Response of Forest Soil Properties to Urbanization Gradients in Three Metropolitan Areas

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Go Giants!

Overarching question of urban ecological systems:

anthropogenic vs. natural drivers in controlling ecosystem structure and function?

Hypothesis: Anthropogenic > natural drivers

Therefore, responses should “converge” across urban ecological systems on global and regional scales, e.g., SOC stocks, LAI, etc.

Similar to species, or phylogenetic, “homogenization” across urban plant and animal communities

Cross system (metropolitan area) comparisons.

- Growth pattern and transportation networks
- Social-cultural
- Political (environmental policy)
- Native systems (biogeophysical factors)
- Size and age

Question as relates to soil formation?

Soil Forming Factors:

S=f (*cl, o, pm, r, t*) →S = f (***a***, *cl, o, pm, r, t*)

Temporal Extent of *a*

a interdependent of factors (environmental change)

S’ = f(***a***, *cl, o, pm, r, t*)

a independent of factors (disturbance, management)

$S=f(\boldsymbol{a})_{cl,o,S1,r,t}$

Pouyat and Effland (1999)

Spatial Extent of *a*

Soil mosaic (patch dynamics)

- Fragmentation (runoff, drainage, plant and animal species, human use)
- Parcelization (management, human use)
- Urban environments (pollution, heat island, invasive species introductions)

Urbanization gradients

- Soil sequences (e.g., toposequence, chronosequence)

$S' = f(\boldsymbol{a})_{cl,\ o,\ pm,\ r,\ t}$ → "Anthroposequence"

Opportunity

Three metropolitan areas with urbanization gradient studies (New York City, Baltimore, Budapest)

Importance of parent material (*pm*) vs. urban environmental change (*a*)

Enhance understanding of anthropogenic effects on soils and mapping soils in urban landscapes.

$S' = f(\boldsymbol{a})_{cl,\ o,\ pm,\ r,\ t}$ → Anthroposequence (New York)

$S' = f(\boldsymbol{pm,\ a})_{cl,\ o,,\ r,\ t}$ → Confounding? (Baltimore, Budapest)

Objectives:

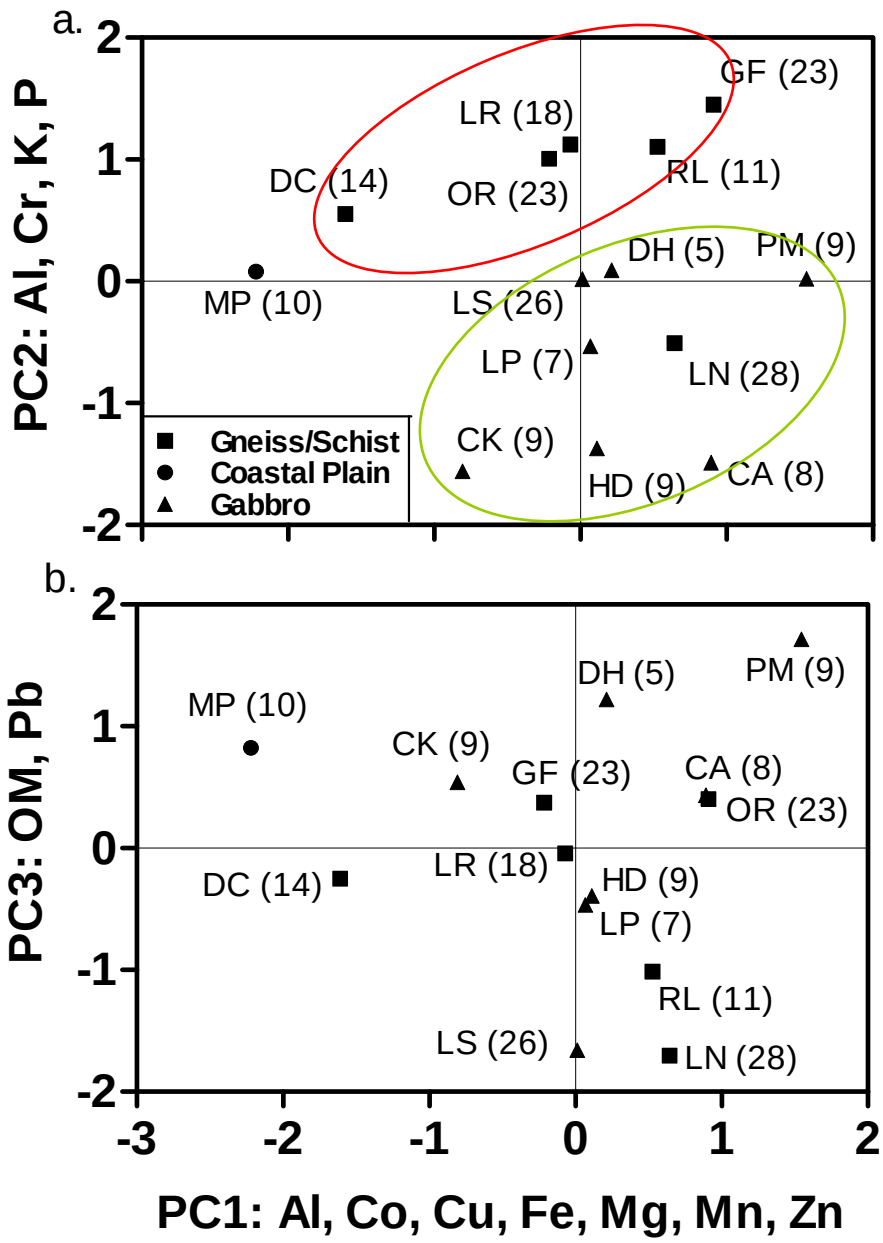
1. Measure soil chemical properties with distance to the urban core and various urban metrics (PCA, correlation)
2. Compare spatial extent & magnitude of chemical changes (city comparisons using regression)
3. Assess effects of parent material vs. urban environment along each gradient (city comparisons using PCA)

Expectations:

- Cities vary in transportation, development patterns, pollution controls, thus sources of pollutants, pattern and amount of emissions
- Anthropogenic chemical effects along each gradient, despite confounding effects of parent material
- NYC greatest spatial extent of contamination

Baltimore	New York	Budapest
Industrial city	Industrial city	Old industrial city
Depopulation in 2000s	Depopulated 60's and 70's	Maintained population
Smart Growth	Extensive growth pattern and transportation networks	Pollution control measures not until 1990s
Major transportation corridor	Economic center of U.S.	Compact development pattern

Baltimore Metropolitan Area



Parent Material

Urban-Rural?

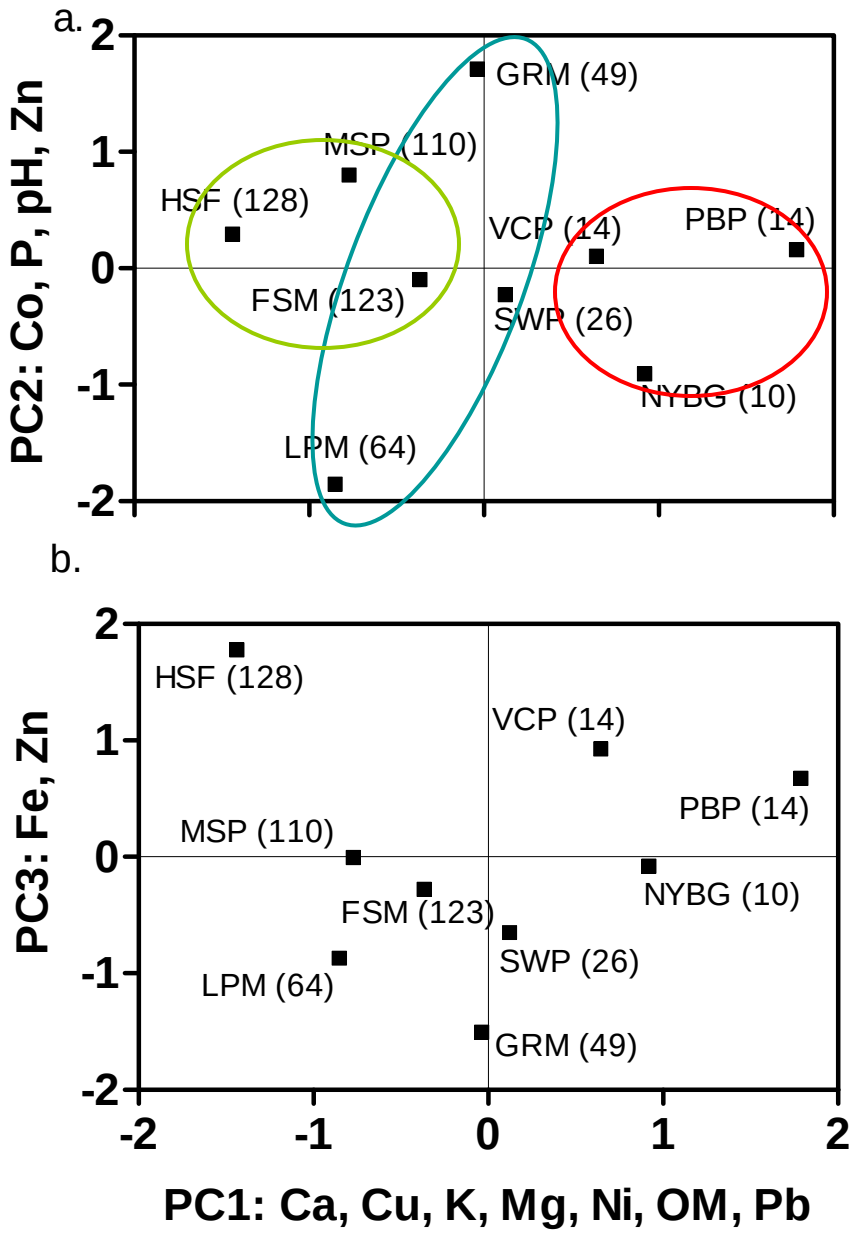
Baltimore Metropolitan Area

	Distance	Purban	Popden	Trafvol	Rdden
Distance	1	-0.72**	-0.89***	-0.72**	-0.90***
Purban	-0.72**	1	0.78***	0.69**	0.85***
Popden	-0.89***	0.78***	1	0.56*	0.98***
Trafvol	-0.72**	0.69**	0.56*	1	0.63*
Rdden	-0.90***	0.85***	0.98***	0.63*	1
PC 1	-0.090	-0.14	-0.046	-0.037	-0.037
PC 2	0.37	-0.27	-0.27	-0.30	-0.24
PC 3	-0.54*	0.72**	0.63*	0.38	0.70**
Ca	-0.53	0.35	0.28	0.49	0.31
K	0.67**	-0.74**	-0.66*	-0.62*	-0.67**
Mg	0.29	-0.50	-0.51	-0.36	-0.52
OM	0.051	0.34	0.15	-0.051	0.21
Pb	-0.80***	0.92***	0.80***	0.68**	0.87***

***P <0.001; **P <0.01; *P <0.05

New York City Metropolitan Area

Rural

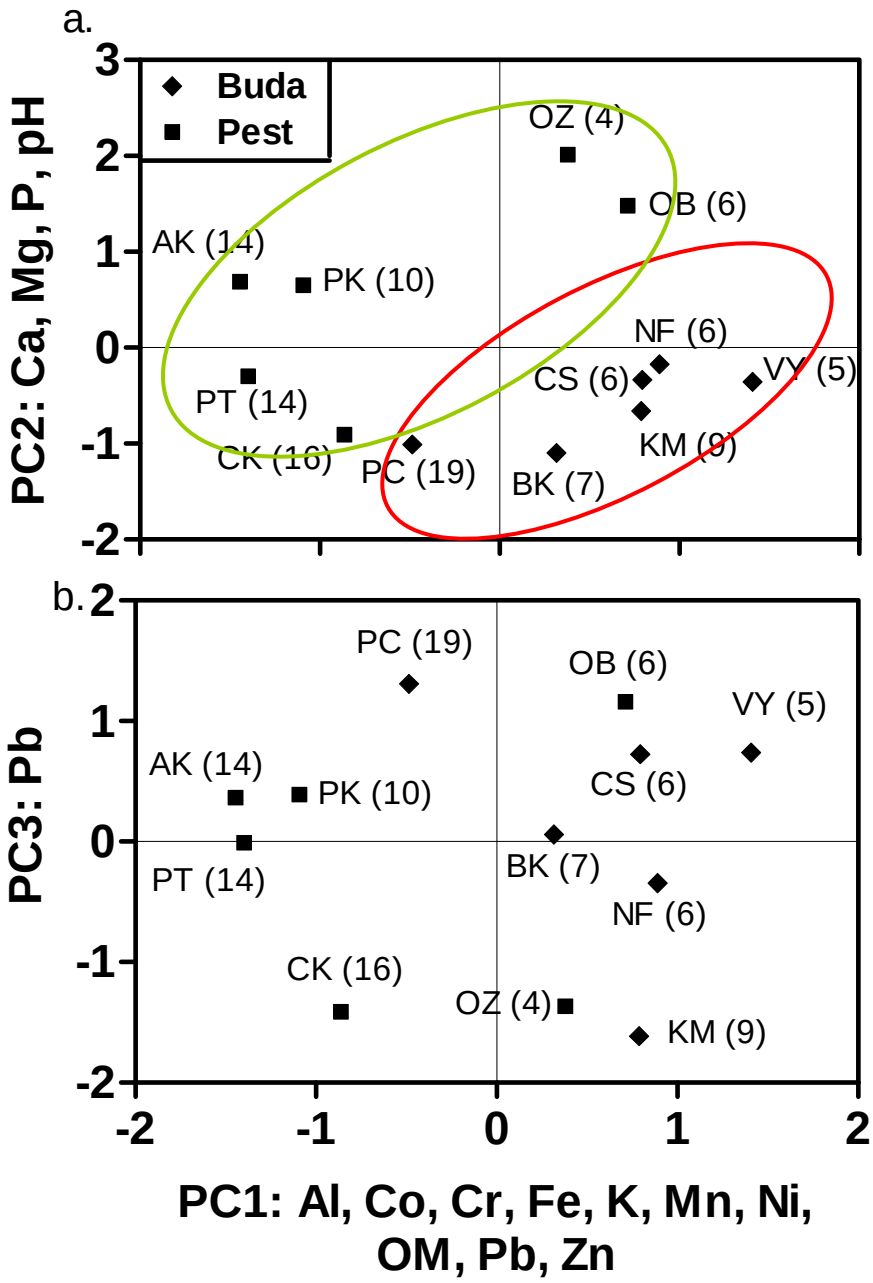


Urban

New York City Metropolitan Area

	Distance	Purban	Popden	Trafvol	Rdden
Distance	1	-0.92***	-0.92***	-0.97***	-0.93***
Purban	-0.92***	1	0.96***	0.93***	0.88**
Popden	-0.92***	0.96***	1	0.92***	0.93***
Trafvol	-0.97***	0.93***	0.92***	1	0.90***
Rdden	-0.93***	0.88**	0.93***	0.90***	1
PC 1	-0.88**	0.82**	0.73*	0.87**	0.82**
PC 2	0.32	-0.16	-0.37	-0.25	-0.53
PC 3	0.017	0.18	0.18	0.050	0.017
Ca	-0.72*	0.72*	0.57	0.67*	0.63
Co	0.50	-0.58	-0.73*	-0.48	-0.68*
Cu	-0.88**	0.78*	0.73*	0.88**	0.72*
K	-0.30	0.35	0.18	0.30	0.33
Mg	-0.85**	0.84**	0.72*	0.82**	0.77*
OM	-0.67*	0.53	0.47	0.67*	0.68*
P	0.55	-0.38	-0.53	-0.45	-0.68*
Pb	-0.85**	0.80**	0.78*	0.85**	0.88**
pH	0.48	-0.44	-0.60	-0.57	-0.68*

Budapest Metropolitan Area

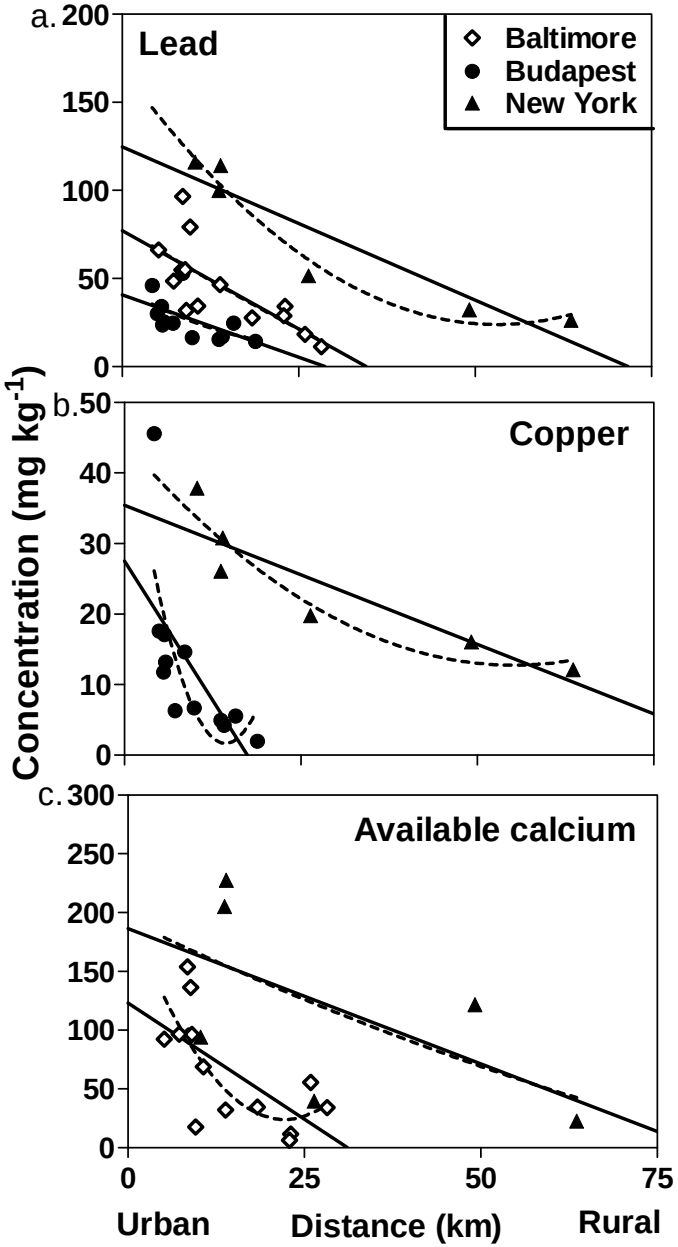


Surface Geology

Rural-Urban?

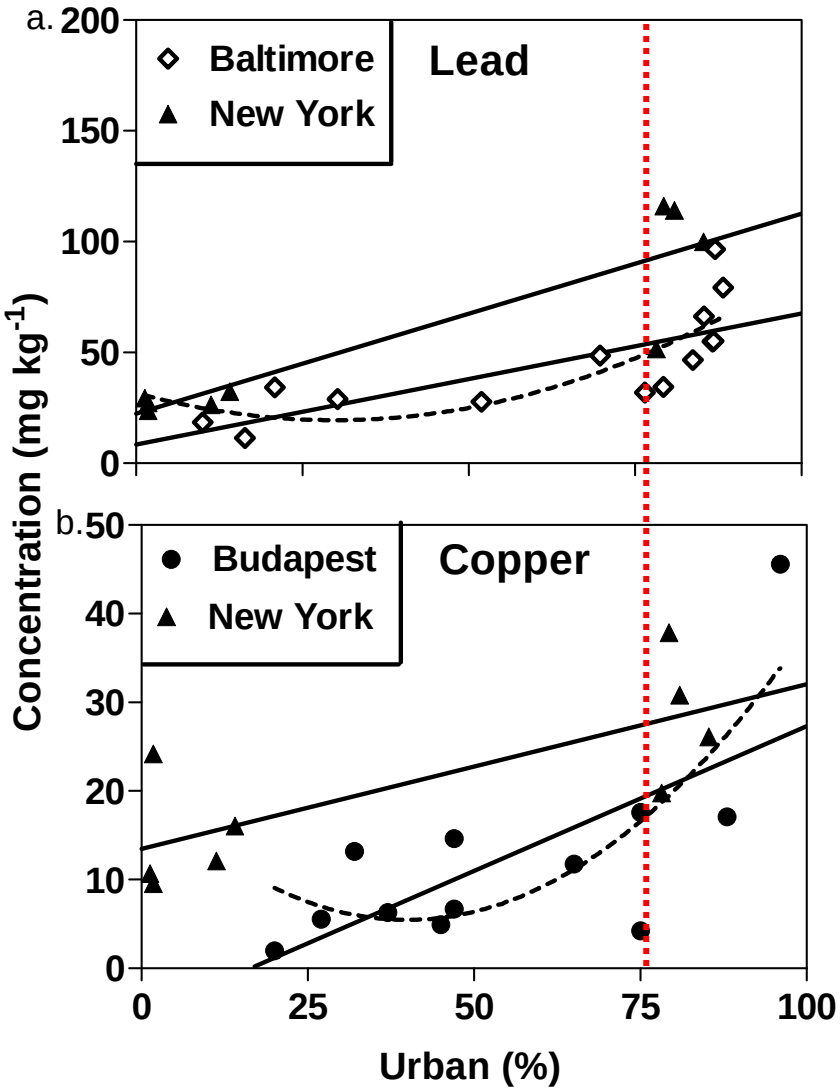
Budapest Metropolitan Area

	Distance	Purban
Distance	1	-0.68*
Purban	-0.68*	1
PC 1	-0.73**	0.25
PC 2	-0.45	0.71*
PC 3	0.02	-0.11
Ca	-0.62*	0.63*
K	-0.62*	0.053
Mg	-0.86***	0.56
OM	-0.76**	0.22
Pb	-0.71**	0.39
Cu	-0.90***	0.65*



City comparisons: Distance to urban core

- NYC flattens out at 50 km
- NYC higher contamination of Pb and Cu
- Ca gradient in New York and Baltimore



City comparisons: % Urban

- Pb, Cu positive relationship
- Slopes similar
- Threshold at 75% urban?

Conclusions:

1. Forest soils responded to gradients in all 3 cities, though features of each city (development pattern, pollution sources, parent material) influenced response
2. Distance corresponded well to soil chemical responses and urban metrics (scale of measurement?)
3. Deposition of Pb & Cu (Ca?) occurs at scale of > 30 m to kilometers. Urban regional phenomenon with vehicle emissions as likely source?
4. New York higher contamination of Pb and Cu than Budapest and Baltimore. (Higher vehicular traffic?)
5. “Anthroposequence” is useful approach to investigate urban environmental effects on forest soils