MLRA 90A - Mille Lacs Uplands Coarse-Loamy Basal Till
A Quantitative & Knowledge-Based Digital Mapping Approach to Reconcile Initial and Updated Soil Surveys

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Raster soil survey products improve or advance the currently existing official SSURGO inventories with detailed, refined, spatially explicit and seamless soil information across county, parish or State boundaries – NSSH 648 (2018)

Raster soil survey products are foundational to providing detailed soil information in unmapped areas as part of the non-MLRA progressive soil survey. Initial raster soil survey project mapping is analogous to a first generation soil survey – NSSH 648 (2018)

**Mille Lacs Uplands Physiographic Area**

- General Soil Association (STATSGO)
  - Coarse-Loamy Till – Milaca Catena
  - Coarse-Loamy Till – Brennyville Catena

**Project Map Units**

- Mille Lacs Uplands Land Type Association
PROJECT OBJECTIVES:
MLRA 90A – Mille Lacs Uplands Coarse-Loamy Basal Till Investigation

- Reconcile legacy correlation issues resulting in extensive spatial and tabular join concerns and re-correlate to MLRA map units as appropriate
- Evaluate spatial trends across geomorphic surface(s) using historical documentation, laboratory analysis and cooperator data to reconcile physical and chemical inconsistencies evident in correlated map units in the area
- Explore digital soil mapping methods to augment consistency and efficiency in applying mapping conventions in conjunction with MLRA updates and initial soil survey projects
- Develop raster soil survey products to render more detailed representation of soil spatial variability across the project area.
SURFICIAL GEOLOGY BACKGROUND
LANDFORM TRAVERSE – INITIAL SOIL SURVEY
HINCKLEY TILL PLAIN - PINE COUNTY, MINNESOTA

Historical Soil Manuscript (1941)

INITIAL FINDINGS – HINCKLEY TILL PLAIN
PINE COUNTY, MINNESOTA

1. Particle-Size Control Section
   • Coarse-Loamy
   • Fine-Loamy

2. Parent Material
   • Wave-Washed materials over Dense Till
   • Dense Till

3. Soil Moisture Status
   • Hydric Indicators
   • Aquic Conditions
   • Oxyaquic Subgroup

Soils are dominantly Alfisols
Glossic horizons are dominantly observed
Upland soils with clay content averaging greater than 25 percent clay exhibit calcium carbonate
INITIAL FINDINGS – HINCKLEY TILL PLAIN
PINE COUNTY, MINNESOTA

Particle size control section:
1. Coarse-loamy
   a. Wind-blown materials over till
      1. Seasonally ponded
         i. Adolph – Typic Epiaquolls
      2. Hydric indicators observed
         i. Cebana – Mollic Glossaqualf
      3. Aquic conditions above
         i. Freer, coarse-loamy – Aeric Glossaqualfs
   4. Aquic conditions above 40 centimeters
      i. Brennyville – Aquic Glossudalfs
   5. Oxyaquic subgroup
      i. Brennyville, taka9adunor – Oxyaquic Glossudalfs
b. Till
   1. Seasonally ponded
      1. Giese – Typic Humaquepts
   2. Hydric indicators present
      1. Fesent – Typic Epiaquolls
   3. Aquic conditions above
      1. Ronney – Aeric Glossaqualfs
   4. Aquic conditions above 40 centimeters
      1. Mora – Aquic Glossudalfs
   5. Oxyaquic subgroup
      1. Milaca – Oxyaquic Glossudalfs

2. Fine-loamy
   a. Till
      1. Seasonally ponded
         1. Beden – Typic Endoaquepts
      2. Hydric indicators present
         1. Ellsbury – Typic Glossaqualfs
      3. Aquic conditions above 40 centimeters
         1. Dusler – Aquic Glossudalfs
      4. Oxyaquic subgroup
         1. Culver – Oxyaquic Glossudalfs

Pedon PSCS
• Coarse-Loamy Till
• Fine-Loamy Till/Other
• Hinckley Till Plain
• Mille Lacs Project Area
Subset Correlation Dates
MLRA 90A – Mille Lacs Uplands Coarse-Loamy Basal Till Project

Subset Boundary
Project Footprint

Available Water Storage
mm upper 100 cm of the soil profile

Soil Organic Carbon
$g/m^2$ upper 100 cm of the soil profile

- 5,000 or less
- 5,000 – 10,000
- 10,000 – 20,000
- 20,000 – 30,000
- Over 30,000

Surface Texture
≥ 40 cm thick
SIL or VFSL
SL or FSL
High Organic

Correlation Date
Pre - 1970
1970 – 1980
1980 – 1990
1990 – 2000
2000 – 2010
NOTCOM
LAND USE MANAGEMENT
MLRA 90A – Mille Lacs Uplands Coarse-Loamy Basal Till Investigation

1.2 Million Acres
40% Deciduous & Mixed Forest
30% Wetlands
30% Agriculture

Dominant Tree Species:
Sugar Maple, Red Oak, Basswood, & Aspen-Birch

Common Crops:
Corn, Oats, & Hay

FIELD INVESTIGATION SITES
MLRA 90A – Mille Lacs Uplands Coarse-Loamy Basal Till Investigation

Agriculture Land Sampling (Private)
71 Historical Pedons (70%)

Wooded Sampling (Public)
57 Historical Pedons (30%)
COVARIATE SELECTION

\[ S = f (S, C, O, R, P, A, N) \]

(McBratney et al., 2003)

MOST IMPORTANT FEATURES OF INTEREST:
- Depth to Aquic Conditions
- Absence or Presence of Silty Mantle

STRONGEST COVARIATE PREDICTORS:
- Wetness Index (SAGA)
- Relative Position
- Slope

<table>
<thead>
<tr>
<th>SCORPAN Covariate</th>
<th>Soil-Landscape Characteristics</th>
<th>Existing Data Layers that Represent Soil-Landscape Characteristics</th>
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<tr>
<td>Soil</td>
<td>Coarse-loamy</td>
<td>$SSURGO$</td>
</tr>
<tr>
<td></td>
<td>Dense Till</td>
<td>$STATSGO$</td>
</tr>
<tr>
<td>Silt Mantle</td>
<td>Alluvial, Inceptisols, Fluvaquents</td>
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</tr>
<tr>
<td>Climate</td>
<td>Degree of Decomposition (Organic Soils)</td>
<td>$PRISM$ (MAAT)</td>
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<td>Thermal band</td>
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<td>$NDMI$</td>
</tr>
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<td>Organisms</td>
<td>Land cover (eg, wooded, organic)</td>
<td>$NLCD$</td>
</tr>
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<td>$NDVI$</td>
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<td>$NDMI$</td>
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<tr>
<td>Relief</td>
<td>Slope</td>
<td>$DEM$</td>
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<td></td>
<td>Depth to Aquic Conditions</td>
<td>Slope, curvature, relative position, relative relief, wetness index, slope heterogeneity</td>
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<td>Parent Material</td>
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<td>$Geology$ map</td>
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<td>$SSURGO$</td>
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<tr>
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<td>organic</td>
<td>Drain cost, dep cost</td>
</tr>
<tr>
<td>Age</td>
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<td>$Historical$ Pedon Data</td>
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<tr>
<td></td>
<td></td>
<td>$Piezometer$ Data</td>
</tr>
</tbody>
</table>
Wetness Index (SAGA)

Mean = 65.08
Std. Dev. = 13.97

Mean = 65.4
Std. Dev. = 15.10

Mean = 65.27
Std. Dev. = 11.06

Relative Position

Mean = 44.71
Std. Dev. = 21.49

Mean = 42.76
Std. Dev. = 23.09

Mean = 48.43
Std. Dev. = 17.15

Slope

Mean = 10.66
Std. Dev. = 11.62

Mean = 10.50
Std. Dev. = 13.24

Mean = 10.42
Std. Dev. = 11.08

TOTAL PROJECT AREA

FORESTED SAMPLING AREAS

AGRICULTURAL SAMPLING AREAS
TRAINING POINT COLLECTION
MLRA 90A – Mille Lacs Uplands Coarse-Loamy Basal Till Investigation

Stratified & cLHS Sampling Methods
12 cLHS Training Points – Agriculture
28 cLHS Training Points – Forested
40 * 2.5 (up/downslope) = 100 Training Points

FEATURES OF INTEREST
Organic Soil Material Thickness
Organic Soil Material Decomposition
Organic Soil Reaction Class

Depth of Aquic Conditions: Observed Depletions & Concentrations
Silty Mantle Material Thickness: Silt Loam or Very Fine Sandy Loam versus Sandy Loam or Fine Sandy Loam

Depth to Densic Contact

PLOT RADIUS

• cLHS Training Points
FINALIZE TRAINING DATA

479 Training Points
- MNDNR Organic Soil Cores (172)
- Historical Documentation (114)
- Landform Traverse (66)
- Laboratory Sites (50)
- Additional Documentation (77)

Identified Soil Taxons:
- Amery, Santiago, Milaca, Freeon, Brennyville, Mora, Freer, Ronneby, Parent, Cebana, Twig, Giese, Beseman, Cathro, Seelyeville, Rifle, Greenwood, Bowstring, Twig, & Millward
MODELING DATASETS

TRAINING DATASETS

1. Mille Lacs Uplands Project Area
   • 479 Training Points
2. Training Data Points Plus Cells Confined Within Plot Radius Buffer
   • 8,061 Training Points
3. Expanded Organic Training Points
   • 418 Training Points
4. Alluvial Training Points
   • SSURGO Data
   • 191,520 Training Points
5. Deep Histosols Training Points
   • SSURGO Data
   • 4,455 Training Points

RESPONSE VARIABLES:
(Physical Property/Feature of Interest):

- DENSIC PROPERTY INDEX (1)
- SILTY MANTLE DEVELOPMENT INDEX (1)
- ORGANIC MATTER THICKNESS
  - Very Deep Organic (>150 cm) (1)
  - Deep Organic (>100 cm) (1)
  - Terric Organic (>50 cm) (1)
  - Histic Epipedon (>30 cm) (1)
  - No Mineral (>0 cm) (1)
- Mucky Mineral Index (1)
- Composite Histic Index (1)
- SOIL MOISTURE CLASS
  - Oxyaquic Subgroup or Wetter (2)
  - Aquic Subgroup or Wetter (2)
  - Aeric Subgroup or Wetter (2)
  - Hydric (2)
  - Ponded (2)
- Composite Hydrology Index (2)
- ORGANIC SOIL REACTION CLASS
  - Dysic Index (1)
- ORGANIC SOIL DECOMPOSITION
  - Hemic (1)
  - Sapric Soil Materials (3)
  - SSURGO Sapric Index (5)
- Composite Sapric Index
- Alluvial Index (4)

PREDICTOR VARIABLES:

1. Terrain
   - Predictor Variable | Description
   - curv30d | Curvature - 30m Diameter (Shi)
   - dep_cost | Depression Cost - Cost distance (slope cost) from natural depression
   - mncv30_210 | Average Curvature Values Generated from 30m Diameter Intervals (Shi) - Mean 30/60/90/120/150/180/210
   - mntdf | Maximum value of 3 iterations of Multi-resolution valley Bottom Rankness (Shi) Thresholds of 7/10/15 and 21.8 21.7
   - plan20d | Plan - 20m Diameter Mean (Shi)
   - pro20d | Profile - 20m Diameter Mean (Shi)
   - rel15_45 | Relative Position 15 -45m Radius Average - Mean 15/25/35/40/45
   - rel200_600 | Relative Position 200-600m Radius Average - Mean 200/300/400/500/600
   - rel50_150 | Relative Position 50-150m Radius Average - Mean 50/75/100/125/150
   - relat100 | Relative Relief Standard Deviation 100m Radius
   - relat200 | Relative Relief Standard Deviation 200m Radius
   - asp20d | Slope Gradient - 20m Diameter (Shi)
   - splitter100 | Relative Slope Heterogeneity - 100m Radius
   - wetness | Wetness (SAGA)

2. Spectral
   - Predictor Variable | Description
   - ndni0510 | LANDSAT 7 Normalized Difference Moisture Index - (Band 4 - Band 5) / (Band 4 + Band 5) - May 19, 2010 Scene
   - ndni0707 | LANDSAT 5 Normalized Difference Moisture Index - (Band 4 - Band 5) / (Band 4 + Band 5) - July 30, 2007 Scene
   - ndni0100 | LANDSAT 8 Normalized Difference Moisture Index - (Band 5 - Band 6) / (Band 5 + Band 6) - October 10, 2016 Scene
   - ndni0510 | LANDSAT 7 Normalized Difference Vegetative Index - (Band 4 - Band 3) / (Band 4 + Band 3) - May 19, 2010 Scene
   - ndni0707 | LANDSAT 5 Normalized Difference Vegetative Index - (Band 4 - Band 3) / (Band 4 + Band 3) - July 30, 2007 Scene
   - ndni1016 | LANDSAT 8 Normalized Difference Vegetative Index - (Band 5 - Band 4) / (Band 5 + Band 4) - October 10, 2016 Scene
   - thmi0510 | LANDSAT 7 Thermal Band 6 - May 10, 2010 Scene
   - thmi0707 | LANDSAT 5 Thermal Band 6 - July 10, 2007 Scene
   - thmi1016 | LANDSAT 8 Thermal Band 10/11 - October 10, 2016 Scene

3. Ancillary Datasets & Secondary Covariates
   - Predictor Variable | Description
   - drain_cost | Drainage Cost - Cost distance (slope cost) from MNDNR NWI stream
   - indfr_mhm | Hydrogeomorph Landform Classification MNDNR NWI
   - hsgp2nrm | Hydrogeomorph Landscape Classification MNDNR NWI
   - mean | Mean Annual Air Temperature (PRISM) 1980 - 2010
   - mntlt | Cost distance (slope cost) from known sources of Sth Loom Mnlr (Gleas Lake Granaburg margin extending across the Lgrindict Lstew of Mnlr Lac)
   - species_bin | Distance weighted importance of Big Woods Indicator species from GLO - PLSB Bazing Tree Data (Sugar Maple - 4/0m - 2/Hickory - 2/Beetwood - 1/Ironwood - 1/Maple - 1/Red Oak - 1)
MODELING FEATURES OF INTEREST – LOGISTIC REGRESSION (RSTUDIO)

Ponded Organic
Hydric or wetter
Mucky or mucky modifier surface
Aeric or wetter
Evidence of seasonal saturation within 25 cm
Aquic or wetter
Evidence of seasonal saturation within 50 cm
Oxyaquic or wetter
Evidence of seasonal saturation within 100 cm

Logistic Regression Model

Ponded = Ponded + mrvbf + msi_dist + re200_900 + relstd100 + alphetr100 + thermo510, data = "MNL_PR"

Aeric or wetter
Evidence of seasonal saturation within 25 cm
Aquic or wetter
Evidence of seasonal saturation within 50 cm
Oxyaquic or wetter
Evidence of seasonal saturation within 100 cm

PROPERTY PROBABILITY

High : 1
Low : 0

Logistic Regression Model

1m(formula = Oxyaquic ~ drain_cost + re200_900 + relstd100 + alphetr100 + wetness, data = "MNL_PR")

Model Likelihood Discrimination Rank Discrim. Ratios Test Indexes Indexes
Obs 8062 LR ch12 485.69 R2 0.297 G 0.891
0 170 d.f. 5 g 2.222 Day 0.782
l 7892 Pr(> ch12) <0.0001 gr 5.229 gamma 0.763
max |deriv| 9e-09 max |deriv| 9e-00 tau-e 0.416 tau-e 0.632

Brier 0.018

Brier 0.018
### MODELING OF SOIL TAXONS – RULE BASED REASONING (SIE)

#### B. Unmanted Upland Sequence - 5 Classes; Inputs - 9 Features of Interest; 0 Covariates

<table>
<thead>
<tr>
<th>Taxon/Soil</th>
<th>Feature/Covariate</th>
<th>Weight(%)</th>
<th>Curve</th>
<th>$v_1$, $w_1$, $r_1$</th>
<th>$v_2$, $w_2$, $r_2$</th>
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<tbody>
<tr>
<td>Milaca</td>
<td>DENSIC</td>
<td>10</td>
<td>Bell</td>
<td>0.225, 0.075, 0</td>
<td>0.325, 0.025, 2.5</td>
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<td></td>
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<td>25</td>
<td>Bell</td>
<td>1, 0.1, 1.4</td>
<td>1.7, 0.6, 2.5</td>
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<td>MANTLE</td>
<td>20</td>
<td>Z</td>
<td>10, 38, 2</td>
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<tr>
<td></td>
<td>OXY</td>
<td>20</td>
<td>S</td>
<td>0.068, 0.25, 2</td>
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<td>AQUIC</td>
<td>5</td>
<td>Bell</td>
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</table>

#### CLASS PROBABILITY

- **High**: 100
- **Low**: 0.00
## ACCURACY ASSESSMENT – PROVISIONAL CORRELATION

**PROVISIONAL RESULTS EVALUATED**

- Training Point Accuracy – Confusion Matrix (310 Points)

<table>
<thead>
<tr>
<th>OBSERVED</th>
<th>Beseman</th>
<th>Bowstring</th>
<th>Brennyville</th>
<th>Cathro</th>
<th>Cebana</th>
<th>Freeon</th>
<th>Freer</th>
<th>Giese</th>
<th>Greenwood</th>
<th>Milaca</th>
<th>Millward</th>
<th>Mora</th>
<th>Parent</th>
<th>Rifle</th>
<th>Ronneby</th>
<th>Santiago</th>
<th>Seelyville</th>
<th>Amery</th>
<th>Tacooosh</th>
<th>Twig</th>
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ACCURACY ASSESSMENT - DESIGN

INDEPENDENT DATASET TARGETING
- 21 Provisional Taxons
- 90 Validation Points
  - 11% Largest Proportion Class
  - 95% Confidence Level
  - 10% Precision Level

SAMPLING DESIGN
- Maximize Efficiency
- Sampling Type
  - Independent
  - Stratified
  - Random
  - Clustered

VALIDATION POINTS (151)
- Additional Points (90)
- MNDNR Organic Cores (41)
- Alluvial & Water (20)
# ACCURACY ASSESSMENT – FINAL CORRELATION

## CLASS CORRELATION

Correlate poorly performing taxons into similar concepts.

21 Provisional Taxons to 14 Final Taxons

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<th>Cebana</th>
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**Overall Accuracy**: 66%

**Area Weighted Accuracy**: 67%

**Kappa**: 63%
**SSURGO LINE PROJECTION USING RASTER DATA**

- **MOST IMPORTANT LINE**
- **SEGMENTATION**
  - Most important classification
- **RECONSTITUTION**
  - Group by Major Breaks
  - Minimum Delineation Size to Separate
- **SUMMARIZE AGGREGATED RASTER**
  - Vector Data

**B. Reconstitution**

Sequence of Eliminate as Grouped by Major Breaks

- **Group 1 - Non-alluvial Histosols & Hydric Soils (21, 120, 121, 122) Vectorized**
  - Greenwood, Rifle, Seelyville, Twigg, Giese
  - Iterative Eliminate 0.5 to 1.5 acre

- **Group 2 - Other mineral Soils (220, 221, 222) Vectorized**
  - Santiago, Milaca, Mora, Ronneby, Parent, Amery, Freeon, Brennyville, Freer, Cebana, Millward
  - Iterative Eliminate 0.5 to 6 acre

- **Group 3 - Exclusions (No Elimination) Water & Alluvial (0,11) Vectorized**
  - Water, Bowstring
  - Merge Group 1, 2, 3
  - Iterative Eliminate 0.1 to 3.5 acre
RASTER ORGANIC SOILS
- Cathro
- Seelyeville
- Greenwood
- Rifle*

RASTER WET MINERAL SOILS
- Twig or Giese

ASSOCIATED SOILS
- Millward Recessional Moraine Unit
- Bowstring Alluvial Unit

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<td>Cebana</td>
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<td>Coarse-loamy, mixed, superactive, frigid Oxyaquic Glossudalfs</td>
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<td>Coarse-loamy, mixed, superactive, frigid Aquic Glossudalfs</td>
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<td>Euic, frigid Typic Haplosaprists</td>
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ASSESSING THE DATA

- USE THE DATA TO POPULATE THE DATA
- JUSTIFIABLE AND DEFENDABLE

Mora-Ronneby complex, 1 to 4 percent slopes, stony

Brennyville-Freer complex, 1 to 4 percent slopes, stony

SSURGO Delineation
- Brennyville
- Freer
- Cebana
- Milaca
- Giese
ASSESSING THE DATA

PIEZOMETER DATA

• Installed 11/02/2017
• 2 Readings per Day

Analysis of Piezometer Data – June 2018

Daily Precipitation

Depth to Water Table

Pipe Depth - 50cm
Pipe Depth - 95cm
Pipe Depth - 150cm

Legend

Wet
Dry
Density Restriction
Lithologic Discontinuity
DSM DOESN’T HAVE TO BE ONLY ABOUT SPATIAL UPDATES

Depth to Restriction – GNATSGO 2019

Depth to Restriction – GNATSGO 2020

DSM Raster Soil Survey (RSS) Projects

Minnesota

- Boundary Waters Canoe Area Wilderness
- MLRA 102A - Fergus Falls Till Plain Formdale Catena Study, Re-correlation and Investigations
- MLRA 88 - Glacial Lake Plain Baudette Catena
- MLRA 90A - Mille Lacs Uplands Coarse-Loamy Basal Till Investigation

USDA-NRCS Digital Soil Mapping (DSM)

https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=stelprdb1254424
ACCESSING THE PRODUCTS
(Once It’s Made Live)

1. nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcseprd1464625

2. gNATSGO_MN.gdb.zip
   Aug 9, 2019 by Jennifer Sweet 1 GB
The process document for this project as well as others completed by the Soil Survey Staff in the North Central Soil Region are available in a user-friendly HTML document available at:

USDA-NRCS Digital Soil Mapping (DSM)
https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=stelprdb1254424