Mapping Potato Productivity over the U.S. Eastern Seaboard using a Geospatial Crop Model

Jonathan P. Resop
ASABE Annual International Meeting
Kansas City, Missouri, July 22nd, 2013
Topics of Discussion

1. Geospatial Crop Model Interface
   – Overview of Methods

2. Regional Crop Production Capacity
   – Water-limited and Non-limited Conditions
   – Current and Potential Land Use Scenarios
   – Biophysical Conditions (Climate, Soil)
   – Resource Requirements (Water, Nitrogen)

3. Possible Future Directions
   – Multiple Crop Yield Index (Potato, Corn, Wheat)
   – Climate Change Scenarios
Interface Overview

1. Develop a Geospatial Crop Modeling tool for simulating crop production at a regional scale

2. Analyze the Potential Production Capacity (PPC) of the U.S. Eastern Seaboard Region (ESR)
   - Evaluate the current production
     - Compare with observed trends
   - Estimate potential production under various scenarios:
     - Different Management Practices
     - Limiting vs. Non-limiting Resources
     - Land Use Change
     - Climate Change
# Crop Model Inputs and Outputs

- **Explanatory, Process-based Crop Models**

<table>
<thead>
<tr>
<th>Crop Model Input Variables</th>
<th>Crop Model Output Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weather Data ¹</td>
<td>Crop Yield</td>
</tr>
<tr>
<td>Precipitation</td>
<td>Water Use</td>
</tr>
<tr>
<td>Minimum Temperature</td>
<td>Nitrogen Uptake</td>
</tr>
<tr>
<td>Maximum Temperature</td>
<td></td>
</tr>
<tr>
<td>Radiation</td>
<td></td>
</tr>
<tr>
<td>Wind Speed</td>
<td></td>
</tr>
<tr>
<td>Relative Humidity</td>
<td></td>
</tr>
<tr>
<td>Atmospheric CO₂</td>
<td></td>
</tr>
<tr>
<td>Number of Horizons</td>
<td></td>
</tr>
<tr>
<td>Horizon Depth</td>
<td></td>
</tr>
<tr>
<td>Sand, Silt, and Clay</td>
<td></td>
</tr>
<tr>
<td>Bulk Density</td>
<td></td>
</tr>
<tr>
<td>Organic Matter</td>
<td></td>
</tr>
<tr>
<td>Soil Water Content</td>
<td></td>
</tr>
<tr>
<td>Hydraulic Conductivity</td>
<td></td>
</tr>
<tr>
<td>Elevation</td>
<td></td>
</tr>
<tr>
<td>Latitude and Longitude</td>
<td></td>
</tr>
<tr>
<td>Cultivar</td>
<td></td>
</tr>
<tr>
<td>Irrigation</td>
<td></td>
</tr>
<tr>
<td>Fertilization</td>
<td></td>
</tr>
<tr>
<td>Planting Depth</td>
<td></td>
</tr>
<tr>
<td>Planting Density</td>
<td></td>
</tr>
<tr>
<td>Planting and Harvest Dates</td>
<td></td>
</tr>
</tbody>
</table>

¹ Weather information is required daily over the length of the growing season.

² Soil information is required for each horizon in the soil profile.

**Weather Model**
- CLIGEN

**Soil Model**
- ROSETTA

**Crop Model**
- SPUDSIM
- 2DSOIL

**Weather Model**
- CLIGEN

**Soil Model**
- ROSETTA
Weather Data

- National Climatic Data Center (NCDC) weather stations from NOAA
- At least 1 per county
- 30 years of daily data is simulated with CLIGEN
- Interpolated spatially with Thiessen Polygons
- Stored by Climate ID
Soil Data

- SSURGO soil profile texture properties
- Dominant soil component used for each map unit
- Data for each horizon
- Hydraulic properties estimated with ROSETTA
- Stored by Soil Map Unit Key
Management Data

- Averaged and stored at the county level
- 30-m NED used for elevation
- Planting and harvest dates, percent irrigated area, and observed yield from NASS
- All other management parameters constant
  - Cultivar (Kennebec)
  - Fertilization (Non-limiting)
  - Plant Density (6.9 pl/m²)
  - Plant Depth (5 cm)
Land Use Data

- Common Land Unit (CLU) data to define field areas
- 30-m 2006 National Land Cover Database (NLCD)
- 30-m 2010 Cropland Data Layer (CDL)
- Combined raster and vector datasets; Used to identify areas to simulate
Field-scale Modeling Units

- Independent, Homogeneous Modeling Units
Potential Production Scenarios

Land Use Classifications

**Current Production**
1) Potato Cropland

**Potential Production**
2) All Cropland
3) Pasture
4) Grassland / Scrub

**Not Considered for Production**
5) Forested
6) Developed / Barren

Off Limits to Production
7) Open Water / Wetlands

---

If we were to increase production
How much land is available?
Where is the potential yield greatest?
What is the potential production range?
What are the resource requirements?
What are the biophysical constraints?
Study Area

- Loss of local production due to the loss of the agricultural land
- Food will need to be imported or produced locally to support the growing population
# Current Land Use - Potato

*(Simulated Over Potato Cropland)*

<table>
<thead>
<tr>
<th>State</th>
<th>Irrigated Area (%)</th>
<th>Yield (Mg ha(^{-1}))</th>
<th>WL (Mg ha(^{-1}))</th>
<th>NL (Mg ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Observed (NASS)</td>
<td>Simulated (SPUDSIM)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ave.</td>
<td>Std.</td>
<td>Ave.</td>
<td>Std.</td>
</tr>
<tr>
<td><strong>Northern ESR / Fall Growing Season</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maine</td>
<td>12%</td>
<td>30.40</td>
<td>28.81</td>
<td>1.54</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>20%</td>
<td>28.89</td>
<td>26.06</td>
<td>1.38</td>
</tr>
<tr>
<td>Rhode Island</td>
<td>21%</td>
<td>28.08</td>
<td>27.93</td>
<td>0.81</td>
</tr>
<tr>
<td>New York</td>
<td>33%</td>
<td>30.97</td>
<td>27.76</td>
<td>1.49</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>22%</td>
<td>26.98</td>
<td>27.61</td>
<td>2.19</td>
</tr>
<tr>
<td><strong>Southern ESR / Summer Growing Season</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Jersey</td>
<td>74%</td>
<td>27.80</td>
<td>7.62</td>
<td>1.46</td>
</tr>
<tr>
<td>Maryland</td>
<td>67%</td>
<td>26.59</td>
<td>15.11</td>
<td>1.78</td>
</tr>
<tr>
<td>Delaware</td>
<td>70%</td>
<td>26.42</td>
<td>17.45</td>
<td>1.24</td>
</tr>
<tr>
<td>Virginia</td>
<td>53%</td>
<td>23.29</td>
<td>11.21</td>
<td>3.22</td>
</tr>
</tbody>
</table>
Current Land Use - Potato

(County-level Averages)

WL Relative Error
Northern ESR 12%
Southern ESR 51%

NL Relative Error
Northern ESR 38%
Southern ESR 10%
Potential Land Use - Cropland

(Simulated Over All Cropland)

(a) Water-limited Potato Yield (Mg/ha)

(b) Non-limited Potato Yield (Mg/ha)

USDA-ARS, Crop Systems and Global Change Lab, Beltsville, Maryland
Potential Land Use - Cropland

(Simulated Over All Cropland)
Summary and Conclusions

• Potato yield mainly limited by temperature, but deficits can be offset by irrigation.
• Production greatest in northern areas where there is already potato cropland, but there is potential in areas like WV.
• The geospatial method used here takes advantage of higher-resolution climate and soil data to get a better understanding of the spatial and temporal variability.
Future Directions

• Expand analysis of current and potential production to include corn and wheat to create an overall yield-index for productivity.

• Study the sensitivity of the region to different scenarios such as climate change and land use change as well as potential adaptation.
Climate Change Scenarios

- Uses IPCC Scenario and the HadCM3 GCM Model
- Monthly parameter changes from the GCM are downscaled using IDW method to the NOAA CLIGEN monthly parameters and then daily data is generated
- Future predictions are averaged over the time frame 2050 to 2080
- Climate Scenarios = A2 (Focus on Economic Development, High CO$_2$ ~600 ppmv)
- Weather Parameters = Max Temp, Min Temp, Precipitation, and CO$_2$
Climate Change Scenarios

Potato Yield (Mg/ha)

- 0.00 - 3.30
- 3.31 - 6.60
- 6.61 - 9.90
- 9.91 - 13.20
- 13.21 - 16.50
- 16.51 - 19.80
- 19.81 - 23.10
- 23.11 - 26.40
- 26.41 - 29.70
- 29.71 - 33.00
- 33.01 - 36.30
- 36.31 - 39.60
- 39.61 - 42.00

Baseline Climate

- Water-limited
- Non-limited

Future Climate (A2)

- Water-limited
- Non-limited

(WV/VA Scenarios Not Complete)
Questions?

This research was supported by the USDA-ARS Headquarters Postdoctoral Research Associate Program and the USDA-NIFA AFRI Grant #2011-68004-30057: Enhancing Food Security of Underserved Populations in the Northeast through Sustainable Regional Food Systems.

Maryland – Post-Doctoral Researcher
The USDA-ARS Crop Systems and Global Change Laboratory in Beltsville, MD is seeking a postdoctoral associate for a 2-year appointment.

QUALIFICATIONS: Recent Ph.D. in one of the following fields: Agricultural Engineering, Agronomy, Plant Physiology, Soil Science, or related discipline. Knowledge of crop responses to biophysical constraints, simulation models for plant growth, and GIS is highly desirable.

HOW TO APPLY: Submit resume or curriculum vitae to Dr. David H. Fleisher, USDA-ARS, (david.fleisher@ars.usda.gov).

USDA is an equal opportunity employer. U.S. Citizenship restrictions apply.