Identifying Ecological Sites, and their susceptibility to human disturbance, in the North Central Appalachians.

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Thanks to: Paul Roth (PADCNR); Dave Clausnitzer (USDA-NRCS); Curtis Talbot (USDA-NRCS); Skye Wills (USDA-NRCS);Brandon Bestelmeyer (USDA-ARS); Jeff Herrick (USDA-ARS); Mike Duniway (USGS).

Before we start…key papers to read

- Bestelmeyer et al 2003. Development and Use of State-and-Transition Models for Rangelands. J. of Range Mgmt.56:114-126.
- Bestelmeyer et al 2004. Land management in the American Southwest: A state-and-transition approach to ecosystem complexity. Environmental Management 34:38-51.
- Monger and Bestelmeyer. 2006. The soil-geomorphic template and biotic change in arid and semi-arid ecosystems. Journal of Arid Environments 65:207–218.
- Bestelmeyer et al 2006. Soil-Geomorphic Heterogeneity Governs Patchy Vegetation Dynamics at an Arid Ecotone. Ecology, 87:963-973.
- Bestelmeyer et al. 2009. State-and-Transition models for heterogeneous landscapes: A strategy for development and application. Rangeland Ecol. And Mgmt. 62:1-15.
- Bestelmeyer et al. 2010. Practical Guidance for Developing State-and-Transition Models. Rangelands 32:23-30.
- Duniway et al. 2010. Soil Processes and Properties That Distinguish Ecological Sites and States. Rangelands. 32:9-15.
- Moseley et al. 2010. Ecological Site Development: A Gentle Introduction. Rangelands 32:16-22.
- Townsend.2010. Ecological Site Descriptions: Developmental Considerations for Woodlands and Forests. Rangelands 32:37-42.

Project Goals

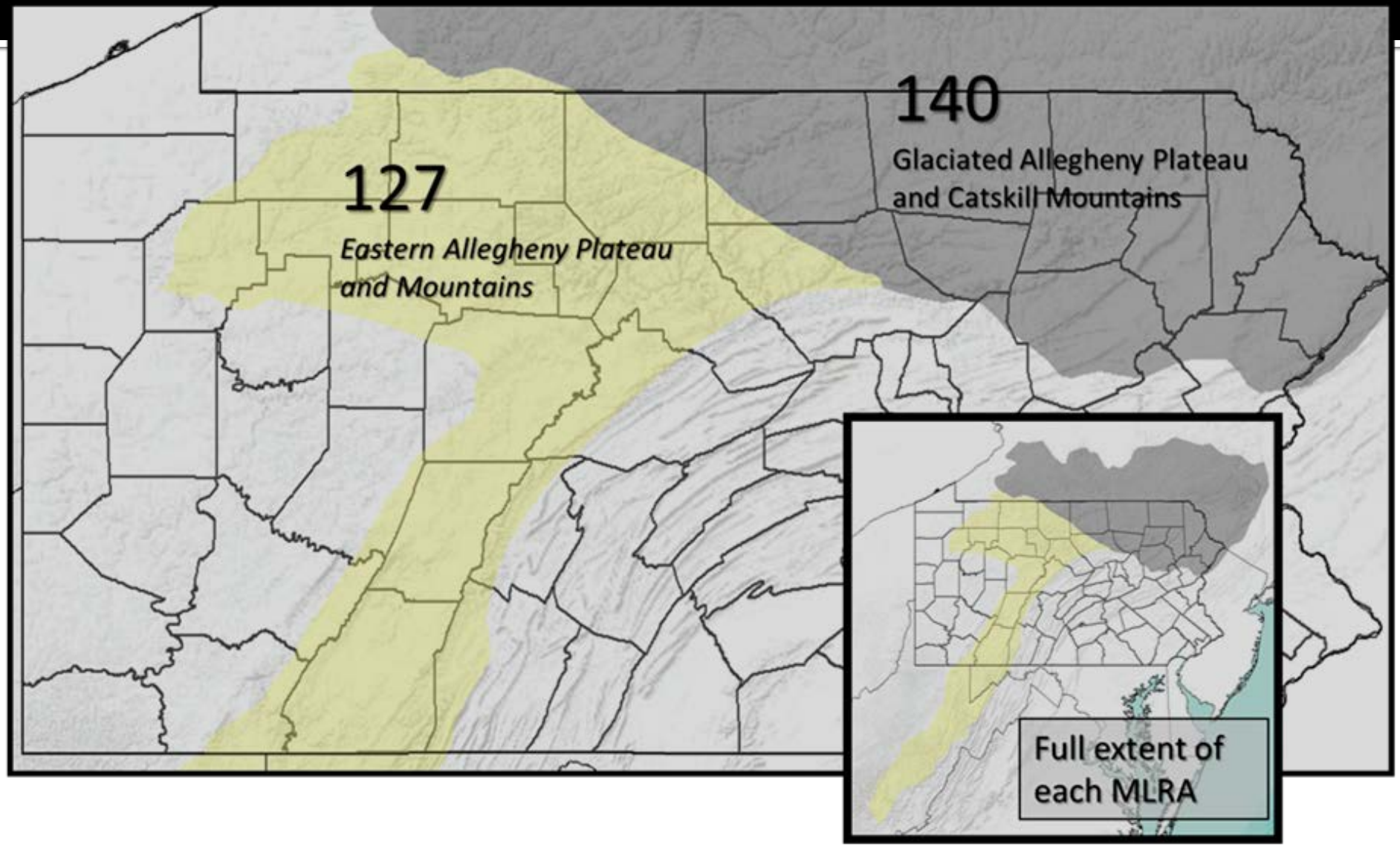
Identify Ecological Sites in MLRAs 127 & 140

Derive State and Transition Models

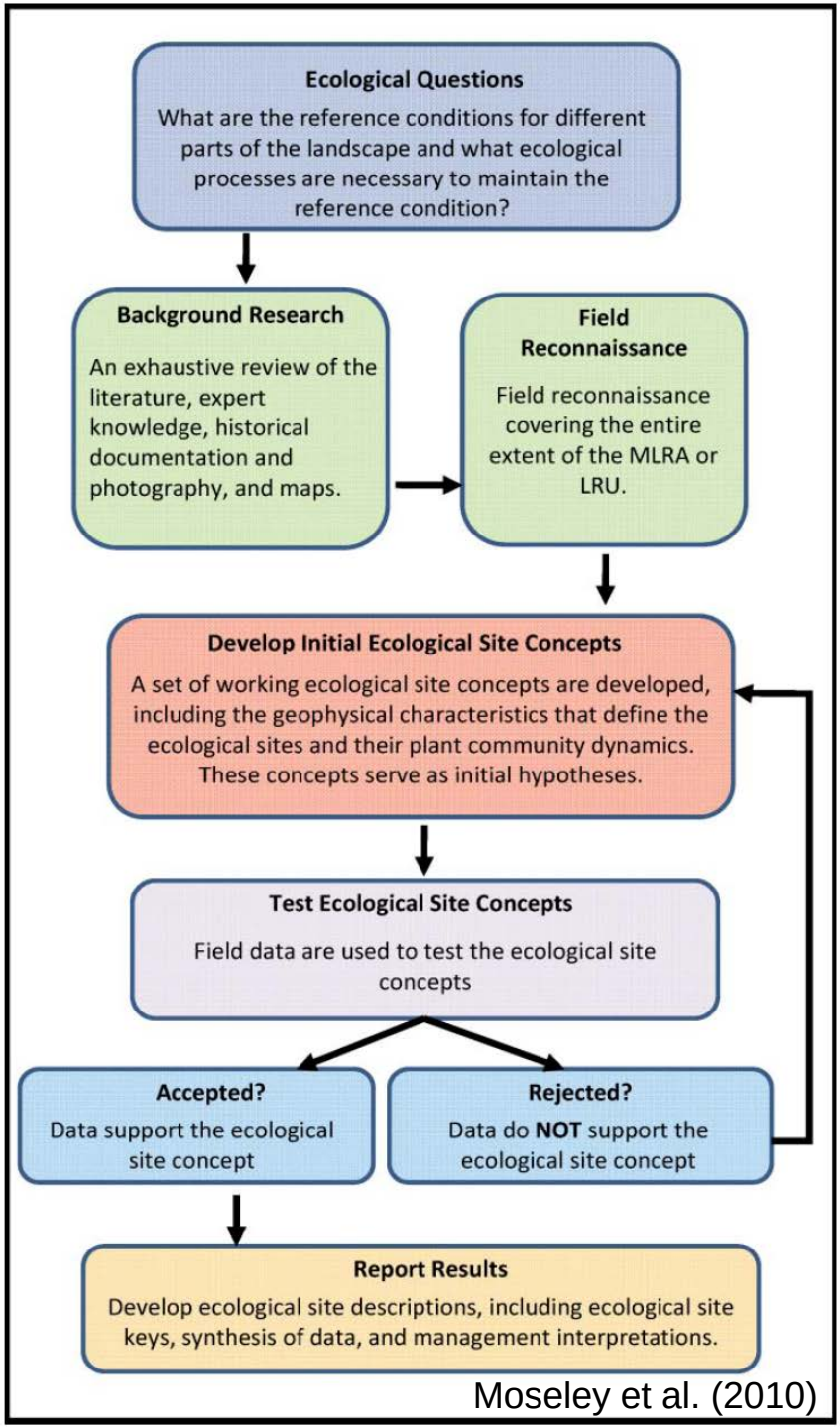
Identify and Measure Dynamic Soil Properties to Quantify Changes in States.

Refine State and Transition Models

Our Study Area



“An ecological site is a distinctive kind of land with specific physical characteristics that differs from other kinds of land in its ability to produce a distinctive kind and amount of vegetation.” *– Nat. For. Manual*



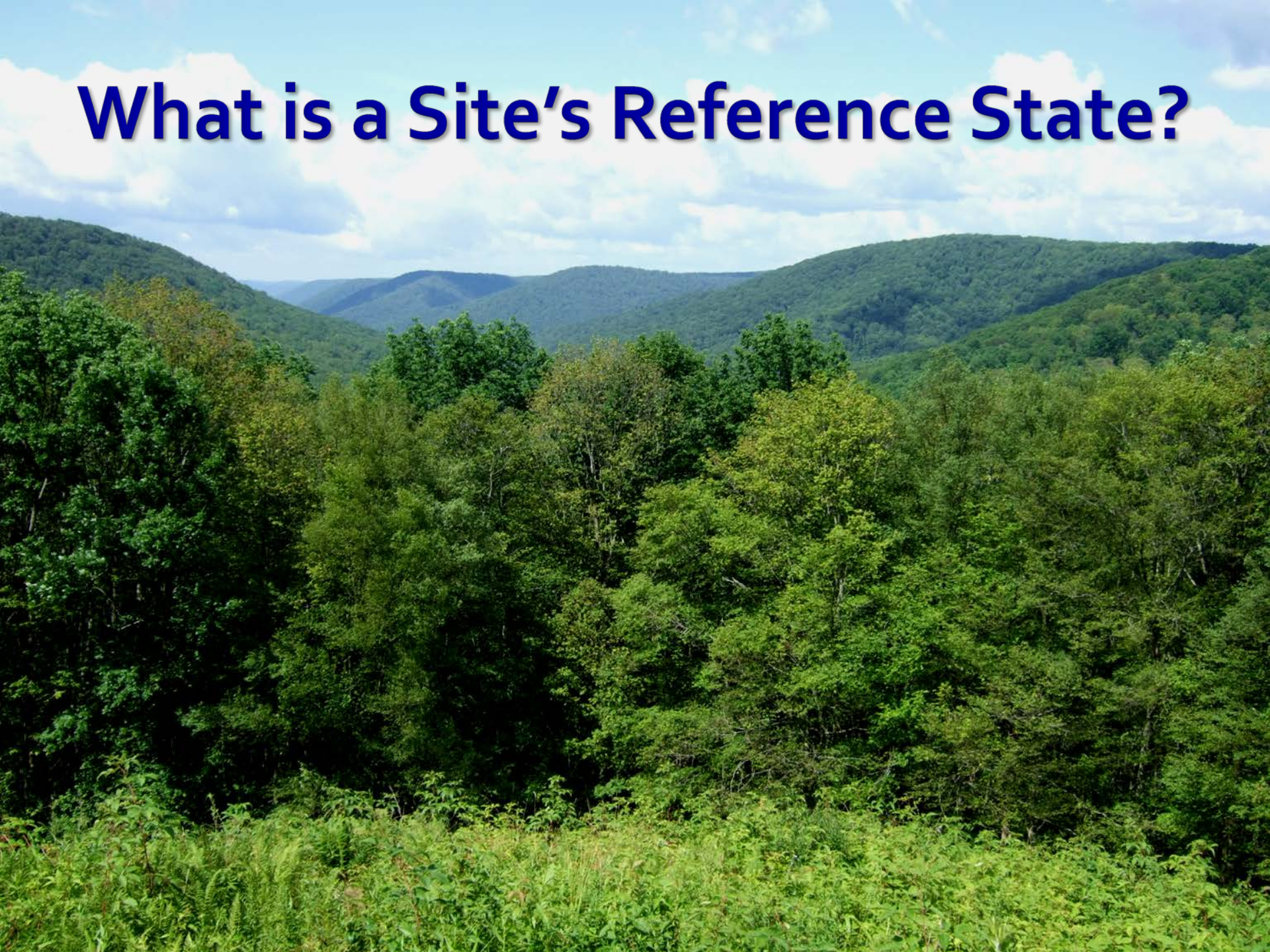
Moseley et al. (2010)

Map Scale and Ecological Sites

- Every Ecological Site is tied to SSURGO mapping unit, but the scale does not have to be equal (Order 3?).
  - Multiple ESs per mapping unit (similar to the concept of inclusions in soil survey)
- Areal extent:
  - Minimum of 200 acres to justify the identification and classification of a new ecological site (this implies the entry of an ecological site name and ID into the Ecological Site Information System).
  - Minimum of 2,000 acres to justify the development of an ecological site description, to include the state and transition model and the accompanying interpretations.

-Curtis Talbot, USDA-NRCS

What is a Site's Reference State?



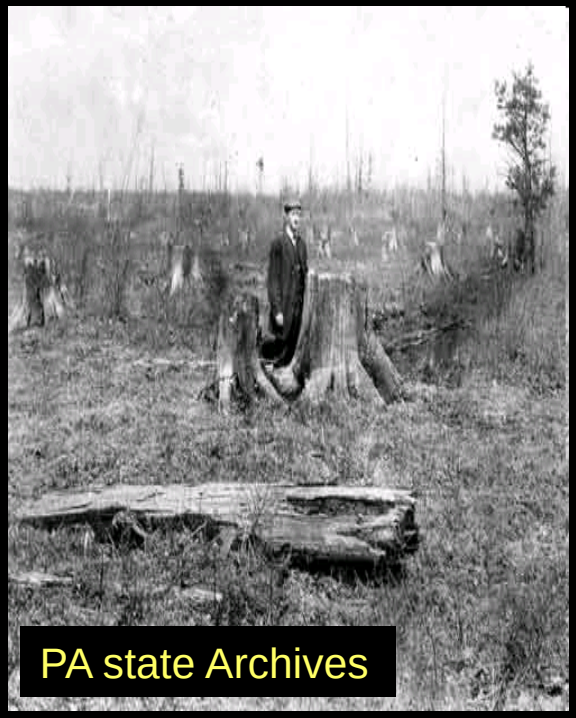
Temporal Forest Composition Change

Species proportion shift following historic logging

Species	*Pre-Settlement*	*Post Settlement*
Beech	44	6
Hemlock	20	6
Sugar Maple	5	13
Red Maple	5	27
White Pine	5	<1
Black Cherry	<1	23

(Whitney, 1990)

Historical Land Disturbance in PA and Possible States.



Other Possible States in PA

Deer browse result (PA DCNR)

Marcellus Shale drilling

USDA-USFS, Allegheny National Forest, Little Arnot Photograph Series

Prior to 1927 harvest

~ 50%; American beech sugar maple and black cherry next most dominant.

Chemical wood harvest

1927 sawtimber removal

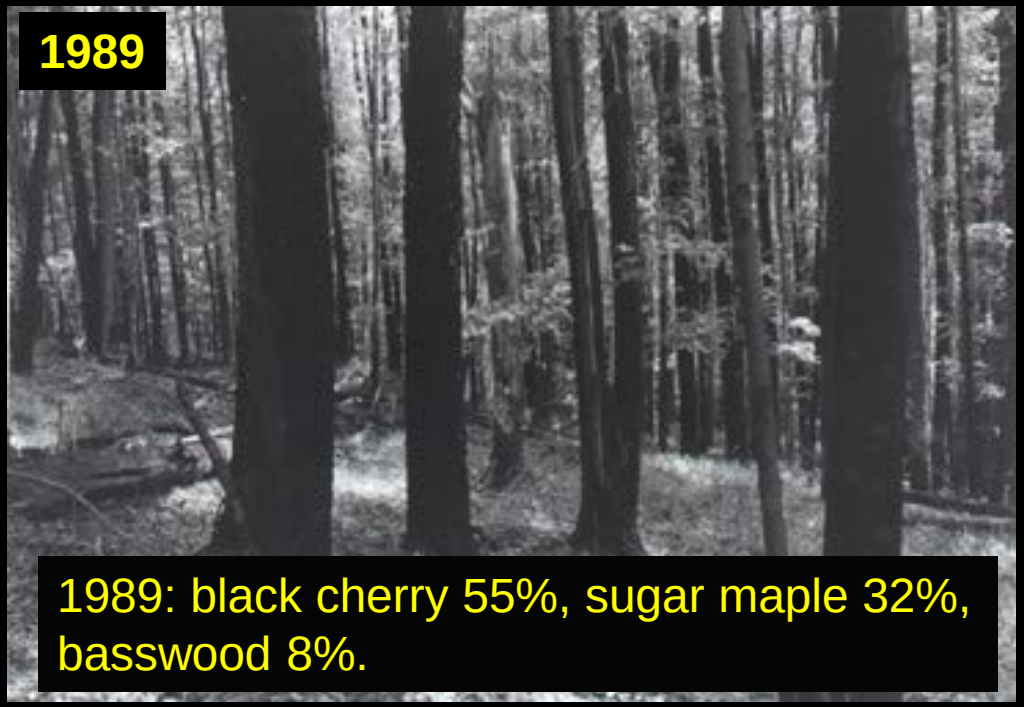
1937

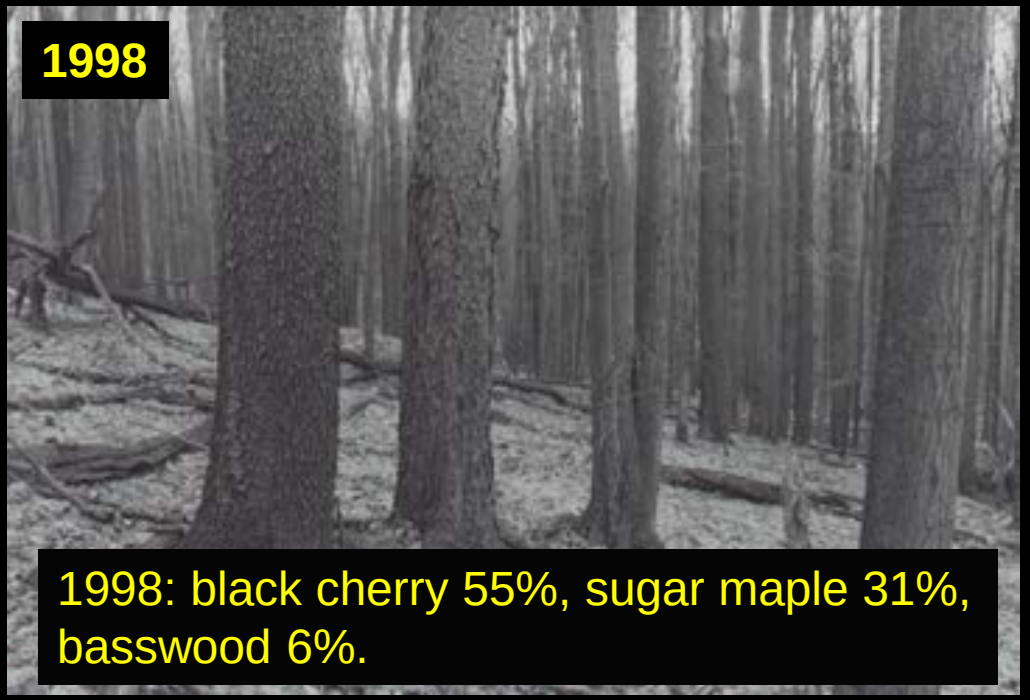
By 1937, shade-intolerant black cherry dominated.

By 1947, shade-tolerant sugar maple develops under the black cherry.

By 1958, black cherry still dominates.

By 1978, black cherry, sugar maple, and basswood comprise most of the stand.

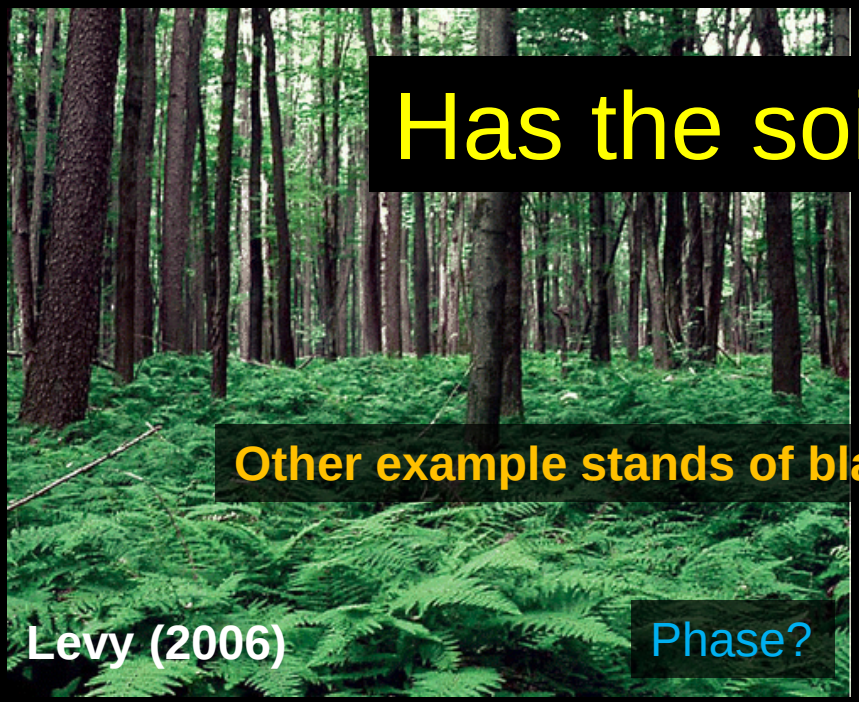

1989
1989: black cherry 55%, sugar maple 32%, basswood 8%.


1998
1998: black cherry 55%, sugar maple 31%, basswood 6%.

Prior to 1927 harvest

1998

Has the soil changed?

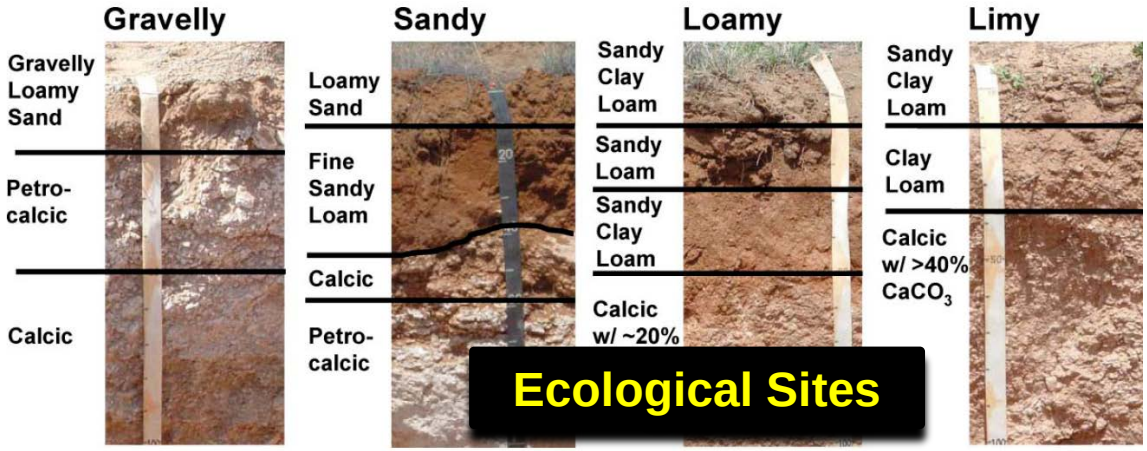


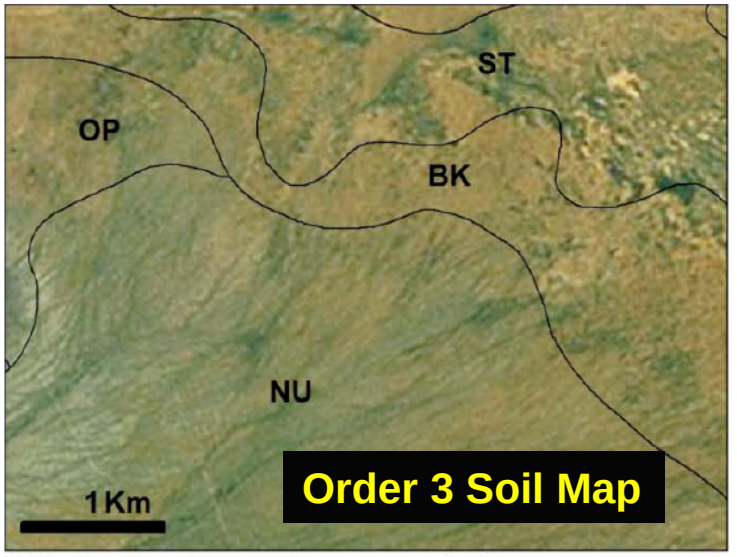
Other example stands of black cherry in Pennsylvania

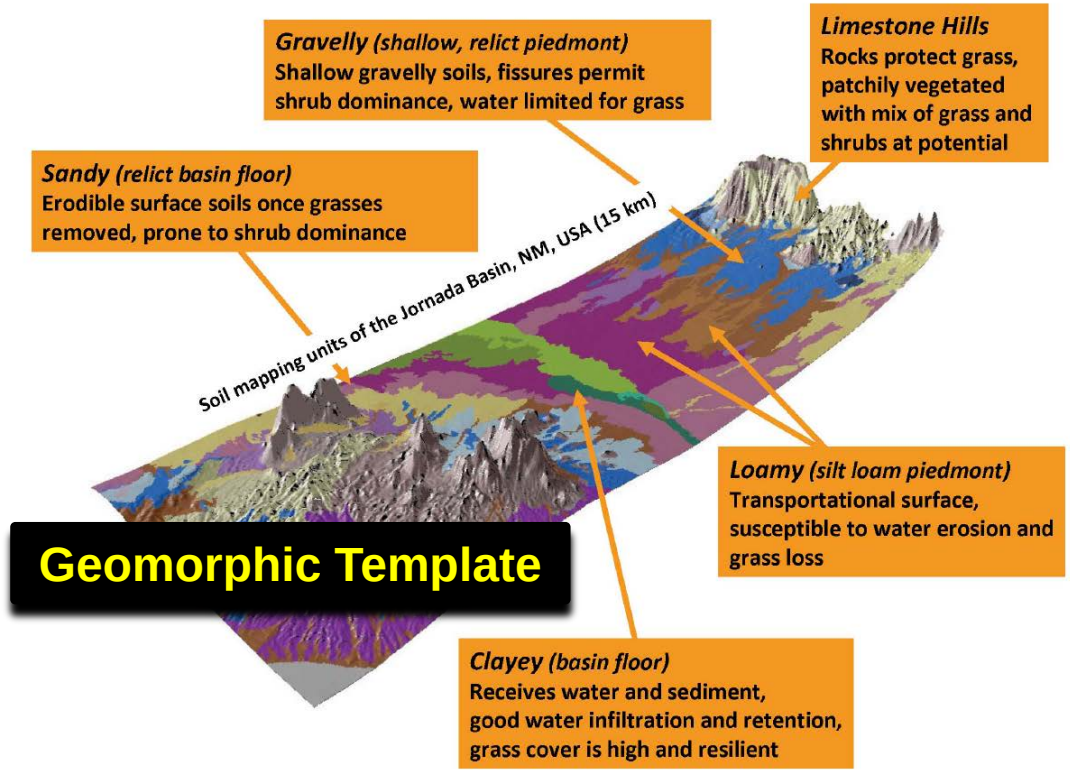
Finding the reference state….

The Geomorphic Template in PA

Duniway et al. (2010)







Bestelmeyer et al. (2010)

BK: Berino-Dona Ana association

50% Berino fine sandy loam, 1-5 % slopes = ***Sandy***

30% Dona Ana fine sandy loam, 1-5% slopes = ***Sandy***

20% inclusions of Reagan, Stellar, Bucklebar, Cacique, and Simona

NU: Nickel-Upton association

50% Nickel very gravelly fine sandy loam, 3-15% slopes = ***Gravelly***

25% Upton gravelly sandy loam, 3-5% slopes = ***Gravelly***

25% inclusions of Cave, Tencee, Simona, and similar soils

OP: Onite-Pajarito association

40% Onite loamy sand, 1-4% slopes = ***Sandy***

30% Pajarito fine sandy loam, 0-5% slopes = ***Sandy***

15% Pintura fine sand, 0-5% slopes= ***Deep sandy***

15% inclusions of Wink, Harrisburg, Simona, Berino, and Dona Ana

ST: Stellar association

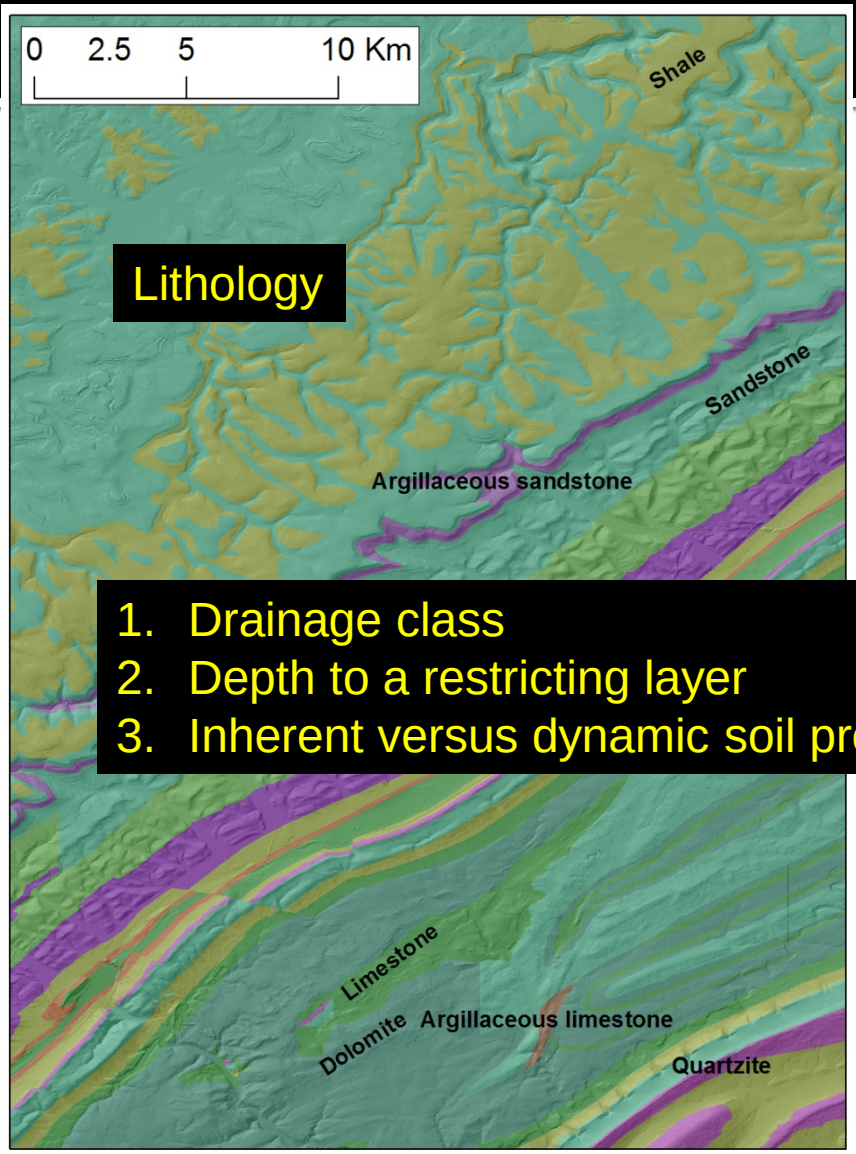
40% Stellar clay loam, 0-3% slopes = ***Clayey***

40% Stellar clay loam, 0-3% slopes, flooded = ***Bottomland***

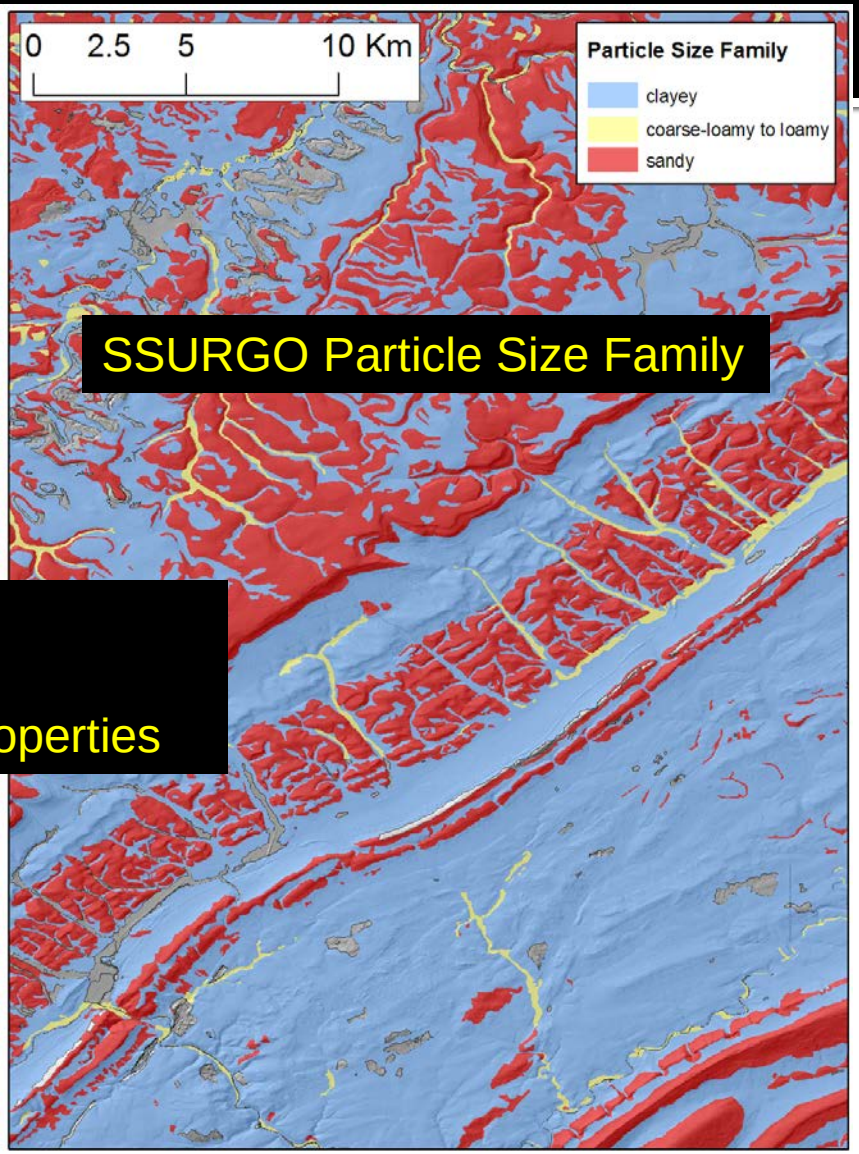
20% inclusions of Reagan, Dona Ana, Berino, and Mimbres

The Geomorphic Template

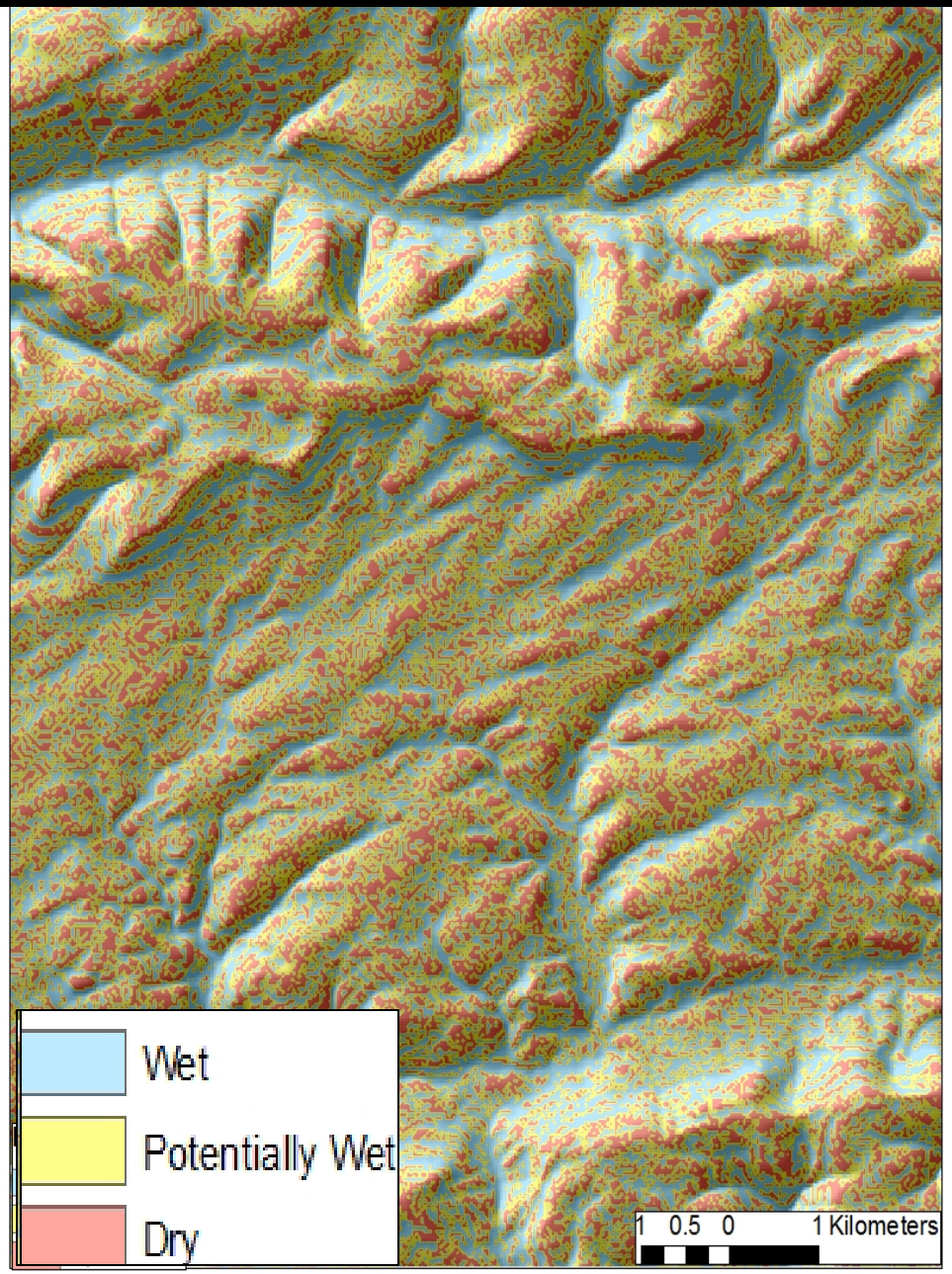
(Monger and Bestelmeyer, 1996)

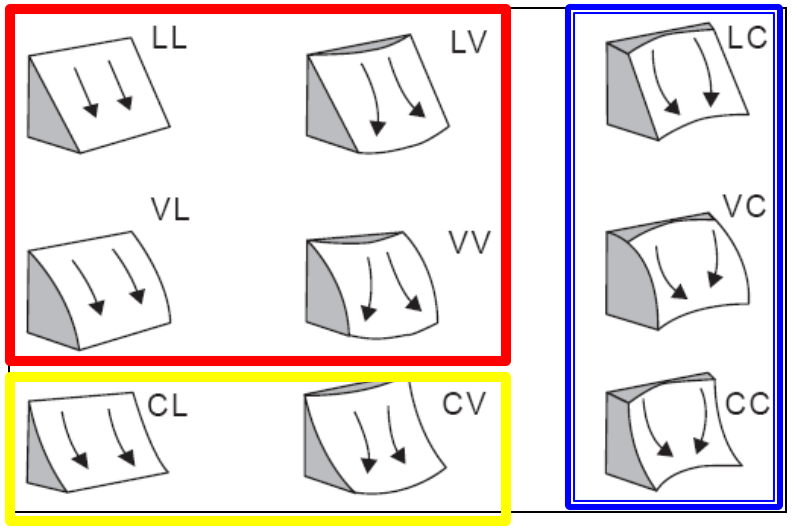


1. Drainage class
2. Depth to a restricting layer
3. Inherent versus dynamic soil properties



The Geomorphic Template (Monger and Bestelmeyer, 1996)





Adapted from Wysocki et al. (2000)

Landform Experiment 1

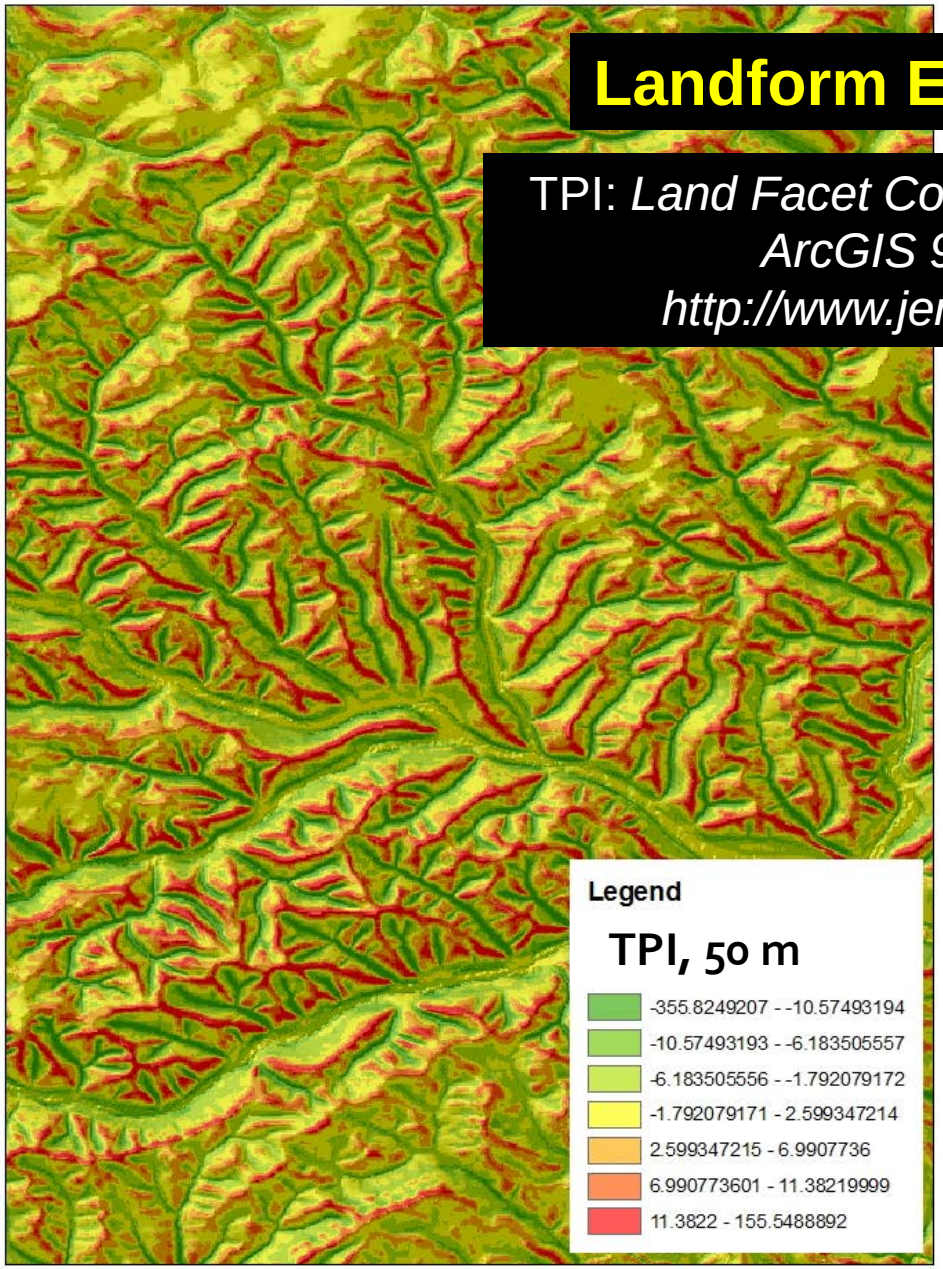
Pennock's Landform Analysis

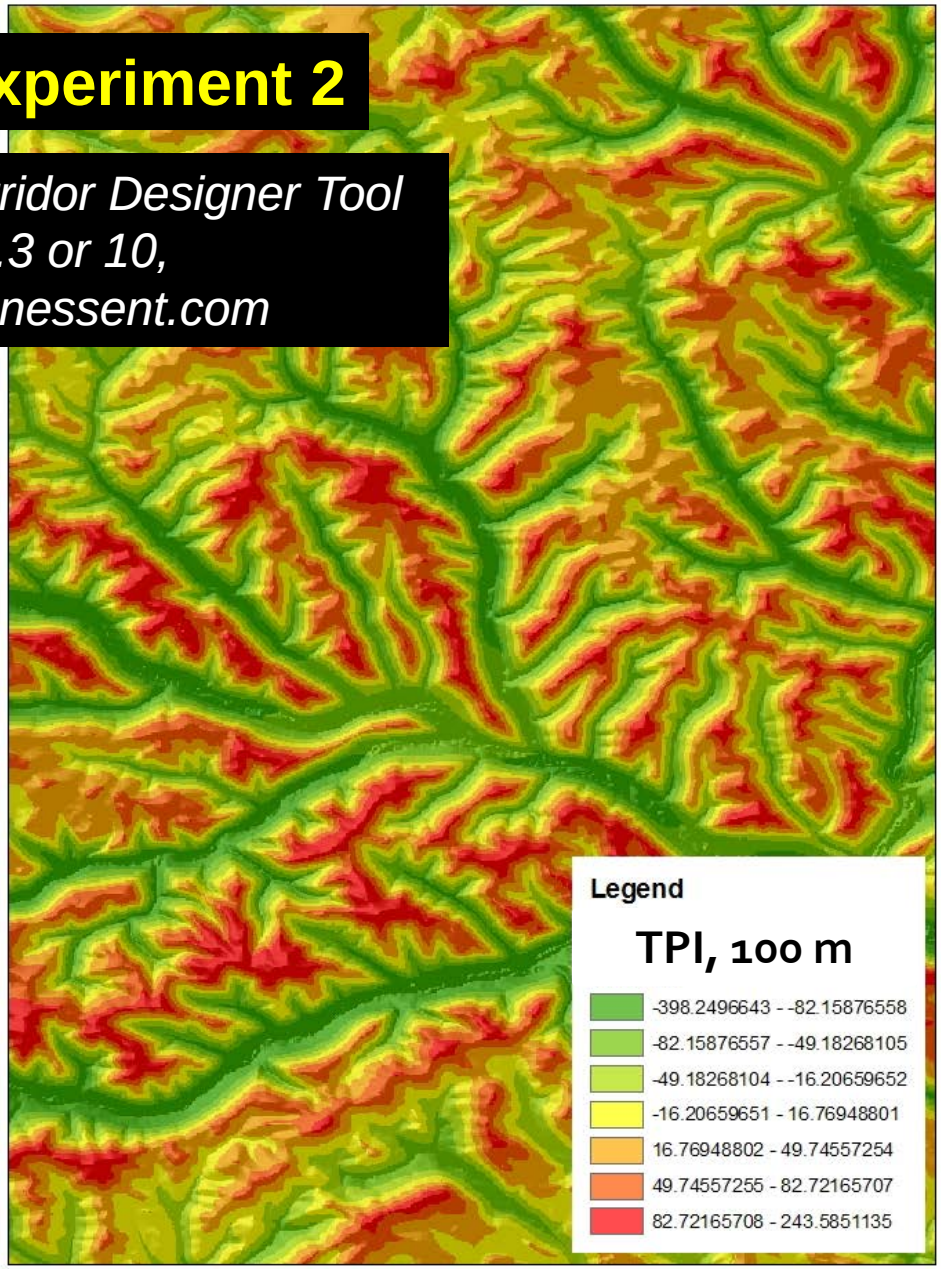
Whitebox Geospatial Analysis Tools*:*
www.uoguelph.ca/~hydrogeo/**Whitebox**/

The Geomorphic Template (Monger and Bestelmeyer, 1996)

Landform Experiment 2

TPI: *Land Facet Corridor Designer Tool*
ArcGIS 9.3 or 10,
http://www.jennessent.com



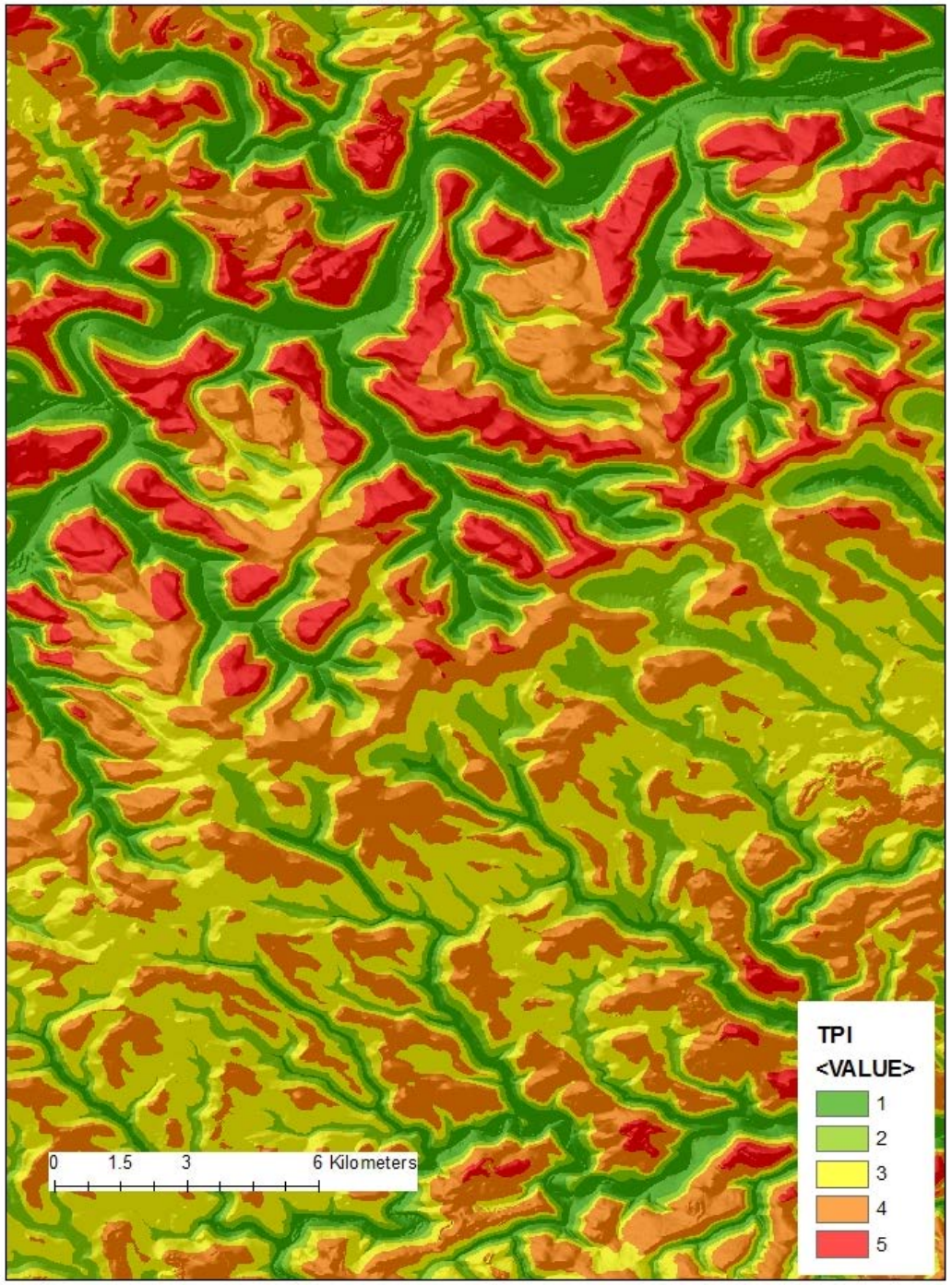


Landform Experiment 3

5 classes

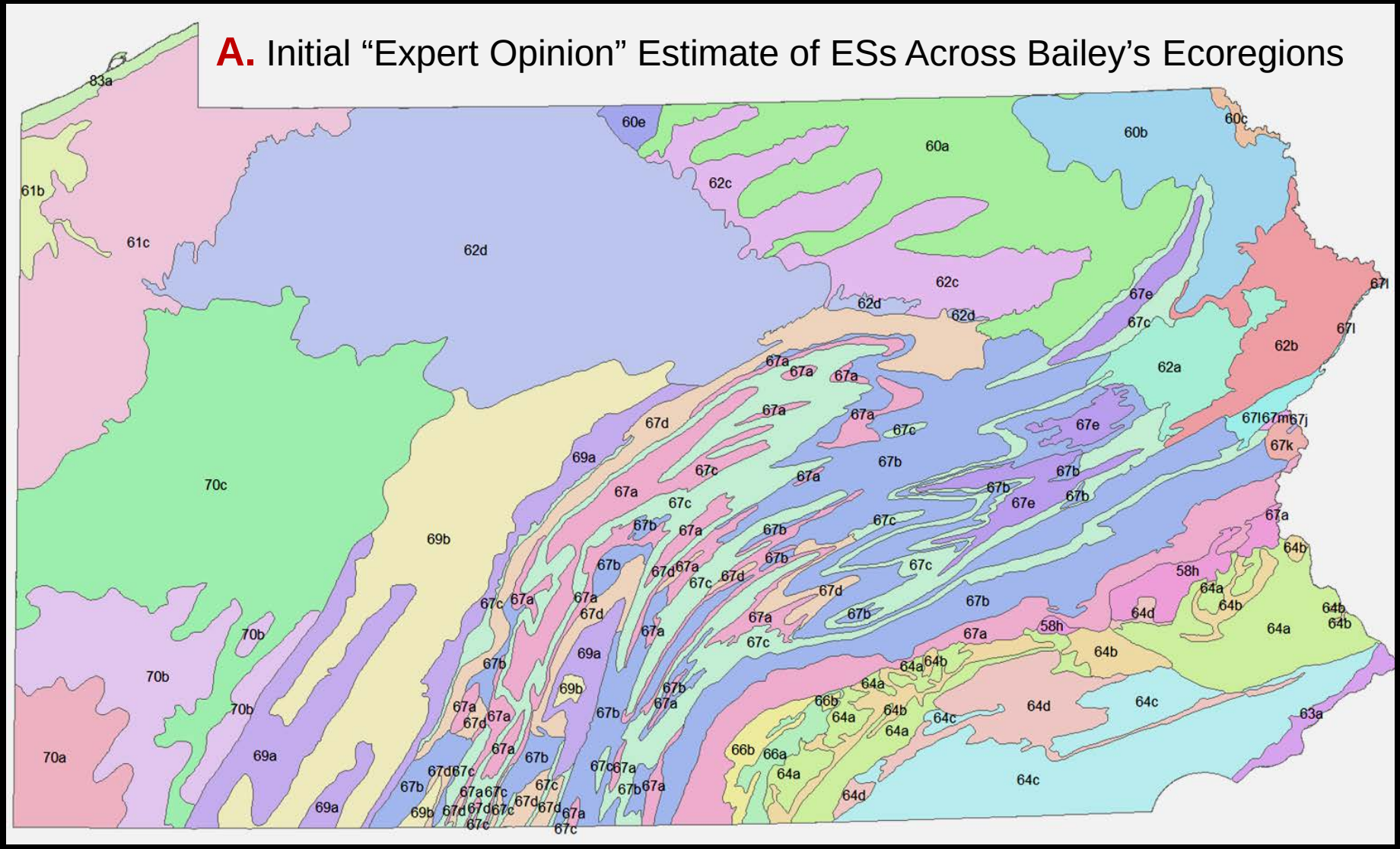
100 m neighborhood, circle

Upper slope break at 8%



Finding the Reference State

Finding Reference States of a Site



Woods et al. (1999)

EPA Lvl 4 Ecoregions

Lots of good info to guide ES development

62e. Low Catskills

The Low Catskills (62e) is a forested and highly dissected ecoregion less than 5 miles (8 km) wide in northeastern Pennsylvania. Here, the Delaware River **has deeply entrenched** into the glaciated Appalachian Plateau, creating cliffs and steep-walled valleys. Many high-gradient tributaries occur and stream organisms associated with riffles are common. **Topography** is rugged for this part of the commonwealth and local relief ranges from about 450 to 800 feet (137-244 m). Crestal elevations are from approximately 1,300 to 1,800 feet (396-549 m) and are high enough to insure a short growing season of about 130 days, varying according to local topography and slope aspect.

The soils of Ecoregion 62e are mostly Inceptisols. Most formed on Olean Till and some developed on Quaternary alluvium. They overlie nearly horizontal, Devonian age sandstone, siltstone, and shale of the Catskill Formation. The **soils** are characterized by stoniness, shallowness, low fertility, and acidity, which, together with the rugged terrain and brief growing season, make the area best suited to woodland (Higbee, 1967). **The natural vegetation** was mostly Northern Hardwoods (dominants: sugar maple, yellow birch, beech, and hemlock) (Cuff and others, 1989, p. 52). Some wetland vegetation occurs on poorly drained sites, and northern rock plants grow on the Delaware River cliffs in northeastern Wayne County (Erdman and Wiegman, 1974, p. 50).

The boundary between Ecoregion 62e and the less dissected Northeastern Uplands (60b) occurs at the forest density and topography break shown on the Scranton 1:250,000-scale topographic map; Ecoregion 62e is much more rugged and wooded than Ecoregion 60b. Ecoregion 62e extends across the Delaware River into New York, where it becomes much more extensive.

1.

2.

3.

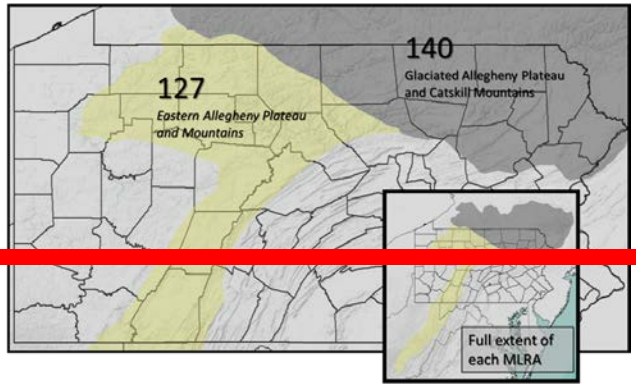
4.

B. The dominant soil series within the two MLRAs, their drainage class, parent material, surface textures, and USDA Taxonomic Classification. Groupings of two or three soil series represent “topographic catenas” of common soils to an area.

Soil Series	Drainage Class[a]	Parent Material	Surface Texture	Subgroup Classification	MLRA of Occurrence	
Wellsboro	MW	Acid Red Till	Silt Loam	Typic Fragiudepts	140	
Lackawanna	W	Acid Red Till	Silt Loam	Typic Fragiudepts	140	1
Morris	W	Acid Red Till	Loam	Aeric Fragiaquept	127 and 140	
Volusia	SPD	Acid Brown Till	Silt Loam	Aeric Fragiaquept	140	
Mardin	W	Acid Brown Till	Silt Loam	Typic Fragiudept	140	2
Lordstown	W	Acid Brown Till	Silt Loam	Typic Dystrochrept	127 and 140	
Hazleton	W	Acid Sandstone	Sandy Loam	Typic Dystrochrept	127	3
Cookport	MW	Acid Sandstone	Loam	Aquic Fragiudult	127	
Gilpin	W	Shale and Sandstone	Silt Loam	Typic Hapludult	127 and 140	
Wharton	W	Shale and Siltstone	Silty Clay Loam	Aquic Hapludult	127	4
Ernest	MW or SWP	Acid shale/siltstone	Silt Loam	Aquic Fragiudults	127	
Leck-Kill	W	Acid Red Shale	Silt Loam	Typic Hapludult	127	
Hartleton	W	Acid Red Shale	Silt Loam	Typic Hapludult	127 and 140	5
Albrights	SPD	Acid Red Till	Silt Loam	Aquic Fragiudalf	127 and 140	
Chenango	W	Alluvium	Silt Loam	Typic Dystudept	127 and 140	
Pope	W	Silty Alluvium	Loam	Fluventic Dystrochrept	127 and 140	6
Holly	P	Loamy Alluvium	Silt Loam	Fluvaquentic Endoaquept	127 and 140	

Initial identification of Reference States

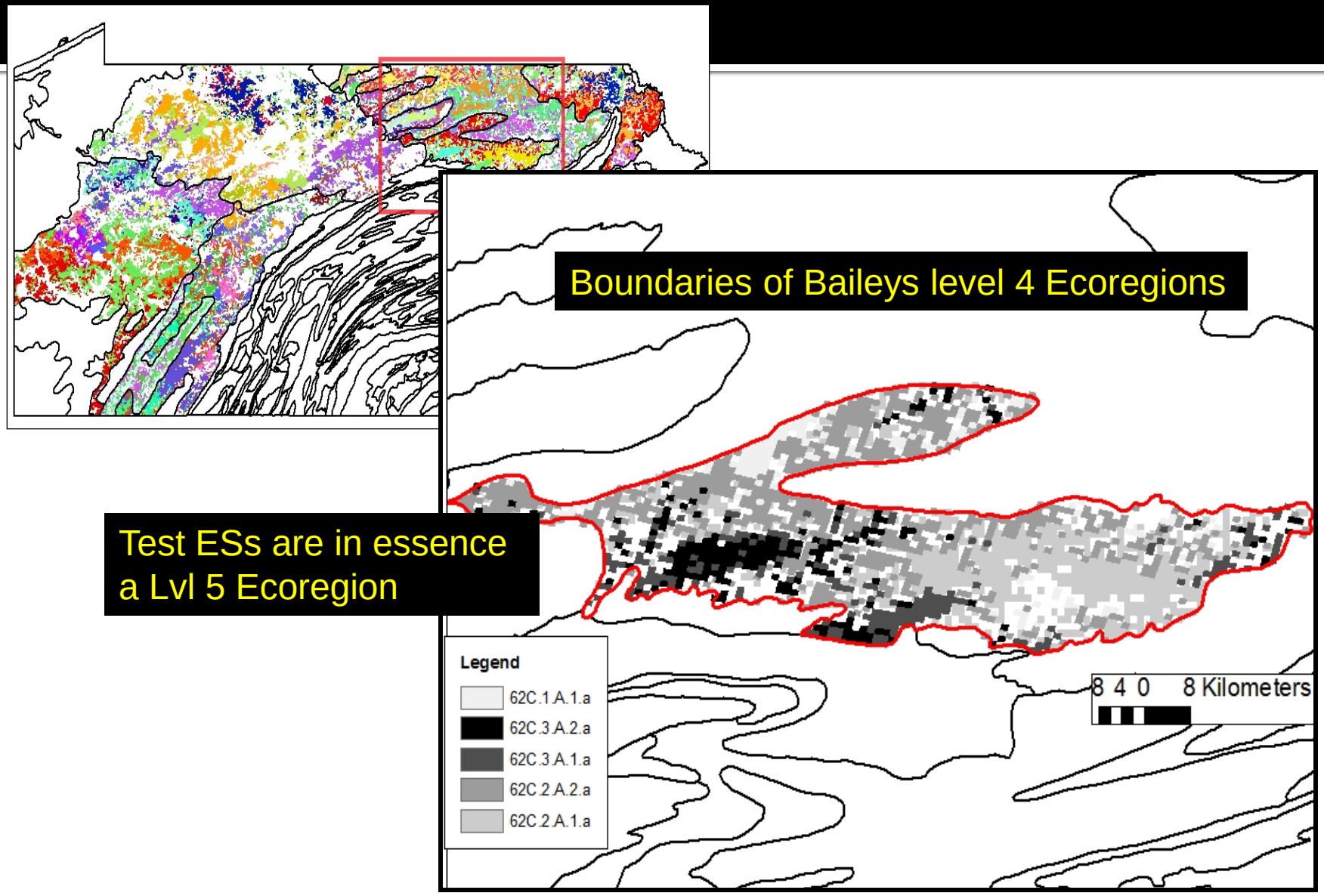
MLRA	Level 4 Ecoregions	Level 5 Ecoregions
127	69B, 62D, 69A	32
140	60B, 62C, 60A	34



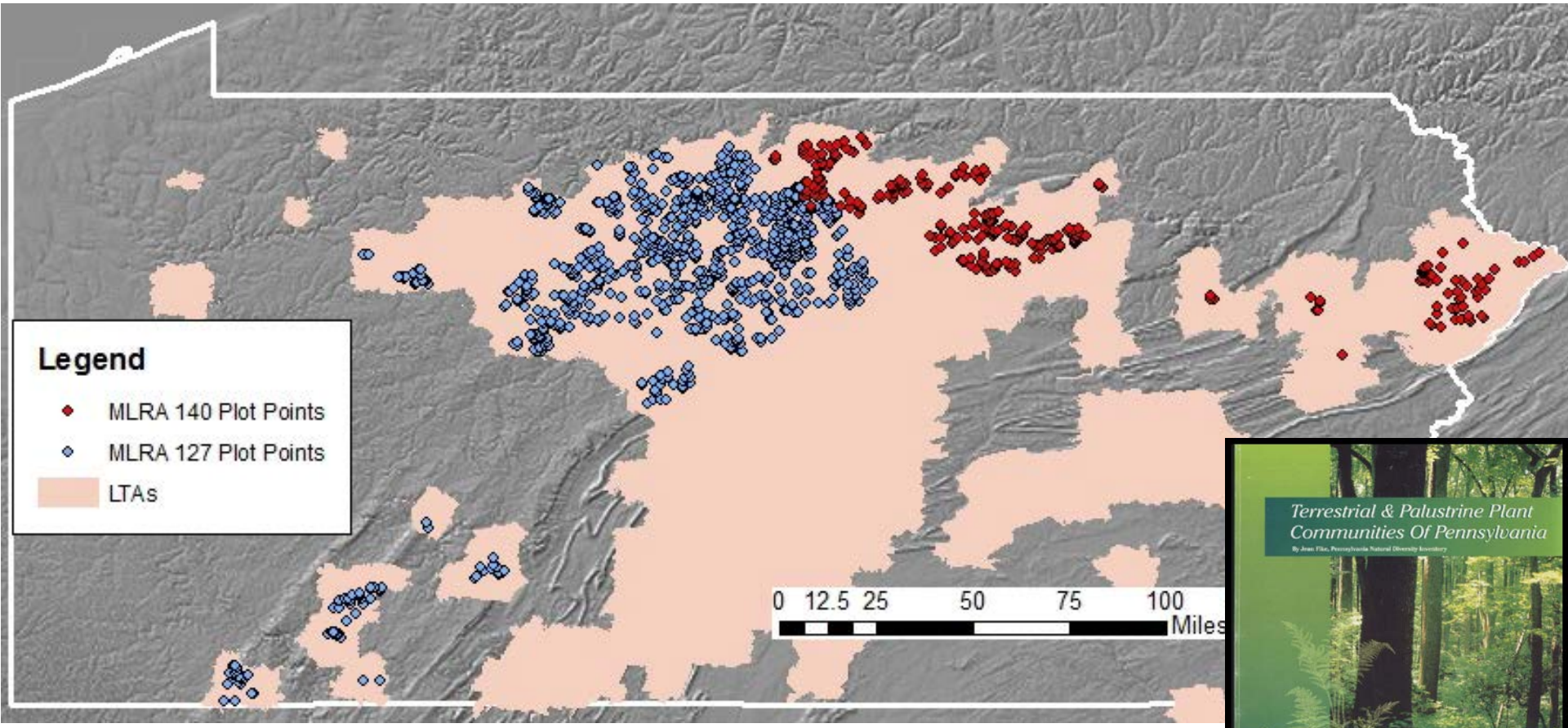
Level 6

Level V Ecoregion	FIA Forest Cover (1 km)	Elevation (m)	Dominant Soi Series	Landscape Wetness Class (% of Ecoregion)	Broad series characteristics
69B.2.A.1.a	Oak-Hickory	500-700	Cavode Rayne/Gilpin Gilpin/Wharton	Wet (51%) Potentially Wet (13%) Dry (36%)	Silty clay loam, shallow Channery, silt loam, shallow Silt loam, shale
69A.1.A.1.a	Oak-Hickory	750-850	Cookport Laidig Dekalb/Hazleto	Wet (43%) Potentially Wet (17%) Dry (40%)	Loam, Bx Channery loam, Bx Very cobbly, sandly loam,

Initial identification of Reference States



c. PA DCNR LTAs and plot data

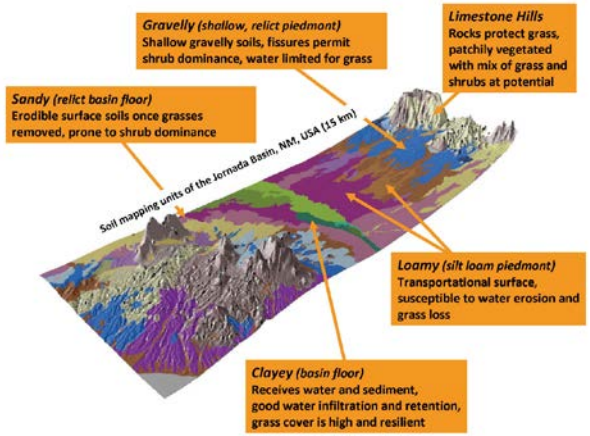


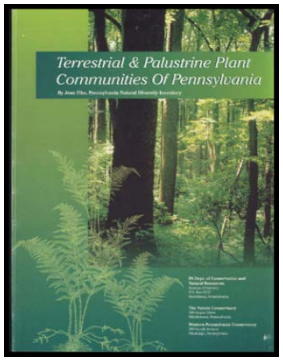
PA DCNR Land Type Associations

Maybe too specific for ESs, but can be grouped

Terrestrial Forests:

AD	Dry Oak – Mixed Hardwood Forest
AH	Dry Oak – Heath Forest
AR	Red Oak – Mixed Hardwood Forest
BB	Northern Hardwood Forest
BC	Black Cherry – Northern Hardwood Forest (Allegheny Hardwoods)
CC	Red Maple Forest
CS	Sugar Maple – Basswood Forest
DD	Aspen / Grey (Paper) Birch
EO	Pitch Pine – Mixed Oak Forest (Oak – Hard Pine)
EV	Virginia Pine – Mixed Hardwood Forest
FF	Hemlock (White Pine) Forest
FA	Dry White Pine (Hemlock) – Oak Forest
FB	Hemlock (White Pine) – Northern Hardwood Forest
FR	Hemlock (White Pine) – Red Oak – Mixed Hardwood Forest
FT	Hemlock - Tuliptree – Birch Forest
FM	Hemlock - Rich Mesic Hardwood Forest





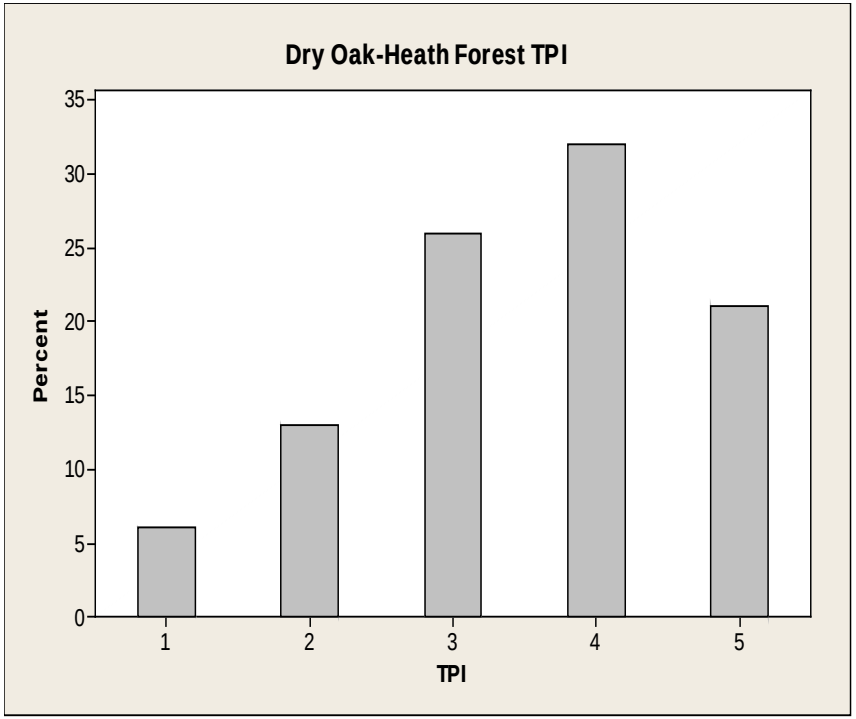
Red maple (terrestrial) forest

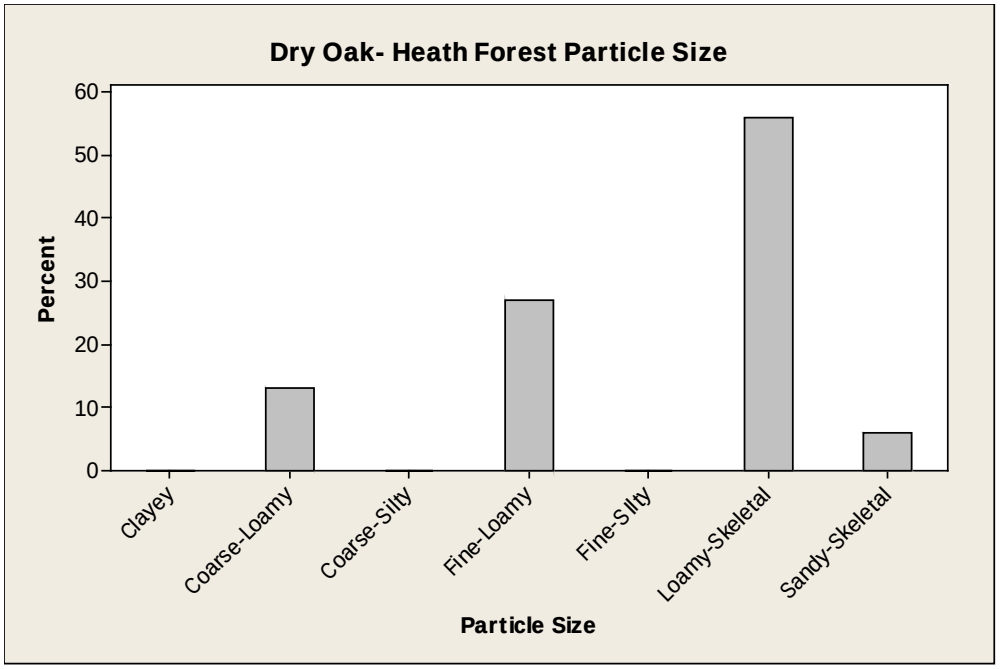
This is generally an early-to mid-successional type that is becoming increasingly common as red maple increases in Pennsylvania's forests. This type is seldom pure, but *Acer rubrum* (red maple) dominates the tree stratum. Associate species include *Quercus* spp. (oaks), *Betula lenta* (sweet birch), *Liriodendron tulipifera* (tuliptree), *Carya* spp. (hickories), *Fraxinus americana* (white ash), *Prunus serotina* (wild black cherry), and other hardwoods. Because *Acer rubrum* (red maple) has such a wide ecological amplitude, this type may occur from the upper through the lower slope. Accordingly, the associated species vary greatly. Some shrubs commonly present include *Viburnum acerifolium* (maple-leaved viburnum), *Lindera benzoin* (spicebush), *Hamamelis virginiana* (witch-hazel), and *Kalmia latifolia* (mountain laurel), *Gaylussacia baccata* (black huckleberry), and *Cornus florida* (flowering dogwood). More information is needed regarding the ecology and species composition of this community type.

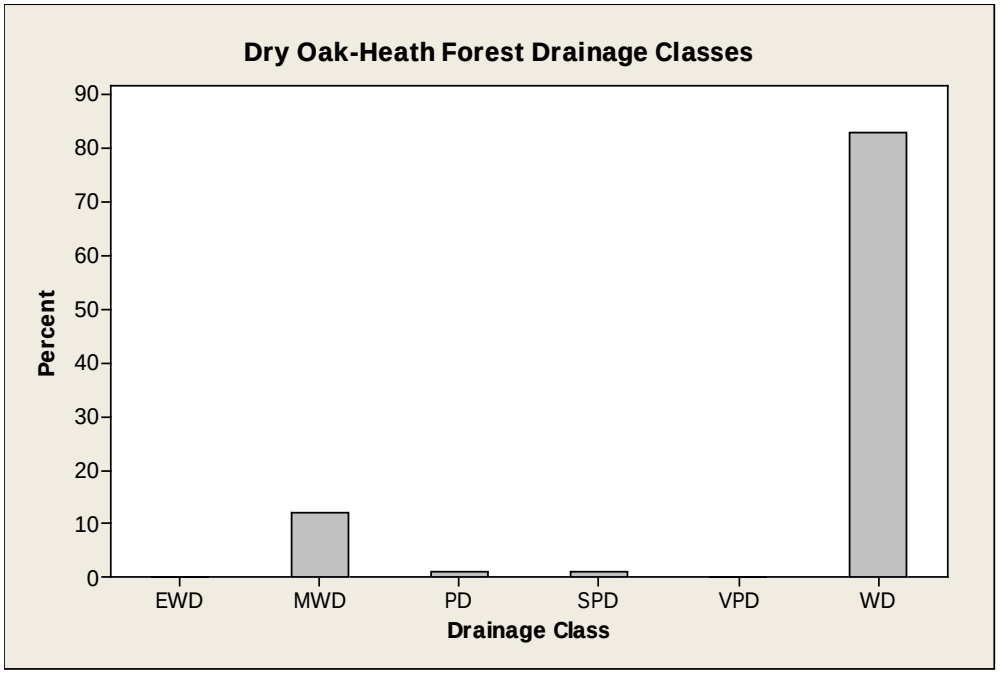
Quantifying Unique ESs

Frigid, Non-Fragi, Skeletal Site

Reference State: **Dry Oak-Heath Forest**







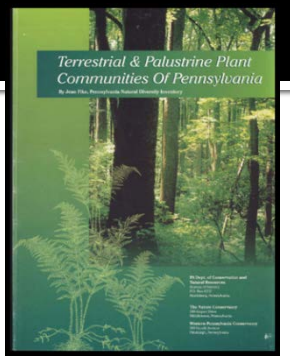
Percent distribution of variables across each LTA

	Drainage Class			*Climate*			*Subsoil Particle Size Family*		
	Droughty	**Neither**	**Wet**	**Frigid**	**Cool**	**Warm**	**Loamy**	**Skeletal**	**Fine**
Dry Oak-Mixed Hardwood	76.39	19.51	4.1	8.5	81.16	10.34	47.34	51.79	0.87
Dry Oak-Heath Forest	84.53	12.83	2.65	2.43	88.74	8.83	38.33	61.12	0.55
Northern Hardwood Forest	82.2	13.42	4.39	22.44	77.1	0.46	37.22	62.08	0.7
Black Cherry/Northern Hardwood	68.06	25.91	6.04	57.73	41.87	0.41	58.74	39.49	1.77

	Aspect				*Topographic Position Index*		
	North	**East**	**South**	**West**	**TPI 1**	**TPI 2**	**TPI 3**
Dry Oak-Mixed Hardwood	25.28	19.21	35.85	19.66	31.37	28.87	39.77
Dry Oak-Heath Forest	28.26	16.64	36.2	18.9	19.48	26.21	54.3
Northern Hardwood Forest	31.44	21.29	26.44	20.83	43.03	24.61	32.37
Black Cherry/Northern Hardwood	25.73	21.26	32.57	20.44	19.13	32.11	48.75

Next: *use the PA DCNR plot data to further quantify whether LTAs in the MLRAs are unique or can be grouped.*

ES: Frigid, Non-Fragi, Sandy Skeletal

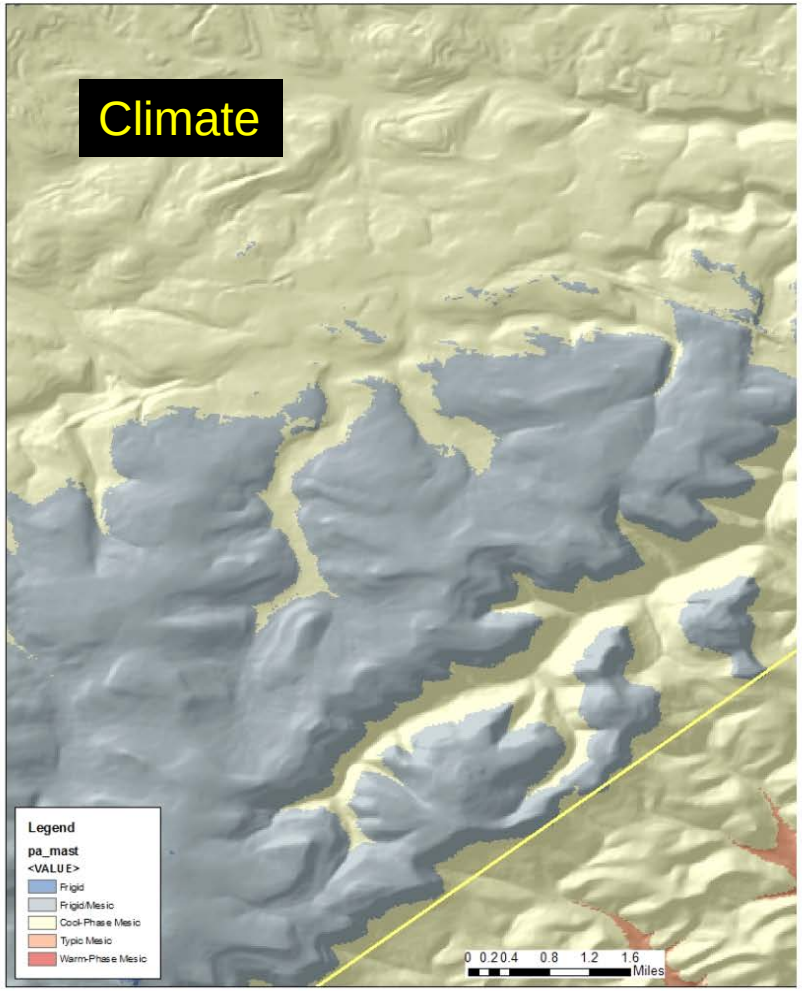


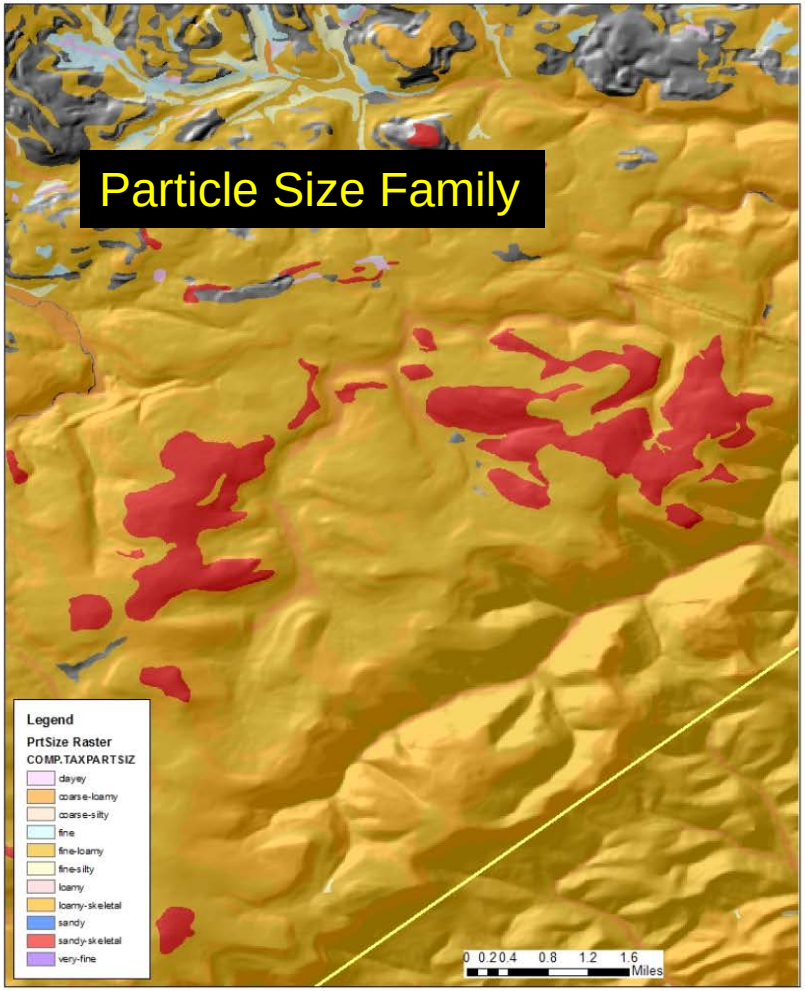
- Temperature Range- Frigid (<8 °C)
- Soil Association- Leetonia
- Particle Size Family - Sandy Skeletal
- Landscape Position- Steep ridge crests and long side slopes
- Soil pH- Extremely Acid
- Drainage- Well to excessively well drained
- Limiting feature and depth - Rock fragment % or depth to bedrock
- Possible Plant Communities
  - Pitch pine- scrub oak woodlands (potential reference state)
  - Pitch pine- mixed hardwood woodland (potential reference state)
  - Red spruce rocky summit (disturbed state)
  - Scrub oak shrublands (disturbed state)
  - Low heath shrublands (disturbed state)
  - Mountain ash shrublands (disturbed state)

Wet equivalent: Black Spruce or Tamarack

ES: Frigid, Non-Fragi, Sandy Skeletal

Soil Temperature and Particle Size for #9

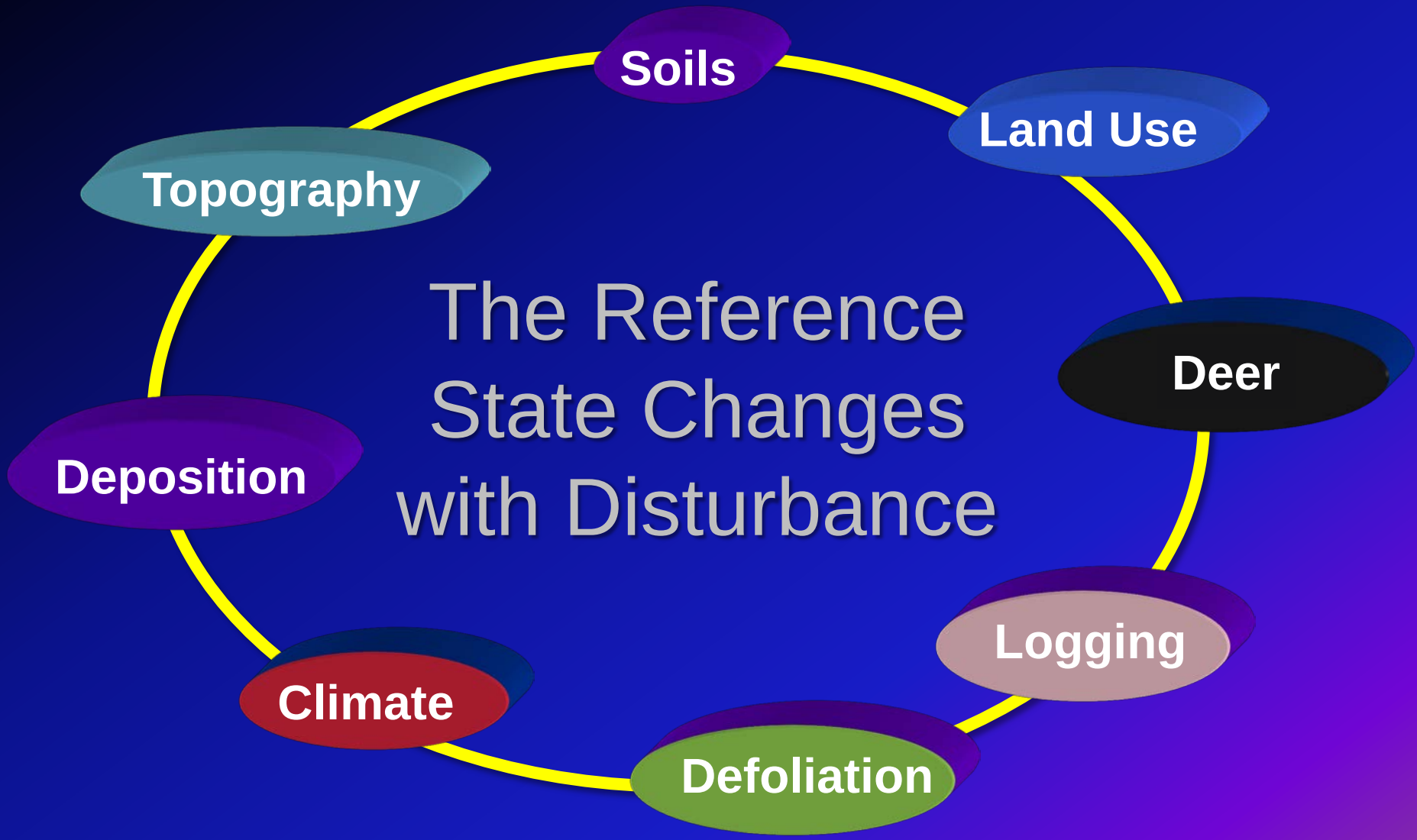




MLRA 127:Somerset, Clearfield, and Cambria Counties

S&T Model Development and Dynamic Soil Properties

Reference State = Least Disturbed



Bunchgrass Savanna S&T Model

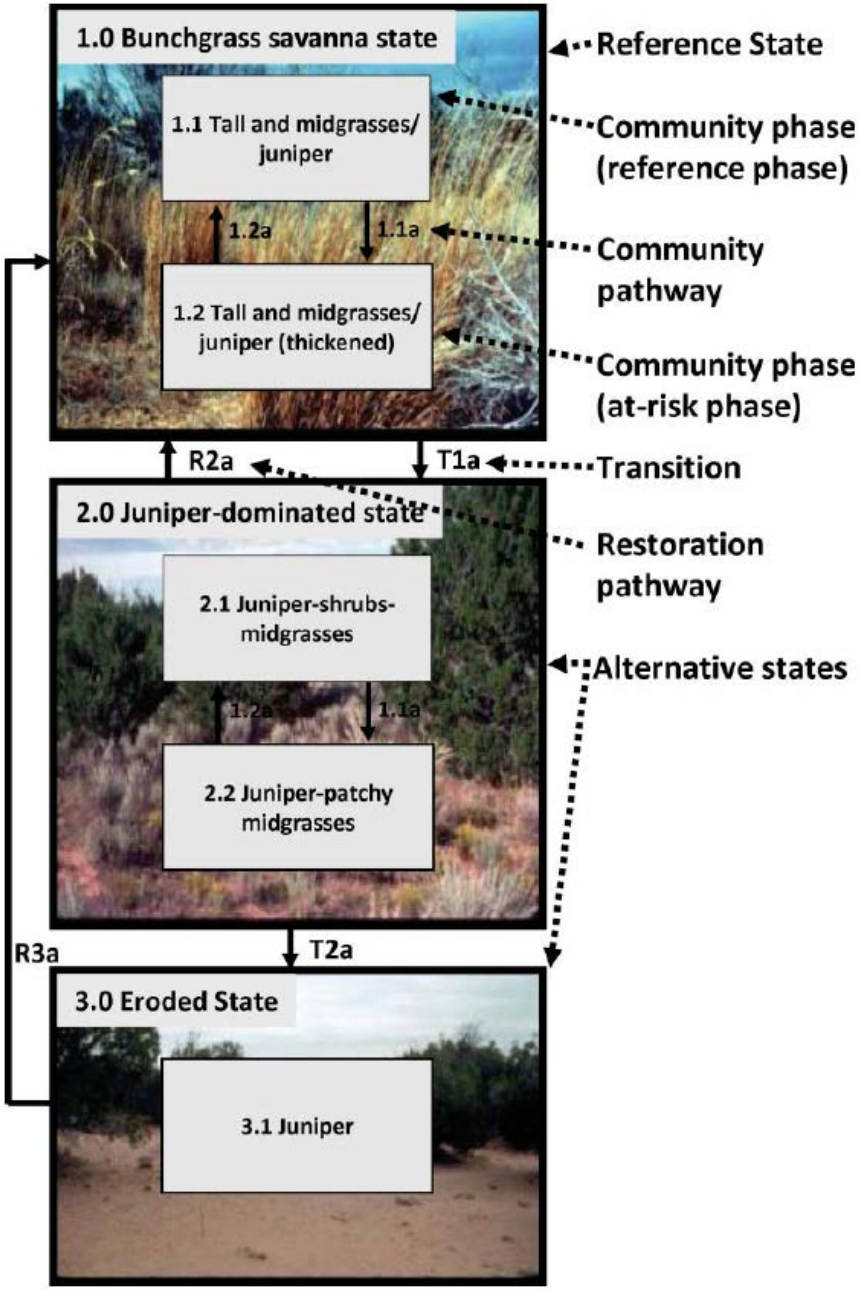


Fig 2. from Bestelmeyer et al. (2010)

State and Transition Models

Unglaciated, loamy

Reference State

Black Cherry S&T Model

Dynamic Soil Properties

- Soil Properties that exhibit change within a human time scale, due to natural or anthropogenic disturbances.
  - See Seybold et al. (1999) and Tugel et al. (2005) for further discussion.
- DSPs can act as indicators of an Ecological Site.
- DSPs can quantify the degree of DSP change on an ES, and thus identify a new "State".

Do properties used on Rangeland and Western Forests work in the East?

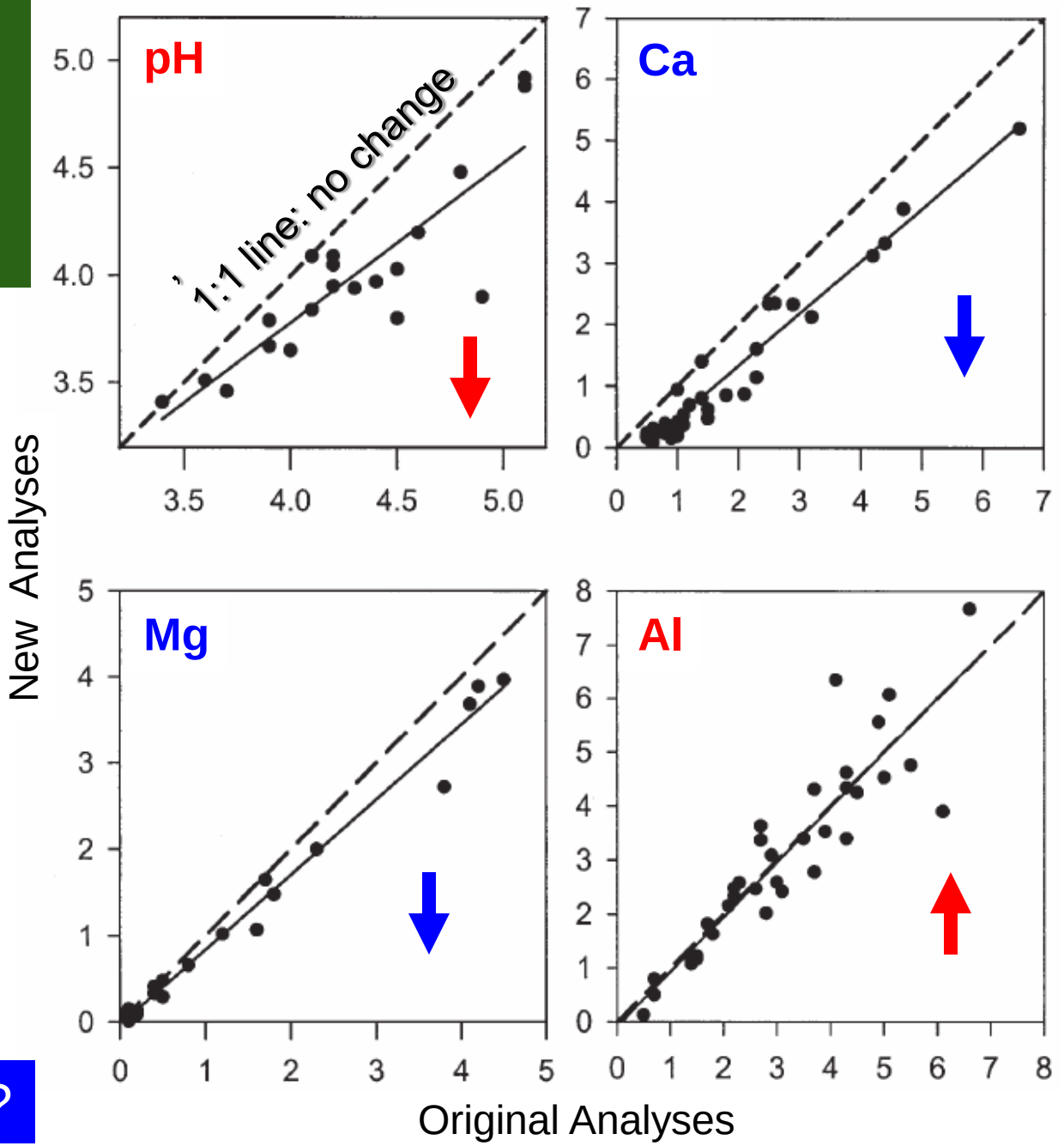
Can we measure soil change across potential States?

Soil chemistry change over 30 years

Original samples taken in 1967

Is there a new “State”?

Bailey et al. (2005)

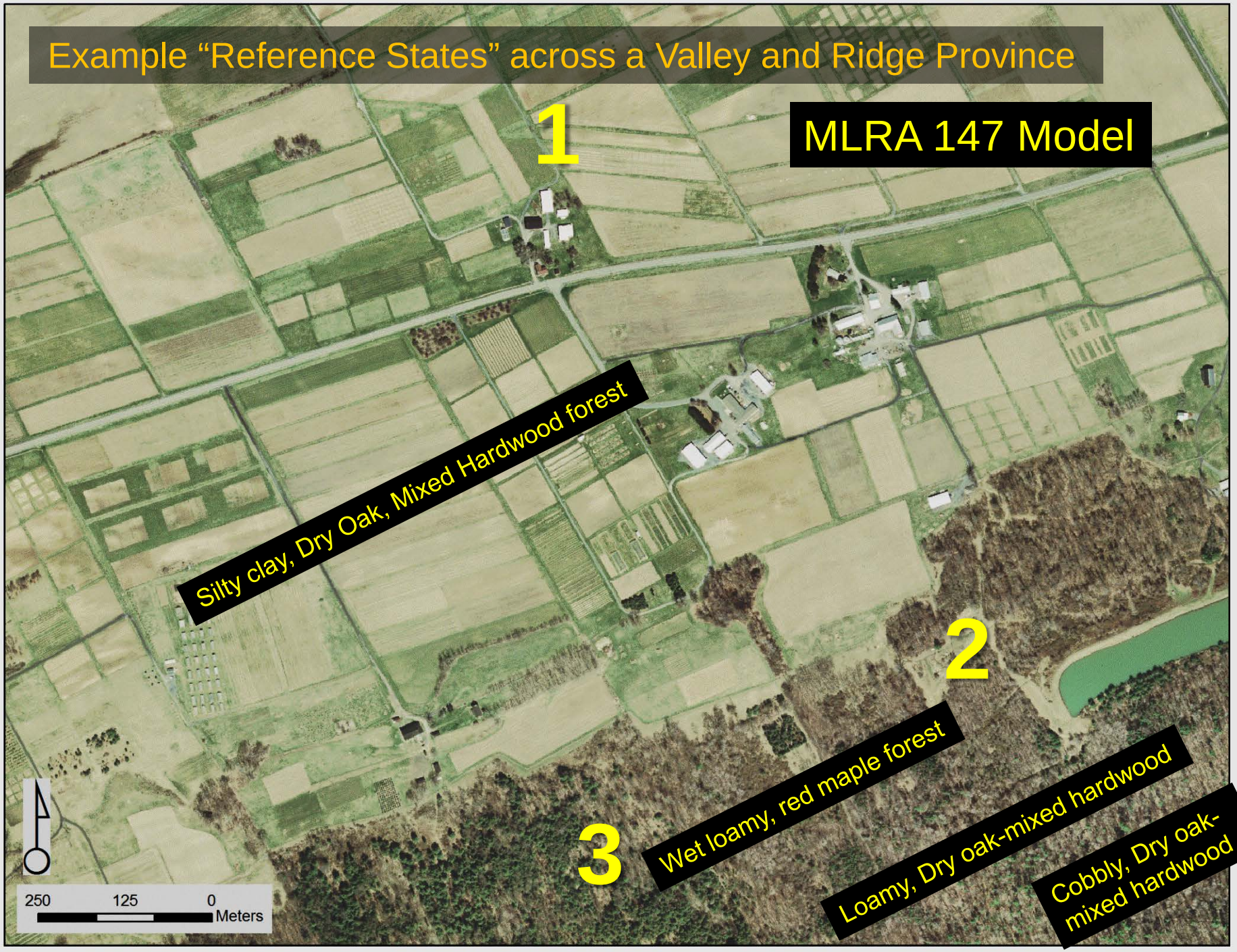


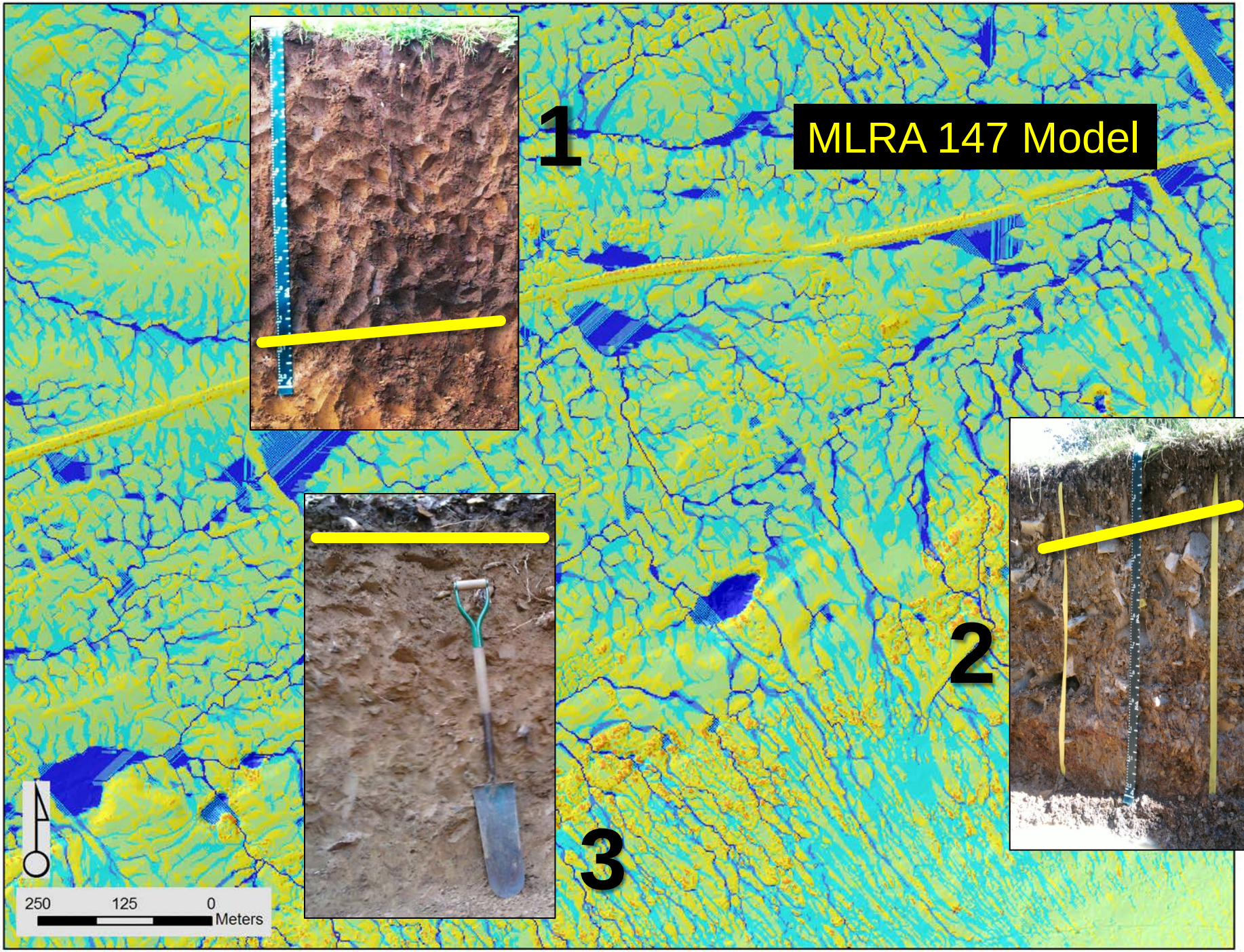
Can we measure soil change across potential States?

Insights and Approaches for Mapping Soil Organic Carbon as a Dynamic Soil Property. Stolt, Drohan, and Richardson. 2010. Soil Sci. Soc. Am. J. 74:1685–1689.

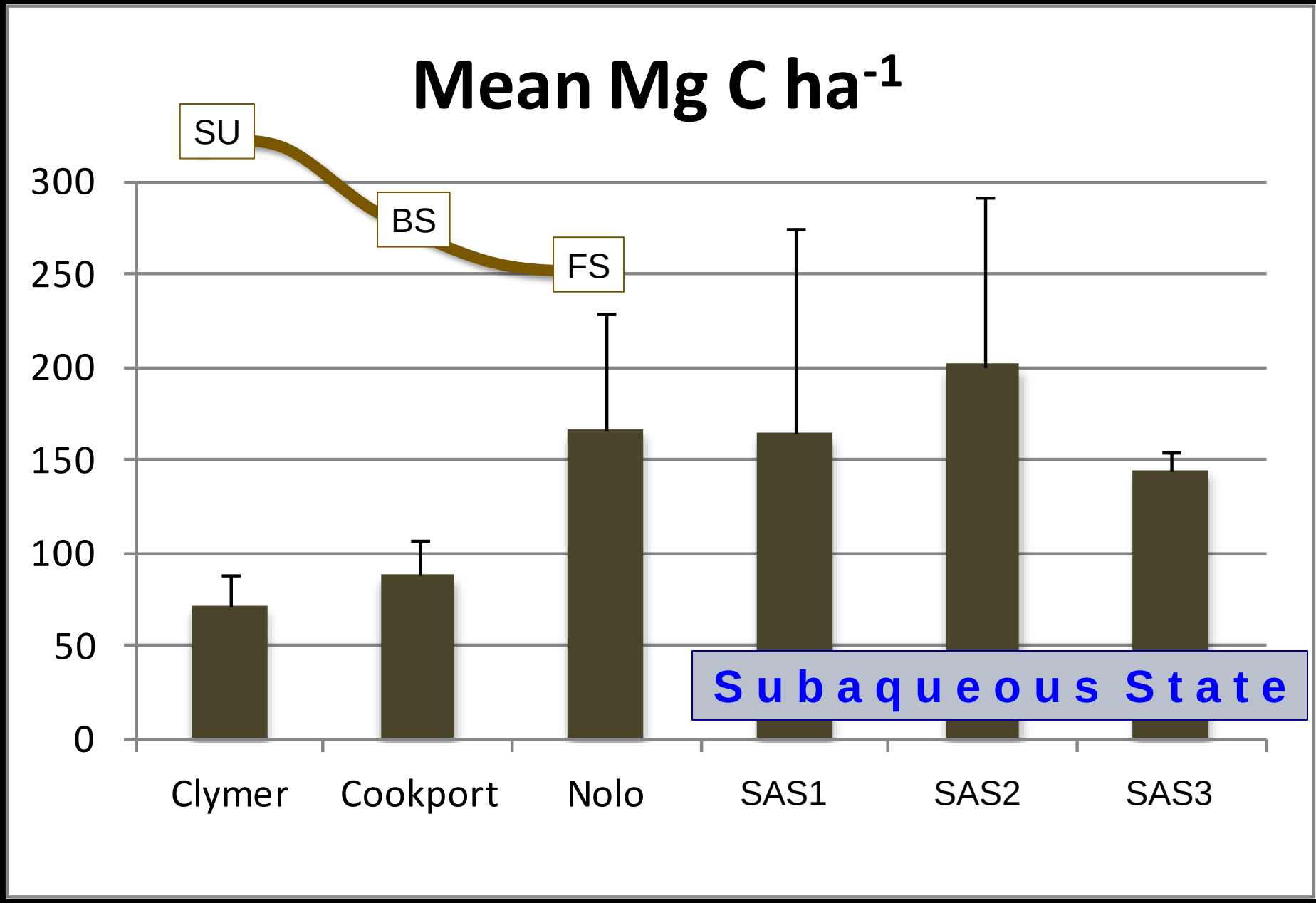
Site	Site-specific land cover	ALCCS Level I	O horizon	A horizon	B horizon	C horizon	Upper 1 m	Upper 1-m SOC pool in O and A horizons	Numeric phase value
			Mg ha^{-1}					%	Mg ha^{-1}
MC3-field	corn	agricultural	0	70	41	15	126	56	70
MC3-forest	coniferous forest	forest	12	76	42	11	141	62	88
MNK2-field	sorghum	agricultural	0	62	50	46	158	39	62
MNK2-forest	deciduous forest	forest	67	46	34	47	194	58	113
MNK10-field	hay	agricultural	0	48	43	ND†	91	53	48
MNK10-forest	deciduous forest	forest	41	32	43	ND	117	62	73
ME1-field	corn	agricultural	0	50	32	9	91	55	50
ME1-forest	coniferous forest	forest	15	59	53	10	138	54	74
MHC1-field	hay	agricultural	0	66	20	2	88	75	66
MHC1-forest	coniferous forest	forest	25	142	20	4	191	87	167
MC2-field	hay	agricultural	0	36	22	5	63	57	36
MC2-forest	coniferous forest	forest	34	67	46	12	159	64	101

Is there a new “State”?


Example “Reference States” across a Valley and Ridge Province
1
MLRA 147 Model
Silty clay, Dry Oak, Mixed Hardwood forest
2
3
Wet loamy, red maple forest
Loamy, Dry oak-mixed hardwood
Cobbly, Dry oak-mixed hardwood
250
125
0
Meters


MLRA 147 Model
1
2
3
250
125
0
Meters

Moving into Aquatic Environments



Soil Change Beyond Rangeland

- O horizon composition/presence
- A horizon thickness (or A over Ap)
- Whole profile and segmented %SOC
- Truncated profiles; no silt loam A horizon
  - *right to a increased clay*.
- Buried surfaces (Euro-alluvium)
- Phosphorus
- Soil pH and conductivity (too flashy?)

Conclusions

- After Baileys Level 4, find potential Ecological Sites with landform and climate analysis;
  - Validate with vegetation and tie to SSURGO.
  - Think "least disturbed" and not "native".
  - Easy to be a splitter.
- Recognize other land type classification systems are in use. These may/may not be compatible with Ecological Sites.
  - e,.g. Pennsylvania Land Type Associations
- "States" have to be more broadly thought of than now used on Rangelands; Ag "States" matter.

Thank You

Skeletal, loamy-upland, Northern Hardwood Forest