Exploring Relationships Between Soil Structure and Climate Across the Conterminous USA

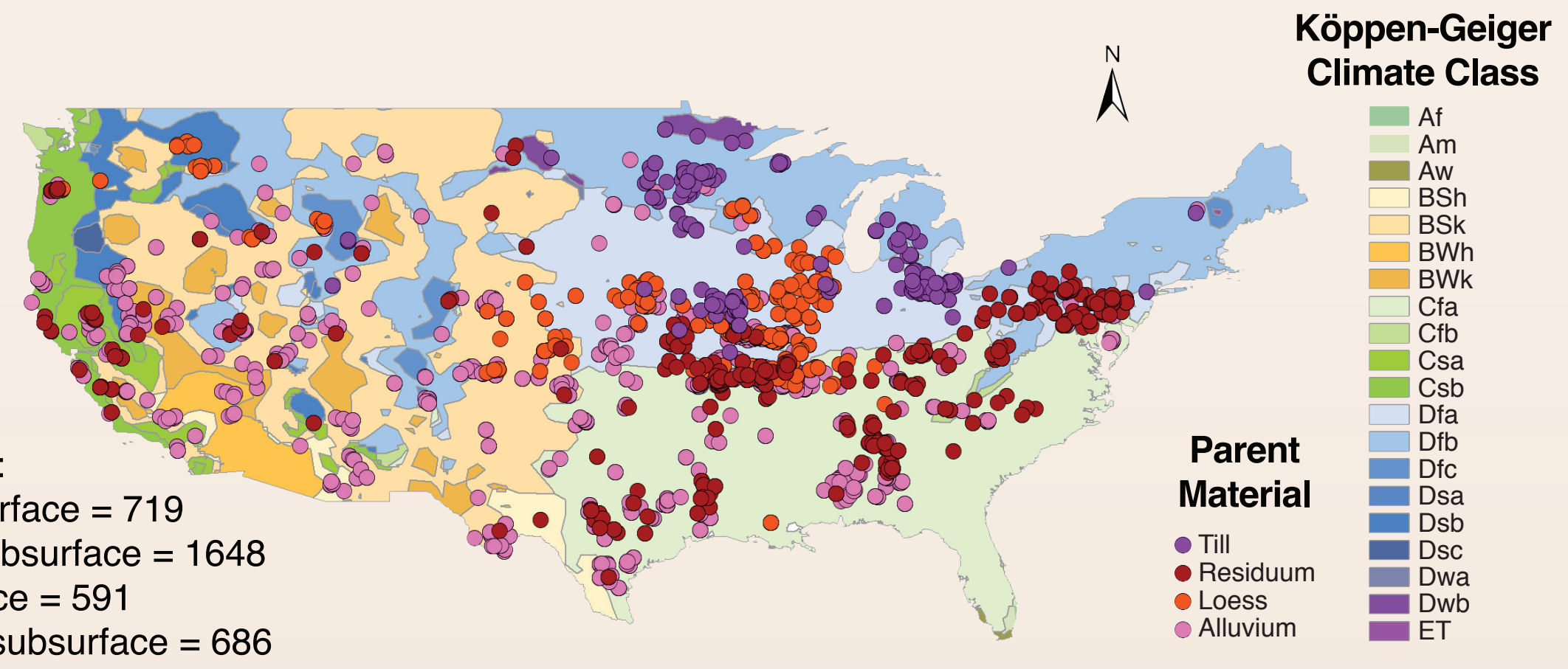
A.K. Mohammed,† D.R. Hirmas,†* D. Giménez,‡ A. Nemes§

† Dep. of Geography and Atmospheric Science, University of Kansas, Lawrence, KS (*hirmas@ku.edu)
‡ Dep. of Environmental Sciences, Rutgers, New Brunswick, NJ
§ Div. for Environment and Natural Resources, Norwegian Institute of Bioeconomy Research, Ås, Norway

Soil and Climate Information

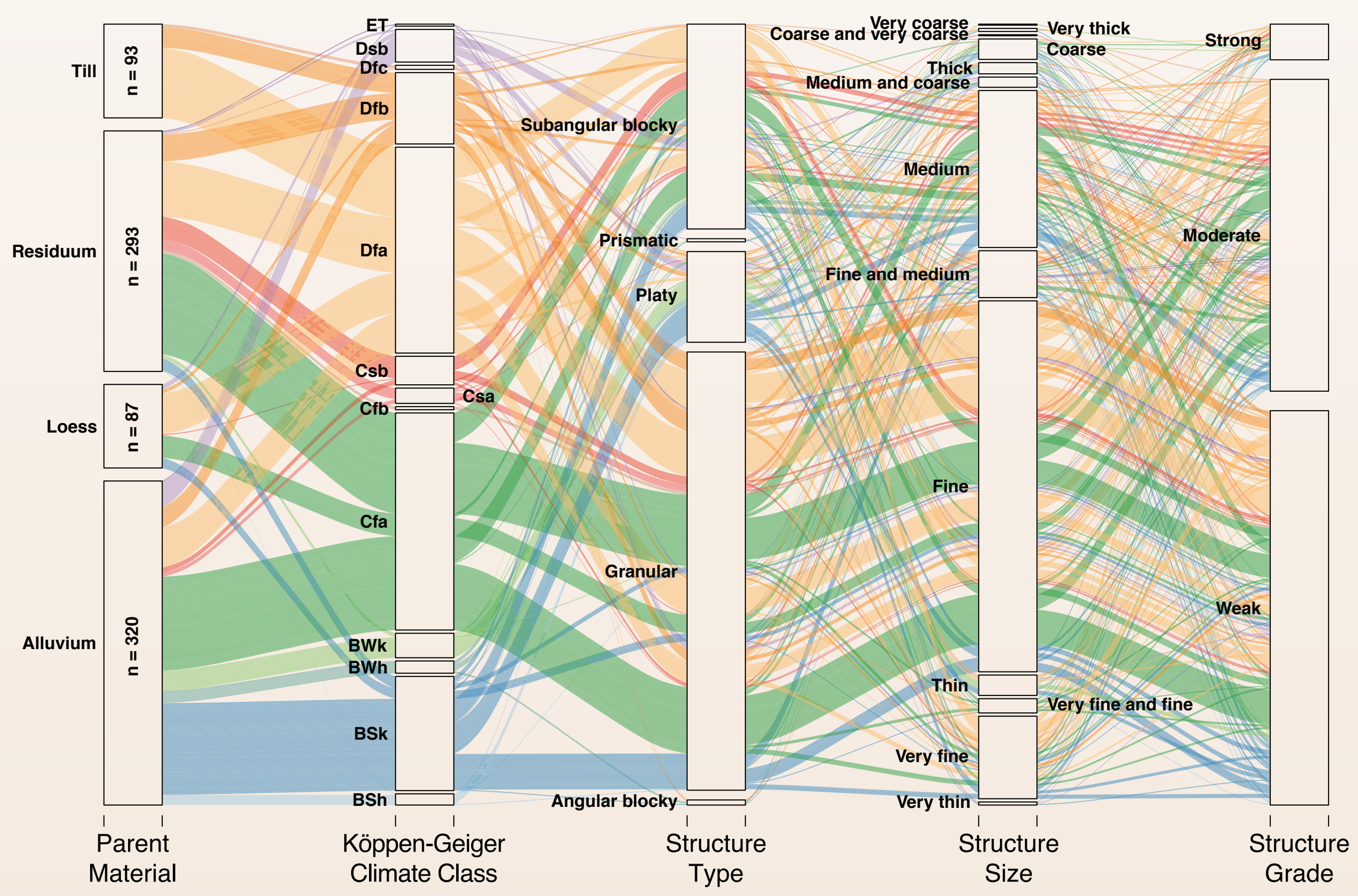
We combined the USDA NRCS Soil Characterization Database with climatological information from the Koppen-Geiger climate classification and PRISM mean annual precipitation (MAP) and mean annual temperature (MAT) data to investigate relationships between soil structure and climate in the US. Surface and subsurface horizons within 4 parent materials were selected.

Only Alfisols, Aridisols, Mollisols, and Ultisols were selected



Numbers of observations chosen for this study were:
Loess surface = 87; subsurface = 719
Alluvium surface = 320; subsurface = 1648
Till surface = 93; subsurface = 591
Residuum surface = 293; subsurface = 686

A horizons (excluding Ap) within 25 cm of the land surface



B horizons deeper than 25 cm below the land surface

Categorical parallel coordinate plots colored by climate class

Grade	Value
Structureless	0.0
Weak	1.0
Weak & moderate	1.5
Moderate	2.0
Moderate & strong	2.5
Strong	3.0
Very strong	3.5

Size Class	Upper Boundary (mm)	Lower Boundary (mm)	Geometric Mean (mm)
Granular/Platy			
V. fine/thin	0.1	1	0.32
Fine/Thin	1	2	1.41
Medium	2	5	3.16
Coarse/Thick	5	10	7.07
V. coarse/thick	10		10.00
Columnar/Prismatic/Wedge			
V. fine	0.1	10	1.00
Fine	10	20	14.14
Medium	20	50	31.62
Coarse	50	100	70.71
V. coarse	100	500	223.61
E. Coarse	500		500.00
Angular Blocky/Subangular Blocky			
V. fine	0.1	5	0.71
Fine	5	10	7.07
Medium	10	20	14.14
Coarse	20	50	31.62
V. coarse	50		50.00

Ped Type	Circularity	Orientation (°)	Width:Height Ratio	Aspect Ratio	Roundness	Solidity
abk	0.91	88.1	0.21	1.00	0.97	0.90
col	0.35	84.0	0.19	4.37	0.07	0.82
gr	1.01	35.0	1.13	1.34	0.76	0.93
pl	0.27	5.73	4.21	6.77	0.08	0.74
pr	0.27	82.2	0.14	5.87	0.04	0.87
sbk	0.75	40.1	1.13	0.97	0.82	0.90
wg	0.48	15.4	1.94	1.00	1.00	0.89

Shape parameters for each type were assigned following Mohammed et al. (2016)

Data Analyses and Results

Occurrence frequency for categorical variables (parent material, climate class, and structure) were examined. Categorical structure variables were converted to quantitative ratio scales and MAP and MAT data were combined into EEMT to analyze relationships on a continuous scale for each type of parent material. Bivariate correlations–Pearson (continuous-continuous), correlation ratio (continuous-multichotomous), and Cramér's V (multichotomous-multichotomous)–were calculated.

Effective Energy and Mass Transfer (Rasmussen and Tabor, 2007)

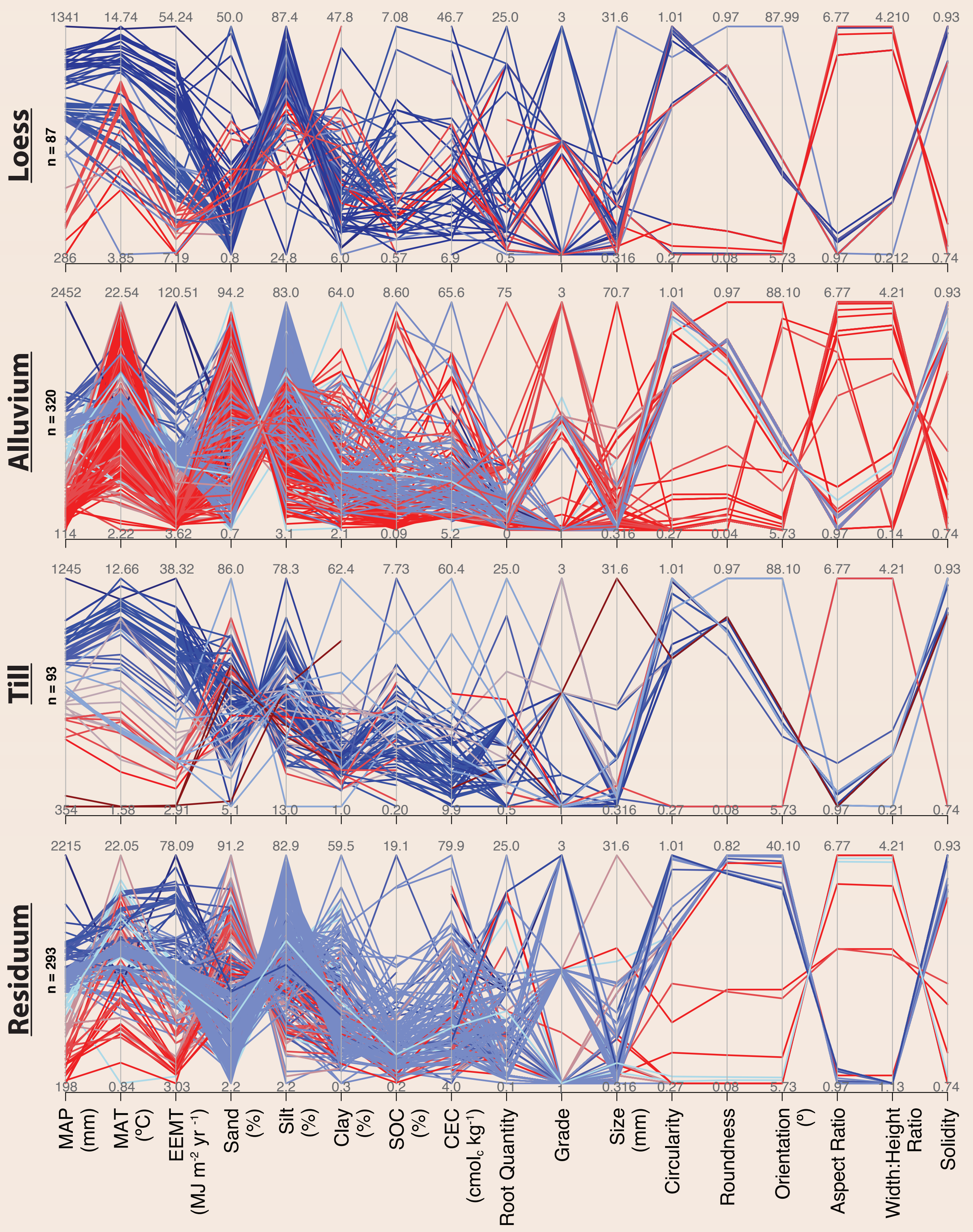
$$\mathrm{EEMT}\ [\mathrm{MJ\ m^2\ y^{-1}}] = 347.134e^{-0.5\left[\left(\frac{\mathrm{MAT}-21.5}{-10.1}\right)^2+\left(\frac{\mathrm{MAP}-4412}{1704}\right)^2\right]}$$

Equation for quantifying grade, size, or type in horizons with compound (C) and non-compound (NC) structures

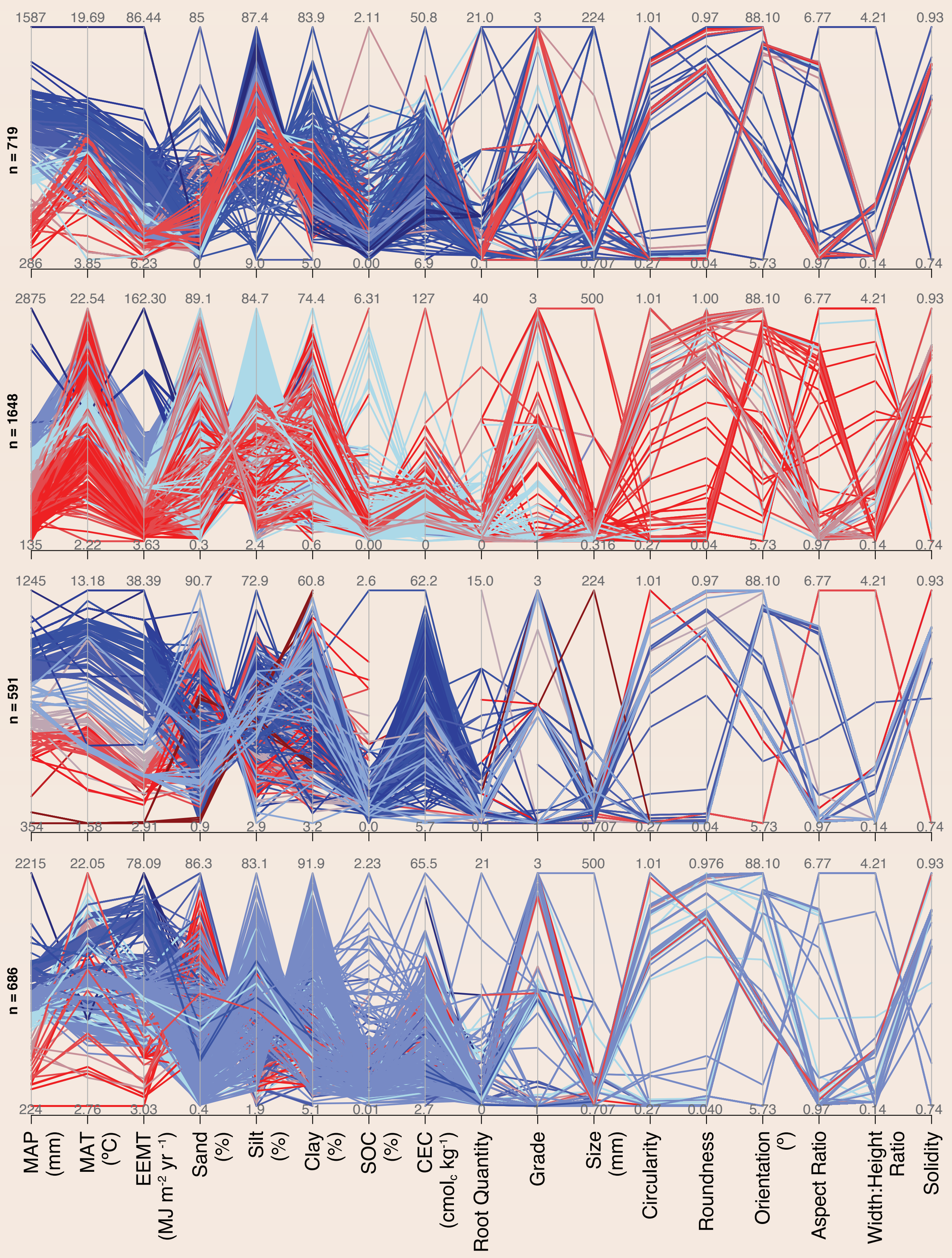
$$\bar{\sigma} = \begin{cases} \frac{1}{A_{xs}} \sum_{k=1}^{o} \left(x_k^2 AR_k f \sigma_k\right) & : \quad \text{only NC} \\ \frac{1}{A_{xs}} \left[\frac{A_{xs_C}}{Q} \sum_{j=1}^{m} \left(q_j \sigma_j\right) + \sum_{k=1}^{o} \left(x_k^2 AR_k f \sigma_k\right)\right] & : \quad \text{either C or both C and NC} \end{cases}$$

Quantitative variable parallel coordinate plots colored by MAP

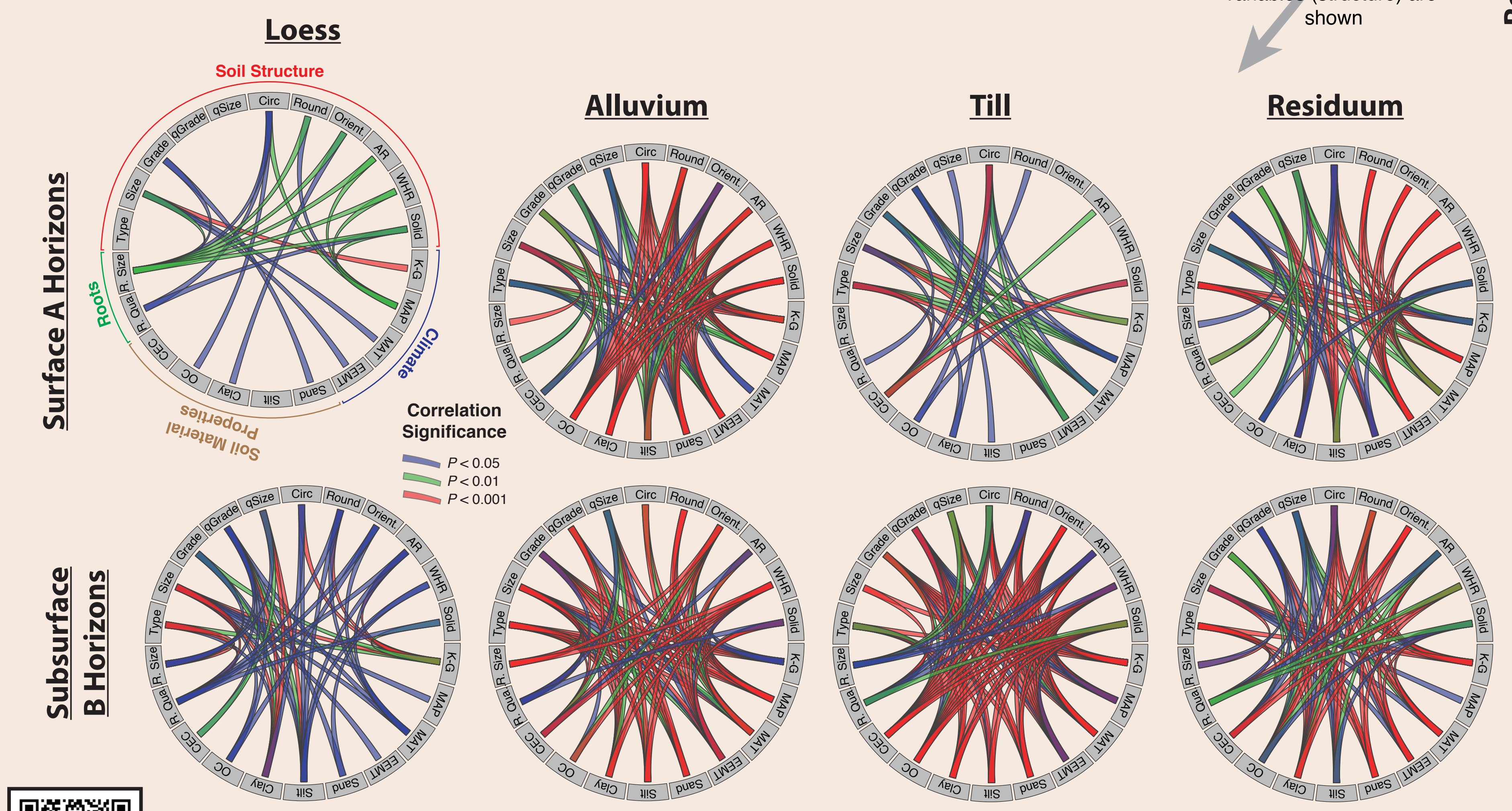
A horizons (excluding Ap) within 25 cm of the land surface



B horizons deeper than 25 cm below the land surface



Circular plots of variables used in this study showing correlation indices as linkages between the variables colored by signficance level; only linkages between x variables (climate, material properties, and vegetation) and y variables (structure) are shown



K-G = Köppen-Geiger Climate Class
R. Qua. = Root quantity class
R. Size = Root size class
Type = Structure type class
Size = Structure type class
Grade = Structure grade class
qGrade = Quantitative structure grade
qSize = Quantitative structure grade
Circ = Circularity
Round = Roundness
Orient. = Orientation
AR = Aspect ratio
WHR = Width:height ratio
Solid = Solidity

Conclusions and Future Work

Quantitative structural parameters for grade, size, and type (i.e., shape parameters) show significant relationships to climate–especially, MAP and EEMT–for the four parent material types studied. For example, parallel coordinate plots show clear separation on shape parameters by MAP. The clarity of the relationship between climate and structure is reduced in horizons below 25 cm likely due to confounding effects from soil material properties as shown in the circular correlation plots. Roots showed significant relationships with structure suggesting that future climate change may influence structure through ecohydrological changes. Future work will examine these relationships with machine learning techniques and structural equation modeling to understand the role, importance, and interactions of the variables studied on structure.

Acknowledgements

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References

Mohammed et al. 2016: [SSSAJ in press]
Rasmussen and Tabor 2007: [SSSAJ 71:1719–1729]