Enhanced Ecosystem Monitoring in New York City's Only Old Growth Forest

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Project Overview and Objectives:

As the world's first urban research forest, the Thain Family Forest (TFF) at the New York Botanical Garden (NYBG) provides an invaluable reference for regional forest ecosystem monitoring for emerging needs. Climate change mitigation and adaptation require healthy forests, especially in cities. However, urban forest monitoring lacks an old-growth reference for soil carbon (C). Furthermore, urban soils may pose unique risks with increasingly heavy rainfall, which can remobilize accumulated heavy metals. This project upgrades the TFF monitoring program to better understand current threats, historical trends and future directions of the urban forested landscape in the Northeast through four related objectives:

Objective 1. Soil C monitoring aligned with aboveground inventory and international standards
Objective 2. Establish a continuous record of forest-water relations
Objective 3. Restart the first regional study of forest urbanization by remeasuring soil health, including heavy metal concentrations
Objective 4. Implement our project in a sustainable, inclusive and equitable way by supporting the NYBG internship program and coordinating with a regional urban forest advocacy group.

Objective 1. Soil C monitoring aligned with aboveground inventory and international standards

1. Completed activities

Project personnel successfully adapted the Smithsonian Forest Global Earth Observatory soil C sampling protocol (ForestGEO, n.d.) to align with the existing Continuous Forest Inventory (CFI) Program in the Thain Family Forest. The result is a set of 20 sampling plots at an intensity of 1 plot per hectare, representing all soil types and maximizing overlap with CFI Plots (Figure 1). Each 20x20 m soil sampling plot consisted of 9 sampling points arrayed in an evenly spaced 3x3 square grid aligned with cardinal directions. The locations of plots and sampling points within plots were adjusted from the original sampling plan using *a priori* rules to ensure the safety of sampling teams and avoid obstructions. The result was a set of 179 precisely mapped permanent points for long-term monitoring of soil health, including detailed standard operating procedures for both field and laboratory measurements (see Objective 1: Outputs). Field measurements included plot and point mapping data, litter structure, soil surface features, depth and quality assurance measurements for samples representing different forest floor strata (Figure 2). Samples of litter (68 total), fixed volume (329 total) and bulk soil samples (198 total) from multiple depths were transported to the NYBG Laboratory for Integrative Biodiversity Science for analysis.

Figure 1: Final Sample Point Map

Figure 2: PI Oberle (right) preparing fixed volume sample, intern Baker (left) examines litter sample while intern Haberle (center records data. Photo copyright Marlon Co.

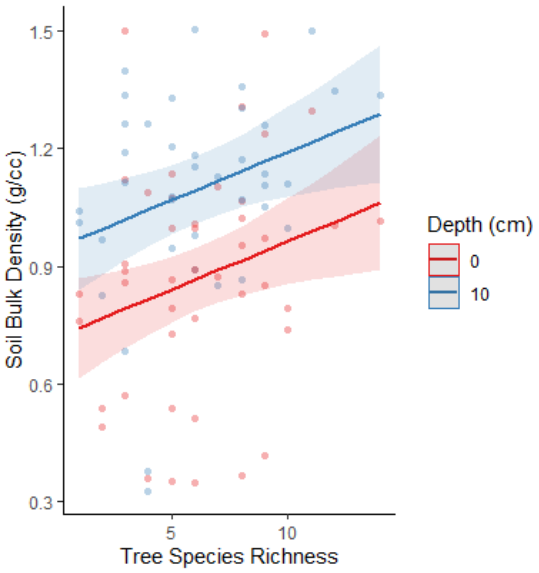


Figure 4: Scatterplots and fitted linear regressions between tree species richness and soil bulk density at two depth strata.

Laboratory measurements included moisture content determination of litter and sieved, fixed-volume soil samples. Personnel also determined the composition of bulk soil samples by sieving, rinsing, sorting, drying and weighing roots, stones and other coarse objects (Figure 3). Following sample processing and stabilization, the Laboratory Technician supported by the project, under the supervision of PI Oberle, subsampled, homogenized, weighed and prepared dried soils, litter and roots for further chemical analyses. For estimating carbon contents and stocks, subsampled, homogenized, weighed and technically replicated soil, litter and root samples were submitted for Carbon Nitrogen Content analysis by the City University of New York Next Generation Environmental Sensor Laboratory. All data were quality checked and posted to the FEMC data portal with standard operating procedures and code for calculating bulk density and carbon stocks.

Figure 3: Rinsed sieve illustrating bulk material composition of a soil sample. Photo copyright Brad Oberle

1.Results

Preliminary analysis supports correlations between aboveground forest structure and belowground forest function. As an example, in 48 points with paired soil samples and CFI inventory data, soil bulk density increases significantly with both depth and tree species richness (Figure 4). Further analyses of other soil and forest composition metrics are ongoing in preparation for at least one peer-reviewed manuscript examining aboveground-belowground impacts on urban forest soil carbon.

1. Outputs

Posted Documents (3)

- Thain Family Forest Soil Field Sampling Standard Operating Procedure 1.1
- Thain Family Forest Soil Dry Composition Standard Operating Procedure 1.1
- Thain Family Forest Soil Metrics R Code

Posted Datasets (5)

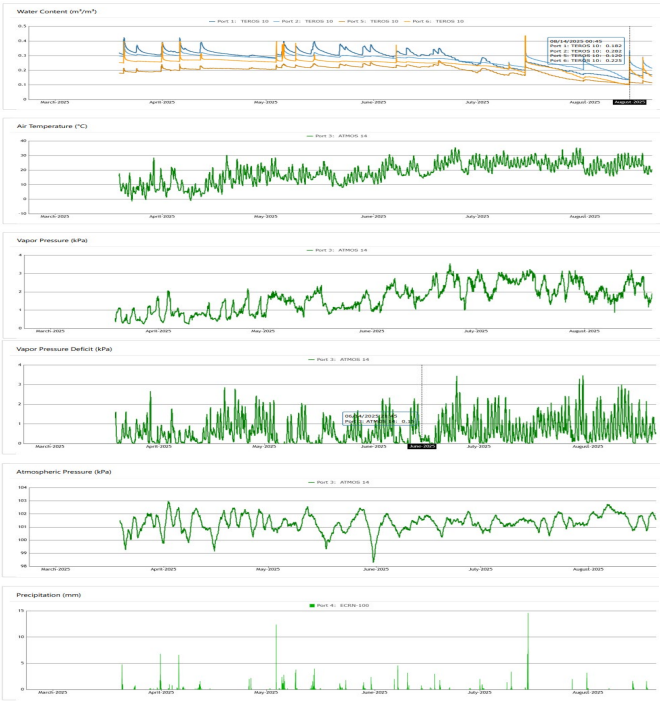
- Thain Family Forest Soil Sample Moisture Contents
- Thain Family Forest Soil Sample Compositions
- Thain Family Forest Litter Sample Moisture Contents
- Thain Family Forest Sample Point Coordinates and Field Measurements
- Thain Family Forest Sample Carbon Nitrogen Concentrations

Figure 5: Laboratory Technician Duby (left) and a volunteer assist with weather station deployment. Photo Copyright Brad Oberle

Objective 2: establish a continuous record of forest-water relations

2: Completed activities

To complement existing hydrological infrastructure in the Thain Family Forest, including a tree sap flux array and the only USGS stream gauge in New York City, project personnel configured, procured, assembled, deployed, tested and maintained the Thain Family Forest's first weather station. Configured for monitoring forest hydrology, with sensors for air temperature and humidity, precipitation and soil moisture and procured from METER Group, the weather station was deployed on March 13th 2025 (Figure 5). The deployment location is immediately south of one of the long-term soil monitoring plots and mid-slope between the sap flux array and the USGS stream gauge. Four soil moisture sensors are located at two depths near the locations of two soil sampling sites with the most intensive sorbed heavy metals data (see Objective 3).



2: Results

After a one week testing period, the station has logged microclimate parameters at 15-minute intervals without interruption (Figure 6). Data have been shared with Dr. Nick Steiner (City University of New York) as supplemental data for his NASA-funded analysis of forests' role in mitigating the urban heat island effect.

2: Outputs

Posted Dataset (1)

- Thain Family Forest Weather Station Observations

Figure 6: Weather station data representing (top to bottom), soil moisture at two depths in two locations, air temperature, vapor pressure, vapor pressure deficit, atmospheric pressure and precipitation in 15-minute intervals from March 19th to August 20th 2025.

Objective 3: Restart the first regional study of forest urbanization by remeasuring soil health, including heavy metal concentrations

3: Completed activities

Building on foundational urban ecology research, which demonstrated that tailpipe emissions had increased lead concentrations in Thain Family Forest Soils before the 1990 Clean Air Act Amendment (Pouyat and McDonnell 1991), we remeasured heavy metal concentrations and other aspects of soil health. After sample collection and stabilization (see Objective 1), we submitted sieved, air-dried soil subsamples for soil nutrient and sorbed metal analysis. The soil nutrient analysis by the University of Connecticut Soil Nutrient Analysis Laboratory measured soil pH, buffer pH, K, Ca, P, Mg, Al, B, Cu, Fe, Mn, Zn, S, Pb and Cation Exchange Capacity for all 68 air-dried soil surface samples using a Modified Morgan Extraction. The total sorbed metals analysis by the University of Massachusetts Soil and Plant Nutrient Analysis Laboratory measured total sorbed Cd, Cr, Cu, Ni, Pb and Zn using Alternate EPA 3050B and 6010 methods for a subset of 37 samples from 8 plots representing all depth strata from every USGS soil type in the Thain Family Forest.

3: Results

in the 40 years since first measured by White and McDonnell (1988), heavy metal concentrations in Thain Family Forest Soils have declined significantly. Average Cu concentrations have dropped by 56%, Ni by 31%, Zn by 27% and Pb by 39%. Soil lead concentrations decrease exponentially with increasing depth, except for in a depositional floodplain environment, where the highest measured soil lead concentrations occurred at 20 cm below the soil surface (Figure 7).

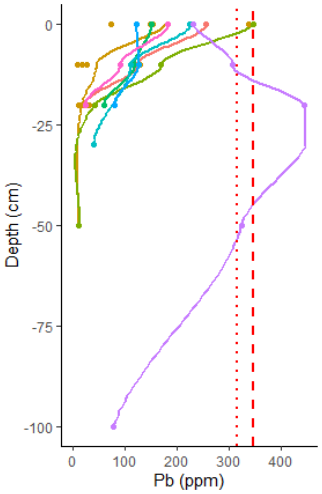


Figure 7: Soil lead concentration profiles by depth at 8 sample locations (colors) with trends interpolated using splines. Purple line represents a soil sampling site in the Bronx River floodplain. Red vertical lines indicate historical measurements of soil lead concentrations from White and McDonnel (1985, long dash) and Pouyat and McDonnel (1990, short dash).

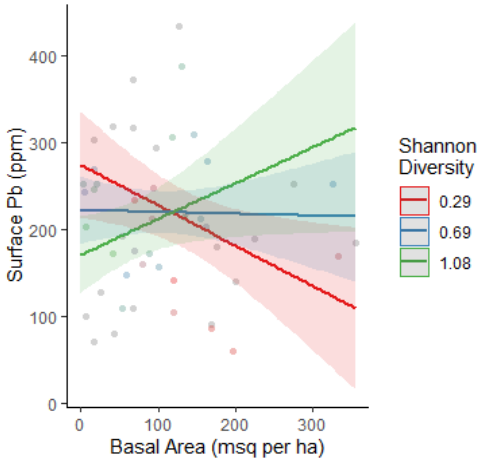


Figure 8: Soil surface lead concentrations vary with basal area and Shannon diversity of trees in 48 sampling plots with estimated lead concentrations and vegetation structure data.

Soil surface lead concentrations varied with two aspects of forest structure (Figure 8). In sites with low tree diversity, lead concentrations decreased with increasing basal area, whereas sites with high diversity showed the opposite relationship, with higher basal area associated with higher soil surface lead concentrations. Further analyses of high-resolution lead concentration data, topographic and hydrological features is ongoing in preparation for a peer-reviewed publication examining urban forests' roles in legacy pollution dynamics.

3: Outputs

Posted datasets (2)

- Thain Family Forest Soil Sample Metal Concentrations
- Thain Family Forest Soil Sample Nutrient Concentrations

Objective 4: Implement long-term soils monitoring in a sustainable, inclusive and equitable manner.

4: Completed activities

The success of the project reflected the engagement of a diverse team of interns (Figure 9). Representing both public and private schools and spanning in age from a rising high school senior to a first-year graduate student, interns brought diverse perspectives and talents to the project. In addition to developing valuable field and laboratory skills, interns participated in other scientific activities as part of the NYBG summer intern program, including weekly science seminars and contributions to a team presentation of preliminary results. All interns have remained engaged with notable outcomes for each.

Figure 9: Field sampling team (Left to Right) Xavier Counsell (Pace University), Mariel Haberle (Bryn Mawr College), Brad Oberle (NYBG), Nicolas Duby (Columbia University), Olivia Baker (New York University. Not pictured William Sweet (New Canaan High School), Fiona Chou (Taft School). Photo copyright Marlon Co.

4: Outcomes

Fiona Chou (Junior, Taft School): Completed Taft-NYBG Intern Program. Posted summary of internship experience on her youtube channel. Invited co-author on resulting publications.

William Sweet (Senior, New Canaan HS): Completed senior year internship program

Olivia Baker (Freshman, New York University): Earned research credit. Presented in NYBG Science Seminar. Invited co-author on resulting publications.

Nicolas Duby (Sophomore, Columbia University): Earned research credit. Presented in NYBG Science Seminar. Hired as FEMC-funded part-time laboratory Technician. Invited co-author on resulting publications.

Mariel Haberle (Junior, Bryn Mawr College): Presented in NYBG Horticulture Seminar. Invited co-author on resulting publications.

Xavier Counsell (Graduate Student, Pace University): Presented in NYBG Science and Horticulture Seminars. Using FEMC data for MS thesis on urban lead. Invited co-author on resulting publications.

Continuing work We are preparing at least two peer-reviewed publications based primarily on data collected with FEMC. PI Oberle will present on preliminary results to Forests For All New York City Action Team 4 (Research and Monitoring) during the October 2025 meeting. We will update the project page with weather station data.

Project Outputs

- FEMC Project page https://www.uvm.edu/femc/manage/project/1858
- 5 interns presented preliminary results as part of the Summer Internship Symposium of the New York Botanical Garden Science Seminar.
- PI Oberle presented preliminary results to the following groups
    - Monthly meeting of the Torrey Botanical Society 10/9/2024
    - FEMC meeting 12/12/2024
    - NYBG / Dumbarton Oaks Plant Humanities Conversations 6/11/2025
    - NYBG Science Seminar 6/26/2025
    - NYBG Science Webinar 7/2/2025
- Intern Fiona Chou interviewed PI-Oberle and posted an overview of the methods to YouTube
    - https://www.youtube.com/watch?v=oIQW9n_Oak0
- PIs Oberle and Zeiger discussed the project in an interview featured on WNBC 10/18/2024
- Project data are being incorporated into the 2025-2030 Thain Family Forest Management Plan

References

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