Urban Underground: Agroecological Functions of Soils in the City

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Introduction

Ecosystem services provided by soils buffer pressures from human development and climate change, which test the resiliency of natural habitats. Urban soils are highly disturbed by human activity and their ecosystem functions can be lost or compromised. Urban agriculture, which utilizes local soils and nutrient rich organic amendments, is recognized for the ability to provide products, income, social benefits, and ecological services. Best management practices for anthropogenic soils (anthrosoils) and metrics to describe and evaluate their health are evolving.

This study compared farmed soils in urban and peri-urban environments to characterize soil formation, soil foodwebs and carbon dynamics, soil nutrients, and contaminants along a gradient of anthropogenic influence (less disturbed to highly disturbed).

Methods and Site Selection

A study of soils in 3 metropolitan areas was conducted between August and October 2022 (Figure 1). In all three metropolitan areas 3 farm types were identified for analysis: 1) peri-urban, 2) urban in-ground, and 3) urban container. Peri-urban and urban farms are farms within and around city boundaries that compete for resources (FAO, 2022).

For each farm type in each of the 3 metropolitan areas three farms were identified and sampled. Sites were sampled within annual vegetables by compositing soil from three areas. Peri-urban and urban in-ground farms were sampled by digging a hole approximately 30 cm diameter and 60 cm deep at each sub-site (Figure 2). Soil from the three subsites was collected and composited at three different depths: 0-15, 15-30, and 30-60 cm. Container farms were sampled at only 0-15 cm.

Surface soils (0-15 cm) were analyzed for organic matter, total C and N, mineralizeable C (MinC), Ca, Mg, Zn, Na, P, S, B, Pb, As, pH, bulk density, texture. Free-living and pathogenic nematodes were also evaluated. Additionally, soils from 15-30 and 30-60 cm were also analyzed for total C and N, texture, and bulk density. Analysis of variance was used to evaluate effects of City, Farm Type, and interactions. Multiple linear regression was attempted to predict MinC, Pb, As, and total nematodes on the basis of other parameters. All data analyses were done with R (R Core Team, 2020).

Figure 2. Soil pit for sampling an in-ground site (a) at an urban farm site in Medellín, Colombia (b) with both container and in-ground production.

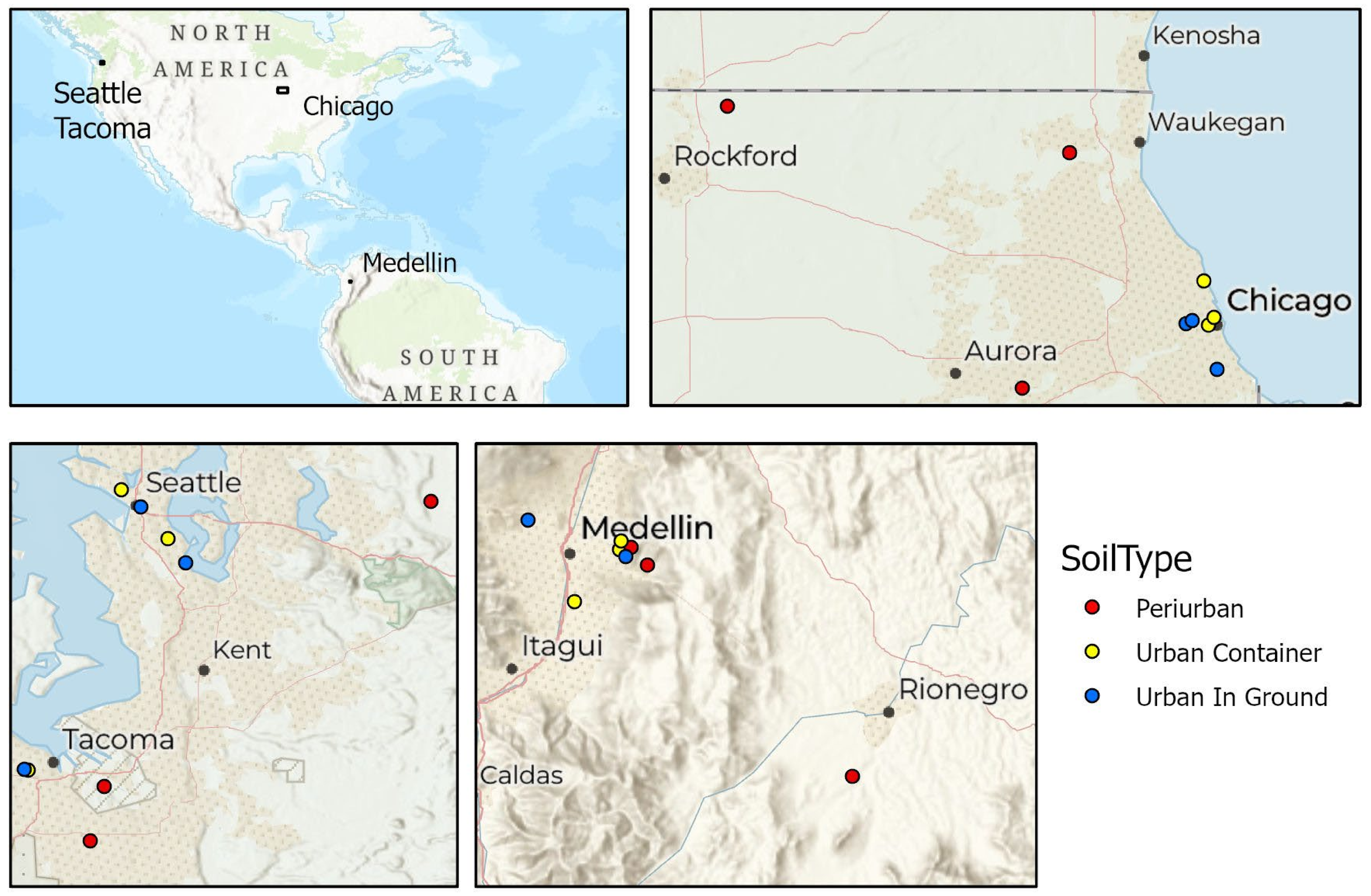

Figure 1. Study site locations in and around Medellín, Colombia and Seattle and Chicago, United States of America. Populations of each metro area are 4 million, 4 million, and 9.6 million for Medellín, Seattle, and Chicago, respectively.

Table 1. Means and statistical significance of selected soil parameters for 0-15 cm. SEM=Standard error of the mean

Parameter	Units	City	Mean value by farm type			SEM	Statistical significance		
			Peri-urban	Urban in-ground	Urban container		City	Farm type	City X Farm
Organic Matter	%	Medellín	12.5	6.13	14.5				
		Seattle	5.27	13.6	13.6	3.15	0.214	**0.013**	0.068
		Chicago	5.87	18.0	21.2				
Total C	%	Medellín	6.86	4.17	8.29				
		Seattle	3.65	9.26	10.4	2.48	0.231	**0.003**	0.053
		Chicago	4.03	13.9	15.9				
C:N		Medellín	18.0	17.2	18.5				
		Seattle	12.5	16.57	13.9	1.78	0.055	0.159	0.500
		Chicago	11.8	17.01	16.2				
Bulk Density	g cm^{-3}	Medellín	0.89	1.15	0.79				
		Seattle	1.43	1.23	0.73	0.10	0.112	**<.001**	**0.024**
		Chicago	1.29	0.92	0.78				
pH		Medellín	6.33	7.53	6.83				
		Seattle	7.47	7.4	7.47	0.26	**<.001**	**0.010**	0.325
		Chicago	5.73	6.13	6.03				
Ca	meq	Medellín	11.3	19.4	18.8				
		Seattle	16.3	19.6	20.3	2.30	0.483	**<.001**	0.148
		Chicago	8.23	21	22.7				
Mg	meq	Medellín	2.07	2.07	3.33				
		Seattle	7.23	7.1	9.33	1.29	**<.001**	**0.021**	0.201
		Chicago	2.13	5.7	6.7				
S	ppm	Medellín	735	386	757				
		Seattle	11.3	26.7	36.4	61.9	**<.001**	0.217	0.388
		Chicago	42.1	20.0	62.9				
P	ppm	Medellín	45.3	93.3	29.3				
		Seattle	171	125	232	55.7	**0.002**	0.553	0.741
		Chicago	113	172	162				
Pb	ppm	Medellín	15.9	50.0	38.5				
		Seattle	16.5	162	14.5	43.5	0.986	**0.017**	0.422
		Chicago	20.1	56.3	27.4				
As	ppm	Medellín	5.18	0.52	6.04				
		Seattle	7.36	5.32	4.10	2.11	0.0750	0.292	0.467
		Chicago	9.68	8.19	6.44				
Sand	%	Medellín	45.3	44	43.3				
		Seattle	16.7	60.3	44.0	7.06	0.316	**0.030**	**0.043**
		Chicago	43.3	49.7	55.0				
Clay	%	Medellín	13.3	15.7	11.3				
		Seattle	27.7	9	8.00	3.58	0.823	0.173	0.055
		Chicago	11	14.7	13.3				
Nematodes	total cm^{-3}	Medellín	597	150	278				
		Seattle	247	558	1080	460	**0.017**	0.412	0.115
		Chicago	1890	550	611				

Results and Discussion

OM and bulk density fit predictable patterns with degree of anthropogenic influence (Table 1).

OM: peri-urban<in-ground<container

BD: peri-urban>in-ground>container

The soil carbon mass (carbon stock; Figure 3) was generally larger in Seattle and Chicago.

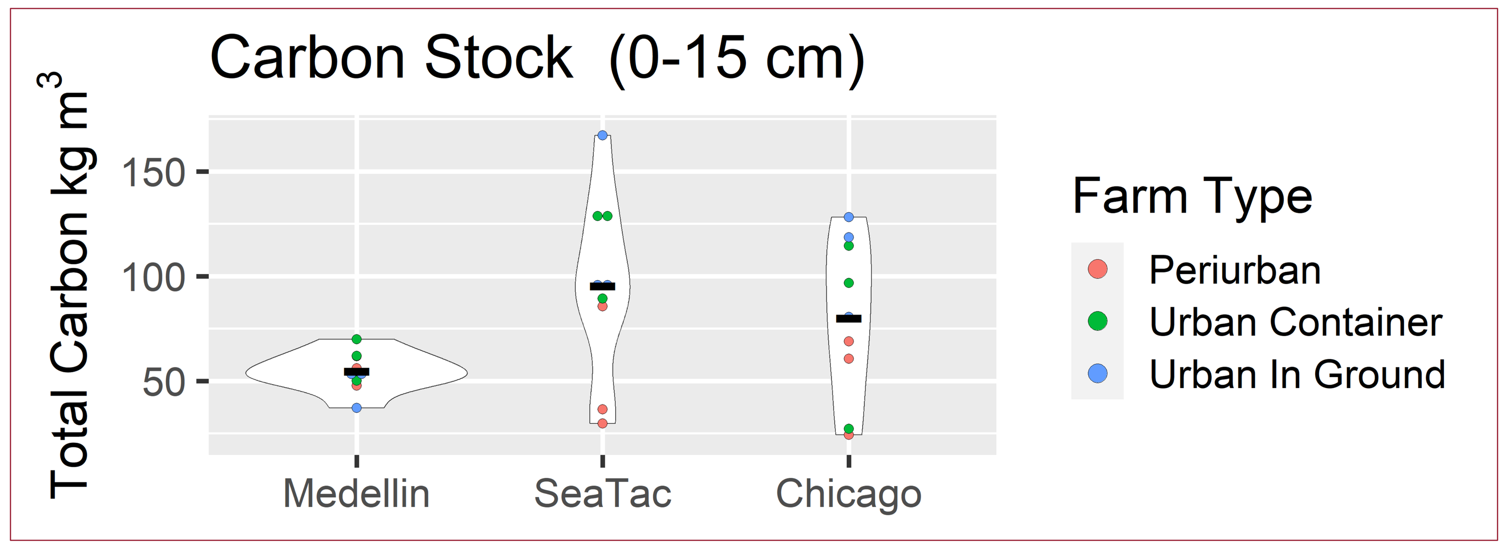

Figure 3. Carbon stock by city and farm type

Much of the variability in MinC was explained by a linear regression equation including *log* Total C, CN ratio, *log* S, and bulk density (Table 2; r^2=0.69). Pb, As, and nematodes were not well explained.

Table 2. Multiple linear regression model for mineralizeable carbon across all sites at 0-15 cm.

Independent variable	Slope	Std. Error	t-ratio	P value
log Total C	85.9	12.5	6.87	<.001
CN ratio	-6.55	1.89	-3.47	0.002
log S	14.1	4.10	3.43	0.002
Bulk Density	121	29.0	4.19	<.001

Sulfur was much higher in Medellín than Seattle or Chicago (Table 1). OM and P, which were generally lower in Medellín, reduce sulfur bonding. More weathered soils, typical of the tropics, also retain sulfur better.

Lead was significantly higher in urban in-ground sites (Table 1, Figure 4). However, only one site had Pb levels above the EPA screening level of 400 ppm. No sites had As levels above the EPA screening level of 37 ppm.

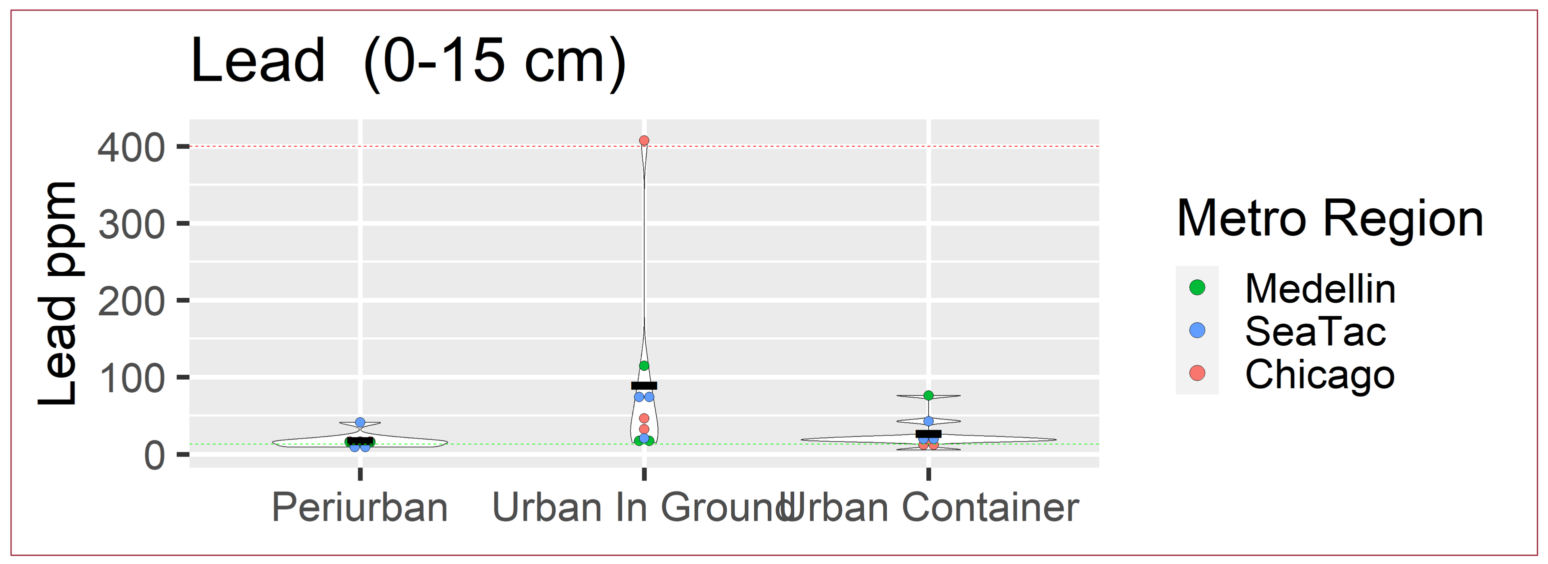

Figure 4. Soil lead content by farm type and city

Conclusions

Both metro region and farm type affected soil parameters. Urban soils in Seattle and Chicago are likely receiving more organic inputs that have increased C stock. MinC, an important agroecological function, was well predicted by factors related to metro area (e.g. S) and inputs (e.g. Total C, CN, BD). Pb and As were not well predicted by other parameters, metro area, or site, indicating the need for site-specific testing for contaminants.

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