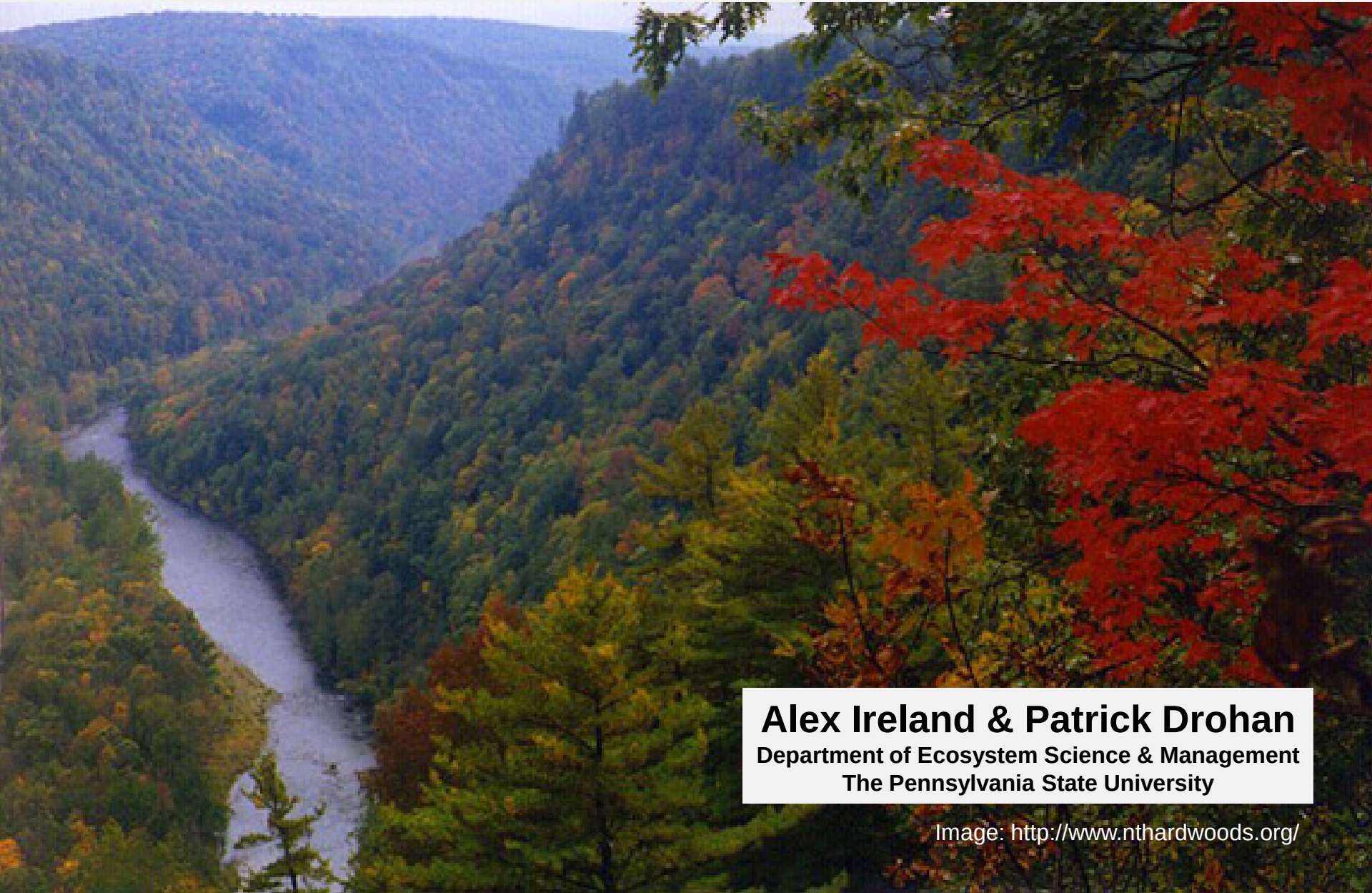
A Novel, GIS-based Approach to Developing Ecological Sites in Highly Variable Landscapes of the Eastern US



Alex Ireland & Patrick Drohan
Department of Ecosystem Science & Management
The Pennsylvania State University

Image: http://www.nthardwoods.org/

Ecological Sites: Defined

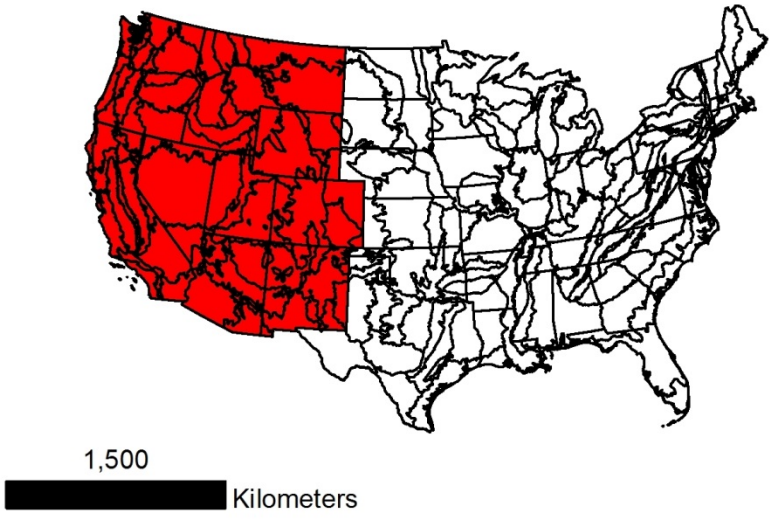
Distinctive components of the landscape

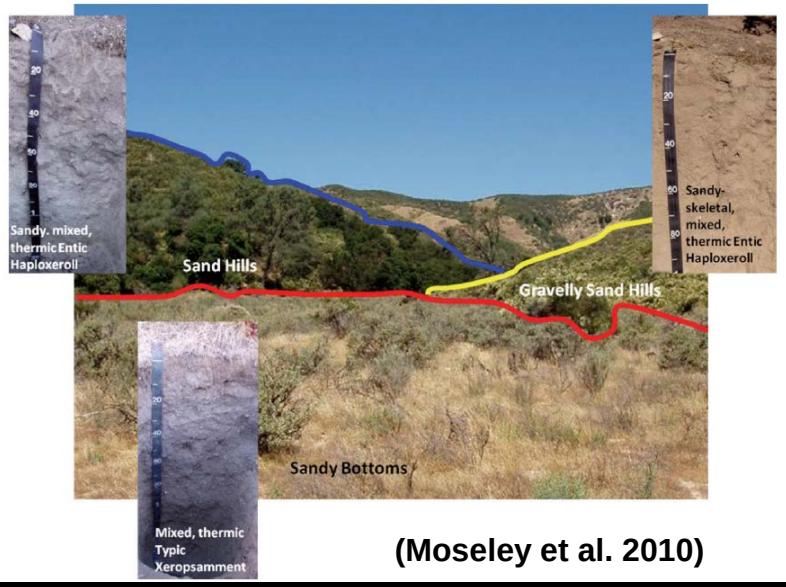
1. Unique physical characteristics, including climate
2. Unique soil properties
3. Characteristic plant communities and productivity
4. Predictable responses to management & disturbance
5. Sub-divisions of existing land-classification schemes

(Modified from: USDA – NRCS)

Context & Background

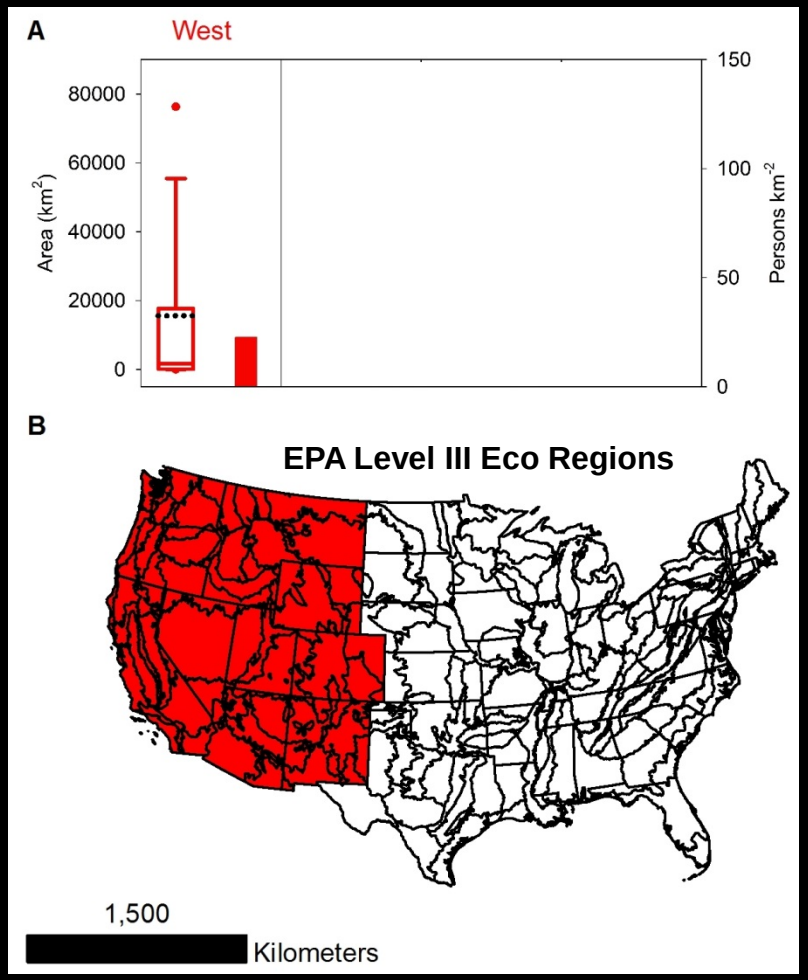
Ecological Sites with State-&-Transition Models were pioneered in the West





(Moseley et al. 2010)

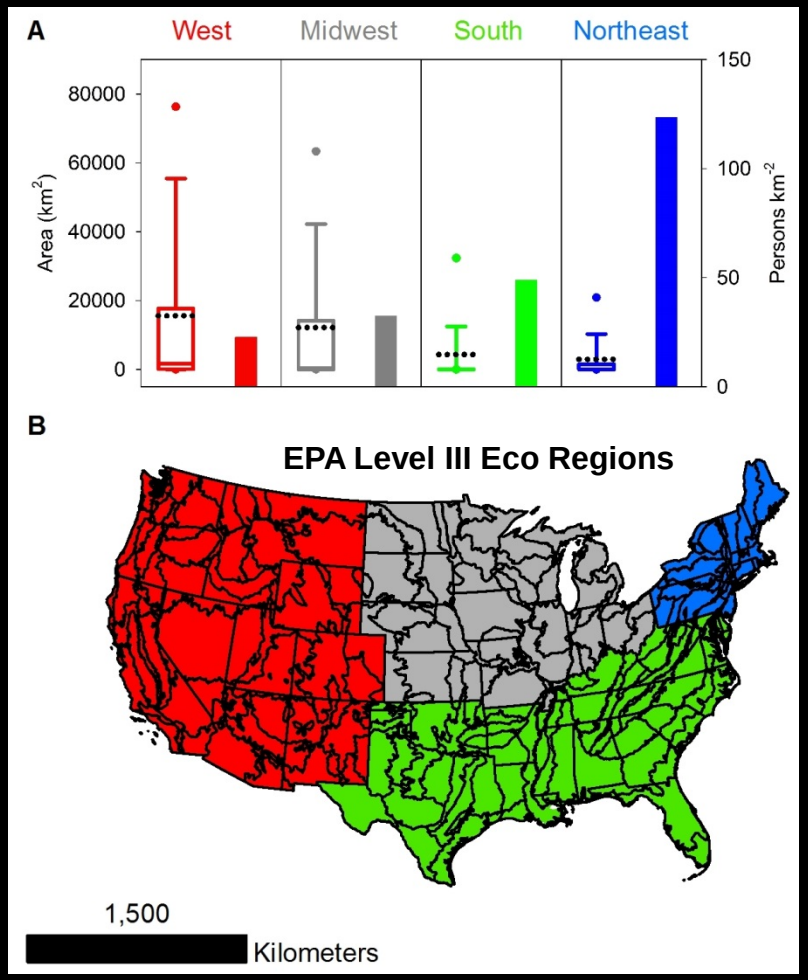
Challenges Beyond the West



1. low-frequency spatial variability

2. Low population density
   (relatively short land-use history)

Challenges Beyond the West



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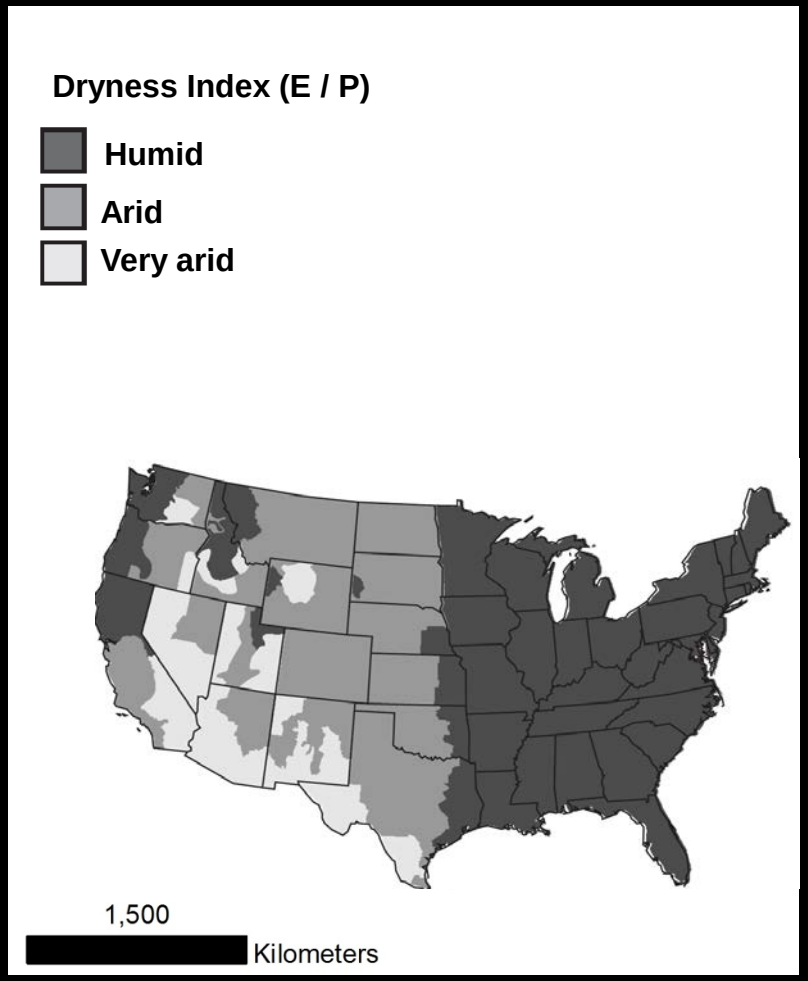
Challenges Beyond the West

(From: Wolock & McCabe 1999)

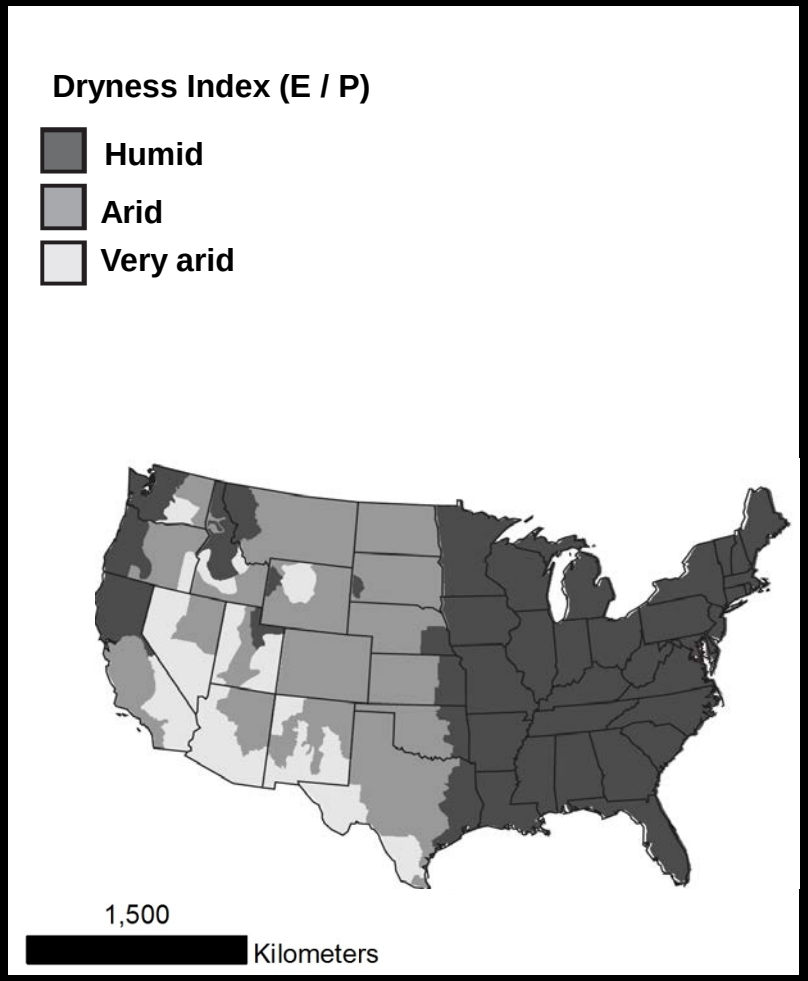


1. In the West,
(Evapotranspiration >> Precipitation)

2. In the East,
(Evapotranspiration << Precipitation)

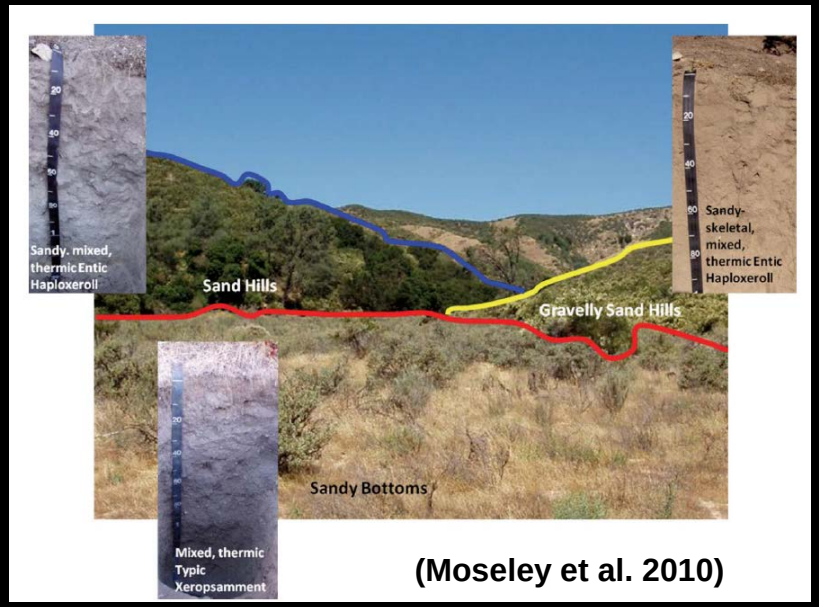
Challenges Beyond the West

(From: Wolock & McCabe 1999)



Severe climate → steep edaphic gradients → sharp ecotones

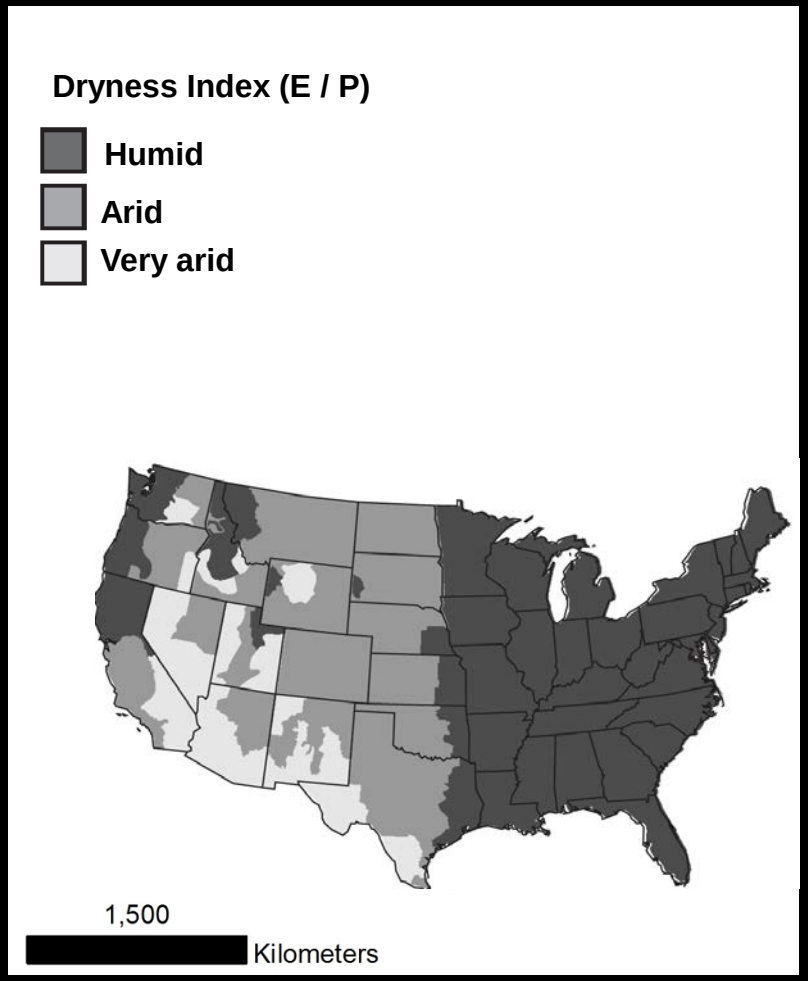
(Didham & Watts 2005)



(Moseley et al. 2010)

Challenges Beyond the West

(From: Wolock & McCabe 1999)



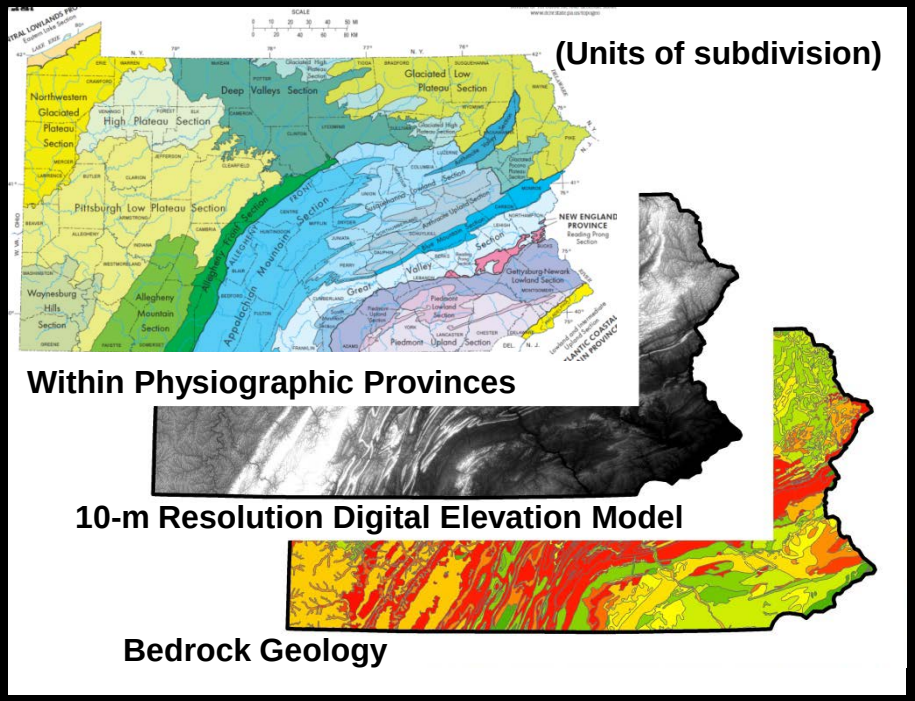
Humid climate → shallow edaphic gradients → diffuse ecotones

(Didham & Watts 2005)

Our Goals in ESD Development

1. Identify ecologically significant thresholds
2. Objective, quantitative, and statistically defensible
3. Simple, straightforward, and reproducible
4. Map-able and meaningful for management

Methodology



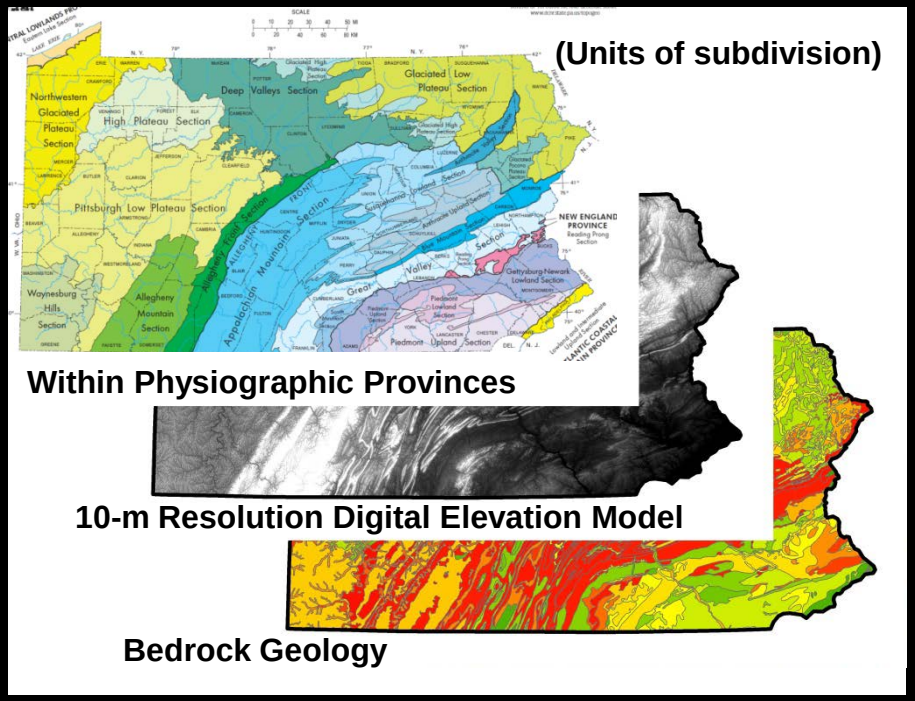
Physiographic Provinces

1. Not divided by Land-use
   (Unlike EPA EcoRegions)

2. Negligible climatic gradients
   (Unlike MLRAs)

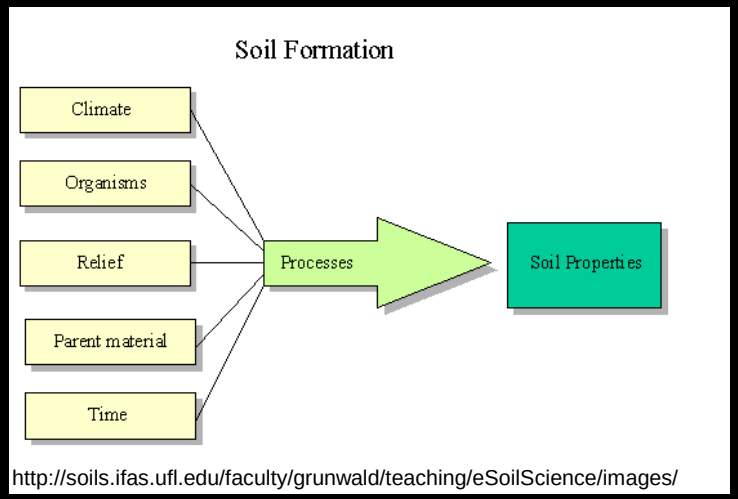
“Soil-Geomorphic Template”
(Monger & Bestelmeyer 2006)

Methodology



No Soil Map Inputs

1. Already mapped by landscape
2. Looking for major thresholds
3. Focusing on soil processes



http://soils.ifas.ufl.edu/faculty/grunwald/teaching/eSoilScience/images/

"Soil-Geomorphic Template"
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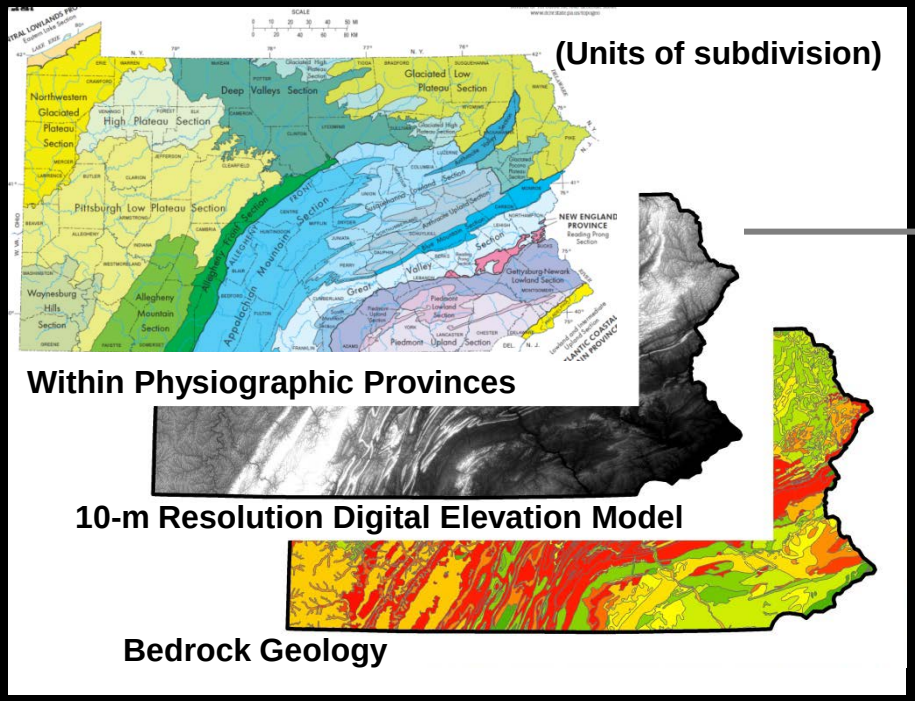
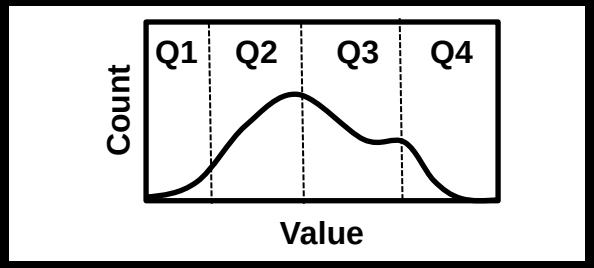


1. Landform Index
   (Topographic position & Slope)
2. Wet – Dry Index
   (TWI & Complex curvature)
3. Aspect
   (North, East, Flat, West, South)
4. Relative Elevation
   (Regional Quartiles)



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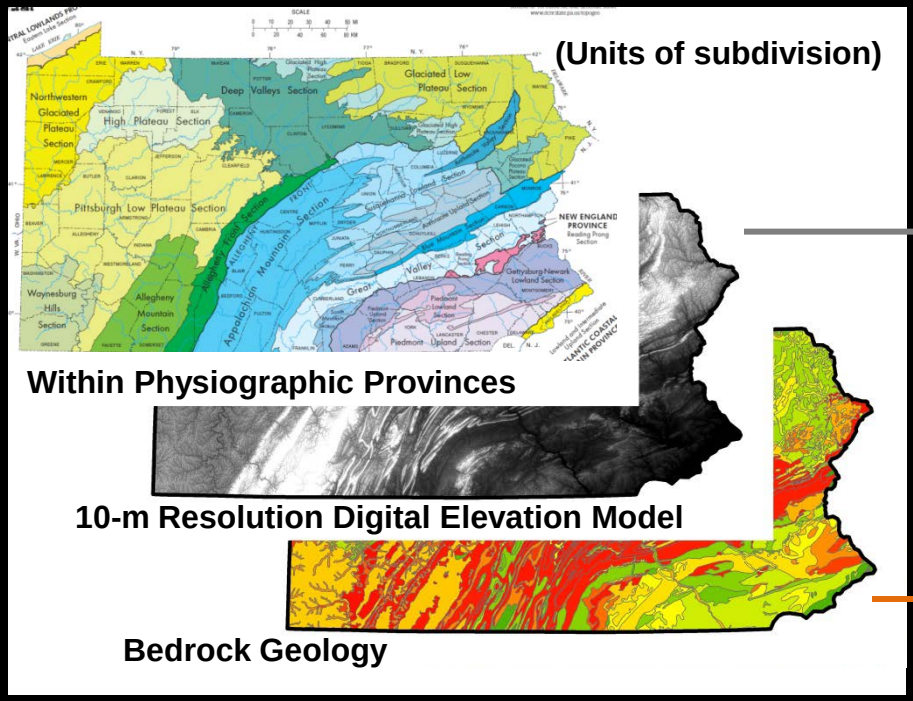

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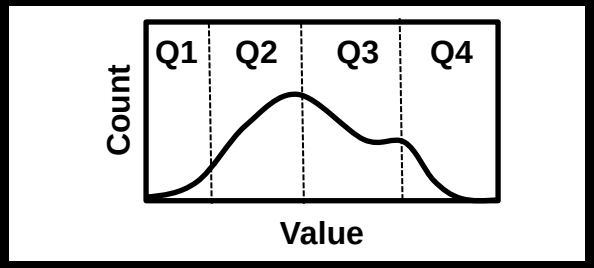
5. Parent Material
   (Rock type 1 and 2)



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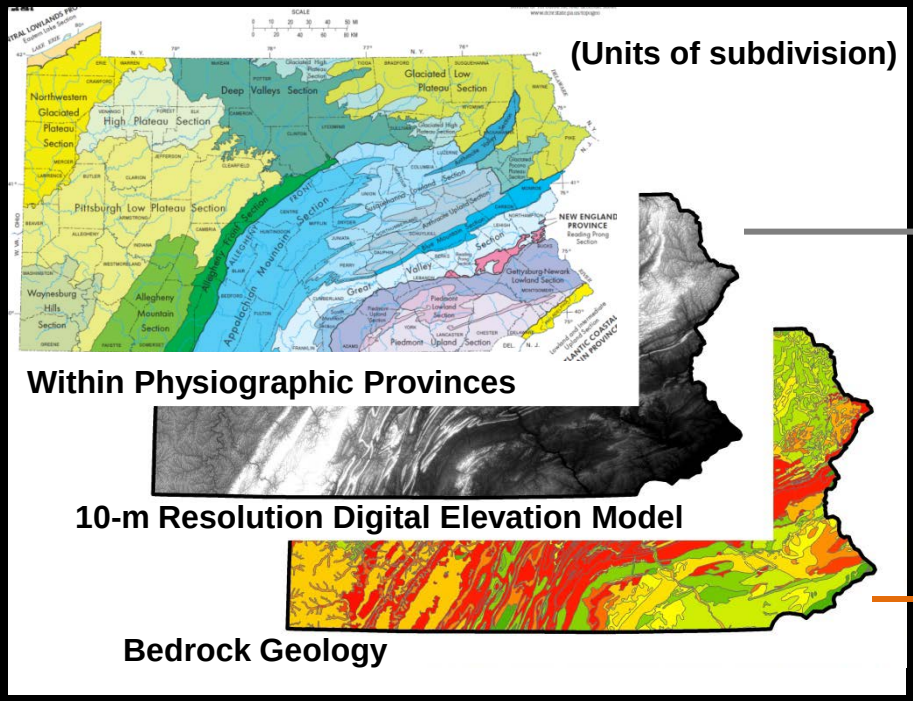

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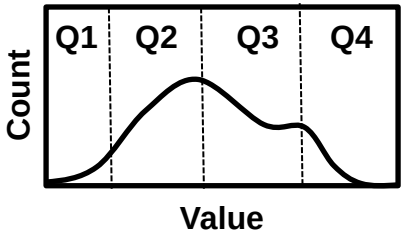
   (Rock type 1 and 2)

All Variables Categorical

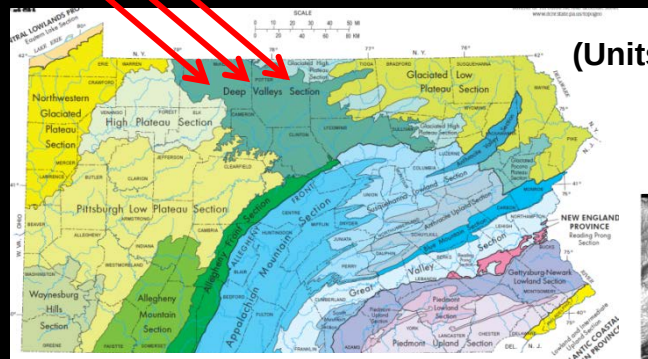
1	2	3	4	5

Wet → Dry



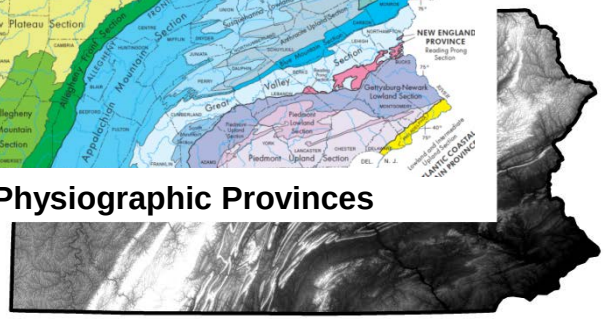
Methodology

Random sampling points (100,000)

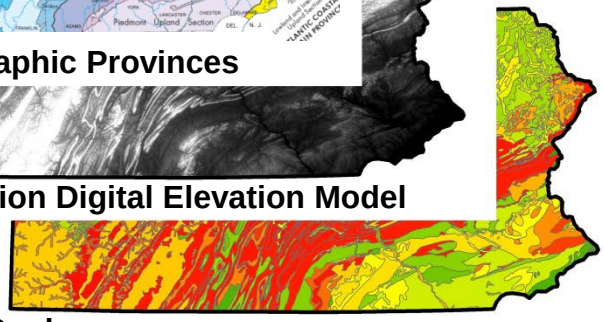


(Units of subdivision)

Within Physiographic Provinces



10-m Resolution Digital Elevation Model



Bedrock Geology

Multivariate Dataset

	V_1	V_2	V_3	V_4	V_5
O_1	…	…	…	…	…
O_2	…	…	…	…	…
O_n	…	…	…	…	…

Methodology

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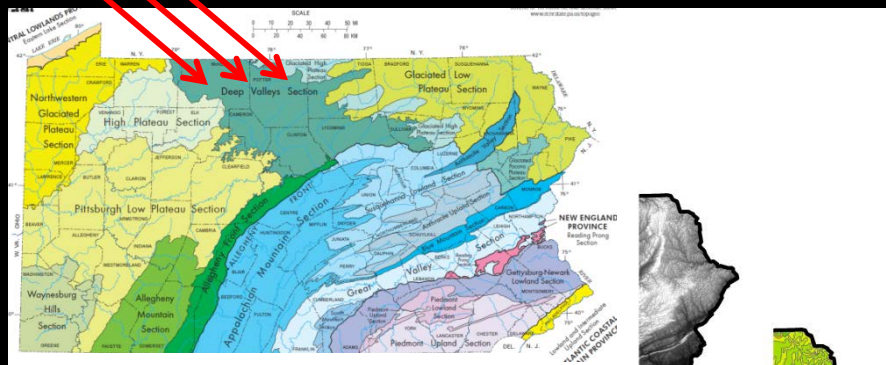

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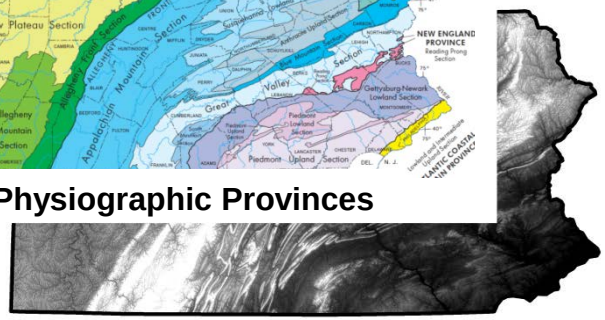

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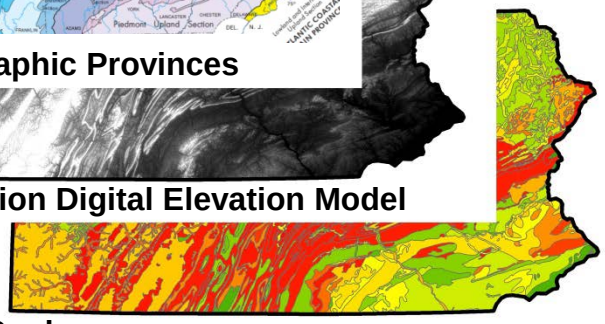
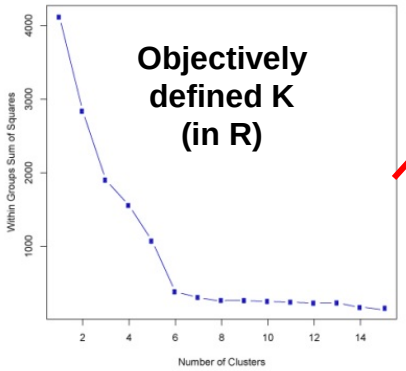


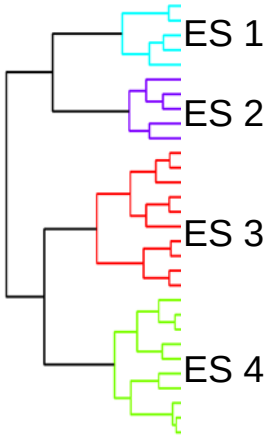
Bedrock Geology

K-means Cluster Analysis



Objectively defined K (in R)

In GIS



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Methodology

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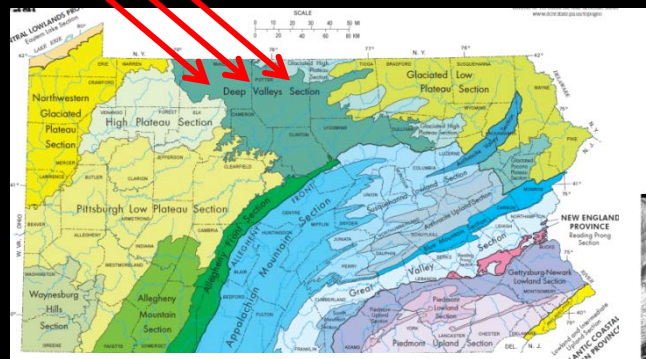

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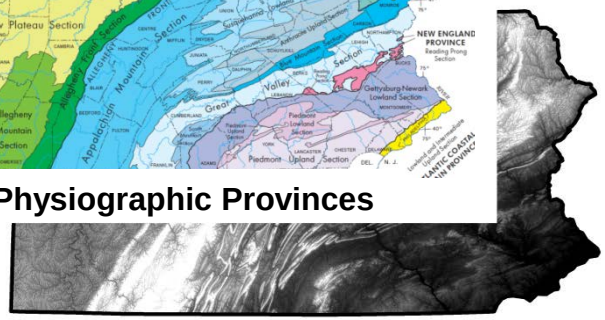

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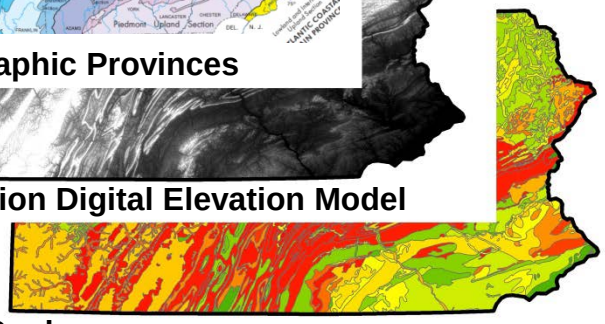
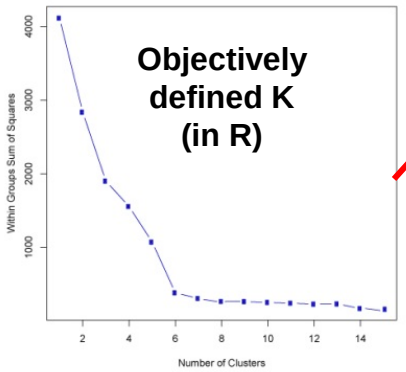


Bedrock Geology

Test significance (Chi-Square)
Map to landscape

K-means Cluster Analysis



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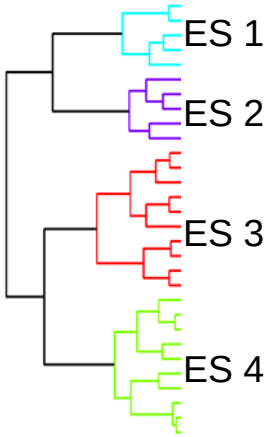

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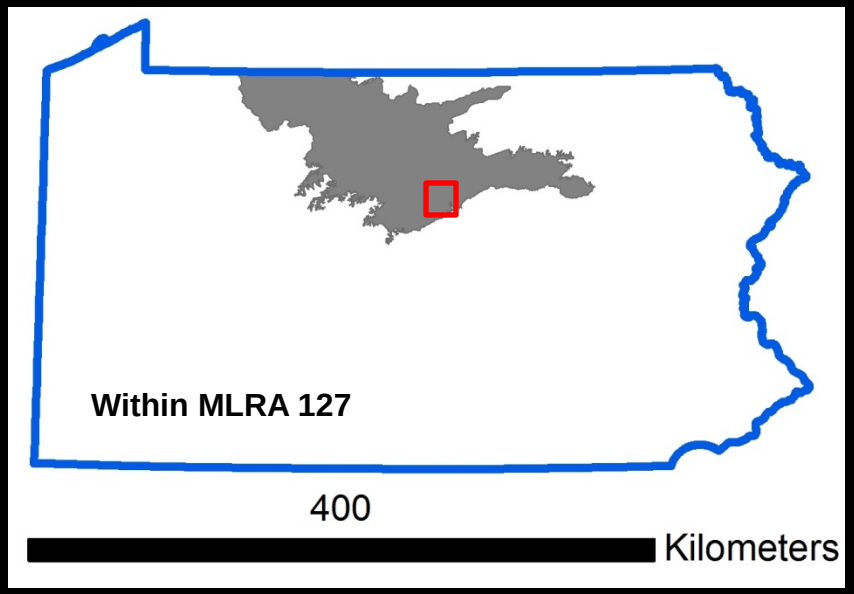
O_n	…	…	…	…	…

An Example

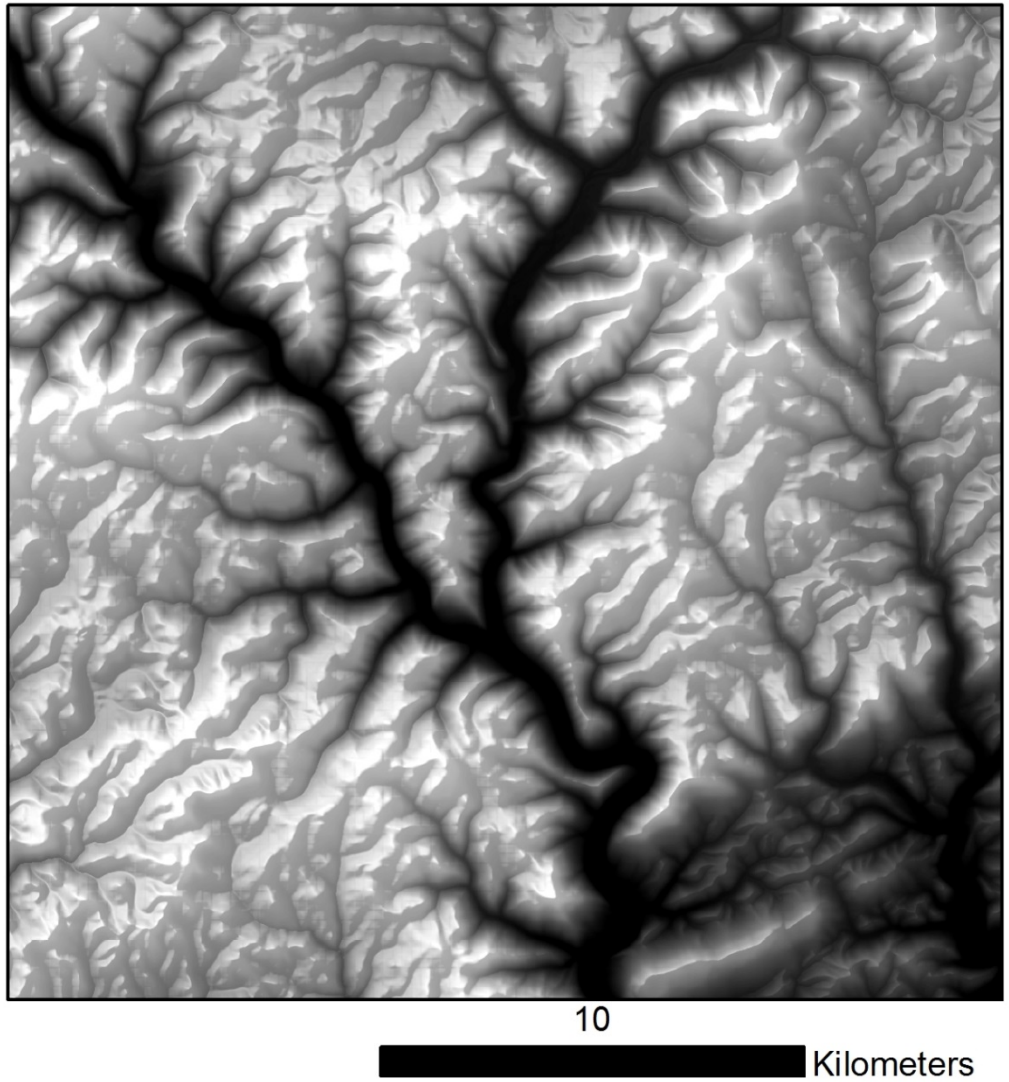
The Deep Valleys Physiographic Province



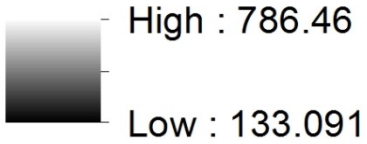
Motivation

http://www.dcnr.state.pa.us/forestry/NaturalGas/index.htm

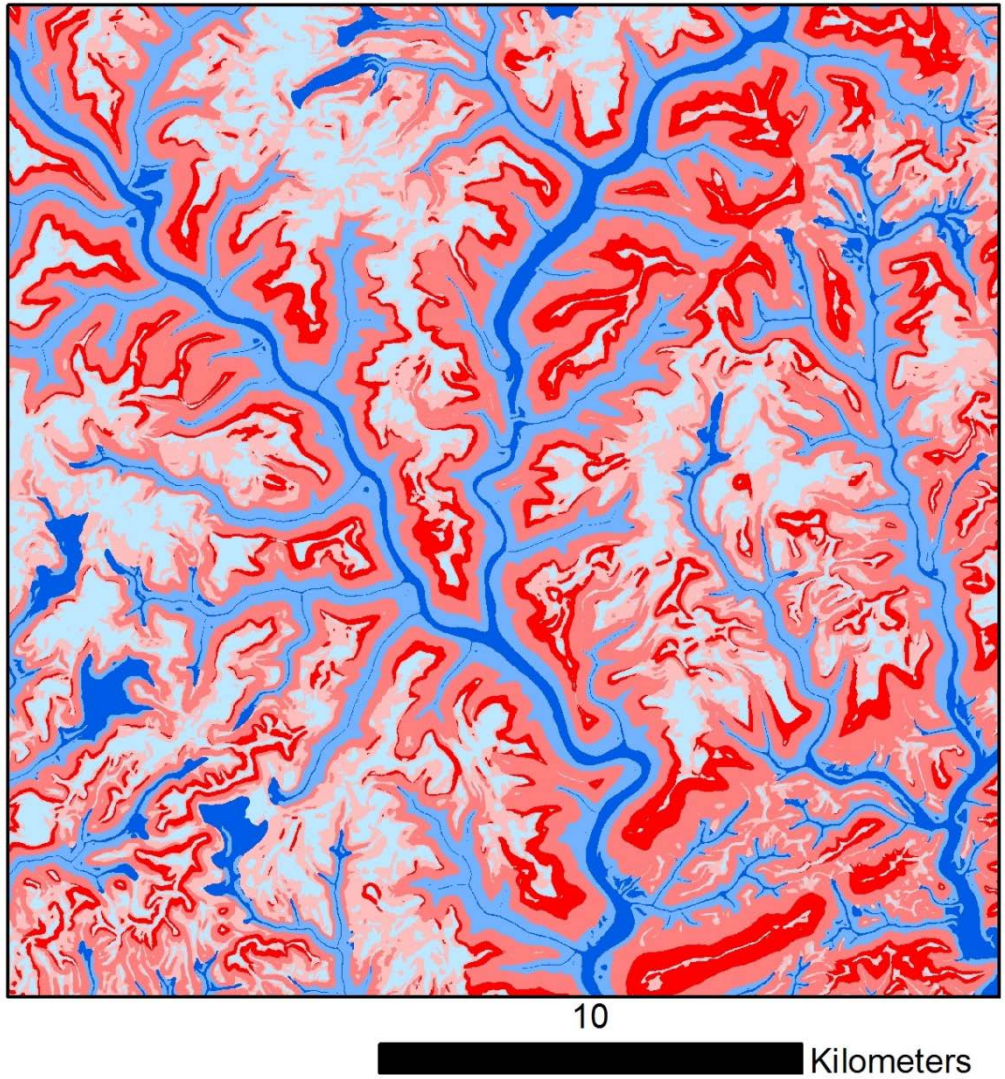
An Example



Digital Elevation Model



An Example

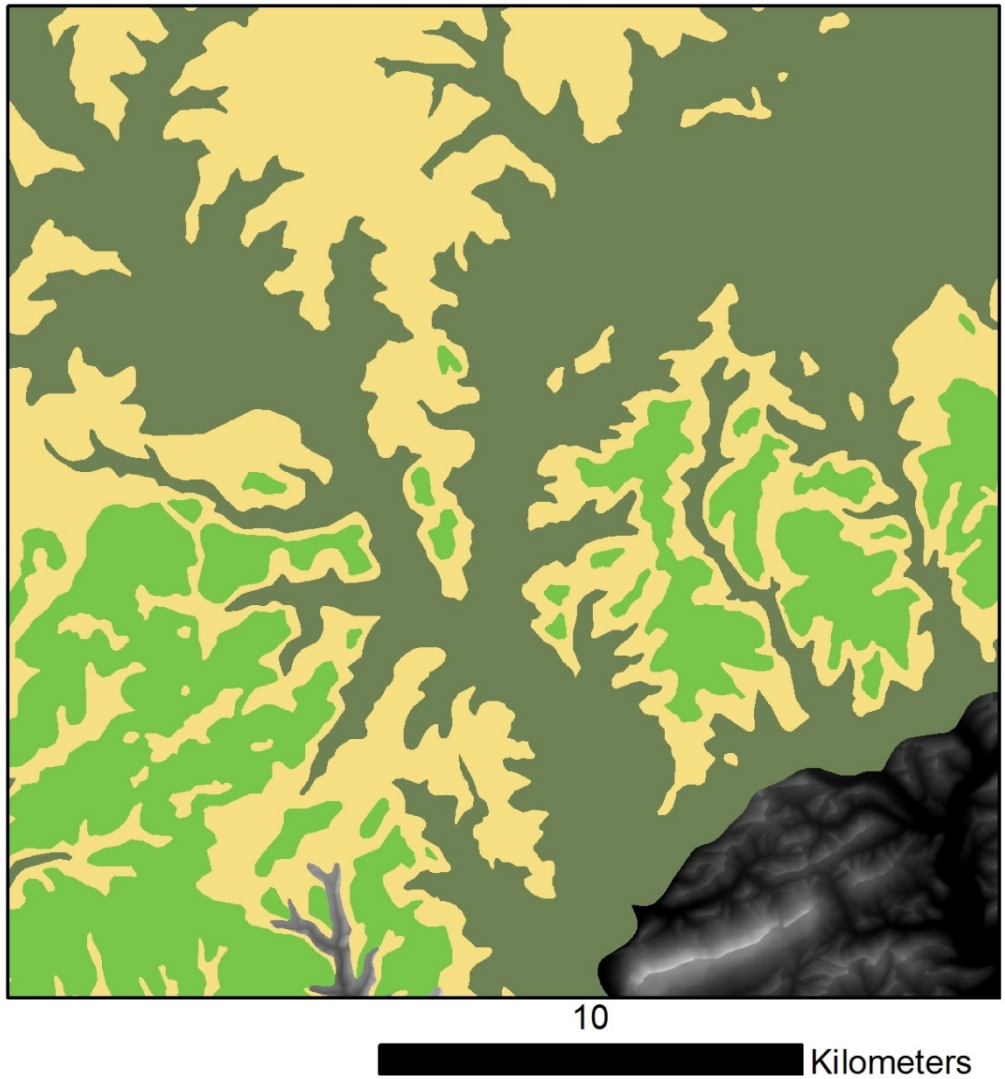


Landform Index

- High RE, Steep
- Int. RE, Steep
- High RE, Low Slope
- High RE, Flat
- Low RE, Steep
- Low RE, Flat

(RE = Relative elevation)

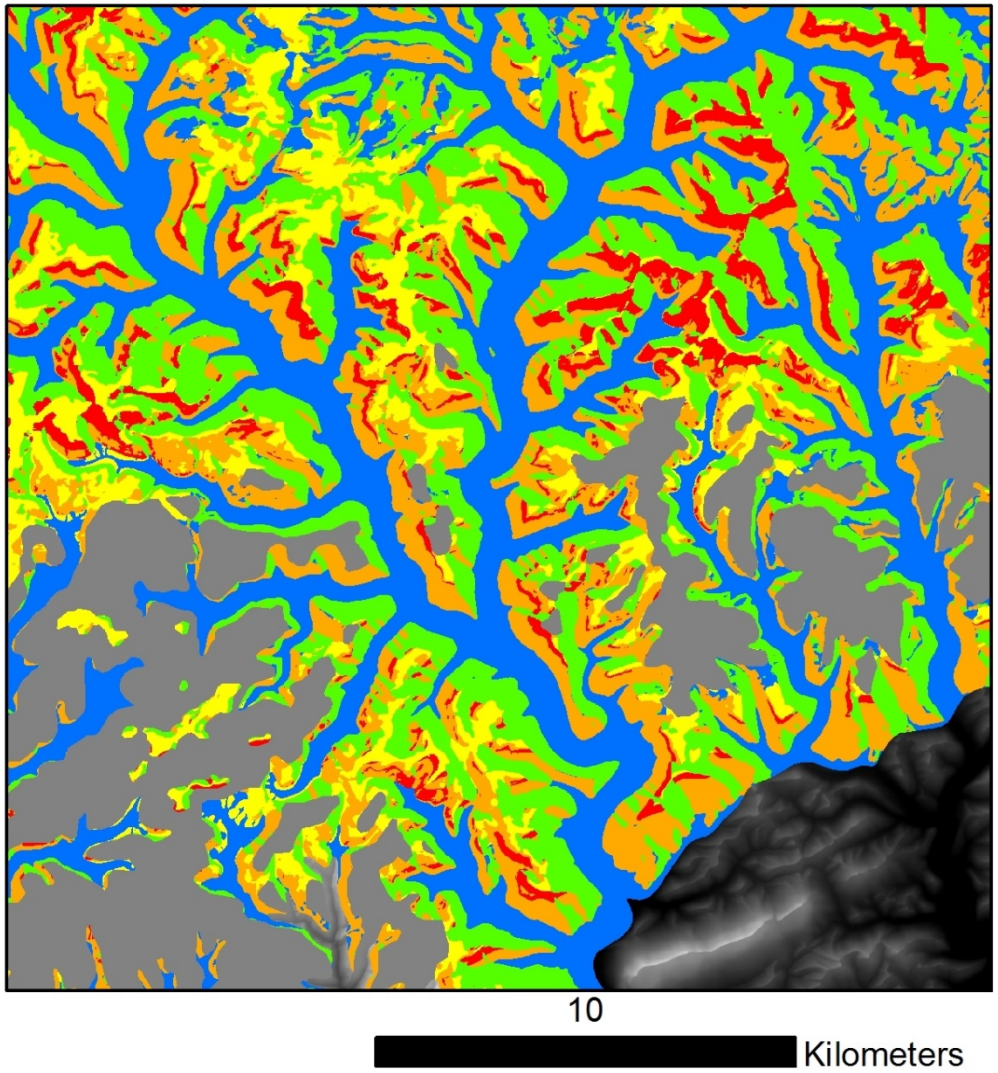
An Example



Geology

	Rock 1	Rock 2
	Sand.	Cong.
	Sand.	Silt.
	Silt.	Sand.
	Sand.	Shale
	Silt.	Shale
	Shale	Silt.
	Mud.	Silt.

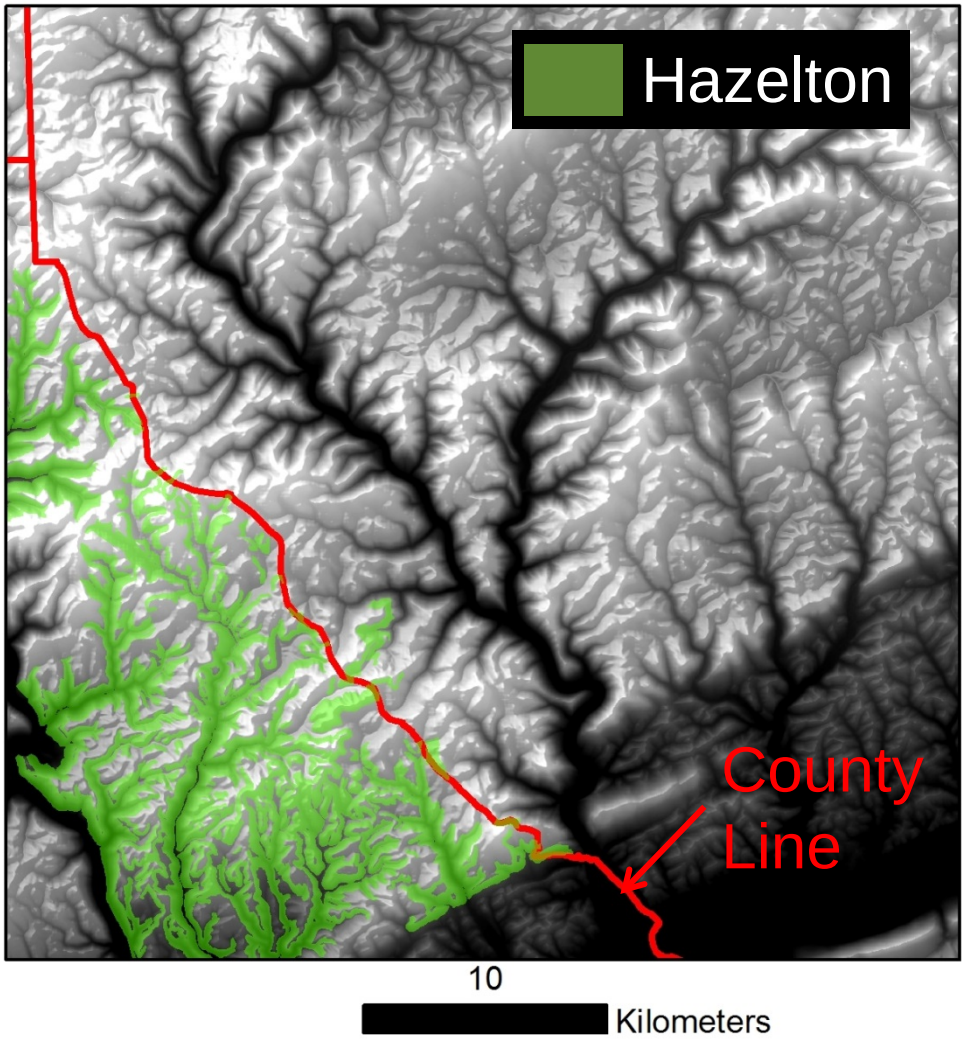
An Example



Ecological Sites

- Dry High Slopes
- Mid-Elevation Shoulders
- Wet High Slopes
- Flat Highlands
- Wet Lowlands
- Fine-Grained Flatlands

Correlation to Soil Maps (?)



Mapped from stream valleys to ridge tops

Mapped on all aspects and slopes

Terminates at the County Line (an SDJR issue)

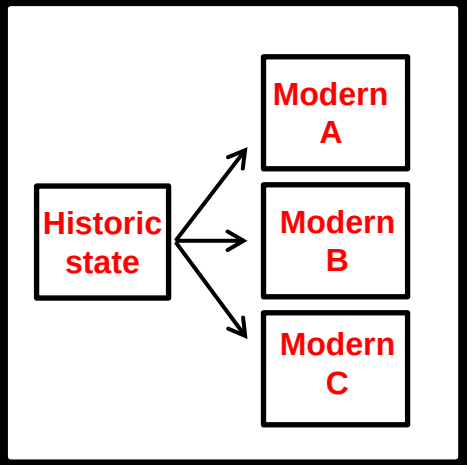
Results (Conceptual)

Ridge Top Ecological Site

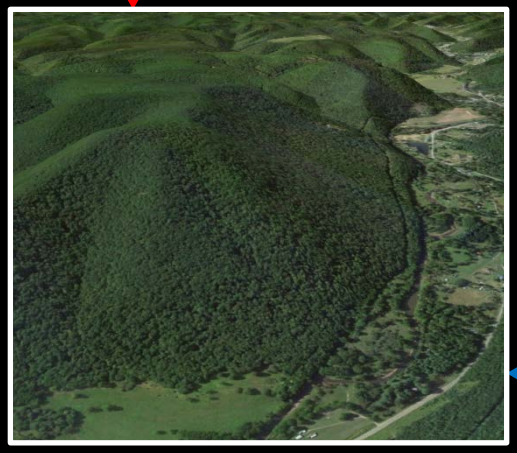
Valley Bottom Ecological Site

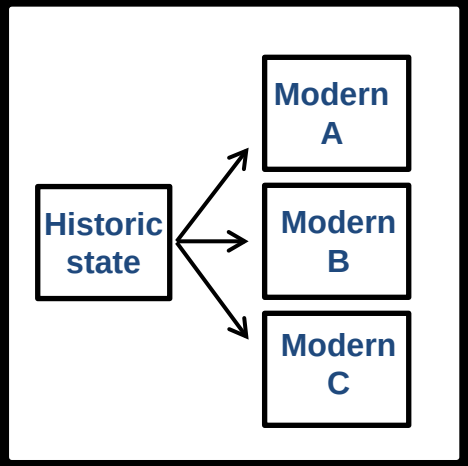
State-&-Transition Models

Represents a synthesis of decades of site-specific research and practice!



Ridge Top Ecological Site





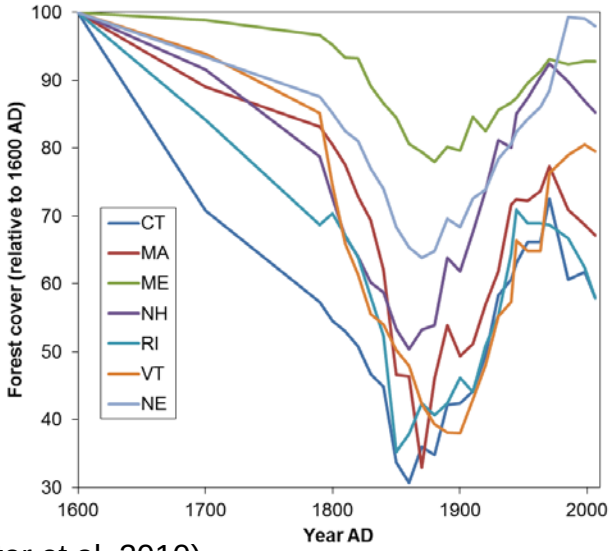
Valley Bottom Ecological Site

Challenges Beyond the West

http://harvardforest.fas.harvard.edu/dioramas

Most Ecosystems of the Northeast are imprinted with legacies of land-use history

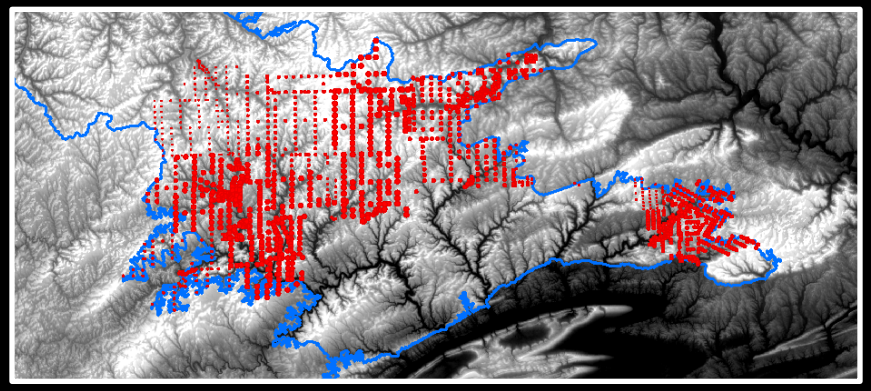
Major challenge for Reference States



(Foster et al. 2010)

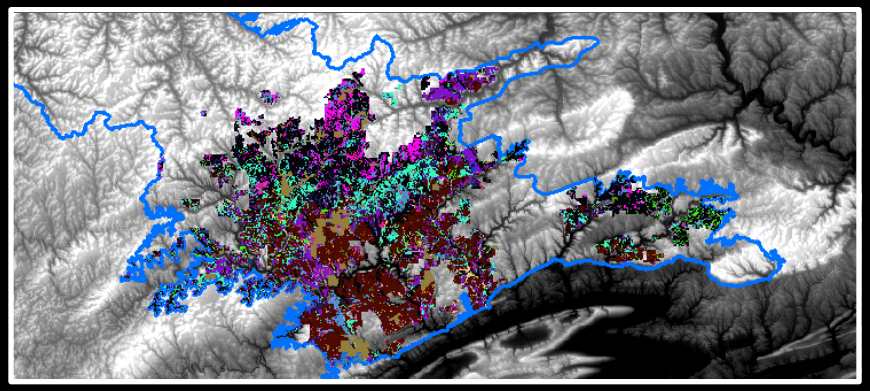
State-&-Transition Models

Reference States



1. Geo-referenced Warrant Maps
2. location of 1718 trees between 1790 and 1810 AD
3. RMSE to handle uncertainty

Modern States



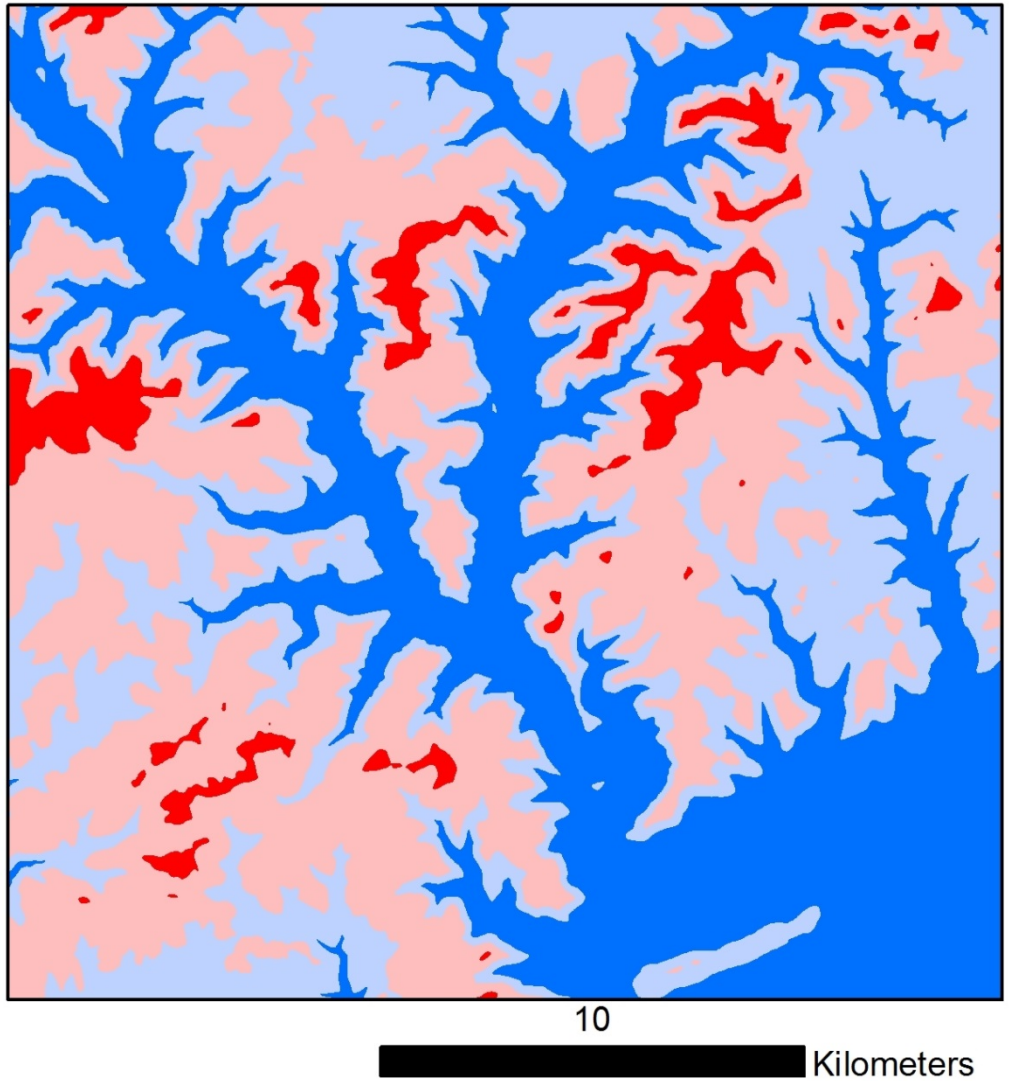
1. Over 1000 plots samples
2. All DCNR lands classified into stand types by foresters
3. Historical records

Conclusions & Thanks

1. ES development might be problematic in the East
2. But, we developed a reproducible process
3. Highlights areas where soil maps may need to be refined
4. ES Development is the easy part (Correct STMs are hard)!

pennsylvania
DEPARTMENT OF CONSERVATION
AND NATURAL RESOURCES

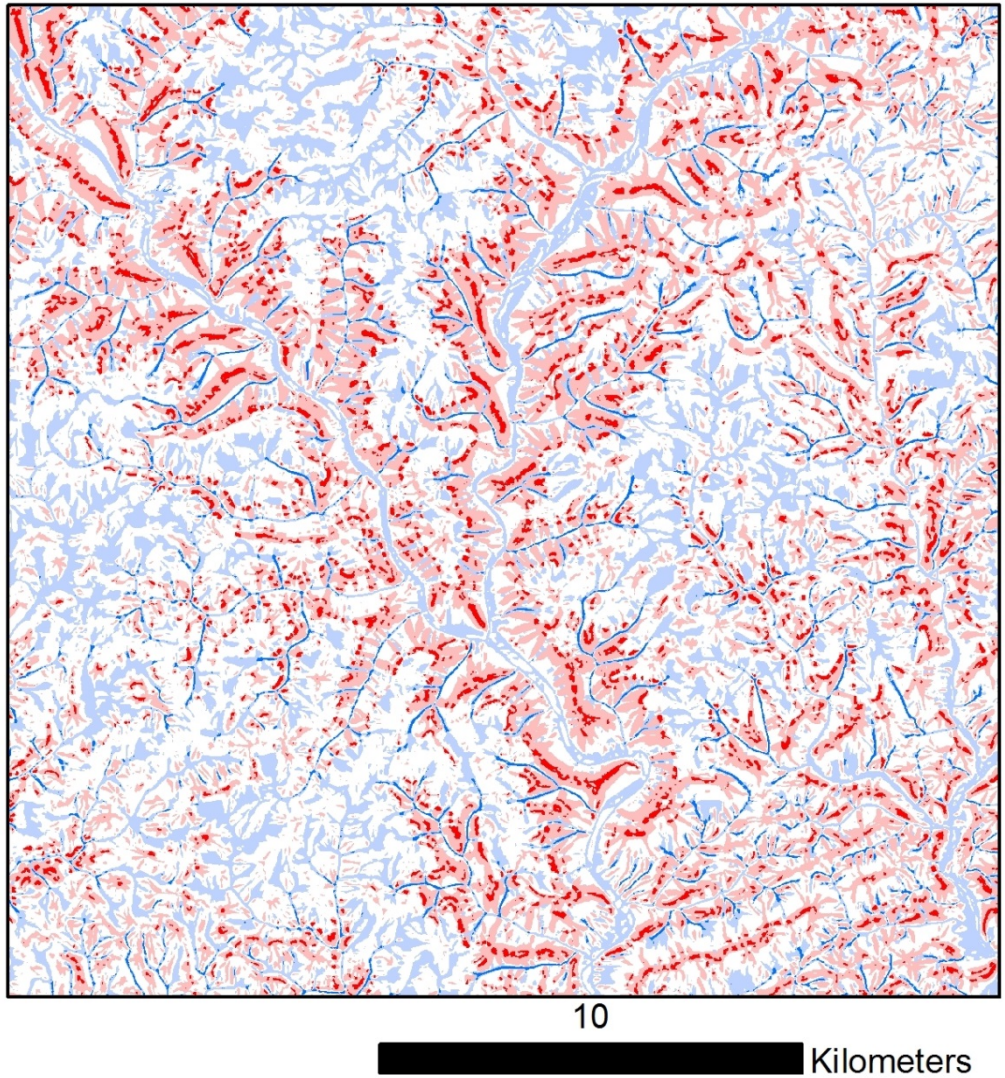
An Example



Relative Elevation

- 4th Quartile
- 3rd Quartile
- 2nd Quartile
- 1st Quartile

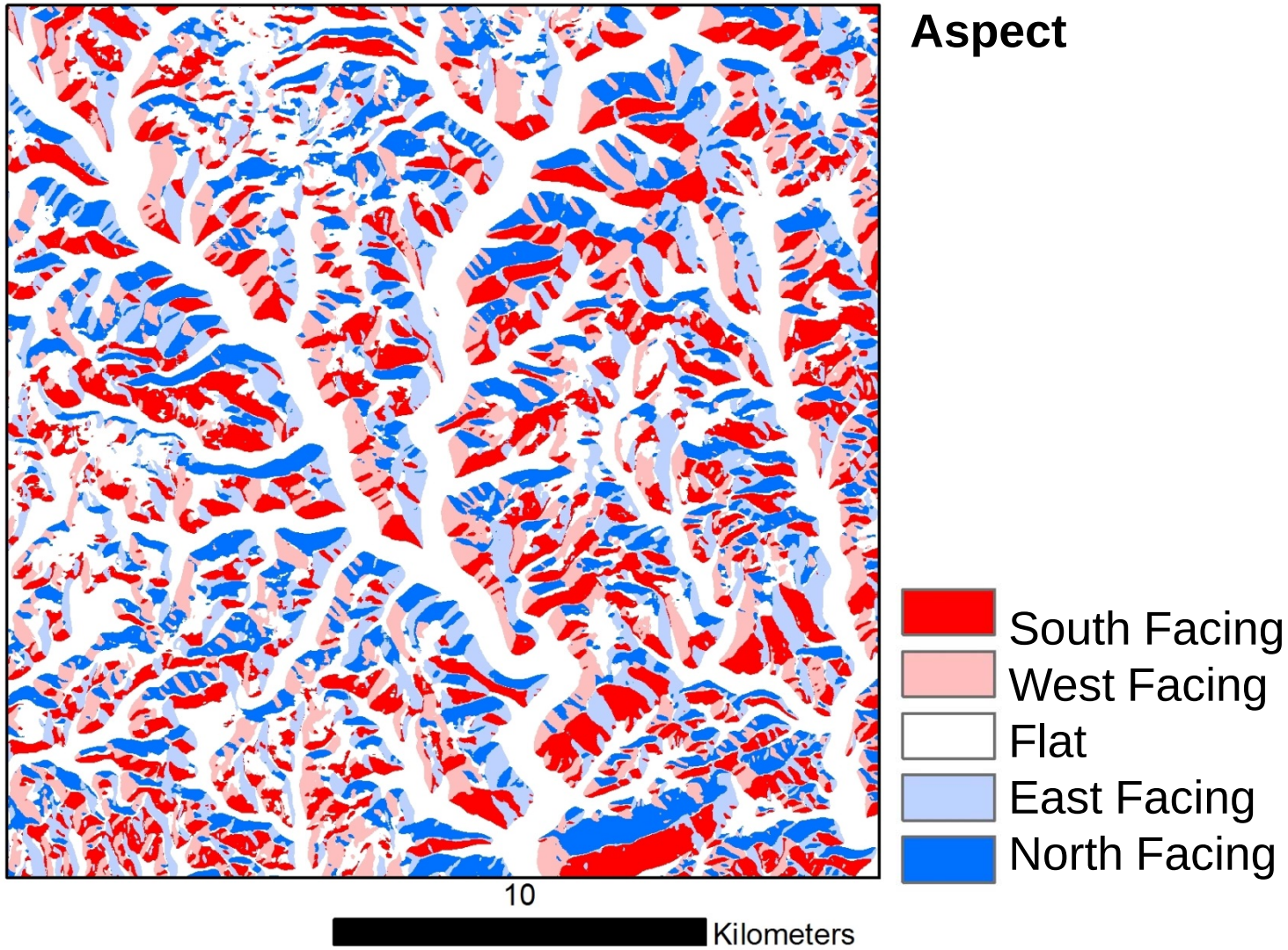
An Example



Wet – Dry Index

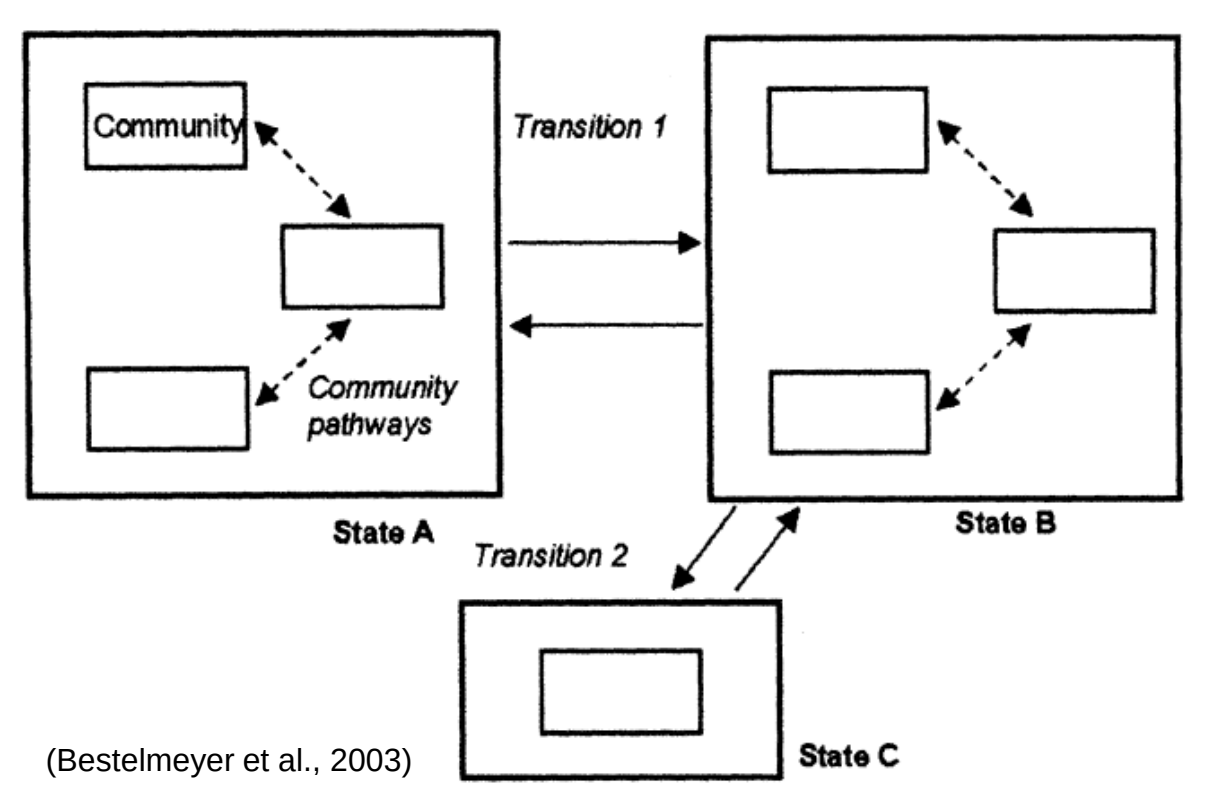
- Convex up + shed
- Convex up or shed
- Neutral (contradictory)
- Concave up or collect
- Concave up and collect

An Example


Aspect
South Facing
West Facing
Flat
East Facing
North Facing
10
Kilometers

State-&-Transition Models

Represents a synthesis of decades of site-specific research and practice!



(Bestelmeyer et al., 2003)

Context & Background

<u>Ecological Site</u>: **“**a distinctive kind of land with specific soil and physical characteristics that differ from other kinds of land in its ability to produce a distinctive kind and amount of vegetation and its ability to respond similarly to management actions and natural disturbances” USDA - NRCS