A Combined Field-modeling Study On Urban Soil Hydrology: Implications For Passive Green Infrastructure

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Background

URBAN SOILS ARE VERY DIFFERENT COMPARED TO NON-URBAN SOILS due to land management, e.g., fill, demolition, etc. For example, urban soils have fewer horizons than non-urban soils, and are also more likely to have lost the "B" horizon [1]. Along similar lines, we hypothesize that urban soils cannot be characterized hydrologically as easily as non-urban soils by commonly-used prediction algorithms (e.g., USEPA National Stormwater Calculator, USDA ROSETTA) to determine ecosystem services provided (Fig 1). **Here we compare hydrologically well-characterized urban soil horizon sequences with pre-urbanized reference soil pedons in HYDRUS1D to understand the overall hydrologic impacts of urbanization.**

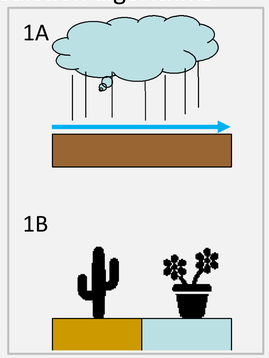

Fig. 1*. Ecosystem services of urban soils assessed using HYDRUS 1D A) runoff mitigation, B) plant-available water*

Methods

Field Data. From 2010-2015 we carried out hydropedological assessments in 11 cities (Atlanta, GA; Camden, NJ; Cincinnati, OH; Cleveland, OH; Detroit, MI; New Orleans, LA; Omaha, NE; Phoenix, AZ; Portland, ME; San Juan, PR; Tacoma, WA). Each horizon was described taxonomically and characterized hydrologically, i.e. infiltration (Mini Disk Infiltrometers set to -2 cm, Decagon Devices, Pullman, WA) and drainage rate (Amoozemeter, Ksat, Inc. Raleigh, NC).

Reference Data. NRCS state soil scientists assisted in identifying soil series representative of the assessed areas pre-urbanization. Based on NSSC lab data of these series we built a database containing K_{sat} that was used for analysis.

Analysis. We compared site hydrologic measurements of each urban pedon with those from national databases (National Stormwater Calculator, SSURGO) and estimates from pedotransfer functions (USDA ROSETTA). We applied root mean square error (RMSE) and mean error (ME) to estimate uncertainty between modeled and measured hydraulic conductivity in urban and non-urban soils. Next we modeled how urbanization of soils in Cleveland and Detroit influences runoff production and plant-available water of soils using HYDRUS 1D.

Findings

Hydrologic characteristics of urban soils at the plot scale are not accurately portrayed by national databases or pedotransfer functions [2]. Measured infiltration (N=357) and drainage rates (N=477) in urban soils exhibit wider range of conductivities than estimated (Fig 2).

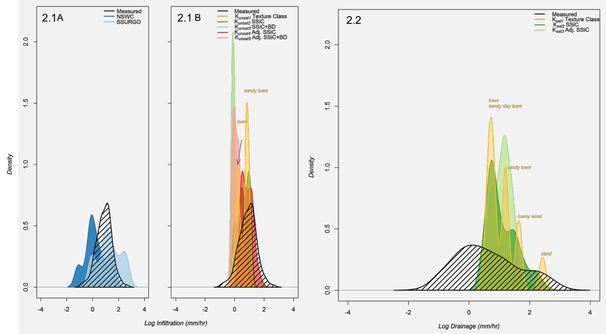

Fig. 2.1*. Distributions of measured infiltration rates juxtaposed against estimates from National Databases (2.1A) and Pedotransfer Functions (2.1B).* ***Fig 2.2*** *Distribution of measured drainage rates juxtaposed against estimates from Pedotransfer Functions.*

Comparing runoff generation in coarse urban and reference soils in Cleveland (Fig 3A) and Detroit (Fig 3B) using field data for urban soils and SSURGO data for reference soils **we observed variations in the frequency that runoff formation occurred.**

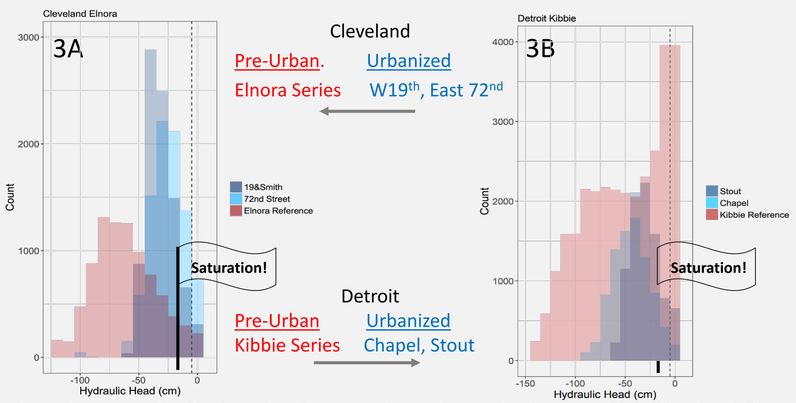

Fig. 3*. Frequency distributions showing how often urban and reference soils in Cleveland (A) and Detroit (B) were saturated and resulted in runoff formation in 2017. Dashed line indicates 0 head, at which ponding occurs. However, we define -5cm head as sufficient for runoff initiation.*

Findings continued

In this comparison neither soil types exceeded the wilting point, however, the top observation node in the model for the reference soil in Cleveland approached the wilting point on a few occasions (Fig 4).

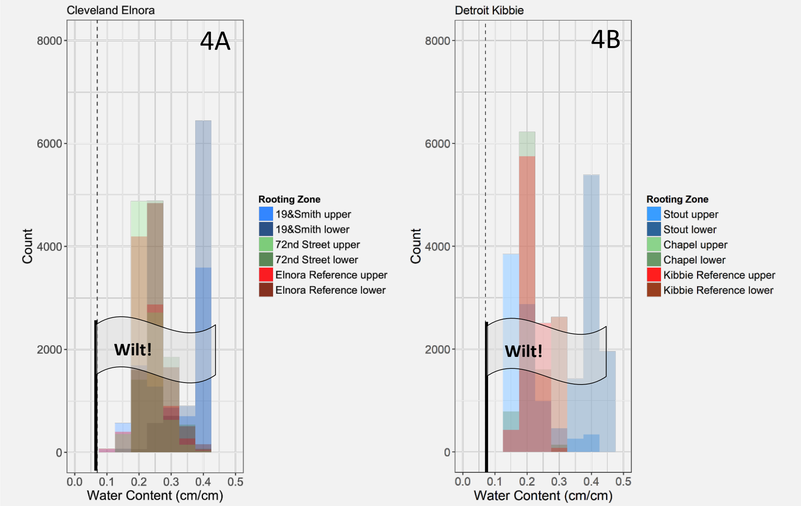

Fig. 4*. Water content for urban (blue and green) and non-urban reference (red) in Cleveland (A) and Detroit (B) soils to compare how urbanization processes influence plant-available water.*

Conclusions

- Hydrologic characteristics of urban soils are not accurately portrayed by national databases or pedotransfer functions.
- If included in hydrologic models, these variations can result in inaccurate simulation of hydrologic processes.
- Variance among measured and unsuitable estimates will affect estimates of runoff control and soil moisture services.
- Understanding how urban soils function hydrologically can inform environmental management decisions and provide an improved prediction of expected ecosystem services at the landscape level

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References. [1] Herrmann, Schifman, Shuster. Widespread loss of intermediate soil horizons in urban landscapes. (in revision *PNAS*). [2] Schifman and Shuster. Measurement of urban soil hydrologic properties and comparison with simulated data. (accepted). ASCE Journal of Hydrologic Engineering.