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Research Fellowship Grant Application

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Applicant

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Degrees	B.A., Environmental Studies, Binghamton University, 1995 M.S., Plant and Soil Sciences, University of Tennessee, 1998 Ph.D., Ecology, University of Georgia, 2003
Relevant citations authored	Pavao-Zuckerman, M.A., and Bossler, B. Assessing ecosystem services with hemispherical photography in a semi-arid urban park (in prep) Pavao-Zuckerman, M.A., and Sookhdeo, C. Biological soil quality indicators of green infrastructure designs in a semi-arid city. Water and Environment Journal (submitted) Hough, M., Scott, C.A., M.A.Pavao-Zuckerman, Using trait-based ecology to identify thresholds in the ecosystem service cascade: a framework for decision making. Ecosphere (in revision) Pavao-Zuckerman M.A. and R.V. Pouyat. (in press, 2016) The effects of urban expansion on soil health and ecosystem services within cities. In (C. Gardi, ed.) Urban expansion, land cover, and ecosystem services, Earthscan: Routledge Tanner, C., F. Adler, N. Grimm, P. Groffman, S. Levin, J. Munshi-South, D. Pataki, M. Pavao-Zuckerman, W. Wilson (2014) Urban ecology: advancing science and society. Frontiers in Ecology and the Environment 12: 574–581. Zhang X., Niu G.-Y., Elshall A.S., Ye M., Barron-Gafford G.A., and Pavao-Zuckerman M. (2014): Assessing five evolving microbial enzyme models against field measurements from a semiarid savannah – What are the mechanisms of soil respiration pulses? Geophysical Research Letters 41 DOI: 10.1002/2014GL061399 2013 Felson, A., M.A. Pavao-Zuckerman, T. Carter, F. Montalto, W. Schuster, E. Stander, and O. Starry. 2013. Mapping the design process for urban ecological researchers. Bioscience 63(11): 852-864 Pavao-Zuckerman, M. 2012. Urbanization, soils, and ecosystem services. D. H. Wall, et al., editors. Soil Ecology and Ecosystem Services. p.270-281. Oxford University Press, Oxford, UK. Pavao-Zuckerman, M.A. and L.B. Byrne. 2009. Ecological theory from the perspective of urban soils: Digging deeper or scratching the surface? Urban Ecosystems. 12:9-20. Pavao-Zuckerman, M.A. 2008. The nature of urban soils and their role in ecological restoration in cities. Restoration Ecology. 16:642-649. Pavao-Zuckerman, M.A., and D.C. Coleman. 2007. Urbanization alters the functional composition, but not taxonomic diversity, of the soil nematode community. Applied Soil Ecology 35:329-339.

	Pavao-Zuckerman, M.A., and D.C. Coleman. 2005. Decomposition of chestnut oak (Quercus prinus) leaves and nitrogen mineralization in an urban environment. Biology and Fertility of Soils 41:343-349.
Has this investigator previously received funding from the TREE Fund?	Yes
If yes, was the funding for this project?	No
Previous TREE Fund awards	13-JD-05 Characterizing urban forest functioning and ecosystem services with digital imaging

Co-Principal Investigator (if applicable)

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Degrees	B.S., Crop Science, Michigan State University, 1970. M.S., Soil Science, Purdue University, 1973. Ph.D., Soil Ecology, Virginia Tech, 1977
Relevant citations authored	Weil, R.R., and N.C. Brady. 2017. The Nature and Properties of Soils (link is external). 15th ed. Pearson, Columbus. 1086 p. ISBN-13: 9780133254488. Wang, F., Y.A. Tong, P. Gao, J. Zhang, R.R. Weil, and J.N. Coffie. 2014. Organic amendments to a wheat crop alter soil aggregation and labile carbon on the loess plateau, China. Soil Science 179:166-173. Chen, G., R.R. Weil and R. Hill. 2014. Effects of Compaction and Cover Crops on Soil Least Limiting Water Range and Air Permeability. Soil & Tillage Research 136:61-69.

Lucas, S.T., and R.R. Weil. 2012. Can a labile carbon test be used to predict crop responses to improve soil organic matter management? Agronomy J. 104:1160-1170.

Gruver, J., R.R. Weil, C. White, and Y. Lawley.2012.Radishes – a new cover crop for organic farming systems. e-Organic e-Extension, http://www.extension.org/pages/64400/radishes-a-new-cover-crop-for-organic-farming-systems (link is external)

Chen, G., and R.R. Weil. 2010. Penetration of cover crop roots through compacted soils. Plant and Soil 10.1007/s11104-009-0223-7.

Dean, Jill E., and Ray R. Weil. 2009. "Brassica cover crops for nitrogen retention in the Mid-Atlantic Coastal Plain." Journal of environmental quality 38.2: 520-528.

Weil, Ray, and Amy Kremen. 2007 "Thinking across and beyond disciplines to make cover crops pay." Journal of the Science of Food and Agriculture 87: 551-557.

Has this investigator previously received funding from the TREE Fund?	No
If yes, was the funding for this project?	
Previous TREE Fund awards	

Students/Interns (if applicable)

Student/Intern 1

Name	Isaac Hametz
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Student/Intern 2

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Project

Project title	Innovative Practices to Enhance Soil Quality for Vacant Urban Lot Afforestation
Research area	Soil biology/soil amelioration
Project summary	Urban forests have great potential to provide ecosystem services and improve well-being and health in cities. However, the quality of urban soils is impaired, thus limiting the potential for urban forests. By investigating approaches to improve urban soil quality, this project addresses the TREE fund soil biology/soil amelioration priority area. Our objectives are to: (1) review current literature on urban soil quality and amelioration, (2) explore the transfer of agricultural best practices for managing soil quality to urban forestry settings, (3) evaluate the impacts of soil amendment practices on soil quality for urban tree growth, (4) explore a soil quality minimum/best data set to characterize urban soil characteristics to support plant growth and establishment. We propose a 3-year field study comparing several soil amendments, including the use of agricultural cover crops, to improve soil quality in vacant lots in Baltimore, MD for reforestation purposes. We will track soil quality and plant response variables over time, and analyze the connections between treatments, soil biological, chemical, and physical quality and their influence on plant responses. Our expected outcomes include: (1) a quantifiable evaluation of soil amendment practices for urban forests, including the adoption of a technique from sustainable agriculture; (2) an assessment of soil quality indices for plant growth and ecosystem services for urban soils in vacant lots, (3) dissemination of results and approaches to academics, industry professionals, and municipal and governmental managers and researchers, and (4) the training of two graduate students and mentoring of one junior faculty member.
Statement of problem and objectives of project	Urbanization is arguably one of the most dramatic forms of landscape change, and an important anthropogenic influence on the structure and function of ecosystems. It is projected that the percentage of the U.S. population living in urban areas will increase from 74% in 1986 to greater than 80% in the year 2025. Cities have obvious impacts on local ecologies and environments, such as shifts in species diversity, alterations to hydrology, urban heat islands, deposition of nutrients and pollutants, and reductions in soil health. While scientists are now familiar with many of these localized impacts of urbanization, cities and suburban areas contribute to 10-15% of surface land cover in the conterminous U.S., pointing to the potential, yet poorly understood, contribution of cities to regional, national, and global energy and carbon budgets. Moreover, the local environments that the majority of people now experience day to day are in urbanized landscapes, with potential affects on well-being and public health.

Much of this knowledge of urban ecology has been referred to as ecology “of” and ecology “in” cities. These two perspectives focus on cities as a new kind of habitat to investigate ecological patterns and processes. Yet, as cities continue to expand, urban ecologists are placing greater emphasis on understanding ecology “for” cities. This refers to the application of ecological knowledge and principles to guide the functions and management of urban ecosystems and the ecosystem services (e.g. habitat, air, and water quality) that cities provide. While studies demonstrate that the urban environment alters the structure and function of remnant patches of native ecosystems relative to their non-urban counterparts, the ability of restoration, planning, and design to increase and improve the provision of ecosystem services is a relatively new approach within ecology.

Management and regrowth of urban forests is a part of this ecology “for” cities approach. There is considerable interest in rehabilitating, reclaiming, and restoring vacant lots to provide ecosystem services. In many aging cities in the US (such as Baltimore, MD) there is a growing abundance of vacant lands and lots that could contribute to urban forest practices. Managing environmental challenges from direct and indirect effects to support urban forest growth in novel areas such as vacant lots is a growing element of the ecology ‘for’ cities. Yet, there is still a need to explore and field-test innovative practices to enhance soil quality to support these afforestation efforts.

The objectives of this project are therefore to:

1. Review current literature on urban soil quality and amelioration
2. Explore the transfer of agricultural best practices for managing soil quality to urban forestry settings.
3. Evaluate the impacts of soil amendment practices on soil quality for urban tree growth
4. Explore a soil quality minimum/best data set to characterize urban soil characteristics to support plant growth and establishment.

Significance of your proposed project as it relates to the profession of arboriculture or urban forestry

This project provides tools and information for commercial and municipal urban forestry – it will refine practices for improving soil quality and a minimum data set to evaluate soil quality. This project will also support the training of PhD students to interface with arboriculture professionals in the generation of scientific knowledge for urban forest management. One of the students supported on this project (Isaac Hametz) is a practicing landscape designer in Baltimore, MD. Supporting his research and training will expand the scope of professions that address soil quality and management issues for urban forestry practice. This research strongly aligns with the “Ten-Year Urban Forestry Action Plan (2016-2026)” produced by the US Forest Service, National Urban and Community Forestry Advisory Council, and American Forest Foundation: (I) Goal 4 (Strengthen Urban and Community Forest Health and Biodiversity for Long-Term Resilience) & Goal 5 (Improve Urban and Community Forest Management, Maintenance and Stewardship) involve addressing site preparation and the use of amendments to meet soil and water needs for urban trees and forests; (II) Understanding the contribution of urban soils to tree growth is needed to better connect urban forest health, environmental health, and ecosystem service provision. Developing these research themes and integrating them into urban forestry training and practice is a key goal for the 10-year action plan and the urban forestry profession. Our project contributes to these goals by implementing a research agenda, training the next generation of urban forest scientists, and connecting with the urban forest profession to disseminate knowledge.

Brief description of what is currently known about proposed project area	Soils are a critical ecosystem component underlying or directly supporting the majority of terrestrial ecosystem services. Soil can be seen as a form of 'natural capital' that supports the provision of ecosystem services. Soil health (the ability of soil to function and provide desired services and maintain environmental quality) is a critical component of a soil's role as natural capital supporting the provision of ecosystem services. It is the knowledge of the interaction of physical, chemical, and biological properties of soils that underlies management of soil health through conservation, forestry, and restoration practice. The characteristics of urban soils vary widely and are dependent on both direct and indirect effects of urban land-use change (Pavao-Zuckerman 2008). Examples of direct effects include soil disturbances such as grading, management inputs such as irrigation and compaction through trampling, while indirect effects include environmental changes such as the urban heat island effect and atmospheric deposition. Urban ecosystems are characterized by an alteration of energy, water, and material fluxes that stem from disturbance, management, and other physical alterations to the environment. Cities therefore can indirectly impact soils through these direct processes associated with urbanization. Such direct and indirect effects on urban soils can significantly impact the ability of urban soils to support tree growth and to provide ecosystem services. Heneghan et al. (2008) and Pavao-Zuckerman (2008) explore the use of soil ecological knowledge for supporting restoration and remediation practices. These reviews suggest that we need to understand the interaction of physical, chemical, and biological properties along a gradient of reclamation, restoration as the nature of disturbance links to the soil quality properties that are most impacted and in need of amelioration. Moreover, it is often the physical and direct effects of urbanization that need to be addressed primarily when attempting to use new sites for plant growth and afforestation practices in cities. Large-scale tree planting efforts have been viewed as a strategy to restore ecosystem services in cities due to the many benefits that trees provide. Vacant lots are an opportunity for growing urban forests and hold great promise for providing many types of ecosystem services in the urban fabric. In an assessment of hydrologic properties of vacant residential lots in Cleveland, OH, Shuster et al. (2015) suggest that policies and procedures for vacant lot management may positively impact soil properties such that these lots become part of the urban green infrastructure. Moreover, similar lot-scale management and processes may allow lots to

function more ecologically, with improvements to soils reducing demand for irrigation as infiltration processes are supported (Shuster et al., 2015). Kremer et al. (2013) conducted a social-ecological assessment of vacant lot utilization in New York City and found a range of uses (including, gardening, park space, parking, and athletic activities). Importantly, they found that the whether and how residents used lots was a localized phenomenon, and was influenced by socio-economic factors (Kremer et al., 2013). This suggests that planning and management of vacant lots for urban forestry programs to provide ecosystem services should take into account local conditions and demand for services might better contribute to urban sustainability (McPhearson et al. 2014). Soil quality management of vacant lots in cities is a critical local management issue that needs to be addressed to ensure successful development of urban forests though time.

Soil carbon management is often the most critical approach to improving urban soil quality. Increasing the soil carbon pool has many direct and indirect ecosystem benefits for improving soil structure, enhancing infiltration rates, and increasing populations of soil biota (Heneghan et al. 2008). This can be achieved through composts and mulches and biochar, where repeated application can improve soil physical properties affected by urbanization, such as bulk density, infiltration rates, and soil water holding capacity (Cogger, 2005). Indirect benefits of compost applications on soil properties may help to also alleviate urbanization impacts on plant productivity (Scharenbroch, 2009), which may have additional indirect benefits for urban soil quality through root and litter production.

There have been several studies that explore the use of amendments in urban forestry and afforestation programs. In the initial stages of an afforestation project in New York City, Oldfield et al. (2014) report that site preparation and soil amendment improves the health of urban soils. Specifically, they observed reductions in bulk density, increases water holding capacities, increased microbially-available carbon, and enhanced carbon storage. However, it should be noted that site preparation itself dominated treatment effects (compost amendment) in the early stages of the afforestation project (Oldfield et al. 2014). Oldfield et al. (2015) suggest that site preparation that included the use of mulching of soils reduced bulk density and increased microbial biomass and labile carbon. They found that soil amendments could impact physical, chemical, biological soil properties that are important for infiltration, mineralization and nutrient retention. Their study implies that considering soil in afforestation approaches can help improve urban environments and increase the contribution of urban forests to ecosystem service provision.

Many types of amendments are utilized to address soil compaction, organic matter, and nutrient issues in urban soils. While fertilizers, compost, and wood chip mulch are common amendments for urban soils, Scharenbroch et al. (2014) identified biochar and biosolids as promising amendments to improve soil quality and impact tree seedling growth. Previous research has focused on tests and trials involving greenhouse microcosm studies. While these studies are important steps for identifying promising BMPs and mechanisms, field trials are necessary to fully evaluate the effectiveness of soil quality amendment practices. This is especially important for urban setting and vacant lots where soil composition can contain considerable amounts of foreign and construction materials in soil profiles that can impact infiltration and compaction.

The use of cover crops in agricultural settings has shown great ability to improve soil quality issues related to compaction and poor nutrient status. Forage radish (Raphanus sativus L. cv. Daikon) has been explored in field applications in agricultural and some urban settings. It has been adopted as a cover crop to address soil quality issues such as compaction (Williams and Weil, 2004), N loss, and erosion (Weil and Kremen 2007, Dean and Weil 2009). Several characteristics make it a promising plant to address urban soil compaction and lack of organic matter issues: forage radish produce a taproot that extend 15 – 30 cm deep and will die and rapidly decompose over winter, leaving taproot holes in surface soils, resulting in less compacted soils with elevated N and P pools.

Cover crops such as forage radish have rapid and dramatic impacts on soil physical properties, setting the stage for accompanying soil chemical and biological improvements (Heneghan et al. 2008, Pavao-Zuckerman 2008). Studies of compost and biochar amendments indicate that it may take repeated applications of amendments through time to see beneficial effects. Moveover, studies have shown the beneficial impact of compost on tree growth and health may take several years to be expressed in measurable tree performance (Oldfield 2014). Due to the dramatic impact on soil physical characteristics and ability to ‘jump-start’ chemical and biological responses (Heneghan et al. 2008), the application of cover crops to urban afforestation settings may result in more rapid amelioration of soil quality issues, and more rapid increases in plant performance. Cover crops, therefore, are an emerging best practice for rehabilitating urban soils targeted for afforestation projects. A goal of this project is to test this assumption using a field study in Baltimore, MD.

Cogger, C. G. Potential compost benefits for restoration of soils disturbed by urban development. Compost Science & Utilization, 13(2005) 243-251.
Dean, J, and R. Weil. "Brassica cover crops for nitrogen retention in the Mid-Atlantic Coastal Plain." Journal of environmental quality 38.2 (2009): 520-528.
Heneghan, L, et al. "Integrating soil ecological knowledge into restoration management." Restoration Ecology 16.4 (2008): 608-617.
Kremer, P., et al. A social-ecological assessment of vacant lots in New York City. Landscape and Urban Planning, 120 (2013) 218-233.
McPhearson, T., et al. Resilience of and through urban ecosystem services. Ecosystem Services (2014)

	Oldfield, E, et al. "Positive effects of afforestation efforts on the health of urban soils." Forest Ecology and Management 313 (2014): 266-273. Oldfield, E, et al. "Growing the urban forest: tree performance in response to biotic and abiotic land management." Restoration Ecology 23.5 (2015): 707-718. Pavao-Zuckerman, M "The nature of urban soils and their role in ecological restoration in cities." Restoration Ecology 16.4 (2008): 642-649. Scharenbroch, B. C. A Meta-analysis of Studies Published in Arboriculture & Urban Forestry Relating to Organic Materials and Impacts on Soil, Tree, and Environmental Properties. Arboriculture & Urban Forestry, 35 (2009) 221-231. Scharenbroch, B.C., et al. "Biochar and biosolids increase tree growth and improve soil quality for urban landscapes." Journal of environmental quality 42.5 (2013): 1372-1385. Shuster, W. D., et al. Hydropedological Assessments of Parcel-Level Infiltration in an Arid Urban Ecosystem. Soil Science Society of America Journal, 79 (2015) 398-406. Weil, R, and A. Kremen. "Thinking across and beyond disciplines to make cover crops pay." Journal of the Science of Food and Agriculture 87.4 (2007): Williams, S RR Weil. Crop cover root
Summary of project goals	The goal of this project is to address research gaps for sustainable urban forests that are specifically linked to improving soil quality for plant performance and the provision of ecosystem services. This research will be conducted in vacant lots, a relatively unexplored, but potentially strong context for expanding the scope of urban forests within many cities, especially our target city, Baltimore, MD. We focus on comparing several approaches to soil treatment and amendments to improve soil quality in these settings. More specifically, we seek to apply and adopt concepts and practices from sustainable agriculture to the practice of urban forestry to meet goals of sustainable urbanism. Ideally these soil amendment practices will help ameliorate urban soil conditions, promote the presence and activity of soil biology, and support the growth of trees within the broader urban forest. This project addresses the urban forest sustainability priority area of soil biology and soil amelioration identified by the TREE Fund and the Science and Research Committee of the International Society of Arboriculture. To meet these goals we have the following objectives: (1) review current literature on urban soil quality and amelioration, (2) explore the transfer of agricultural best practices for managing soil quality to urban forestry settings, (3) evaluate the impacts of soil amendment practices on soil quality for urban tree growth, and (4) to explore a soil quality minimum/best data set to characterize urban soil characteristics to support plant growth and establishment.
Brief description of measurable outcomes expected	This project will produce: (1) a quantifiable evaluation of soil amendment practices for urban forests, including the adoption of a technique from sustainable agriculture, (2) an assessment of soil quality indices for plant growth and

ecosystem services for urban soils in vacant lots,
(3) a method applicable to other urban forest settings & locations that is adaptable for academics, industry professionals, and municipal and governmental researchers,
(4) at least two papers in relevant professional journals (one from the literature review, one from the field study),
(5) a broader proposal to a federal funding agency (National Science Foundation, US Forest Service/US Department of Agriculture) that leverages this project to expand its scope to include connections between urban forests and soils to ecosystem services such as the mitigation of stormwater, urban heat islands, and enhanced public access to forests in cities,
(6) the training and mentoring of two graduate students (and their dissertations) and one pre-tenured professor. I have identified Dr. Ray Weil as a Co-Investigator to provide mentoring to meet the goals and objectives of the project. Dr. Weil is a leader in researching and promoting the adoption of more sustainable agricultural systems, and has a research focus on organic matter management for enhanced soil quality for water quality and sustainability. He has been the major advisor for 40 MS and PhD students, and is the author of the most widely used textbook in soil science. I am excited to work with him to translate these ideas to urban forest sustainability.

Project plan including design, hypotheses, methodology and analyses

Overarching Design: This project will be implemented over 3 years. It includes both a field study and a literature synthesis project. For the field study, we will identify field sites in Y1 and establish plots and amendment treatments in Y1. We will measure soil quality variables pre/post treatment in Y1 and establish plants at end of Y1. We will monitor responses of soils and plants to treatments in Y2 & 3.

We will conduct the literature synthesis in Y1, continuing into Y2 if needed. We will start with a broader focus on soil quality in urban settings and narrow the scope to focus on the use of different amendments in urban forests (rather than analyzing a single best practice). The scope will reflect our interests in linking soil quality, afforestation, and ecosystem services. Standard bibliometric approaches will be used to select literature based upon keywords, methodological and, metadata coding of papers (Koricheva et al. 2013). Metanalysis techniques will be used to assess relative treatment effects within the studies we review (Koricheva et al. 2013).

Field Study Hypotheses: We expect that soils in urban vacant lots should be impacted through compaction, decreased infiltration, reduced organic matter and nutrient availability, and limited microbial activity. We hypothesize that the use of soil amendments will improve these aspects of urban soil quality. Further, we expect that the use of cover crops will have a greater impact on soil physical, chemical, and biological soil quality than the other amendments used alone. The significant physical transformation of soil structure by the roots of the cover crop will jump-start transformations of soil chemical and biological aspects of soil quality. The greatest response should be seen in amendments used in conjunction with the cover crop. We hypothesize that microbial activity will be a stronger indicator of soil response than soil faunal (nematode community) analysis given the short duration of treatments in this study. However, we predict that through time, soil faunal indices will become a stronger indicator of soil response as the soil food web develops. To test these hypotheses, we will use a combination of data types that indicate soil quality and plant growth responses collected before and after the application of a variety of amendment treatments.

Site Selection: This project will be conducted in vacant lots located in the city of Baltimore, MD. There is a great abundance of vacant sites in Baltimore (14,000 vacant lots and 16,000 abandoned houses within its border in 2013) and the. considerable interest in rehabilitating, reclaiming, and restoring these vacant lots to contribute to ecosystem functioning in cities, an initiative spearheaded by the Baltimore Growing Green Initiative. Four vacant lots will be established as research sites, selecting lots large enough to accommodate multiple treatment plots within each lot. We will select candidate vacant lot sites to control for variables such as: watershed position, age of site (including time vacant), topography, and soil series. Candidate sites will be further assessed visually and through consultation with Baltimore Growing Green Initiative representatives, local community groups, and the Baltimore Ecosystem Study- Long-Term Ecological Research site.

Treatment and study design: Within each lot site, 6-100m2 study plots will be established in which we will apply 6 treatments, one per plot per vacant lot site (giving 4 plots per treatment over the set of lot sites). The amendment treatments that will be tested in this study are: (1) compost, (2) biochar, (3) cover crop (forage radish), (4) combined cover crop with compost treatment, (5) combined cover crop with biochar treatment, and (6) no amendment (control). Treatments will be applied as specified by current best practices for soil amendment applications (compost and biochar at 25 Mg ha-1 y-1, forage radish seeded at 7 kg ha-1) in summer of year 1 of the project.

The characteristics of the biochar and compost amendments will be determined at time of application (%C, %N, C:N ratio, electrical conductivity, pH, bulk density). Forage radish characteristics (depth of tap root, above and belowground biomass, %C, %N, C:N ratio) will be determined in late fall but prior to onset of radish-killing temperatures (below -8C) in Y1 using samples collected within two randomly located quadrats (0.25 m^2) per treatment plot.

We will plant 2 tree species per treatment plot at each vacant lot site in Y2 of the project: Red buckeye (Aesculus pavia) and White oak (Quercus alba). Trees were selected in consultation of targeted and common native urban tree species for reforestation programs in Baltimore, MD. Inclusion of red buckeye vs. white oak provides a contrast between trees that are small and large at maturity. Saplings 3-5 years old (roughly 0.5 – 1.5 m tall) will be targeted for planting in the study. We anticipate being able to plant 12 individuals of each species in each treatment plot per vacant lot.

Sampling and Data Collection: To assess the “health” of an ecosystem, we will measure key variables and processes. We will combine these ecological characteristics with selected statistical ordination techniques to create indicators of ecosystem health and soil quality that can then be related to plant growth responses. Soil quality indicators have been used primarily conditions leading to the sustainable production of food and fiber, critical “ecosystem services”, by agroecosystems (Andrews and Carroll 2001, Doran and Parkin 1994). Using recommended data sets from recent urban applications (Scheyer and Hipple, 2005, Vrščaj et al. 2008.), we will develop indices of soil quality for urban ecosystem health.

We will sample soils from plots before and after treatments are applied in Y1 and then again in Y2 & 3 – plant monitoring will occur in Y2 & 3 with harvesting of some trees to help estimate treatment effects. Soil samples will be collected twice per year: in the spring, and summer/fall using the following approach:

-6 samples will be collected at each sampling time in each treatment plot using a randomized grid,
-Each sample will consist of 4 neighboring 2.5-cm diameter soil cores collected to a depth of 25 cm (grouping multiple cores accounts for fine-scale heterogeneity)
-Each of those soil samples will be split into two depths: top 0-5 cm and bottom 5-25cm to account for depth effects of the amendment treatments

Standard soil methods will be applied to these samples to collect data that represent soil quality indices (Robertson et al. 1999). These data will include:
• Soil physical properties: bulk density, texture, infiltration, compaction
• Soil chemical properties: soil organic matter content, total C content, labile C content, N availability, metal availability
• Soil biological properties: microbial biomass, nematode community analysis
• Soil processes: decomposition rates (using cotton strips), soil respiration

Plant samples will be collected using the following approaches:
-Cover Crop: using two randomly located quadrats (0.25 m^2) per treatment plot, all aboveground and belowground biomass of the forage radish will be harvested at the end of Y1
-Trees: Using the same randomized locations as the soil samples (for each treatment plot for each tree species), we will harvest aboveground and belowground biomass at the end of Y3 – co-location of soil and tree samples will allow analysis of correlation of properties. Additional properties will be measured on standing plants before harvest described below.
We will measure plant growth responses and performance in response to soil treatment and amendments:

• Status (living, dead, missing)
• Height and diameter at root collar
• Estimation of crown volume •
Above and belowground biomass, %C, %N, C:N ratio
• Hyperspectral imagery (with a point&shoot camera to indicate NDVI)
• Stomatal conductance (as an ecophysiological measure activity)

These soil and plant data sets also are proxies and drivers for ecosystem services (Dominati et al. 2012), allowing us to assess the influence of soil amendments and plant responses to the provision of ecosystem services, such as, C-sequestration (soil C, plant C accumulation), stormwater mitigation potential (infiltration capacity), nutrient retention (available N).

Data Analysis: These data will be integrated into a multivariate statistical model (following Andrews and Carroll 2001) to determine which soil quality variables are the best predictors of plant growth responses. Path analysis and structural equation modeling will be used to trace causality between soil treatments, soil variables, and plant responses. We will use plant growth and health data as response variables in our analysis, and soil quality data as predictor/driver variables.

Andrews, Susan S., and C. Ronald Carroll. "Designing a soil quality assessment tool for sustainable agroecosystem management." Ecological Applications 11.6 (2001): 1573-1585.
Dominati, E., et al. "A framework for classifying and quantifying the natural capital and ecosystem services of soils." Ecological Economics 69.9 (2010): 1858-1868.
Koricheva, Julia, et al., eds. Handbook of meta-analysis in ecology and evolution. Princeton University Press, 2013.
Robertson, G.P., et al. (eds.). Standard soil methods for long-term ecological research. Vol. 2. Oxford University Press on Demand, 1999.
Scheyer, J., and K. Hipple. Urban Soil Primer. USDA, NRCS, National Soil Survey Center, Lincoln, Nebraska (http://soils.usda.gov/use), 2005
Vrščaj, B et al. "A method for soil environmental quality evaluation for management and planning in urban areas." Landscape and Urban Planning 88.2 (2008):

Description of plan for disseminating the results of this project	Results from this project will be disseminated to local and regional community and practitioners interested in urban forestry and soil quality. This will be done in consultation with groups such as the USFS Northeastern Area Urban and Community Regional Coordinator office, Baltimore’s Growing Green and TreeBaltimore initiatives and affiliated NGOs. We will work with the University of Maryland Extension program to develop extension documents. We will also work with UM Extension to produce a video related to the project for their YouTube channels (Woodland stewardship and SeaGrant/Watershed Management) and work with Maryland Public TV to host a short video on the subject as well.

	Pavao-Zuckerman is an affiliated Co-PI on the Baltimore Ecosystem Long-Term Ecological Research project, and will work with their outreach programs (including, community day, connections with local urban forestry professionals, and connections with local NGOs). We will submit two blog entries on the project (1) to the SSSA “Soils Matter” Blog: https://soilsmatter.wordpress.com and (2) to the Future Earth Urban and Global Environmental Change viewpoints blog: https://ugec.org/viewpoints/, and will submit an article to the international Society of Arboriculture’s Arborist News magazine. Results will also be disseminated in professional journals related to arboriculture, urban forests, and urban ecology. The TREE Fund will be notified to assist with publicizing when findings are published in academic and professional journals, conferences, and extension/outreach materials. We will comply with TREE Fund requirements regarding reporting, requests for web content, and acknowledgement of funding support.
Project start date	01/01/2017
Project completion date	12/31/2019
Geographic range of project	USA & Canada

Budget

Compensation/Stipend

Proposed project budget	81349
Requesting from TREE Fund	49882
Funding from other sources	31467
Value of in-kind support from other sources	0

Employee Benefits

Proposed project budget	48768
Requesting from TREE Fund	32164
Funding from other sources	16604
Value of in-kind support from other sources	0

Travel (> 50 miles)

Proposed project budget	0
Requesting from TREE Fund	0
Funding from other sources	0

Value of in-kind support from other sources	0

Local Transportation (< 50 miles)

Proposed project budget	900
Requesting from TREE Fund	900
Funding from other sources	0
Value of in-kind support from other sources	0

Equipment (vehicles, growth chambers, etc.)

Proposed project budget	0
Requesting from TREE Fund	0
Funding from other sources	0
Value of in-kind support from other sources	0

Supplies (paper, ink, toner, etc.)

Proposed project budget	7900
Requesting from TREE Fund	7900
Funding from other sources	0
Value of in-kind support from other sources	0

Contract Labor (contractor, speaker, etc.)

Proposed project budget	0
Requesting from TREE Fund	0
Funding from other sources	0
Value of in-kind support from other sources	0

Other/Misc.

Proposed project budget	13032
Requesting from TREE Fund	9085

Funding from other sources	3947
Value of in-kind support from other sources	0
Description of other/misc. expenses	10% IDC

Total

Proposed project budget	151949
Requesting from TREE Fund	99931
Funding from other sources	52018
Value of in-kind support from other sources	0

Funds already received from other sources	52018
Funds pending from other sources	0
Value of in-kind support already received from other sources	0
Value of in-kind support pending from other sources	0

How did you hear about this grant?	TREE Fund website Social media (Facebook, LinkedIn)

Applications will be scored on the following scale:

- Applicant is qualified (10 points)
- Applicant has experience (10 points)
- Project directly meets one or all TREE Fund priorities (10 points)
- Project has clearly stated need (10 points)
- Project is clearly linked to arboriculture and/or urban forestry (10 points)
- Research has practical application (10 points)
- Methods are clear (10 points)
- Objectives are achievable within proposed time frame (10 points)
- Objectives are achievable within proposed budget (10 points)
- Requested funds are matched cash or in-kind (10 points)

**Your application will not be available for editing after it has been submitted.
Please review your application for completion before submission.**