. National Department of Agriculture,
RSA. Available from:
[Accessed 07 May 2012]

DU PREEZ JC, DE JONG F, BOTS PJ and LATEGAN PM (1985) Fermentation alcohol from


GÖRGENS J (2013) Personal communication. Professor of Chemical Engineering, Department of Process Engineering, Stellenbosch University. 16th January 2013.


http://www.pnas.org/cgi/doi/10.1073/pnas.0604600103/
[Accessed 17 November 2009]

HOEKSTRA AY, CHAPAGAIN AK, ALDAYA MM and MEKONNEN MM (2011) *The water footprint assessment manual: Setting the global standard*. [Internet]. Earthscan, Washington, DC, USA. Available from:
[Accessed 30 November 2015]


[Accessed 04 February 2010]


IDC (2011) Expressions of interest for grain sorghum feedstock supply for the Cradock ethanol project. [Internet]. Industrial Development Corporation (IDC), Johannesburg, RSA. Available from: http://www.agbiz.co.za/LinkClick.aspx?fileticket=7TuUUJnWjZc%3D&tabid=362 [Accessed 30 January 2012]

IDC (2013) Request for proposals for the blasting and excavation for the Cradock ethanol project. [Internet]. Tender document T41/06/13 issued by the Industrial Development Corporation of SA Ltd (IDC), Johannesburg, RSA. Available from: http://www.idc.co.za/tenders/T41-06-13_RFP_Blasting_and_Excavation_for_the_Cradock_Ethanol_Project.pdf [Accessed 02 September 2013]


JØKER D and JEPSEN J (2003) Jatropha curcas L. Danida Forest Seed Centre (DFSC), Seed Leaflet 83.


KOTZE C (2012b) SA biofuels industry awaits implementation of regulations. Engineering News 32(06), 21-27 September 2012, p 68. Creamer Media (Pty) Ltd, Johannesburg, RSA.


MACLACHLAN R (2012) Personal communication. Senior Farm Support and Development Manager, Agrarian Research & Development Agency (ARDA), Eastern Cape, RSA.


ocial_Life_Cycle_Assessment_of_Biodiesel_in_South_Africa-769_b.pdf [Accessed 14 April 2012]


https://www.agronomy.org/publications/aj/abstracts/102/1/60
[Accessed 05 March 2012]

MOKONOTO O (2012) Mapping areas potentially suitable for soybean feedstock growth for biodiesel production. Unpublished Hydrology Honours project, School of Agricultural, Earth and Environmental Sciences (SAEES), University of KwaZulu-Natal, Pietermaritzburg, RSA.


http://link.springer.com/article/10.1071%2FAP09049#page-1


MORGAN J (2012) Crop file tuning for local conditions. [Internet]. Food and Agricultural Organisation (FAO), Land and Water Division, Rome Italy. Available from:
[Accessed 01 August 2015]


http://cesanluisobispo.ucanr.edu/files/89518.pdf
[Accessed 08 May 2014]


[Accessed 30 September 2013]


[Accessed 22 October 2015]

[Accessed 11 March 2014]

[Accessed 11 March 2014]


http://royalsociety.org/WorkArea/DownloadAsset.aspx?id=5501
[Accessed 09 February 2011]

[Accessed 17 December 2013]


SCHULZE RE (2014) Personal communication. Centre for Water Resources Research (CWRR), University of KwaZulu-Natal (UKZN), Pietermaritzburg, RSA. 14th August 2014.


SEETSENG KA (2008) Effect of water application and plant density on Canola (Brassica napus L.) in the Free State. Unpublished MSc Agriculture dissertation. Department of Soil, Crop and Climate Sciences, Faculty of Natural and Agricultural Sciences, University of the Free State, Bloemfontein, RSA.


200


http://edepot.wur.nl/121640  
[Accessed 24 August 2011]


DOI:10.1016/j.fcr.2005.01.017  


https://dl.sciencesocieties.org/publications/vzj/abstracts/2/4/492


TURHOLLOW AF, WEBB EG and DOWNING ME (2010) Review of sorghum production practices: Applications for bioenergy. [Internet]. ORNL/TM-2010/7. Oak Ridge National Laboratory, Tennessee, USA. Available from: 


VAN DER WESTHUIZEN L (2013) Biofuel industry struggling in South Africa. [Internet]. Frontier Market Network. Global Africa Network Pty Ltd, Cape Town, RSA. Available from: 


http://researchspace.ukzn.ac.za/xmlui/handle/10413/2115


http://link.springer.com/article/10.1007%2Fs10295-008-0313-1


https://dl.sciencesocieties.org/publications/aj/abstracts/103/6/1610


APPENDIX A

(a) Water Use Relative to Acoks Veld Type (mm) For Sugarcane (Ratoon)

Annual (mm)
- > 10
- 0 to 10
- 0 to -30
- 10 to -60
- 60 to -90
- 90 to -120
- 120 to -150
- <= -150

Hydrological Model: ACRU
Period: 1950 - 1999

(b) Water Use Relative to Acoks Veld Type (mm) For Grain Sorghum (November Planting)

Annual (mm)
- > 10
- 0 to 10
- 0 to -30
- 10 to -60
- 60 to -90
- 90 to -120
- 120 to -150
- <= -150

Hydrological Model: ACRU
Period: 1950 - 1999
Figure 72  Water use (expressed in mm) of each bioethanol feedstock relative to the baseline (i.e. $MAR_{\text{base}} - MAR_{\text{crop}}$)
Water Use Relative to A cocks Veld Type (mm) For Soybean (November Planting)

Annual (mm)

- > 10
- 0 to 10
- 0 to -30
- -60 to -90
- -90 to -120
- -120 to -150
- < -150

Hydrological Model: ACRU

Period: 1950 - 1999

Water Use Relative to A cocks Veld Type (mm) For Sunflower (November Planting)

Annual (mm)

- > 10
- 0 to 10
- 0 to -30
- -60 to -90
- -90 to -120
- -120 to -150
- < -150

Hydrological Model: ACRU

Period: 1950 - 1999
Figure 73 Water use (expressed in mm) of each biodiesel feedstock relative to the baseline (i.e. $MAR_{\text{base}} - MAR_{\text{crop}}$)
Figure 74 Median seasonal yield (dry t ha\(^{-1}\)) estimated using AQUACROP for selected bioethanol feedstocks (a-e) planted on different dates.
Figure 75  Median seasonal yield (dry t ha$^{-1}$) estimated using AQUACROP for selected biodiesel feedstocks (a-c) planted on different dates
Figure 76  Mean annual sugarcane yield (dry t ha$^{-1}$) for sugarcane transplanted in February (a) and April (b)
(c) Median Seasonal WUE (at maturity) Per Quinary Sub-catchment Sugarbeet September Planting

(d) Median Seasonal WUE (at maturity) Per Quinary Sub-catchment Sugarbeet June Planting
Figure 77  Median seasonal WUE (dry kg m\(^{-3}\)) calculated at maturity for selected bioethanol feedstocks (a-e) planted on different dates
Figure 78  Median seasonal WUE (dry kg m$^{-3}$) calculated at maturity for selected biodiesel feedstocks (a-c) planted on different dates
APPENDIX E

(a) Median Seasonal WUE (at peak) Per Quinary Sub-catchment Sugarcane February Ratoon

(b) Median Seasonal WUE (at peak) Per Quinary Sub-catchment Sugarcane April Ratoon
Figure 79  Median seasonal WUE (dry kg m$^{-3}$) calculated by AQUACROP (peak) for selected bioethanol feedstocks (a-e) planted on different dates.
Figure 80  Median seasonal WUE (dry kg m\(^{-3}\)) calculated by AQUACROP (peak) for selected biodiesel feedstocks (a-c) planted on different dates.
Figure 81  Variability of inter-seasonal WUE (%) calculated by AQUACROP (peak) for selected bioethanol feedstocks (a-e) planted on different dates.
Figure 82  Variability of inter-seasonal WUE (%) calculated by AQUACROP (peak) for selected biodiesel feedstocks (a-c) planted on different dates
Figure 83  Median length of the growing season (from germination to peak yield) as determined by AQUACROP for selected bioethanol feedstocks (a-e) planted on different dates.
Figure 84  Median length of the growing season (from germination to peak yield) as determined by AQUACROP for selected biodiesel feedstocks (a-c) planted on different dates
APPENDIX H

(a)

(b)
Figure 85  Median length of the growing season (from planting to maturity date) for selected bioethanol feedstocks (a-e) planted on different dates
Figure 86  Median length of the growing season (from planting to maturity date) for selected biodiesel feedstocks (a-c) planted on different dates
Figure 87  Median month in which the crop matures (i.e. expected harvest date) for selected bioethanol feedstocks (a-e) planted on different dates
Figure 88 Median month in which the crop matures (i.e. expected harvest date) for selected biodiesel feedstocks (a-c) planted on different dates.
17 APPENDIX J

17.1 Introduction

17.1.1 Installation

The Biofuels Assessment Utility is made up of four parts:

a) The software utility (Application).

b) The spatial data (GIS coverages).

c) A demo database which contains time series data for only nine quinary sub-catchments (i.e. ACRU BIN files) per land use.

d) A complete database which contains time series data for 5,018 quinary sub-catchments (i.e. ACRU BIN files) per land use.

To install the Biofuels Assessment Utility (i.e. part a and part b above):

1) Run the setup.exe on the DVD.

2) This will install the application and the GIS coverages.

To install the demo time series database for each land use (i.e. part c above):

1) Copy the demo_data.exe file (~40 Mb) from the DVD/Blu-ray to the installation folder which is the following (by default):

   Win XP: C:\Program Files\CWRR\Biofuels Assessment Utility
   Win 7/8 32-bit: C:\Program Files\CWRR\Biofuels Assessment Utility
   Win 7/8 64-bit: C:\Program Files (x86)\CWRR\Biofuels Assessment Utility

2) Run demo_data.exe and make sure the destination folder is correct (as shown above). Then select Extract. This will extract time series data for quinary sub-catchments A10A1 to A10C3 (i.e. nine sub-catchments per land use). This allows the user to test that the application is working correctly on the installed computer.

3) This step requires approximately 260 Mb of hard drive space.

4) One the utility has been tested and is working correctly, the user should delete the demo_data.exe file which was manually copied to the application’s installation folder. This will recover approximately 40 Mb of disk space.
To install the times series database for each land use (i.e. part d above):

1) Copy the `<Land_Use>_db.exe` file (∼2.5 Gb) from the DVD/Blu-ray to the installation folder which is the following (by default):

Win XP: C:\Program Files\CWRR\Biofuels Assessment Utility
Win 7/8 32-bit: C:\Program Files\CWRR\Biofuels Assessment Utility
Win 7/8 64-bit: C:\Program Files (x86)\CWRR\Biofuels Assessment Utility

2) Run `<Land_Use>_db.exe` and make sure the destination folder is correct (as shown above). Then select Extract, followed by Yes to All. This will extract all the time series data files for the selected land use.

3) This step requires approximately 66 GB of hard drive space to complete all 10 land uses.

4) Once the full database has been installed, the user should delete the `<Land_Use>_db.exe` file which was manually copied to the application’s installation folder. This will recover approximately 22.72 Gb of disk space.

5) Thus, the total amount of disk space required for the complete time series data files (stored in the Bins folder) is 43.26 Gb.

**Note:** When installing the land use databases, the demo data does not need to be re-installed (i.e. don’t run the demo_data.exe file again). The Baseline data (i.e. Acocks_Veld_Types_db.exe) is required and must be installed, then the required land use databases can be installed, depending on available disk space and user requirements.

**Minimum Requirements**

1) PC running Microsoft Windows XP or Windows 7/8 (32- or 64-bit).

2) On Windows XP, Dot Net Framework 2 must be installed for the application to run. These files are included on the installation DVD for the user’s convenience.

3) On Windows 7/8, Dot Net Framework 2 is already pre-installed (i.e. no need to install this package).

4) Minimum of 260 Mb of data free hard drive space for testing the application.

5) An additional 66 Gb for installing the full time series database in the “Bins” folder, which decreases to 43.26 Gb once all the `<Land_Use>_db.exe` files have been deleted.

6) Please check the Microsoft® Web site for updates/patches for the Dot Net Framework.
7) The application has been tested on Windows XP (SP3) and Windows 7 (SP1; both the 32- and 64-bit version).

8) The application was installed and tested on Windows 8 Pro (64-bit). The application should also work on Windows 8.1 and Windows 10 (32- and 64-bit versions).

9) Please refer to the guide for Windows 8 installations, which deals with the activation of Dot Net version 2.

17.2 Using the Biofuels Assessment Utility

The Biofuels Assessment Utility.exe is run by selecting the shortcut from Start…Programs…CWRR, or by double-clicking the shortcut on the user's Desktop. The User Interface (UI) is shown in Figure 89.

![Figure 89: Biofuels Assessment Utility's User Interface](image)

The main user interface comprises of Combo Boxes, as displayed in Figure 90 and described in Table 30, and Display Option Tabs, as shown in Figure 91.

![Figure 90: Biofuels Assessment Utility's Combo Boxes](image)
Table 30  The Combo Box headings and descriptions

<table>
<thead>
<tr>
<th>Combo Boxes</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filter</td>
<td>The general land use used to filter the map display</td>
</tr>
<tr>
<td>Baseline Land Use</td>
<td>Land use to be compared against (usually Acocks Veld Types)</td>
</tr>
<tr>
<td>Proposed Land Use</td>
<td>The proposed land use to be analysed</td>
</tr>
<tr>
<td>Variable</td>
<td>The output variable to be analysed (as listed in Table 32)</td>
</tr>
<tr>
<td>Sub-Catchment</td>
<td>The quinary catchment to be analysed</td>
</tr>
<tr>
<td>Stats</td>
<td>Select the start month for the annual statistics (October is the default)</td>
</tr>
</tbody>
</table>

Figure 91  Biofuels Assessment Utility's Display Option Tabs

Click on the Down arrow on the Filter Combo Box and select the desired land use grouping from the available filter options as shown in Figure 92. The default option selected is all the quinary sub-catchments with a Mean Annual Precipitation (MAP) greater than 250 mm. Once the Filter has been selected, the corresponding map is shown in the Map display tab, which highlights possible growing areas for the selected crop. The Proposed Land Use is populated with the corresponding land uses as displayed by an example in Figure 93, and the Sub-Catchment list is then filtered to match the available regions.

Figure 92  Biofuels Assessment Utility's filter selection
Next, the **Baseline Land Use** is selected, which is typically **Acocks_Veld_Types** by default. The **Proposed Land use** is selected, (e.g. sugarcane) from the available options in the **Proposed Land Use** drop-down Combo Box. The available options will vary depending on the **Filter** selected as shown in **Figure 93** above. **Table 31** contains more detail on each of the proposed land use options.

**Table 31** Proposed land use options, the assumed planting date and the location of the trial, from which the monthly crop coefficients were derived

<table>
<thead>
<tr>
<th>Land Use</th>
<th>Planting date</th>
<th>Location of trial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugarcane_RAT_AVE</td>
<td>Ratooned</td>
<td>Eston, Umzinto &amp; Kearsney</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(KwaZulu-Natal)</td>
</tr>
<tr>
<td>Sugar_Beet_WIN_KZN</td>
<td>Winter (June)</td>
<td>Ukulinga (KwaZulu-Natal)</td>
</tr>
<tr>
<td>Sugar_Beet_SUM_KZN</td>
<td>Summer (September)</td>
<td>Ukulinga (KwaZulu-Natal)</td>
</tr>
<tr>
<td>Sweet_Sorghum_SUM_INL</td>
<td>Summer (December)</td>
<td>Ukulinga (KwaZulu-Natal)</td>
</tr>
<tr>
<td>Sweet_Sorghum_SUM_INT</td>
<td>Summer (December)</td>
<td>Hatfield (Gauteng)</td>
</tr>
<tr>
<td>Grain_Sorghum_SUM_KZN</td>
<td>Summer (November)</td>
<td>Ukulinga (KwaZulu-Natal)</td>
</tr>
<tr>
<td>Soya_Bean_SUM_KZN</td>
<td>Summer (November)</td>
<td>Baynesfield (KwaZulu-Natal)</td>
</tr>
<tr>
<td>Canola_WIN</td>
<td>Winter (April)</td>
<td>International</td>
</tr>
<tr>
<td>Sunflower_SUM</td>
<td>Summer (November)</td>
<td>International</td>
</tr>
</tbody>
</table>

Then, select the desired output variable (See **Table 32** from the **Variable** drop-down Combo Box. The default output variable selected is **SIMSQ**, *i.e.* simulated runoff (storm flow + base flow) from the sub-catchment selected. **SIMSQ** does not include contributions from upstream sub-catchments.
Table 32 Description (and units) of each ACRU output variable

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Aggregation</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>AET</td>
<td>Total evaporation (i.e. actual evapotranspiration)</td>
<td>Sum</td>
<td>mm</td>
</tr>
<tr>
<td>APAN</td>
<td>A-pan equivalent reference evaporation</td>
<td>Sum</td>
<td>mm</td>
</tr>
<tr>
<td>ASOEV</td>
<td>Actual evaporation from the soil surface</td>
<td>Sum</td>
<td>mm</td>
</tr>
<tr>
<td>ATRAN1</td>
<td>Actual transpiration from the A-horizon</td>
<td>Sum</td>
<td>mm</td>
</tr>
<tr>
<td>ATRAN2</td>
<td>Actual transpiration from the B-horizon</td>
<td>Sum</td>
<td>mm</td>
</tr>
<tr>
<td>CAYD</td>
<td>Crop coefficient</td>
<td>Average</td>
<td>-</td>
</tr>
<tr>
<td>DPE</td>
<td>Maximum evaporation (potential evapotranspiration)</td>
<td>Sum</td>
<td>mm</td>
</tr>
<tr>
<td>EFRL</td>
<td>Effective rainfall (rainfall available for plant growth)</td>
<td>Sum</td>
<td>mm</td>
</tr>
<tr>
<td>QUICKF</td>
<td>Storm flow leaving catchment outlet on a given day</td>
<td>Sum</td>
<td>mm</td>
</tr>
<tr>
<td>RFL</td>
<td>Input rainfall, adjusted by monthly CORPPT values</td>
<td>Sum</td>
<td>mm</td>
</tr>
<tr>
<td>RUN</td>
<td>Base flow</td>
<td>Sum</td>
<td>mm</td>
</tr>
<tr>
<td>SIMSQ</td>
<td>Simulated runoff (storm flow + base flow) from the sub-catchment, excluding upstream contributions</td>
<td>Sum</td>
<td>mm</td>
</tr>
</tbody>
</table>

A quinary sub-catchment can then be selected via the drop-down Combo Box called Sub-Catchment, as shown in Figure 94.

Figure 94 Sub-Catchment drop-down Combo Box

Alternatively, the user can input a particular co-ordinate of interest in the Long and Lat input boxes (See Figure 95) and the utility will attempt to locate in which quinary the point of interest resides when the search button is pressed.

Figure 95 Map search by location controls

Note: Data for each of the first 12 quinaries (comprising of Quaternary’s A10A, A21B and A21C) are installed when the demo dataset is installed (i.e. demo_data.exe). Alternatively, if the user installed the full database (i.e. the <Land_Use>_db.exe files), then data are available for a total of 5 018 quinaries.

The utility then loads the time series data for the selected Baseline Land Use as well as the Proposed Land Use. This enables the comparison of data for the selected Sub-catchment (i.e. quinary) and the statistical analysis to be performed. The utility also calculates the
change (i.e. Baseline Land Use - Proposed Land use), which is expressed in mm and as a percentage change relative to the Baseline (c.f. Time Series below for more information).

17.2.1 Display option tabs

The Display Option Tabs enable simple navigation between the map view, simulated time series (data & graphs) and statistics (data & graphs).

17.2.2 Map

This display tab has various tools to navigate to a particular sub-catchment (as listed in Table 33), which allows the user to visualise the quinary boundaries (Figure 96).

Table 33  Map navigation tools

<table>
<thead>
<tr>
<th>Icon</th>
<th>Name</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="zoom" /></td>
<td>Zoom</td>
<td>In the map window, left-click and hold, then drag the mouse to select an area of interest to zoom into</td>
</tr>
<tr>
<td><img src="image" alt="zoom_out" /></td>
<td>Zoom Out</td>
<td>Left click on the map to zoom out</td>
</tr>
<tr>
<td><img src="image" alt="pan" /></td>
<td>Pan</td>
<td>On the map, left click and hold, then drag the mouse to pan around the map view</td>
</tr>
<tr>
<td><img src="image" alt="full" /></td>
<td>Full</td>
<td>Zoom out to full extent of the map</td>
</tr>
<tr>
<td><img src="image" alt="identify" /></td>
<td>Identify</td>
<td>Left click on a polygon to identify the sub-catchment</td>
</tr>
<tr>
<td><img src="image" alt="find" /></td>
<td>Find</td>
<td>Find a sub-catchment by inputting the Longitude and Latitude (in decimal degrees, with latitude negative)</td>
</tr>
</tbody>
</table>

| Long (x): 28.36 | Lat (y): -25.95 | ![Find](image) |
17.2.3 Time series

This displays the time series for the selected sub-catchment’s Baseline Land Use and the Proposed Land Use in tabular format (see Figure 97), as well as the calculated reduction (i.e. Baseline Land Use - Proposed Land Use). The times series can be viewed in either the original daily format, or aggregated to monthly values. However, the calculated reduction table is only available as monthly values. These tables can be exported to comma delimited (.CSV) files by selecting the corresponding Save To Text File button.

Figure 96  Biofuels Assessment Utility's Map tab

Figure 97  Biofuels Assessment Utility's Time Series tab
17.2.4 Time series graphs

This displays the time series for the selected sub-catchment’s **Baseline Land Use** and **Proposed Land use** in graphical format (See **Figure 98**). Similarly, the time series can be either viewed in the original daily format or aggregated to monthly values. The graphical view option has various buttons to enable closer inspection of the time series.

The time series graph can also be navigated by various left and right mouse clicks:

- **Reset graph**: Double click (left or right)
- **Pan graph**: Right click, hold and drag mouse
- **Zoom graph**: Left click, hold and drag mouse

![Zoom, Pan, Reset buttons](image)

**Figure 98** Biofuels Assessment Utility's Time Series Graphs tab

17.2.5 Stats tables

Statistics are only done on the monthly aggregated data. The start month for the calculation of annual statistics can be selected from the **Stats drop-down** option. These statistics can also be exported as comma separated (CSV) files. The **Stats Tables** tab displays the calculated statistics in tabular format for the selected sub-catchment’s:

- **Baseline Land Use** (Figure 99), or
- **Proposed Land Use** (Figure 100), or
- the calculated **Change in Streamflow**, i.e. **Baseline Land Use - Proposed Land Use** (Figure 101), or
- the calculated change in the Mean represented as a percentage, i.e. **Baseline Land Use - Proposed Land Use as %** (Figure 102).
The Baseline Land Use - Proposed Land Use (as %) is calculated by first determining the monthly and annual mean values for the respective land uses, and then subtracting the Proposed Land Use means from the corresponding Baseline Land Use means to determine their differences. The differences are then divided by the corresponding Baseline values and multiplied by 100 to get the monthly and annual changes as percentages. Subtracting the percentiles does not make mathematical sense, thus these are left empty in the table and only the Mean row is highlighted as seen in Figure 102.
17.2.6 Stats graphs

This displays the probability of exceedance values in graphical format. The Graph Options enables annual or monthly curves to be switched on or off in the display. The graphs corresponding to the selection made on the Stats Tables tab will be plotted on this tab with the exception of Baseline Land Use - Proposed Land use (as %) as there are no percentiles calculated for this table. For the Baseline Land Use - Proposed Land use and Baseline Land Use options, the graphs in Figure 103 and Figure 104 are displayed respectively.
Figure 103  Time Statistics Graphs tab (Baseline Land Use - Proposed Land Use)

Figure 104  Time Statistics Graphs tab (Baseline Land Use)

17.3 Batch Export

The Batch Export button is linked to the options on the Stats Tables tab (c.f. Section 17.2.5 for more information) and will thus export the calculated mean based on the option selected in this tab. The start month for the annual statistics is dependent on the selection from the Stats drop-down option. The data are exported to a comma delimited file (*.csv) for the catchments listed in an input file. An example file (“CatchmentList.txt”) is provided.