USDA United States Department of Agriculture

The Future of Soil Mapping using LiDAR Technology

Jessica Philippe

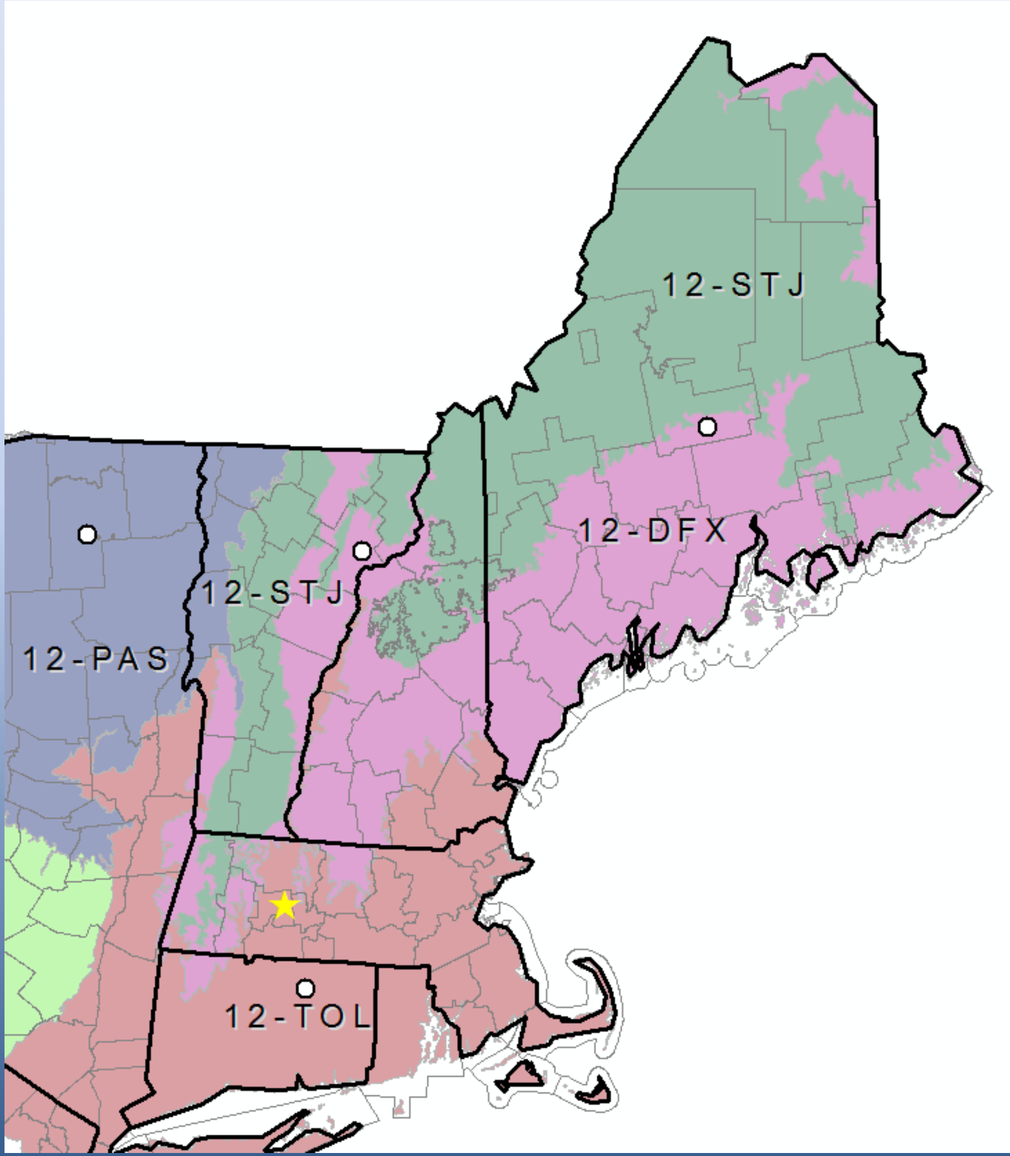
Soil Scientist/GIS Specialist

March 24, 2016

United States Department of Agriculture

Area 12-STJ covers parts of 5 states and dozens of traditional, non-MLRA soil survey areas; about 17 million acres.

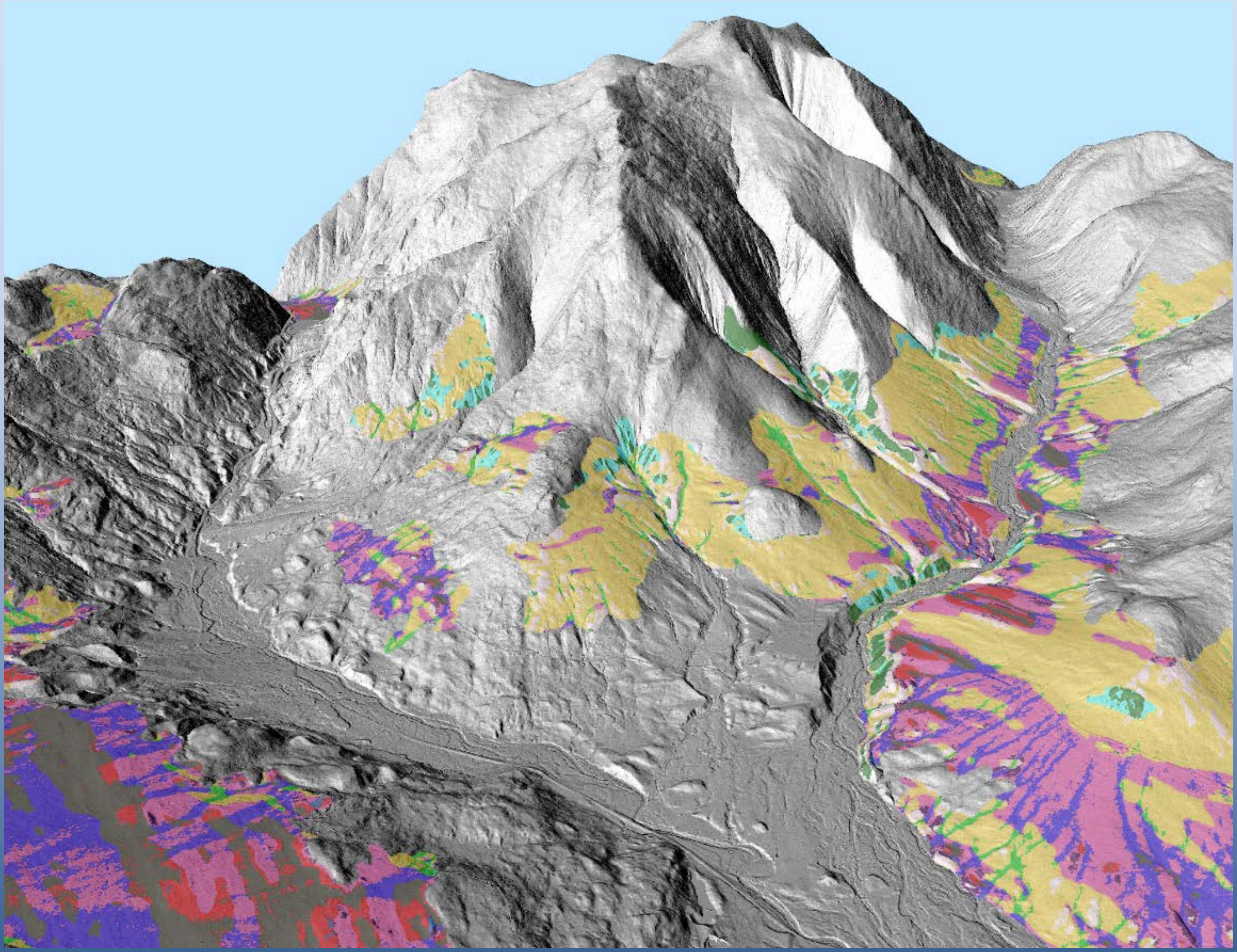
Responsible for MLRA 143, Northeastern Mountains (excluding Adirondack region, NY).



USDA

United States Department of Agriculture

12-STJ specialty: knowledge based raster soil mapping

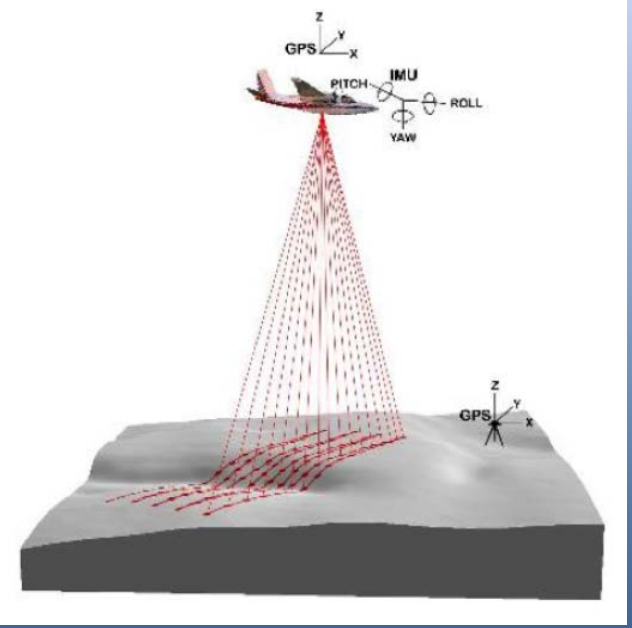


Essential Soil Survey Procedures

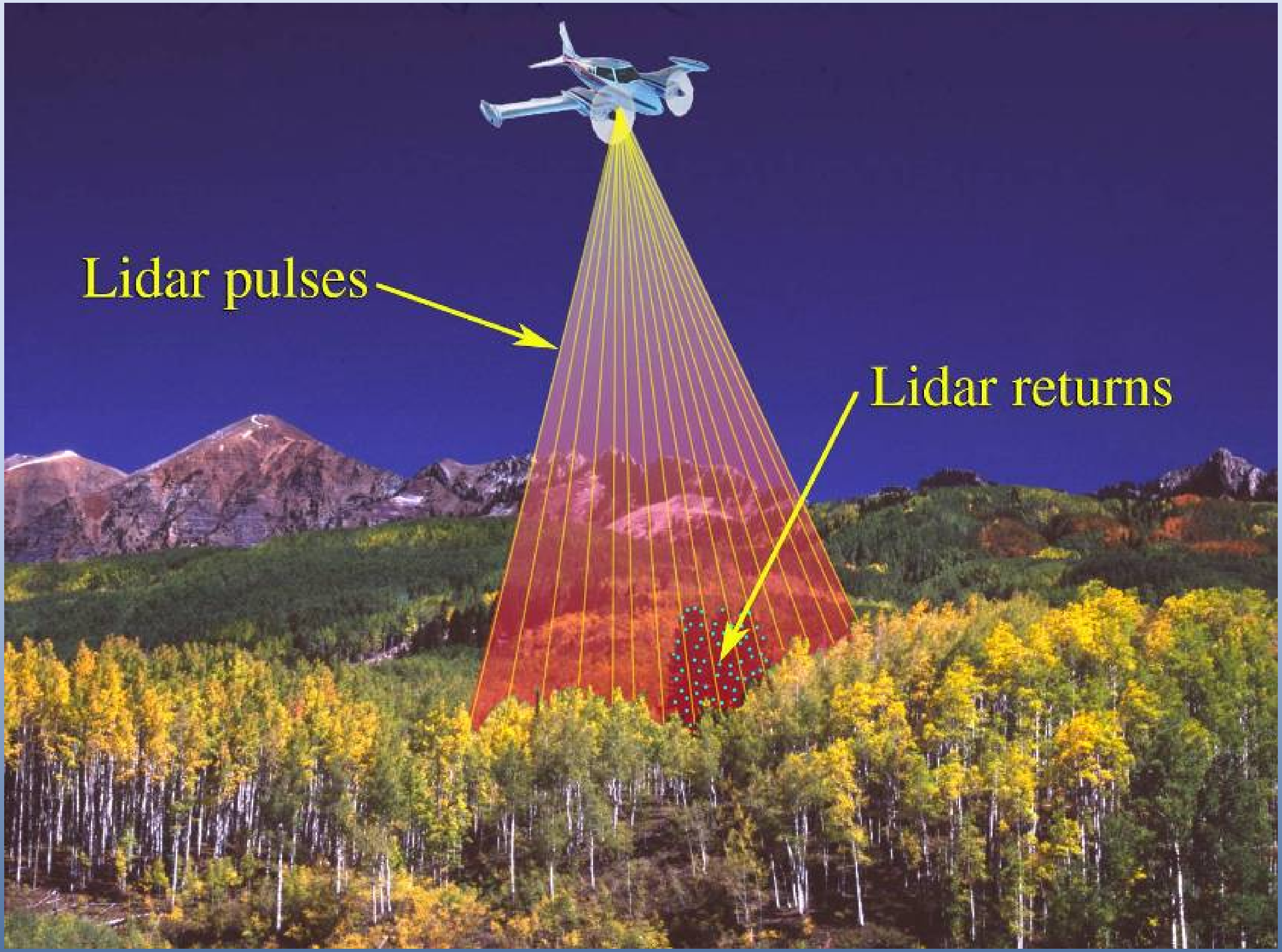
- Delineate landforms and soil parent materials
  - LiDAR signatures, terrain derivatives, imagery alongside extensive field reconnaissance
- Perform soil inference (ArcSIE) in suitable areas
  - Lodgment till has a full catena model
  - Ablation till and bedrock controlled areas have wet and dry components along with classic slope breaks
- Use other Digital Soil Mapping techniques as appropriate
  - Slope stratification
  - Possible “traditional” mapping in outwash and alluvial areas

Main uses of LiDAR in support of soil survey:

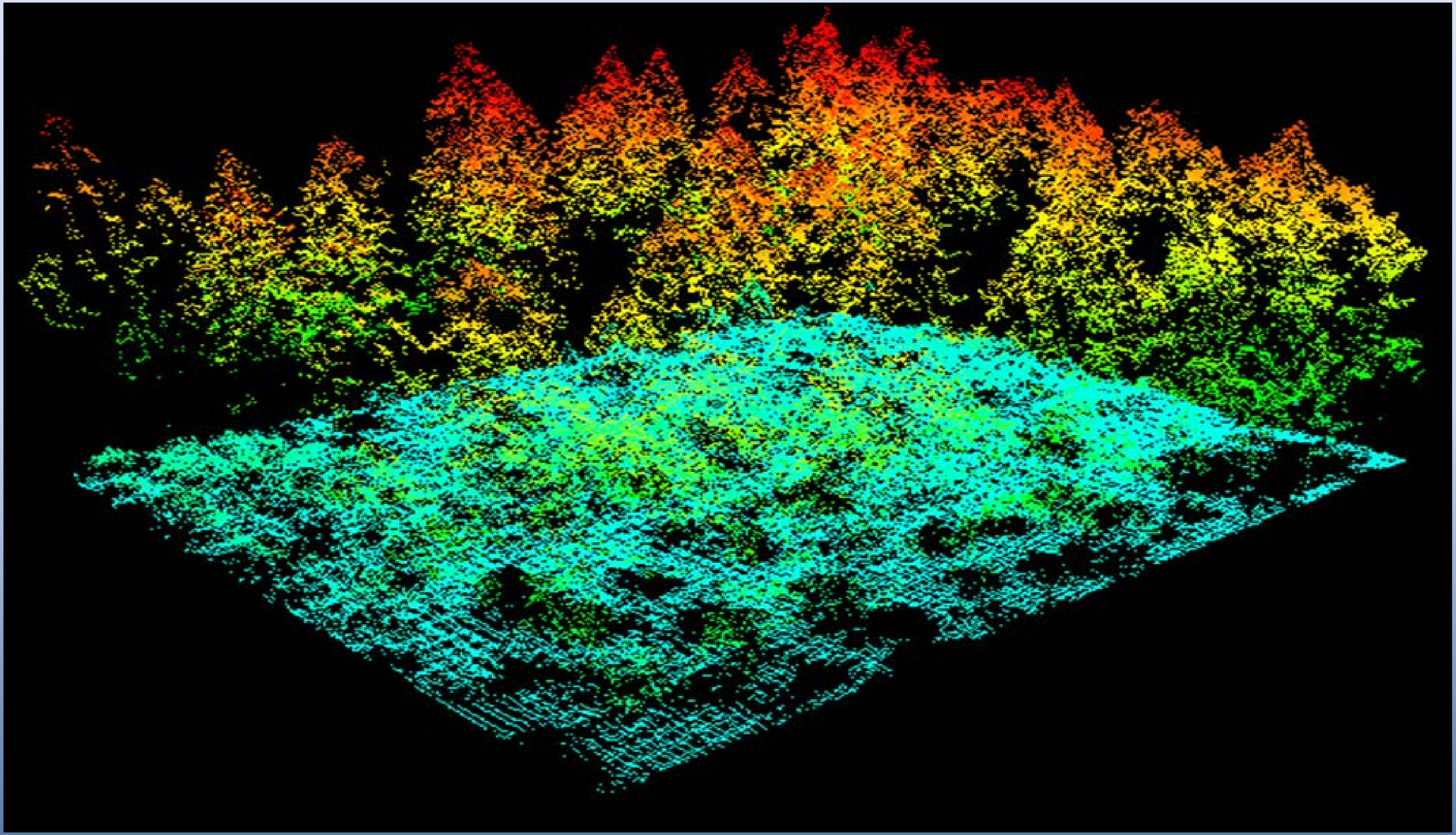
- A tool for landscape/landform/soil parent material visualization and stratification
- A source of terrain derivatives for soil predictive models



Light Detection and Ranging System (LiDAR)

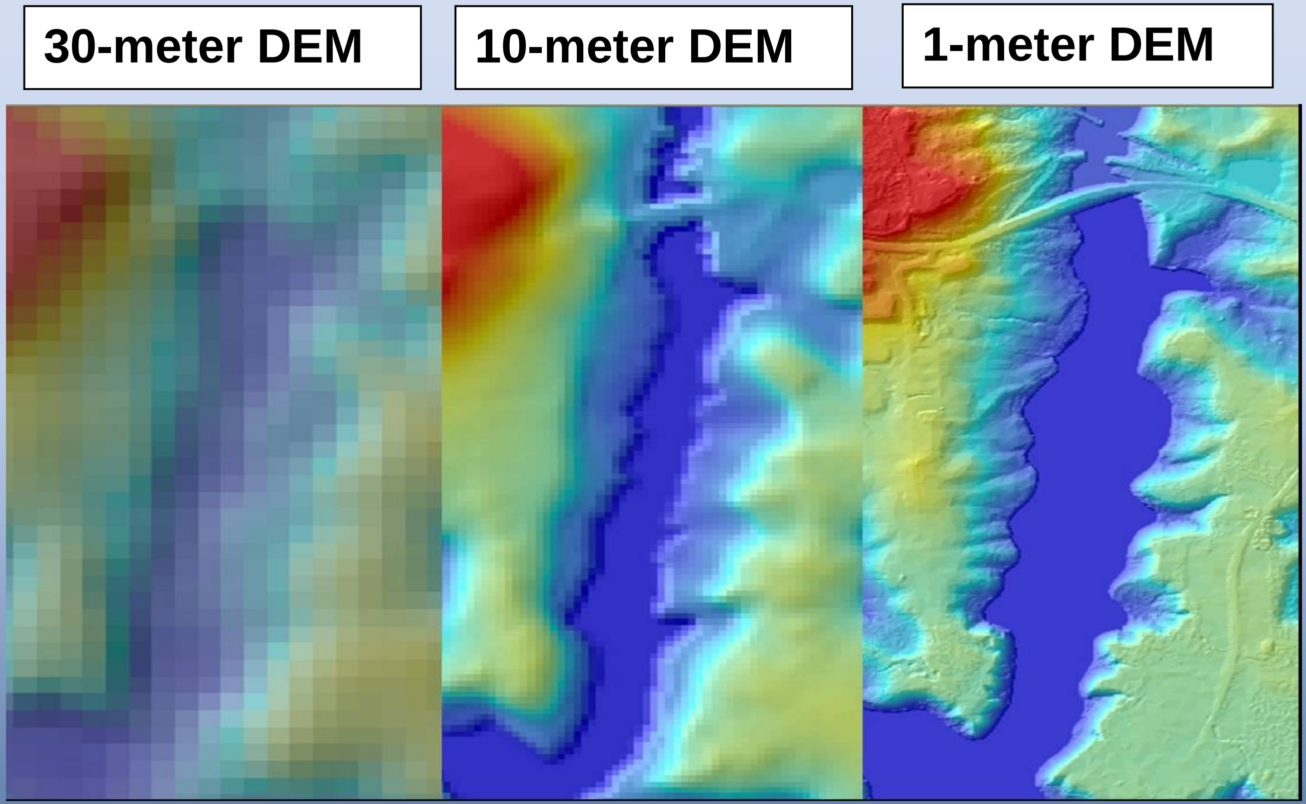


courtesy of the US Geological Survey



LiDAR Point Cloud

United States Department of Agriculture

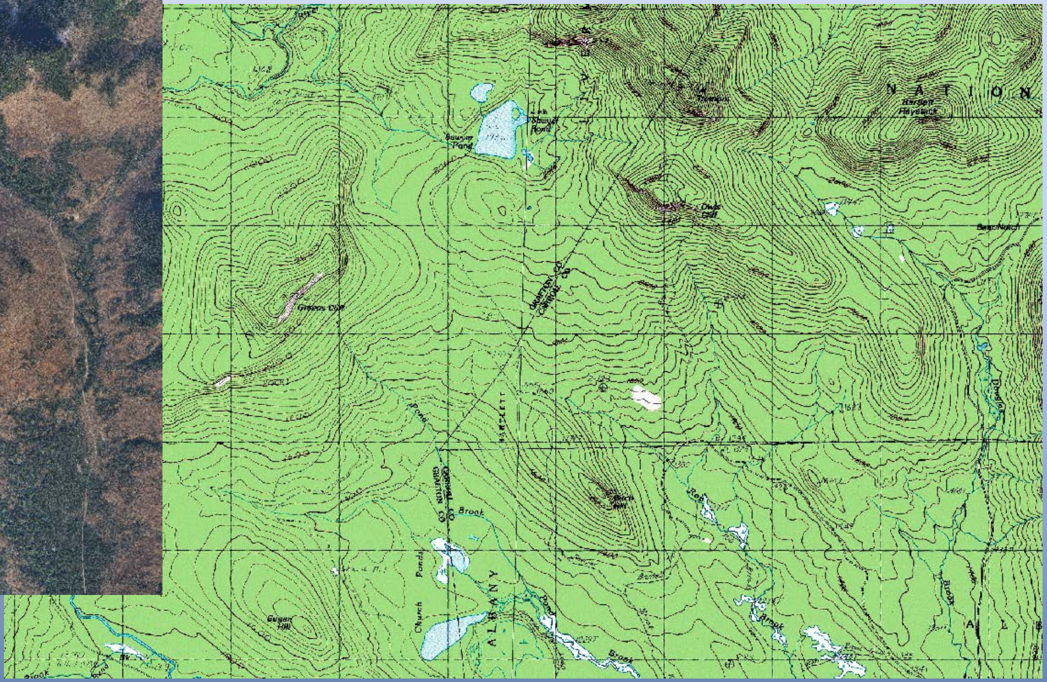


Comparison of terrain models for Fresh Creek, Strafford County, NH: NED 30-meter and 10-meter DEMs versus 1-meter LiDAR

Essential Soil Survey Procedures

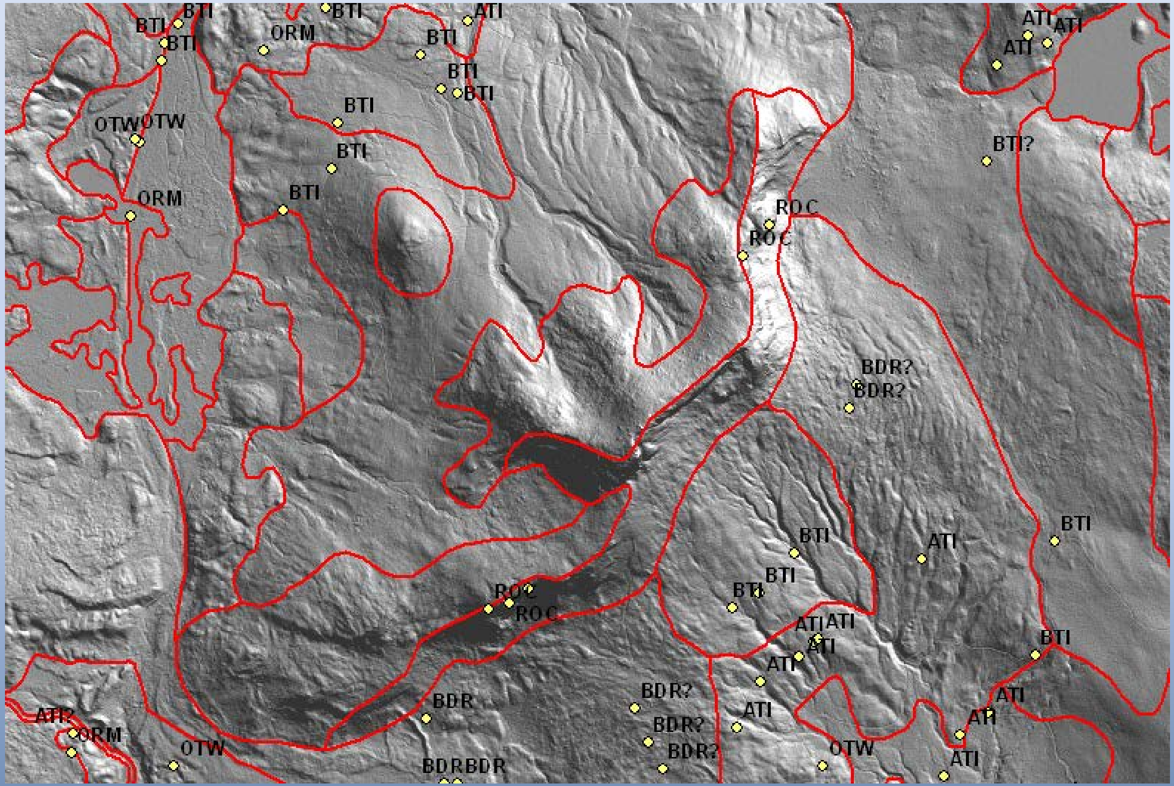
- Delineate landforms and soil parent materials
  - LiDAR signatures, terrain derivatives, imagery alongside extensive field reconnaissance
- Perform soil inference (ArcSIE) in suitable areas
  - Lodgment till has a full catena model
  - Ablation till and bedrock controlled areas have wet and dry components along with classic slope breaks
- Use other Digital Soil Mapping techniques as appropriate
  - Slope stratification
  - Possible “traditional” mapping in outwash and alluvial areas

Visualization



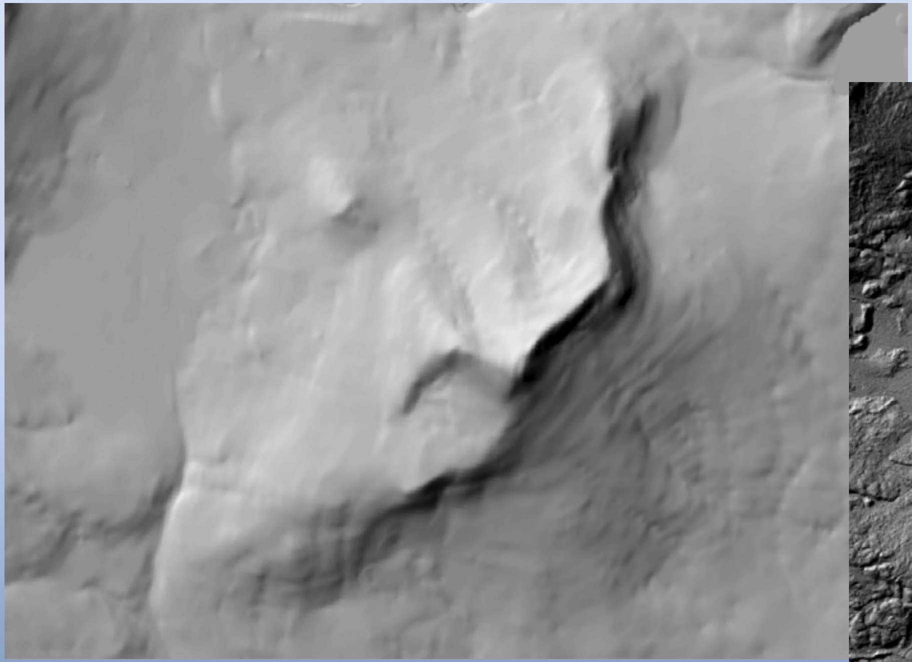
Prior to 2000 and the implementation of GIS in soil survey offices, landscape/landform visualization was via aerial photography and topographic maps.

United States Department of Agriculture

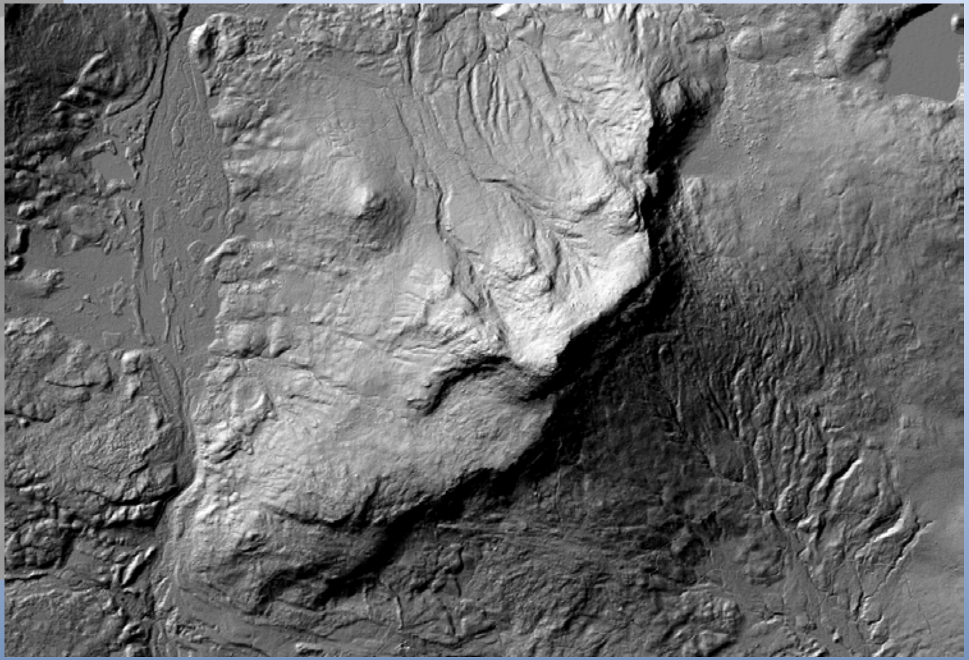


Now, bare-earth LiDAR elevation data, terrain derivatives, CIR (and other imagery), and GPS waypoints from reconnaissance are used for initial landscape stratification.

High Resolution Data (LiDAR) is Essential



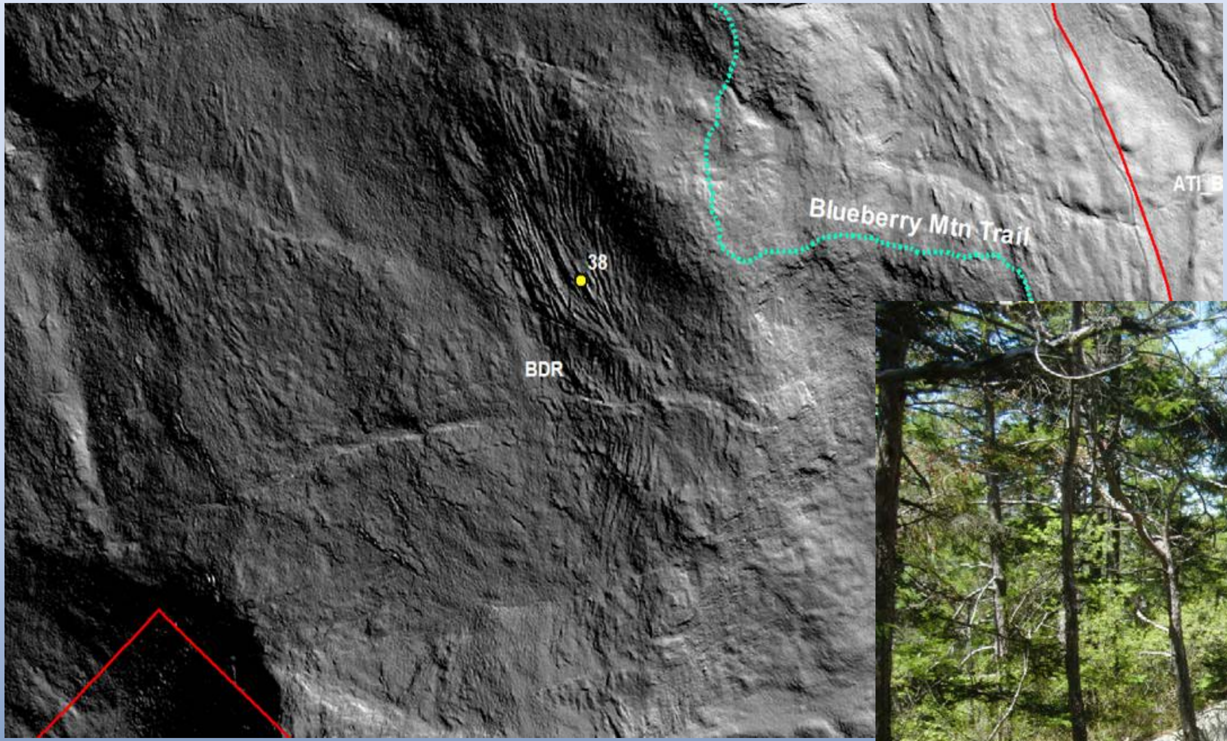
Hillshade from USGS 10m DEM



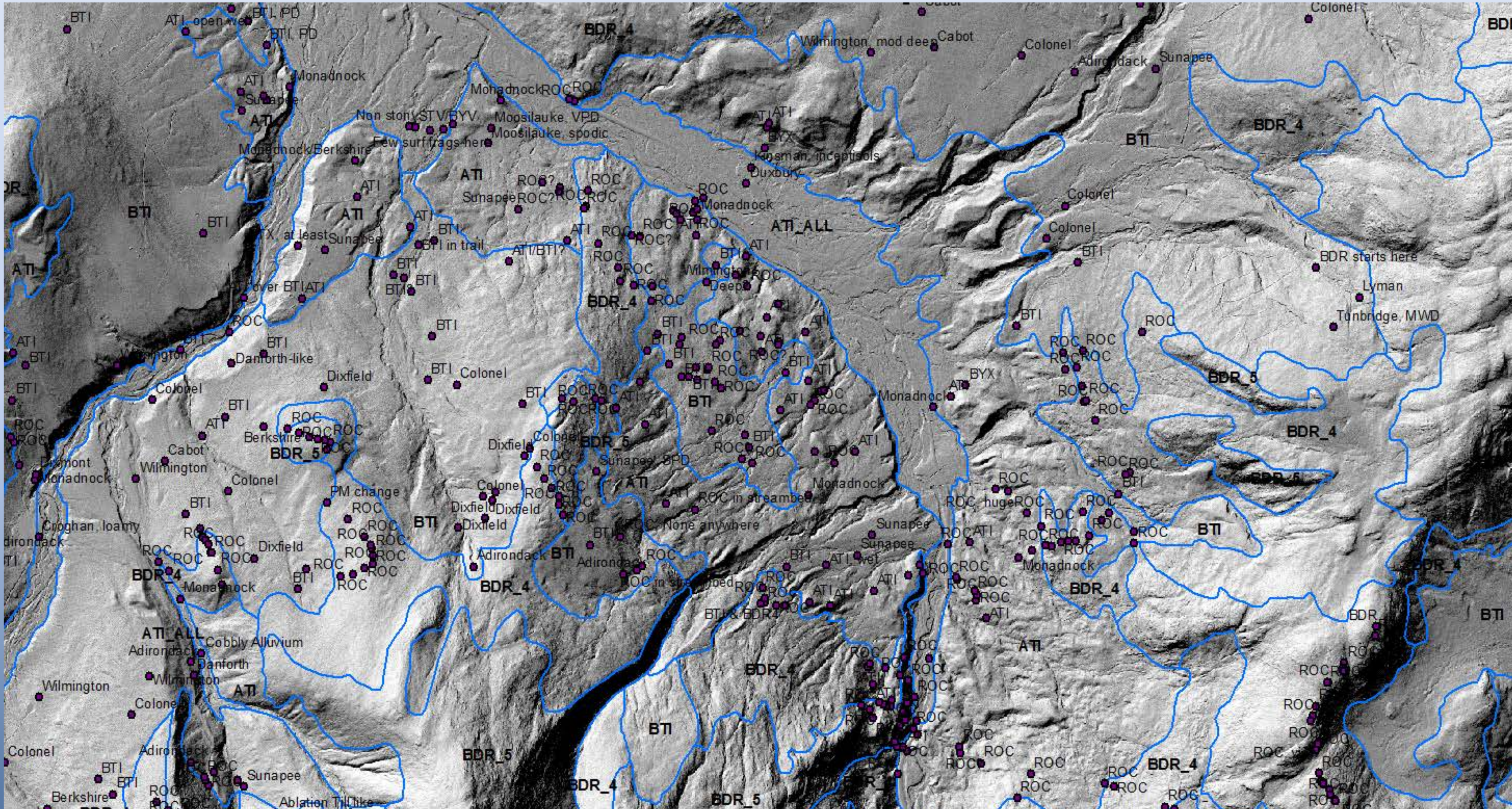
Hillshade from 3m LiDAR DEM

With the implementation of GIS, spatial analysis techniques became more sophisticated. However, inadequate terrain data remains a limiting factor.

High-resolution elevation data from LiDAR overcomes this limitation.


Blueberry Mtn Trail
38
BDR

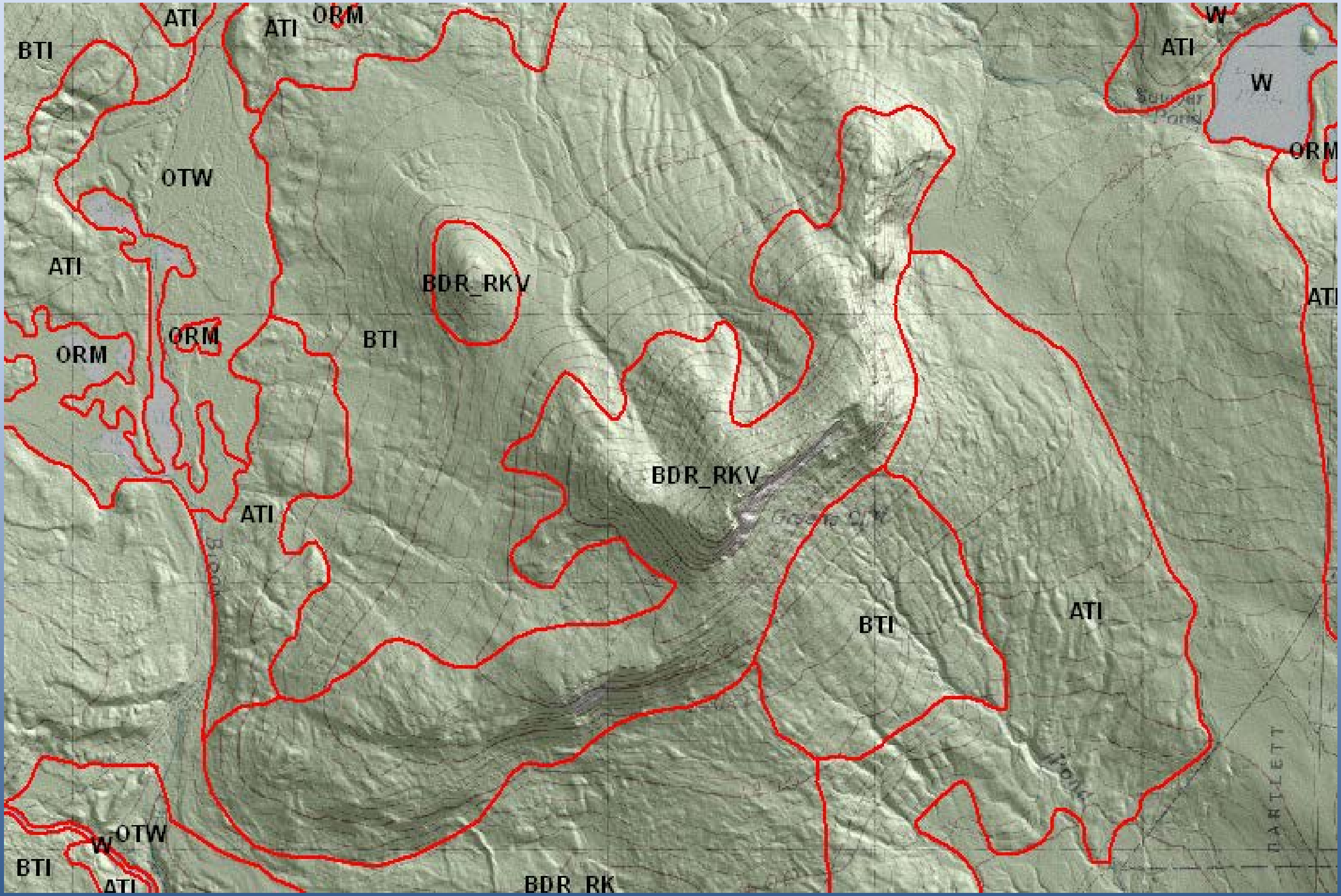

5/21/2015

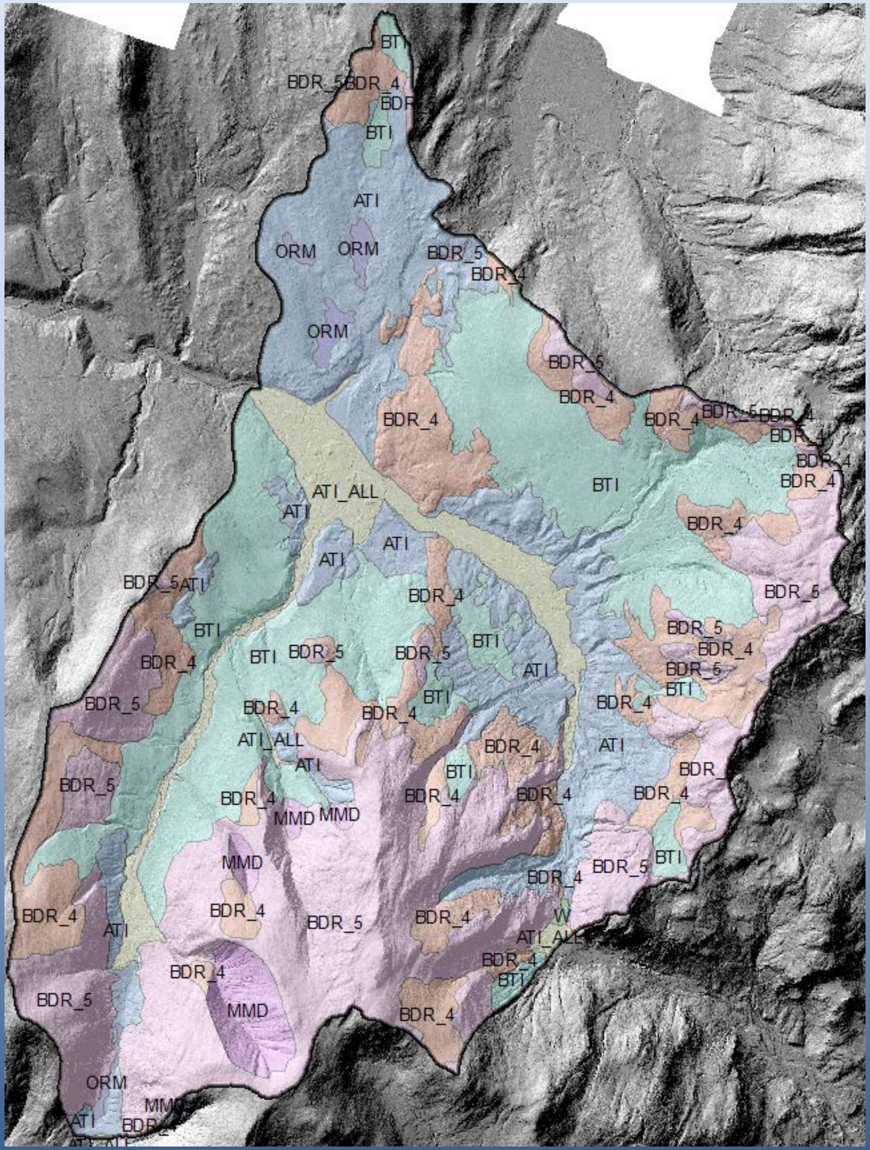


Parent material delineations are thoroughly critiqued and field checked. Field investigations are specifically directed.

United States Department of Agriculture

Parent Material and Landform Maps Provide the Basis for all Subsequent Soil Mapping





Next step is to further stratify each type of parent material into appropriate soil classes.

These classes could be as narrow as one soil component, but more realistically encompass multiple soil components/series that occur on similar landscape positions.

The Arc Soil Inference Engine (ArcSIE) is used to model the typical soil formative environment for each class.

The soil classes that make up a given model generally encompass a catena.

Poorly Drained

Somewhat Poorly Drained

Moderately Well Drained

- Digital soil mapping (DSM) is a very broad concept.

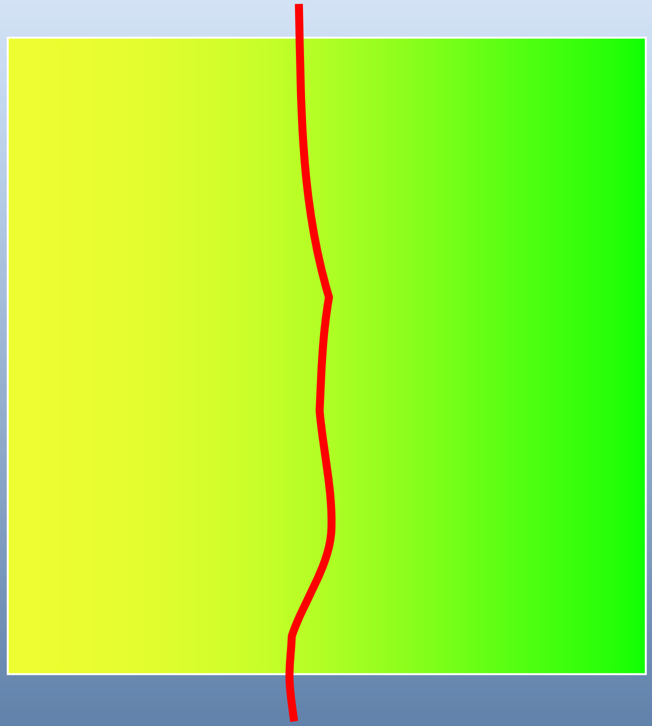
- **Knowledge**-based **Raster** Soil Mapping is a specific approach to DSM

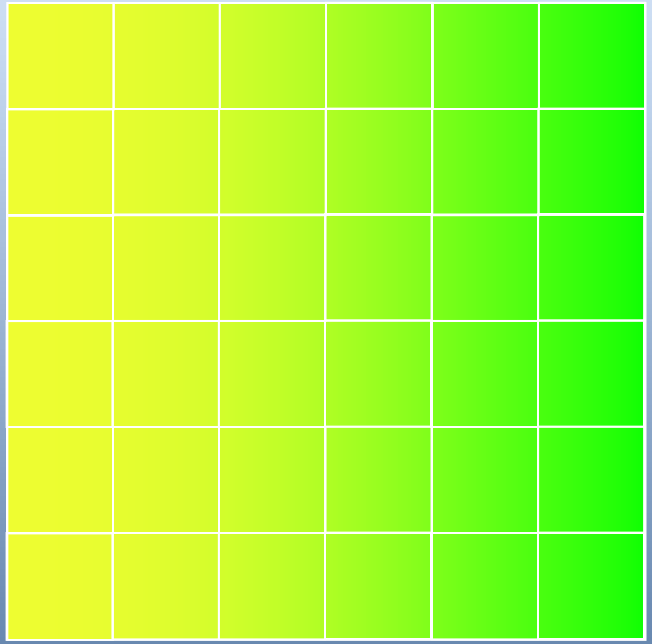
Raster Soil Mapping

ArcSIE is a proven tool, designed for *field soil scientists* to implement knowledge-based raster soil mapping.

We define the typical soil formative environment in the model, and the resulting fuzzy membership values represent the similarity of the soil at each pixel location to a particular soil series.

The focus in mapping shifts





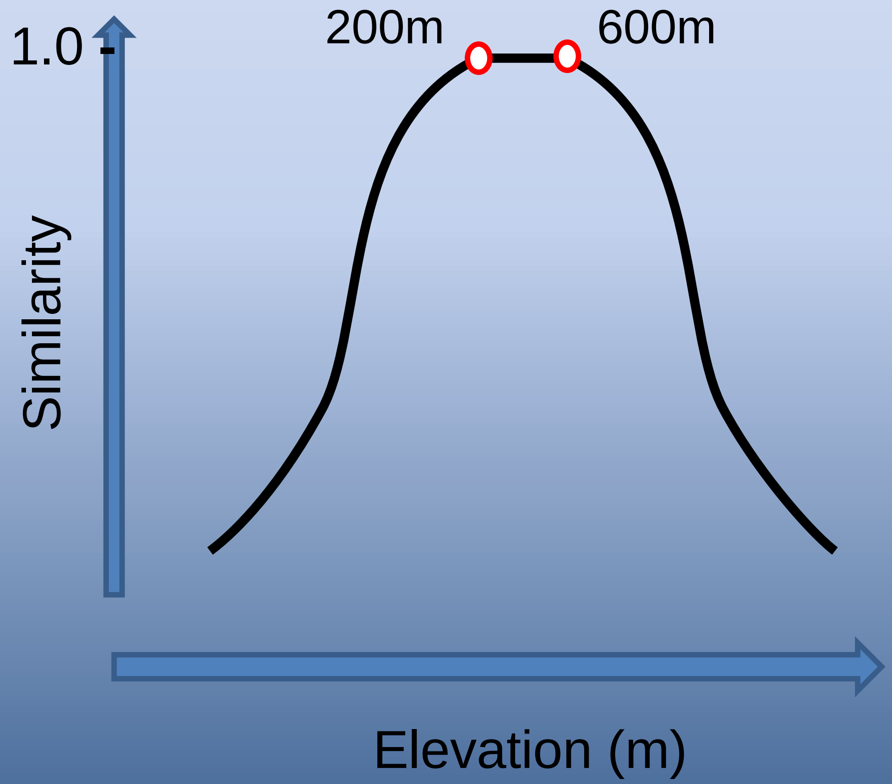
In conventional mapping, the primary question is “Where is the boundary between two soils?” and the focus is on those marginal areas.

In fuzzy mapping, the primary question is “Where is the typical soil for this type?” and the focus is on those “central” areas.

Knowledge Represented as a Rule

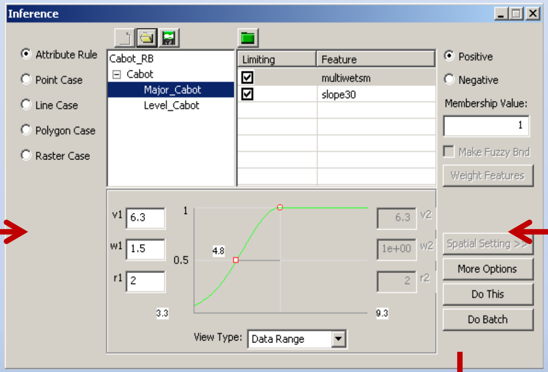
Elevation 200–600m is typical for soil A.

As elevation deviates from this range, the soil's similarity to type A gradually decreases.

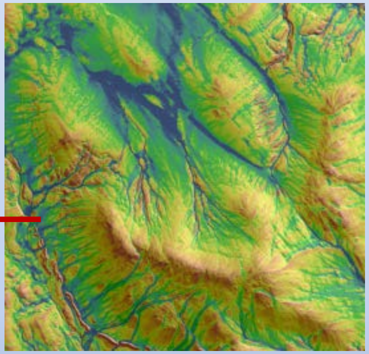


Soil Inference Components

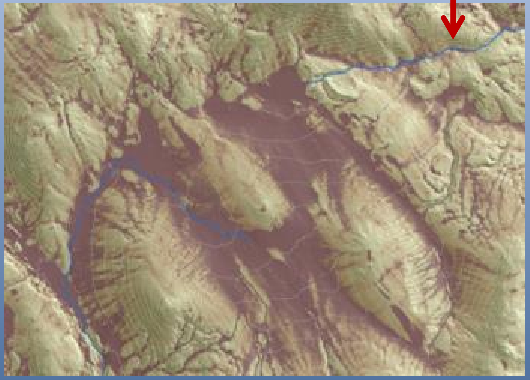
Soil Scientists' Knowledge



Soil Inference Engine

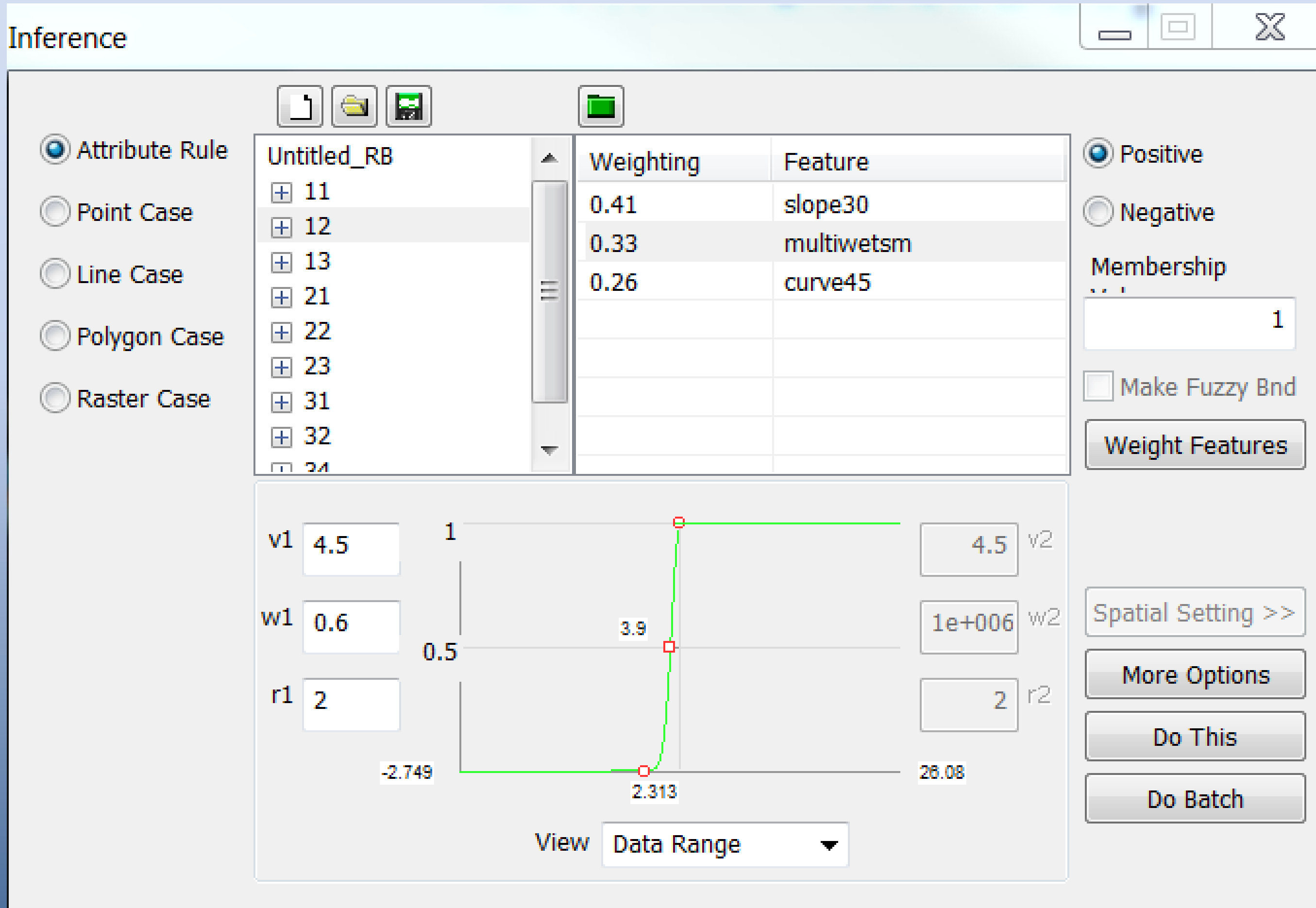


Environmental Data



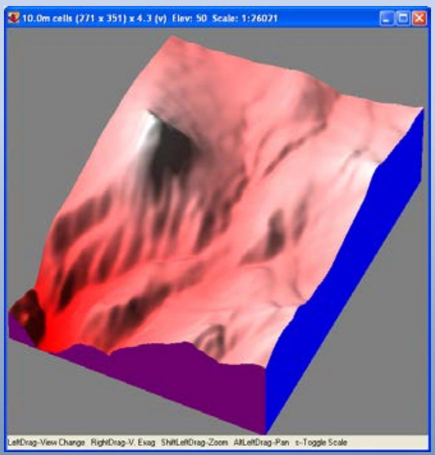
Fuzzy Soil Membership Map

ArcSIE Interface

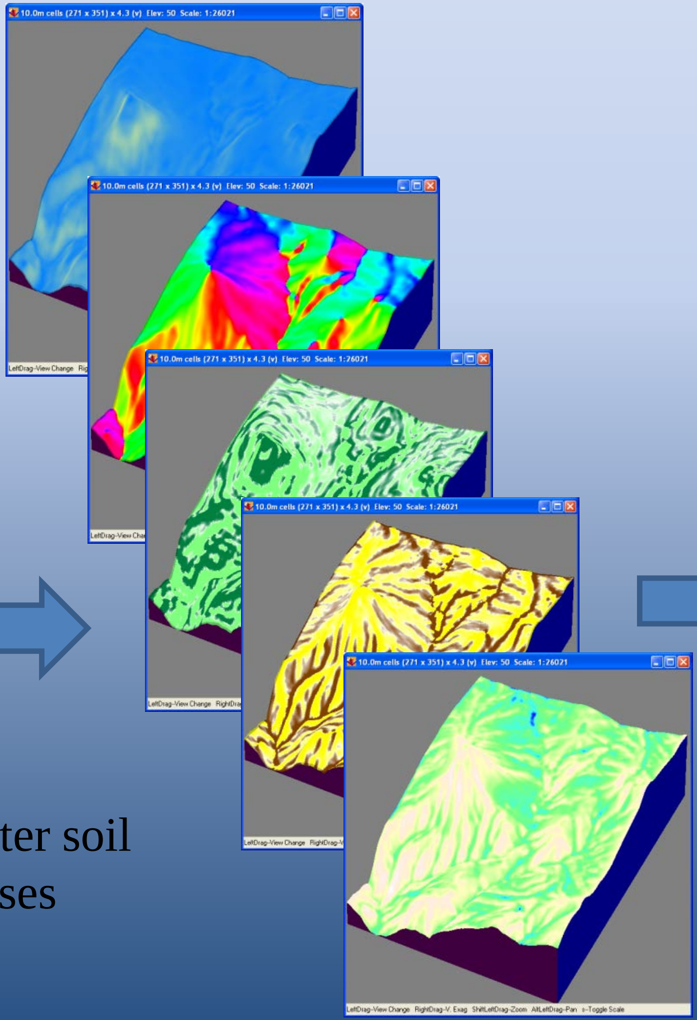


Wetness index rule for poorly drained soils on moderate slopes

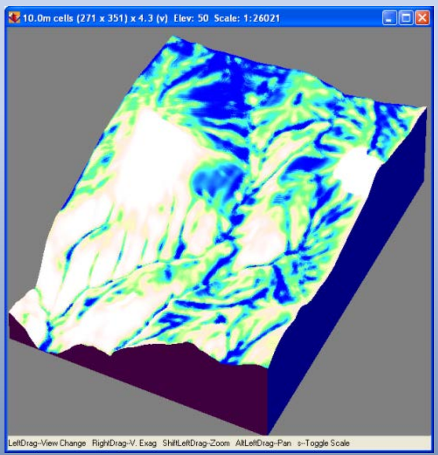
Raster Soil Mapping



DEM



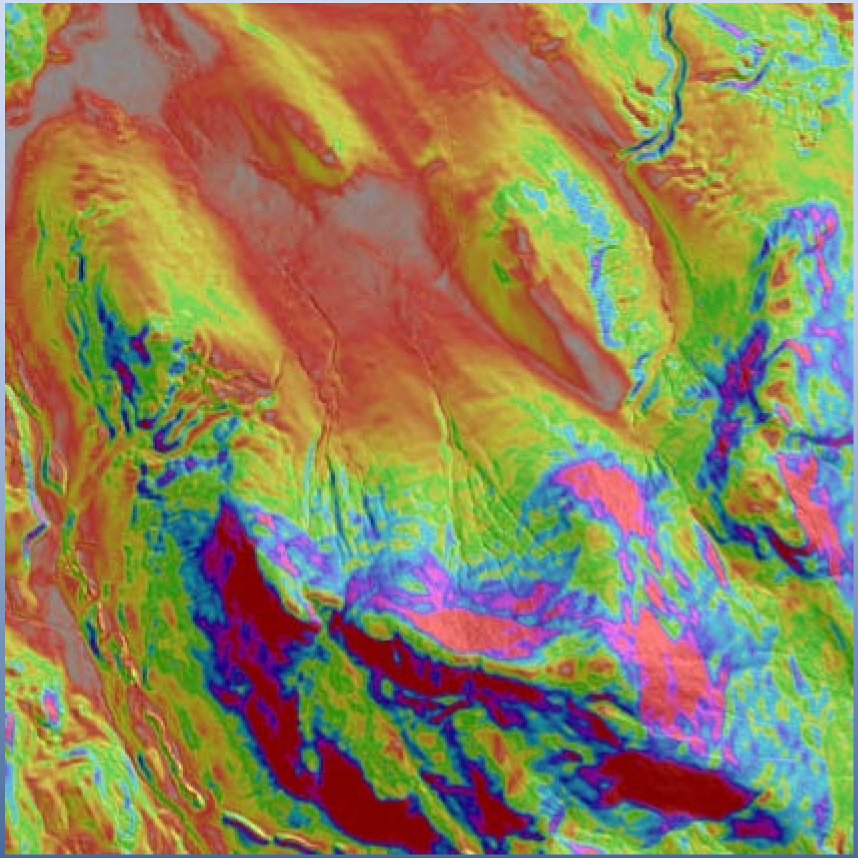
Terrain Attributes



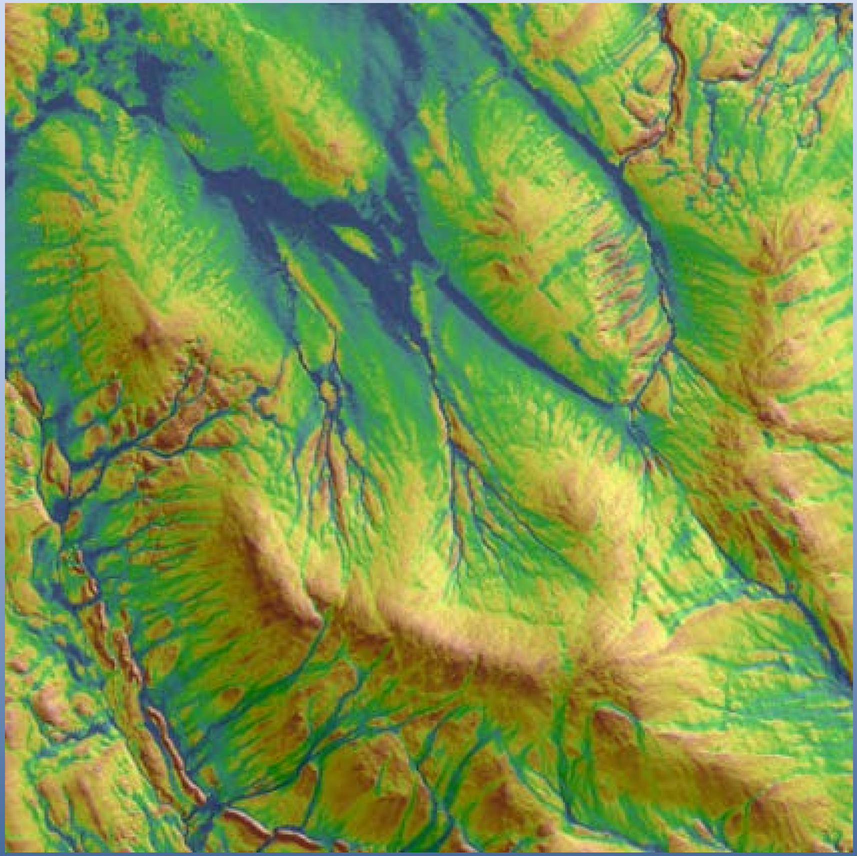
Cabot

An illustration of a basic raster soil mapping process that only uses terrain attributes.

Terrain Derivatives

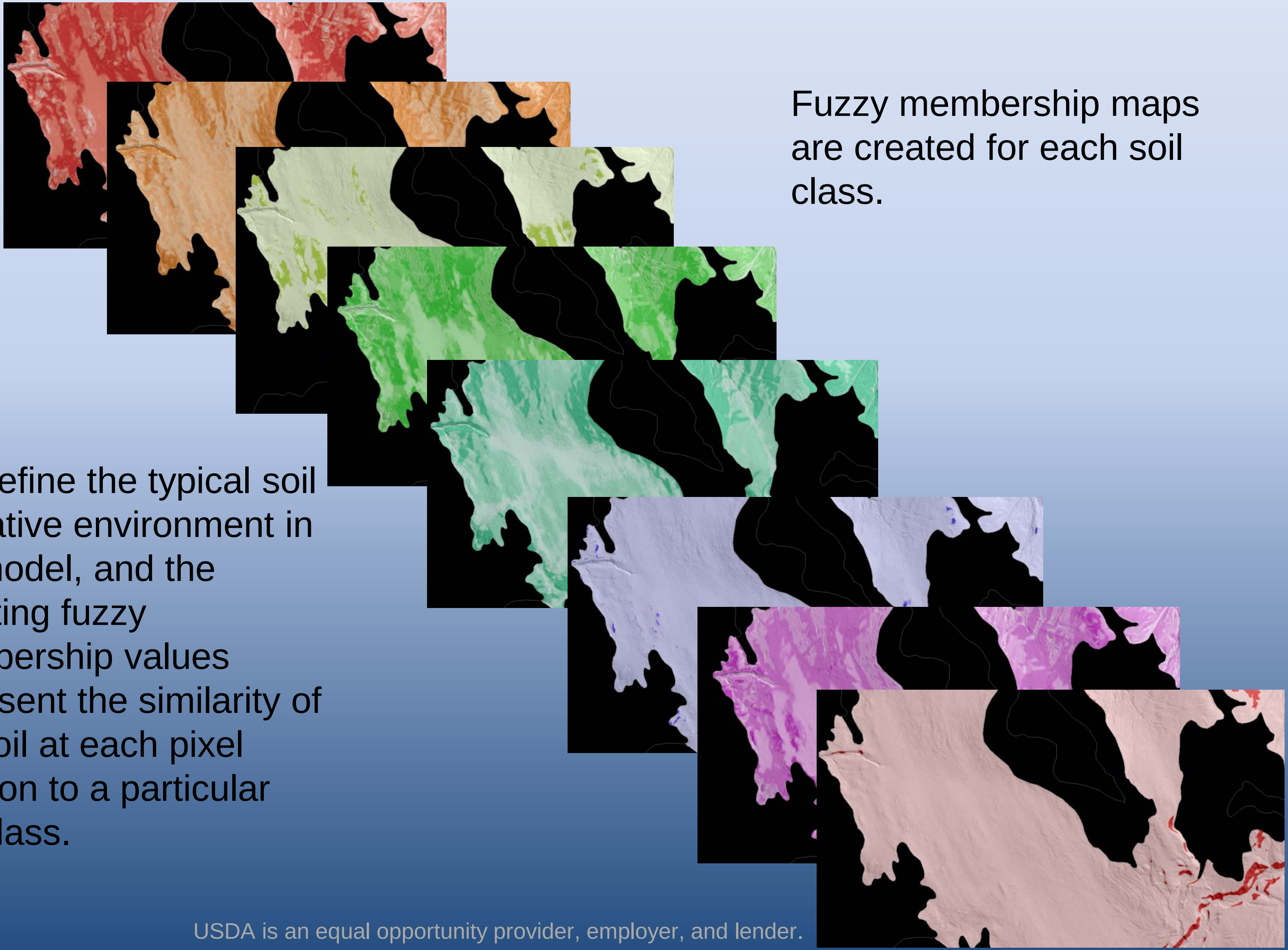


30m slope



Multi-path smoothed wetness index

United States Department of Agriculture

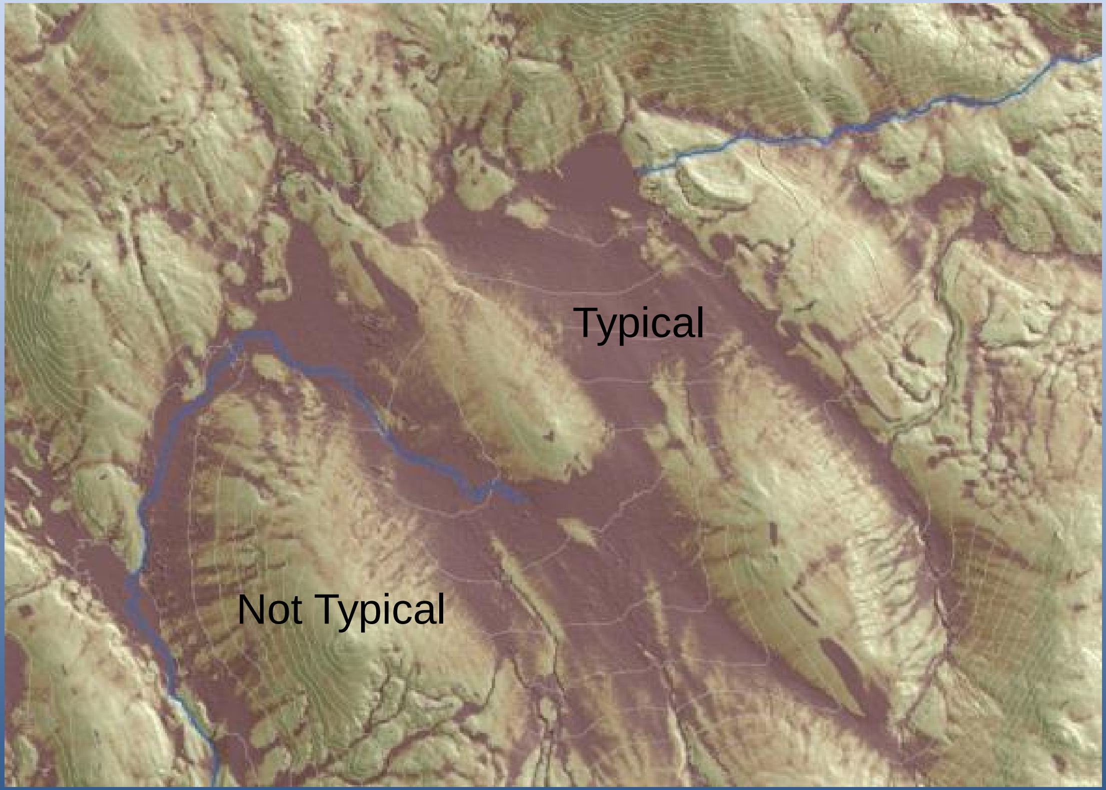


Fuzzy membership maps are created for each soil class.

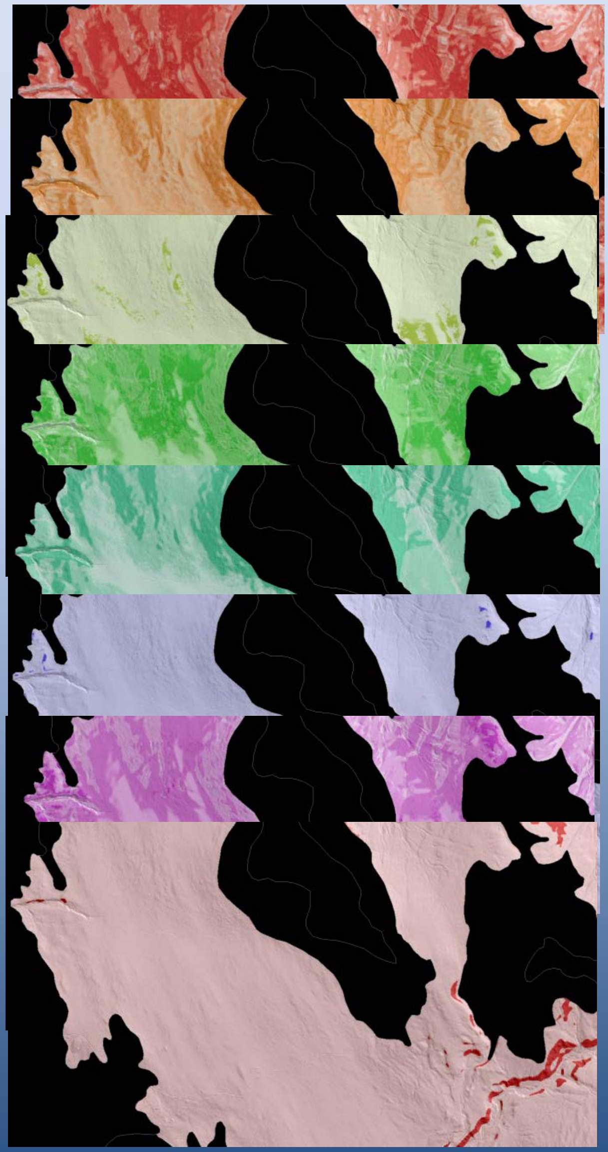
We define the typical soil formative environment in the model, and the resulting fuzzy membership values represent the similarity of the soil at each pixel location to a particular soil class.

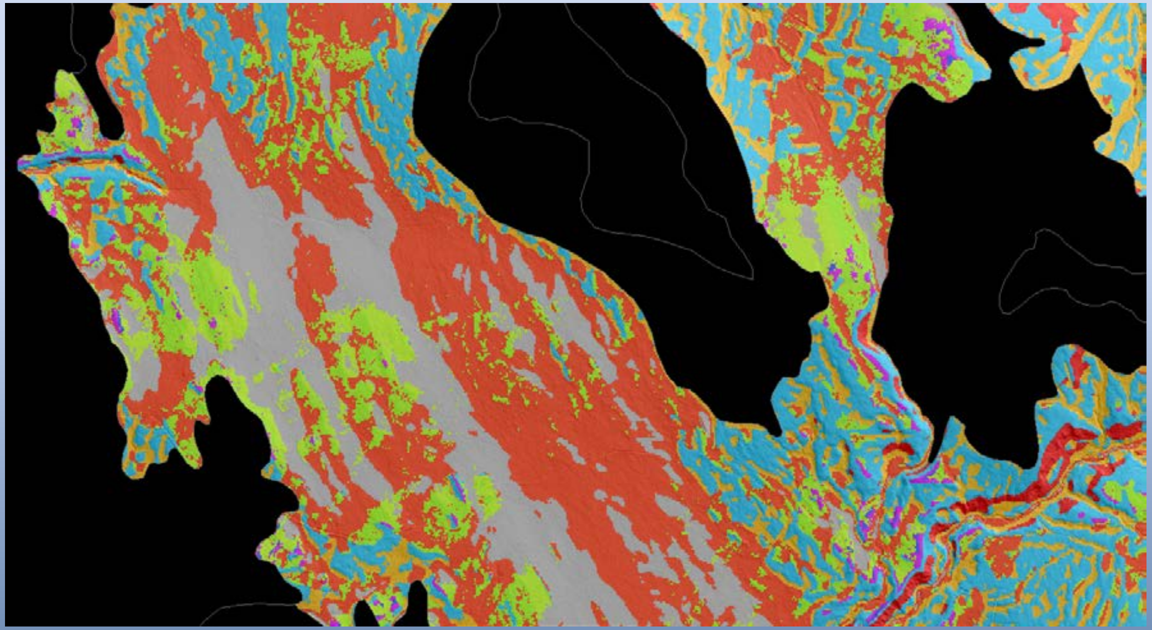
United States Department of Agriculture

The fuzzy membership values represent the similarities of the pixel location to the typical soil formative environment.



Hardening (Defuzzification)

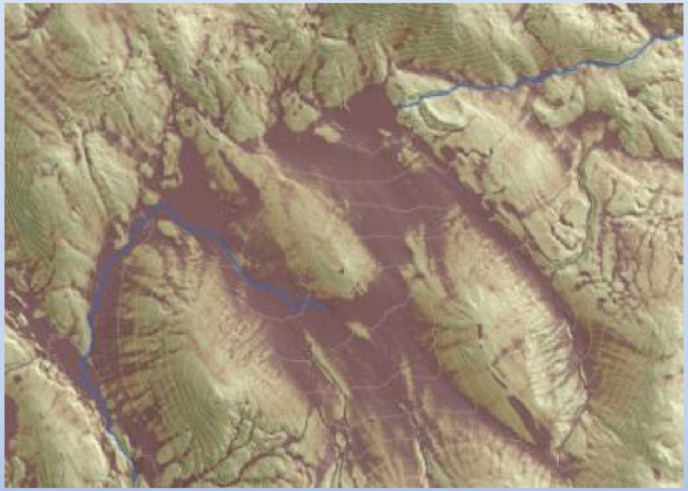




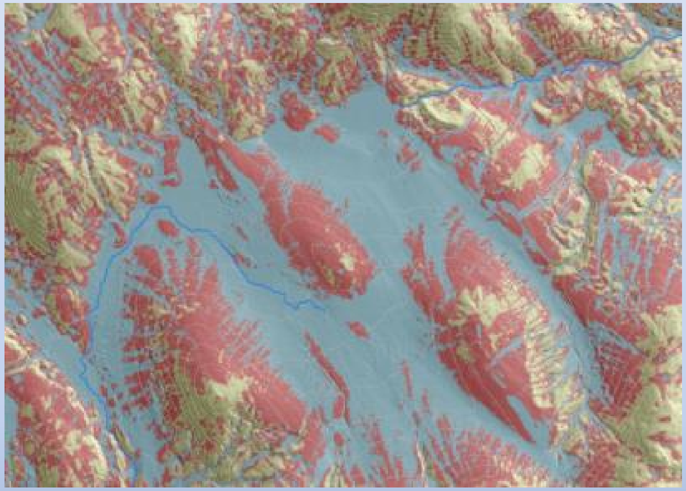
Each pixel is assigned to the soil class with the highest fuzzy membership at that location.

SIE Results are Validated in the Field

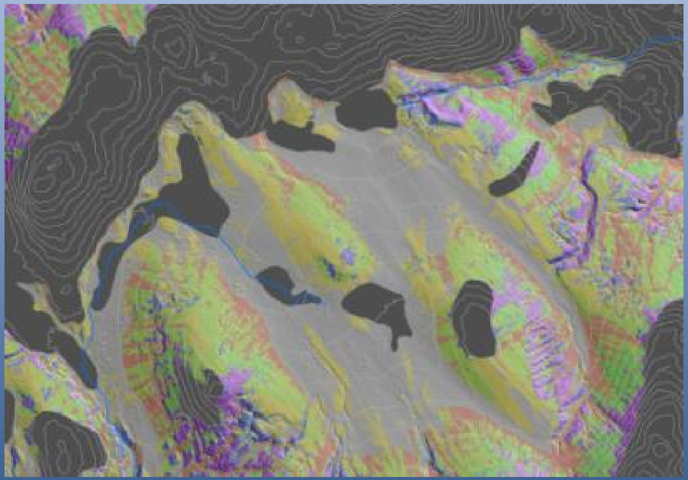
Traditional ArcSIE Process Steps



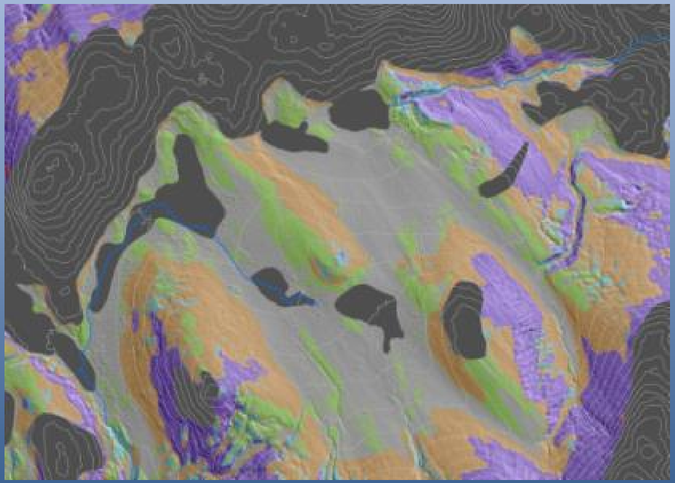
Inference by Soil Series



Harden Results

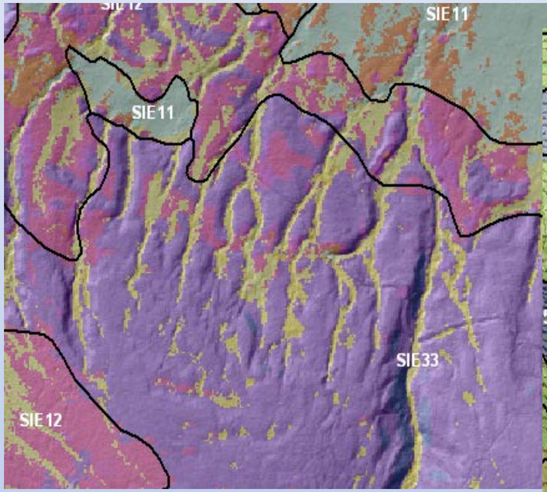


Integrate Slope Phases

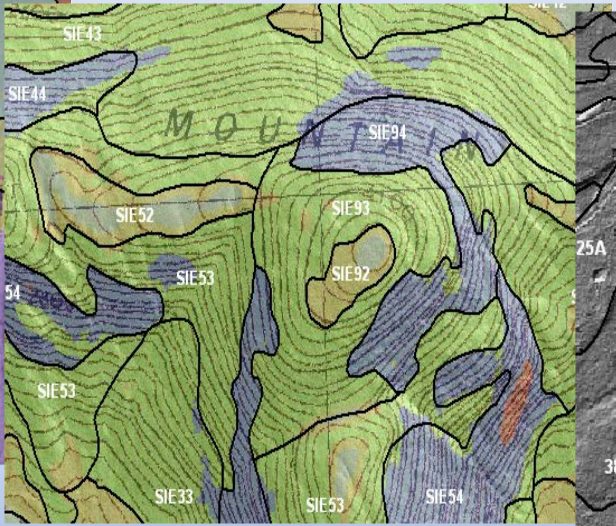


Create Logical Map Units

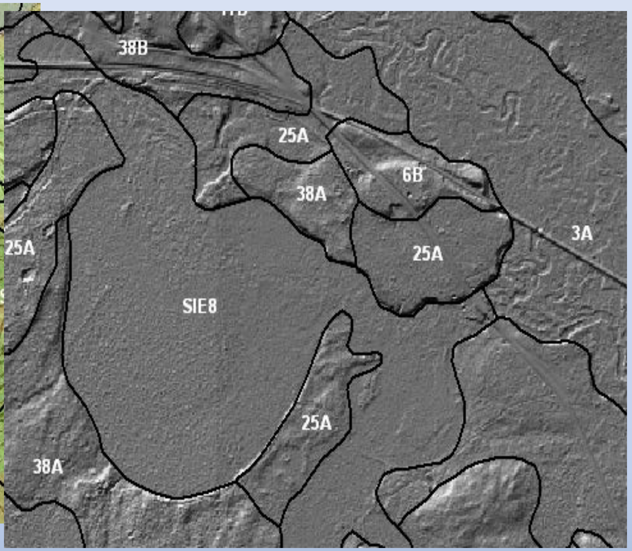
USDA
United States Department of Agriculture



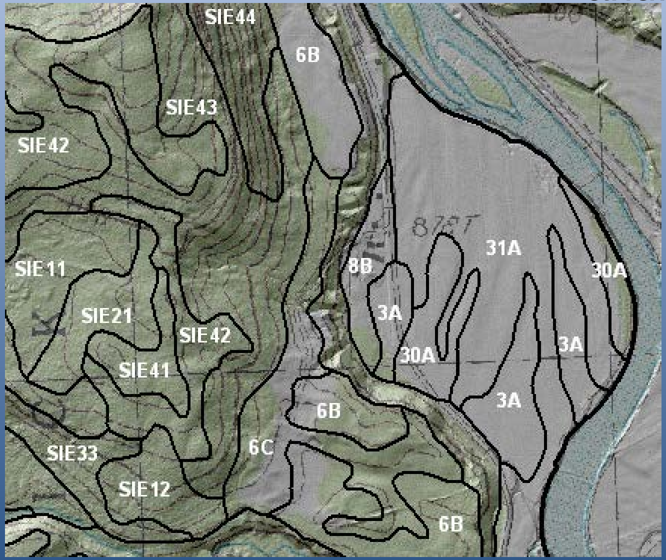
Predictive modeling by soil series



Brute force modeling by landform and slope class



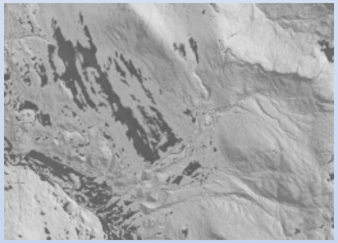
Traditional mapping with modern enhancements

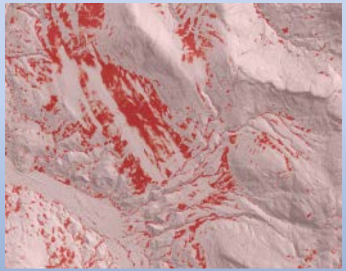


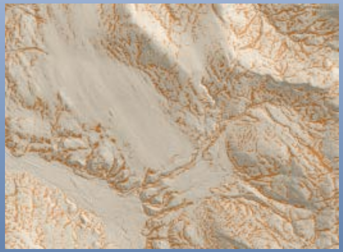
←--- All combined to create the SSURGO product

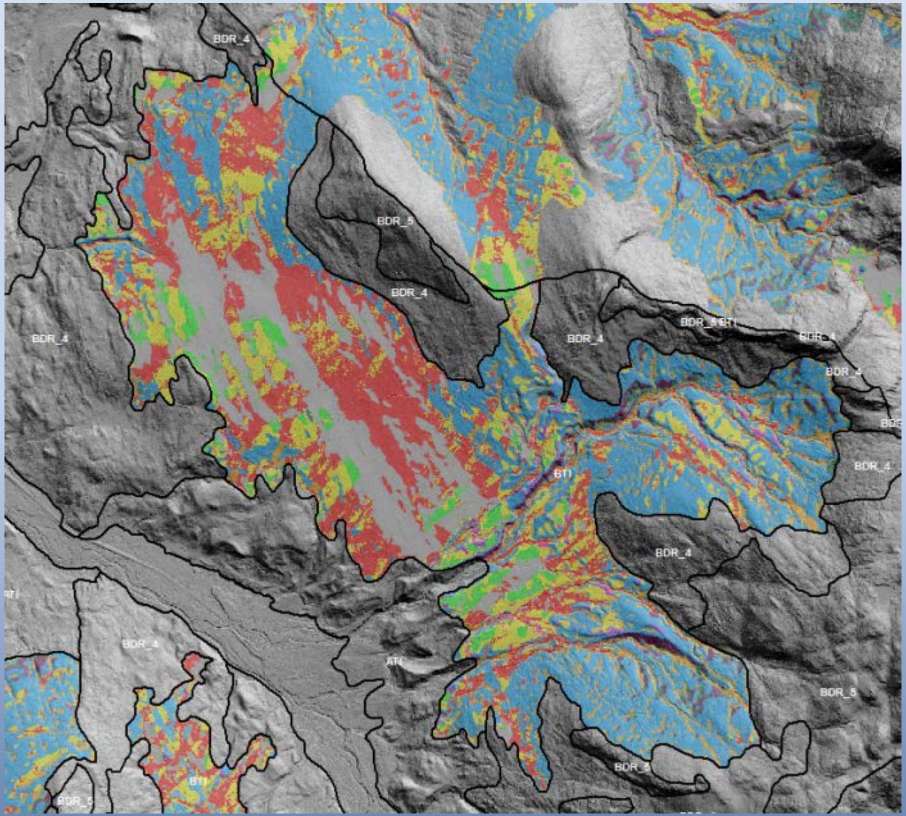
USDA
United States Department of Agriculture

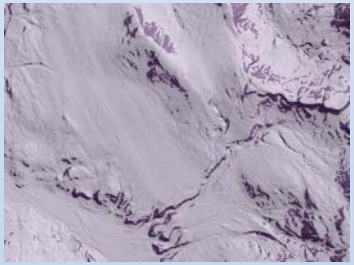
Inference by component

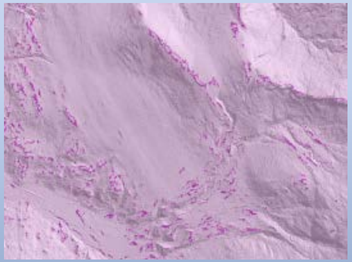


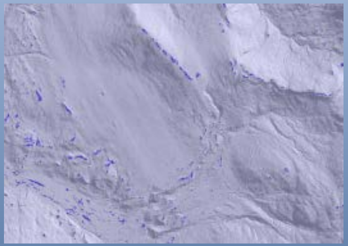


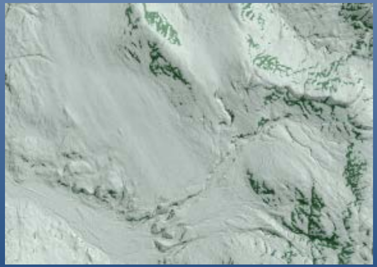


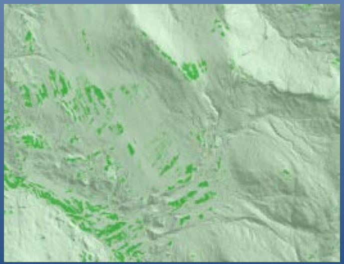


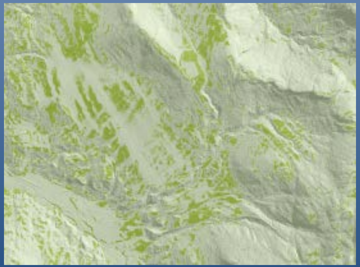


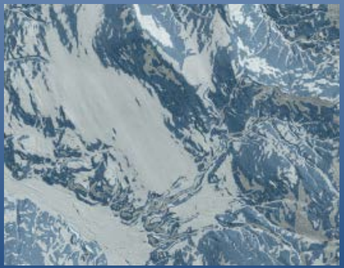












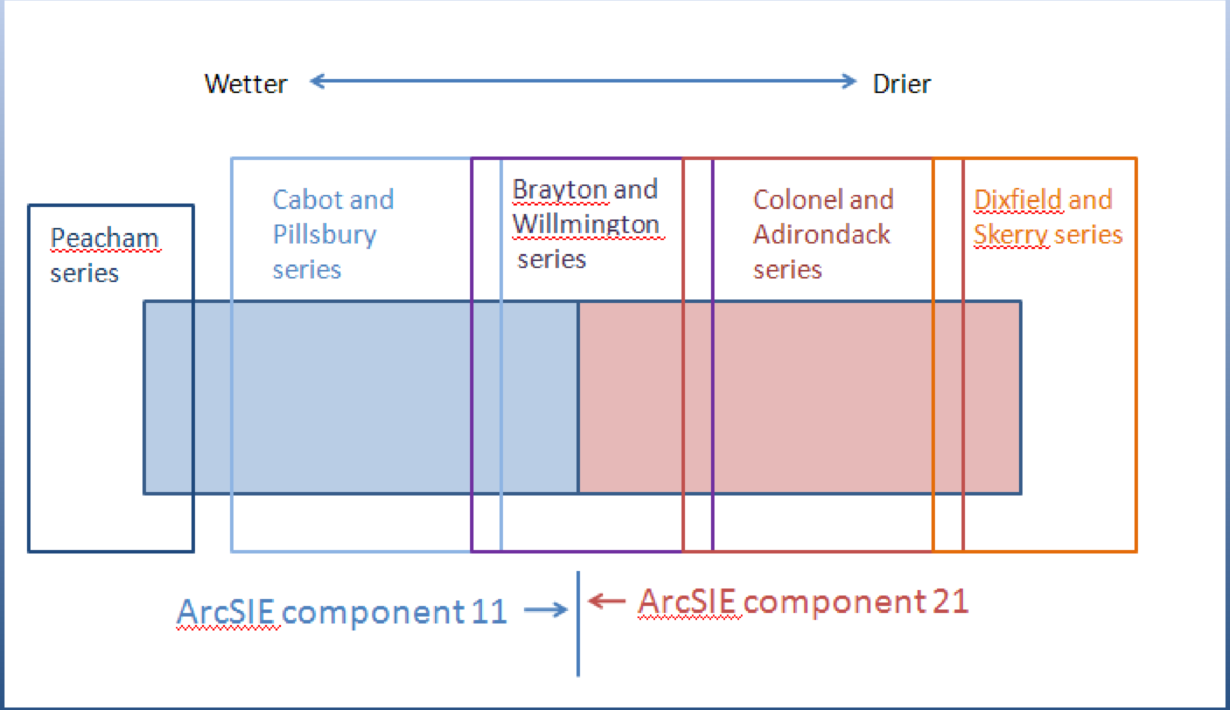
What is a raster component?

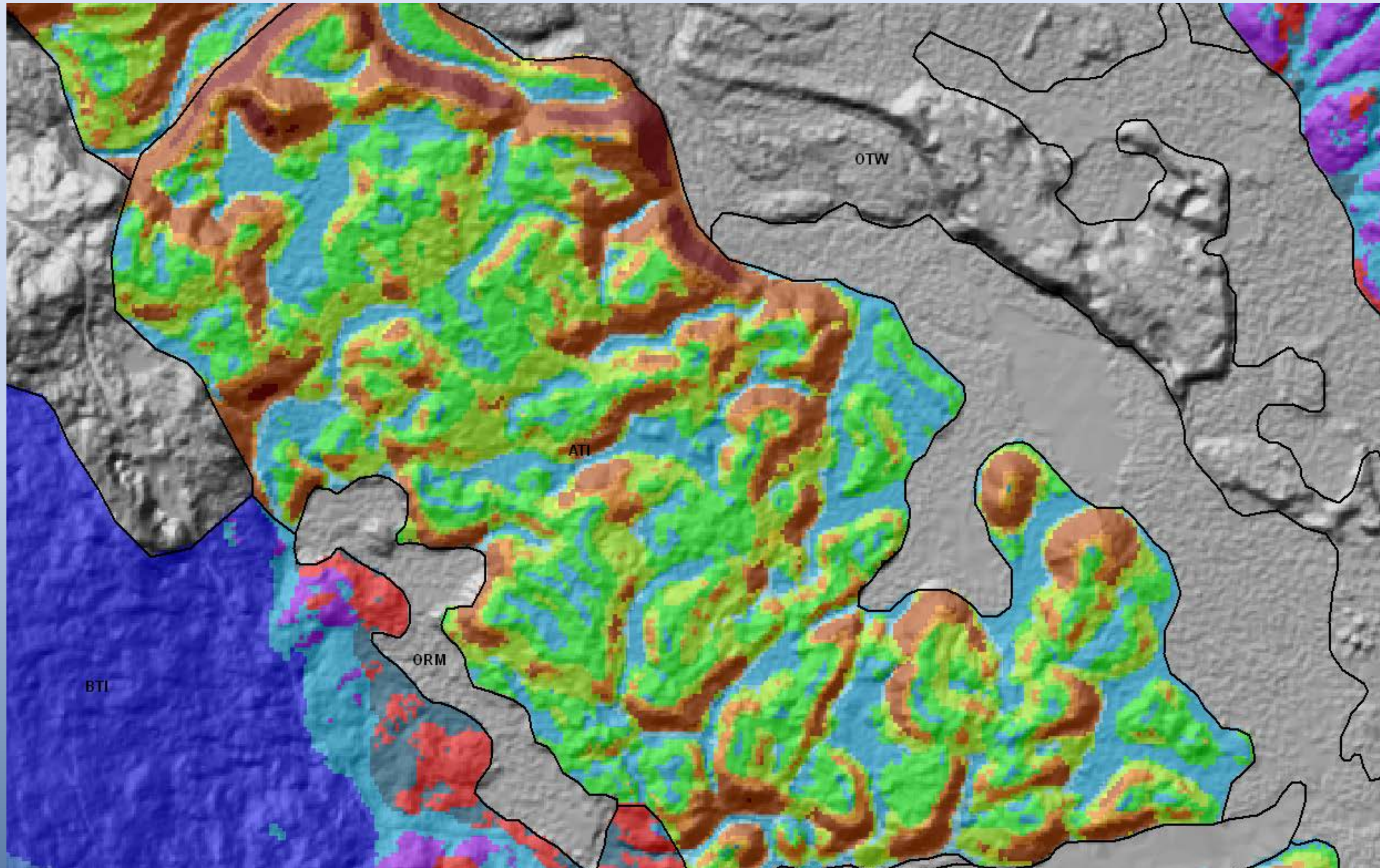
- Maybe better termed a "soil class". Defined specifically by soil characteristics and position on the landform, such as:

11 – nearly level to gently sloping wet soils on footslopes and in depressions

21 – nearly level to gently sloping somewhat poorly drained soils on footslopes

- The model is designed to cover a catena of soils, and each modeled soil component/class is not limited in definition to a single soil series.



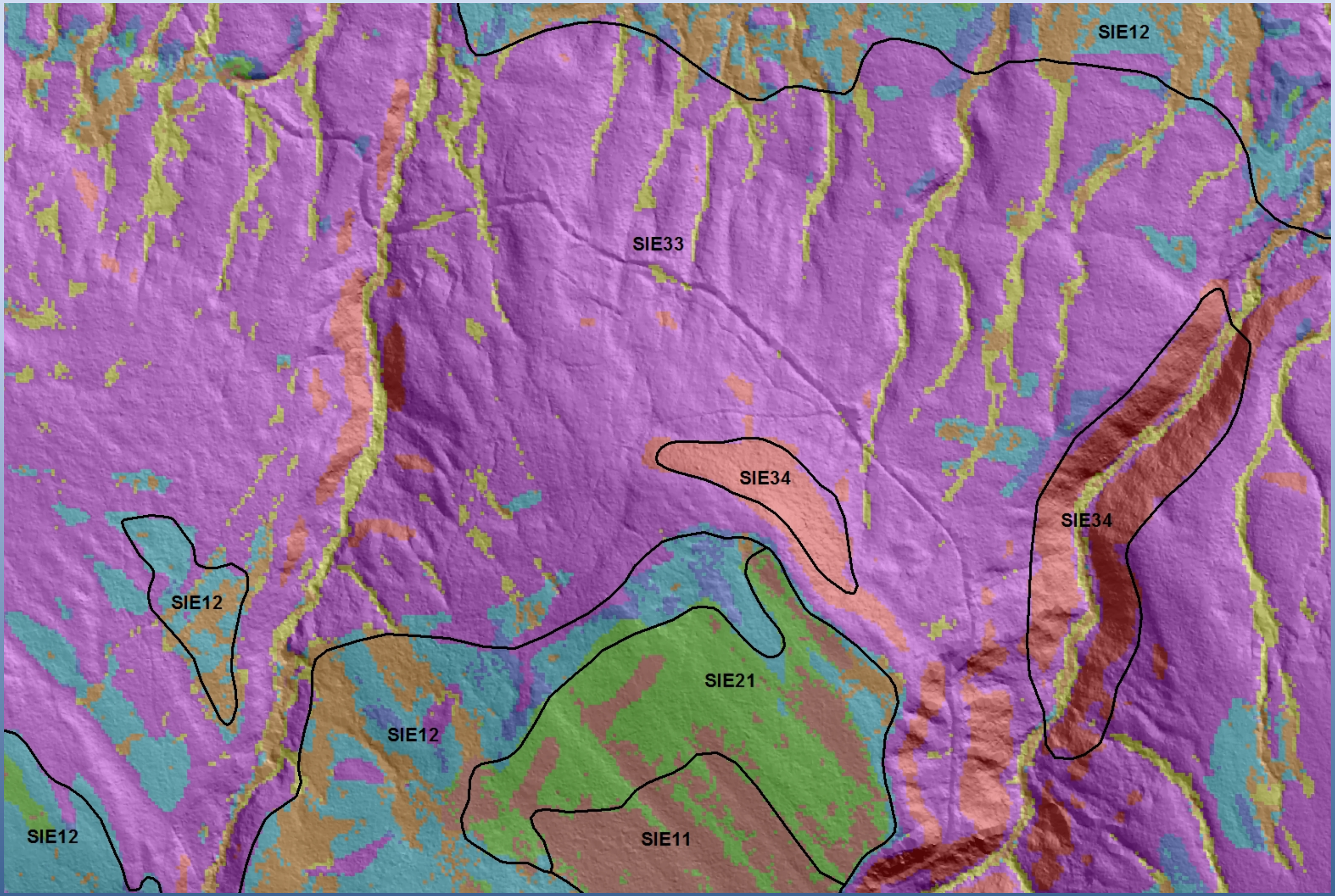


The catena models allows us to visualize where different components occur within a “traditional” map unit.

USDA

United States Department of Agriculture

Essex County, VT is the first published raster soil survey in the country

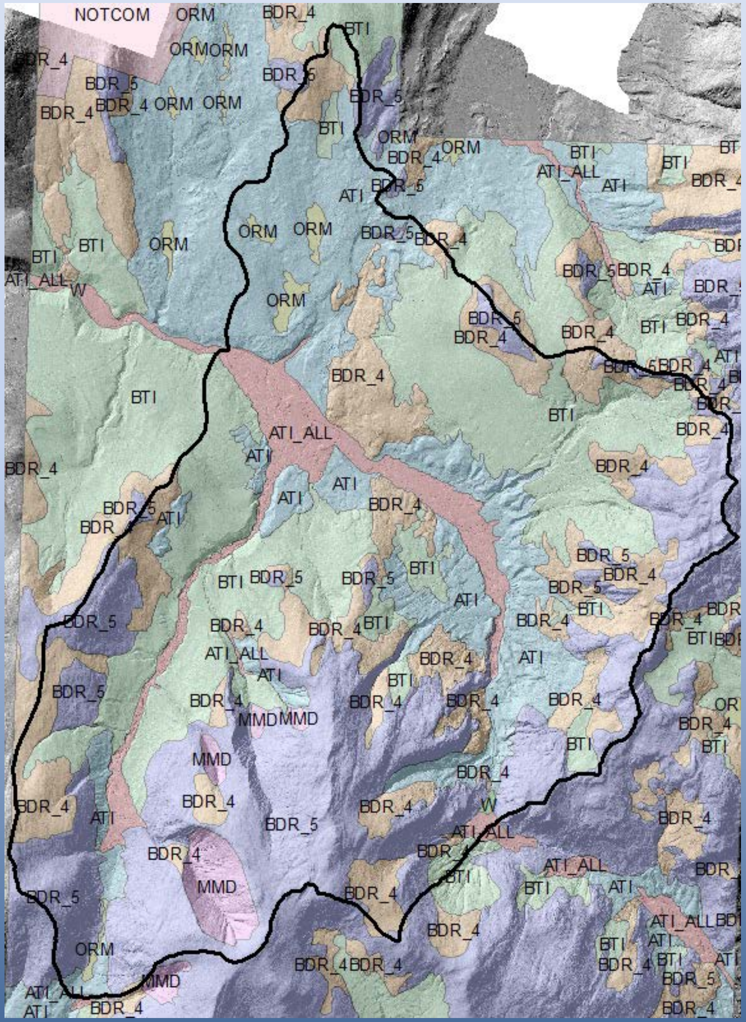


USDA

United States Department of Agriculture

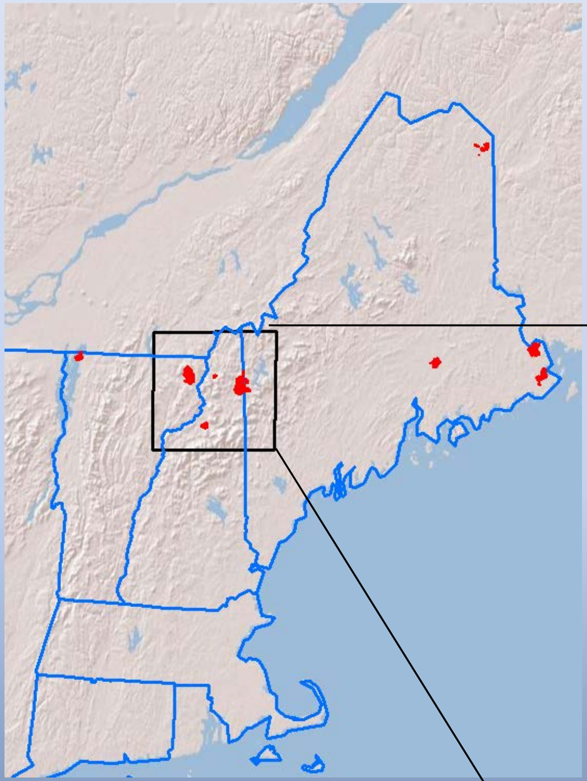
Since 2010 – the focus has been on joint (USFS, UNH, and NRCS) soil, site, and vegetation investigations in the 17,000 acre upper Wild Ammonoosuc River watershed in the White Mountain National Forest.

This information is being used to develop models for soil survey (SSURGO), USFS Terrestrial Ecological Unit Inventory (TEUI), and NRCS Ecological Site Description (ESD)

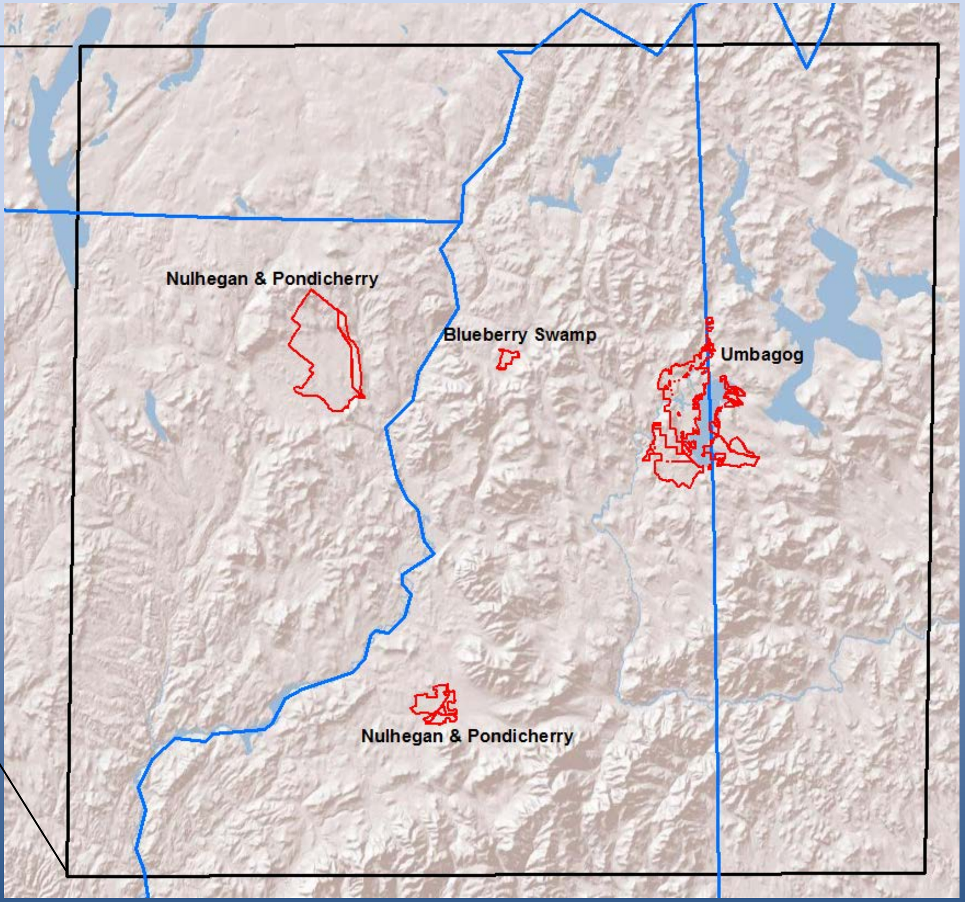


Right: draft soil parent materials in upper Wild Ammo watershed

United States Department of Agriculture

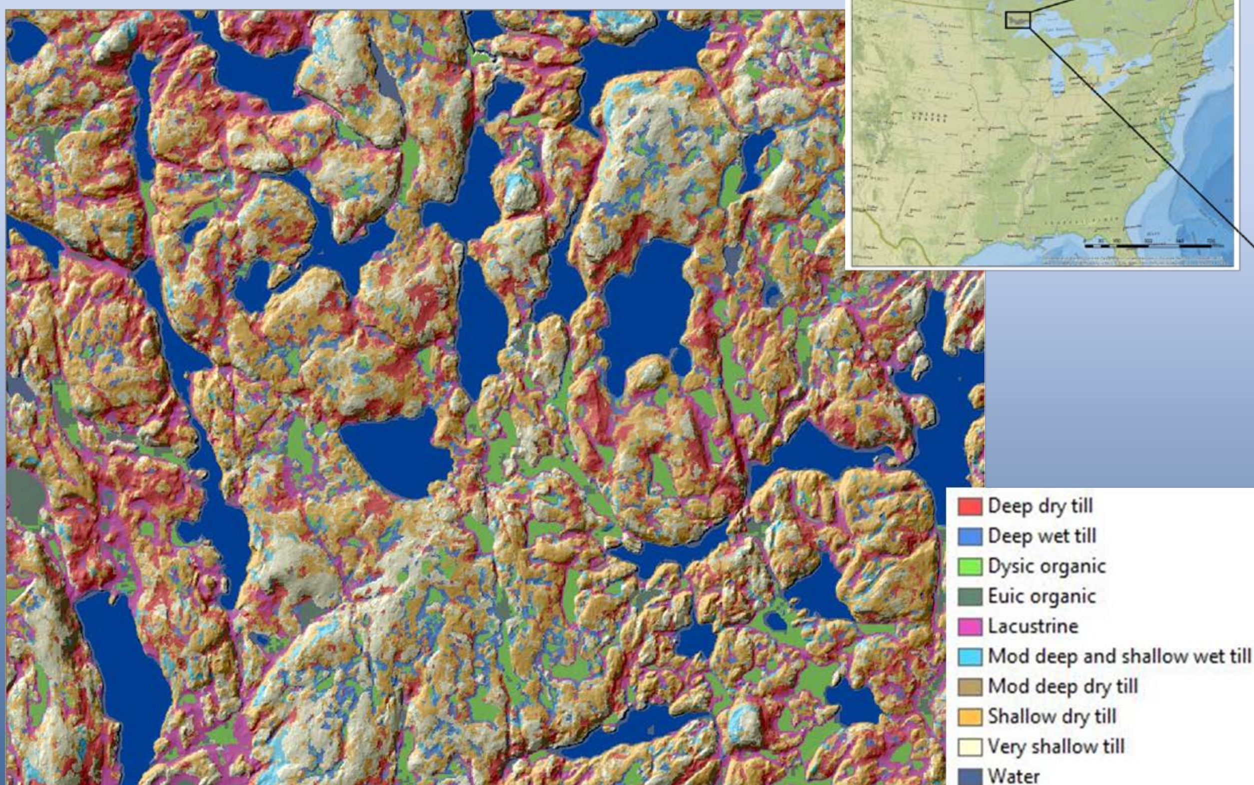


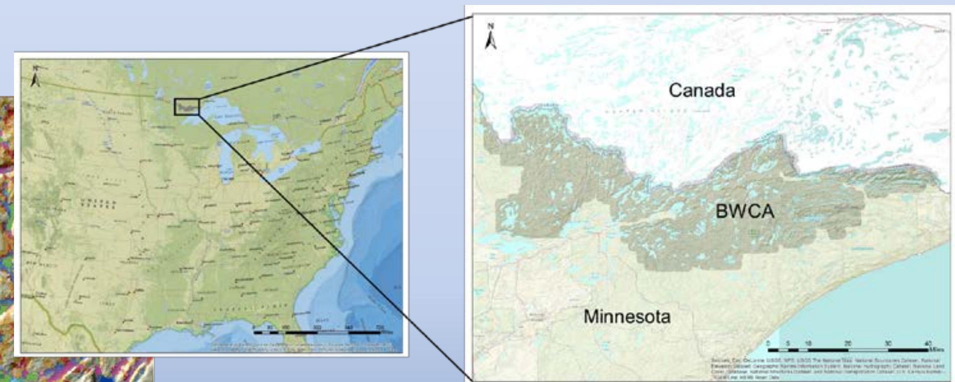
The St. Johnsbury Soil Survey Office is also supporting efforts to develop Ecological Site Descriptions (ESDs) for the Northern Forest Wildlife Refuges through a partnership with USFWS.



USDA
United States Department of Agriculture

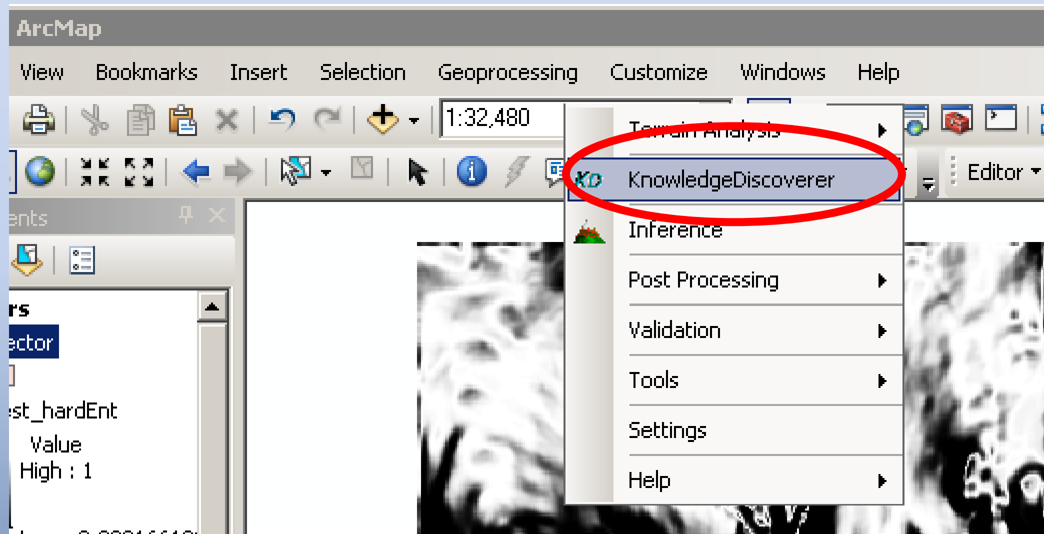
The St. Johnsbury Soil Survey Office is part of a team charged with mapping soils in the Boundary Waters Canoe Area Wilderness in Minnesota



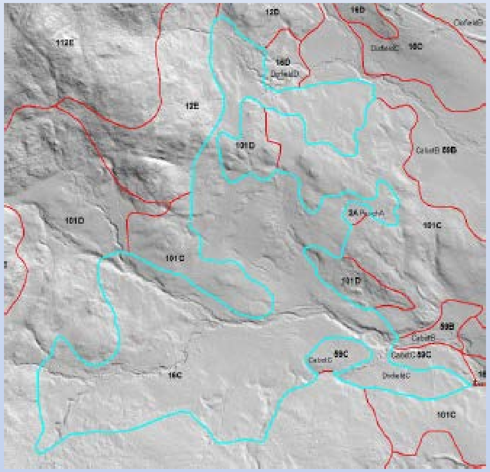


Knowledge-based modeling is being used in concert with logistic regression and random forests modeling to create the final raster soil map.

Knowledge Discoverer (KD) is a module in **ArcSIE** for soil survey update.

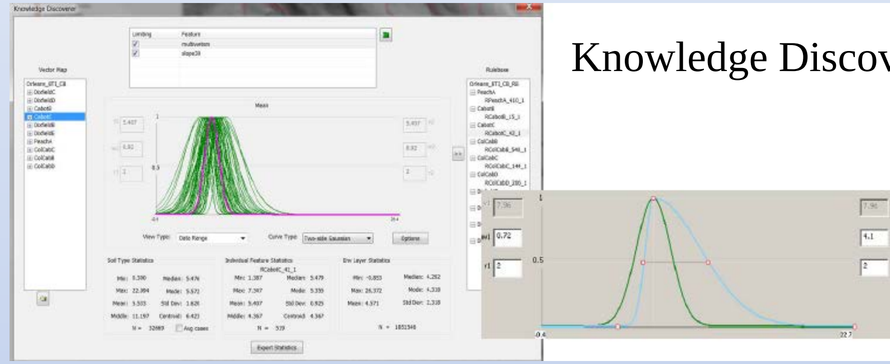


The approach is to *discover*, *revise*, and *reuse* the knowledge (soil-landscape model) implicitly represented by an existing soil map, during which it incorporates updated (better) knowledge and data.



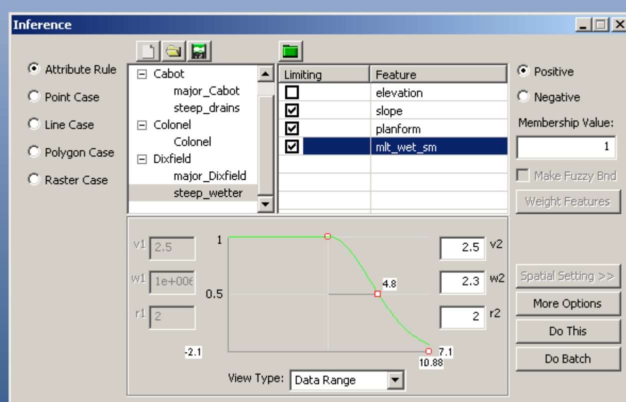
Original SSURGO polygon of Dixfield sandy loam, 8-15 percent slope

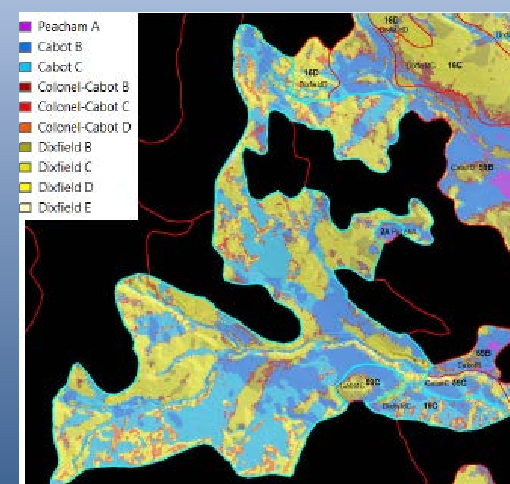
Knowledge Discoverer



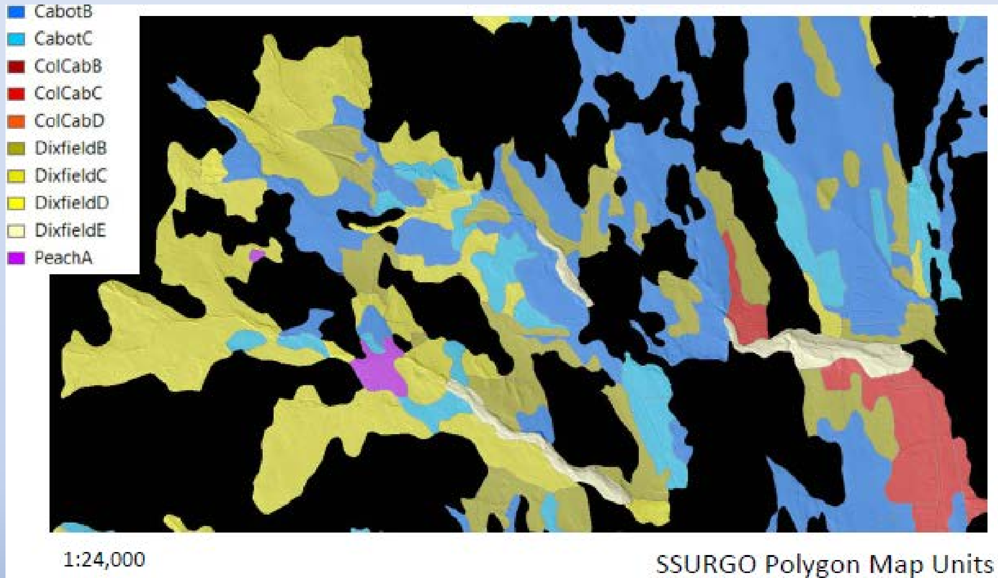
One "typical" curve was selected to represent each map unit, and edited according to new knowledge/better data (in this case LiDAR derivatives)

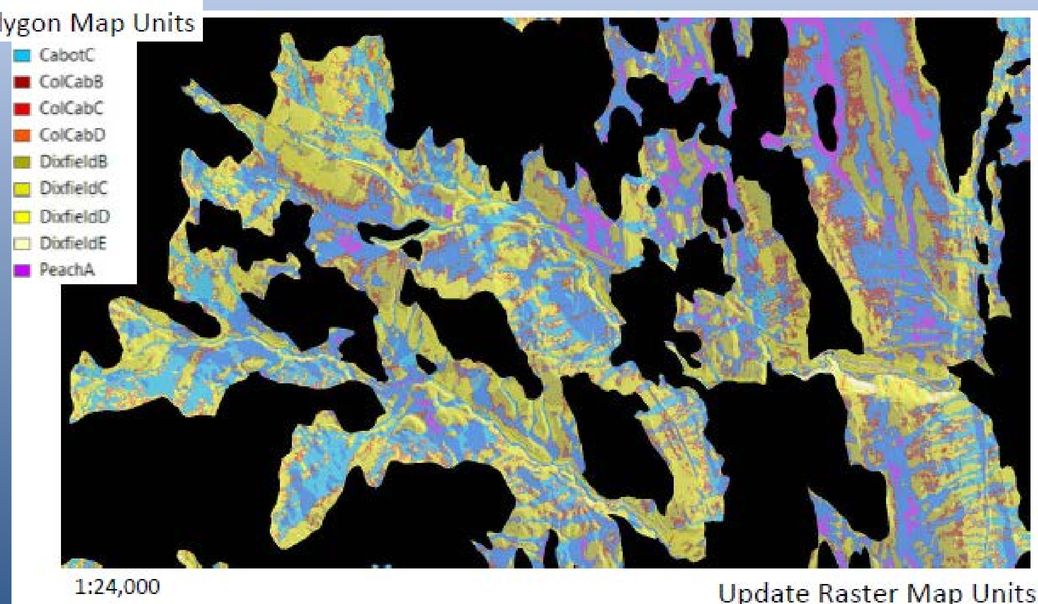
Soil Inference Engine





Updated map


CabotB
CabotC
ColCabB
ColCabC
ColCabD
DixfieldB
DixfieldC
DixfieldD
DixfieldE
PeachA
1:24,000
SSURGO Polygon Map Units


CabotC
ColCabB
ColCabC
ColCabD
DixfieldB
DixfieldC
DixfieldD
DixfieldE
PeachA
1:24,000
Update Raster Map Units

Thank You!

For more information, email me: Jessica.Philippe@vt.usda.gov