Terrain Attribute Soil Mapping for Functional Property Maps

Zamir Libohova [1, 2]
Phillip R. Owens [1]
Edwin H. Winzeler [1]
Travis Neely [2]
John Hempel [3]

[1] Purdue University, West Lafayette, Indiana

[2] State Soil Scientist/MO Leader, USDA-NRCS-Soil Survey Program, Indianapolis, Indiana

[3] USDA-NRCS-NGDC, Morgan Town, West Virginia

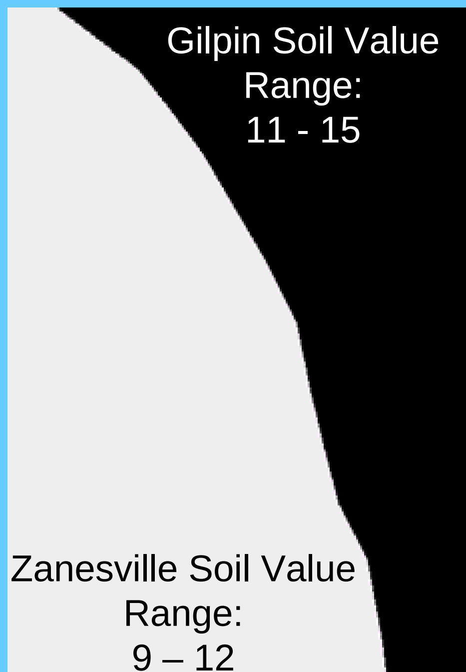
Cooperators

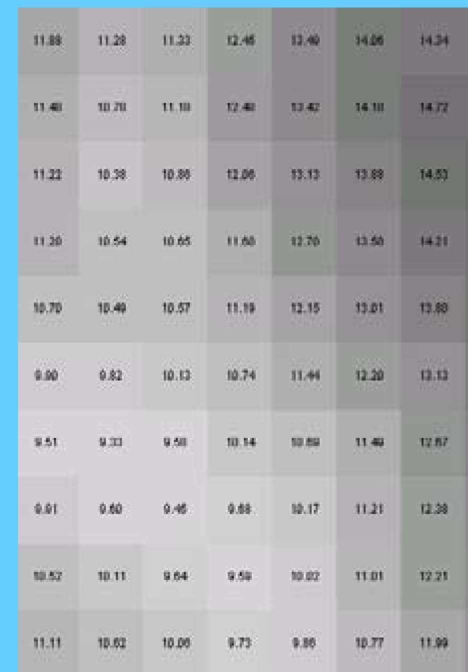
- Purdue University, Department of Agronomy
- USDA-NRCS, Soil Survey Program, Indiana
  - Kevin Norwood;
  - Stephen Norm
  - John Allen;
- USDA-ARS, National Soil Erosion Laboratory
  - Diane Stott

Rationale and Background

- The completion of the initial Soil Survey for the United States is projected around 2010;
- The launching of Web Soil Survey (WSS) and other on-line soil information;
- New high resolution spatial data and spatial analysis software.

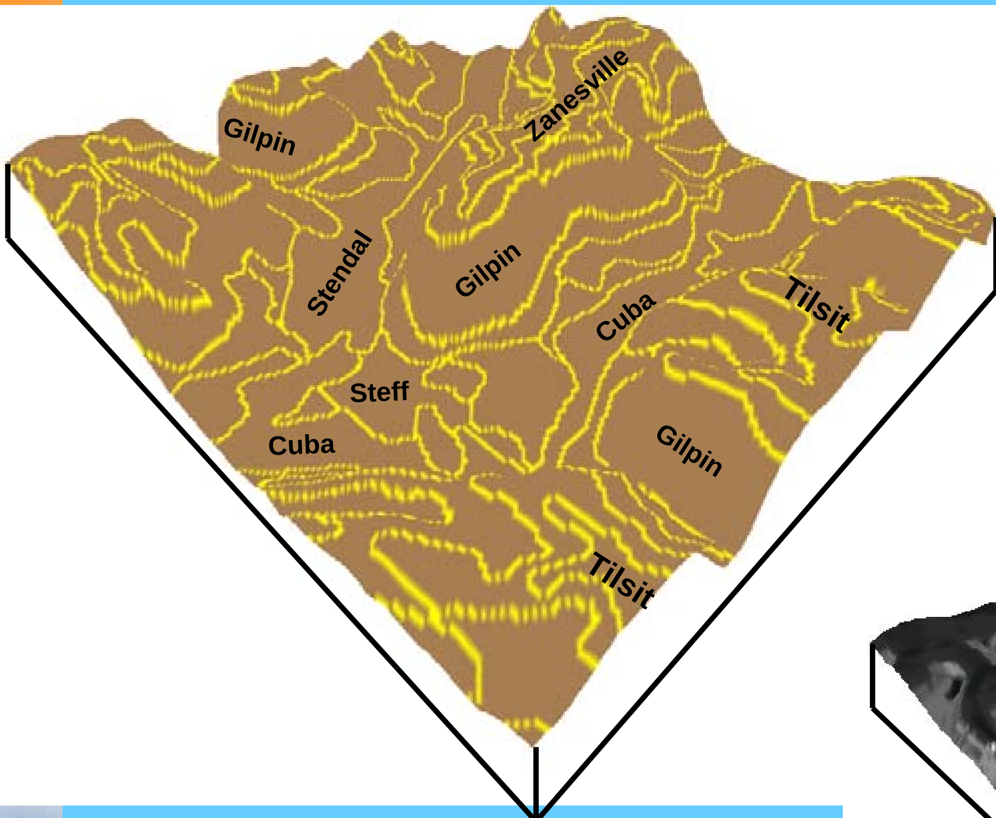
Polygon vs. Raster





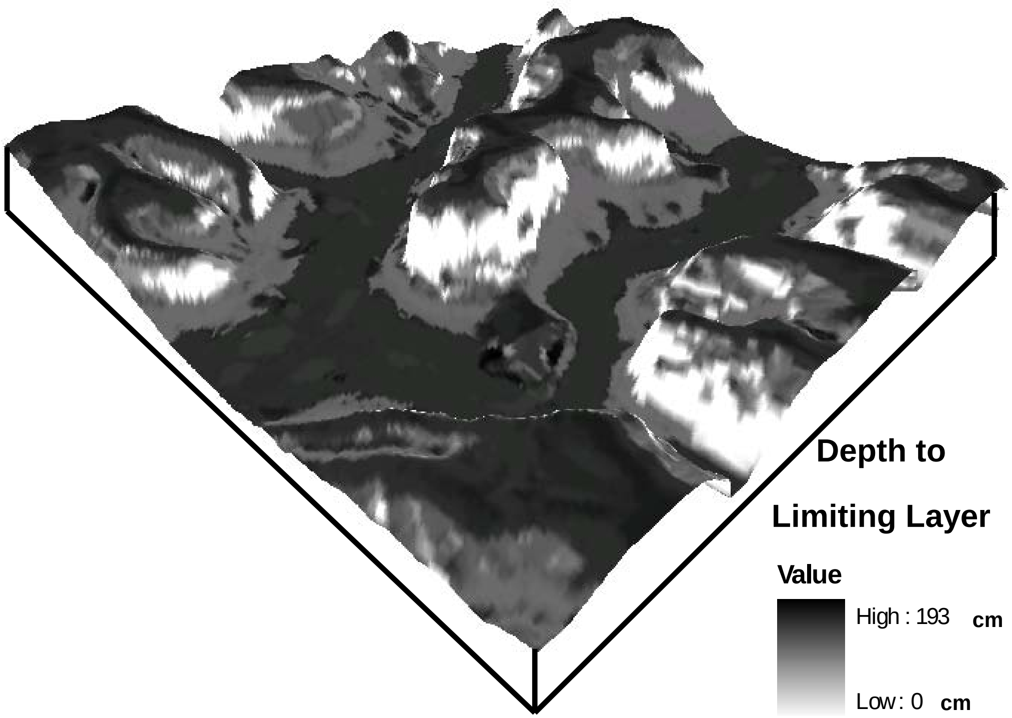
- **<u>Polygons</u>**
- Discreet boundaries
- Broken interconnectedness
- Vague predictions (value ranges)
- Incompatibility with raster-based models
- Simplicity of representation, complexity of interpretation

- **<u>Rasters</u>**
- Fuzzy boundaries
- High degree of interconnectedness
- Specific predictions at specific geographic intervals
- High compatibility with raster models
- Complexity of representation, simplicity of interpretation



From Soil Polygon Maps

To Raster Soil Property Maps



TASM Processes

Data Mining from digital and analog sources to establish soil-landscape relationships → **Quantifying relationships between soils and their environment (Terrain Attributes)** → **Formalizing the relationships between soils and Terrain Attributes (Rules)** → **Creating Rater based maps and Predicted Soil Property maps**

Data Mining from digital and analog sources to establish soil-landscape relationships

- County Soil Survey;
- OSD;
- SSURGO;
- Aerial Photography;
- DEM – Terrain Attributes;
- Tacit Knowledge;
- Field data and observations;
- Block Diagrams.

Quantifying relationships between soils and their environment (Terrain Attributes)

- TWI;
- Slope;
- Curvature;
- Valley Bottom Flattens;
- Ridgetop Flattenss;
- Soil Knowledge miner;
- Histograms

Formalizing the relationships between soils and Terrain Attributes (Rules)

- Decisions Tree for terrain/soil relationships for each relevant terrain attribute:
- IF..THEN..EITHER/OR
- IF Slope < 10 THEN Soil A;
- IF TWI > 10 THEN Soil B;
- IF Slope < 10 AND >15 and

  TWI<5 AND >10 THEN Soil C.

Creating Rater based maps and Predicted Soil Property maps

- Assign a property value for each soil;
- Depth to Limiting Layer
- Available Water Holding Capacity; etc.
- Based on Fuzzy membership values predict the soil property (V_{ij}) at ij location;

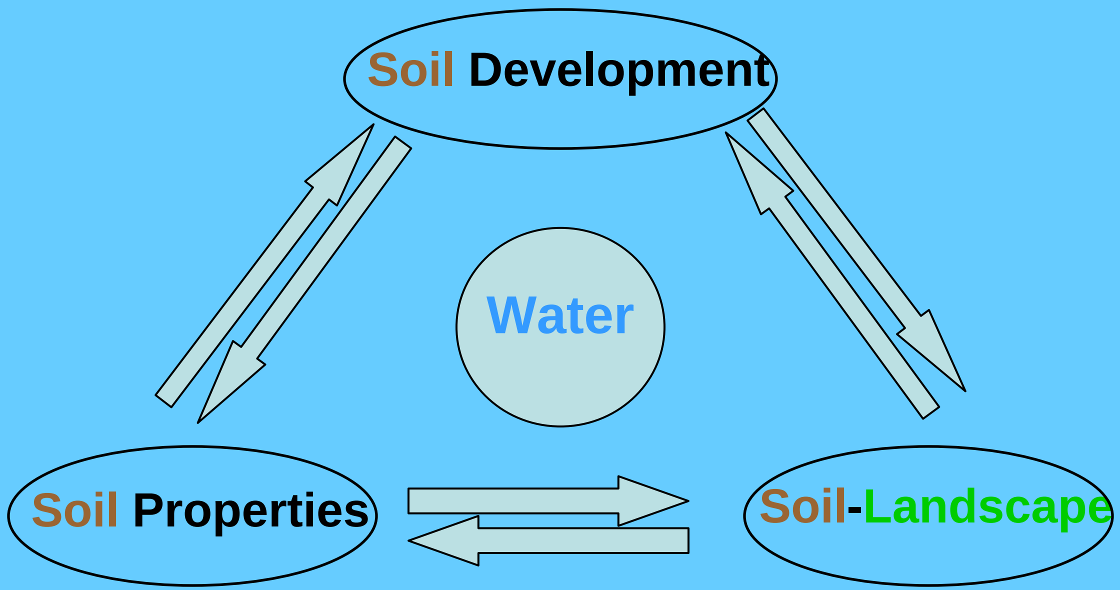
$$V_{ij} = \frac{\sum_{k=1}^{n} S_{ij}^{k} \bullet V^{K}}{\sum_{k=1}^{n} S_{ij}^{k}}$$

S_{ij} – assigned property value;

S^{k}_{ij} – fuzzy membership value.

TASM Principle

Soil-Water Relationships



TASM Principle

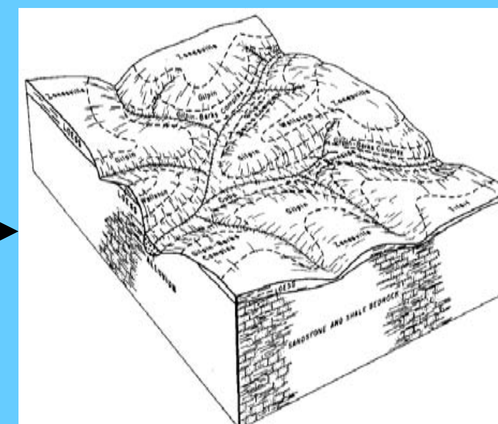
From Qualitative to Numerical Soil-Landscape relationships via Terrain Attributes

Expert/Tacit Knowledge

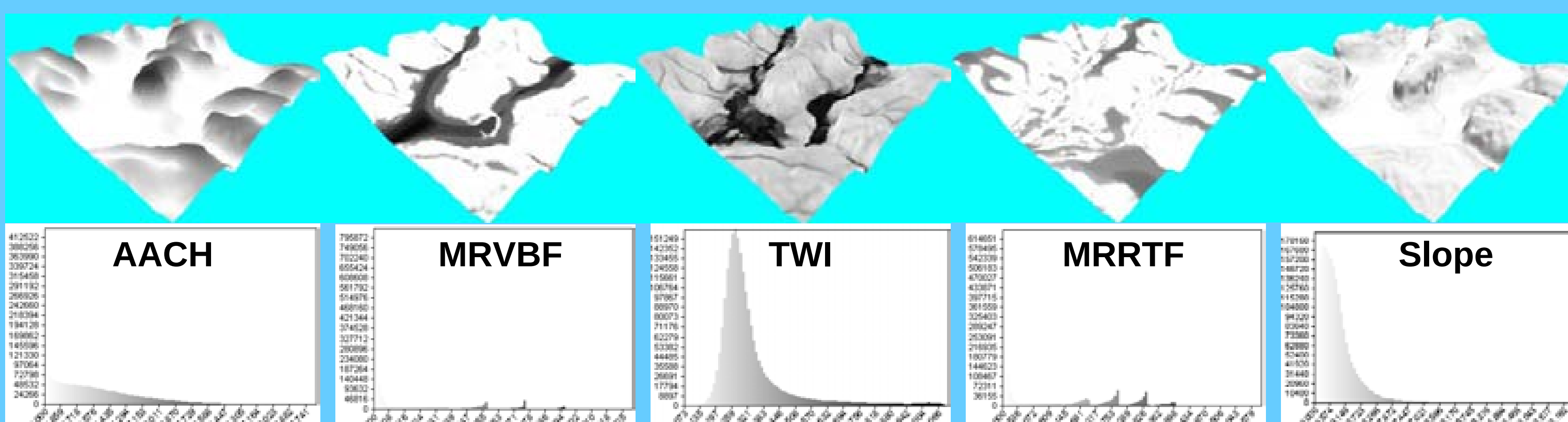
→

- Expert gains knowledge
- Expert examines landscapes
- Expert applies knowledge to new landscapes
- Knowledge communicated via the soil map

→



Block Diagrams/Qualitative Soil-Landscape relationships



Terrain Attributes Soil Relationships

Gilpin

MRRTF < 2.4

MRVBF < 2.9

Slope 12-18 %

Cuba

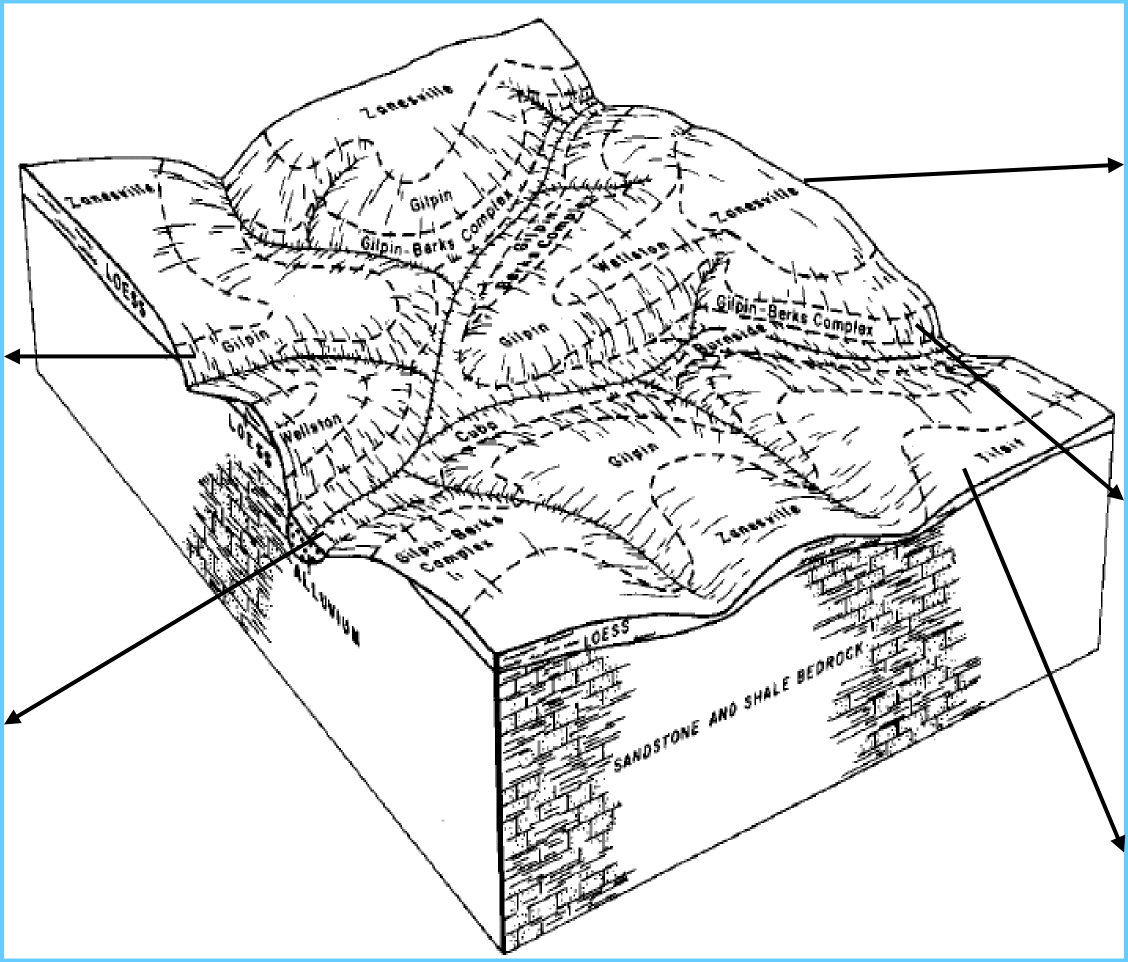
MRRTF < 2.4

MRVBF < 2.9

Slope 0-2 %

AACH >0.09

TWI <12



Zanesville

MRRTF > 2.4

MRVBF < 2.9

Slope 6-12 %

Gilpin-Berks complex

MRRTF < 2.4

MRVBF < 2.9

Slope 18-50 %

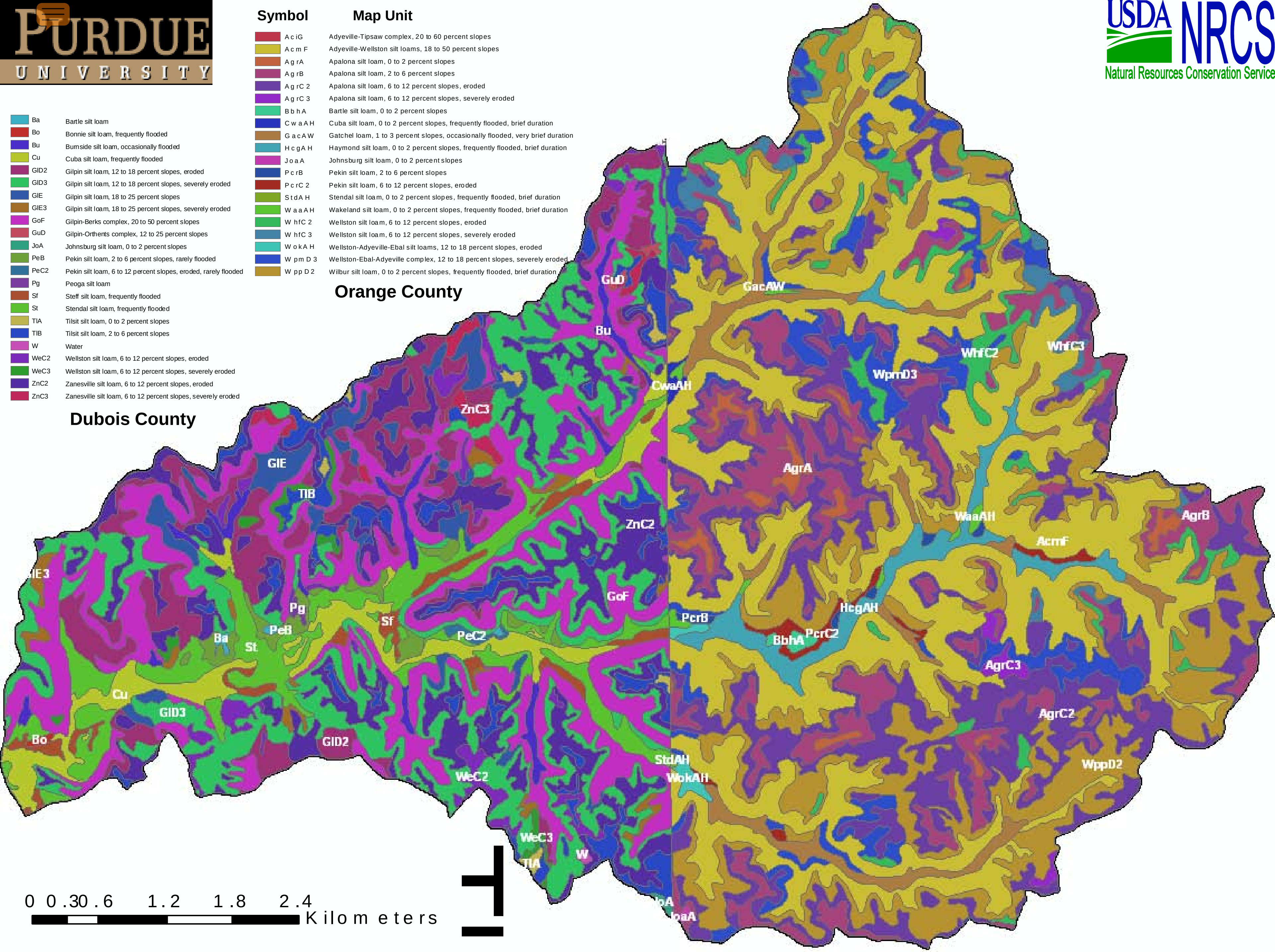
AACH 0.5-2.0

Tilsit

MRRTF > 2.4

MRVBF < 2.9

Slope < 2%



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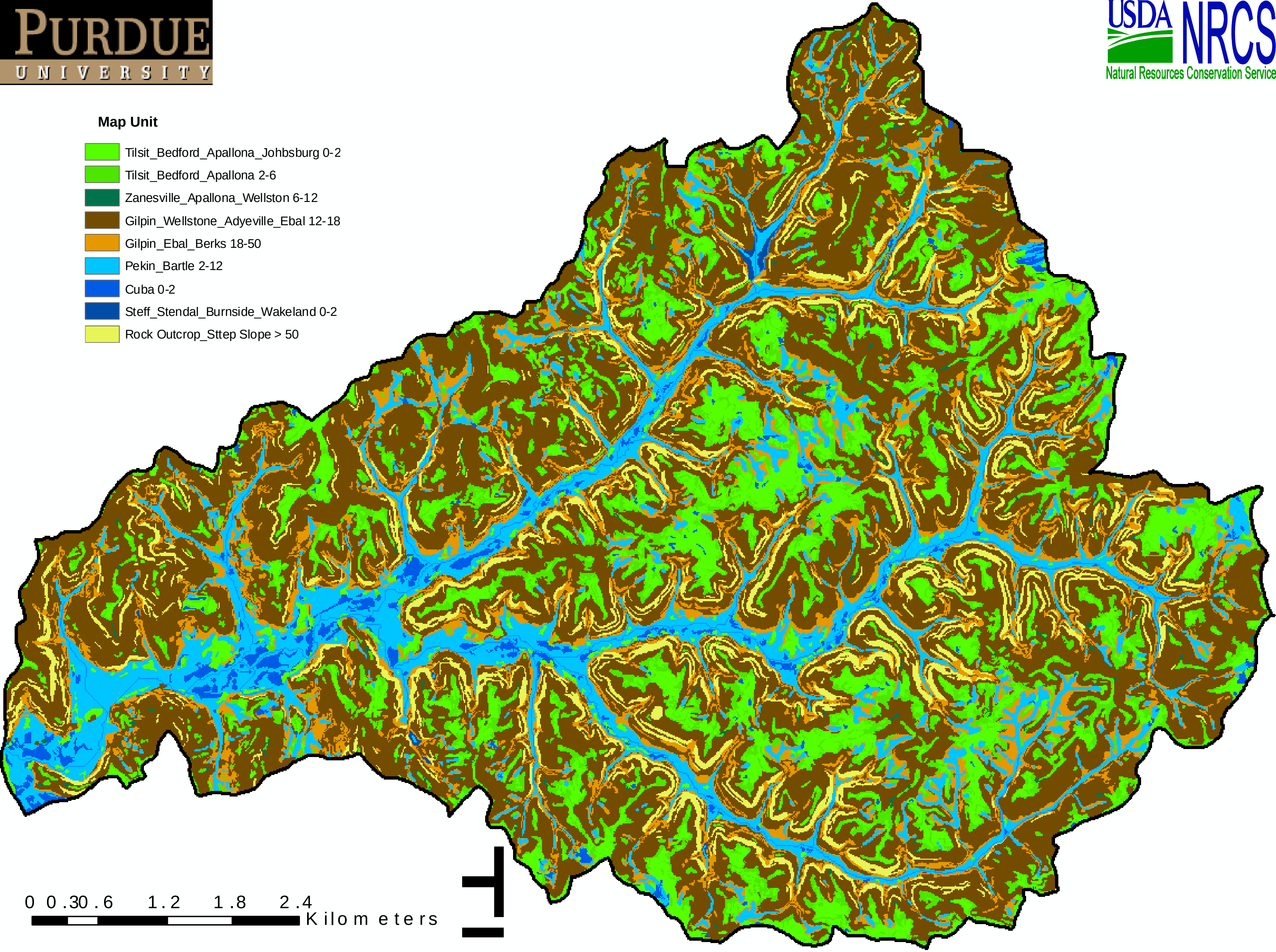
Symbol Map Unit
AciG Adyeville-Tipsaw complex, 20 to 60 percent slopes
AcmF Adyeville-Wellston silt loams, 18 to 50 percent slopes
AgrA Apalona silt loam, 0 to 2 percent slopes
AgrB Apalona silt loam, 2 to 6 percent slopes
AgrC2 Apalona silt loam, 6 to 12 percent slopes, eroded
AgrC3 Apalona silt loam, 6 to 12 percent slopes, severely eroded
BbhA Bartle silt loam, 0 to 2 percent slopes
CwaAH Cuba silt loam, 0 to 2 percent slopes, frequently flooded, brief duration
GacAW Gatchel loam, 1 to 3 percent slopes, occasionally flooded, very brief duration
HcgAH Haymond silt loam, 0 to 2 percent slopes, frequently flooded, brief duration
JoaA Johnsburg silt loam, 0 to 2 percent slopes
PcrB Pekin silt loam, 2 to 6 percent slopes
PcrC2 Pekin silt loam, 6 to 12 percent slopes, eroded
StdAH Stendal silt loam, 0 to 2 percent slopes, frequently flooded, brief duration
WaaAH Wakeland silt loam, 0 to 2 percent slopes, frequently flooded, brief duration
WhfC2 Wellston silt loam, 6 to 12 percent slopes, eroded
WhfC3 Wellston silt loam, 6 to 12 percent slopes, severely eroded
WokAH Wellston-Adyeville-Ebal silt loams, 12 to 18 percent slopes, eroded
WpmD3 Wellston-Ebal-Adyeville complex, 12 to 18 percent slopes, severely eroded
WppD2 Wilbur silt loam, 0 to 2 percent slopes, frequently flooded, brief duration
Orange County
Ba Bartle silt loam
Bo Bonnie silt loam, frequently flooded
Bu Burnside silt loam, occasionally flooded
Cu Cuba silt loam, frequently flooded
GlD2 Gilpin silt loam, 12 to 18 percent slopes, eroded
GlD3 Gilpin silt loam, 12 to 18 percent slopes, severely eroded
GlE Gilpin silt loam, 18 to 25 percent slopes
GlE3 Gilpin silt loam, 18 to 25 percent slopes, severely eroded
GoF Gilpin-Berks complex, 20 to 50 percent slopes
GuD Gilpin-Orthents complex, 12 to 25 percent slopes
JoA Johnsburg silt loam, 0 to 2 percent slopes
PeB Pekin silt loam, 2 to 6 percent slopes, rarely flooded
PeC2 Pekin silt loam, 6 to 12 percent slopes, eroded, rarely flooded
Pg Peoga silt loam
Sf Steff silt loam, frequently flooded
St Stendal silt loam, frequently flooded
TlA Tilsit silt loam, 0 to 2 percent slopes
TlB Tilsit silt loam, 2 to 6 percent slopes
W Water
WeC2 Wellston silt loam, 6 to 12 percent slopes, eroded
WeC3 Wellston silt loam, 6 to 12 percent slopes, severely eroded
ZnC2 Zanesville silt loam, 6 to 12 percent slopes, eroded
ZnC3 Zanesville silt loam, 6 to 12 percent slopes, severely eroded
Dubois County
GuD
GacAW
Bu
WhfC2
WhfC3
WpmD3
CwaAH
ZnC3
GlE
AgrA
TlB
ZnC2
WaaAH
AgrB
AcmF
GlE3
GoF
Pg
HcgAH
PcrB
Sf
PeB
PcrC2
BbhA
Ba
St
PeC2
AgrC3
Cu
GlD3
AgrC2
Bo
GlD2
StdAH
WokAH
WppD2
WeC2
WeC3
TlA
W
JoA
JoaA
0 0.3 0.6 1.2 1.8 2.4
Kilometers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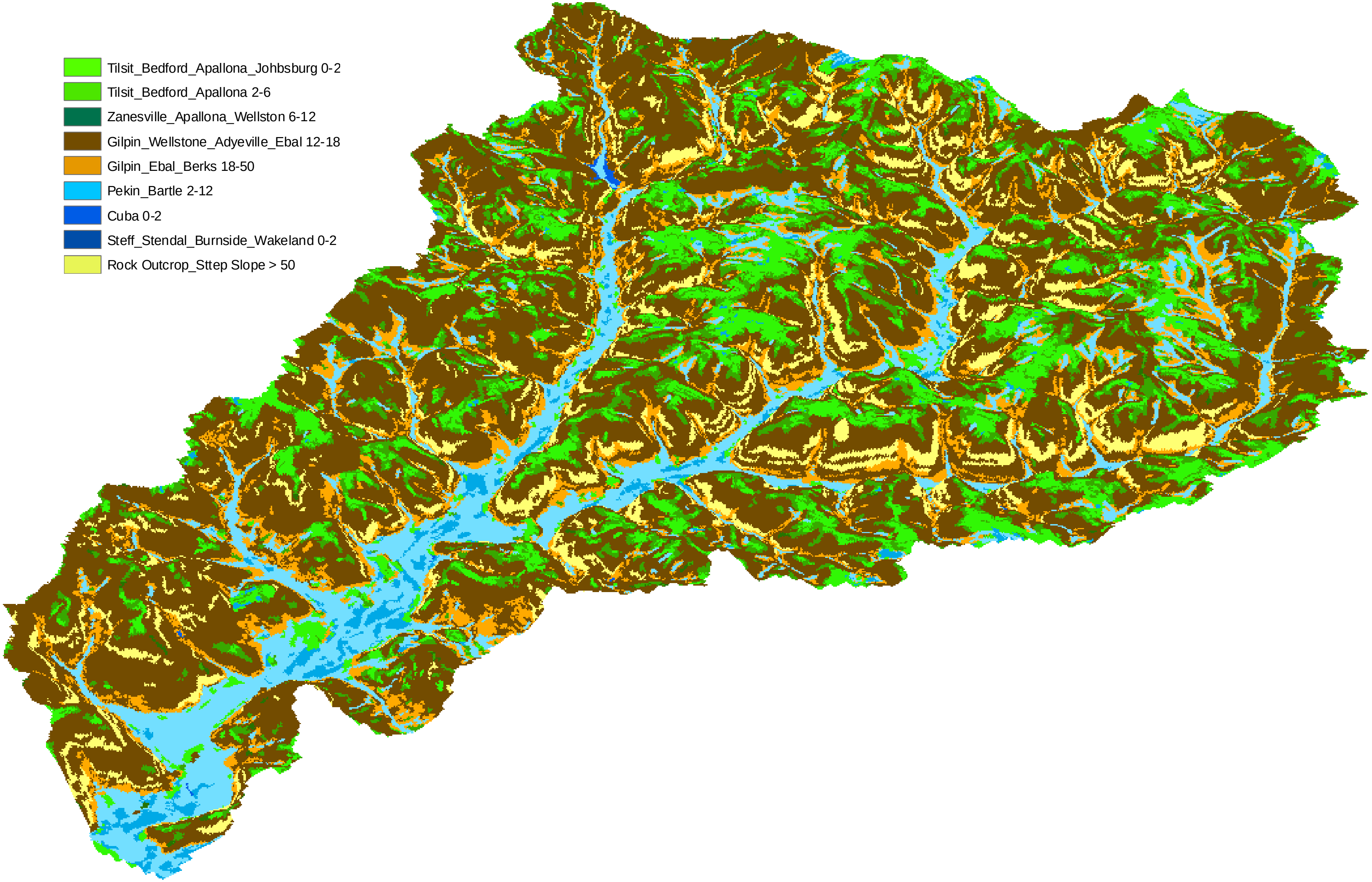
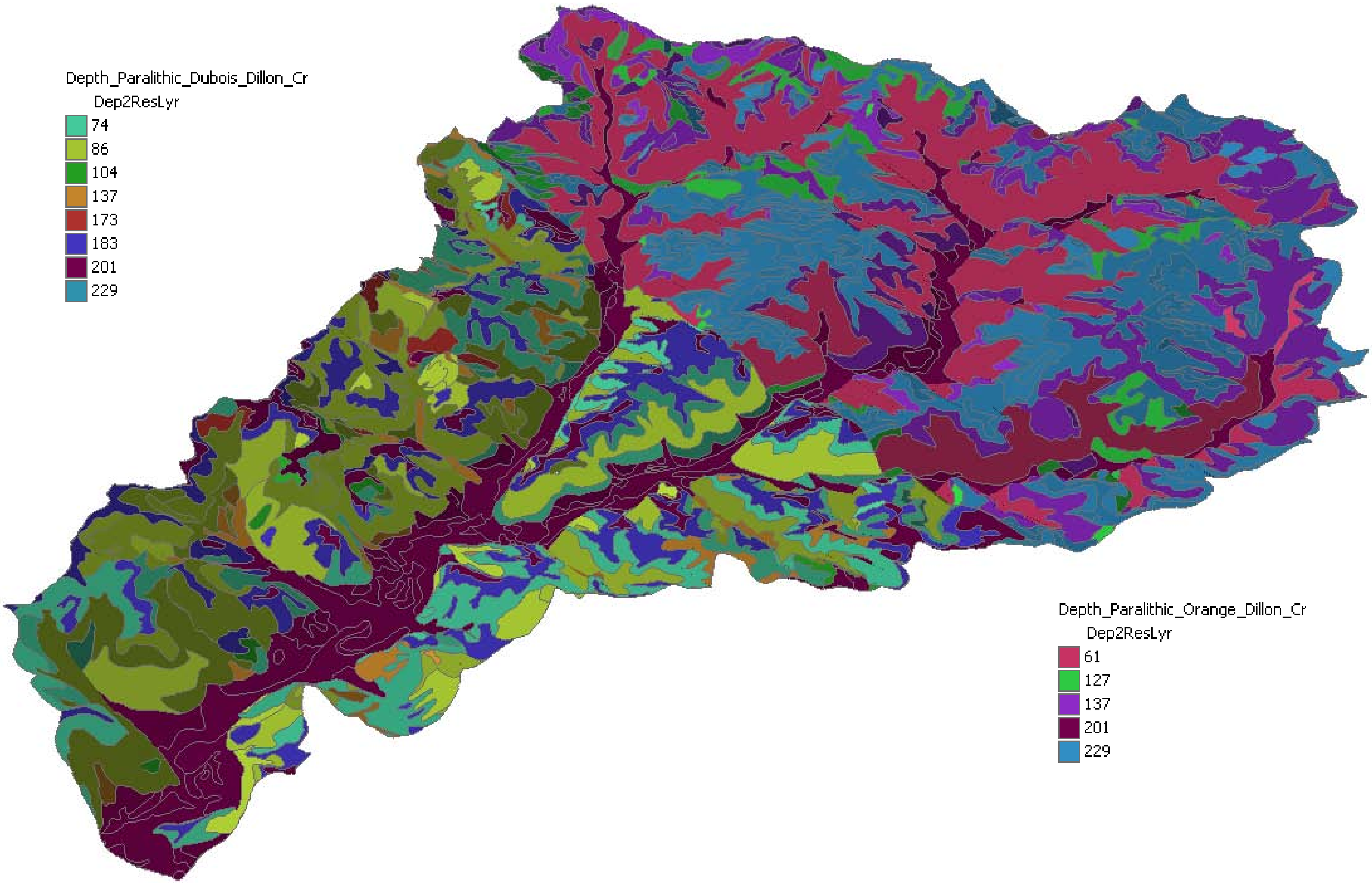
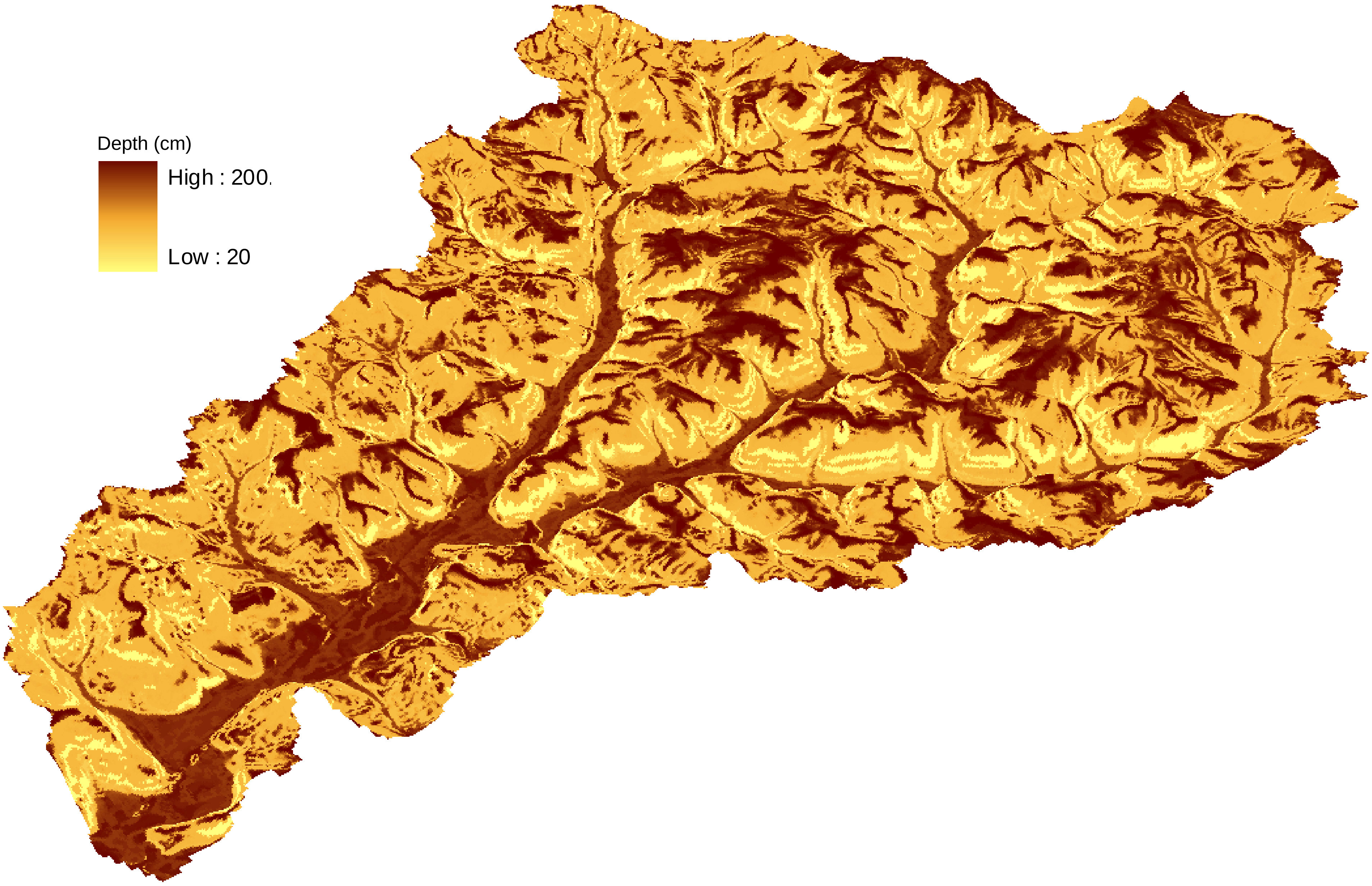
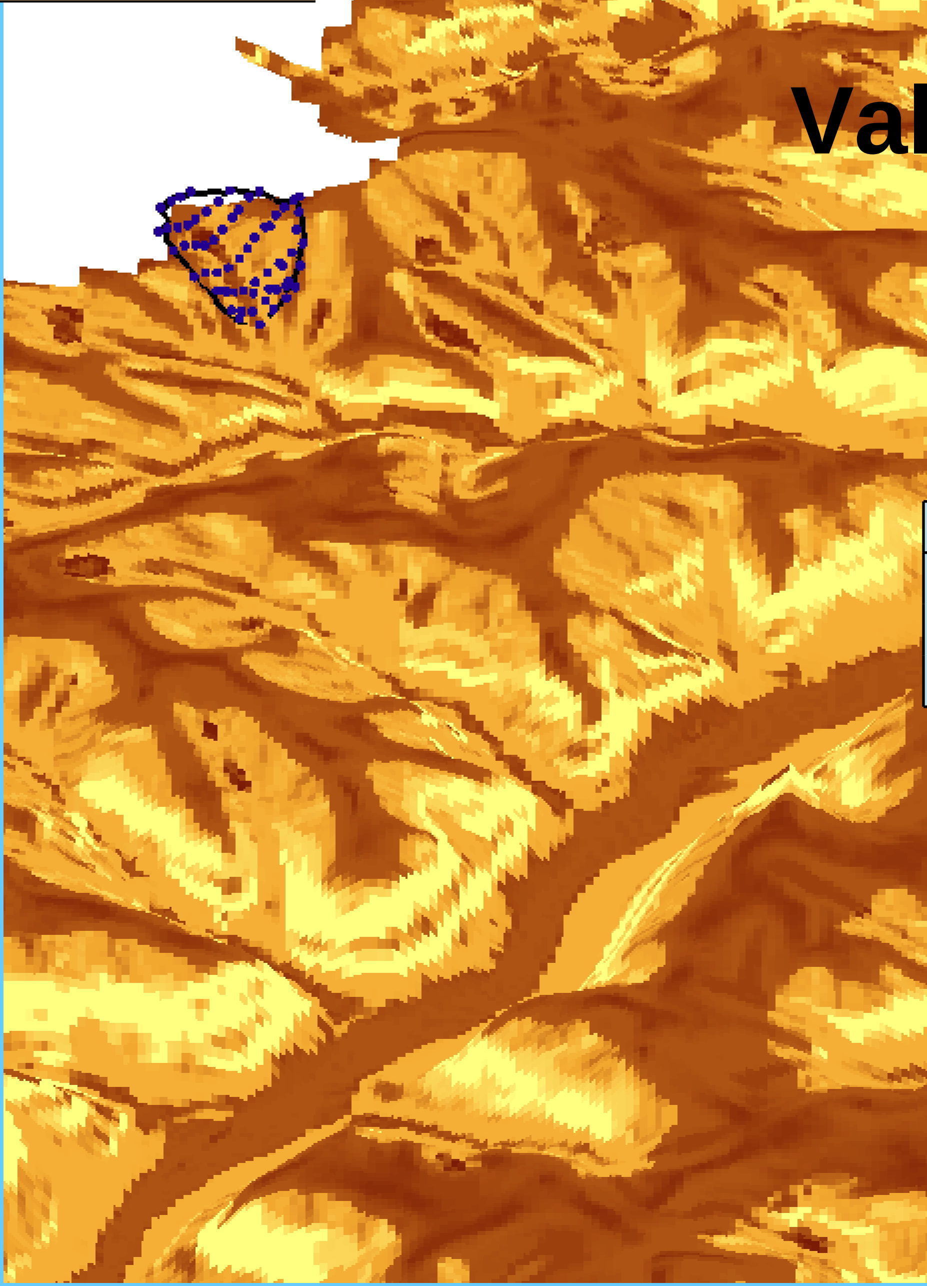
Map Unit
Tilsit_Bedford_Apallona_Johbsburg 0-2
Tilsit_Bedford_Apallona 2-6
Zanesville_Apallona_Wellston 6-12
Gilpin_Wellstone_Adyeville_Ebal 12-18
Gilpin_Ebal_Berks 18-50
Pekin_Bartle 2-12
Cuba 0-2
Steff_Stendal_Burnside_Wakeland 0-2
Rock Outcrop_Sttep Slope > 50
0 0.3 0.6 1.2 1.8 2.4
Kilometers


Tilsit_Bedford_Apallona_Johbsburg 0-2
Tilsit_Bedford_Apallona 2-6
Zanesville_Apallona_Wellston 6-12
Gilpin_Wellstone_Adyeville_Ebal 12-18
Gilpin_Ebal_Berks 18-50
Pekin_Bartle 2-12
Cuba 0-2
Steff_Stendal_Burnside_Wakeland 0-2
Rock Outcrop_Sttep Slope > 50


Depth_Paralithic_Dubois_Dillon_Cr
Dep2ResLyr
74
86
104
137
173
183
201
229
Depth_Paralithic_Orange_Dillon_Cr
Dep2ResLyr
61
127
137
201
229

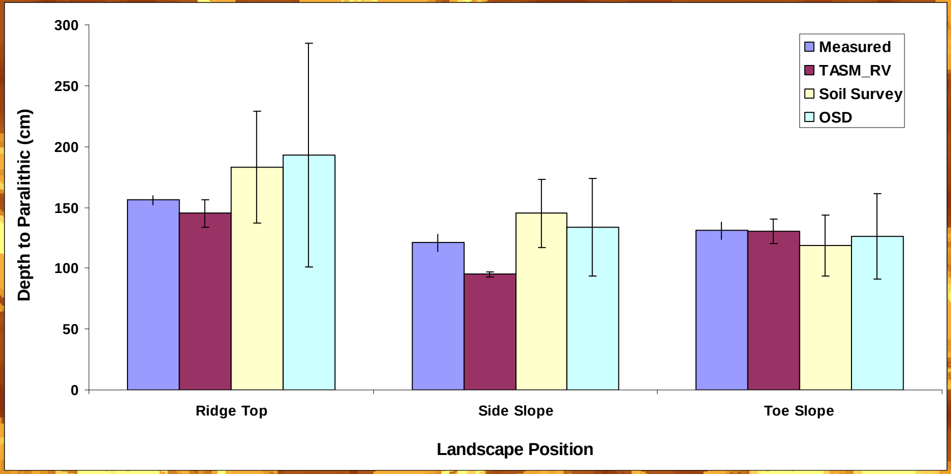

Depth (cm)
High : 200.
Low : 20

Validation



Analysis of Variance Results

Source of Variability	F Value	P Value	Statistical Differences
Landscape position (LP)	19.6	< 0.0001	Significant
Method (TASM vs. Measured)	4.22	0.04	Marginal
LP*Method	1.72	0.18	Not significant



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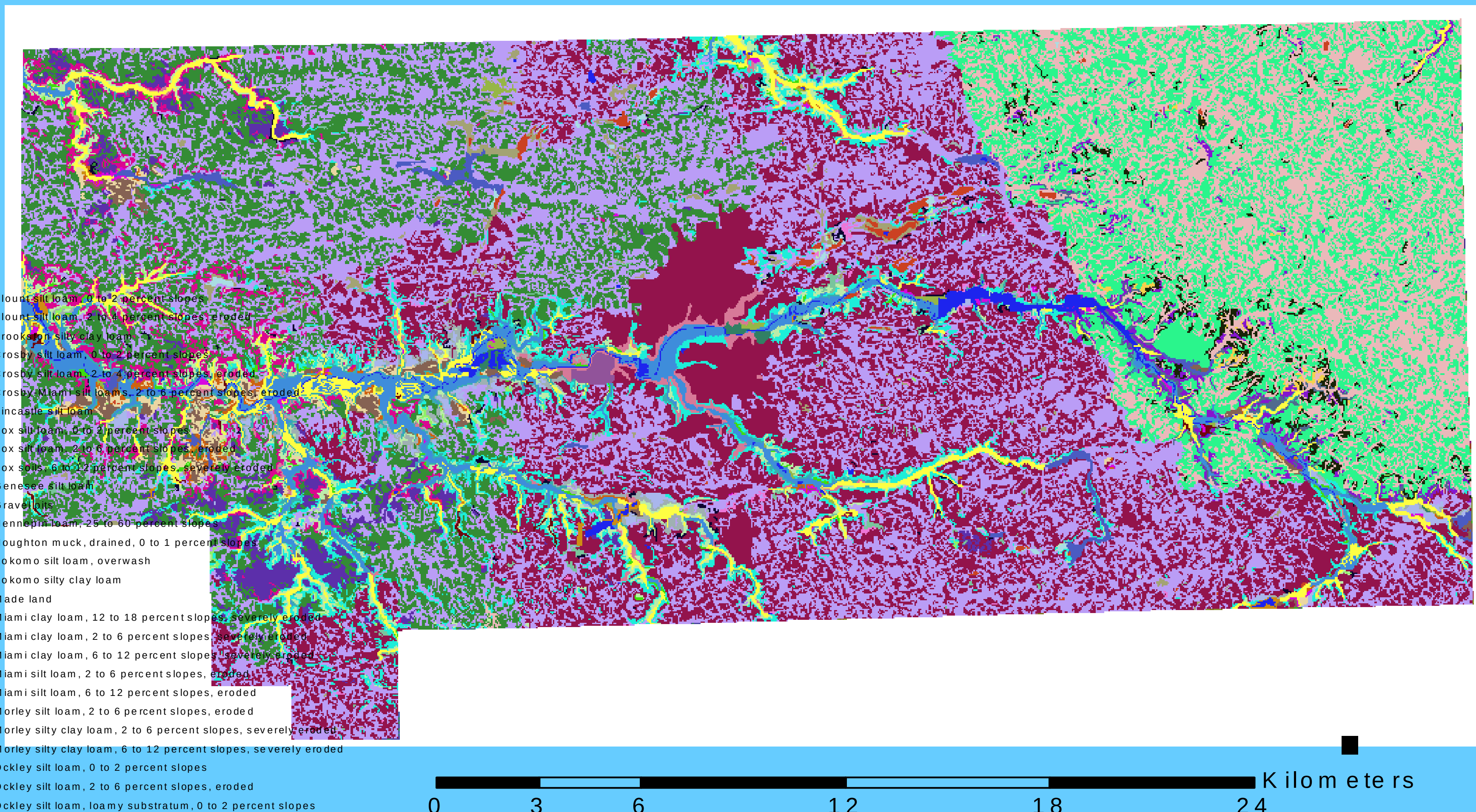

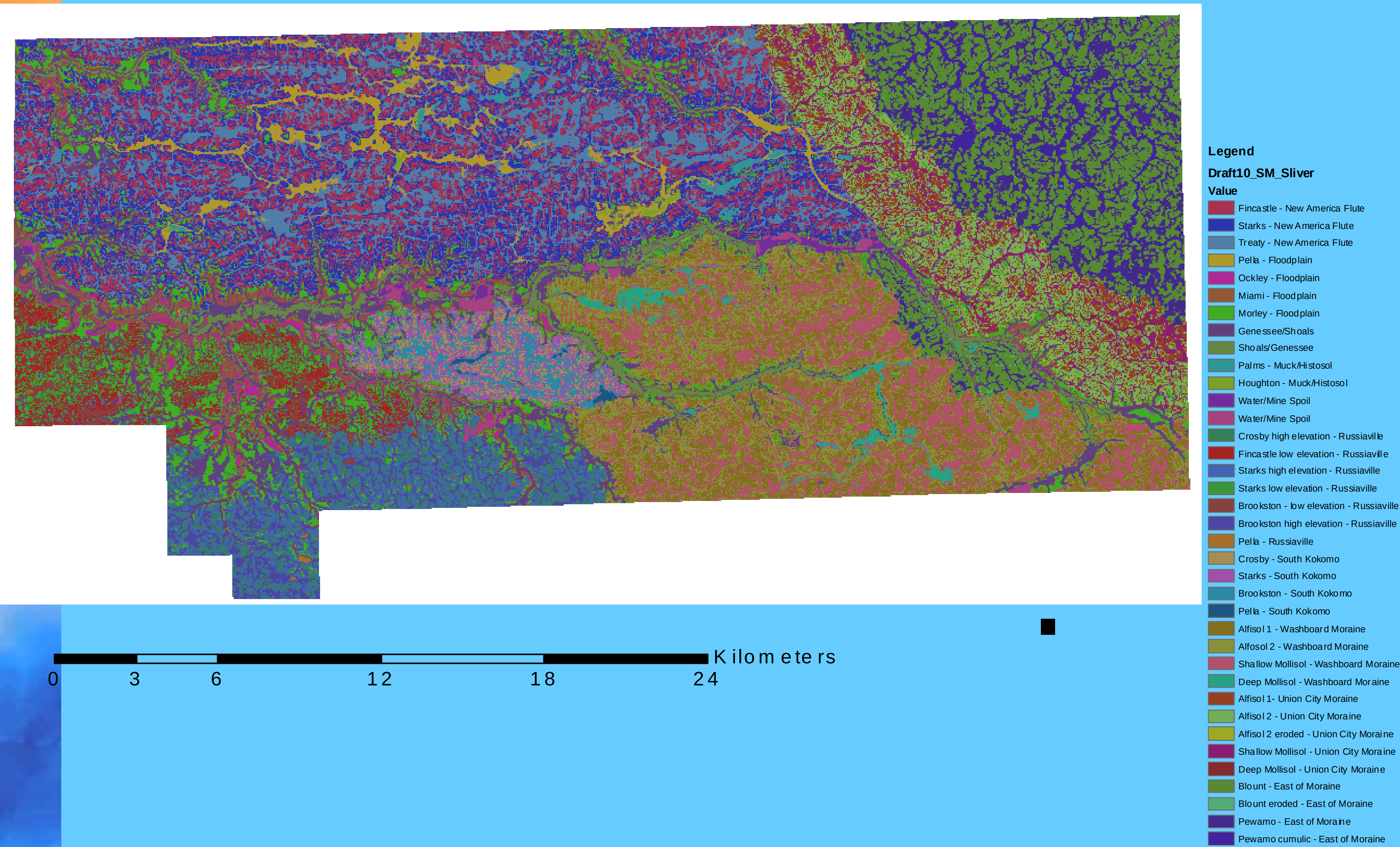
Legend
Draft10_SM_Sliver
Value
Fincastle - New America Flute
Starks - New America Flute
Treaty - New America Flute
Pella - Floodplain
Ockley - Floodplain
Miami - Floodplain
Morley - Floodplain
Genessee/Shoals
Shoals/Genessee
Palms - Muck/Histosol
Houghton - Muck/Histosol
Water/Mine Spoil
Water/Mine Spoil
Crosby high elevation - Russiaville
Fincastle low elevation - Russiaville
Starks high elevation - Russiaville
Starks low elevation - Russiaville
Brookston - low elevation - Russiaville
Brookston high elevation - Russiaville
Pella - Russiaville
Crosby - South Kokomo
Starks - South Kokomo
Brookston - South Kokomo
Pella - South Kokomo
Alfisol 1 - Washboard Moraine
Alfosol 2 - Washboard Moraine
Shallow Mollisol - Washboard Moraine
Deep Mollisol - Washboard Moraine
Alfisol 1- Union City Moraine
Alfisol 2 - Union City Moraine
Alfisol 2 eroded - Union City Moraine
Shallow Mollisol - Union City Moraine
Deep Mollisol - Union City Moraine
Blount - East of Moraine
Blount eroded - East of Moraine
Pewamo - East of Moraine
Pewamo cumulic - East of Moraine
Kilometers
0 3 6 12 18 24

The Accuracy assessment results of validation between TASM (Producer) and SSURGO (User), for the main soil series

Soil Series	Accuracy (%)	
	Producer	User
Fincastle	0.87	0.92
Brookston	0.90	0.77
Crosby	0.90	0.78
Blount	0.68	0.84
Powamo	0.61	0.36
Shoals	0.21	0.37
Morley	0.20	1
Patton	1	1
Miami	1	0.09
Overall Accuracy (%)	**0.77**	

Validation based on 460 geo-referenced points

The kappa coefficient was 0.74 suggesting that the substantial agreement between TASM and SSURGO was not random

κappa	Interpretation
< 0 —	No agreement
0.0 — 0.20	Slight agreement
0.21 — 0.40	Fair agreement
0.41 — 0.60	Moderate agreement
0.61 — 0.80	Substantial agreement
0.81 — 1.00	Almost perfect agreement

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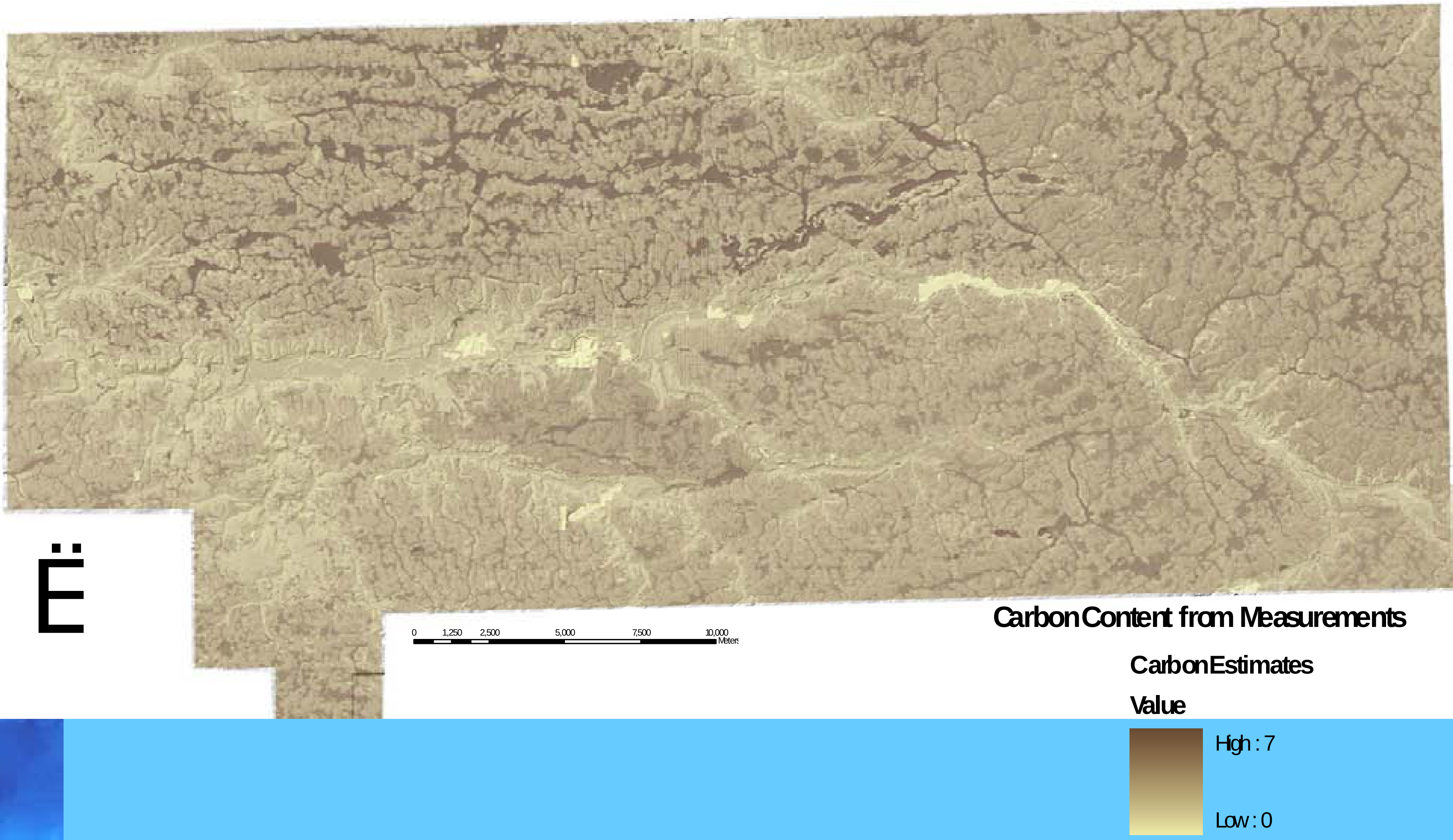
Spatial Distribution of Total C



Discussion

- There are no fixed rules about the relationship between terrain attributes and predicted soils. (e.g. TWI and Cuba relationship – specific values – will not necessarily hold in multiple watersheds)
- Fuzzy membership maps are not a substitute for established NRCS soil maps, however as an additional product will provide tremendous value.
- Fuzzy membership maps can aid interpretation and prediction of specific soil properties.
- Soil mapping is STILL “an art and a science.”

Conclusions

- We have the tools to map gradations of soil variability;
- Terrain attributes are useful for estimating soil properties;
- Structural heterogeneity of soils can be simplified for hydrological response predictions because of functional homogeneity of soil properties.