Soil functional maps for crop management and planning

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Soils – What do we want to know?

• The role of soil in yield and yield variability
• Nutrient release and response
• Soil-plant relationships
• Water storage and availability
• Manage soil for long-term sustainability
Soils in Howard County Indiana

**Fc** – Fincastle: Fine-silty, mixed, superactive, mesic Aeric Epiaqualfs

**Bs** – Brookston: Fine-Loamy, mixed, superactive, mesic Typic Argiaquolls

**Kk** – Kokomo: Fine, mixed, superactive, mesic, Typic Argiaquolls

**Pa** – Patton: Fine-silty, mixed, superactive, mesic, Typic Endoaquolls

**Ca** – Carlisle muck: Euic, mesic, Typic Haplosaprist

**Limitations**
- Soil Survey has hard boundaries
- Up to 0.8 Ha inclusions
- Created using best available technology at the time
Soil Variability

- Current maps illustrate how soils look differently or how they classify differently

- Maps are needed to show how soils work the same

- Structural heterogeneity vs. functional homogeneity
Potassium variability across a drainage catena
Nonexchangeable K

K
mg/kg

2600
800

5 cm
30 cm
60 cm
* - Need to sample approximately 30 m (100 ft) to capture variability
* - Soil properties were predictable by using topography
TWI = ln(a/tan(B)) (Quinn et al 1995).
Catena Concept – G.A. Milne, 1934

Soils follow repeatable patterns based on topography
DSM - Approach

• Soil State Model (Jenny, 1941)

• Five soil forming state factors:

\[ S = f(cl, o, r, p, t) \]

where:
\[ cl = \text{climate} \]
\[ o = \text{organisms} \]
\[ r = \text{relief (topography)} \]
\[ p = \text{parent material} \]
\[ t = \text{time} \]

• Solve for one factor (topography) in Jenny’s equation of the soil forming factors.
Mental Models for predicting patterns

- Conceptual block diagram models
- Regular repeating patterns based on five state factors.
Solutions
Soils in Howard County

• 5 soils cover 80% of the land on Howard County

• Are there relationships between these 5 soils and terrain attributes?

• Can we use those relationships to improve the survey in an update context?
Frequency distributions

- Fincastle: Terrain attribute: Curvature
- Brookston: Terrain attribute: Altitude above channel network

*Data extracted with Knowledge Miner Software*
Frequency, Wetness Index

Terrain attribute: Wetness Index

Fincastle

Brookston

*Data extracted with Knowledge Miner Software
Formalize the Relationship

Example:

- If the TWI = 14 then assign Brookston
- If TWI = 10 then assign Fincastle
- Other related terrain attributes (or other spatial data with unique numbers) can be used.
- That provides a membership probability to each pixel
Terrain-Soil Matching for Brookston

Fuzzy membership values (from 0 to 100%)

*Information derived from Soil landscape Interface Model (SoLIM)
Create Property Map with SoLIM

- To estimate the soil property SoLIM/SIE uses:

\[
D_{ij} = \frac{\sum_{k=1}^{n} S_{ij}^{k} \times D^{k}}{\sum_{k=1}^{n} S_{ij}^{k}}
\]

- \(D_{ij}\): the estimated soil property value at (i, j);
- \(S_{ij}^{k}\): the fuzzy membership value for kth soil at (i, j);
- \(D^{k}\): the representative property value for kth soil.
Wilbur silt loam, 0 to 2 percent slopes, frequently flooded, brief duration
Wellston-Adyeville-Ebal silt loams, 12 to 18 percent slopes, eroded
Wellston silt loam, 6 to 12 percent slopes, severely eroded
Pekin silt loam, 6 to 12 percent slopes, eroded
Johnsburg silt loam, 0 to 2 percent slopes
Haymond silt loam, 0 to 2 percent slopes, frequently flooded, brief duration
Gatchel loam, 1 to 3 percent slopes, occasionally flooded, very brief duration
Bartle silt loam, 0 to 2 percent slopes
Apalona silt loam, 6 to 12 percent slopes, severely eroded
Apalona silt loam, 6 to 12 percent slopes, eroded
Apalona silt loam, 2 to 6 percent slopes
Adyeville-Wellston silt loams, 18 to 50 percent slopes
Adyeville-Tipsaw complex, 20 to 60 percent slopes
Zanesville silt loam, 6 to 12 percent slopes, eroded
Wellston silt loam, 6 to 12 percent slopes, severely eroded
Wellston silt loam, 6 to 12 percent slopes
Water
Tilsit silt loam, 2 to 6 percent slopes
Tilsit silt loam, 0 to 2 percent slopes
Steff silt loam, frequently flooded
Peoga silt loam
Pekin silt loam, 6 to 12 percent slopes, eroded, rarely flooded
Pekin silt loam, 2 to 6 percent slopes, rarely flooded
Johnsburg silt loam, 0 to 2 percent slopes
Gilpin-Berks complex, 20 to 50 percent slopes
Gilpin silt loam, 18 to 25 percent slopes, severely eroded
Gilpin silt loam, 18 to 25 percent slopes
Gilpin silt loam, 12 to 18 percent slopes, severely eroded
Gilpin silt loam, 12 to 18 percent slopes, eroded
Cuba silt loam, frequently flooded
Burnside silt loam, occasionally flooded
Bonnie silt loam, frequently flooded
Bartle silt loam
Validation

• Dillion Creek Watershed – 127 geo-referenced field observations
• Compared SSURGO RV predictions vs. measured: Average difference = 57 cm
• Compared TASM predictions vs. measured: Average difference = 22 cm
Yield Relationships
Soil Property Maps: available water storage, CFF, 0 – 100 cm

SSURGO

TASM
Soil Property Maps: CEC, OM
Indiana Family Farm
Indiana Family Farm
Proposed Management Index Strategy

1. High Fertility transfer zones (erosion)
2. Stability of fertility. Profitable additions to field system
3. Yield and fertility Volatility

Zone 1: not conducive to high fertility additions
Zone 2: profitable additions to field system without loss. Zone 2 losses are moved from zone 1 to zone 3.
Zone 3: Yield and fertility volatility expected. Overlap of zones is usual (no need for discreet boundaries). When zone 3 overlaps with 1 avoid heavy fertilizer additions because of expected losses. When 3 overlaps with 2 heavier fertility additions are helpful.
Steps for Predicting Soil Properties

1. Legacy Data
2. Landform Classification
3. Geology
4. Soil Class Map
5. Terrain Attributes
6. ALIM
7. Continuous Soil Property Maps
Multiple different “geomorphon” show the presence of a valley. Notice how similar the “geomorphon” or patterns are for points A through D.
Namasigue Watershed Study Area at Los Espabeles - Honduras

Approximate 10 m DEM was created from topography paper map of contours
Creating Continuous Soil Property Maps

Soil Sand (%)

Soil Clay (%)

Soil Silt (%)

Soil CEC (ppm)
Creating Continuous Soil Property Maps

- Soil Organic maps are created to show uncertainty.
- More point data gives better predictions.
- The following example will demonstrate the importance of having accurate and high resolution data.
Crop Soil Suitability Index - Example

<table>
<thead>
<tr>
<th>Property</th>
<th>Weight (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope</td>
<td>30</td>
</tr>
<tr>
<td>Soil Depth</td>
<td>20</td>
</tr>
<tr>
<td>SOM</td>
<td>15</td>
</tr>
<tr>
<td>Slope position</td>
<td>10</td>
</tr>
<tr>
<td>pH</td>
<td>5</td>
</tr>
<tr>
<td>CEC</td>
<td>5</td>
</tr>
<tr>
<td>Silt</td>
<td>5</td>
</tr>
<tr>
<td>Sand</td>
<td>5</td>
</tr>
<tr>
<td>Clay</td>
<td>5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>
Future

• Need to automate the soil mapping process

• Need to take automated process to allow input from new data input

• Couple the soil data with crop models as a decision tool – “what if” tools?; Economic maps?
Impact of soil type and N rate on corn grain yield, 2012 – Brad Joern