Soil Quality, Invertebrates, and Trees: A Tri-Harmony Analysis of Urban Forest Health

Liridona Asani, Rokhaya Diagne, Anais Loja, Alani Nardo, Kerwyn Jean
NYCSRMC Summer Research Symposium | August 2025

Introduction

Trees are essential to urban ecosystems, providing shade, improving air quality, supporting biodiversity, and enhancing the overall environmental health of cities (Woodward et al. 2023); maintaining healthy trees is critical for sustaining these ecosystem services, especially in urban areas where they face pollution and habitat fragmentation. Tree health can be monitored by testing soil nutrient content, conducting health assessments, and observing the arthropod abundance and species diversity present within the trees (US EPA et al. 2024). Informing people on the importance of trees and continuing to conduct these metrics to observe and maintain the trees' health is essential

Soils are also important for ecosystems for nutrient cycling and supporting plant growth. However, soil quality can suffer in cities due to pollution and a lack of nutrients. The soil's chemical composition, specifically the pH, nitrogen, phosphorus, and potassium levels, impacts tree nutrient uptake and physiological processes related to the tree's health. For instance, the soil's pH influences plant's abilities to absorb nutrients (Gentili et al. 2018), nitrogen supports the leaf and shoot development of plants (Zhang et al. 2018), phosphorus contributes to root and the overall growth of trees and plants (Zhao et al. 2023), and potassium regulates their water balance and disease resistance (Xu et al. 2020).

Arthropods like ants, beetles, and spiders are among the most abundant and diverse organisms associated with trees, using trees as habitats, feeding sites, and breeding grounds. Their presence, diversity, and abundance can function as bioindicators of the trees' and environmental health (Sollai et al. 2024). A decline of arthropods would be influenced by a reduction of food availability, poor tree health, or other ecosystem-wide factors (Sollai et al. 2024).

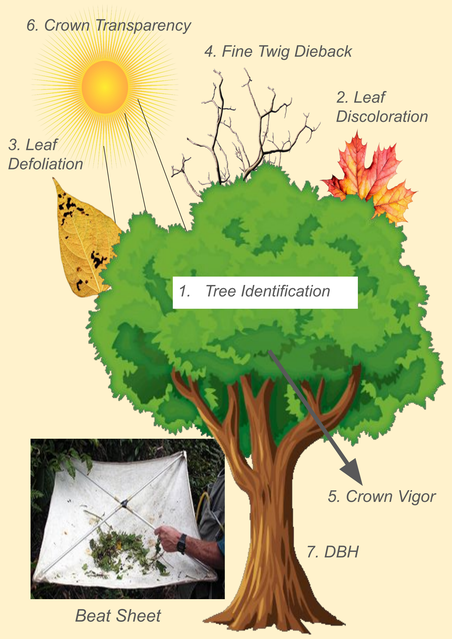
This project investigated these relationships at three sites within the Bronx Zoo, combining soil chemistry analysis with tree health metrics and conducting arthropod abundance surveys to identify potential associations and assess the utility of arthropods as bioindicators in an urban ecological context. This research also promotes conservation and better management of urban green spaces.

Methodology

Tree Health Metrics: Using the citizen science application, Healthy Trees, Healthy Cities, three sites were selected based on level of public activity. Each site was visited three times throughout the four-week study period to analyze the health of trees, arthropod abundance, and soil quality. Tree Health was assessed using protocol from the *Healthy Trees, Healthy Cities* project. A total of 15 trees were assessed at each site. A coordinate plane that was 16 × 22 meters was outlined. Trees were selected based on a point-quarter transect method to reduce selection bias. Four 16-meter transects were established at each site. At every four meters, the nearest eligible tree was assessed. To determine tree health, the following metrics were measured: tree species, discoloration, leaf defoliation, fine twig dieback, crown vigor, crown transparency and DBH.

Soil Methods: To collect soil samples, the materials used were a soil sampler, a mallet, and a gardening shovel. The survey plot (16 × 22 meters) in each site was divided into a grid. 12 points within the plot were randomly selected at each site, and a soil sample was collected at each point. All 12 samples from each site were mixed together to make one composite sample. Each composite sample was stored in a refrigerator for approximately 24 hours before testing. The pH, nitrate, potassium, and phosphorous levels were tested 2 times using Aldon and LaMotte testing kits. These two tests were used to ensure accuracy.

Arthropod Methods: Arthropod diversity was assessed using beat sheet survey methods as outlined by Caterpillars Count protocol. The protocol would be using a sheet held under a tree's branch, and "beating" the branch a multitude of times, we then analyze the arthropods that fall onto the beat sheet, count and identify them to an order level. Arthropod length is then measured by estimating the length of the abdomen in millimeters. The leaf size and number of leaves on the tree is measured in centimeters. Herbivory from arthropods is estimated by counting the number of leaves on the tree's branches that have holes in them from arthropods eating them.



1. **Tree species**, based on leaf definition & shape using iNaturalist, the Trees of New York Field Guide (Tekiela 2022), and NYC Parks leaf identification sheet.
2. **Discoloration -** Visually examining the leaves and comparing their color to that of a healthy tree of the same species noting areas that appear yellow, brown or lighter than normal.
3. **Leaf defoliation -** Estimating the amount of holes in the leaves or missing sections due to arthropods or other factors.
4. **Fine twig dieback-** Estimating the percentage of dead branches on a tree which indicates a decline in tree health.
5. **Crown vigor-** Combining (add) the percentages and finding a total measure of overall tree health based on fine twig dieback, leaf discoloration & defoliation. Class 1 is indicative of great health while Class 5 acknowledges the tree is dead.
6. **Crown transparency-** Estimating the percentage of the skylight that can be seen through a tree's crown by standing underneath the tree and looking up.
7. **Diameter at Breast Height (DBH)** of trees, measured in meters using transect tape.

Abstract

The health of a tree is a determining factor of a healthy ecosystem and environment. Humans and wildlife, alike, rely on healthy trees to live a healthy life. This project is concerned with researching tree health in relation to arthropod abundance and soil quality. Crown vigor scoring was used to regulate overall tree fitness, beat sheets to identify and count arthropods, and soil testing kits to determine soil quality. It was found that a desirable soil quality is associated with a healthy tree and high arthropod abundance. This indicates soil is a deciding factor for a biodiverse and sound ecosystem.

Research Questions & Hypotheses

Research Question 1: How do soil properties and quality relate to tree health indicators within the Bronx Zoo?

Hypothesis 1: Tree health will be at its highest at a balanced soil pH (≈6–7), with poorer health at lower or higher pH, because most tree species have the best nutrient uptake within this range, and more acidic or basic soil levels limit nutrient availability and can become toxic to those trees.

Hypothesis 2: Lower nitrate and phosphorus levels will be associated with poorer tree health, because nitrogen supports leaf and shoot growth, and phosphorus promotes root development and overall plant vigor. Any deficiencies in either chemicals would limit overall growth within the plants.

Hypothesis 3: Lower potassium levels will be associated with poorer tree health, because potassium is known for regulating water balance, and disease resistance, making it important for plants to adapt effectively in urban environments.

Research Question 2: How do tree-associated arthropod community factors relate to the same tree health indicators?

Hypothesis 1: Higher arthropod abundance and species richness will be associated with a healthier tree because healthier trees would be able to support and contain a larger number of insects.

Results & Figures

Testing Materials	Sites	Elements (Nitrate)	Elements (Potassium)	Elements (Phosphorus)	Elements (pH levels)
La Motte	Asia Parking	Deficient	Abundant	Deficient	
Aldon	Asia Parking	Deficient	Abundant	Deficient	6.5
La Motte	Riverwalk	Deficient	Abundant	Deficient	
Aldon	Riverwalk	Deficient	Abundant	Deficient	7.5
La Motte	Education Center	Deficient	Abundant	Deficient	
Aldon	Education Center	Deficient	Deficient	None	7.5

***Table 1**: pH levels were recorded to be in a normal range. Nitrate and phosphorus levels were introduced to be deficient. However, potassium levels were abundant in almost all tests.*

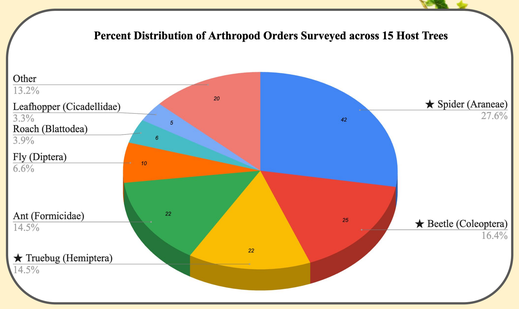


***Figure 2**: Spiders, beetles, true bugs, and ants were found in ample numbers. Aphids, lacewing larvae, roaches, flies, leafhoppers, and unknown insects were all found under the other percentages.*

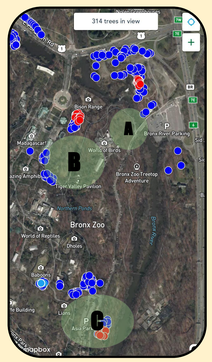


Figure 1 *(right).*

Location of all three sites:

A: Mitsubishi Riverwalk

B: Education Center

C: Asia Parking

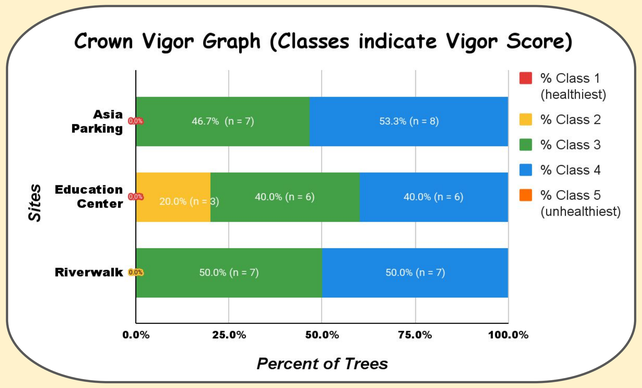


***Figure 3**: A crown vigor of 4 was most frequently identified at Asia Parking. The Education Center had equal parts of crown vigor scores of 3 and 4 with a small percentage pertaining to 2. The Riverwalk also had equal parts of crown vigor scores of 3 and 4.*

Discussion

The findings supported hypothesis one, as tree health was generally high where soil pH was within the predicted optimal range. Across all three Bronx Zoo sites, pH values ranged from 6.5 to 7.5. This suggests that soil pH was not a limiting factor for tree health in this study. Hypothesis two was also supported. Nitrate and phosphorus levels were deficient across all sites, and majority of trees displayed moderate crown vigor scores (3–4) rather than the highest score. Trees with lower vigor scores were relatively rare, but their occurrence in nutrient-deficient areas suggests that nitrate and phosphorus shortages may constrain tree growth and physiological function. However, hypothesis three was not supported, as potassium was abundant in all soil samples, but there was no clear association between potassium levels and tree health. This likely reflects the fact that potassium availability was already above the threshold needed for tree function, making it a non-limiting nutrient under the conditions measured.

The hypothesis for arthropods was partially supported. A total of 187 arthropods were collected using the beat sheet method, with spiders and beetles being the most common groups. The herbivory percentages of the trees provided an indirect link, specifically survey codes with lower herbivory (<10% leaf area removed) typically had higher arthropod richness (5–7 taxa), while codes with higher herbivory (>15%) tended to have fewer taxa (often fewer than 4). This pattern suggests that healthier trees may support more diverse arthropod communities.

However, the relationship between arthropod abundance and tree health appeared more complex. Some trees with higher herbivory still had moderate arthropod abundance, indicating that abundance alone may not reliably signal tree condition. Environmental factors such as temperature, rainfall, canopy cover, and closeness to human traffic may also influence arthropod activity and detection rates.

These results emphasize the role of soil nutrient deficiencies, particularly nitrate and phosphorus, in influencing urban tree health, and suggest that arthropod community richness, rather than sheer abundance, may be a more consistent indicator of tree condition. Future studies could incorporate ammonia testing to better characterize nitrogen availability (Gentili et al. 2018) and use environmental DNA (eDNA) to profile soil microbial communities (Ariza et al. 2022). Employing advanced statistical analyses in R would also allow for more stronger modeling of the combined effects of soil chemistry, arthropod metrics, and environmental variables on tree health (Gao et al. 2025).

***Image 1:** Research Team conducting Arthropod surveys using Beat Shee Method*

***Image 2:** Research Team conducting chemical tests on the soils looking at on pH, Phosphorus, Potassium, and Nitrate*

Acknowledgements

We would like to extend our gratitude to Fordham University and the Wildlife Conservation Society. A very special thanks to Max Falkenberg, Lowell Iporac, Brian Saville, and Michelle Johnson from the Nature Conservancy/Healthy Trees, Healthy Cities for helping us throughout our research.

References

Ariza, M., Fouks, B., Mauvisseau, Q., Halvorsen, R., Alsos, I. G., & Boer, H. J. (2022). Plant biodiversity assessment through soil eDNA reflects temporal and local diversity. Methods in Ecology and Evolution. https://doi.org/10.1111/2041-210x.13865
Caterpillars Count! (n.d.-b). Conduct a survey. In Caterpillars Count!. Retrieved August 12, 2025, from https://caterpillarscount.unc.edu/conductASurvey/
Gao, M., Ye, Y., Zheng, Y., & Lai, J. (2025). A comprehensive analysis of R's application in ecological research from 2008 to 2023. Journal of Plant Ecology. https://doi.org/10.1093/jpe/rtaf010
Gentili, R., Ambrosini, R., Montagnani, C., Caronni, S., & Citterio, S. (2018). Effect of Soil pH on the Growth, Reproductive Investment and Pollen Allergenicity of Ambrosia artemisiifolia L. Frontiers in Plant Science, 9(1335). https://doi.org/10.3389/fpls.2018.01335
Khan, F., Siddique, A. B., Shabala, S., Zhou, M., & Zhao, C. (2023). Phosphorus Plays Key Roles in Regulating Plants' Physiological Responses to Abiotic Stresses. Plants, 12(15), 2861. https://doi.org/10.3390/plants12152861
O'Brien, M. J., Brezzi, M., Schuldt, A., Zhang, J.-Y., Ma, K., Schmid, B., & Niklaus, P. A. (2017). Tree diversity drives diversity of arthropod herbivores, but successional stage mediates detritivores. Ecology and Evolution, 7(21), 8753–8760. https://doi.org/10.1002/ece3.3411
Sollai, G., Giglio, A., Giulianini, P. G., Crnjar, R., & Solari, P. (2024). Topic: Arthropod Biodiversity: Ecological and Functional Aspects. Insects, 15(10), 766. https://doi.org/10.3390/insects15100766
Tekiela, Stan. (2022). Trees of New York Field Guide (Tree Identification Guides)
US EPA. (2024, March 29). Benefits of Trees and Vegetation. Www.epa.gov. https://www.epa.gov/heatislands/benefits-trees-and-vegetation
Woodward, A., Hinwood, A., Bennett, D., Grear, B., Sotiris Vardoulakis, Neha Kishan Lalchandani, Lyne, K., & Williams, C. (2023). Trees, Climate Change, and Health: An Urban Planning, Greening and Implementation Perspective. International Journal of Environmental Research and Public Health, 20(18), 6798–6798. https://doi.org/10.3390/ijerph20186798
Xia, Y., Feng, J., Zhang, H., Xiong, D., Kong, L., Seviour, R., & Kong, Y. (2024). Effects of soil pH on the growth, soil nutrient composition, and rhizosphere microbiome of Ageratina adenophora. PeerJ, 12, e17231–e17231. https://doi.org/10.7717/peerj.17231
Xu, X., Du, X., Wang, F., Sha, J., Chen, Q., Tian, G., Zhu, Z., Ge, S., & Jiang, Y. (2020). Effects of Potassium Levels on Plant Growth, Accumulation and Distribution of Carbon, and Nitrate Metabolism in Apple Dwarf Rootstock Seedlings. Frontiers in Plant Science, 11(904). https://doi.org/10.3389/fpls.2020.00904
Zhang, G.-B., Meng, S., & Gong, J.-M. (2018). The Expected and Unexpected Roles of Nitrate Transporters in Plant Abiotic Stress Resistance and Their Regulation. International Journal of Molecular Sciences, 19(11), 3535. https://doi.org/10.3390/ijms19113535