The Agriculture Opportunities in Missouri site includes model-based ratings of natural suitability for selected alternative crops. These ratings are based on research by C. Roger Bowen of the University of Illinois and Steven E. Hollinger of the Illinois State Water Survey. A description of their work is available at http://www.isws.illinois.edu/data/altcrops/docs/AltCropsModel2004.pdf. The model supporting the recommendations on this web site extends the previous work through the use of more detailed input information, resulting in a model detailing variability in suitability at the farm management scale.

The objective of the model is to evaluate plant suitability to local soil and climate conditions utilizing geographic information system (GIS) databases and analysis tools. The output of the model is a series of suitability maps for each evaluated plant species and each of the soil and climate parameters as well as an overall weighted suitability rating.

The model relies on seven soil and climate measures to describe the natural resource conditions of an area. These are Soil Texture, Soil pH, Soil Drainage, Precipitation, Temperature, Growing Days, and Winter Minimum Temperature. Each measure is score on a scale of 0 to 4, with 0 indicating a condition that is unsuitable for the crop, and 4 indicating a condition that is highly suitable to the crop. These individual measures are then combined to produce an overall suitability score for an area.

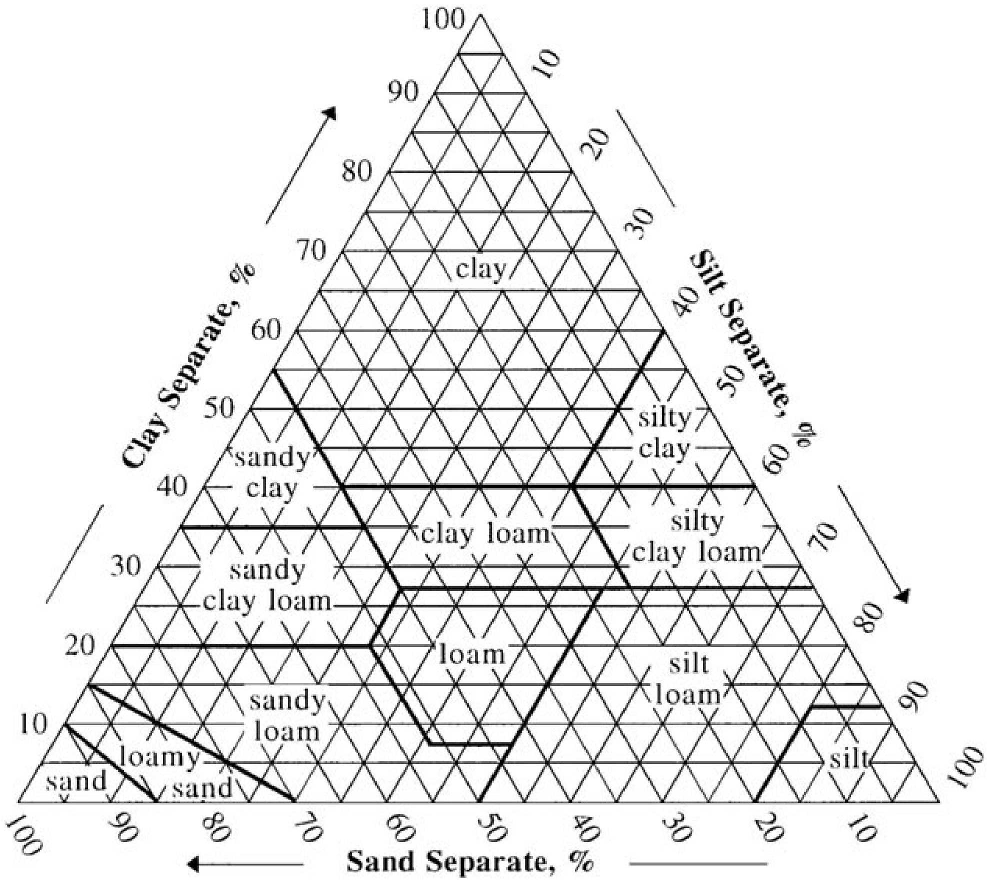
Soil Data

The original model by Bowen and Hollinger relied on the NRCS STATSGO database for soil property inputs. The analysis supporting this web site updates this approach to utilize the NRCS SSURGO database. SSURGO data is the most detailed soil data available on a national basis from NRCS. In Missouri, most of the SSURGO information was derived from published soil surveys originally mapped at a scale of 1:24,000. In comparison, the STATSGO data, which generalizes and groups soil series, was mapped at a scale of 1:250,000. For a detailed comparison of SSURGO and STATSGO data, see http://www.nrcs.usda.gov/wps/portal/nrcs/detail/il/soils/surveys/?cid=nrcs141p2_030690.

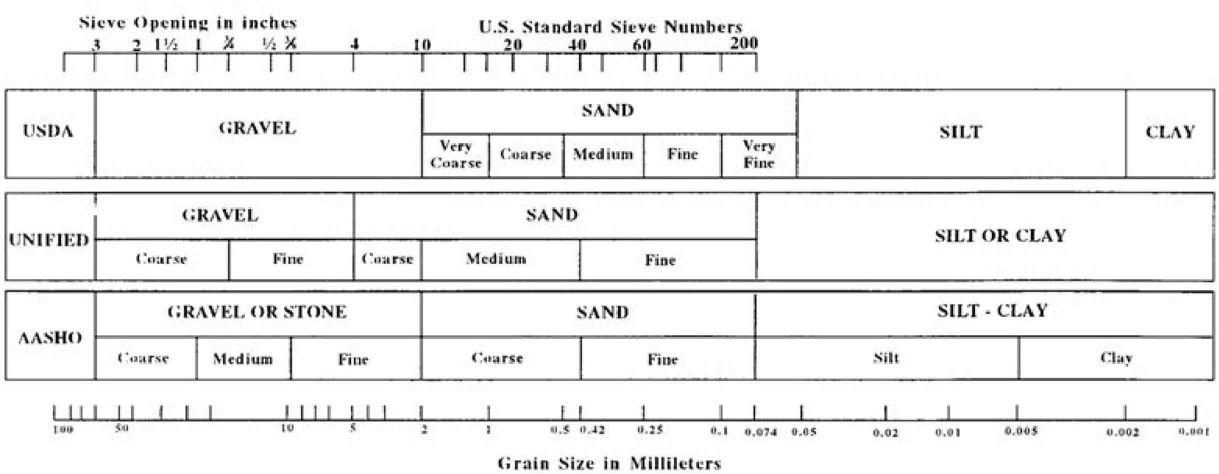
SSURGO data includes both the geographic data and tables describing soil properties. For this model, soil properties are assigned to the map unit level (the smallest soil geographic unit) based on weighted properties of soil components and soil horizons with in the map unit. This approach was used to develop data for the three soils factors: Soil Texture, Soil pH, and Soil Drainage.

For ***Soil Texture***, the approach utilized in this analysis is a modification of Bowen and Hollinger that attempts to assign a rating to all soil texture groups rather than identifying a preferred soil texture. The soils in Missouri are classified according to the ratio of sand, silt, and clay present in the surface horizon (typically the A horizon). For ease of use, texture group names have been assigned to each of these classifications (e.g. “Sandy Clay Loam”). These classifications are taken from the standard USDA soil triangle shown in Figure 1.

Figure 1. Soil Texture Triangle



COMPARISON OF PARTICLE SIZE SCALES

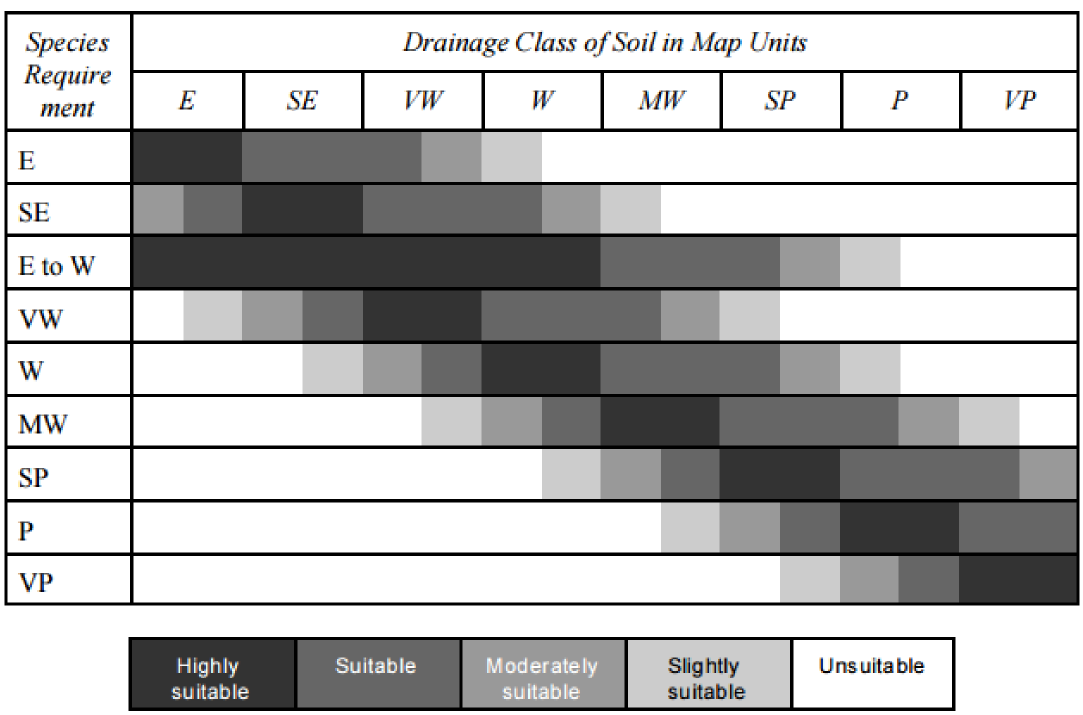


For each alternative crop a suitability rating, from 0 (unsuitable) to 4 (highly suitable), is assigned to each soil texture based on how well the soil texture supported the crop growth requirements. A highly suitable rating indicates the value for the input parameter is ideally suited for the crop, and an unsuitable rating indicates the crop should not be expected to produce. Expert advice from University of Missouri crop specialists was used to determine the final ratings for each alternative crop species.

Soil pH is derived from the soil horizon data within the SSURGO database. The representative pH rating is extracted for the surface horizon (typically the A horizon) for the dominant soil component within each soil mapping unit. The maximum and minimum pH tolerances for each alternative crop species is compared to the soil pH property, with values nearest the center of the crop pH range receiving a highly suitable rating. As soil pH values approach the bounds of the acceptable plant pH range, the suitability rating is lowered. Soil pH values outside the plant pH range are rated unsuitable.

Soil Drainage is based on the dominant condition drainage rating within the map unit aggregated attribute (muaggatt) table in the SSURGO database. The alternative crops are assigned an ideal drainage class, ranging from excessively drained to very poorly drained. Suitability for each soil is then assigned to the crop based on the ranges in Figure 2.

Figure 2. Soil Drainage Suitability Ratings.



(E = excessively drained, SW = somewhat excessively drained, VW = very well drained, W = well drained, MW = moderately well drained, SP = somewhat poorly drained, P = poorly drained, and VP = very poorly drained)

Climate Data

Bowen and Hollinger relied on interpolated values between weather stations for climate information. The current approach uses modeled climate information from the PRISM Climate Group at Oregon State University to support the four climate factors: Precipitation, Temperature, Growing Days, and Winter Minimum. The PRISM model integrates data from multiples sources and utilizes an estimation model that accounts for elevation variances when assigning data to each 4km grid cell. See http://www.prism.oregonstate.edu/ for more information.

Precipitation data is based on the 30-year average annual precipitation (1981 – 2010). Precipitation ratings are based on the range between the minimum precipitation required by a plant and the maximum precipitation tolerated by a plant. The middle of the precipitation range is considered ideal, with lower suitability ratings assigned as the precipitation deviates from the middle range. Two different precipitation rating scales are used, depending on the crop's tolerable precipitation range. For areas where precipitation was less than the crop's minimum precipitation, an allowance of 350 mm of water applied through irrigation was applied. Figure 3 shows the rating assignments.

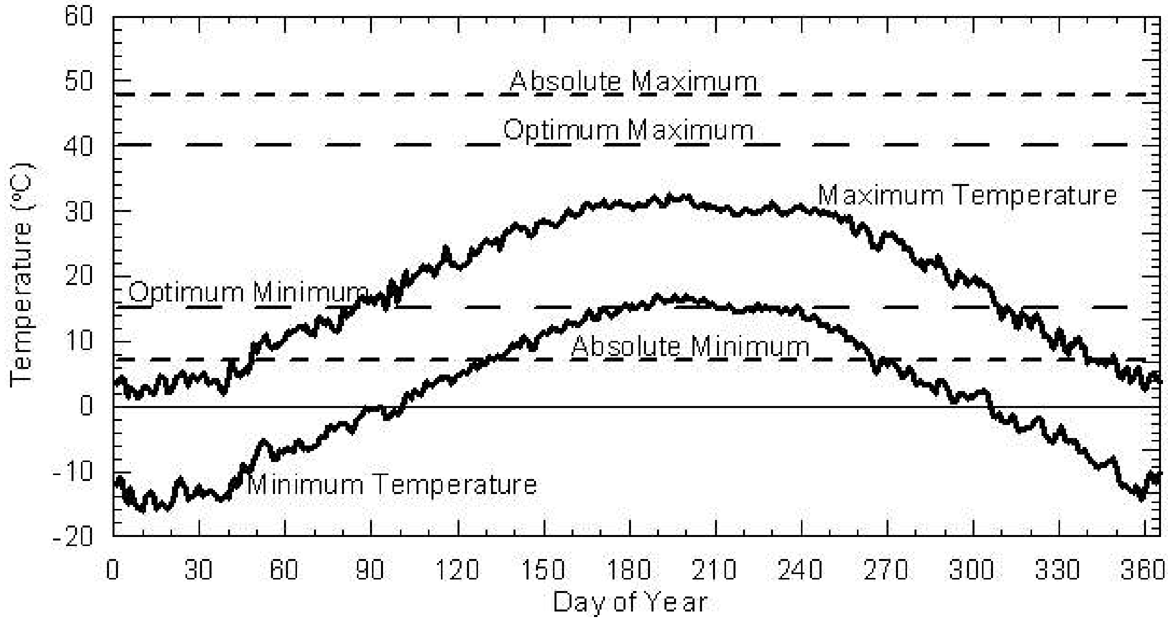
Figure 3. Precipitation Suitability Ratings.

Crops with precipitation range ≥300 mm yr^{-1}								
<Min-350 mm	≥Min-350 mm	≥Min-150 mm	≥Min	≥Min+1/3 of range	≤Max+range*1.25	≤Max+range*1.6	≤Max+range*1.8	>Max+range*1.25
Crops with precipitation range <300 mm yr^{-1}								
<Min-350 mm	≥Min-2/3 range	≥Min-1/3 range	≥Min	≥Min+1/3 of range	≤Max+350 mm	≤Max+480 mm	≤Max+600 mm	>Max+600 mm

Highly suitable	Suitable	Moderately suitable	Slightly suitable	Unsuitable

Suitability ratings for ***Temperature*** are also based on data provided by the PRISM Climate Group. Observed daily maximum and minimum temperatures estimated on a 4km grid were downloaded from the PRISM Climate Group website for the period 1981 to 2010. The expected maximum and minimum temperatures for three in four years are calculated for each grid cell. These temperature values were then compared to the optimal and absolute temperature ranges for each of the alternative crops. The model assumes that the absolute temperatures bounds are descriptive of the range for plant cell division or elongation and that temperature values outside these bounds do not necessarily kill the plant. Cold tolerance and growing days are considered in separate input parameters.

Figure 4. Example of Temperature Range and Plant Minimum and Maximum Ranges



Growing Days suitability is based on the range between the last spring frost and the first fall frost. Frost dates are determined based on the same three in four years approach employed for the temperature suitability rating. Areas with fewer than the minimum number of growing days required by a crop are considered unsuitable. As the number of growing days increases above the required minimum, the area is rated with increasing suitability. Maximum suitability is reached when the number of growing days exceeds the minimum by 37.5%.

Winter Minimum Temperature suitability applies to overwintering crops, measuring the plant ability to withstand extreme cold. This factor is only applied to perennial and winter annual crops in this analysis. The one year in four extreme winter temperature was determined utilizing the PRISM daily minimum temperature data. Areas where the winter minimum temperature was below the extreme winter minimum tolerated by the crop are rated unsuitable. For every 1° C rise in minimum temperature, the suitability rating was increased, with areas with minimum temperatures more than four degrees above the crop minimum considered highly suitable. For annual crops, which do not overwinter, all areas were considered highly suitable for winter minimum temperature.

Overall Suitability

The overall suitability rating is based directly on the methodology developed by Bowen and Hollinger (http://www.isws.illinois.edu/data/altcrops/docs/AltCropsModel2004.pdf). The final rating is the product of the average of the Soil Drainage, Soil Texture, Soil pH, and Temperature suitability scores and the product of Winter Minimum Temperature, Growing Days, and Precipitation. Figure 5 shows the mathematical representation of this approach.

The four model components that were averaged represent components that at some time during the growing season meet the species requirements (temperature), that affect growth and yield rates without killing the crop (temperature or soil texture), or that can be modified by management practices (soil drainage or pH). The average of these four components has a 0-4 range but is rarely, if ever, 0.

The three components that are multiplied together individually can have extremely limiting effects on the suitability of a location for a crop. The law of the minimum was applied to these three components; thus, if precipitation was unsuitable, the location was unsuitable regardless of suitability of the other components. The 64 in the denominator scales the value of the expression on the right to a range of zero to one. The exponent of 0.3 distributes the suitability scores more evenly between 0 and 1.

The final suitability score is a value ranging between 0 and 4. These values are rescaled as follows: 0 – 0.5 = unsuitable, 0.5 – 1.5 = slightly suitable, 1.5 – 2.5 = moderately suitable, 2.5 – 3.5 = suitable, and 3.5 – 4.0 = highly suitable. Figure 6 displays the overall suitability rating for Switchgrass in Missouri.

Figure 5. Computation of the overall suitability score.

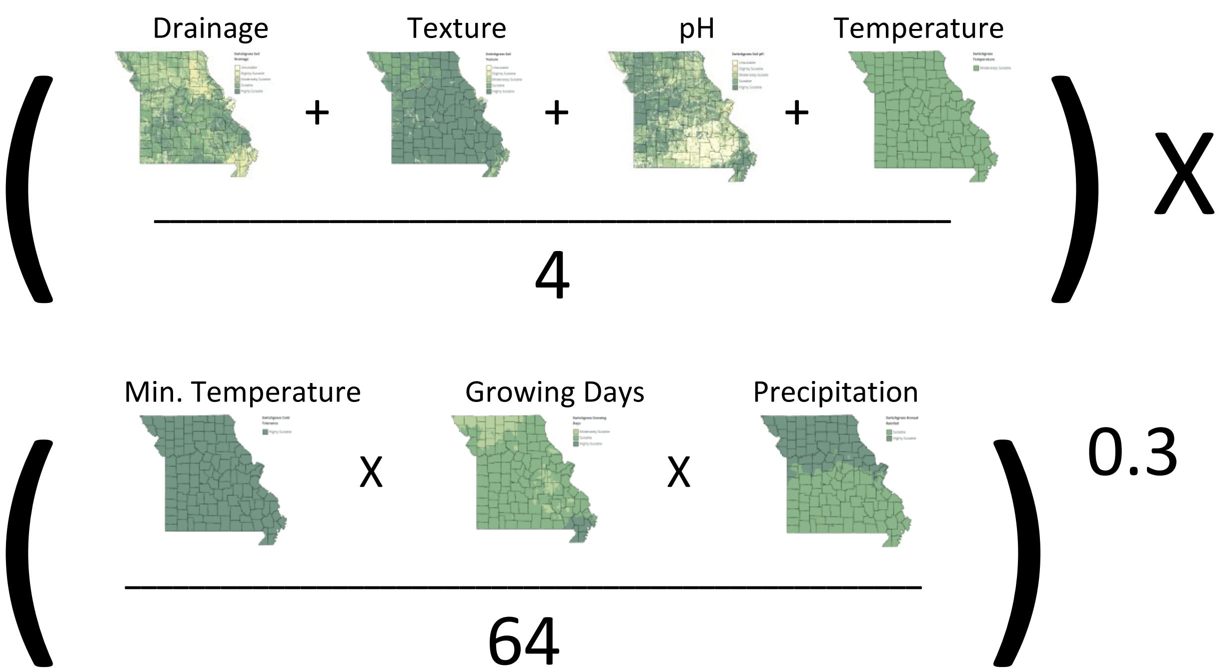
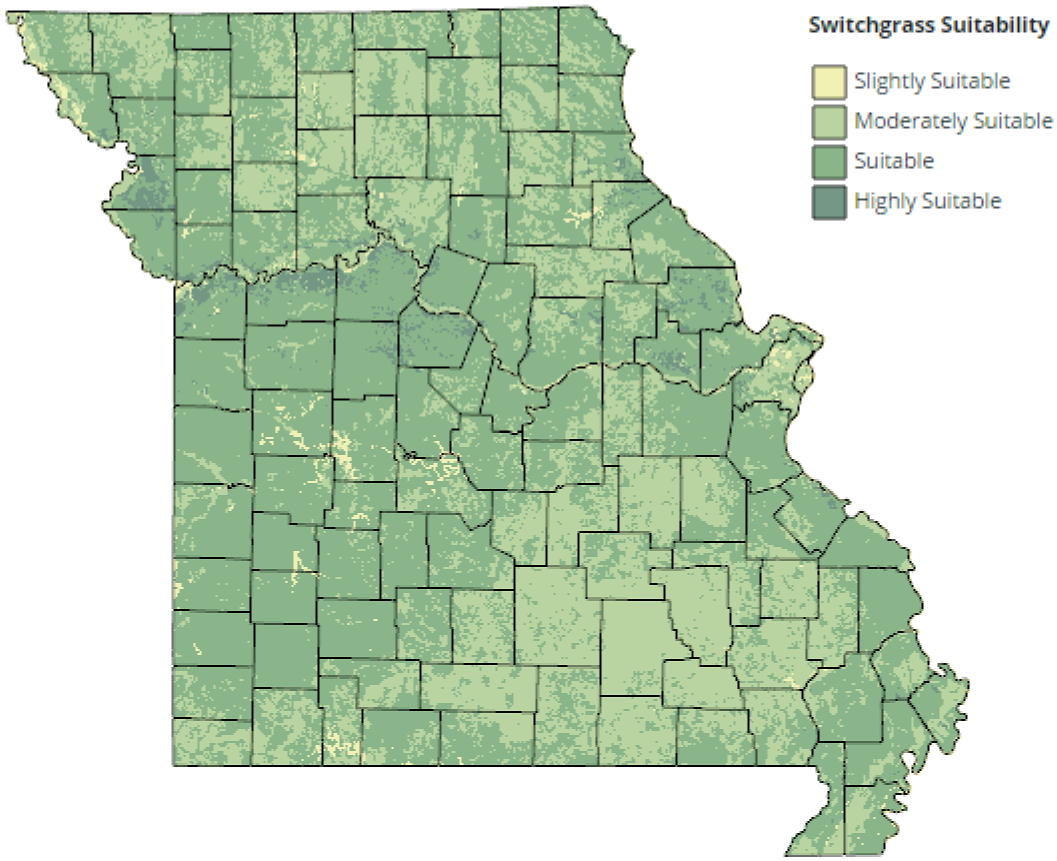


Figure 6. Overall Suitability.



Conclusion

The analysis successfully applies the NRCS SSURGO data and PRISM climate data to the methodology developed by Bowen and Hollinger. The use of these data sets both simplifies the inputs required for the analysis and provides a much greater level of detail. The analysis also shows a great reliance on expertise in soil, climate, and plant science to interpret the model requirements. For instance, the assignment of soil texture suitability ratings by texture group required an understanding of the properties of the soil texture group as well as the plant response to those properties. The ability to apply this model to other plant species or other areas of the United States is not limited by lack of supporting data (soils and climate data), but by the accurate interpretation of plant specific requirements.