Soil Heterogeneity in Six Patches of the Phoenix Metropolitan Region: Implications for Scaling

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Abstract

How does soil heterogeneity vary throughout the CAP-LTER region? To address this question we intensively sampled six patches, two agricultural, two mesic yards, and two native desert sites. At each patch, we used a dual-density spatially-stratified design covering an extant of 6400 m^2 and a minimum grain size of 5m. At each sampling locations we extracted a soil core (10cm depth) and determined its location using laser-based surveying. We analyzed each soil core to determine a suite of physical and biogeochemical variables including: mass of rock material, bulk density, water content, topography, and soil organic matter (SOM), total nitrogen and stable isotope nitrogen ratios. We analyzed these data to answer three specific questions. 1) Are the means of each variable different between patches? 2) Are the variances of each variable different between patches? 3) Does the range of spatial dependence for each variable differ between patches? We discuss the answers to these questions as they pertain to scaling between individual patches and the Phoenix, AZ metropolitan region.

Research Questions

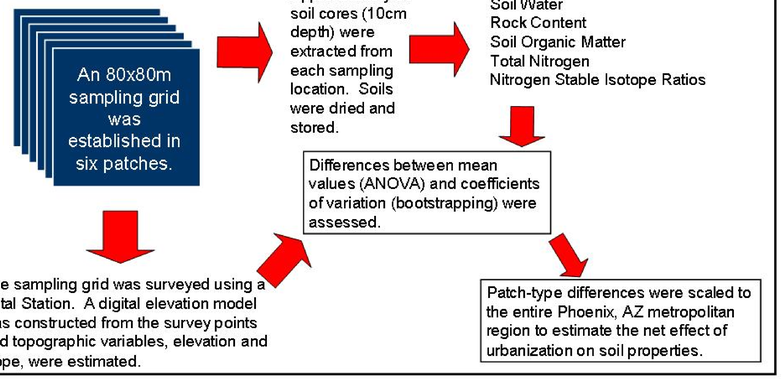
Are the pool sizes of physical and biological variables different between patches?

Does the variation of physical and biological pool sizes vary between patches?

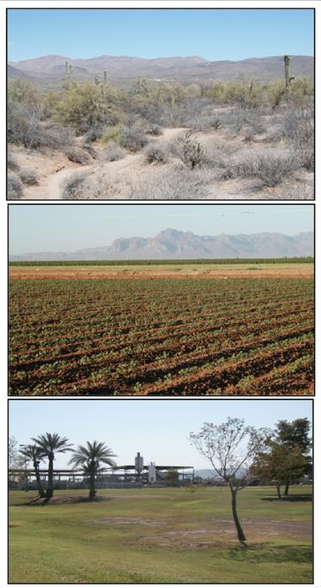
Does the spatial pattern of physical and biological pool sizes vary between patches?

How does the patch heterogeneity scale-up to the Phoenix, AZ metropolitan region?

Methods



Patch Descriptions



Two Native Desert Patches

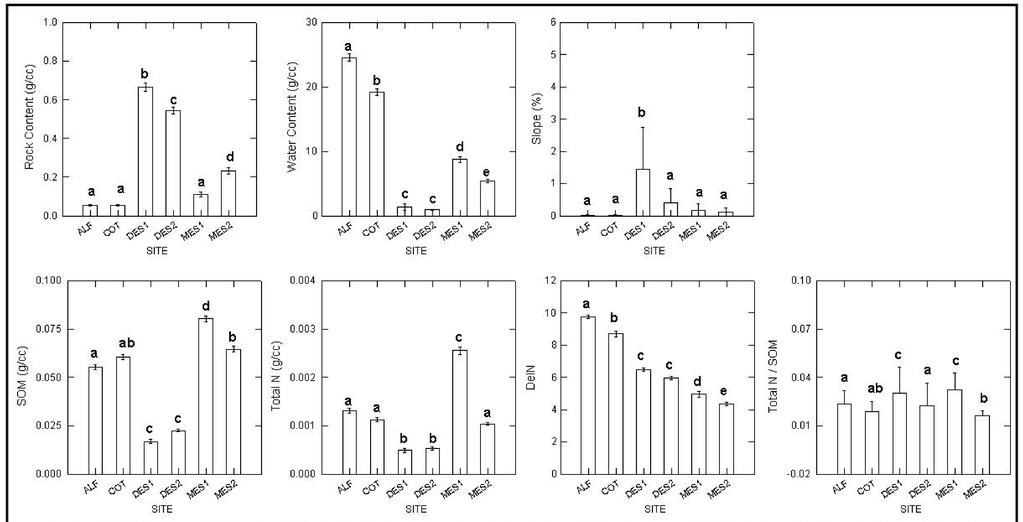
We sampled a patch within the urbanized core (Des1) and adjacent to the extent of urbanization (Des2) to characterized the soil properties of desert patch types. Des1 N = 94; Des2 N = 97;

Two Agricultural Patches

We sampled at an alfalfa field (Alf) and a cotton field (Cot) to characterize the soil properties of agricultural fields. Both sites were located in the East valley. Alf N = 80; Cot N = 72.

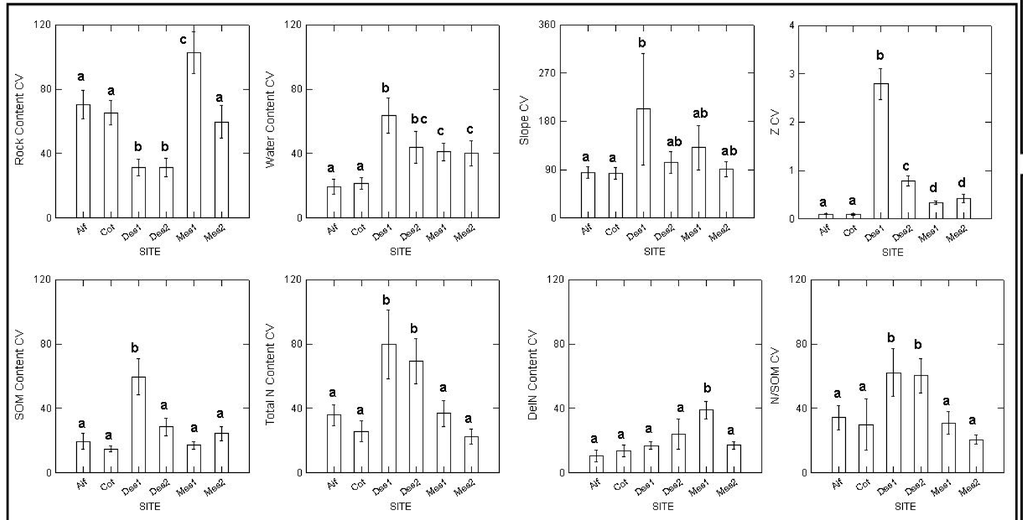
Two Mesic Grass Patches

We sampled grassy patches of urban parks to characterized the soil properties of mesic patch types. Mes1 was a old park (>30 years) in a lower income neighborhood. Mes2 was a new park (<5 years) in an upper income neighborhood. Mes1 N = 97; Mes2 = 78.



Mean Differences For Physical and Biological Variables Between Different Patches

We computed the mean and standard error of all samples from each patch. Differences between patches were estimated using an ANOVA ($p<0.05$) with Bonferroni post-hoc tests; letters indicate significantly different groups.



Coefficient of Variation Differences For Physical and Biological Variables Between Different Patches

We used bootstrapping to estimate 95% confidence intervals and to examine for differences ($p<0.05$; Bonferroni correction used for each variable) between sites of the coefficients of variation for each variable; letters indicate significantly different groups. For each analysis 100,000 bootstrapped samples were obtained.

		DelN	N	N/SOM	SOM	Rock	B.D.	Water	Slope	Z
Alf	1-Nugget/Sill	0	0	0	0	0.644	Trend	0	0	Trend
	Range	0	0	0	0	38.25	Trend	0	0	Trend
	Fit	0.028	0.008	0.068	0.064	0.011	Trend	0.007	0.004	Trend
Cot	1-Nugget/Sill	0.186	0	0.818	0	0.111	0	0	0	Trend
	Range	24	0	20.398	0	14.278	0	0	0	Trend
	Fit	0.068	0.004	0.047	0.047	0.020	0.014	0.017	0.006	Trend
Des1	1-Nugget/Sill	0	0	0	0	0.931	.920	0.358	0.731	Trend
	Range	0	0	0	0	20	23	26.5	29.51	Trend
	Fit	0.017	0.159	0.264	0.025	.216	0.019	0.002	0.028	Trend
Des2	1-Nugget/Sill	0	0.941	0.9215	0.2307	0	0	0	0	Trend
	Range	0	18	15	34	0	0	0	0	Trend
	Fit	0.112	0.009	0.022	0.016	0.045	0.012	0.011	0.030	Trend
Mes1	1-Nugget/Sill	0.807	0.447	0.444	0	0	0.917	0	0	0.916
	Range	40.8	72.0	51	0	0	24.48	0	0	45.39
	Fit	0.001	0.014	0.007	0.037	0.132	0.052	0.010	0.892	0.002
Mes2	1-Nugget/Sill	0.278	0	0.794	0	0	Trend	0.920	Trend	Trend
	Range	16.32	0	15.81	0	0	Trend	15.3	Trend	Trend
	Fit	0.015	0.046	0.066	0.003	0.100	Trend	0.294	Trend	Trend

Spatial Correlation of Physical and Biological Variables in Each Patch

We modeled semi-variogram patterns to estimate the strength of spatial dependence (1-Nugget/Sill), the range of spatial dependence, and the fit of the model to the data (0.0 = perfect agreement).

	Agriculture	Mesic Yards	Total	Total % Increase
Area (km^2)	864.29	233.15	1097.46	NA
Total Nitrogen (kg)	6.09×10^7	3.17×10^7	9.26×10^7	166%
Soil Organic Matter (kg)	3.31×10^9	1.29×10^9	4.60×10^9	213%
Water (kg)	1.54×10^{12}	1.45×10^{11}	1.69×10^{12}	1341%

Urbanization Effect on Soil Nitrogen, Organic Matter, and Water Pool Sizes in Greater Phoenix

We multiplied satellite derived areas of each patch type (Stefanov et al. 2000) by the average mass / c^3 to scale these patch estimates to the CAP region. While simple, this estimate provides a useful baseline for future studies of urbanization.

Conclusions

1) The patches differ markedly in the mean, coefficients of variation, and spatial pattern for selected physical and biological variables.

2) There were similarities between patches of the same land use type. The desert patches had the least organic matter and nitrogen, but were the most variable. For many variables, mesic yards were similar to agricultural fields.

3) Urbanization has dramatically altered regional pools and patterns of variability in the Phoenix metropolitan area.

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