Harnessing Collaborative Partnerships Toward Sustainability: A Community-Based Learning Initiative

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Abstract

Sustainable planning is a vital tool for municipalities seeking to promote equitable economic and environmental development within their communities. Successful implementation of sustainability initiatives involves many factors, ranging from engaging stakeholders for input to combining and leveraging existing resources from both community and institutional stakeholder groups. This study illustrates how collaborative partnerships formed through community-university relationships can facilitate community-based learning and community-engaged scholarship initiatives centered on sustainable planning. Using the example of a student-led tree audit in a partner community, the study demonstrates how community-based learning and community-engaged scholarship principles may be applied to achieve municipal sustainability goals. The study outlines how community-based learning agendas formed through community-institution collaborative partnerships can generate actionable insights for communities pursuing sustainability initiatives.

Over the past several decades, the adoption of sustainable development concepts within communities across the country have contributed to economic growth, increased use of renewable resources, and the creation of dynamic social spaces. While these developments have positively affected community and citizen well-being, city planners are quickly realizing the added importance of understanding city green space for promoting environmental equity and mitigating urban heat conditions induced by climate change. Equipped with a growing understanding of the importance of environmental planning, planning professionals and community leaders are using a variety of methods to promote environmental stewardship, sustainable planning, and ecological preservation. Information concerning the community-level impact of environmental change has become a vital tool of municipal governance, as the effects of climate change can have detrimental consequences to public health and environmental safety (Stone et al., 2019). Across the country, municipalities are combating urban heat through green infrastructure initiatives that increase trees and community green spaces. One common approach involves tree audits.

A tree audit, or tree inventory, is best described as a method for studying the past and present conditions of an urban forest. The data collected can be utilized in the development and implementation of urban forest management. Tree audits help municipalities understand community tree health, catalog species diversity, and assess risk for damage to surrounding properties (Ma et al., 2021). Tree audits also facilitate a better understanding of the carbon sequestration capacity within public green spaces. According to the U.S. Forestry Service, forests have substantial capacity for capturing carbon and thus reducing carbon in the atmosphere (Domke et al., 2019). Additionally, tree audits can increase municipal awareness of pocket park accessibility and environmental safety. Jasmani, Ravn, and Konijnendijk van den Bosch (2016) illustrated the value of pocket parks not only as a resource for community members but also as a habitat for native flora and fauna, noting that enhancing biodiversity increases pocket park quality and habitat availability. Moreover, tree audits can help planners understand what green infrastructure exists throughout a city, identify best methods for tree management and care, and glean insights into best practices for avoiding adverse impacts to city infrastructure.

Despite the growing value of sustainability initiatives as community-enhancing tools, not all communities have the resources and capacity to develop and implement sustainability planning agendas. In contrast to urban and suburban areas, many of which are able to harness sufficient resources and organizational capacity, exurban and rural communities face greater challenges in sustainable planning due to fewer available resources and limited opportunities to collaborate with experienced partners that have access to necessary resources. Emergent approaches that fuse experiential learning with civic and community engagement, such as community service-learning (CSL) or community-based learning (CBL), represent novel frameworks for enhancing capacity, efficiency, networking ability, and project outcomes in communities partnering with higher education institutions (Paulson & Davis, 2024). Building upon the work of Kennedy et al. (2022), this study applies CBL toward sustainability initiatives through a collaborative partnership with a rural exurban community.

This study describes the outcomes of a student-led sustainability project that originated in an ongoing collaborative partnership between municipal leaders and a local higher education institution. The paper begins with a literature review that discusses the intrinsic value of sustainability and sustainable development through the lens of CBL, followed by a description of the history and demographic composition of the community partner participating in the project. Next, the parameters of the project are discussed, along with data collection and analysis techniques used, prior to presentation of the results, discussion, and identification of limitations. We conclude with suggestions for future study that may further integrate sustainability-focused initiatives into CBL concepts.

Literature Review

The Critical Value of Sustainability and Sustainable Development

As community leaders across the country continue to pursue opportunities to stimulate economies, revitalize communities, and modernize landscapes, city officials have begun to investigate the value of incorporating sustainable development into such opportunities. The definition of sustainable development (SD) varies across published literature but can broadly be understood as methods for development that meet the needs of the current generation without negatively impacting future generations' ability to meet their own needs (Butlin, 1989). SD typically consists of three primary components or "pillars"— economic sustainability, social sustainability, and environmental sustainability — that are interconnected and interdependent throughout urban expansion processes (Ruggerio, 2021). *Economic sustainability* is concerned with operating a system of production that satisfies current demands without impacting future needs; *social sustainability* promotes equity in access to social services, community empowerment, cultural pride, and personal identity; and *environmental sustainability* is centered on local ecosystems and promotes economic development to further conserve and protect important natural resources (Mensah, 2019). Although SD consists of three separate focus areas, its three pillars promote an interconnected examination of how development can impact society and the ecosystems that make up surrounding landscapes.

Applications of SD concepts were recently recognized in the United Nations Sustainable Development Goals (UN SDGs). Announced in 2015, these goals aim to build a cleaner, more equitable world by 2030 and include a variety of objectives, from eliminating poverty and hunger to reducing inequalities and increasing climate action (United Nations [UN], 2023). Of the 17 UN SDGs, three in particular are relevant to the proliferation of sustainability initiatives in communities nationally, regionally, and locally. Specifically, SDG 12 (Sustainable Cities and Communities), SDG 14 (Climate Action), and SDG 17 (Partnerships for the Goals) are important when examining how national, regional, and local entities are implementing SD practices in urban planning and CBL. The UN SDGs have directed increased attention to international, regional, and local ecological communities.

Internationally, SD applications addressing tree canopy carbon sequestration can be seen in Russo et al. (2014), in which researchers compared U.S. methods for assessing above-ground storage capacity in local tree species (the Urban Forest Effects Model and the Center for Urban Forest Research Tree Carbon Calculator) to Italian methodology. Researchers found variability in the calculation methods developed in the United States and determined that a combination of Italian and U.S. methods would yield more accurate estimates (Russo et al., 2014). Results from Russo et al. (2014) highlight the importance of international cooperation when examining carbon storage and large-scale CBL on a national level.

Applications of SD not only positively impact urban environments but also have the potential to improve regional human well-being and perceived happiness. Cloutier et al. (2014) compared the self-reported happiness of citizens in 192 U.S. cities (data derived from the Gallup Healthways Well-Being Index) to various sustainability index rankings (the Green City Index, Our Green Cities, Popular Science U.S. City Rankings, and the SustainLane U.S. Green City Rankings). The study found positive associations between SD and happiness as well as significant correlations between happiness and two of the four sustainability indices (Cloutier et al., 2014). Building upon these premises, the current study aims to highlight the importance of SD applications to regional communities and their effect on community well-being and happiness. Additionally, this study emphasizes the need for SD in urban environments to promote community well-being and facilitate community engagement through the promotion of healthy environments.

As urban areas continue to expand due to national and international economic trends, small towns have begun to promote sustainability efforts to attract new residents, including young families and the next generation of leaders. Mayer and Knox (2010) examined four methods of sustainable growth in towns with less than 50,000 residents. International small-town sustainability efforts include the Slow Food Movement in Bra, Italy, which encourages the growth of locally run restaurants supported by local agriculture; the Natural-Step Framework in Robertsfors, Sweden, a systems-based approach to sustainability centered on consensus and communication across communities; and the Creative City approach in Pogradec, Albania, which highlights local landscapes, art, and culture to promote community engagement and SD. Additionally, Mayer and Knox (2010) highlighted how U.S. towns like Littleton, Colorado, have begun to take steps toward localized sustainability. Littleton's Economic Gardening program helps local businesses grow by providing financial planning assistance, sustainable operational initiative development, and community support in places where construction might otherwise fall to large chain organizations. These efforts illustrate SD's benefits to local communities, ecosystems, and economies.

SD applications have also supported the advancement of methods and technology for understanding land and resource use. Geographic information systems (GIS) applications have long served as methods for tracking resource use, analyzing large data sets, and conceptualizing relationships between people and the places they call home. Researchers have leveraged GIS and other geospatial technologies to track the sustainability of urban trees and their benefits to local communities for nearly 30 years (Aniello et al., 1995; Dwyer & Miller, 1999; Goodwin, 1996).

GIS has been used for data collection and analysis both historically and in recent studies. Ward and Johnson (2007) highlighted applications of GIS, finding that GIS, global positioning systems (GPS) and remote sensing serve as comprehensive and easy to access platforms for understanding urban forest health and its associated impact on communities. Additionally, their results underscored the utility of GIS for analyzing the environmental impacts of trees on communities, such as mitigating urban heat and stormwater runoff; visualizing data; facilitating community understanding; and catalyzing community engagement. More recently, GIS has been shown to be useful for urban planning in localized communities. Tasoulas et al. (2013) found GIS to be an appropriate tool for urban forestry management due to its ability to tie geographic information such as location with tree attribute data such as health, species, diameter at breast height, and canopy cover. These analytical features compliment GIS's ability to make information publicly available and understandable. GIS thus facilitates direct communication between local leaders and community members and fosters the development of municipally hosted website domains for community information (Alpan & Sekeroglu, 2020; Tasoulas et al., 2013).

Although SD has been applied on various scales, research focusing on SD efforts in towns with populations less than 10,000 will become paramount as younger generations and new families begin to move away from large urban cities toward rural communities. With limited existing research on SD's effects in small American towns such as Charlestown, Indiana, the present study serves as a crucial starting point for understanding efforts to increase community collaboration through CBL, citizen science, and SD on a local scale.

University-Community Partnership

The University of Louisville, an anchor institution and a recipient of the Carnegie Community Engagement Classification, is well positioned to partner with the City of Charlestown to promote and engage in sustainability initiatives. The Carnegie Classification is awarded by the American Council in Education (2024) to institutions with sufficient infrastructure, policies, practices, and systems in place to support mutually beneficial collaboration with community partners. Obtaining the designation requires institutions to conduct a self-study and determine what measures and programs need to be implemented to ensure that students and faculty members have opportunities for meaningful collaboration with community partners. Being an engaged institution can positively impact student learning, faculty teaching and research, and community well-being, while building good will with the community.

Anchor institutions like the University of Louisville have a responsibility to use their intellectual and financial capital to collaborate with community partners to address community challenges (Cunningham et al., 2015; Taylor & Luter, 2013; Yamamura & Koth, 2018). Anchor institutions are rooted in their communities and therefore stable (Harkavy & Hodges, 2012; Hodges & Dubb, 2012), which makes them great collaborative partners. For higher education institutions, engagement with community partners serves to enhance university-community collaboration and consequently improve the community's perception of higher education (Powell & Walsh, 2018; Yamamura & Koth, 2018). It may also fulfill the university's institutional mission, meet the expectations of community partners (Bringle & Hatcher, 2002), and address societal challenges (Association of Public and Land-grant Universities [APLU], 2019, 2020; Cunningham et al., 2015). For many institutions, it is an opportunity to better educate students through experiential learning activities, whereby students actively apply concepts to real-world situations (Gamboa et al., 2023). Such experiences benefit students both academically and socially by delivering enhanced learning (Gamboa et al., 2023; Kuh, 2008; Moore, 2023), increasing their likelihood of completing college (Lockman & Pelco, 2013), and fostering an elevated sense of social responsibility (Eyler et al., 2001; Jacoby, 2015), among other benefits. Ehlenz (2019) argued that universities are now actively engaging with their neighborhoods through place-based research, community outreach and engagement, and CBL courses. Resultingly, such partnerships have the potential to contribute to community success and facilitate greater public trust in higher education through opportunities to share knowledge and resources (*see*: APLU, 2019; Fischer, 2023; Holley & Harris, 2017; Powell & Walsh, 2018; Yamamura & Koth, 2018).

There are many challenges to university-community partnerships, such as negative perceptions of universities (Cooper et al., 2014), differences in views on the project (Nystrom et al., 2018), research not benefiting community partners, and lack of follow-up by university researchers (Holley & Harris, 2017). Strier (2014) agreed with many of these challenges and noted the community perception that these partnerships benefit universities more, which leads to mistrust and resentment. To offset these challenges, factors that enhance university-community partnerships must be considered. Established relationships between the university and community partner, alignment of goals between the two, and regular communication can all help to facilitate a productive partnership (Nystrom et al., 2018). Vaterlaus, Skogrand, Higginbotham, and Bradford (2016) added that successful partnerships require strong interpersonal relationships and common goals, values, and objectives. To further strengthen the university-community relationship, the authors suggested that universities should find ways to affirm partnerships by publicly acknowledging community partners for their contributions and publicizing the collaborative efforts to the broader community.

Background of Study Location

The study was conducted during the summer of 2023 in Charlestown, Indiana. An incorporated city located in Clark County, Indiana, the Charlestown community was home to over 8,400 residents as of 2022 (U.S. Census Bureau, 2024). An increasingly diverse community, the city of Charlestown has experienced considerable change since the beginning of the century; it expanded from a population of 5,993 in 2000 to 7,775 in 2020, a 23% increase in residential growth (U.S. Census Bureau, 2022). Charlestown is one of the top five fastest growing communities in the state of Indiana and boasts the largest population increase of any incorporated or unincorporated community in Southern Indiana. Whereas the residential growth of Charlestown may be overshadowed due to its inclusion with the Louisville, Kentucky, metropolitan statistical area, the background and history of both the Charlestown community and Clark County, Indiana, provide a unique setting for understanding the intrinsic value of community-engaged scholarship with sustainability initiatives.

The value of SD in the Charlestown community derives from the contrast between its recent growth and its boomtown history. Founded in 1808, the population of Charlestown grew steadily between the late 1880s and late 1930s to just shy of 1,000 residents. The trajectory of the community would change in 1940 with the construction of the U.S. Department of Defense's Indiana Ordnance Works (IOW) 1 mile southeast of Charlestown. Development of the IOW, spanning over 10,400 acres and comprising approximately 1,400 buildings, structures, and storage facilities at its peak (Hess, 1984), resulted in considerable economic growth for the community. While the economic activity supported multiple communities in Clark County, Charlestown had difficulty adapting to the population increase from 939 residents to over 3,000 residents within the span of several years. Particular challenges concerned adequate housing, infrastructure capacity, and effective planning. Operation of the IOW, later renamed the Indiana Army Ammunition Plant (INAAP), continued until assessments in the 1980s determined that the plant's outdated facilities and manufacturing abilities did not warrant further investment.

Throughout the 1990s and early 2000s, INAAP land was disaggregated and distributed among private investors and the Indiana Department of Natural Resources, resulting in the creation of Charlestown State Park in 1996. By the mid 1990s, environmental restoration efforts had begun. Nearly $70 million in federal and state funds were used to remediate INAAP lands, demolish existing buildings, and decontaminate facilities to ensure destruction of any volatile materials associated with ordinance manufacturing. In 2016, the federal government ceded the remaining land to River Ridge Development and granted Clark County autonomy to proceed with development of the River Ridge Commerce Center. Since obtaining the remaining land from the U.S. Department of the Army, the River Ridge Commerce Center has flourished as a vital economic driver for Clark County. Numerous logistics and distribution facilities have launched operations in the area, bringing thousands of new employment opportunities. However, the integration of key INAAP infrastructure systems into the Charlestown community, such as water treatment facilities, resulted in formidable challenges for local leaders seeking to sustainably modernize community infrastructure.

In early 2023, a collaborative partnership was formed between representatives from the University of Louisville and community leaders from Charlestown to develop initiatives rooted in economic, environmental, and equitable principles of sustainability. The partnership was driven by municipal leadership's familiarity with the University of Louisville. As a recent alumnus of the university with an advanced degree, the mayor of Charlestown demonstrated a considerable appreciation for the value of applied research and reflected a deep understanding of the resources that could be leveraged by the university. This facilitated a unique opportunity to implement theory-to-praxis initiatives involving various institutional, personal, and local community leaders in Charlestown. The resulting partnership, as supported by Nystrom et al. (2018), sought to provide a foundation for ongoing institutional efforts to strengthen CBL and community-engaged scholarship opportunities with exurban and rural communities in the greater Louisville metro area.

The Carnegie Foundation uses the terms "collaboration" and "partnership" (American Council on Education, 2024) to describe the relationship between educational institutions and their community partners. Collaboration and partnerships enable the community to have a voice in joint initiatives, thus driving their overall success. Successful partnerships require the university and community to have a good understanding of each other's needs, wants, and values (Curwood et al., 2011). This understanding ensures that community partners have input in determining the project as well as opportunities to provide feedback throughout the process. The partnership with Charlestown included faculty and students from multiple departments spanning different academic disciplines, the university's Office of Community Engagement, as well as the Charlestown mayor's office and other key community stakeholders; all worked collaboratively to determine the projects to pursue that would benefit both the university and the city. A local ISA Certified Arborist also offered their time and expertise to the project, creating a multidisciplinary team. The projects had to align with the city's goals and students' experiential learning opportunities, placing these interests at the forefront of all discussions. Conducting a tree audit of the city was a joint decision.

As a first step, community partners provided input that helped determine the scope and focus of the first phase of the community-based project. Student applicants for the program were selected based on their expressed interests and field of study to promote practical experiential learning dynamics. The project team included undergraduate students and a graduate student mentor, with a full-time faculty member serving as facilitator and community liaison. The established timeframe for project completion was

8 weeks during the summer of 2023. Student team members coordinated with Charlestown leaders to secure remote workspace, gain access to areas for data collection, and develop a data collection schedule. Upon completion of the tree audit, project team members presented the findings to both community partners and peer community-based project groups participating in the National Science Foundation–funded CEEEM program. Collected data and data visualization outputs were remitted to Charlestown officials for public access.

Data and Methods

Scope of Data Collection

Data for the municipal tree asset study was collected through multiple phases over 60 days during the summer of 2023. First, the project team and municipal officials coordinated to establish a scope of study connected to existing tree assets on municipal property. The project team identified 19 such properties varying in size from less than one acre to over 65 acres. The properties identified for data collection were dispersed throughout the 11.45 square miles of land area representing the municipal jurisdiction (U.S. Census Bureau, 2022). To aid in the data collection process, municipal leaders provided access to a remote workspace in a municipally owned events center close to the identified properties, and they facilitated the project team's access to otherwise inaccessible properties. After verifying the project scope and identifying data collection sites, the project team developed a comprehensive schedule for data collection per location to occur over the course of 30 days during the summer of 2023.

Data Collection

Measurement and Reference Tools

To ensure accurate collection of data, project team members deployed a number of tools for both tree measurement and identification. Essential data points including tree diameter at breast height, tree circumference, and tree canopy coverage were obtained using a standard 100-foot reel tape measure. Due to practical limitations, a tangent tree height gauge was used to obtain tree height measurements in lieu of the heavy machinery needed for physical access to measure treetop height.

Jackson, Harrington, and Rathfon's *101 Trees of Indiana: A Field Guide* (2004), with detailed descriptions and images of local tree species, was used as a primary source of initial tree species identification. Secondary resources, including mobile applications such as *iNaturalist* and *PictureThis*, were used to determine and verify tree species not identified by initial sources of identification. Through partnership with a community business, the project team met with a certified arborist on multiple occasions to verify and validate both the tree asset measurement and tree species identification process, providing an additional layer of reliability and validity to the data collection process.

Data Recording Tools

The ArcGIS Field Maps (ESRI, 2024) program was used as the project's main technology platform, particularly for in-field data collection. This GIS tool allowed for efficient on-site mobile data entry and geographical recording. For each tree surveyed, a point was georeferenced using ArcGIS Field Maps, allowing geospatial information to be easily transferred to other platforms for data analysis. Combined with the aforementioned measurement and reference tools, the use of ArcGIS Field Maps as a data recording tool minimized potential measurement and data entry errors. ArcGIS Pro was used following data collection to visualize, map, and manage the dataset. Figure 1.1 illustrates how this tool was used to create 2D maps showcasing the land use of the surrounding area and location of data points.

Data Collection Process

Prior to data collection, a process of operations was adopted to ensure optimal results for each tree surveyed throughout the study. ArcGIS Field Maps were used to record the geospatial location of every tree, along with a photo captured, which was then added to the data point. The project team then identified tree species using multiple identification tools, including the aforementioned reference texts and mobile applications. Each tree was then measured with a 100-foot reel tape measure to obtain trunk diameter, trunk circumference, and tree canopy area. The tree canopy measurements in square feet were calculated on-site using the following formula (Birdsey, 1992; A. Clark et al., 1986; DeWald et al., 2005; Myers & Goreau, 1991), where B_1, B_2, B_3, and B_4 are the longest-reaching branch on four sides of the tree.

1. Measure the longest-reaching branch on four sides of the tree and add each;
2. Divide the sum by four to obtain an average;
3. Square the averaged value; and
4. Multiply the squared value by pi.

Figure 1.1. Observation and Data Collection Process Using ArcGIS FieldMaps

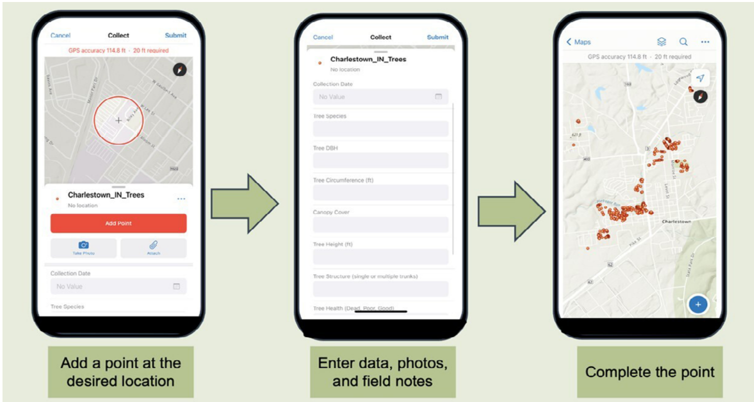
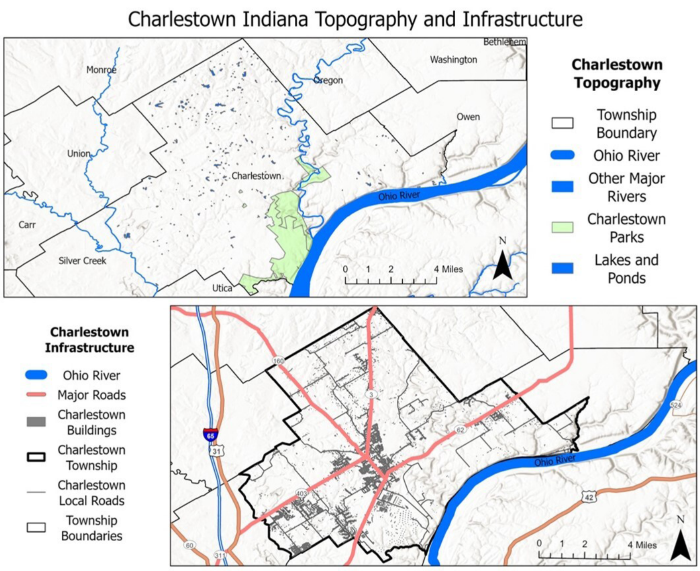


Image 1.1. ArcGIS FieldMaps Images of Area of Study (2023)



$$Tree\ Canopy = \left(\frac{B_1 + B_2 + B_3 + B_4}{4}\right)^2 \pi$$

The data collection team then assessed the overall health and vitality of each tree, looking for signs of rot, disease, and pests. Finally, the structure of the tree was observed and documented by categorizing the trunk structure using a range of one to three trunk structures. Trees observed with more than three trunk structures were recorded as multiple within the data. All collected data was entered into ArcGIS Field Maps. Examples of collected data visualized using ArcGIS FieldMaps are provided in Images 1.1, 1.2, and 1.3.

Once data collection was complete, members of the project team coordinated with municipal leaders to determine how best to apply and use the collected information. Charlestown officials expressed interest in leveraging the project data toward certification as a Tree City USA community by the Arbor Day Foundation. In support of this effort, the project team delivered cleaned and smoothed data files to Charlestown leadership to include in their Tree City USA application. Charlestown leadership also wanted to use the data to raise public awareness of sustainable planning initiatives in the Charlestown community. The project team provided links to an interactive ArcGIS Field Map, which could be embedded into the municipality's official website to facilitate community engagement. An overview of all data points identified and collected across designated categorical sites is provided in Table 1.1.

Image 1.2. ArcGIS FieldMaps Data Visualization, Sections 1 and 2

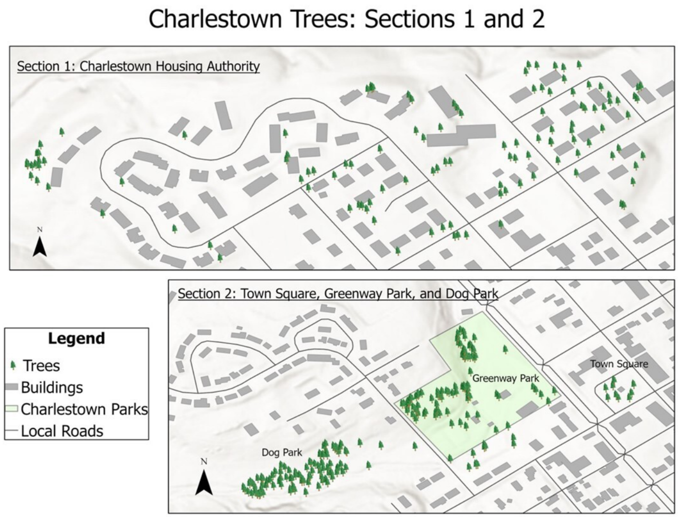


Image 1.3. ArcGIS FieldMaps Data Visualization, Sections 3, 4, and 5

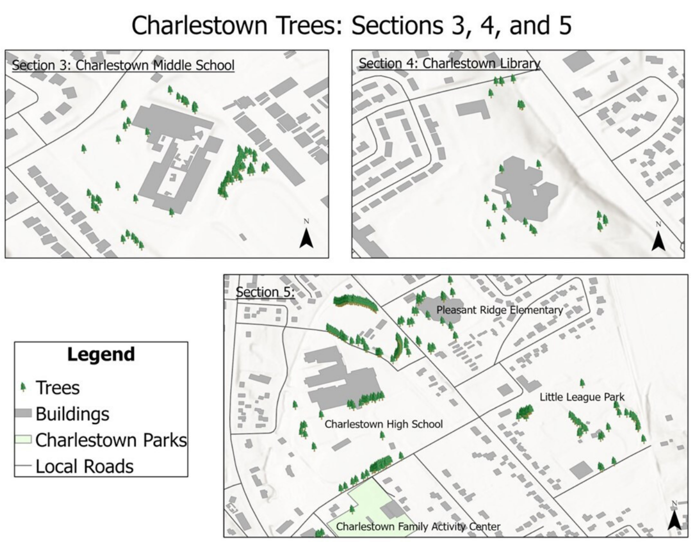


Table 1.1. Total Measured Values For All Site Areas

	Parks	Schools Properties	Civic Properties
Total Trees (n)	306	294	126
Total Canopy (sq. ft.)	33,497.84	26,004.06	48,813.82
Total Dry Weight (lbs.)	103,977.80	65,903.82	21,061.75
Total Green Weight (lbs.)	119,514.71	75,751.50	202,614.36
Total Green Weight² (lbs.)	143,417.67	90,901.81	243,137.22
Total C Weight (lbs.)	51,988.91	32,951.96	10,530.86
Total CO_2 Seq. (lbs.)	198,902.69	120,702.82	38,574.63

Analysis and Results

Once all data was recorded from designated sites, raw data was prepared for processing. The data collected was migrated from ArcGIS Field Maps to ArcGIS Pro prior to importation into data management file formats for analysis. Data was cleaned and prepared for analysis, which included deriving carbon sequestration estimates for individual parks and the entire collection sample. Due to constraints prohibiting the calculation of annual carbon sequestration, estimates of cumulative carbon sequestration of each data point were determined. The process for calculating estimated cumulative carbon sequestration consisted of four steps:

1. Determine the total green weight (W) of the tree.

   W = green weight of tree in pounds

   D = diameter of tree in inches

   H = height of tree in feet

   For trees with a diameter less than 11 inches:

   $W = (0.25D^2H) \times 1.20$

   For Trees with a diameter greater than 11 inches:

   $W = (0.15D^2H) \times 1.20$

2. Determine the dry weight (DW) of the tree.

   $DW = W \times 0.725$

3. Determine the weight of carbon (WC) in the tree.

   $WC = DW \times 0.50$

4. Determine the weight of carbon dioxide sequestered (CO_2S) in the tree.

   $CO_2S = WC \times 3.6663$

The carbon sequestration calculations were completed and used to create data visualizations as part of the collaborative partnership deliverables component of the project. Results of the data analysis estimating the cumulative carbon sequestration of data points were presented in categorical form based on designation. Three categories of municipal assets were assigned to illustrate areas of concentration: municipal parks properties, municipal civic properties, and municipal school properties.

Municipal Parks Properties

Analysis of data collected for all municipal parks properties included data points from the city square, two municipal pocket parks less than or equal to one acre, a large public park, a large public dog park, and a municipal sports park. Across all municipal park properties, data points observed and recorded produced n = 306. In sum, 39 different tree species were observed and recorded, with the inclusion of a category for unidentifiable tree species (though the species could not be identified, the diameter-breast-height could be measured and the tree canopy estimated, thus providing the basis for estimating cumulative carbon sequestration regardless of tree species). Of the 306 trees observed and recorded, 3.9% (n = 12) were identified as non-native invasive tree species per the Indiana Department of Natural Resources and Indiana Invasive Species Council's Invasive Plant Advisory Committee (Purdue University College of Agriculture Indiana Invasive Species Council, 2023). Conversely, 84.3% (n = 258) of all trees observed and recorded were native, non-invasive species, and 11.7% (n = 36) of trees were observed and recorded as non-native, non-invasive species. Among native, non-invasive tree species observed and recorded, Hackberry trees were the most frequently observed species (n = 55), while American Elm trees comprised both the greatest volume of estimated cumulative carbon sequestration by species, with a mean estimated cumulative carbon sequestration of 30,986.62 lbs., and the greatest estimated canopy coverage, at 2,946.38 square feet. Table 1.2 provides a summary of all data points collected across all municipal park properties.

Municipal Civic Properties

The second phase of data collection involved observing and recording data points at designated civic properties within the municipality. Two civic properties were designated for data collection: Charlestown Public Library and the Charlestown Housing Authority. Spanning both designated civic properties of the municipality, observation and recording of data produced n = 126. Across both civic properties, 33 different tree species were observed and recorded. Of the 126 trees observed and recorded, 3.2% (n = 4) were identified as non-native invasive tree species, with the remaining 96.8% (n = 122) trees identified and recorded as native, non-invasive species. Of the native, non-invasive tree species observed and recorded, Black Locust trees were the most frequently observed species (n = 19, 15.1%), while the American Elm trees reflected the greatest volume of estimated cumulative carbon sequestration (9,354.85 lbs.). Cottonwood trees produced the greatest estimated canopy coverage, at 6,900 square feet. A summary of all data points collected across municipal civic properties is provided in Table 1.3.

Table 1.2. All Parks [City Square, Large Park, Dog Parks, Pocket Parks, and Little League Park]

Tree Species	*n*	Canopy (sq. ft)	Dry Weight (lbs.)	Green Weight (lbs.)	Green Weight2 (lbs.)	Carbon Weight (lbs.)	CO_2 Seq. (lbs.)
American Elm[2]	8	2,946.38	16,918.71	19,446.80	23,336.15	8,459.36	30,986.62
Bald Cypress	2	342.50	579.42	666.00	799.20	289.71	2,122.42
Black Cherry[2]	5	1,256.80	3,193.51	3,670.70	4,404.84	1,596.76	6,035.07
Black Gum[2]	2	422.00	435.35	500.40	600.48	217.67	1,439.80
Black Locust[2]	26	1,114.46	1,958.25	2,250.86	2,701.03	979.12	3,878.49
Black Maple[2]	4	1,696.50	5,537.53	6,364.98	7,637.98	2,768.77	10,141.99
Black Walnut[2]	47	1,572.39	2,896.13	3,328.88	3,994.66	1,448.06	5,307.00
Black Willow[2]	1	433.70	10,147.68	11,664.00	13,996.80	5,073.84	18,585.48
Blue Ash	1	1,134.00	1,900.81	2,184.84	2,621.81	950.41	3,481.33
Boxelder[2]	8	1,084.25	2,308.62	2,653.58	3,184.30	1,154.31	4,292.76
Bradford Pear[1]	1	255.00	195.75	225.00	270.00	97.88	717.03
Cherry Bark Oak	1	4,071.00	10,272.65	11,807.64	14,169.17	5,136.32	18,814.35
Eastern Red Cedar	2	284.00	1,054.54	1,212.12	1,454.54	527.27	1,931.40
Eastern White Pine	1	200.00	117.45	135.00	162.00	58.73	430.22
Green Ash	3	435.29	177.44	203.95	244.74	88.72	599.36
Hackberry[2]	55	1,378.28	2,082.93	2,394.17	2,873.01	1,041.46	3,814.89
Honey Locust[2]	11	753.91	592.89	681.48	817.78	296.44	1,204.77
Japanese Maple	1	13.00	14.09	16.20	19.44	7.05	25.81
Magnolia	1	254.00	405.91	466.56	559.87	202.95	743.42
Mulberry	8	2,198.29	4,191.28	4,817.57	5,781.08	2,095.64	7,676.33
Unidentifiable [N/A]	9	n/a	1,700.26	1,954.32	2,345.18	850.13	3,114.02
Northern Catalpa[2]	1	110.00	18.79	21.60	25.92	9.40	68.84
Osage Orange[2]	1	0.00	701.57	806.40	967.68	350.78	1,284.92
Persimmon[2]	11	702.87	2,046.85	2,352.70	2,823.24	1,023.42	3,748.80
Pin Oak[2]	3	1,555.20	3,196.73	3,674.40	4,409.28	1,598.36	6,182.73
Princess Tree[1]	1	1,050.00	1,657.45	1,905.12	2,286.14	828.73	3,035.63
Red Elm	1	n/a	42.28	48.60	58.32	21.14	77.44
Red Maple[2]	7	714.71	2,306.49	2,651.14	3,181.37	1,153.25	5,513.36
Red Mulberry[2]	5	689.80	1,232.96	1,417.20	1,700.64	616.48	2,282.56
Redbud[2]	1	63.60	2,443.90	2,809.08	3,370.90	1,221.95	4,476.00
Sassafras[2]	8	570.13	526.49	605.16	726.19	263.24	1,214.51
Scarlet Oak	1	1,225.00	2,645.91	3,041.28	3,649.54	1,322.96	4,845.99
Silver Maple[2]	29	1,228.00	2,467.64	2,836.36	3,403.64	1,233.82	6,033.93
Sugar Maple[2]	9	984.00	1,839.21	2,114.04	2,536.85	919.61	3,368.52
Sweet Gum[2]	14	755.79	12,689.23	14,585.32	17,502.39	6,344.62	23,240.33
Sweetbay Magnolia	3	144.77	987.21	1,134.72	1,361.66	493.60	3,616.14
Tree of Heaven[1]	10	871.22	739.65	850.18	1,020.21	369.83	1,354.67
Blue Beech	2	24.00	7.52	8.64	10.37	3.76	13.77
Northern Hackberry	2	963.00	1,746.72	2,007.72	2,409.27	873.36	3,201.99
Mean		***905.35***	***2,666.10***	***3,064.48***	***3,677.38***	***1,333.05***	***5,100.07***

[1]Indicates invasive species per Indiana Department of Natural Resources and Indiana Invasive Species Council. Source: *IISC Invasive Plant Advisory Committee, 2020*

[2]Indicates native, non-invasive species per Indiana Department of Natural Resources and Indiana Invasive Species Council. Source: *IISC Invasive Plant Advisory Committee, 2020*

Table 1.3. All School Properties [High School, Middle School, Elementary Schools]

Tree Species	*n*	Canopy (sq. ft)	Dry Weight (lbs.)	Green Weight (lbs.)	Green Weight2 (lbs.)	C Weight (lbs.)	CO_2 Seq. (lbs.)
American Holly	8	35.00	169.13	194.40	233.28	84.56	309.76
Apple	2	675.00	559.06	642.60	771.12	279.53	1,023.92
Bald Cypress	7	162.14	225.95	259.71	311.66	112.98	413.83
Black Hawthorn	2	20.00	6.26	7.20	8.64	3.13	11.47
Black Maple[2]	2	2,325.00	9,053.52	10,406.34	12,487.61	4,526.76	16,581.51
Black Walnut[2]	1	115.00	394.63	453.60	544.32	197.32	722.77
Bradford Pear[1]	12	567.92	522.50	600.57	720.68	261.25	956.95
Cherry Plum	3	233.33	228.11	262.20	314.64	114.06	417.79
Common Serviceberry	6	50.83	30.54	35.10	42.12	15.27	55.93
Crabapple	2	125.00	326.51	375.30	450.36	163.26	598.00
Crape Myrte	3	61.67	3.65	4.20	5.04	1.83	6.69
Creeping Juniper	1	100.00	117.45	135.00	162.00	58.73	215.11
Eastern Red Cedar	128	24.61	145.47	167.21	200.65	72.74	266.44
Eastern Redbud	1	225.00	380.54	437.40	524.88	190.27	696.96
Eastern White Cedar	1	700.00	15,348.37	17,641.80	21,170.16	7,674.18	28,110.53
Eastern White Pine	7	560.71	1,263.22	1,451.97	1,742.37	631.61	2,313.58
Green Ash	5	272.00	175.08	201.24	241.49	87.54	320.66
Hackberry[2]	6	552.50	534.95	614.88	737.86	267.47	979.75
Japanese Maple	1	300.00	39.15	45.00	54.00	19.58	71.70
Japanese Snowball	1	20.00	1.57	1.80	2.16	0.78	2.87
Mulberry	1	1,900.00	3,348.73	3,849.12	4,618.94	1,674.37	6,133.21
N/A	1	0.00	42.28	48.60	58.32	21.14	77.44
Northern White Cedar	20	105.75	460.58	529.40	635.28	230.29	843.55
Norway Maple[1]	1	315.00	383.67	441.00	529.20	191.84	702.69
Norway Spruce	2	470.00	1,594.03	1,832.22	2,198.66	797.02	2,919.47
Peach	1	30.00	39.15	45.00	54.00	19.58	71.70
Pin Oak[2]	6	1,518.33	4,408.60	5,067.36	6,080.83	2,204.30	8,074.36
Red Maple[2]	9	597.78	621.81	714.72	857.66	310.90	1,138.84
Red Mulberry[2]	9	1,030.56	633.95	728.68	874.42	316.98	1,161.08
River Birch[2]	11	1,748.18	1,420.13	1,632.34	1,958.81	710.07	2,600.98
Rose of Sharon	3	271.67	150.34	172.80	207.36	75.17	275.34
Shortleaf Pine	1	185.00	3,957.60	4,548.96	5,458.75	1,978.80	7,248.34
Silver Maple[2]	3	978.33	3,342.37	3,841.80	4,610.16	1,671.18	6,121.54
Southern Magnolia	1	30.00	117.45	135.00	162.00	58.73	215.11
Sugar Maple[2]	1	1,800.00	2,025.78	2,328.48	2,794.18	1,012.89	3,710.21
Sweet Gum[2]	4	896.25	1,249.51	1,436.22	1,723.46	624.76	2,288.48
Sycamore[2]	2	1,385.00	1,773.96	2,039.04	2,446.85	886.98	3,249.02
Tulip Tree[2]	2	2,125.00	6,460.69	7,426.08	8,911.30	3,230.34	11,832.75
White Ash[2]	1	2,500.00	2,645.91	3,041.28	3,649.54	1,322.96	4,845.99
White Cedar	10	91.50	379.60	436.32	523.58	189.80	695.23
White Spruce	1	250.00	795.84	914.76	1,097.71	397.92	1,457.58
Willow Oak[2]	5	650.00	526.18	604.80	725.76	263.09	963.69
Mean		***619.14***	***1569.14***	***1803.61***	***2164.33***	***784.57***	***2873.88***

[1]Indicates invasive species per Indiana Department of Natural Resources and Indiana Invasive Species Council. Source: *IISC Invasive Plant Advisory Committee, 2020*

[2]Indicates native, non-invasive species per Indiana Department of Natural Resources and Indiana Invasive Species Council. Source: *IISC Invasive Plant Advisory Committee, 2020*

Municipal School Properties

The final phase of data collection involved observing and recording data points across all school properties within the municipality. Although members of the project team collected data outside of the established academic year for each school, project team members coordinated with municipal leaders and school system representatives to receive approval and access to school properties. In total, four school properties were included within the third phase of the data collection process: Charlestown High School, Charlestown Middle School, Jonathan Jenning Elementary School, and Pleasant Ridge Elementary School. For all school properties within the municipality, observation and recording of data yielded n = 294, with a total of 42 tree species identified across the school properties. Similar to data collection across all parks properties, categorization of tree species for school properties included a category for trees unable to be identified by species.

Of the 294 trees observed and recorded, 4.4% (n = 13) were identified as non-native invasive species, while 21.1% (n = 62) were identified as native, non-invasive species. The remaining 74.5% (n = 219) of trees recorded were identified as non-native, non-invasive species. The most frequently observed tree species, the non-native and non-invasive Eastern Red Cedar, represented a disproportionate volume of all trees observed and recorded n = 128 (43.5%). Among native, non-invasive tree species, the Black Maple tree reflected the greatest volume of average estimated cumulative carbon sequestration (16,581.51 lbs.), though the White Ash tree species reflected the greatest estimated canopy coverage at 2,500 square feet. Table 1.4 outlines a summary of all data points observed and collected across all school properties. [Insert Table 1.4 About Here]

Discussion

As stewards of a community experiencing considerable growth following decades of population contraction, municipal leaders of Charlestown, Indiana, face the challenge of balancing the preservation of community values with burgeoning economic growth. Catalyzing SD through collaborative partnerships with higher education institutions in the greater Louisville metro area represents a potent and viable pathway for leveraging resources to cultivate mutually beneficial sustainability initiatives. Moreover, as demonstrated by the Charlestown Tree Audit project, initiatives formed through collaborative partnerships carry the latent ability to fuse sustainability, professional network development, theory-to-praxis practices, and community-engaged scholarship into tangible skills-building sustainability experiences for students, faculty, staff, and community leaders (Soyer et al., 2023). Resultingly, these factors combine to demonstrate commitment to high levels of community engaged research by institutions receiving Community Engaged Certification by the Carnegie Foundation.

The 2023 Charlestown Tree Audit illustrates the impact that community-engaged scholarship can generate for both student participants and the community involved—in this case, the greater Charlestown community. Through regular communication, goal alignment, shared values, and agreed-upon objectives - hallmarks of effective university-community partnerships - the project generated tangible outputs and data that will be useful to Charlestown municipal leaders (Nystrom et al., 2018; Vaterlaus et al., 2016). The data that the project team collected, assembled, analyzed, and conveyed to municipal leaders in Charlestown satisfied a pivotal requirement of the Arbor Day Foundation and its Tree City certification program. Moreover, equipped with a dataset that inventories and identifies both native tree species and invasive tree species on municipal properties, Charlestown leaders can now develop and codify municipal ordinances guiding tree planting and maintenance guidelines as part of future SD initiatives. These efforts, combined with municipal leaders leveraging the project's data and imaging outputs toward external grant funding opportunities, demonstrate the scope of application and potential benefits deriving from a collaborative partnership between local communities and institutions of higher education pursuing community-engaged research.

Beyond the tangible benefits for the community partner, students participating in the tree audit program gained unique professional development opportunities to enhance their educational experience. Undergraduate student members of the project team were presented with growth opportunities closely associated with experiential learning and practical skills development. Within the project's 8-week timeframe, students gained a foundational understanding of advanced software applications such as ArcGIS, proactively constructed a viable timeframe for project completion, confirmed the availability and coordinated the accessibility of data collection locations, and maintained community partner relationships through regular communications. Engaging in both soft and hard

Table 1.4. All Civic Properties [Public Library & Housing Authority]

Tree Species	***n***	**Canopy (sq. ft)**	**Dry Weight (lbs.)**	**Green Weight (lbs.)**	**Green Weight2 (lbs.)**	**C Weight (lbs.)**	**CO_2 Seq. (lbs.)**
American Elm[2]	4	3,300.00	5,107.75	58,709.79	70,451.75	2,553.88	9,354.85
Amur Honeysuckle[1]	1	200.00	1.88	21.60	25.92	0.94	3.44
Black Cherry[2]	3	1,346.67	285.39	3,215.52	3,858.62	142.69	522.69
Black Locust[2]	19	1,310.00	1,304.13	5,469.50	6,563.40	652.06	2,388.51
Black Maple[2]	18	1,979.17	928.20	6,955.44	8,346.53	464.10	1,700.01
Black Oak[2]	1	2,575.00	1,330.19	15,289.56	18,347.47	665.10	2,436.25
Boxelder[2]	2	1,010.00	118.80	1,365.48	1,638.58	59.40	217.58
Bradford Pear[1]	1	40.00	18.79	21.60	25.92	9.40	34.42
Cherry Bark Oak	1	2,800.00	811.81	9,331.20	11,197.44	405.91	1,486.84
Cherry Plum	2	125.00	1.25	14.40	17.28	0.63	2.29
Cottonwood[2]	1	6,900.00	1,726.52	19,845.00	23,814.00	863.26	3,162.11
Eastern Red Cedar	2	640.00	78.22	899.10	1,078.92	39.11	143.26
Flowering Dogwood	3	583.33	41.78	480.24	576.29	20.89	76.52
Green Ash	3	343.33	16.13	185.40	222.48	8.06	29.54
Hackberry	3	1,600.00	496.61	5,708.16	6,849.79	248.30	909.54
Japanese Maple	1	25.00	1.41	16.20	19.44	0.70	2.58
Leatherleaf Viburnum	1	50.00	1.88	21.60	25.92	0.94	3.44
London Plane Tree	2	3,250.00	763.43	8,775.00	10,530.00	381.71	1,398.21
Mulberry	1	20.00	0.63	7.20	8.64	0.31	1.15
Pin Oak	4	2,912.50	1,154.06	13,265.10	15,918.12	577.03	2,113.67
Red Maple	8	1,712.50	411.91	4,734.59	5,681.50	205.95	754.41
Red Mulberry	5	601.00	25.53	293.43	352.12	12.76	46.76
Redbud	1	800.00	63.42	729.00	874.80	31.71	116.16
Rose of Sharon	4	40.00	20.41	234.63	281.56	10.21	37.39
Rough Leaf Dogwood	1	450.00	7.05	81.00	97.20	3.52	12.91
Siberian Elm[1]	3	2,133.33	2,614.44	4,069.44	4,883.33	1,307.22	4,788.34
Silver Maple	9	2,522.22	1,255.36	14,429.40	17,315.28	627.68	2,299.19
Southern Red Oak	1	3,200.00	571.65	6,570.72	7,884.86	285.83	1,046.98
Sugar Maple	11	2,502.27	819.44	9,418.88	11,302.65	409.72	1,500.81
Sycamore	4	1,820.00	411.37	4,728.42	5,674.10	205.69	753.43
Weeping Willow	1	350.00	38.37	441.00	529.20	19.18	70.27
White Ash	4	972.50	220.52	2,534.76	3,041.71	110.26	403.89
Yellow Buckeye	1	700.00	413.42	4,752.00	5,702.40	206.71	757.19
Mean		***1,479.21***	***638.23***	***6,139.83***	***7,367.79***	***319.12***	***1,168.93***

[1]Indicates invasive species per Indiana Department of Natural Resources and Indiana Invasive Species Council. Source: *IISC Invasive Plant Advisory Committee, 2020*

[2]Indicates native, non-invasive species per Indiana Department of Natural Resources and Indiana Invasive Species Council. Source: *IISC Invasive Plant Advisory Committee, 2020*

skills development, student project team members were afforded balanced opportunities to continue their professional growth and development while contributing positively to a local community's progress toward sustainability.

In addition to providing members of the project team an opportunity to participate in a community-engaged service initiative, the municipal tree audit illustrated higher education institutions' ongoing efforts to pursue collaborative, community-based initiatives that facilitate stable relationships between community stakeholders and representatives from higher education institutions. Uniquely, the tree audit project reflects the fruition of a collaborative partnership that includes institutional stakeholders spanning multiple disciplines and community leaders who are intimately familiar with how higher education resources can be applied toward community-based projects.

In light of both the scholarly and practical contributions of the project, the study contains latent limitations that warrant consideration. The primary limitation of the study concerns the application of the external morphology method of calculating existing tree metrics. While this methodology can reflect a considerable degree of accuracy through predictable growth assessment, the technique is time extensive and may not lend itself neatly to application across all tree species (Tsen et al., 2016). Optimizing the project team's ability to estimate the annual carbon sequestration rate of trees would have required the use of increment core boring (IBC), which involves drilling into each tree observed to retrieve a heartwood sample for analysis. Although IBC has been roundly accepted as a dendrochronological technique producing more accurate samples for analysis, the technique is time-consuming and may make the trees sampled vulnerable to threats such as invasive insects, cankerous growth, heartwood decay, and fungal growth (see F. B. Clark, 1966; Lorenz, 1944; Vuokila, 1976). Absent appropriate tools and equipment, as well as coordination with certified arborists familiar and experienced with IBC techniques, the present study eschewed more accurate estimates of annual carbon sequestration rates in favor of an estimated cumulative carbon sequestration by individual trees observed and recoded during data collection. Regardless of this limitation, both the research team and community partners derived considerable value from the data collected and analyzed, ensuring that actionable information was produced to support initiatives building upon the study at hand.

The current study represents just one component of a multifaceted agenda involving the Charlestown community as a university partner. Using data collected through the Charlestown Tree Audit in 2023, a second phase of the agenda was scheduled for summer 2024 involving a student-led project team that leveraged the tree audit data to develop a strategic plan for municipal tree planning and maintenance. Additionally, the second phase of the agenda will aid in the formation of a local ordinance codifying policy and procedure for municipal tree planning and maintenance, along with actionable steps toward Tree City USA certification from the Arbor Day Foundation (Arbor Day Foundation, 2024). Potential avenues for future research initiatives and agenda development continue to unfold as the university-community partnership solidifies, thus providing additional opportunities to build upon the initial goals of the partnership formed with Charlestown.

Conclusion

University-community partnerships continue to represent a key strategy for leveraging shared resources toward mutually beneficial outcomes for institutions and communities alike. This study illustrates the instrumental role institutions play in the development of CBL and community-engaged scholarship agendas that seek to enhance the communities they serve. Importantly, this study showcases potential outcomes of university-community partnerships founded upon relationships with shared knowledge and understanding of capacity and resource application. The study demonstrates tangible and actionable outcomes related to student learning, utilization of the university's intellectual capacity to address community needs, and enhanced university-community collaborations.

The outcomes of the project demonstrated that the priorities and needs of both the university and city were met. Students benefited from working on a community-engaged project for broader impact. This was most students' first exposure to using GIS, conducting research, and engaging in project management. Such practical experience enhanced their understanding of their field of study and chosen profession, and their interaction with city officials and community residents helped them grow their relationship-building skills. Moreover, data collected from the research project was shared with city officials, who published it on their website. The city is developing plans for how the data can be used to maintain the tree canopy, with the aim of facilitating positive long-term sustainability impacts for the community. The collaborative nature of this project from beginning to end ensured that it was a true university-community partnership that was mutually beneficial.

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