United States Department of Agriculture

Digital Soil Mapping using LiDAR

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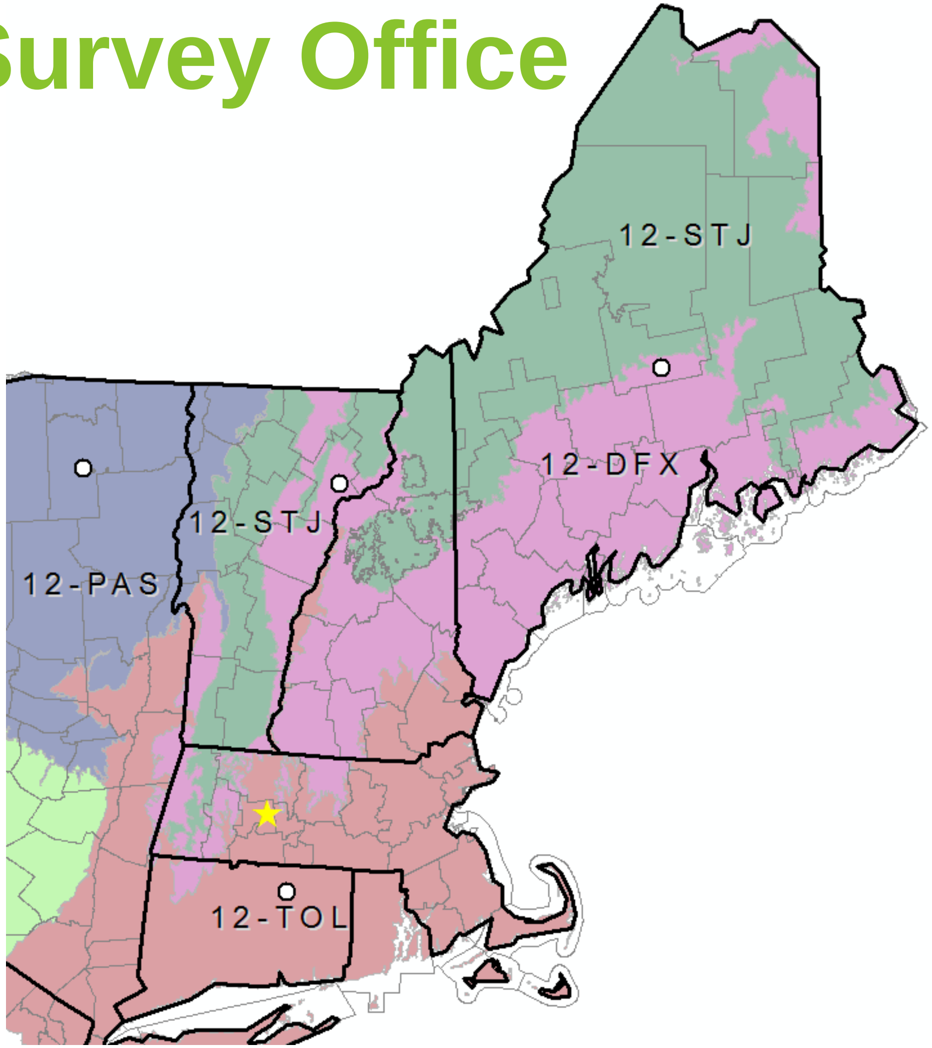
Natural Resources Conservation Service

nrcs.usda.gov/

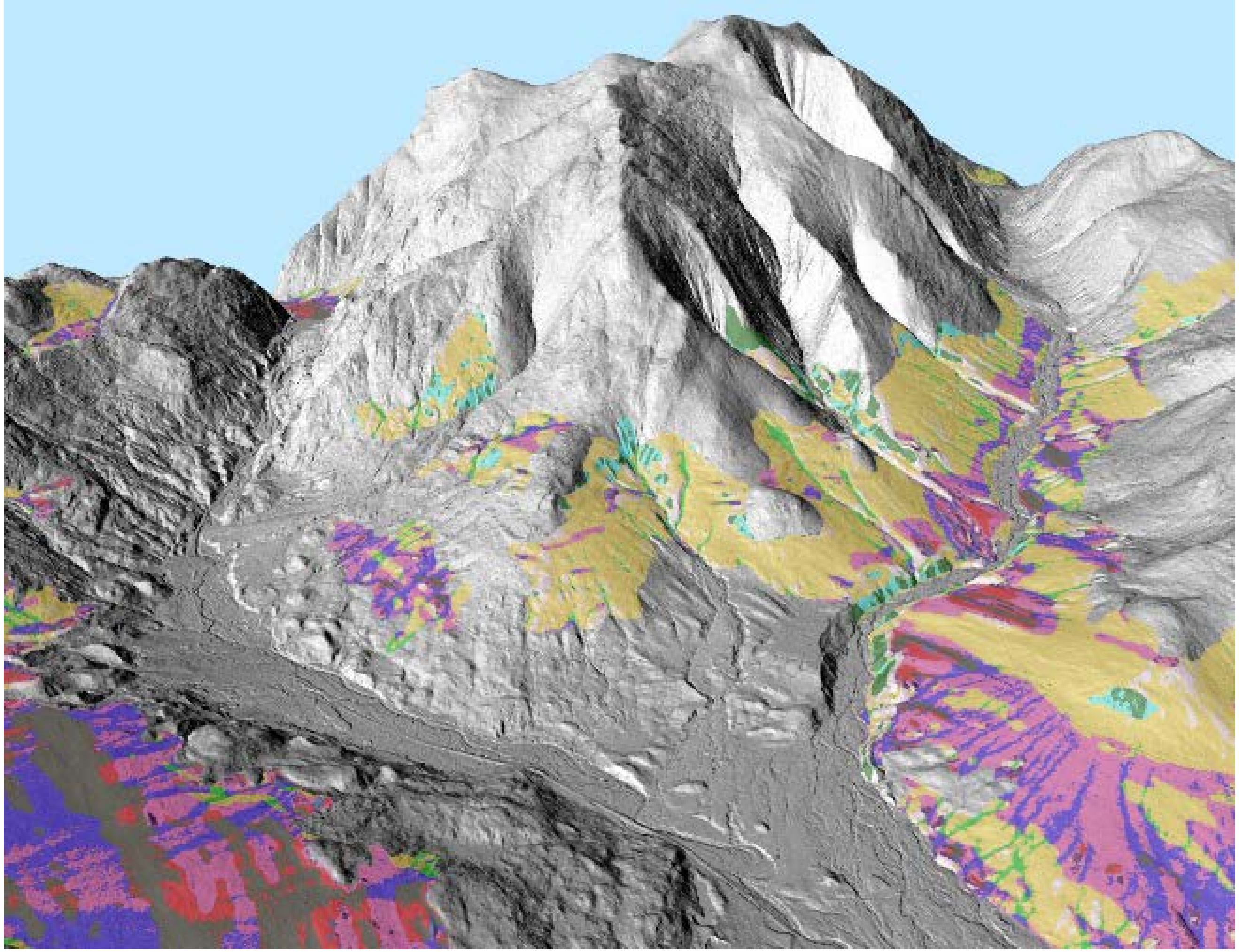
MLRA Soil Survey Office

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).



12-STJ Specialty: knowledge based raster soil mapping

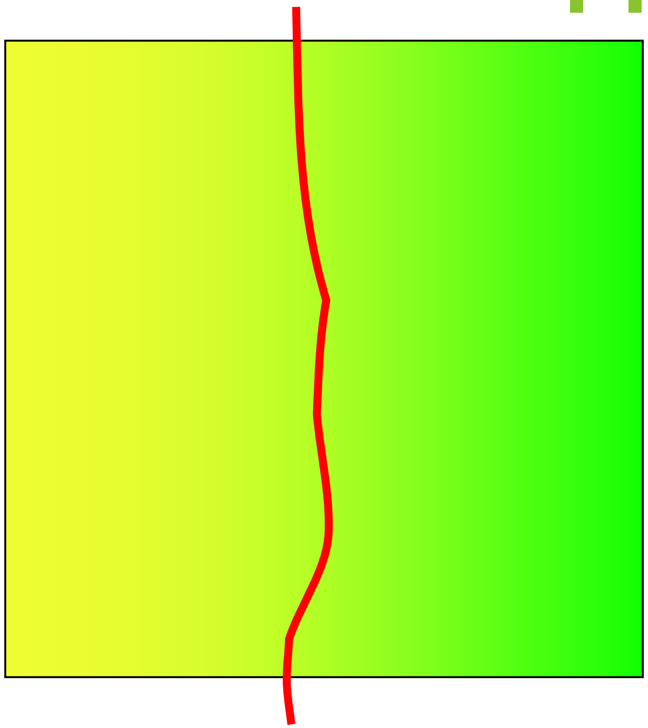


Raster Soil Mapping

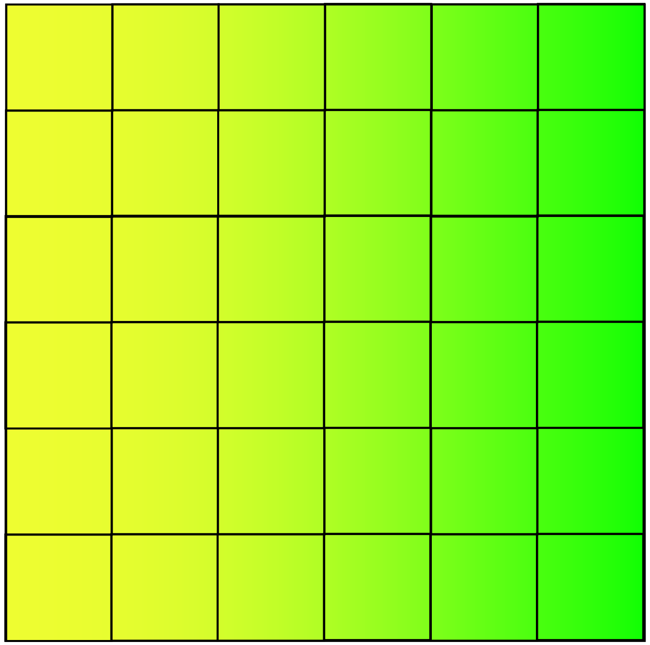
- Digital soil mapping (DSM) is a very broad concept.

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

Raster Soil Mapping

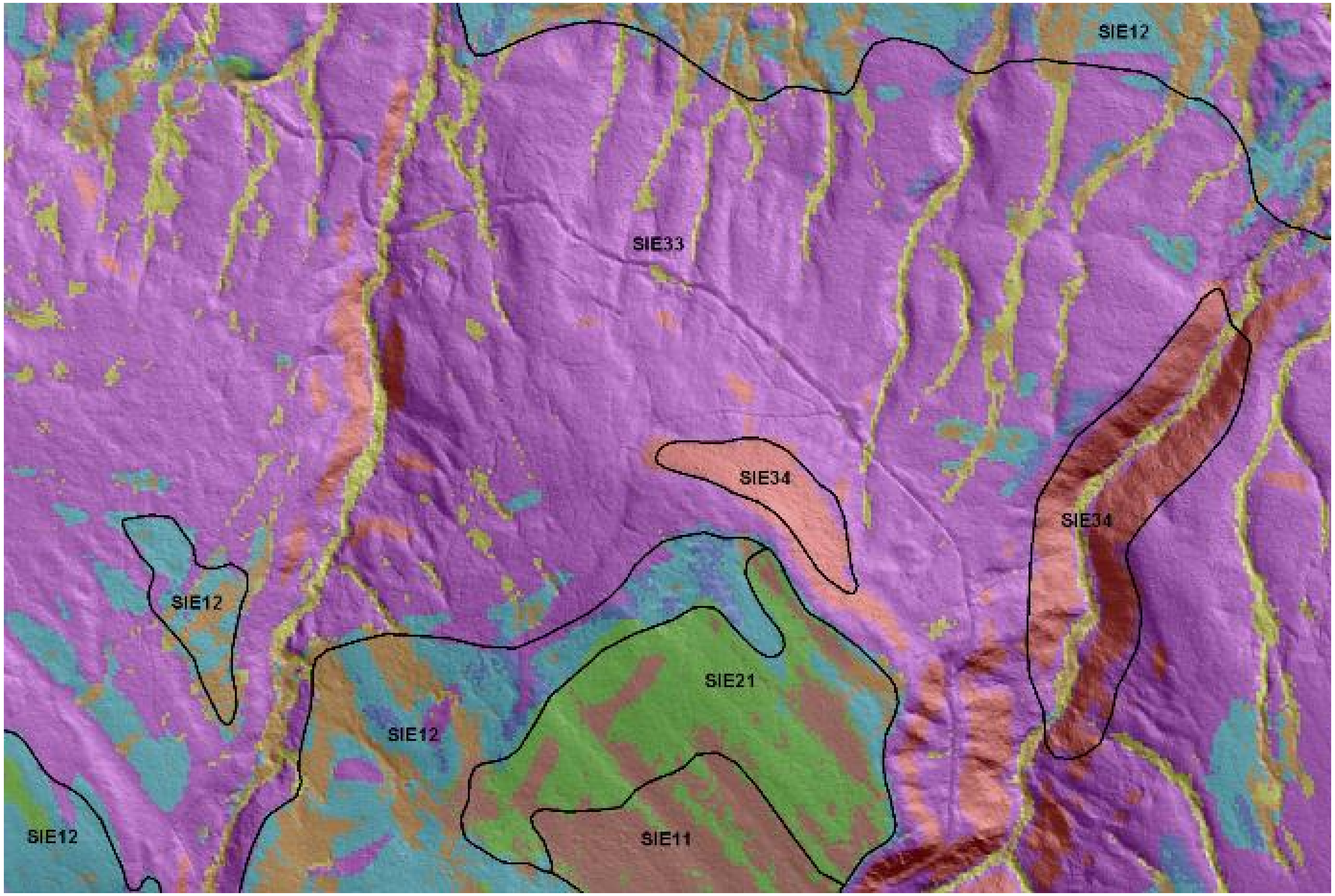


In conventional mapping, the primary question is “Where is the boundary between two soils?” and the focus is on those marginal areas.



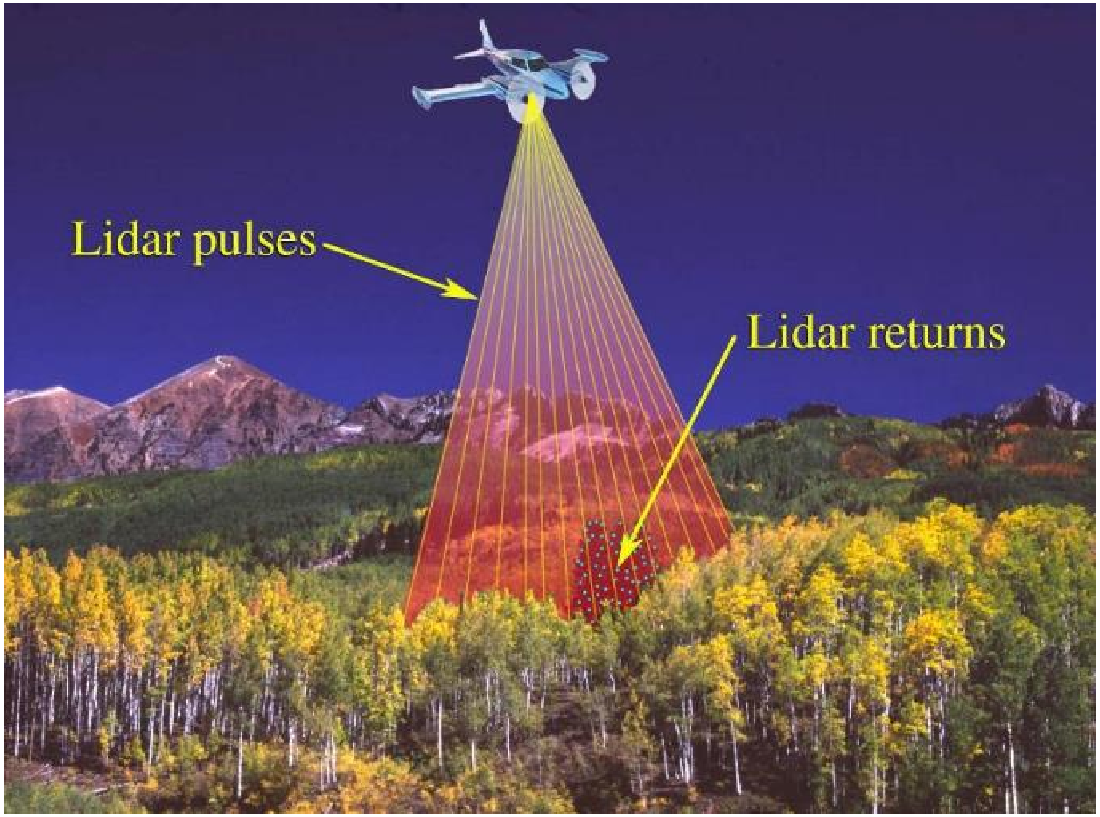
In fuzzy mapping, the primary question is “Where is the typical soil for this type?” and the focus is on those “central” areas.

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



It all starts with…

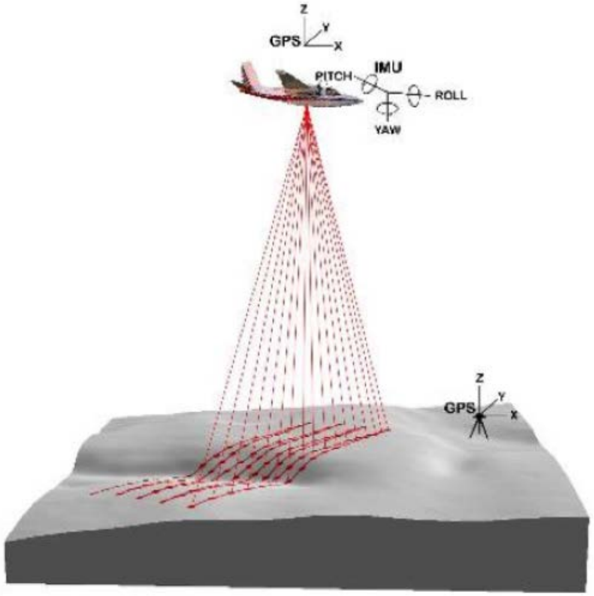
Light Detection and Ranging System (LiDAR)

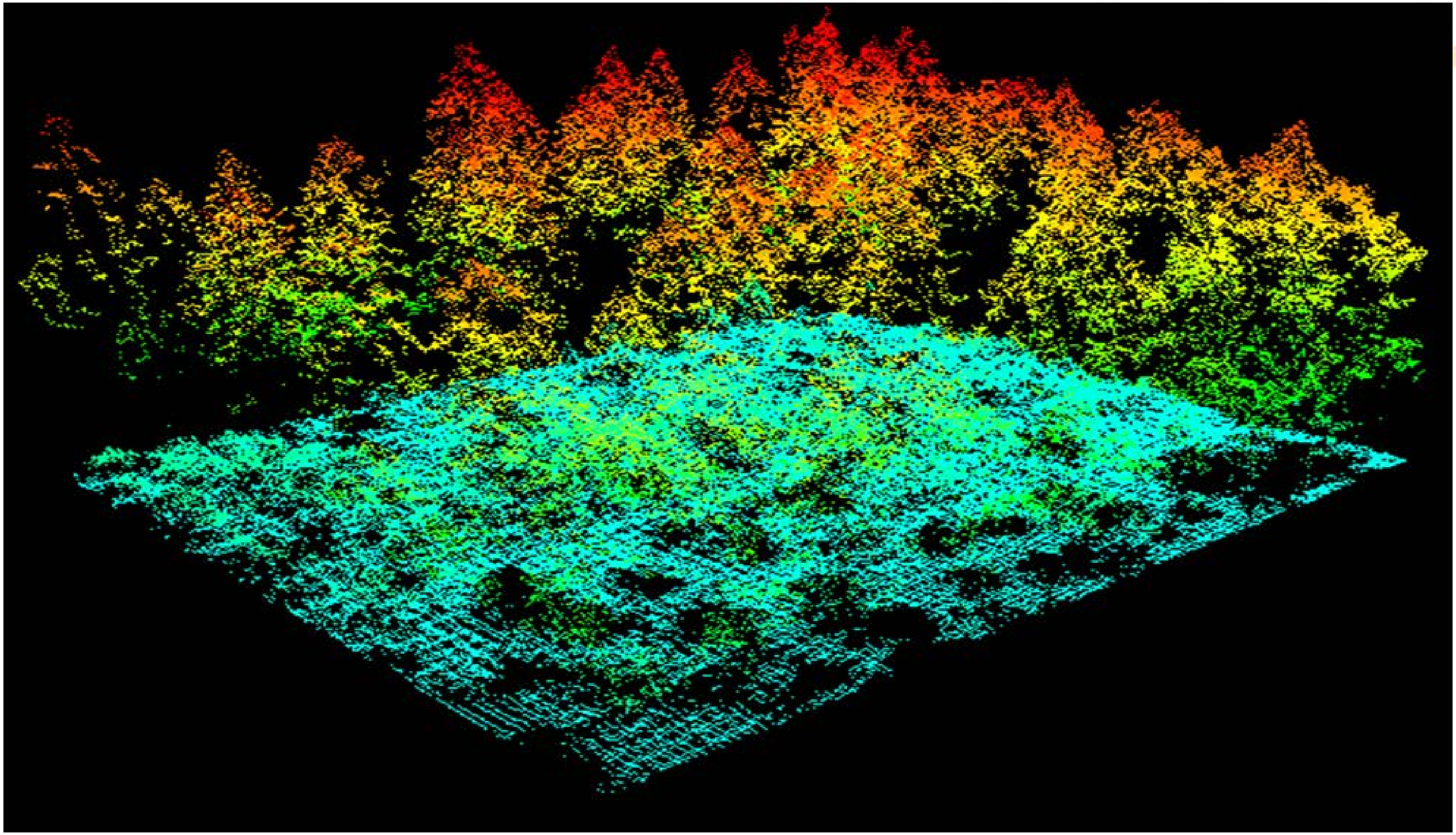


courtesy of the US Geological Survey

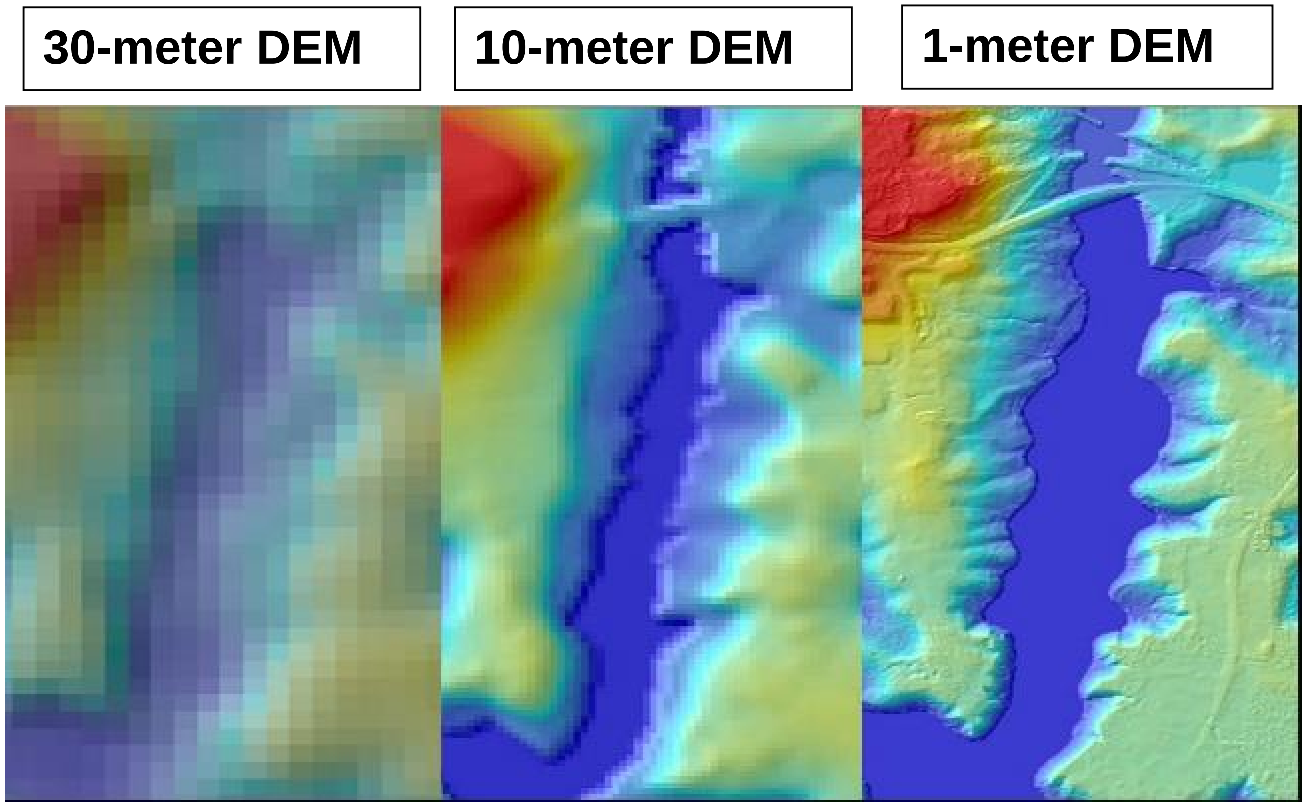
The need for LiDAR Data cannot be overestimated for initial and update Soil Survey projects. The main uses of LiDAR in support of soil survey are:

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



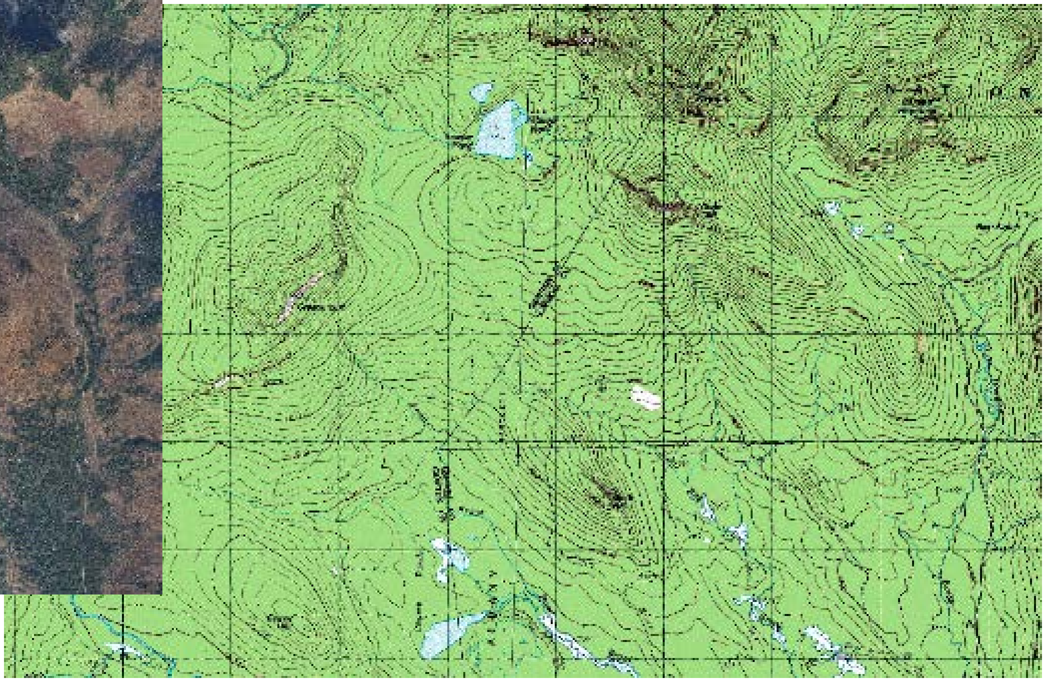


LiDAR Point Cloud



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

Visualization & Landscape Stratification



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

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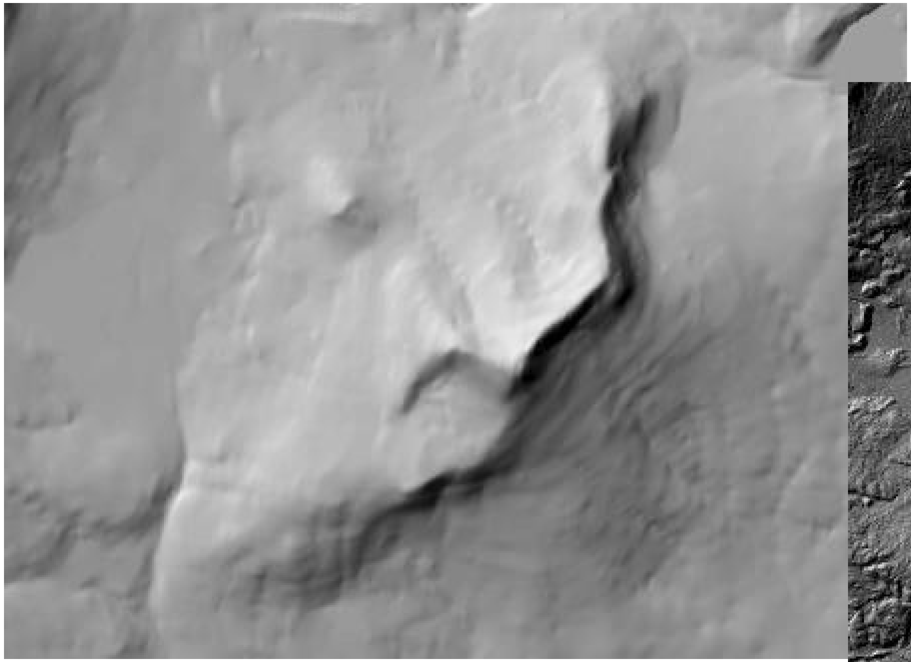
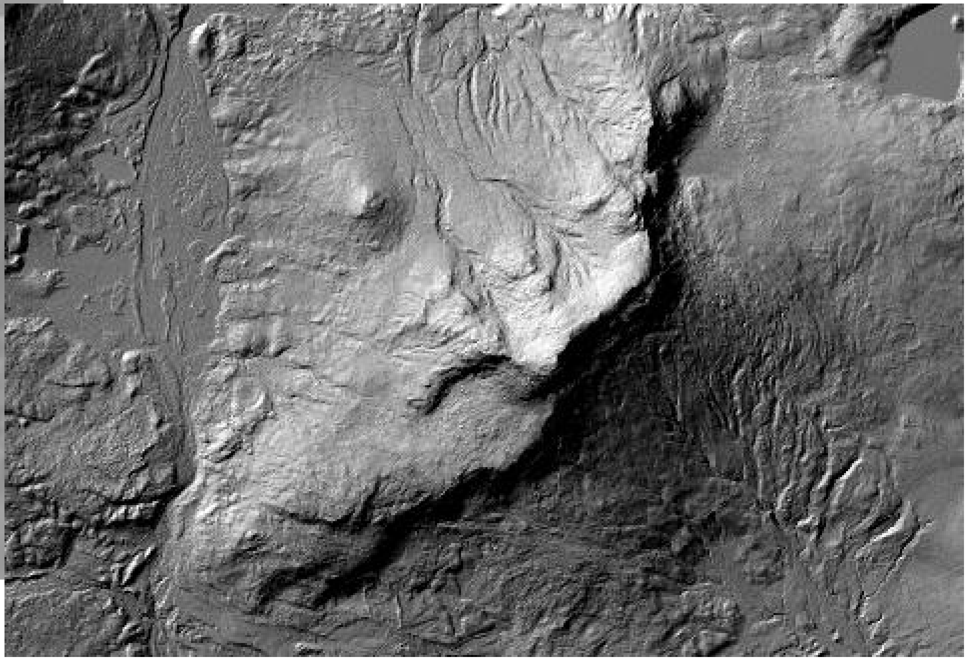
Visualization & Landscape Stratification



Hillshade from USGS 10m DEM

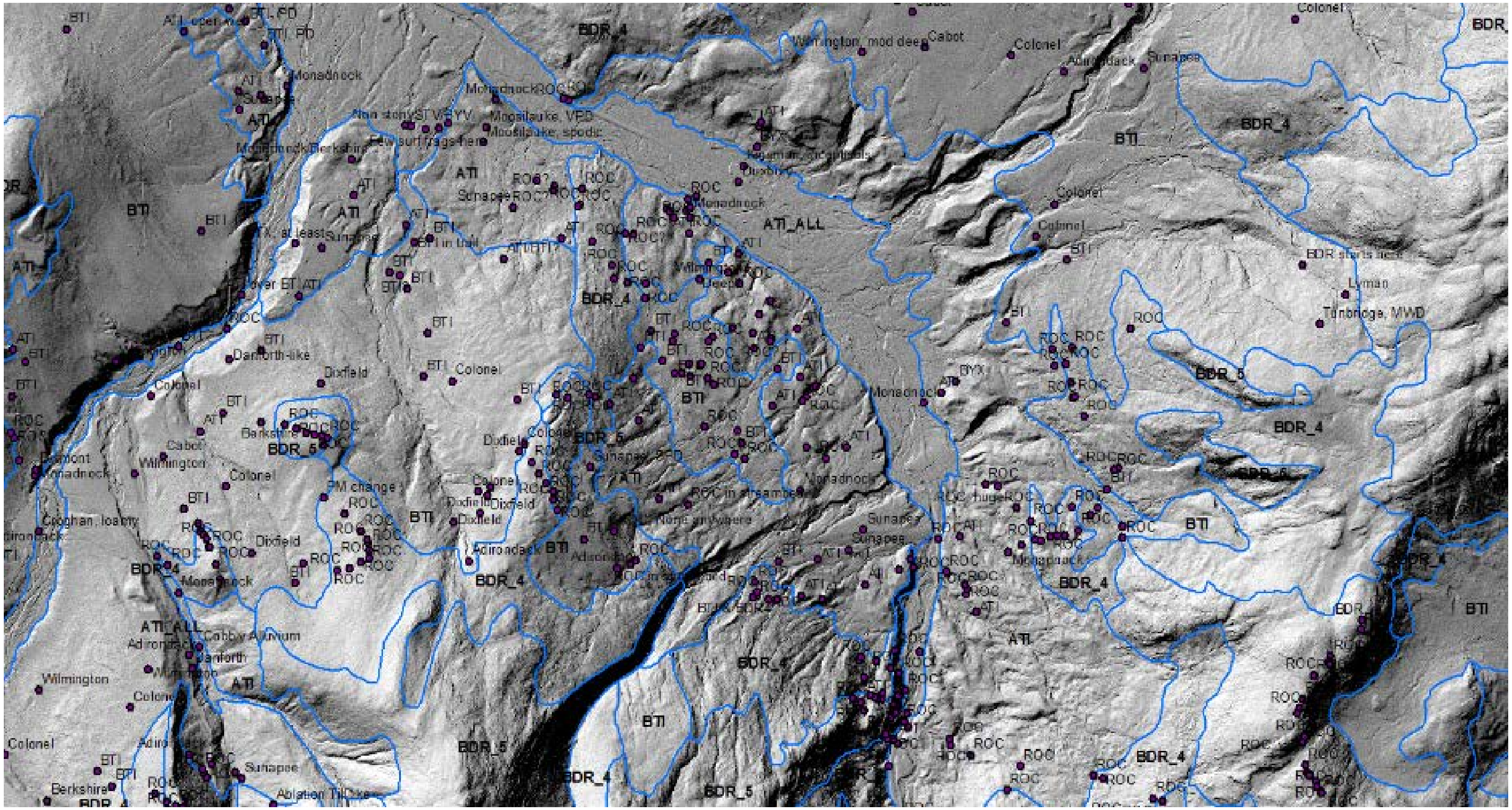


Hillshade from 3m LiDAR DEM

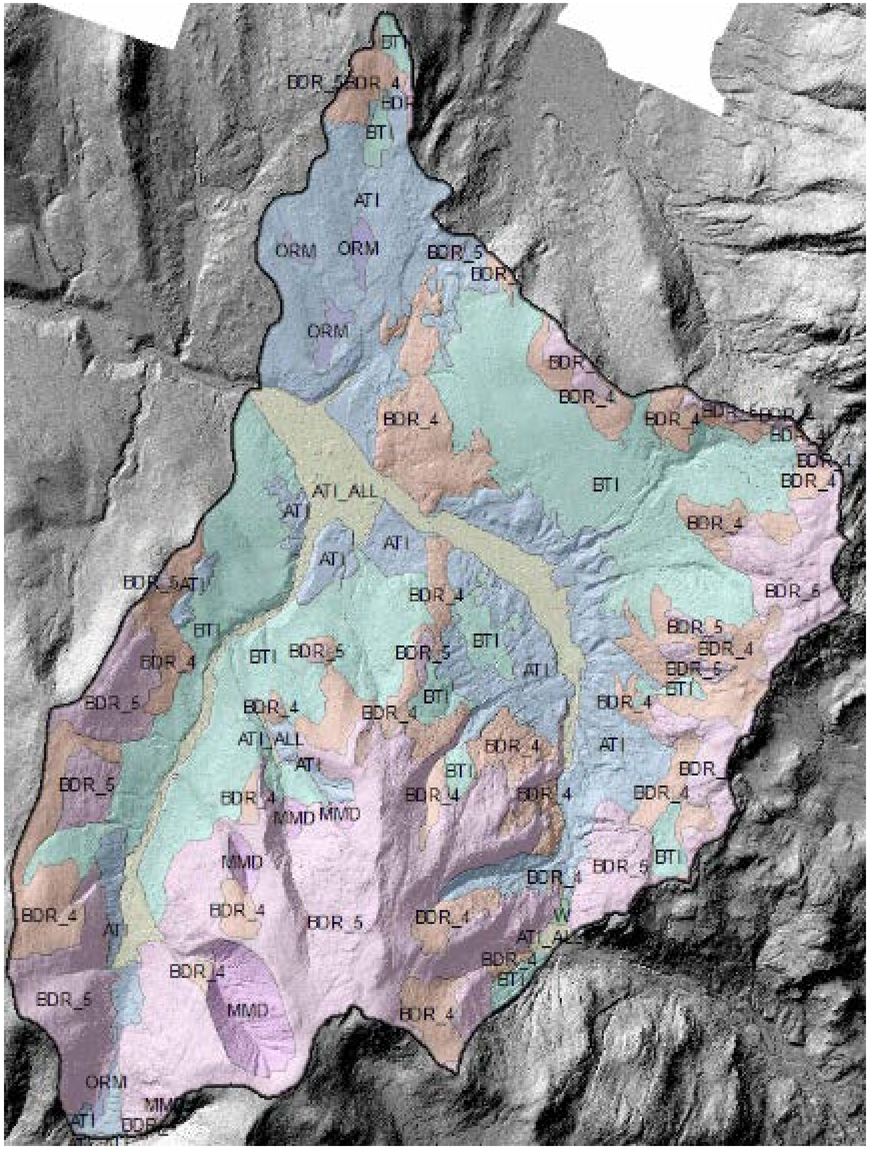
With the implementation of GIS, spatial analysis techniques became more sophisticated. However, inadequate terrain data remains a limiting factor.

High-resolution elevation data from LiDAR overcomes this limitation.

Visualization & Landscape Stratification



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



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.

Poorly Drained

Somewhat Poorly Drained

Moderately Well Drained

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

Raster Soil Mapping

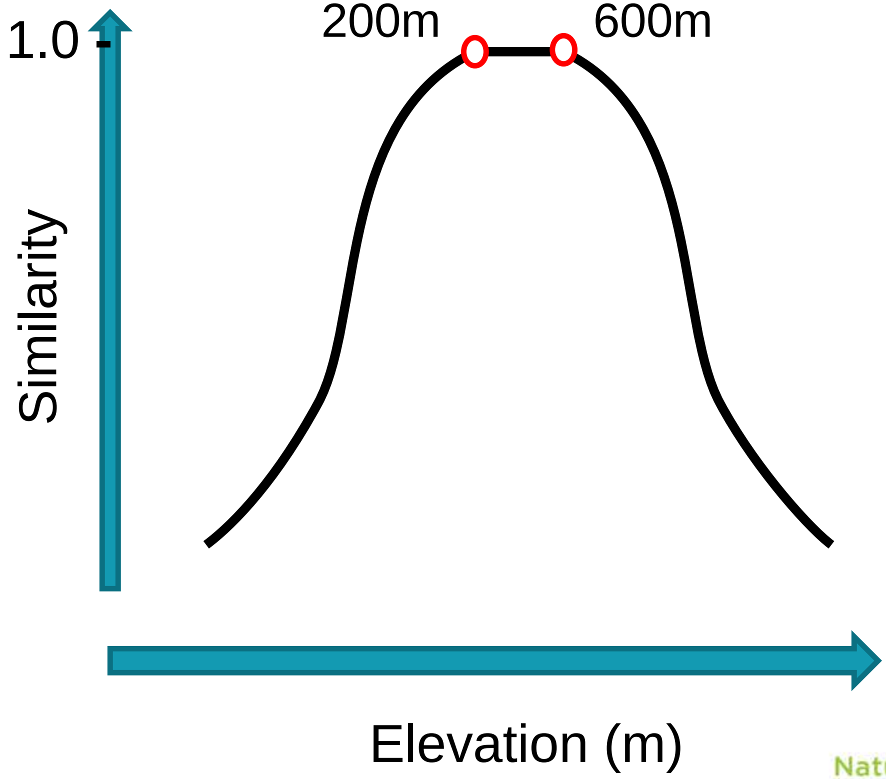
ArcSIE is a proven tool, designed for *field soil scientists* to implement knowledge-based raster soil mapping.

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.

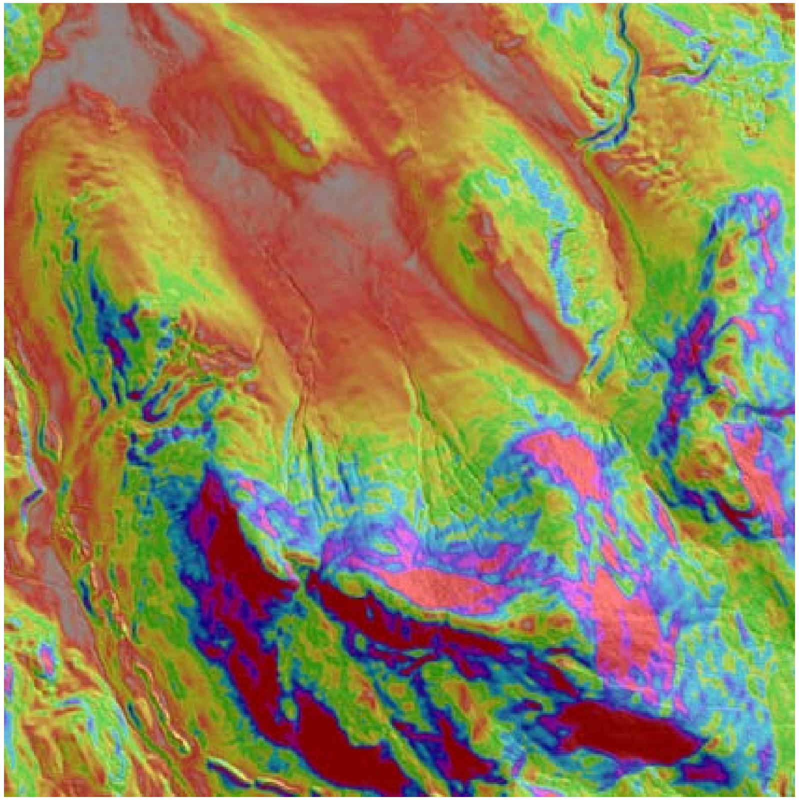
Knowledge Represented as a Rule

Elevation 200–600m is typical for soil A.

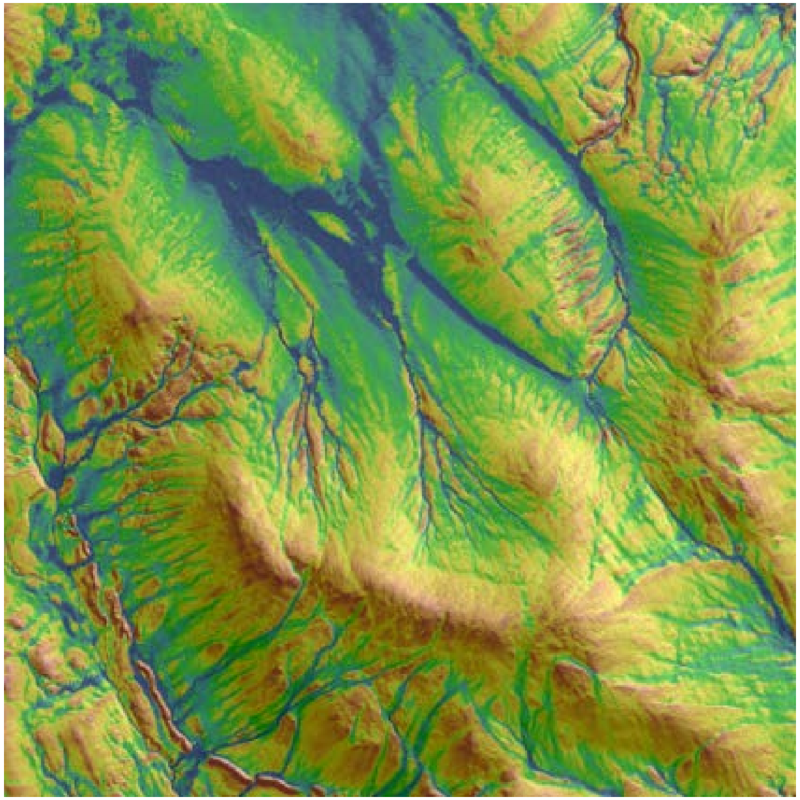
As elevation deviates from this range, the soil's similarity to type A gradually decreases.



Terrain Derivatives



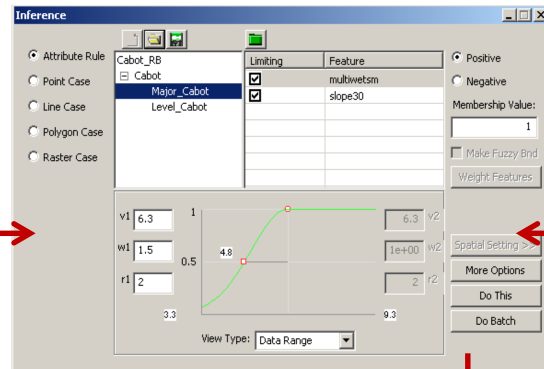
30m slope



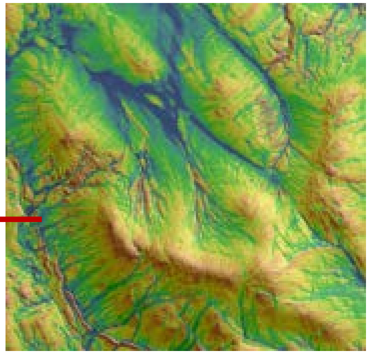
Multi-path smoothed wetness index

Soil Inference Components

Soil Scientists' Knowledge



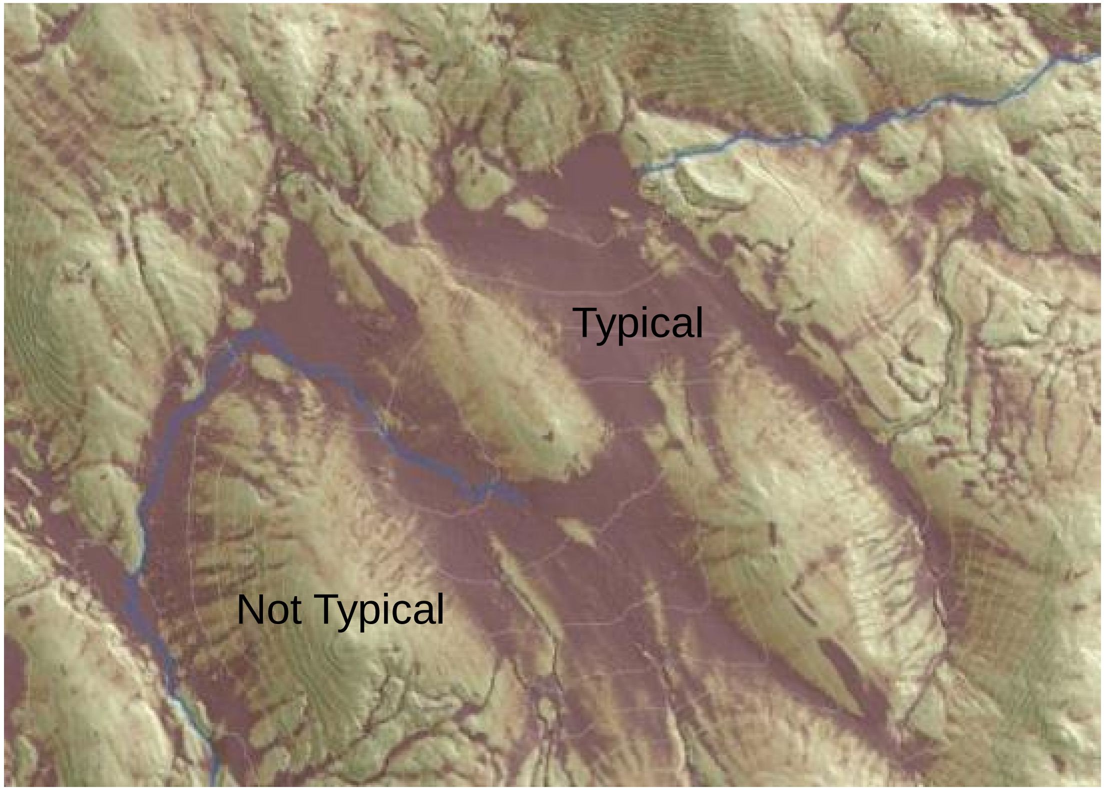
Soil Inference Engine



Environmental Data

Fuzzy Soil Membership Map

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

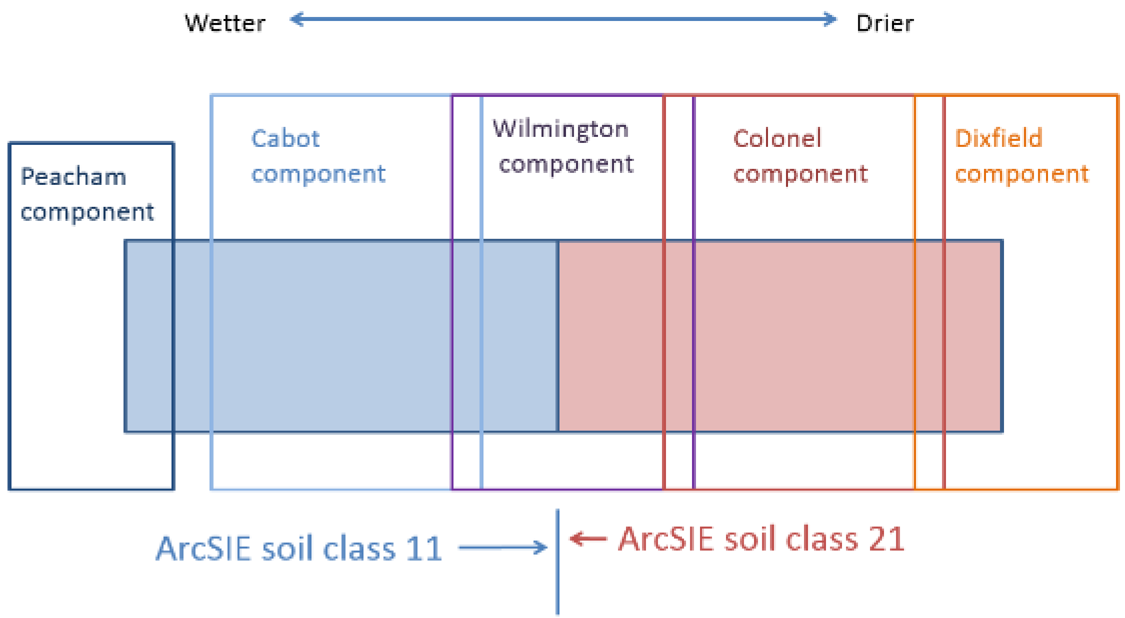


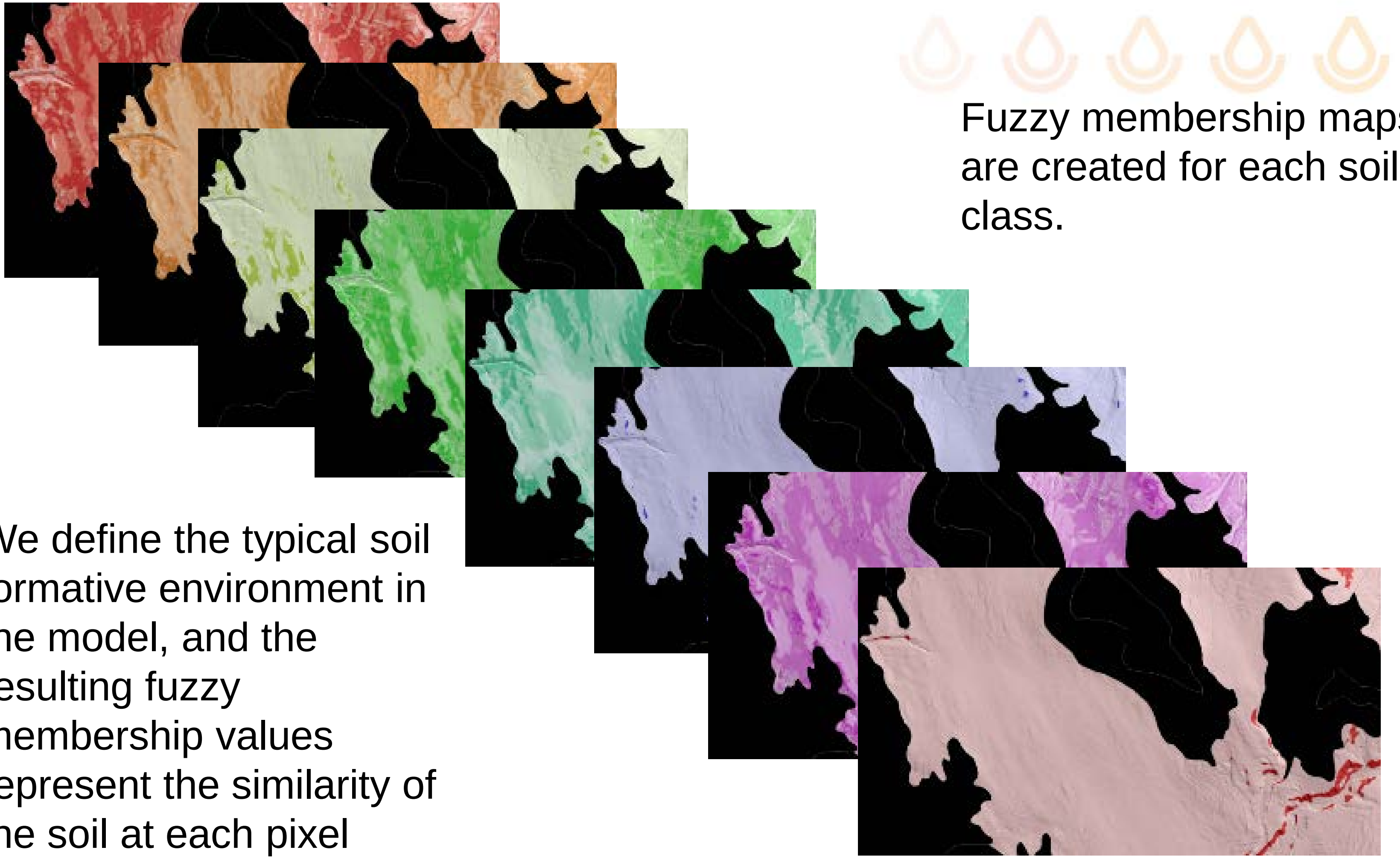
What is a raster component?

- 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.

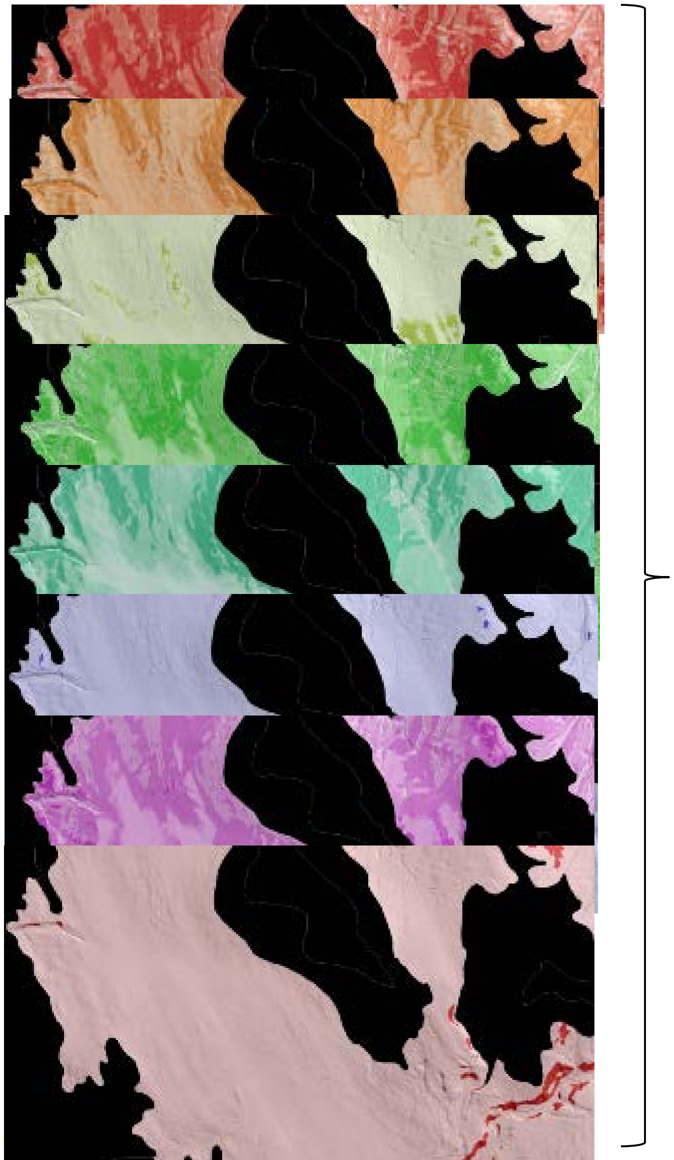


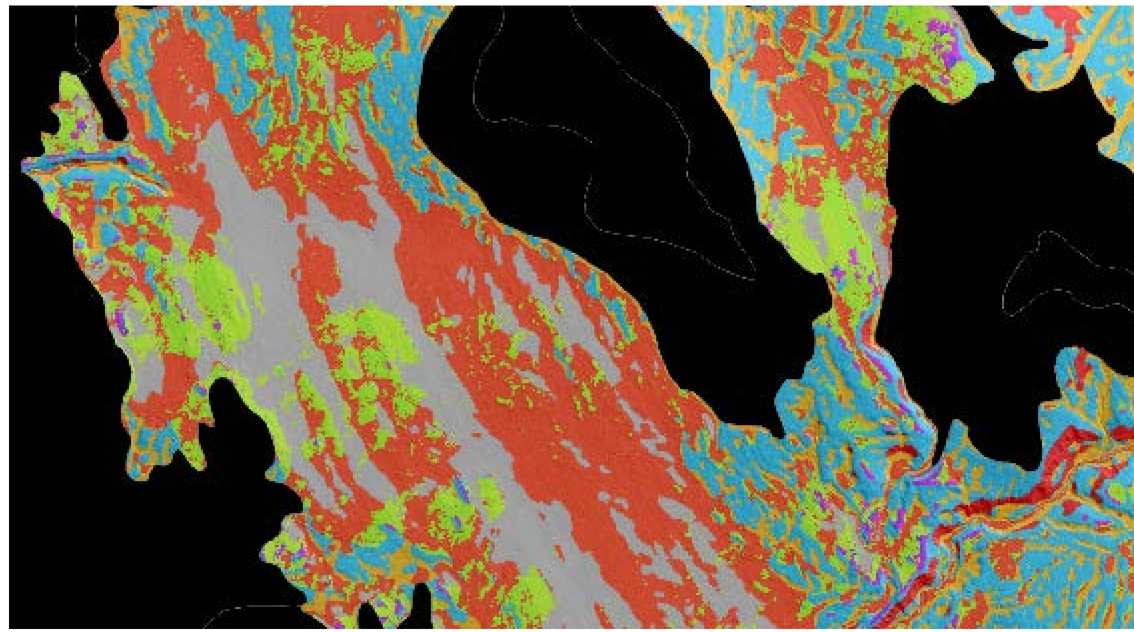


Fuzzy membership maps are created for each soil class.

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.

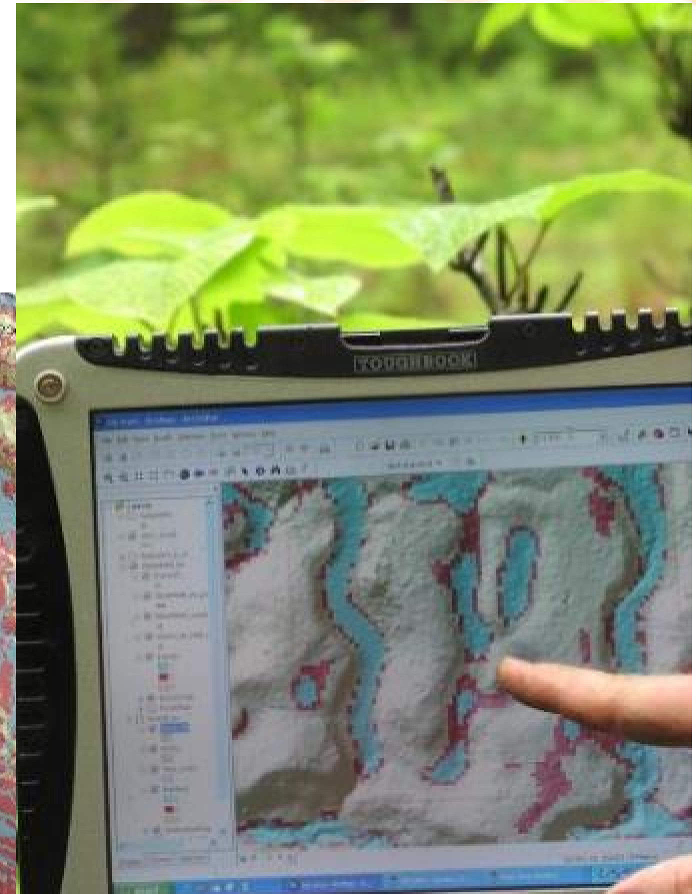
Hardening (Defuzzification)

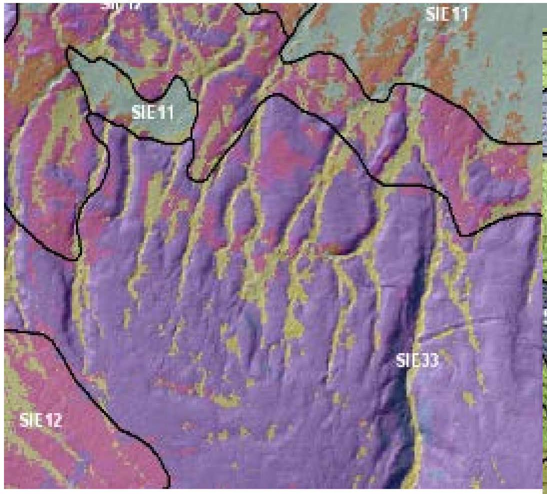




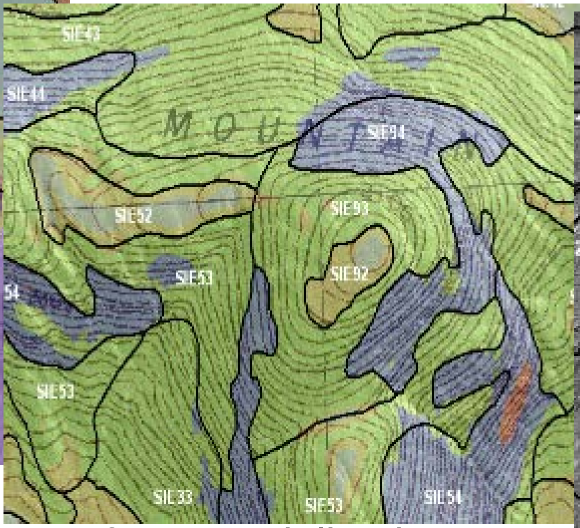
Each pixel is assigned to the soil class with the highest fuzzy membership at that location.

SIE Results are Validated in the Field

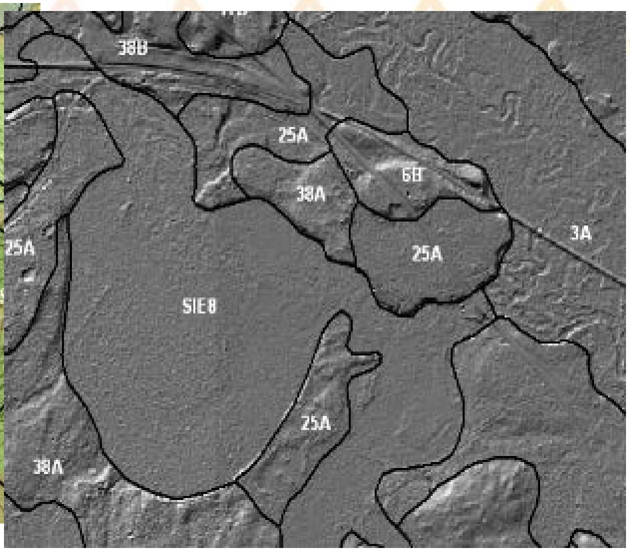




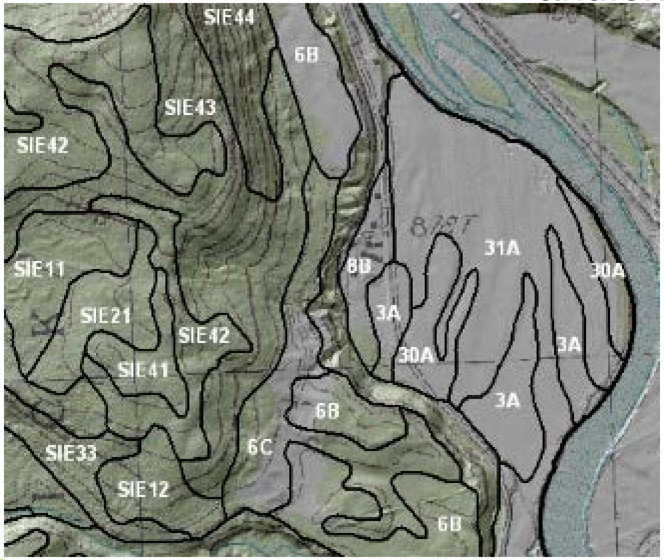
Predictive modeling by soil series



Brute force modeling by landform and slope class



Traditional mapping with modern enhancements



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All ***can*** be combined to create a SSURGO product

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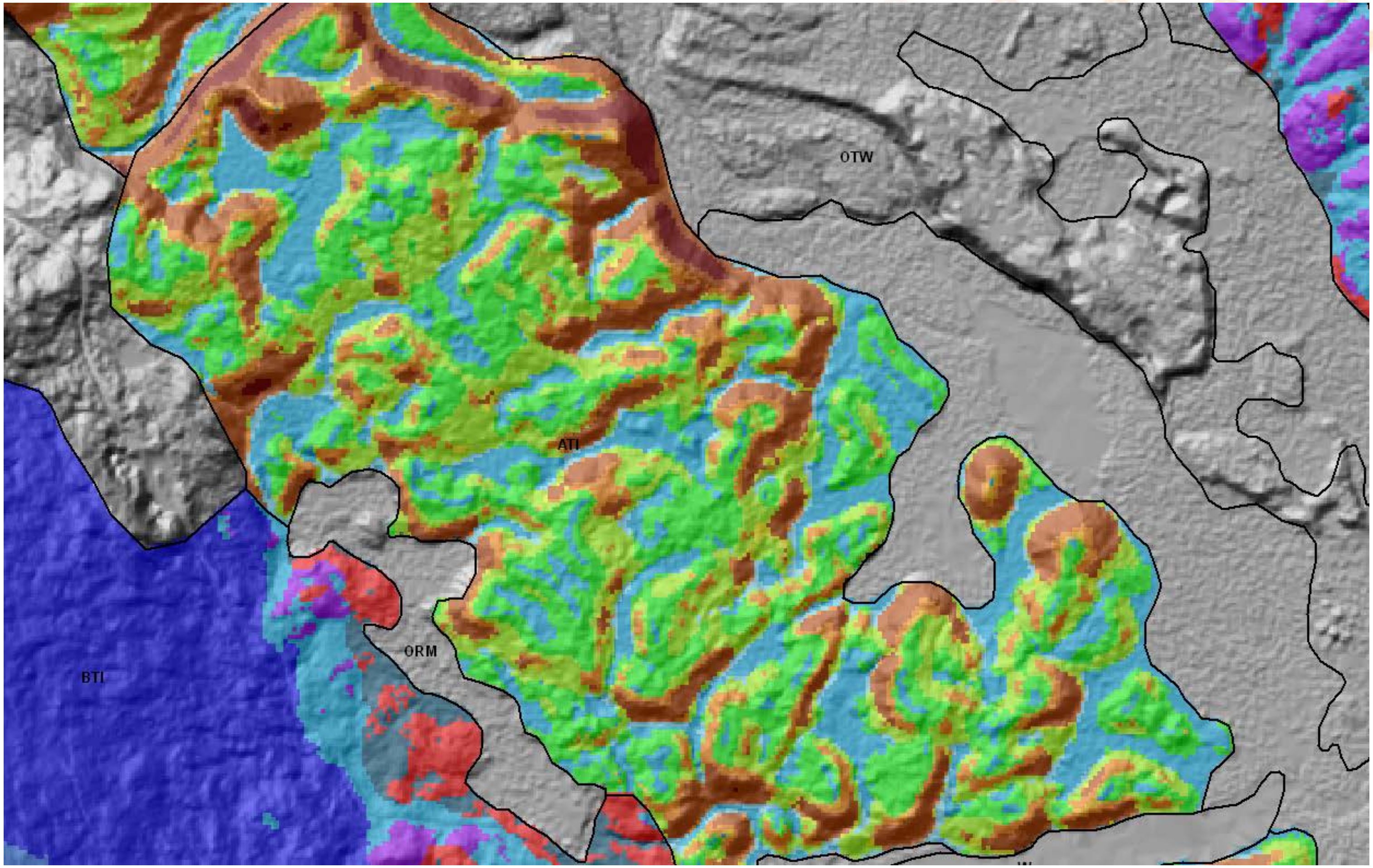

The catena models allows us to visualize where different components occur within a “traditional” map unit.

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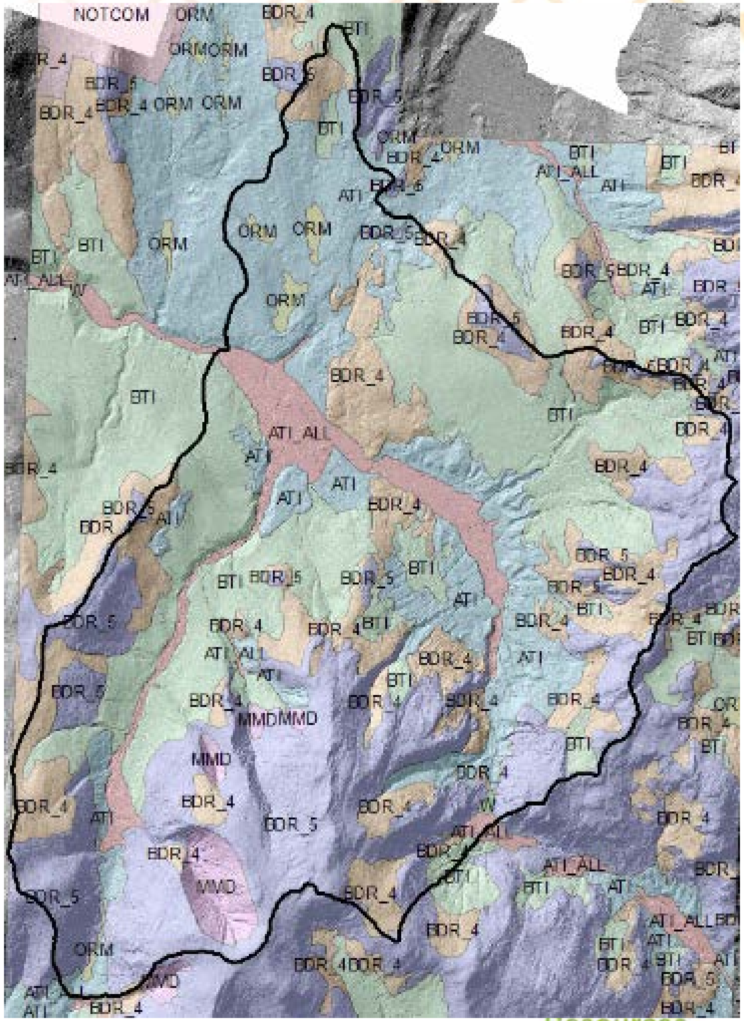
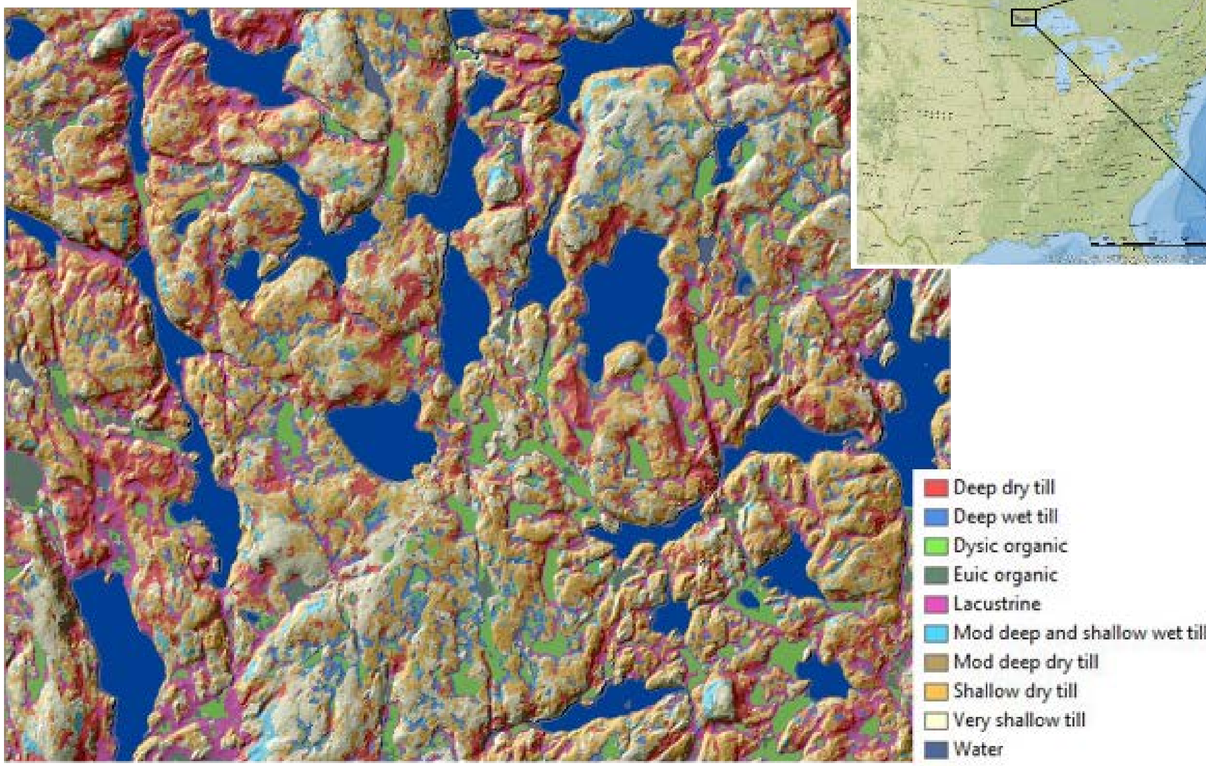
Since 2010 – the focus has been on joint (USFS, UNH, and NRCS) soil, site, and vegetation investigations in the 17,000 acre upper Wild Ammonoosuc River watershed in the White Mountain National Forest.

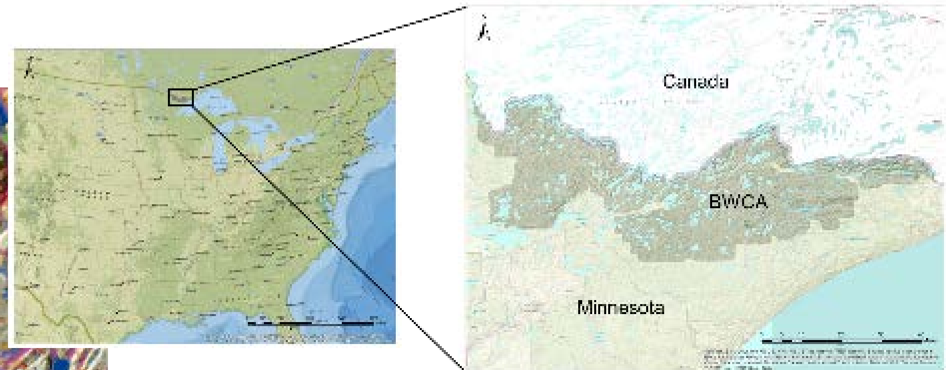
This information is being used to develop models for soil survey (SSURGO), USFS Terrestrial Ecological Unit Inventory (TEUI), and NRCS Ecological Site Description (ESD)



Right: draft soil parent materials in upper Wild Ammo watershed

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

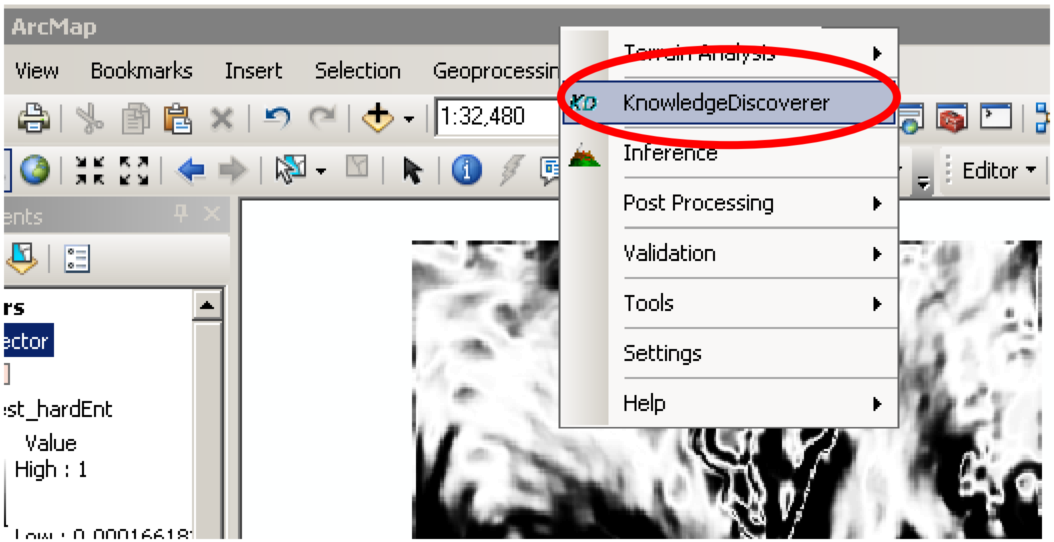




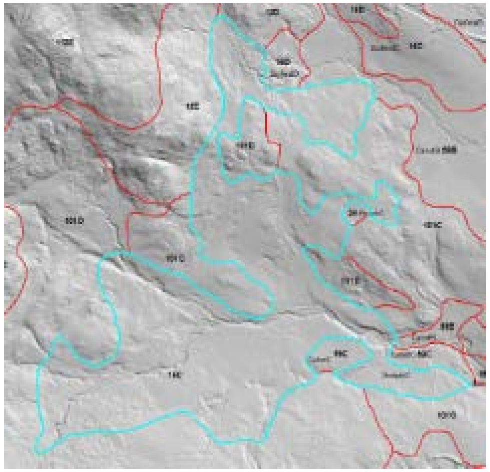
Knowledge-based modeling is being used in concert with logistic regression and random forests modeling to create the final raster soil map.

Knowledge Discoverer

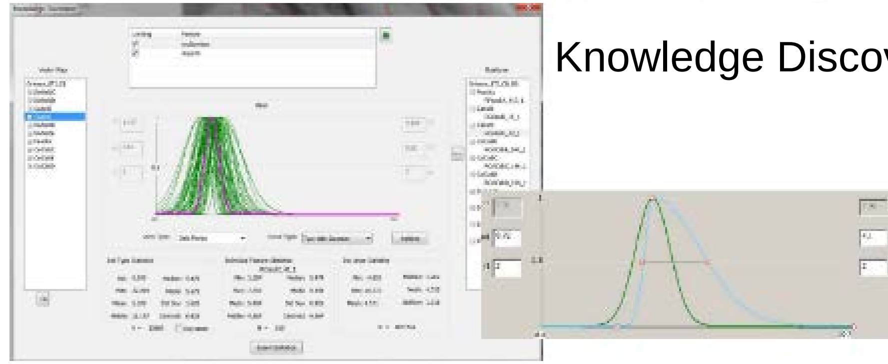
A module in **ArcSIE** for soil survey update.



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.



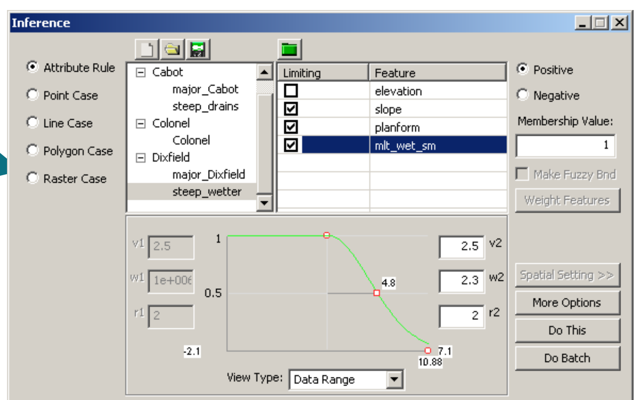
Original SSURGO polygon of Dixfield sandy loam, 8-15 percent slope

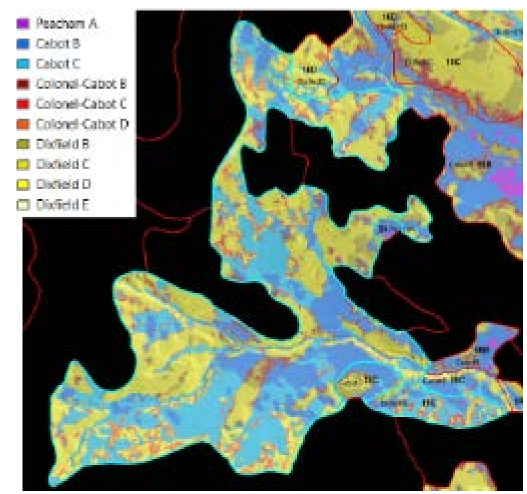


Knowledge Discoverer

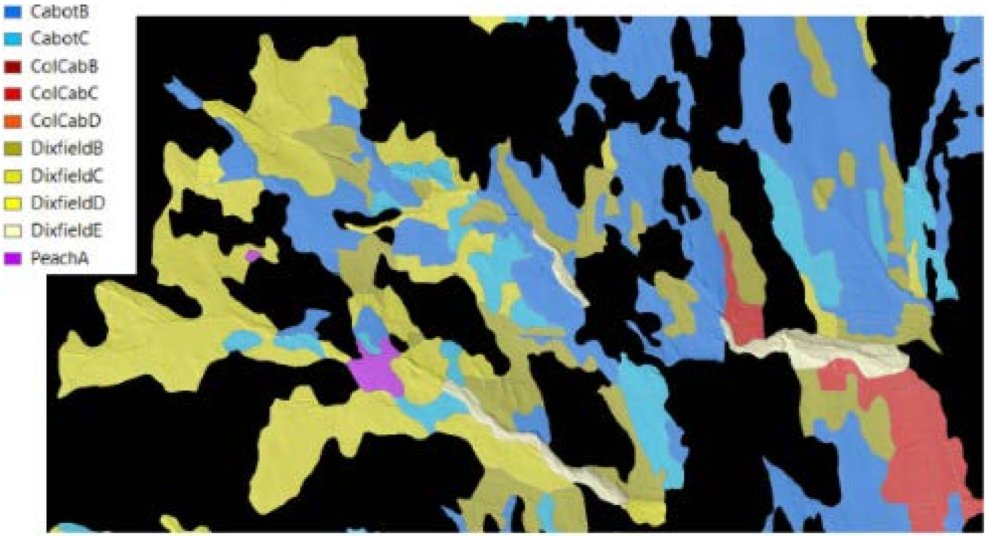
One “typical” curve was selected to represent each map unit, and edited according to new knowledge/better data (in this case LiDAR derivatives)

Soil Inference Engine



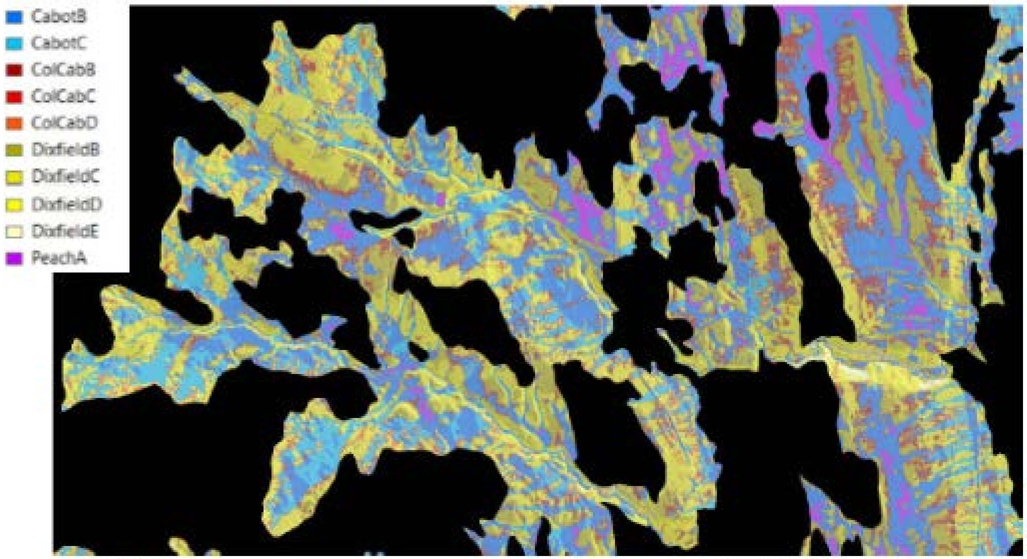


Updated map



1:24,000

SSURGO Polygon Map Units



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Update Raster Map Units

Thank You!

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

References

Shi, X., Girod, L., Long, R., DeKett, R., Philippe, J., Burke, T., 2012. A Comparison of LiDAR-based DEMs and USGS DEMs in Terrain Analysis for Digital Soil Mapping. Geoderma, 170, 217-226.

McKay, J., Grunwald, S., Shi, X., Long, R., 2010. Evaluation of the Transferability of a Knowledge-Based Soil-Landscape Model. In: J.L. Boettinger, D.W. Howell, A.C. Moore, A.E. Hartemink & S. Kienast-Brown (Eds.), Digital Soil Mapping: Bridging Research, Environmental Application, and Operation. Springer, New York, pp. 165-179.

Shi, X., Long, R., DeKett, R., McKay, J., 2009, Integrating Different Types of Knowledge for Digital Soil Mapping, Soil Science Society of America Journal, 73, 1682-1692