Predicted Switchgrass Yields in Oklahoma by Soil and Climate Region

Part 1: Switchgrass Results

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Methods

The Soil and Water Assessment Tool (SWAT) model was used to predict Switchgrass yield on 468 soils under five levels of fertilization and nine climate zones in Oklahoma. Yield is defined as the fraction of above ground biomass which is harvested. The state was broken into nine climate zones based on annual rainfall as estimated by the Parameter-elevation Regressions on Independent Slopes Model (PRISM) Model. Each county was assigned to a single climate zone; a single Cooperative Observer network station was selected within each zone to represent the climate for that zone.

Figure 1 Oklahoma climatic zones and Cooperative Observer Network weather station locations selected for each zone.

Table 1 Precipitation from 1955 - 2004 at representative Cooperative Observer Network stations for each zone.

<table>
<thead>
<tr>
<th>Climate Zone</th>
<th>Precipitation (mm/yr)</th>
<th>Precipitation (in/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>429</td>
<td>16.9</td>
</tr>
<tr>
<td>2</td>
<td>543</td>
<td>21.4</td>
</tr>
<tr>
<td>3</td>
<td>701</td>
<td>27.6</td>
</tr>
<tr>
<td>4</td>
<td>737</td>
<td>29.0</td>
</tr>
<tr>
<td>5</td>
<td>865</td>
<td>34.1</td>
</tr>
<tr>
<td>6</td>
<td>1021</td>
<td>40.2</td>
</tr>
<tr>
<td>7</td>
<td>1123</td>
<td>44.2</td>
</tr>
<tr>
<td>8</td>
<td>1166</td>
<td>45.9</td>
</tr>
<tr>
<td>9</td>
<td>1385</td>
<td>54.5</td>
</tr>
</tbody>
</table>

Soils were derived from the State Soil Geographic (STATSGO) database. These soil data were native to the SWAT model and were already parameterized for use with the model. Other soils information, such as Soil Survey Geographic (SSURGO) were preferable, but required significant effort to utilize these data with the SWAT model.
A single Hydraulic Response Unit (HRU) SWAT model was developed to simulate one soil, one management scenario, and one climate zone at a time. The model was run 21,285 times to cover all possible combinations. The SWAT model was directed by custom software written in Microsoft Visual Basic to perform each run and record the necessary statistics. Each simulation took approximately four seconds, and the entire set required 22 hours.

The SWAT Model was not calibrated for switchgrass yield, as model results with default values were adequate. Switchgrass yields predicted by the SWAT model were verified using two datasets, Fuentes and Taliaferro (2002) and Muir et al., (2001). Fuentes and Taliaferro (2002) reported switchgrass yields for several cultivars, including Alamo Switchgrass, for two sites (Chickasha and Haskell, Oklahoma) annually from 1994 to 2000. These plots received 78 and 90 kg N/ha, respectively, and were harvested only once each fall (October 31).

Climate for the reported location was derived from the nearest Cooperative Observer Network station. The SWAT model was used with the appropriate soil, climate, and fertilization at each site to predict annual dry biomass yield. These predictions were compared with observed yields (Figures 2 and 3). On average the model slightly over predicted yield. One likely cause is the precipitation data used in the model was not collected on site. The study reported an average of 798 and 1057 mm for Chickasha and Haskell, respectively. The weather stations selected to represent the study plots averaged 916 and 1140 mm for the same period, a difference of 15% and 8%. The model over predicted yields by 16% and 18% for Chickasha and Haskell, respectively. The difference in weather data was also likely responsible for a portion of the year to year variability between observed and predicted yields.

Figure 2 Predicted and observed switchgrass yield at Chickasha and Haskell Oklahoma.
Figure 3 Predicted and observed biomass at Chickasha and Haskell Oklahoma.

These data from Fuentes and Taliaferro (2002) were collected under a constant fertilizer application rate. To ensure that the model predicted reasonable biomass yield at differing levels of fertility, additional data were taken from Muir et al. (2001). These data were collected at plots in Stephenville, Texas from 1992 to 1998 with nitrogen applications ranging from 0 to 224 kg N/ha. Stephenville is located in the cross-timbers ecoregion and had 786 mm of precipitation, making it very similar to many regions of Oklahoma. Climate data for Stephenville were taken from the nearest Cooperative Observer network station. As in the previous study, the climate data from the nearest station had greater precipitation (881 mm) than these data reported by the study (786 mm), a difference of 12%.

The model was applied to the Stephenville data set using default SWAT parameter values (Figures 4 and 5). The model did an excellent job of predicting the fertilizer response curve in Figure 4. There was a 13% over prediction in biomass yield by the model likely due in part to the 12% difference in rainfall between the climate station used in the model and that observed at the study site. The model was able to explain 60% of the variation in biomass yield without calibration.
Figure 4 Observed and predicted average (1992-1998) biomass at Stephensville, Texas at differing nitrogen application rates.

Figure 5 Observed and predicted (1992-1998) biomass at Stephensville, Texas at differing nitrogen application rates.
Fuentes and Taliaferro (2002) found a significant response in yield from increased nitrogen application. Other studies differ as to the true response of switchgrass to nitrogen. Thomason et al. (2004) found little response to nitrogen in Chickasha and Perkins Oklahoma. The predictions by SWAT agree with the data used in the verification without calibration, but can be further improved with the addition of more study sites.

Results

The single HRU model was used to predict biomass yields on each combination of soil and climate. Due to the large amount of data, only a few results were given in this document. Figure 6 illustrates model predictions of biomass yield for a common Oklahoma agricultural soil (Kirkland). Figure 7 illustrates the degree of annual variability in yields, and Figure 8 illustrates the variability among soil types. Figure 9 shows the variability due to annual weather.

Figures 10 and 11 are maps of MIADS soil series with model estimated biomass yield. Some soils available in MIADS were not simulated because these soil were not contained in STATSGO. For these areas the average yield from of all soils was used. Approximately 15% of soils listed in MIADS did not appear in STATSGO. Manual substitution of similar soils for missing soils could lower this fraction to less than 5%, but this was not done due to time constraints. Figure 11 includes the MIADS landcover, which was used to remove areas likely unsuitable for Switchgrass production.

The entire database is available in a single Microsoft Excel Workbook. Included are summary statistics for each simulation.
Figure 6 Yield by climate zone and fertilization for the Kirkland soil series.

Figure 7 Biomass yield by climate zone by year for the Kirkland soil series receiving 100 kg N/ha.
Figure 8 Histogram of average annual biomass yield across all soils. Restricted to climate Zone 5 receiving 100 kg N/ha.

Figure 9 Histogram of annual yield across all years. Restricted to Kirkland soil type, climate zone 5, and 100 kg N/ha.
Figure 10 Biomass yield extrapolated to MIADS GIS data for the state of Oklahoma.

Figure 11 Biomass yield extrapolated to MIADS GIS data for the state of Oklahoma excluding areas typically not suitable for Switchgrass production.
References

