From Landscape to Domain: Soils Role in Landscape Classifications

Shawn W. Salley[1] and Joel R. Brown[2]

[1]*USDA-ARS* (shsalley@nmsu.edu), [2]*USDA-NRCS, Jornada Experimental Range, Las Cruces, NM*

Introduction

Soil landscape classifications are designed to divide landscapes into units with significance for the provisioning and regulating of ecosystem services and the development of conservation plans for natural resources. More specifically, such classifications serve as the basis for stratifying management strategies relevant to any given ecosystem's biotic and abiotic properties. The purpose for delineating resource units is to identify geographical areas at different levels of resolution that have similar capabilities and potentials for management. As soil variability is scale-dependent in both space and time, it is important to understand spatial and temporal variables controlling soil and ecosystem function at specific scales of interest (Table 1).

Principle Environmental Covariates	NRCS Land Resource Hierarchical Framework	
CLIMATE, PHYSIOGRAPHY	Land Resource Regions	Land Resource Regions
GEOLOGY	Major Land Resource Areas	Major Land Resource Areas
LANDFORM	Land Resource Units	Land Resource Units
TOPOGRAPHY	STATSGO General Soil Map	Ecological Sites Groups
SOIL & VEG Dynamics	SSURGO Detailed Soil Map	Ecological Sites
	Component	
	Soil Pedon	Patch

Table 1. Proposed relationships between predictor variables and the NRCS Land Resource Hierarchy. Land Resource Regions (LRR's) are large scale (small cartographic scale, (approx. 1:8 million) which corresponds to domain scale temporal and spatial processes. LRR's are used for organizing and operating resource conservation planning, coordinating technical guides, stratifying resource inventories, and making decisions about agricultural issues.

Often soil geographic models at regional and domain scales are based on up-scaled data aggregated from the downscale soil properties. Yet at macroscales soil ecosystems are controlled by macroclimatic properties that control daily and seasonal fluxes of energy and moisture, such as latitude (variability of soil energy), distance from the sea (continentality or oceanic influences), and elevation. It is only at the mesoscale and microscale levels that landform properties (such as geology and topography) modify macroclimates by regulating the intensity of other key factors important to soil formation (Table 1). By adopting a scale-dependent covariate approach, here we propose new Land Resource Regions (LRR's) for the Natural Resources Conservation Service (NRCS) Land Resource Hierarchy based climate envelope models and generalized elevation.

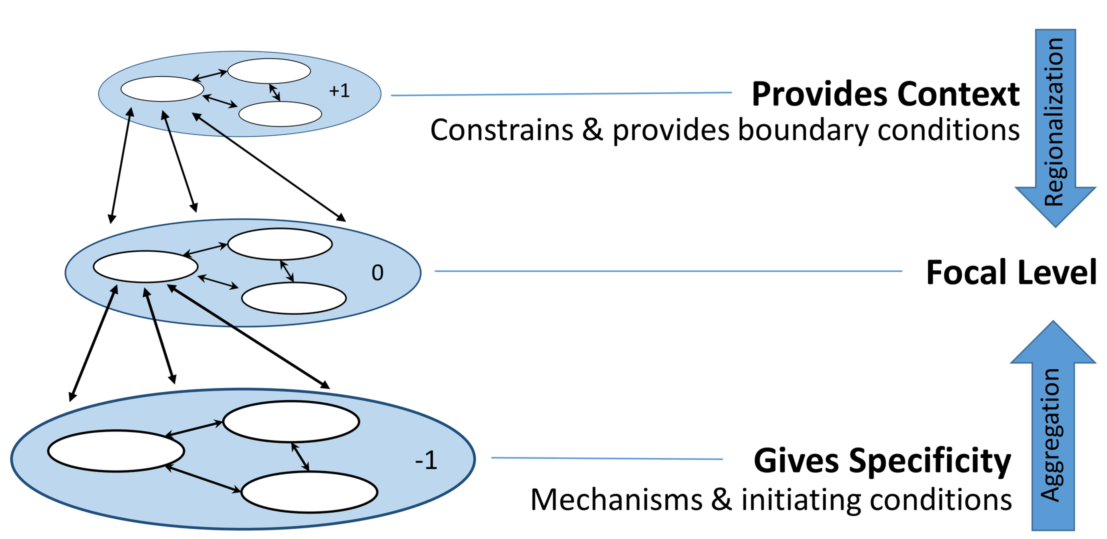
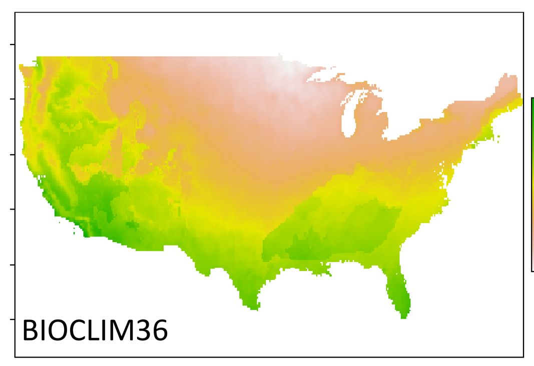


Fig 1. Scales of Organization showing feedbacks and feedforwards from the topmost scale (the domain) and the lowest-most scale (soils).

Methods

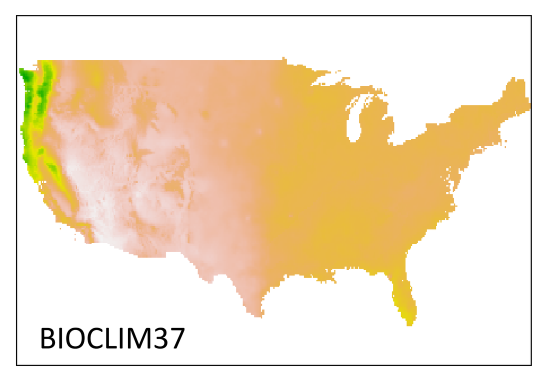
To implement a quantitative regionalization of the NRCS Land Resource Regions (LRR's), we applied a K-means algorithm base on climatic and physiographic variables (Fig. 2). The first 19 BIOCLIM (Bio-Climatic) variables are derived from temperature and precipitation variables (see Table 4) modeled from daily 1950-2000. The remainder (Bio20-Bio35) variables require additional incident radiation or soil water balance variables for the calculation. We used Bio36 to Bio40 variables, which are the first five principle components, reducing all 35 variables into 5 significant components. Bio36 to Bio40 were proposed by Kriticos (2014) to reduce the risk of overfitting of species distribution models with climate envelopes.

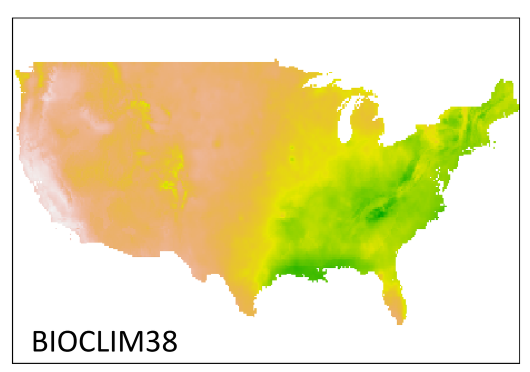
Cluster analysis was preformed using the "R" package 'stats'. Optimal cluster pattern was identified using Euclidian distance and Ward's linkage modeling scaled transformed variables. Zonal statistics were then preformed from the 18 identified clusters on the first 19 BIOCLIM variable (tables 3 and 4).



BIOCLIM36: First Principle Component of Bio01 to Bio35: Temperature dominated variable. (Strong relationship with Bio06, Bio11; moderate contributions from Bio01, Bio05, Bio09; minor contributions from temperature variables (Bio03, Bio07) and radiation variables (Bio22, Bio23, Bio27).

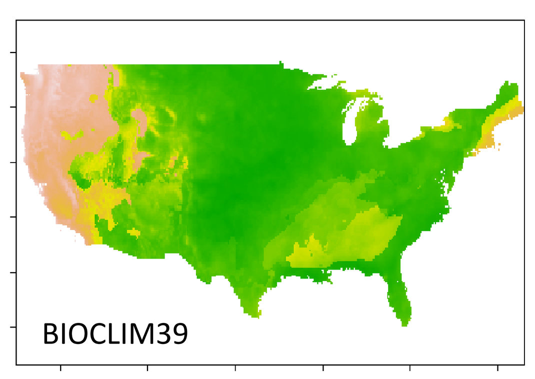
BIOCLIM37: Second principal component of Bio01 to Bio35: A wetness index, driven mainly by Bio29, with minor contributions from Bio13, Bio16.

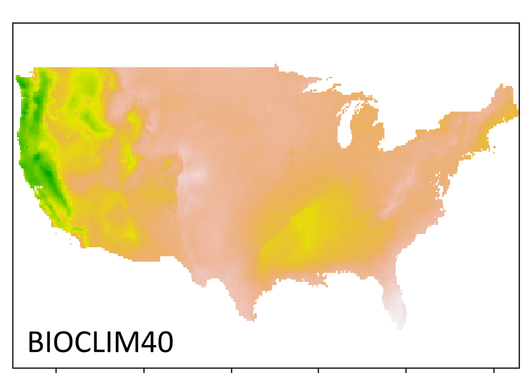




BIOCLIM38: Third principal component of Bio01 to Bio35: A dryness index, related to Bio14, Bio17.

BIOCLIM39: Fourth principal component of Bio01 to Bio35: Mostly, radiation during the wettest quarter (Bio24).





BIOCLIM40: Fifth principal component of Bio01 to Bio35: Mostly, radiation during the warmest quarter (Bio26) and maximum weekly radiation (Bio21)

Physiographic: National elevation dataset used for physical geography.

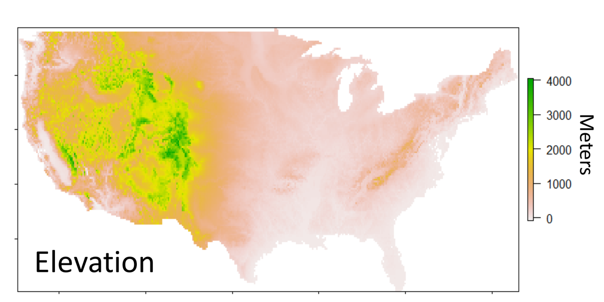


Fig 2. Input model variables. BIOCLIM variables taken from Kriticos et al. (2014) and are the principle components of the Bio1 to Bio35. Elevation model is up-scaled from 800 m resolution image available from PRISM.

Results

Results of our cluster analysis are shown in Fig. 3. Eighteen clusters were identified and summary statistics of climatic variables are presented in tables 2 and 3. Our proposed regionalization varies significantly from the current NRCS LRR map (Fig. 4) which is primarily based on aggregated soil information.

Table 2. Zonal statistics of the modeled Land Resource Regions (Fig. 3) and the average climate envelope temperature variables (Bio1 – Bio11).

Map Cluster	Average BIOCLIM Temperature Variables (°C)								
	BIO1	BIO4	BIO5	BIO6	BIO7	BIO8	BIO9	BIO10	BIO11
1	9	533	25	-2	27	3	16	16	3
2	15	749	34	-4	37	24	9	25	5
3	9	941	31	-12	43	18	-3	21	-3
4	2	785	23	-16	38	7	1	12	-8
5	7	1132	30	-17	46	19	-8	21	-9
6	10	675	29	-4	33	2	18	19	2
7	16	760	32	-1	34	13	21	25	6
8	13	921	32	-7	39	19	0	24	0
9	19	764	39	2	37	19	23	29	10
10	7	964	27	-12	39	14	-5	19	-6
11	19	723	35	1	34	24	10	28	9
12	6	755	27	-11	38	-2	15	16	-4
13	9	803	31	-9	39	13	14	20	-1
14	22	440	33	9	24	27	18	27	16
15	7	855	29	-12	41	13	-3	18	-4
16	9	898	27	-10	37	18	-2	20	-3
17	16	708	32	0	32	24	13	25	7
18	7	1106	28	-16	44	20	-8	20	-8

Table 3. Zonal statistics of the modeled Land Resource Regions (Fig.3) and the average climate envelope precipitation variables (Bio12 – Bio19).

Map Cluster	Average BIOCLIM Precipitation Variables (mm)							
	BI12	BIO13	BIO14	BIO15	BIO16	BIO17	BIO18	BIO19
1	1572	267	19	69	755	91	100	711
2	357	67	9	65	172	31	156	41
3	425	74	11	60	197	37	169	38
4	547	65	31	22	174	107	153	126
5	488	85	10	61	223	37	208	37
6	531	85	11	57	237	46	53	223
7	1319	143	77	18	391	261	302	350
8	994	120	44	28	324	159	283	159
9	185	30	3	51	73	15	45	62
10	880	99	47	21	269	162	251	172
11	673	101	27	41	239	99	185	101
12	441	56	18	32	156	66	77	146
13	317	44	13	32	113	49	89	78
14	1300	201	48	50	556	168	538	195
15	326	49	14	39	128	48	110	49
16	1075	112	67	15	315	219	307	223
17	1276	144	76	18	393	256	384	301
18	792	109	21	47	309	78	306	78

Table 4. List of BIOCLIM variables based on temperature (1-11) and precipitation (12-19) used in summary statistics in tables 2 and 3.

Variables	Details	Variables	Details
BIO1	Annual mean temperature	BIO12	Annual precipitation
BIO2	Mean diurnal temperature range [month (max temp–min temp)]	BIO13	Precipitation of wettest month
		BIO14	Precipitation of driest month
BIO3	Isothermality (P2/P7) (×100)	BIO15	Precipitation seasonality (coefficient)
BIO4	Temperature seasonality (standard dev	BIO16	Precipitation of wettest quarter
BIO5	Max temperature of warmest month	BIO17	Precipitation of driest quarter
BIO6	Min temperature of coldest month	BIO18	Precipitation of warmest quarter
BIO7	Temperature annual range (P5–P6)	BIO19	Precipitation of coldest quarter
BIO8	Mean temperature of wettest quarter		
BIO9	Mean temperature of driest quarter		
BIO10	Mean temperature of warmest quarter		
BIO11	Mean temperature of coldest quarter		

Proposed LRR Regionalizations

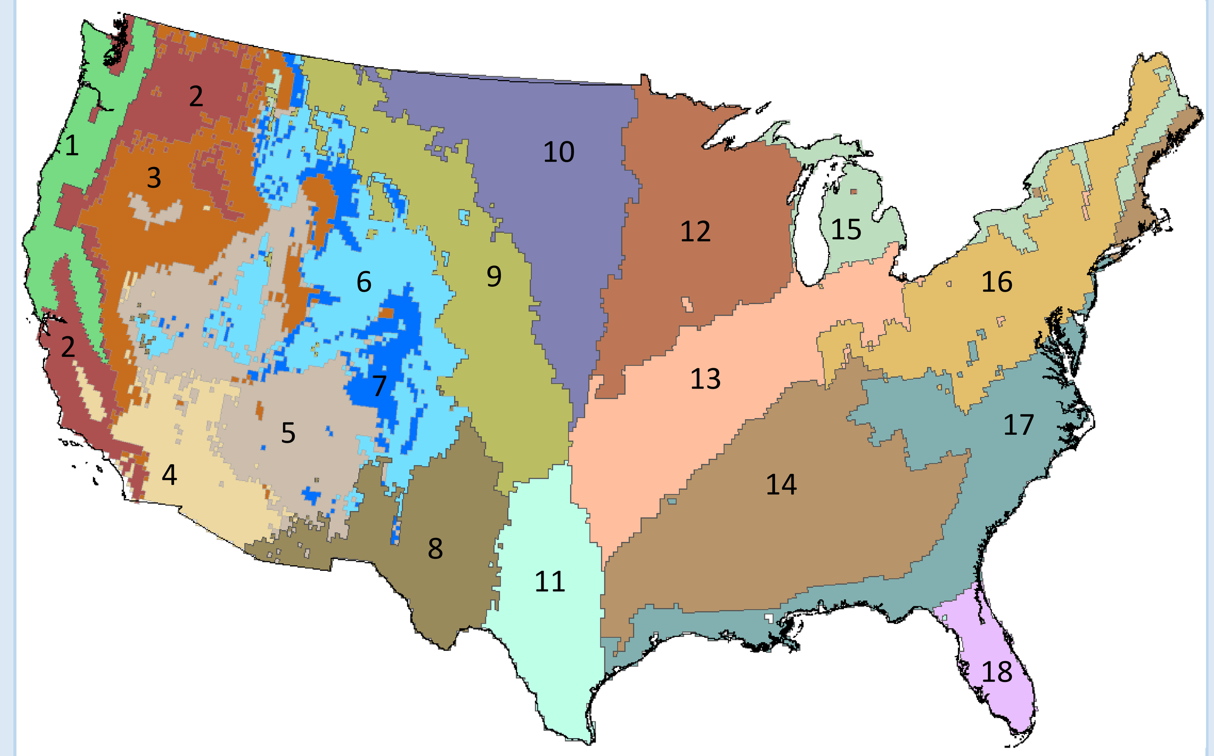


Fig. 3: Proposed regionalization of Land Resource Regions based on K-means clustering of climatic and physiographic variables. Cluster numbers (1-18) are used for the descriptive statics in tables 3 and 4.

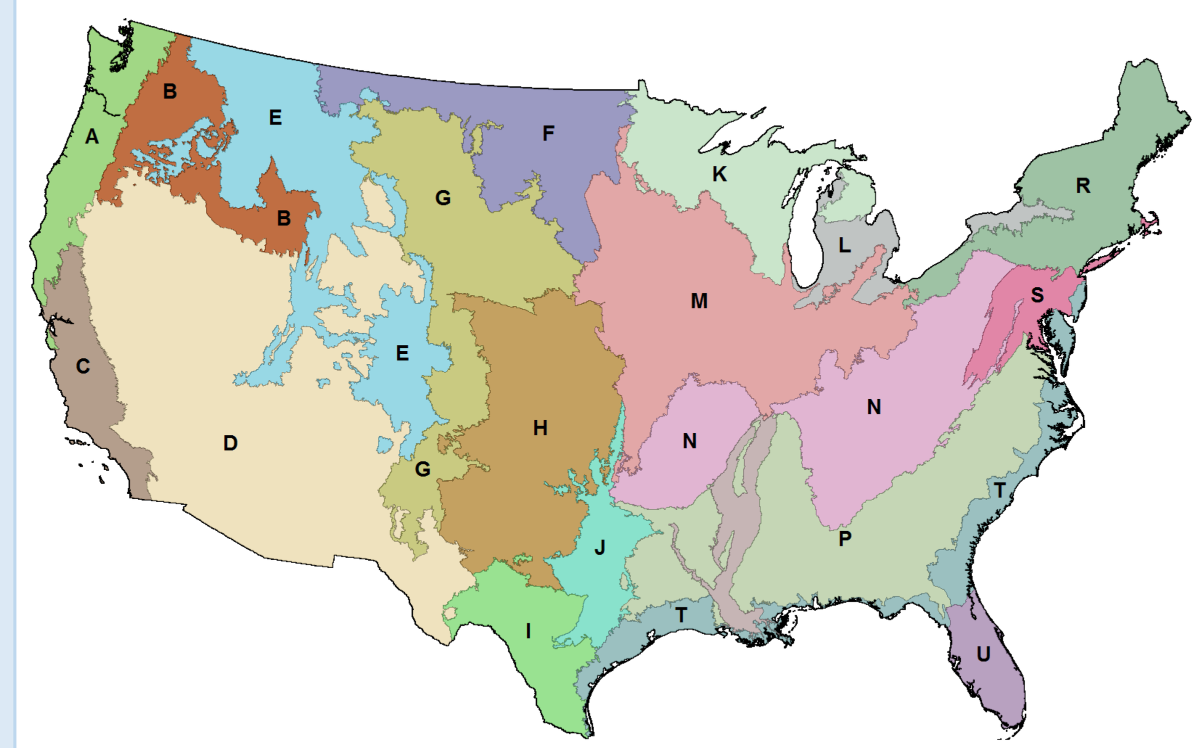


Fig. 4: The current NRCS's Land Resource Regions (LRR) geography. This map was originally based on aggregated soil information from the 1960's and based on broad agricultural regions (USDA-NRCS, 2006).

Conclusions

While a national effort is currently underway to update the NRCS's Major Land Resource Areas (MLRA's), our results provide a quantitative regionalization of the up-scale product (Land Resource Regions). Soil landscape classifications cannot be exclusively based on aggregations alone, as the upscale product provides context by constraining and identifying the boundary conditions for lower scales in the hierarchy (Fig. 1). Our unsupervised classification of Land Resource Regions derived from climate and physiographic variables offers an algorithm driven product that remove geographer bias in the landscape classification.

Resources:

Kriticos, D.J, *et al*, 2014, Extending the suite of BIOCLIM variables: a proposed registry of sytem and case study using principal component analysis, Methods in Ecology and Evolution, 5(956-960).

USDA-NRCS, 2006, Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin, USDA Agriculture Handbook #296.