PROPOSAL COVER SHEET

Please complete and submit this Cover Sheet with your grant The completed Cover Sheet can be scanned and emailed to Thomas.anderson@mass.gov Responses can also be sent in by regular mail to Executive Office of Energy & Environmental Affairs, Division of Conservation Services, 100 Cambridge St., 10th
Floor, Boston MA 02114.

Organization information to be used for the contract:

Organization Name: University of Massachusetts Lowell

Mailing address: 220 Pawtucket St, Lowell, MA 01854

Phone: 978-934-3148

Email: Awards@uml.edu

Website: https://www.uml.edu/

Commonwealth of Massachusetts, Vendor Code: VC6000178134
(if our organization has one)

CHIEF EXECUTIVE or authorized signatory:

PRIMARY CONTACT FOR THIS GRANT REQUEST AND POSITION (provide name, phone, e-mail and address if different from above):

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Jasmina Burek, +1 978 934-5937, jasmina_burek@uml.edu, 1 University Ave, DAN234, Lowell, MA, 01854

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Authorized Signature

Sara Akashian — Print Name

Assistant Director, Grants & Contracts — Title

FY 25 GRANT PROJECT INFORMATION

GRANT AMOUNT REQUESTED:

Total $76,541

TOTAL PROJECT BUDGET (from all sources, including grant.)

$115,153

Total project match

$38,612

Project name: Urban Food Forests for Healthy Soils

SUMMARY OF GRANT PROJECT (limit to 75 words) (Please also forward this summary of project electronically to thomas.anderson@mass.gov so we can easily cut and paste it in summary reports :

This project seeks to protect and improve soil quality, ensuring it remains an abundant resource for future generations. Urban food forests are popular alternative greenspaces on degraded soils. The UML Food Forest, a living laboratory, had a successful first season, fostering collaborative research and education. The project objectives include soil monitoring, community engagement, and developing an open-source community engagement tool using R Shiny, which will promote food forests' role in maintaining healthy soils in Massachusetts.

Title: Urban Food Forests for Healthy Soils

Section 1. Overview

The creation of Food Forests are increasing in popularity within urban areas and are being created on a variety of different soil types that are often highly degraded due to prior urban land use history. In the first round of Healthy Soils Plan Implementation Challenge Grants supported by the Commonwealth of Massachusetts Executive Office of Energy and Environmental Affairs our team received one of the grants to establish and study the creation of an urban food forest on the University of Massachusetts Lowell (UML)'s urban campus compared to lawns, the business-as-usual approach to green infrastructure in cities (**Figure 1**). This grant was built on existing funding provided by UML S.E.E.D. grant awarded to PhD candidate Alana Smith in 2022 to create an UML food forest. In 2023, Dr. Winbourne and Dr. Burek were awarded the UML Seed Award from the Office of Research and Innovation to collect baseline data prior to the creation of the UML food forest. The Healthy Soils Plan Implementation Challenge grant has expanded that research program, allowing ongoing monitoring of soil conditions as the food forest site is established and soils develop over time, compared to adjacent lawn areas on UML urban campus.

This application is submitted as a continuation of "Urban Food Forests for Healthy Soils" grant. Here, we propose a plan to continue this project and introduce new ideas to advance our overall objective of understanding and promoting the role of urban food forests in maintaining and developing healthy soils in Massachusetts.

Figure 1. Pictures showing the completion of UML Food Forest site and instrumentation of both the Food Forest site and nearby reference lawn.

Section 2. Motivation

Cities are looking to implement urban green infrastructure (GI) as a solution to address challenges associated with urbanization and climate change such as extreme temperatures, flooding, and harmful air pollutants (Lamb et al., 2019). GI, defined here as urban areas dominated by plant-soil systems, can help offset some of the negative effects of urbanization by providing a suite of ecosystem services (ES) (Pataki et al., 2011). ES are defined as "the aspects of ecosystems utilized (actively or passively) to produce human well-being" (Fisher et al., 2009). In urban areas, this includes mitigation of criteria air pollutants (e.g. particulate matter, ozone), uptake and retention of atmospheric carbon dioxide (CO_2), stormwater mitigation, and improved heat resilience from shading and evapotranspiration (Pataki et al., 2011). A food forest is a type of alternative greenspace that is increasingly being implemented in urban areas that has the

potential to address the above mentioned environmental, social, and economic concerns facing urban dwellers (Albrecht & Wiek, 2021). It is a multifunctional biodiverse agroforestry system consisting of edible plants that uses multiple vertical plant layers (3-7) to maximize the ES of the system (Albrecht & Wiek, 2021). In the City of Boston alone, they plan to expand from having nine food forests to thirty by 2030 ("Urban Forest Plan," 2022).

Creation of spaces that enhance ES provisioning comes at a cost often in the form of investment of resources in creation and continued maintenance (Pataki et al., 2011). Accurate quantification of the benefits associated with urban GI is necessary for decision making and implementation. In contrast to the lawns – the 'business as usual' model covering 50-70% of urban GI globally (Ignatieva et al., 2020) – a food forest theoretically requires fewer inputs (e.g., irrigation, fertilizer, mechanized landscape management), however, there is limited data demonstrating that is the case (Rugani et al., 2019).

Section 3. Project Description

Our overarching goal of the "Urban Food Forests for Healthy Soil" project is to develop a life cycle assessment(LCA)-ES framework for urban food forests compared to lawns, validated with field datasets from the demonstration site established on the UML urban campus. Our original project (**FY2024)** had four primary objectives (Obj):

- **FY2024 Objective 1:** Develop a novel framework for urban soil health LCA-ES when establishing a food forest from vacant lots.
- **FY2024 Objective 2:** Validate the modified LCA-ES framework with novel empirical field datasets.
- **FY2024 Objective 3:** Integrate empirical findings into the newly developed LCA-ES framework and apply it to other food forest developments in the Greater Boston Area.
- **FY2024 Objective 4:** Outreach and community engagement to translate findings and tools to the community.

Over the remaining seven months we will finalize the objectives from the initial phase to (a) develop a novel LCA-ES framework for urban soil health (**FY2024 Obj 1**), (b) validate the LCA-ES framework with empirical field datasets (**FY2024 Obj 2**), and (c) apply to other food forest developments in the Greater Boston Area (**FY2024 Obj 3**).

For FY2025 Healthy Soils Plan Implementation Challenge grant cycle, our plan is to sustain soil monitoring, data collection, and analysis efforts (**FY2025 Obj. 1**). The continuous monitoring nature of our proposed work allows us to examine how these ES respond to extreme weather events (drought, heat waves, excess precipitation) that occur seasonally. Also, we will continue outreach and community engagement to translate findings and tools to the community (**FY2025 Obj 2).** We will engage with residents and the university community through workshops, tours, and hands-on activities through existing courses at UML Food Forest. Community workshops at the UML Food Forest will showcase techniques for improving soil quality, such as mulching and planting diverse crops, and will also gauge community interest in creating food forests in their backyards.

We also propose adding another objective:

- **FY2025 Objective 3:** Develop an open-source community friendly tool using R Shiny app of the LCA-ES framework and underlying empirical datasets that can be used in decision making, which will not only enhance our research but also foster greater community involvement.

FY2025 Objective 1: Soil monitoring, data collection, and analysis efforts

In the second phase of the project, we will sustain activities for soil monitoring, data collection, and analysis efforts. We will continue to monitor micro-meteorological and soil conditions using HOBO sensors (in-kind contributions) that were installed in April 2024. These sensors continuously monitor soil moisture, soil temperature, solar radiation inputs, air temperature and air humidity. We have also continued to make measurements of greenhouse gas fluxes.

FY2025 Objective 2: The food forest as a living classroom

The Food Forest serves as a living classroom, empowering community members with the knowledge and skills needed to cultivate their own healthy, productive gardens while fostering a deeper connection to the environment. We will organize engaging workshops and demonstrations that showcase how food forests can transform small spaces into productive, sustainable ecosystems. We will share success stories and testimonials from UML Food Forest and other Food Forests in the area (Boston and Western Massachusetts) and their positive impacts on community health, environment, and food security. We will create and disseminate informative materials through the workshops, such as brochures and online resources, that outline the steps to start a backyard food forest, including plant selection, soil preparation, and maintenance tips. Hands-on activities for students through existing courses will continue to evolve. For example, in Spring 2025, an engineering capstone project is planned for students to design a sustainable rainwater harvesting system for watering the UML Food Forest.

FY2025 Objective 3: Open-source LCA – ES and community engagement tool

In addition to scientific LCA-ES framework development used by researchers, we will create an open-source LCA– ES and community engagement tool to explore ES provided by the UML Food Forest. The App will feature a user-friendly interface, educational resources, and opportunities for community members to contribute their observations and data. This will enhance the accuracy and usability of soil data.

Shiny App, an R package, will be used to visualize and analyze data collected from the UML Food Forest. The App will incorporate various datasets related to ES, such as soil health, nutrient cycling, and micro-climate, and will allow the community to explore data dynamically, which will help the community understand the multifaceted benefits of Food Forests. In addition, we will include educational content that (1) explains the importance of ES and how they contribute to environmental health and human well-being and (2) outline the steps to start a backyard food forest, including plant selection, soil preparation, and maintenance tips. Finally, we will collect feedback from community members on their experiences, challenges, and successes with their food forests. This qualitative data can provide insights into the social and educational impacts of the project. By fostering greater community involvement, we aim to enhance our research impact and create a collaborative platform for environmental stewardship focused on soil health.

Section 4. Healthy soils challenge grant program objectives

Our proposed project addresses all the healthy soils challenge grant program objectives:

- **Promote Soil Health:** In the FY24 year we converted a vacant lot dominated by grasses and invasive species into a food forest. We have been documenting the trajectory of soil health metrics and other features of biogeochemical cycles of water, energy, carbon, and nutrients as the food forest is established, and comparing these to a nearby lawn with intensive management practices common in urban areas.
- **Sustainable Land Management:** Food forests are deeply rooted in permaculture principles, and thus we have used sustainable management techniques on our site which are thought to provide many ES, yet have limited empirical evidence to prove it, especially in urban environments. Our project will help to advance our understanding of these systems and provide guidance for development in urban settings.
- **Community Engagement:** Community engagement has been central to our proposed project, and we will continue to work closely with the local community in the development of the UML Food Forest site. This spring, we hosted a community Arbor Day planting event where we educated members of the community on food forests and planted our first fruit trees with volunteers from the community. We will be hosting annual workshops to engage the community and teach best practices.
- **Refine Tools for Municipal soil mapping, assessment + planning:** A key tool that will emerge from our proposed project is the development of a novel framework for conducting full LCA on soil health development in urban areas with the establishment of a food forest. In our renewal proposal, we will convert this framework into an R Shiny app decision-making tool for community members and city officials. We have established a webpage for the food forest hosted by UML RIST Institute that will be the home for the proposed tool generated in **FY2025 Obj 3** of this project.

Section 5. Preliminary Findings and Project Progress

The UML Food Forest had a successful first season and is a living laboratory home to collaborative research and educational experiences. We have made several significant advancements towards our goals and objectives. The UML Food Forest was established in the Spring of 2024. The team, led by Dr. Joy Winbourne, has instrumented the Food Forest and a neighboring lawn with sensors and soil collars to monitor soil changes. Students have sampled soils for COPI Winbourne's classes, students from art & design classes learned about landscape design, and sustainable food system alternatives, and students from a biology class have conducted a biodiversity assessment at the food forest.

The Food Forest has also become a place for wellbeing. In the Fall 2024, we added hardscape items to the food forest, including a meditation labyrinth, benches and swing co-sponsored by the FY2024 Healthy Soils grant, the Office of Student Life & Wellbeing, and Facilities Management. We also added a greenhouse co-sponsored by the Rist Institute for Sustainability & Energy, where we intend to start our own seedlings. Figure 1 shows images of each field site from August 2024 and Fall 2024, illustrating how we have completed our first set of plantings at the food forest site and installed several benches and a shed with attached greenhouse (all with in-kind contributions). We have completed the installation of the meditation labyrinth with the proposed funds as planned. Since the installation of these features, more visitors have come to enjoy the space. Our next step will be adding educational signage to inform the community of the food forest and our research with a link to the online tool we propose to create.

We are continuing to monitor micro-meteorological and soil conditions using HOBO sensors (in-kind contributions) that were installed in April 2024 at both the food forest site and nearby lawn. These sensors continuously monitor soil moisture, soil temperature, solar radiation inputs, air temperature and air humidity. We have also continued to make measurements of greenhouse gas fluxes with undergraduate assistant supported by the grant and continued to track anthropogenic resource contributions to maintain sites (irrigation, mowing, etc.).

Figure 2 shows preliminary data from August 2024 on carbon dioxide fluxes from soils (or soil respiration) – the primary pathway by which carbon leaves an ecosystem. We installed three pairs of soil respiration collars to monitor respiration at the food forest and additional three lawn sites across UML south campus, as well as areas with more traditional landscape mulching around open ground trees. Among traditional landscape areas, we are finding rates of soil respiration consistent with those observed in the literature (for which we are only aware of one other study in Boston, MA) with elevated rates of soil respiration in areas with mulch. Perhaps unsurprisingly we found very high rates of soil respiration in our raised beds (composed of loam and mulch). We are currently investigating why this might be the case, both by conducting more in-depth QC/QA analysis on raw datasets and determining potential physical drivers such as irrigation (with continuous soil moisture sensors) and nutrient availability.

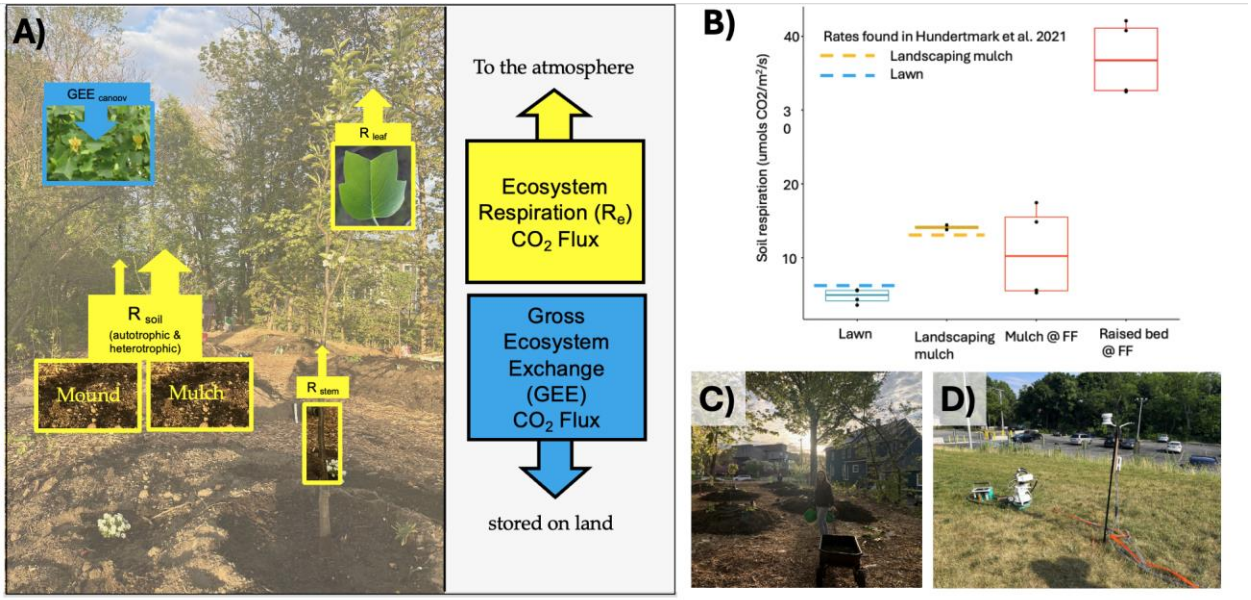

Figure 2. A) Figure demonstrating the measurements being made to conduct site level carbon budget; **B)** Preliminary data on soil respiration rates among areas within the food forest (red), nearby lawns (blue), and classic landscape mulch (yellow). Dashed lines show rates found in similar landscape types by study conducted in Boston, MA by Hundertmark et al. 2021. **C)** Picture showing food forest; **D)** Picture of lawn site with instrumentation for measuring fluxes.

Also, in Fall 2024, we conducted an end of the growing season soil sampling effort at the proposed site and archived soil and mulch samples in a minus 80-degree Celsius freezer for future analyses. Samples are currently being processed for quantification of soil organic matter and nutrient pools.

Finally, the graduate student Alana Smith is leading the efforts to develop the LCA-ES framework for food forest with her advisor Dr. Burek. This work is part of her dissertation research. She has successfully defended her dissertation proposal, which included the approach

for generating the LCA-ES framework. She is currently working on addressing feedback raised by her committee members.

The promotion and support of the UML food forest shows what can come from a previously unmanaged city lot, and how we can use these spaces to better the environment and uplift the community. The 2024 Arbor Day planting event was our first community workshop, and it was a success. We were joined by students, faculty, staff, local businesses, and members of the community where we gave an educational workshop on what a food forest is, the creation of the food forest, our research, and finished with the planting of our fruit trees. The audience was well engaged and excited about the project, and we got good feedback from them on ideas for what we can include in the future.

We have connected with a new group, regenerative roots association in Nashua, NH, to source plants locally for fall 2025 planting. Alana Smith and Joy Winbourne gave a talk at Hampshire College on preliminary findings and visited the Hampshire College food forest. We have launched a website hosted by the UML RIST institute and an email for directing questions regarding the project (food_forest@uml.edu). Additionally, funds have been donated to create a sign for the site, which we hope will help continue to engage the community with the project. In June 2024, Dr. Winbourne organized the first Lowell food forest tour with members from the City of Lowell, Audubon Society, Mill City Grows, Lowell Parks and Conservation Trust, University of New Hampshire, and Boston Food Forest Coalition. This included tours of the UML food forest and Pawtucket Farm (site of a future food forest). Several classes at UML have had field trips at the UML food forest site including Dr. Winbourne's Soil Science course where they conducted soil tests. Dr. Jessica Wilson's (adjunct professor at UML and City of Lowell urban planner) brought her course in urban planning for environmental justice for a site visit. Dr. Hamilton's Ecology field course for a second year in a row made estimates of biodiversity at the site. Currently, we are beginning to organize spring workshops we have proposed to conduct.

Our research efforts until the end of the first year of funding are focused on linking LCA and nutrient cycling (carbon and nitrogen) ES using teams' expertise (Burek and Winbourne, along with PhD candidate Alana Smith) in engineering, LCA, and biogeochemistry. Also, the team will finalize (a) developing a novel framework for urban soil health LCA (FY2024 Obj 1), (b) validate the LCA-ES framework with empirical field datasets (FY2024 Obj 2), and (c) apply to other food forest developments in the Greater Boston Area (FY2024 Obj 3). We will submit our first publication to the Plants, People, Planet journal end of November 2024.

Section 6. Methodology

Section 6.1. Measuring biogeochemical cycles

A central hypothesis of our proposed research is that urban food forests have unique biogeochemistry (Kaye et al., 2006) compared to other types of urban GI. Advancing our understanding of urban biogeochemistry across different types of GI will be essential to developing an accurate framework for determining the full LCA of net benefits to society and the environment. Thus, at each site, we have a suite of measurements to capture changes in the biogeochemical cycles across each type of GI and over the course of the development of each food forest site. We focus our measurements on five categories, mapping to each of our study hypotheses and the ES we evaluate in the LCA-ES. An overarching project focus include five categories of ES representing those most commonly cited by urban areas as particular concerns

(Babí Almenar et al., 2021). This includes: (1) urban heat resiliency, (2) greenhouse gas regulation, (3) nutrient cycling/retention, (4) reduced resource consumption (water, pesticides, land, and fertilizer), and (5) enhanced biodiversity. Establishment of healthy resilient soils in urban areas is central to all of these key ES we have been tracking over the long-term trajectory of this project. In the short term, we focus our analysis on greenhouse gas regulation and nutrient cycling/retention as pertains to the development of healthy soils.

Section 6.2. Life cycle assessment

LCA is a standardized method for evaluating environmental impacts of a product, system, waste, or service (ISO, 2006a, 2006b). LCA is used to help decision makers identify environmentally sustainable options and opportunities for improvements at each stage of the life cycle. Despite LCA's many applications, it is lacking the inclusion of many ES - benefits natural systems provide to people and the environment - resulting in undervaluation of these benefits in current methods for environmental assessments. As a result, the advantages of nature-based solutions may be undervalued, and stakeholders might not recognize their benefits. Our currently funded FY2024 project proposed a modified LCA-ES framework in which the main objective of the LCA portion was to develop the LCA method to assess the impacts of conventional and agroforestry practices on soil health and their role in the provision of ES. We have focused on measuring soil organic carbon and the provision of ES (i.e., greenhouse gas regulation) and their on-site (same soil) and off-site (life cycle perspective) effects. Beyond this grant, our research includes urban heat resiliency, reduced resource consumption (water, pesticides, land, and fertilizer), and enhanced biodiversity. LCA is an iterative process, and our field measurements are necessary to inform and validate the method we are creating. Additional funding will allow the completion of this iterative process, and validation from two growing seasons' worth of data post-establishment of the food forest. In FY2025, we will translate data on greenhouse gas regulation and nutrient cycling/retention to Shiny App platform for broader dissemination.

Section 7. Expected Outcomes and/or Deliverables

FY2025 Objective 1: Sustain soil monitoring, data collection, and analysis efforts

Deliverables:

- continuous data collection of soil moisture, soil temperature, solar radiation, air temperature, and humidity that will be integrated into Shiny App.
- continuous greenhouse gas fluxes measurements that will be integrated into Shiny App.
- data analysis reports analyzing the collected data to track soil health trends and micro-meteorological conditions.
- database maintenance: update and manage a comprehensive database of all collected soil and environmental data.

FY2025 Objective 2: The food forest as a living classroom

Deliverables:

- workshops and demonstrations: we will organize and conduct at least two workshops and demonstrations on food forest practices and soil health.

- educational materials including brochures, online resources, and instructional guides on starting and maintaining backyard food forests.
- community engagement: collect and share success stories and testimonials from the UML Food Forest and other regional food forests.
- impact assessment: gather feedback from workshop participants to assess the educational impact and community engagement.
- collect data from student hands-on activities through existing courses.

FY2025 Objective 3: Open-source LCA – ES and community engagement tool

Deliverables:

- Shiny App development: create and launch an open-source Shiny app for visualizing and analyzing ES data from the UML Food Forest.
- community data contribution: implement features that allow community members to contribute their observations and data to the app.
- educational content: include comprehensive educational content within the app, explaining ES and providing guidance on starting backyard food forests.
- gather qualitative data from community members on their experiences with the app and their food forests to inform future improvements and assess social and educational impacts.

These deliverables will ensure the project's objectives are met and provide a clear framework for tracking progress and outcomes.

Section 8. Budget

The funding breakdown details for the entire project, including estimated EEA Grant Funding, In-kind contributions, and other funding is shown in Table 1.

Table 1. Funding breakdown details for the entire project.

	EEA Grant funding	**In-kind contributions**	**Cost share**
PI Jasmina Burek	$3,103		$26,601 course teaching release
COPI Joy Winbourne	$3,038		
Student Research Assistant (RA) 2-semesters and summer	$46,670		
Tuition (1 year)	$10,000		$2,575
Equipment			$2,000 Provided by Winbourne lab
Indirect cost	$13,731		$7,436
Undergraduate students		UML fellowship program	
Volunteers		UML students	

	EEA Grant funding	In-kind contributions	Cost share
Additional trees and shrubs for Fall 2025		Sponsored by Regenerative Roots	
UMass Lowell		Equipment and facilities	
TOTAL	**$76,541**		**$38,612**

Section 8.1. Budget justification

An investment of $76,541 includes:

Senior Personnel

Burek Jasmina, PhD, PI, will receive 0.25 summer months support for one year of project. Dr. Burek is an Assistant Professor of Mechanical Engineering at the University of Massachusetts Lowell and will be responsible for the overall coordination of the project and supervision of the project personnel. She will use her extensive experience in energy systems and LCA method development to lead the advancements in integrating LCA and ES for green infrastructure.

Year 1: $3,039; Cumulative: $3,039

Joy Winbourne, PhD, COPI, will receive 0.25 summer months support for one year of project. Dr. Winbourne is an Assistant Professor of Urban Ecology and Biogeochemistry at the University of Massachusetts Lowell and will be responsible for the overall coordination of the project. Dr. Winbourne has extensive experience in measurement and modeling of urban biogeochemical cycles, such as those proposed.

Year 1: $2,975; Cumulative: $2,975

Other Personnel

PhD student Alana Smith is currently working as a full-time Student Research Assistant (RA) on activities in support of the project work, which includes 2 semesters and summer. Alana Smith, Doctoral Student Research Assistant, will receive 9 academic months, 3 summer months of calendar support each year of the project. The RA will work on LCA-ES method development, analysis, and write publications. An additional year of funding support will allow her to continue to work full-time in efforts related to the creation and validation of the LCA-ES method.

Year 1: Academic $24,690, Summer: $18,762; Cumulative: $43,454

Fringe Benefits

Fringe benefits included in the estimates for personnel were calculated in accordance with the University of Massachusetts Lowell rate agreement negotiated with the Department of Health and Human Services on November 8, 2023.

Fringe rates are calculated as follows:

2.11% for PI summer support and student employees (Student Research Assistant)

11.43% for Graduate Student Research Assistants

45.31% plus $16.50 per week for Health and Welfare costs, for full-time benefited employees (PI Academic Time, Data Analyst, Project Manager, Post-Doctoral Fellow

Total fringe benefits for 2 PI is $127

Total fringe benefits for 1 Doctoral Student Research Assistant is $3,218

Cumulative: $3,345

Other

Student Research Assistant (RA) Fees - The University of Massachusetts Lowell requires an $10,000 contribution from all funded research projects per year, per student, be applied towards the tuition and fees for any employed academic graduate research assistant. Funds of $10,000 are requested to cover these fees.

Calculation: 1 Graduate Student Research Assistants (RA) x $10,000 x 1 years. Cumulative: $10,000.

Data Management and Sharing Justification

No costs will be incurred for Data Management and Sharing.

Indirect Costs

The University of Massachusetts Lowell's (UML) indirect costs are calculated based on Modified Total Direct Costs (MTDC) using a rate of 26% for State of Massachusetts funded research. Modified total direct costs exclude equipment, capital expenditures, charges for patient care, rental costs, tuition remission, scholarships and fellowships, participant support costs and the portion of each subcontract in excess of $25,000.

1-year total indirect cost is estimated to be $13,731

Cost Share

The cost share covers 1.5 months of an academic year of Professor Burek’s salary, resulting in total cost share of $18,233. The total fringe benefits contributions for 1.5 months is $8,368.

Winbourne’s research group will be contributing $2,000 in direct costs for consumables used in proposed equipment and analytical tests that will be conducted in the proposed research.

UML waives the remaining portion of graduate research assistants’ tuition during their work on the project. This comes to $2,575.

Indirect costs on the cost shared costs: $7,436

Professors Burek and Winbourne’s involvement is critical to the project’s success due to their extensive experience and expertise in LCA and biogeochemistry, respectively. Their contribution will ensure high-quality research and project outcomes, aligning with the project’s goals and objectives.

Cumulative; $38,612

In-Kind Contributions include equipment and facilities that are necessary for the project. In the Fall of 2025, additional trees and shrubs will be sponsored by Regenerative Roots, a non-profit sponsoring the creation of food forests in New England.

We are committed to ensuring the sustainability of our project beyond the conclusion of the grant period. Additionally, our partnership with the Arboretum and support from the RIST Institute will provide long-term resources and expertise, further securing the project's future. These collaborations will not only offer financial backing but also enhance our capacity to maintain and expand the project, ensuring its continued success and impact on urban soil health. At the same time, we have been submitting partnership and collaborative grant proposals to USDA and NSF.

Section 9. Organizational Capacity

Section 9.1. List and details of previous achievements

Agreement Title: RCR: NRT: Sustainable Water Innovations in Materials: Mentoring, Education, and Research (SWIMMER)

Year Awarded: 2021

Total Award Amount: $ 2,998,922

Funding Agency: National Science Foundation

Using funds from this agreement awarded in 2021, researchers created a National Science Foundation Research Traineeship program at UMass Lowell centered around Sustainable Water Innovations in Materials – Mentoring, Education, & Research (SWIMMER). Ten graduate students have entered the SWIMMER program as trainees, mentored by ten participating faculty members. Trainees are currently engaged in the SWIMMER program, which features bias and inclusion training, communication skills training, immersion experiences in industrial history, a two-semester interdisciplinary core course, team capstone projects, and a seminar speaker series.

UMass Lowell has a consistent track record of meeting reporting requirements for previous assistance agreements, such as the example projects listed above. UML's Office of Sponsored Programs (OSP) is responsible for ensuring timely reporting and the completion of deliverable requirements for funded assistance agreements. The OSP Award Management Team consists of seven Grants and Contracts Administrators, seven Financial Research Administrators, and four College Research Administrators to support university researchers with the administrative and financial reporting for awards, including technical, progress, patent, and property reports or financial invoices. Specifically, the Financial Research Administrators complete all financial reporting requirements and have experience with this for all sizes of grants.

UML also maintains multiple online tools, SUMMIT and PeopleSoft, to support financial reporting by OSP and faculty researchers. UML's SUMMIT Enterprise Reporting System is a dashboard-designed reporting system that provides users with a single reporting application to access data across multiple areas, including financial reporting. Data is displayed in table or graphs formats in dashboards that track key performance indicators and provide updates. UML's PeopleSoft reporting environment updates financial information every 24 hours and can be accessed 24/7. This tool allows the end user access to monthly reports as well as access to ad-hoc reporting to view transaction detail, budgets, and fund balances.

Section 10. Qualifications and expertise details of the organization, demonstrating its ability to carry out the tasks and to work with other expertise in the field.

PI Jasmina Burek's research focuses on sustainability and resilience engineering. Burek develops decision-making models to measure and minimize environmental, social, and economic impacts (footprint assessment) of agri-food systems, products, materials, buildings using LCA. Burek has contributed to LCA method development, including an assessment of positive sustainability (handprint assessment) for organizations' decarbonization, for example, handprint assessment of eco-innovation. She has integrated swine growth model and LCA to increase sustainability of swine diets and production systems in the Global South working with researchers from Brazil including UNESP, UFRGS, EMBRAPA, and Elanco, Nigeria (FutuX Agri-consult LTD), and Kenya (Ministry of Livestock Development). Also, she was a contributing author to "Life Cycle Assessment of Corn Production Practices in the United States," a report prepared for the National Corn Growers' Association in which she integrated crop growth model with LCA. At UML, Burek wants to intensify its positive impact (handprint) through on-campus projects, including evaluating the handprint of this research project Food Forest which will include interdisciplinary research to integrate LCA and ES assessment.

COPI Winbourne's research focuses on measurement and modeling of urban biogeochemical cycles and ES. PI Winbourne currently is partnered with the City of Lowell, Lowell High School, Harvard Forest Schoolyard program, Mass Audubon, and non-profit Lowell Parks & Conservation Trust, working to develop a new curriculum for High School students to provide experiential learning opportunities on quantification of urban tree evapotranspiration. Additionally, PI Winbourne works closely with the City of Worcester on the development of their Master Urban Forestry Plan as chair of the Worcester Urban Forestry Commission.

PI Burek and COPI Winbourne have currently funded research for (1) "Urban Food Forests for Healthy Soils" supported by Commonwealth of Massachusetts Executive Office of Energy and Environmental Affairs, through Challenge Grants as part of the Commonwealth's Healthy Soils Action Plan, (2) "Developing a framework for assessing the net benefits and costs of urban food forests on environmental systems", and (3) "Handprint Assessment Framework of Hands-on Climate-Related University Projects".

We plan to monitor the project deliverables progress towards the specified measurable objectives. This includes an evaluation of the project's success. For example, in the case of data collection, we will develop data collection tools. Finally, after data analysis and interpretation, we will prepare it for publication in a journal.

The Office of Sponsored Programs ("OSP") at UML is fully capable of administering (managing, expending, and accounting for) this grant on behalf of the UML team. ORA has experience handling hundreds of federal grant projects and has well supported all past EPA projects awarded to UML, providing financial reports as needed for each quarterly and final report submitted to EPA. UML is able to accept a cost reimbursement award where UML will expend the funds prior to requesting reimbursement.

Section 11. Key personnel, qualifications, and their roles in the project

Principal Investigator, Dr. Jasmina Burek, PhD.

- **Expertise:** Assistant Professor of Mechanical and Industrial Engineering and Principal Investigator at BUilding REsilience through Knowledge (BUREK) Lab located at the University of Massachusetts Lowell. Dr. Burek has expertise in mathematical and computer modeling of complex socio-environmental systems, environmental process design, and LCA. Dr. Burek is committed to interdisciplinary collaboration and providing an industrial engineering perspective. Dr. Burek's unique combination of mechanical, industrial, and environmental engineering, quantitative modeling, and the ability to understand and combine research across disciplines will contribute to the success of the proposed research. Her current research focuses broadly on sustainability and resilience engineering using systems thinking approaches and the development of decision-making models to measure and minimize environmental, social, and economic impacts (footprint assessment) of agri-food systems, products, materials, and buildings. Dr. Burek has been teaching the LCA Sustainability course at UML, serves as chair and panelist on multiple Critical Reviews for agricultural LCA studies, and is on the Early-Career Editorial Board for Sustainable Production and Consumption Journal. She has been COPI on the ASEE Grant to Infuse Sustainability in Engineering Education pursuing new methods in sustainability curriculum development.
- **Tasks:** Dr. Burek is responsible for leading the development of the LCA-ES framework (FY2024 Obj. 1) and works closely with Dr. Winbourne in co-production of integrating empirical findings into the advancement of LCA-ES framework (FY2024 Obj. 3). Dr. Burek will advise and mentor graduate student Alana Smith that will assist with the execution of the LCA-ES and Shiny App (FY2025 Obj. 3). Also, Dr. Burek will organize community workshops in partnership with the Rist Institute and Mill City Grows (FY2025 Obj. 2). Dr. Burek will provide cross-disciplinary training to environmental sustainability students working with PI Winbourne.

Co-Principal Investigator: Dr. Joy Winbourne, PhD.

- **Expertise:** Assistant Professor of Urban Ecology and Biogeochemistry at the University of Massachusetts Lowell with extensive experience in measurement and modeling of urban biogeochemical cycles and ES. Dr. Winbourne has over a decade of experience leading environmental outreach activities and engaging local communities in co-production of research. Dr. Winbourne currently is partnered with the City of Lowell, Lowell High School, Harvard Forest Schoolyard program, Mass Audubon, and non-profit Lowell Parks & Conservation Trust, working to develop a new curriculum for High School students to provide experiential learning opportunities on quantification of urban tree evapotranspiration. Additionally, Dr. Winbourne works closely with the City of Worcester on the development of their Master Urban Forestry Plan as chair of the Worcester Urban Forestry Commission.
- **Tasks:** Dr. Winbourne will be responsible for the overall coordination of the project. Specifically, Dr. Winbourne will oversee the execution of field studies quantifying ES from different types of GI under consideration (FY2024 Obj. 2 and **FY2025 Obj. 1**). Working closely with COPI Burek, Dr. Winbourne advances the production of the LCA-ES; FY2024 Obj. 1 and integration of empirical findings into the newly developed framework for predicting net benefits of different proposed food forest sites in the Boston Food Forest Coalition (FY2024 Obj. 3). Dr. Winbourne has university fellowships

available for several undergraduate assistants (to be hired) to assist in field and laboratory work. Dr. Winbourne will provide cross-disciplinary training in biogeochemistry methodologies to mechanical and industrial engineering students working with COPI Burek. Also, Dr. Winbourne will continue to bring students to engage in hands-on activities and organize community workshops (**FY2025 Obj. 2**)

Graduate Student in Mechanical and Industrial Engineering, Alana Smith.

- **Expertise:** Graduate research assistant in the Department of Mechanical and Industrial Engineering at UMass Lowell and a PhD Candidate (Fall 2024). Smith created the initial vision for the project, formed the core team, and gained preliminary university support through RIST Institute seed funding. Smith has expertise in LCA and sustainable systems. Finally, Smith is a fellow within the NSF NRT The Sustainable Water Innovations in Materials—Mentoring, Education & Research (SWIMMER) program, which will additionally equip her with technical development skills necessary to address the multi-faceted problems. Smith is currently sponsored by the FY2024 Healthy Soils Challenge Grant. Smith is also involved in community outreach educating the community in food forest education and food system resilience, and student member of the UML Arboretum Advisory Committee.
- **Tasks**: Smith led the establishment of the food forest on the UML campus, including planting, landscaping, etc., and is working with Dr. Burek to develop and implement the LCA-ES. Additionally, Smith is being provided with training in biogeochemistry and helps with some of the field studies proposed in FY2024 Obj. 2 and contributes to community workshops. In addition, Smith will work on developing the Shiny App LCA-ES and community engagement tool (**FY2025 Obj.3**).

Section 12. Project timeline

Table 2 shows research and other activities timeline and planned tasks.

Table 2: Research and other activities timeline.

	Months after award											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Obj. 1. Sustain soil monitoring, data collection, and analysis efforts												
Weekly flux measurements	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Soil sampling			**X**								**X**	
Analyze data												
Obj. 2. The Food Forest as a Living Classroom												
Community workshops		**W**								**W**		
Hands-on student activities			**C**					**C**				
Obj. 3. Open-source LCA – ES and Community Engagement Shiny App												
Shiny App development												
Include educational content												
Develop features for community												

X - measurements
W – community workshops
C – hands-on activities for students through existing courses

Section 13. Project evaluation and monitoring

Section 13.1. Performance metrics

Tracking key metrics of ES in the unmanaged forested natural area will serve as a reference for testing the extent to which food forests are mimicking natural forested areas. This will be achieved by comparing the magnitude of services observed among these two forested sites. Tracking website and Shiny App tool visits, including number of distinct individuals visiting out website or app.

Section 13.2. Reporting

We have submitted our 1st quarterly report for FY2024 to the program manager. In FY2025 we will also have quarterly reports. Also, twice a year we have an annual team workshop where we will evaluate our success towards reaching goals, write a bi-annual report on findings, discuss challenges and solutions for mitigation of any issues that come up during the course of the project. For educational outreach and workshop activities, we are working with UML experts in project evaluation to maximize our success in reaching desired educational goals with community members and students.

Section 14. Post grant project sustainability assessment

Section 14.1. Continued Funding

We are actively seeking additional funding from USDA and NSF, partnerships (Rist), and community donations to ensure financial stability.

Section 14.2. Community engagement

The UML Food Forest is located on our university's South Campus, in a residential area embedded in an environmental justice community with the second largest Cambodian refugee population in the United States. UML works closely with the local community to help address food security concerns. The food forest was designed with the intention that it should also be a place where neighbors can participate. It has become a place for students, faculty, and the community. We are working towards increasing engagement for the following years through workshops, website, and Shiny App. By creating a website and Shiny App, and installing informative signage on-site, we aim to increase our outreach by 50%, thereby raising awareness and understanding of food forests among a broader audience.

Results from a complete LCA-ES study will provide a full picture of the net benefits of food forests compared to other greenspace options and help develop a method that cities can use when making greenspace investment decisions. The results will directly affect the quality of life for urban dwellers by evaluating the mitigation potential of food forests on threats like urban heat island effects. The Rist Institute works closely with the community and City of Lowell to help achieve such sustainability goals, and our work will inform decision makers and community members.

Results will also be disseminated via seminars, such as in the UML Climate Change Initiative speaker series, of which Alana Smith gave a seminar on food forests prior to the creation of the UML Food Forest. Finally, the project will be showcased internationally at the XI International Conference on Life Cycle Assessment in Latin America CILCA 2025 in Mexico City, Mexico and the 2025 International Health Promoting Campuses Conference in Limerick, Ireland.

Section 14.3. Partners involved and role

Existing partnership includes the Rist Institute for Sustainability & Energy which has played a critical role in the success of the food forest. Rist has promoted events held at the food forest through its social media platforms, and is home to our webpage in creation, which a Rist intern is designing for us. Under Rist, we have the recently established UMass Lowell Arboretum, and Arboretum committee which has provided resources for the food forest. The food forest now has a donation account within the arboretum for donors to contribute to its long-term success.

Future partnerships include Mill City Grows, which will help expand our community outreach and educational programs.

Section 14.4. Identification of risk considerations and mitigation strategies

We have identified several risks and have put in place the appropriate mitigation strategies:

- Equipment malfunction or failure of HOBO sensors and other monitoring equipment. For example, this year, the collars in the lawn area were accidentally pulled up. Mitigation will be checking sensors and other measurements on a weekly basis, use multiple of the same sensor, and put signage “research in progress”. Also, we will keep spare sensors and equipment on hand to replace any that fail.
- Variability in data collection due to extreme weather events or human error. The mitigation strategy is to schedule regular maintenance and calibration of sensors to ensure accurate readings.
- Insufficient funds to maintain equipment and data collection efforts. Mitigation strategy includes that we are actively seeking additional funding from grants (USDA and NSF), partnerships, and community donations to ensure financial stability.
- Urban ecological research often must consider what to do in the case of vandalism. We have been instrumenting the site with micro-meteorological equipment for the past two years and have had no issues with vandalism of our research equipment, however, we will continue to use low-cost sensors that are discreetly located to minimize the impact of potential vandalism and have budgeted for equipment to potentially get broken or vandalized.
- Limited participation from the community in workshops and activities. Mitigation strategy includes using Rist Institute social media platforms and mailing lists, and partnerships with community organizations such as Mill City Grows to increase awareness and participation.
- Difficulties in developing and maintaining the R Shiny app. Mitigation strategy includes working with experienced developers and data scientists to create a robust and user-friendly app.

Bibliography

Albrecht, S., & Wiek, A. (2021). Food forests: Their services and sustainability. *Journal of Agriculture, Food Systems, and Community Development*, 1–15. https://doi.org/10.5304/jafscd.2021.103.014

Babí Almenar, J., Elliot, T., Rugani, B., Philippe, B., Navarrete Gutierrez, T., Sonnemann, G., & Geneletti, D. (2021). Nexus between nature-based solutions, ecosystem services and urban challenges. *Land Use Policy*, *100*, 104898. https://doi.org/10.1016/j.landusepol.2020.104898

Fisher, B., Turner, R. K., & Morling, P. (2009). Defining and classifying ecosystem services for decision making. *Ecological Economics*, *68*(3), 643–653. https://doi.org/10.1016/j.ecolecon.2008.09.014

Ignatieva, M., Haase, D., Dushkova, D., & Haase, A. (2020). Lawns in cities: From a globalised urban green space phenomenon to sustainable nature-based solutions. *Land*, *9*(3). https://doi.org/10.3390/land9030073

Kaye, J., Groffman, P., Grimm, N., Baker, L., & Pouyat, R. (2006). A distinct urban biogeochemistry? *Trends in Ecology & Evolution*, *21*(4), 192–199. https://doi.org/10.1016/j.tree.2005.12.006

Lamb, W. F., Creutzig, F., Callaghan, M. W., & Minx, J. C. (2019). Learning about urban climate solutions from case studies. *Nature Climate Change*, *9*(4), 279–287. https://doi.org/10.1038/s41558-019-0440-x

Pataki, D. E., Carreiro, M. M., Cherrier, J., Grulke, N. E., Jennings, V., Pincetl, S., Pouyat, R. V., Whitlow, T. H., & Zipperer, W. C. (2011). Coupling biogeochemical cycles in urban environments: Ecosystem services, green solutions, and misconceptions. *Frontiers in Ecology and the Environment*, *9*(1), 27–36. https://doi.org/10.1890/090220

Rugani, B., Maia de Souza, D., Weidema, B. P., Bare, J., Bakshi, B., Grann, B., Johnston, J. M., Pavan, A. L. R., Liu, X., Laurent, A., & Verones, F. (2019). Towards integrating the ecosystem services cascade framework within the Life Cycle Assessment (LCA) cause-effect methodology. *Science of the Total Environment*, *690*, 1284–1298. https://doi.org/10.1016/j.scitotenv.2019.07.023

Urban Forest Plan. (2022). *Boston.Gov*. https://www.boston.gov/departments/parks-and-recreation/urban-forest-plan