Urban Tree Canopy Assessment Summary Report for Evansville, IN

Urban Green Infrastructure Resilience Cohort

October 2024

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Acknowledgments

A fundamental inspiration for this project was the vision of Indiana University's Environmental Resilience Institute (ERI) to promote and preserve Indiana's urban forest and improve the management of public trees by addressing climate change and sustainable ecosystem services. The collaborative project team of research educators, student fellows, local government staff and stakeholders, urban forestry consultants, and GIS specialists through baseline data analysis established mitigation and adaptation tools for future tree planting projects and canopy continuity and resiliency focused initiatives. Indiana University is thankful for the grant funding it received from the Indiana Department of Natural Resources, Division of Forestry, Community and Urban Forestry program (IDNR CUF) in cooperation with the U.S. Forest Service (USFS) through its Urban and Community Forestry (U&CF) Grant Program. The IDNR CUF grant program is designed to encourage communities to create and support long-term and sustained urban and community forestry programs throughout Indiana.

The ERI recognizes the following Urban Green Infrastructure Cohort partners.

Local Governments:
City of Evansville

Climate Fellows:
Larson Parker

Urban Forestry Consultant and GIS Specialist:
Davey Resource Group, Inc.

Executive Summary

Urban tree canopy is an essential part of municipal infrastructure. Trees provide more than the traditional values of aesthetics and shade. They provide numerous quantifiable environmental benefits, including stormwater management, watershed protection, water quality improvements, temperature moderation and cooling, reduction of air pollutants, and energy conservation. The amount of urban tree canopy determines the amount of economic, environmental, and social benefit a community receives. Trees contribute greatly to the quality of life in Indiana communities. Unlike the other components of community infrastructure, urban tree canopy, with proper care and protection, will continue to increase in value with each passing year.

Over the last 20 years, there have been great advances in quantifying the urban forest. Geographic information systems (GIS) has become more available to local governments and community stakeholders to assist with planning and management, and the value of trees and green spaces in communities has shifted. The results of urban tree canopy assessments are especially valuable for reasonable, rational, and defensible planning of tree planting and canopy preservation projects.

For the Urban Green Infrastructure (UGI) Resilience Cohort, Indiana University's Environmental Resilience Institute (ERI) contracted Davey Resource Group, Inc. (DRG) to translate digital imagery showing detailed leaf-on conditions into different land cover classifications for the Evansville community. In addition to consultant and climate fellow participation, local government cohort participation included the City of Evansville. This consultant-fellow-government cohort partnership has provided a resource for community planning and tools that illustrates current baseline land cover percentages, including an improved understanding of tree canopy and preferred plantable area.

The project area includes the municipal boundary of Evansville, Indiana. The project area is approximately 47.8 square miles or 30,623 acres (Table 1). Today, Evansville's existing tree canopy cover is 24%. The analysis projects an attainable tree canopy of 51%; this is the sum of the existing tree canopy and preferred plantable area (27%). Reaching the maximum tree canopy will be a challenge; however, preserving existing tree canopy, establishing realistic canopy goals, and harnessing the maximum amount of ecosystem benefits by planting, maintaining, and caring for trees (particularly large-growing trees) when appropriate are prudent and responsible endeavors.

Table 1. Tree canopy cover in Evansville, part of the Urban Green Infrastructure Resilience Cohort Urban Tree Canopy Assessment Project Partnership

Local Government	Total Acres	Tree Canopy Acres	Preferred Plantable Acres	Maximum Tree Canopy
City of Evansville	30,623	7,313	8,277	15,590
Percent of Total	100%	24%	27%	51%

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Assignment

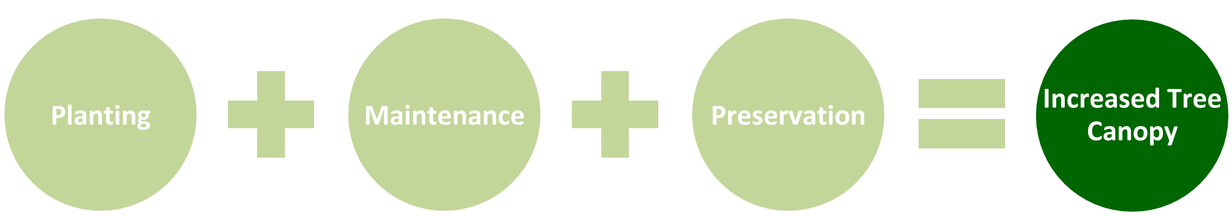
The assignment by ERI was to translate digital imagery showing detailed leaf-on conditions into different land cover classifications represented as individual geographic information system (GIS) layers. DRG created five land cover GIS layers for the City of Evansville, Indiana. Land cover classifications included tree canopy (trees/forest/shrub); pervious (grass /low-lying vegetation); impervious surface; bare soil; and open water. Appendix A contains the land cover classification assessment methodology.

The existing, possible, and preferred tree canopy of Evansville was analyzed, and preferred plantable area was prioritized. Possible tree canopy is the amount of land that is theoretically available for the establishment of tree canopy. This includes all pervious and bare soil surfaces. Preferred plantable area was determined by DRG, the local government, and climate fellows identifying reasonable "real world" areas to plant trees. These areas are pervious surfaces likely within rights-of-way (ROW) of highways and streets; private property parcels of residential, commercial, or industrial uses; and parks or other vacant lands. Appendix B contains the prioritized plantable area assessment methodology.

Percentage of tree canopy for Evansville was calculated and summarized by geographic unit. Climate fellows met with the local government representatives to identify and select geographic units; then, local government provided DRG with necessary GIS boundaries for these selected units. The analyzed geographic units for Evansville included public vs private property, canopy percent by City Council, flood hazard areas, right-of-way, and urban heat island. Selected geographic units are shown in Appendix C.

Accompanying this *Urban Tree Canopy Assessment Summary Report*, DRG delivered the assessment and analysis results as GIS data files, metadata, Excel™ spreadsheets containing land cover metrics and geographic unit analyses, and a slide show results summary.

Growing tree canopy must consist of a mix of tree maintenance activities. Tree planting is part of the equation, but also includes existing tree routine maintenance and tree preservation related to development impacts. Having a tree canopy assessment is one of the first tools necessary to grow, maintain, and protect tree canopy for the enjoyment by future generations efficiently and effectively.



Summary of City of Evansville, IN Existing Tree Governance

Public Tree Governance

Public tree governance in the City of Evansville is sanctioned by the Evansville Tree Ordinance. The Evansville Tree Ordinance establishes a framework for the management and preservation of trees within the city limits of Evansville, Indiana. The ordinance creates a seven-member Tree Advisory Board appointed by the Mayor and City Council, comprising representatives from city departments, utilities, and community organizations. The board is tasked with studying local tree issues, disseminating tree care information, and advising on city tree projects in coordination with other municipal bodies. Enforcement mechanisms within the ordinance include fines for violations, ensuring compliance with its provisions aimed at promoting public health, safety, and the aesthetic enhancement of Evansville's urban environment. Adopted with the intent to be the minimum requirement, the ordinance respects more stringent local rules or covenants where applicable.

There are non-profits and voluntary organizations within Evansville that help maintain public trees and do some tree planting. Primarily, these organizations are Keep Evansville Beautiful and Wesselman Woods, sometimes in partnership with the Department of Urban Forestry. Keep Evansville Beautiful is an affiliate of Keep America Beautiful and focuses on beautification, recycling programs, and youth environmental programs. They have previously done tree plantings for the city over the past 20 years.

Wesselman Woods is a non-profit 501c3 that manages the Wesselman Woods property and does environmental education at their property as well as in Evansville broadly. Wesselman Woods is the largest protected virgin (old-growth) forest within the city limits of any city in the United States of America. Typically, Evansville's Arbor Day events are held here as it is a well-protected area of Evansville.

Trees on Private Land

Trees on private land are maintained by the property owner. The City of Evansville, however, does maintenance pruning in alleys and streets to allow for safe traffic passage. Trees near utility lines may also be managed by the utility company without a permit. They may trim public tree branches and roots as necessary for the installation and maintenance of utility services as long as such work is done in accordance with provisions set forth in the Evansville Tree Ordinance. Private property owners are also governed by rules concerning trees that affect public spaces, requiring consultation with the Tree Advisory Board before taking action on planting or removing trees in public land.

Land Cover Assessment

Evansville's current land cover was identified and assessed using the 2022 National Agricultural Imagery Program (NAIP) leaf-on, multispectral imagery—see Appendix A for methods. Classified land cover data includes pervious, impervious, bare soils, open water, and tree canopy. Figure 1 illustrates the resulting distribution of land cover for the municipal boundary of Evansville.

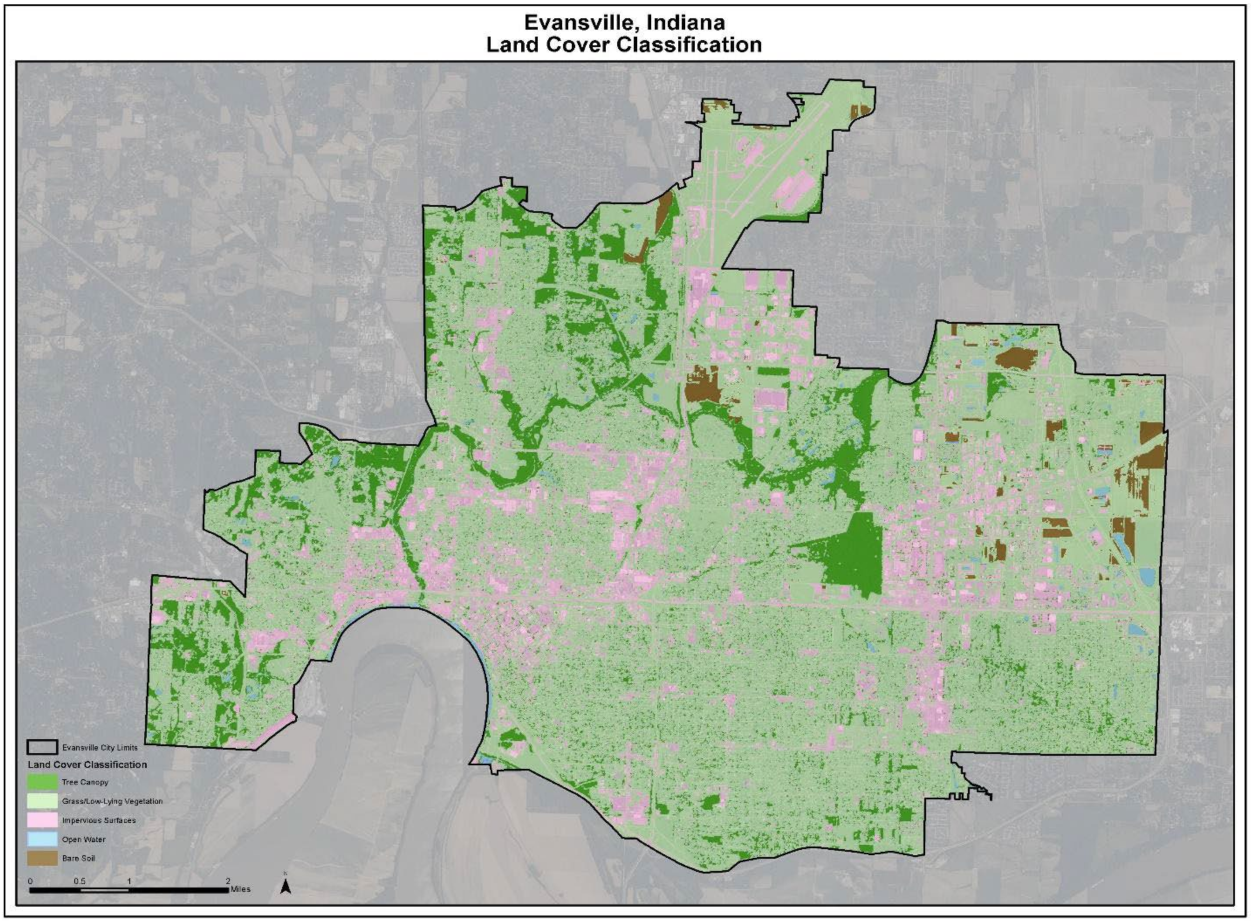


Figure 1. City of Evansville land cover.

Table 2 and Figure 2 present the land cover results within Evansville's municipal boundary. The study area covers 30,623 acres or approximately 48 square miles. The tree canopy cover is 24%, with a total of 7,313 acres of existing tree canopy. Pervious surfaces and bare soils cover 35% of total land area, and impervious and open water make up the remaining 41%.

Table 2. Land cover in Evansville.

Local Government	Total Acres	Tree Canopy Acres	Impervious Acres	Pervious Acres	Bare Soil Acres	Water Acres
City of Evansville	30,623	7,313	12,188	9,881	784	457
Percent of Total	100%	24%	40%	32%	3%	1%

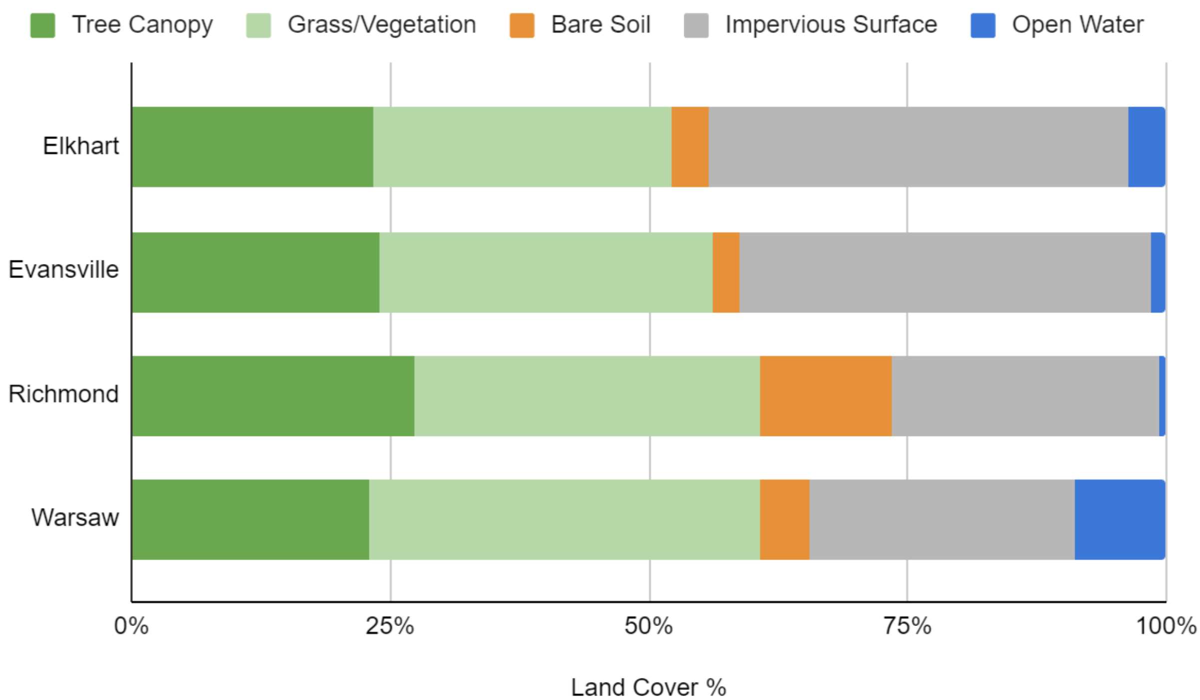


Figure 2. Land cover for each of four municipalities who participated in the 2024 Urban Green Infrastructure Resilience Cohort

Urban Tree Canopy Analysis

Land cover data were further analyzed to better understand the potential for urban tree canopy (UTC) within the local government study area. Theoretically, all pervious surfaces and bare soils previously reported in the land cover analysis could be planted with trees for future tree canopy—collectively, these represent possible UTC. However, the planting of all land use areas is understandably not practical for implementing actual planting projects, nor is it realistic for urban forest planning and management. In this analysis, possible UTC is refined to provide consideration for land use. Land use generally excluded agricultural land, cemeteries, golf courses, utility rights-of-way, recreational fields, etc. The resulting area is called preferred plantable. The preferred plantable area is based on a "real world" approach to the identification of reasonable areas to plant trees.

Table 3 and Figure 3 present the UTC analysis results within Evansville's municipal boundary. There are 10,665 acres of grass/vegetation (pervious) land and bare soil, which represents the possible tree canopy area. When considering only the practical or preferred plantable area within this, however, the acreage available to future tree canopy is 8,277 acres (27%). The sum of existing tree canopy and preferred plantable area presents a maximum of approximately 51% tree cover.

Table 3. Tree canopy cover in Evansville.

Local Government	Total Acres	Tree Canopy Acres	Possible Tree Canopy Acres	Preferred Plantable Acres	Maximum Tree Canopy
City of Evansville	30,623	7,313	10,665	8,277	15,590
Percent of Total	100%	24%	35%	27%	51%

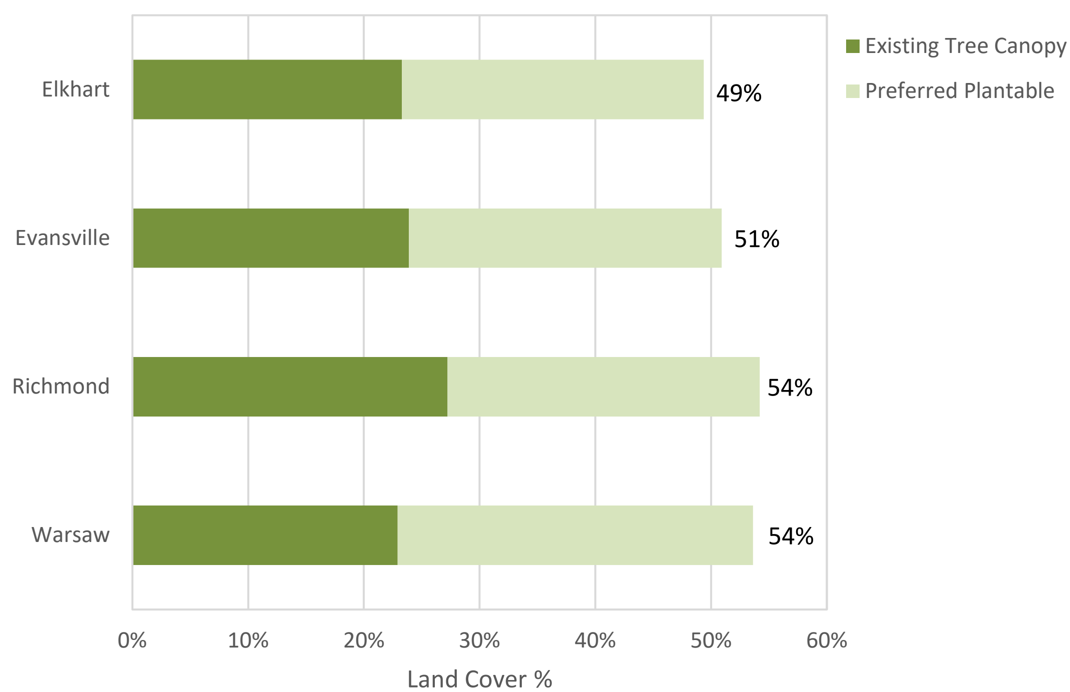


Figure 3. Percentage of existing tree canopy cover, preferred plantable area, and maximum tree cover for each of four municipalities who participated in the 2024 Urban Green Infrastructure Resilience Cohort.

Prioritized Planting Areas

Planting urban trees improves community health by reducing the risks of urban heat island effect and degradation from rain and flood events as well as increases urban forest connectivity and human well-being. To study where trees will make the most community impact, the climate fellows, with DRG's guidance and local government input, categorized the preferred planting areas by creating a prioritized planting area analysis. Several community factors were selected, weighted, indexed by grid, and averaged within polygons across the study area to prioritize planting areas; see Appendix B for methods. Typical factors include existing tree canopy percent, proximity to hardscape, urban heat island index, floodplain proximity, soil permeability, soil erosion factor (K-factor), slope, population density, minority population, and median household income. Analysis results concluded with preferred planting polygons/areas assigned 1 of 5 classifications between very low to very high.

The plantable area analysis found 8183.48 acres of land with the potential for new tree canopy categorized as Very High, High, Moderate, Low, and Very Low for the purpose of returned community benefit; see Table 4. Very High and High plantable areas average 12% and 19%, respectively, totaling an estimated 54,759 plantable locations. Figure 4 presents an account of the number of plantable locations by priority within the study area. Figure 4 illustrates the resulting prioritized plantable areas for the municipal boundary of Evansville, Indiana.

Table 4. Results of Prioritized Plantable Area Analysis

	Very High Acres	High Acres	Moderate Acres	Low Acres	Very Low Acres	Total Acres
City of Evansville	976.38	1584.24	2016.77	2324.31	1281.78	8183.48
Percent of Total	12%	19%	25%	28%	16%	100%

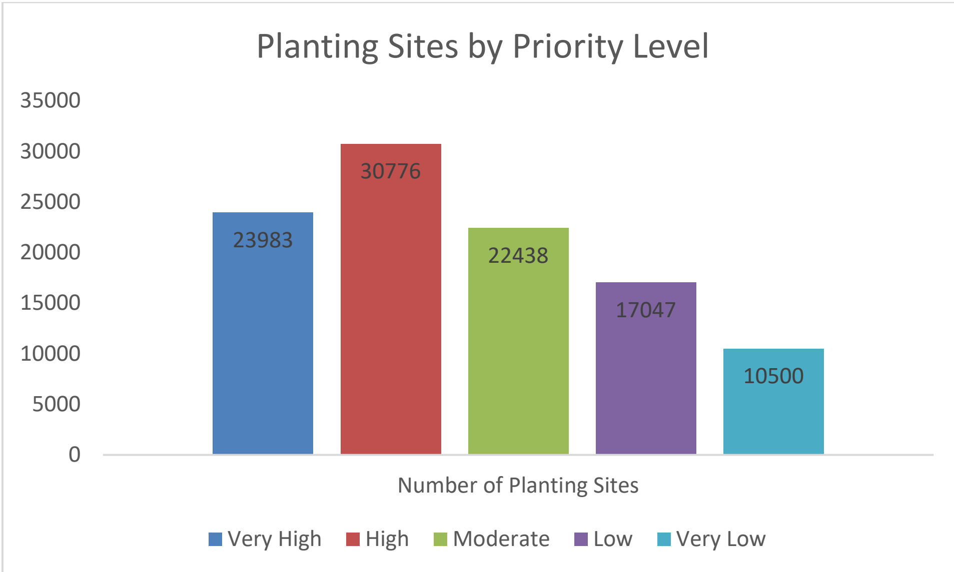


Figure 4. Count of locations of prioritized plantable areas

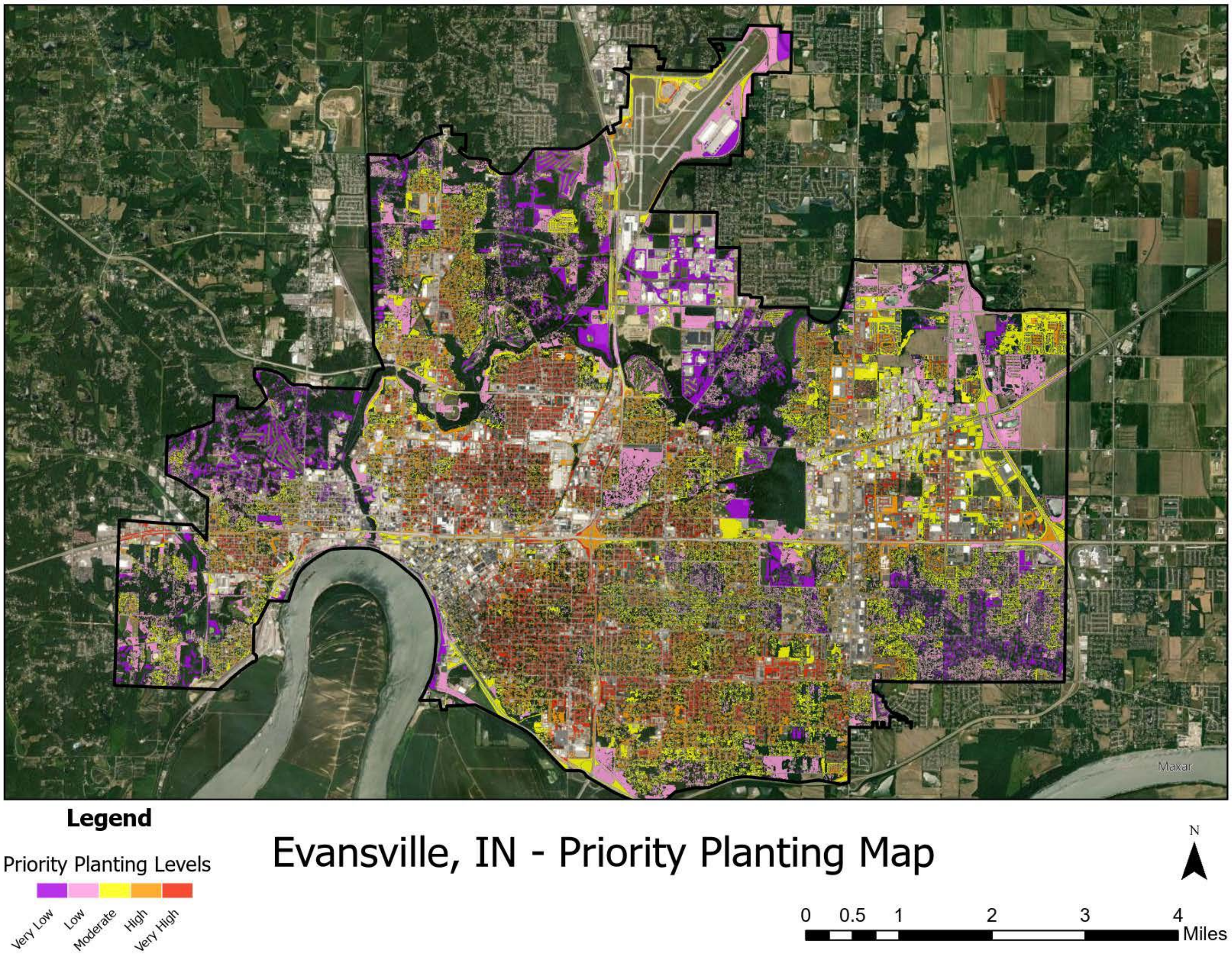


Figure 5 Prioritized plantable areas within Evansville, Indiana

Geographic UTC Analysis

For developing planting strategies and working with community stakeholders, DRG mapped tree canopy cover by geographies that were chosen by the City of Evansville. Appendix C contains a list of selected geographic units. This report summarizes the UTC assessment by public versus private, City Council ward, ROW, flood hazard areas, and urban heat island.

Tree planting strategies are necessary to meet tree canopy goals. Typically, after conducting a land cover and UTC assessment, tree canopy goal setting is the next step. There will be difficult-to-meet strategies and easy-to-meet strategies. This summary supports two easy-to-meet strategies: (1) Tree preservation policy development within geographic areas that have the most existing tree canopy, and (2) tree planting within geographic areas that have the lowest existing tree canopy and/or the largest preferred plantable area.

Tree Canopy on Private Versus Public Land

Figure 5 shows private and public land within the City of Evansville's municipal boundaries. There are 8,336 acres of public land and 22,285 acres of private land. Existing tree canopy on public land is 23% and tree canopy on private land is 24%. Where canopy exists most in a community is where there is more potential for creating tree preservation policy.

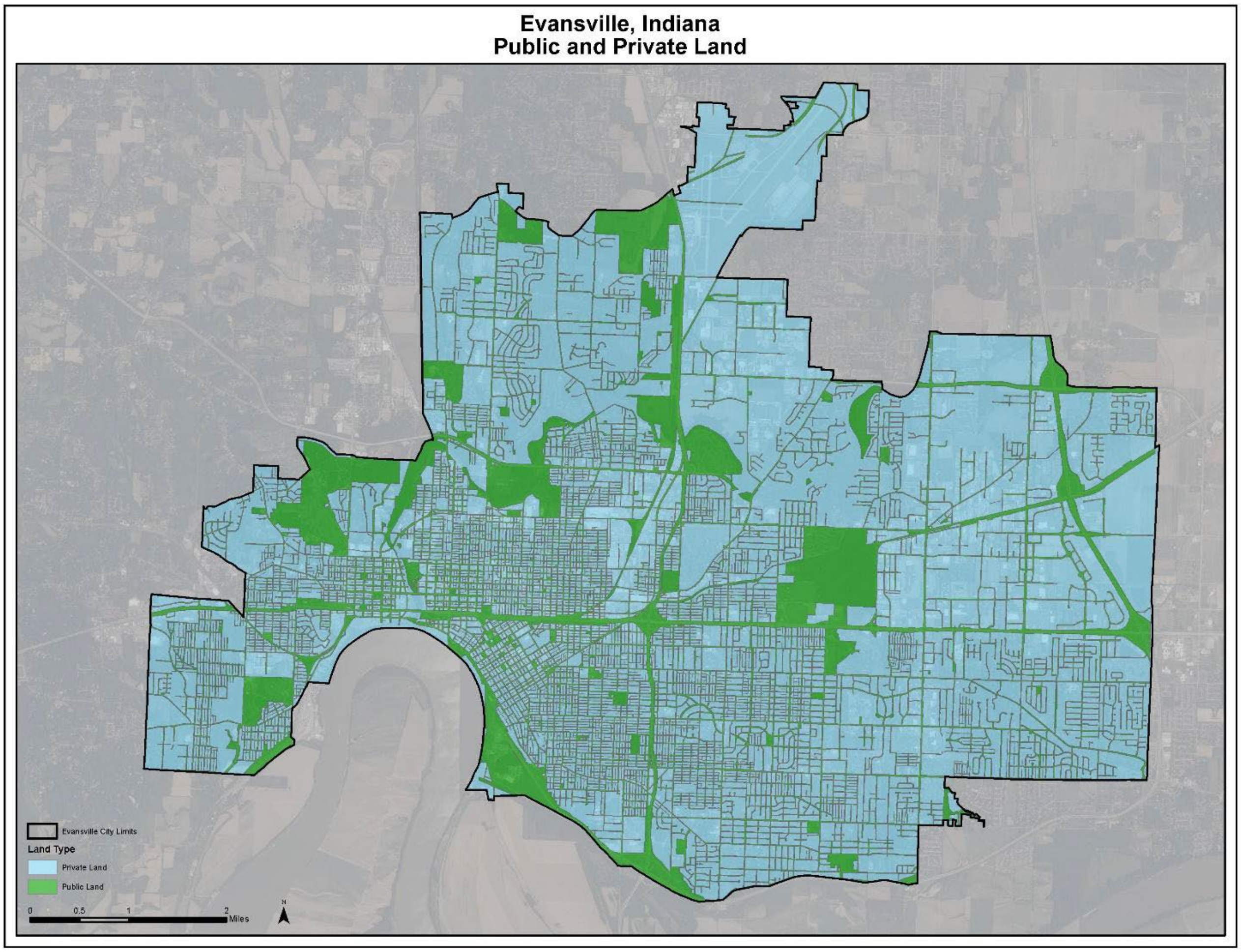


Figure 6. City of Evansville privately owned land (blue) and publicly owned land (green).

If communities were to plant all preferred plantable area, tree canopy area could increase to 39% on public land and 52% on private land. The City of Evansville has the most potential for change within privately owned land, which has 6,167 acres of preferred plantable land area.

Table 5. Tree canopy cover on private land versus public land.

Local Government	Land Ownership	Acres	Tree Canopy Acres Percent		Preferred Plantable Acres Percent		Maximum Tree Canopy Acres Percent	
City of Evansville	Public	8,336	1,926	23%	2,110	25%	4,036	48%
	Private	22,285	5,386	24%	6,167	28%	11,553	52%

Tree Canopy by City Council Ward

Figure 6 shows existing canopy cover within Evansville's six city council wards. Average tree canopy cover varies among wards from 16% in Wards 1 and 4 to 30% in Wards 2 and 6 (Table 6). Ward 5 is the largest ward and has the most opportunity for future tree canopy. Planting all available preferred planting area (2,743 acres) would raise canopy cover in Ward 5 from 26% to 55%.

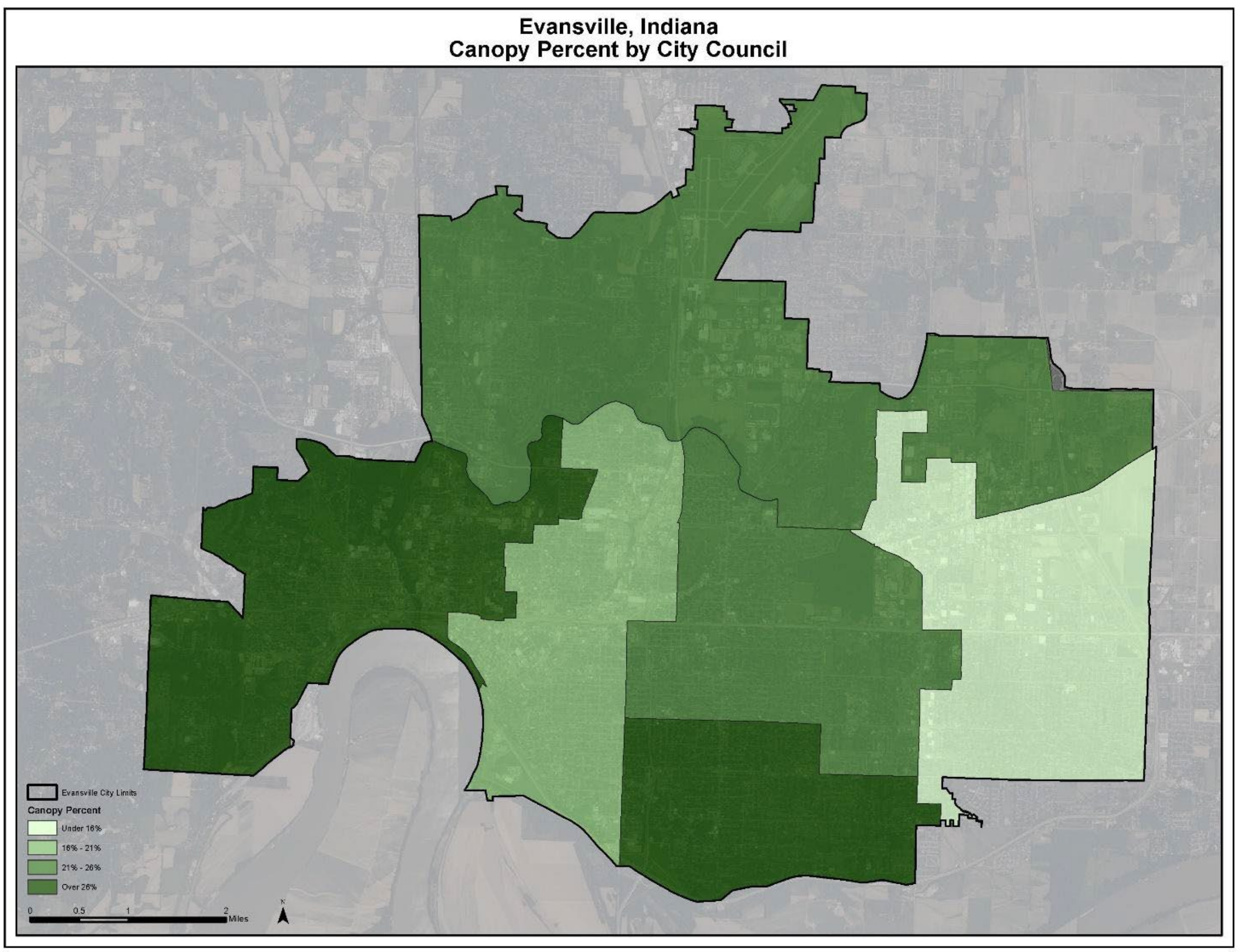


Figure 7. Tree canopy cover by city council ward.

Table 6. Tree canopy cover by city council ward.

City of Evansville Council Wards	Total Acres	Canopy		Preferred Plantable		Maximum Tree Canopy	
		Acres	Percent	Acres	Percent	Acres	Percent
Ward 1	4,845	757	16%	1,356	28%	2,113	44%
Ward 2	2,895	860	30%	958	33%	1,818	63%
Ward 3	4,300	1,078	25%	1,163	27%	2,241	52%
Ward 4	3,806	607	16%	868	23%	1,474	39%
Ward 5	9,575	2,480	26%	2,743	29%	5,223	55%
Ward 6	5,160	1,526	30%	1,164	23%	2,690	52%

Tree Canopy Within Rights-of-Way

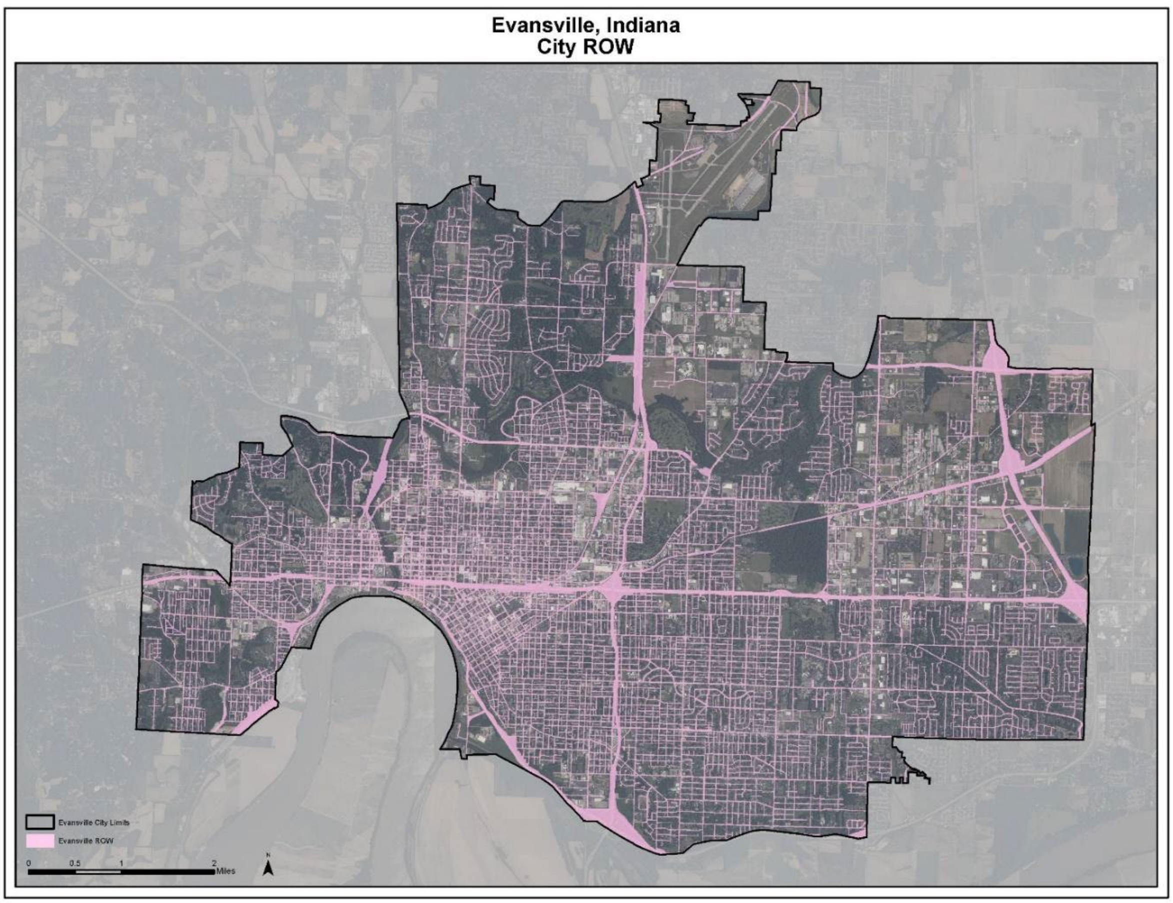


Figure 8. Street rights-of-way (ROW; pink) within Evansville.

Table 7. Tree canopy cover within street rights-of-way.

Local Government	Geographic Unit	Acres	Tree Canopy Acres Percent		Preferred Plantable Acres Percent		Maximum Tree Canopy Acres Percent	
City of Evansville	Street ROW	5,907	901	15%	1,408	24%	2,309	39%

City of Evansville Prioritized Planting Areas- 2024 UGI Cohort

The following sections describe the work done by the 2024 UGI Cohort. This Inflation Reduction Act (IRA)-funded project was a collaboration between multiple partners, including the city of Evansville, Indiana University's Environmental Resilience Institute (ERI), Davey Resource Group (DRG), and Jane Rogan Connect.

Project Background

Evansville was among four Indiana communities (Elkhart, Evansville, Richmond, and Warsaw) selected by the ERI for the 2024 UGI Cohort. Each community was paired with a McKinney Climate Fellow, who applied GIS-based analysis to the landcover data provided by DRG. Priority Planting Areas were first found for the entire city. Because the project supports work done in disadvantaged communities (DACs) as defined by the Climate and Economic Justice Screening Tool (CEJST), Fellows then clipped the Priority Planting Areas to the DAC census tracts. The resulting data allowed for Fellows, with their city supervisors, to select sites for up to 100 trees to be planted in areas where they are most needed. The following sections contain the maps generated by this work.

Priority Planting Analysis

The maps below show the Priority Planting Analysis for the entire city of Evansville, along with those for two biophysical components that contribute to the data included in the analysis: variations in urban heat island effect, and vulnerability from flooding. Methods used to create these maps can be found in Appendix B.

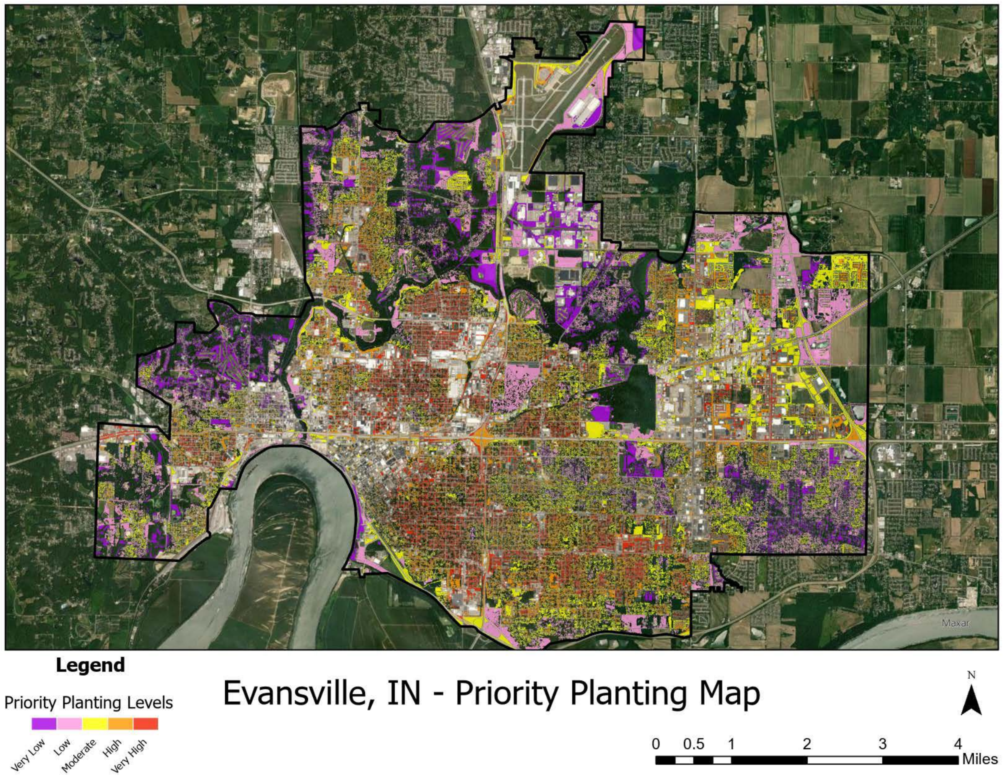


Figure 9. City of Evansville Planting Analysis.

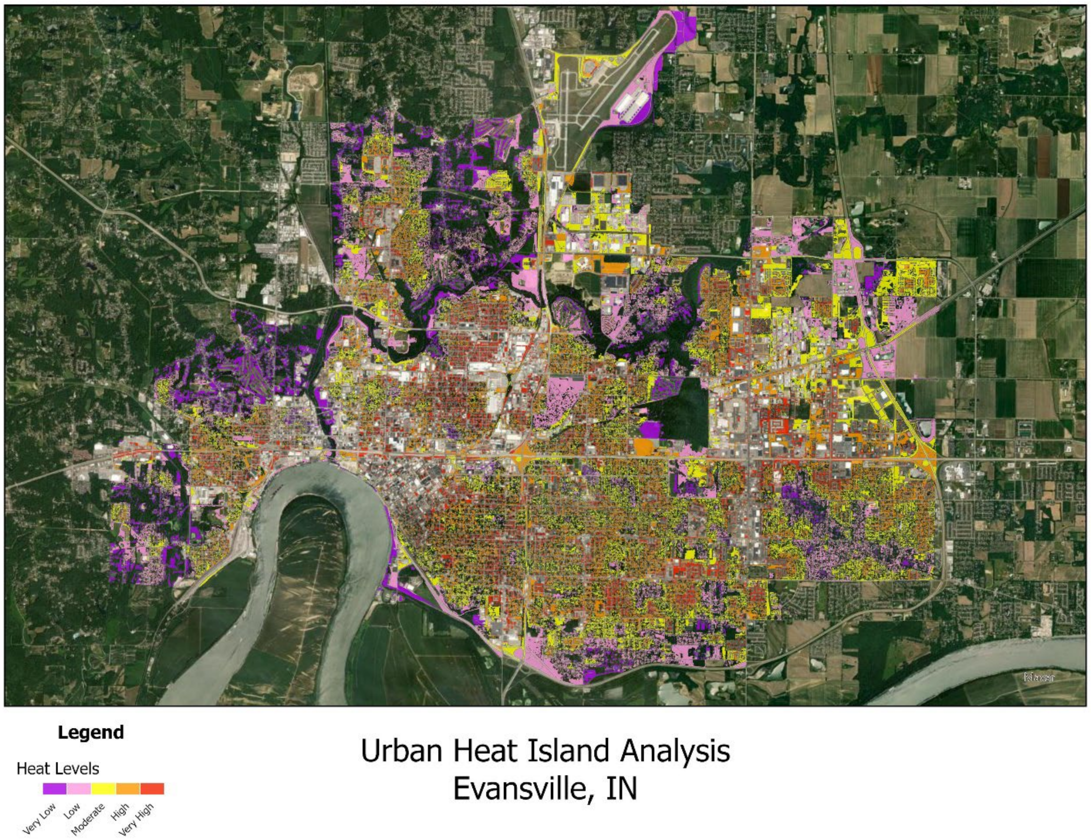


Figure 10. City of Evansville Urban Heat Island Analysis

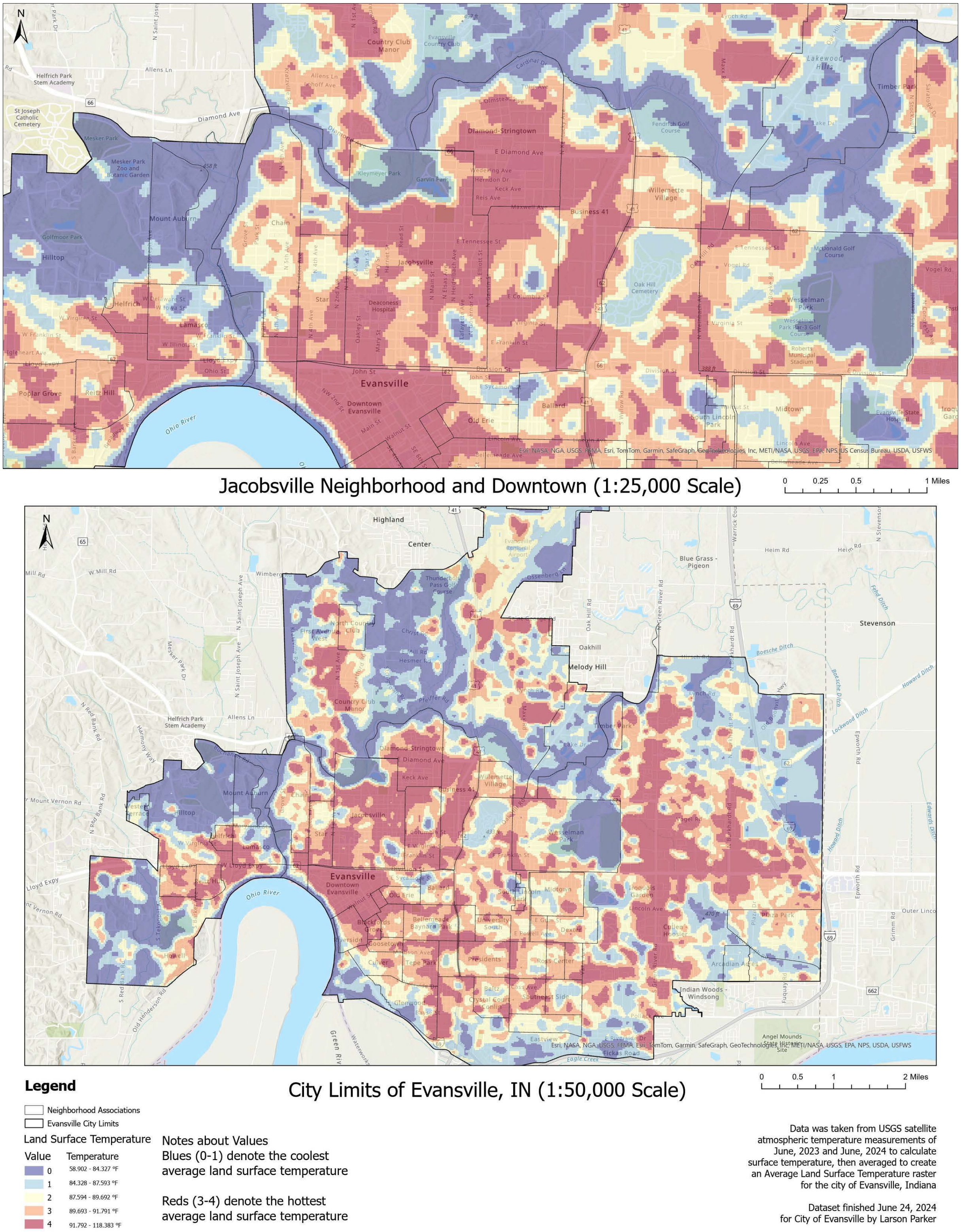


Figure 11. City of Evansville Urban Heat Island Analysis at neighborhood and city scales

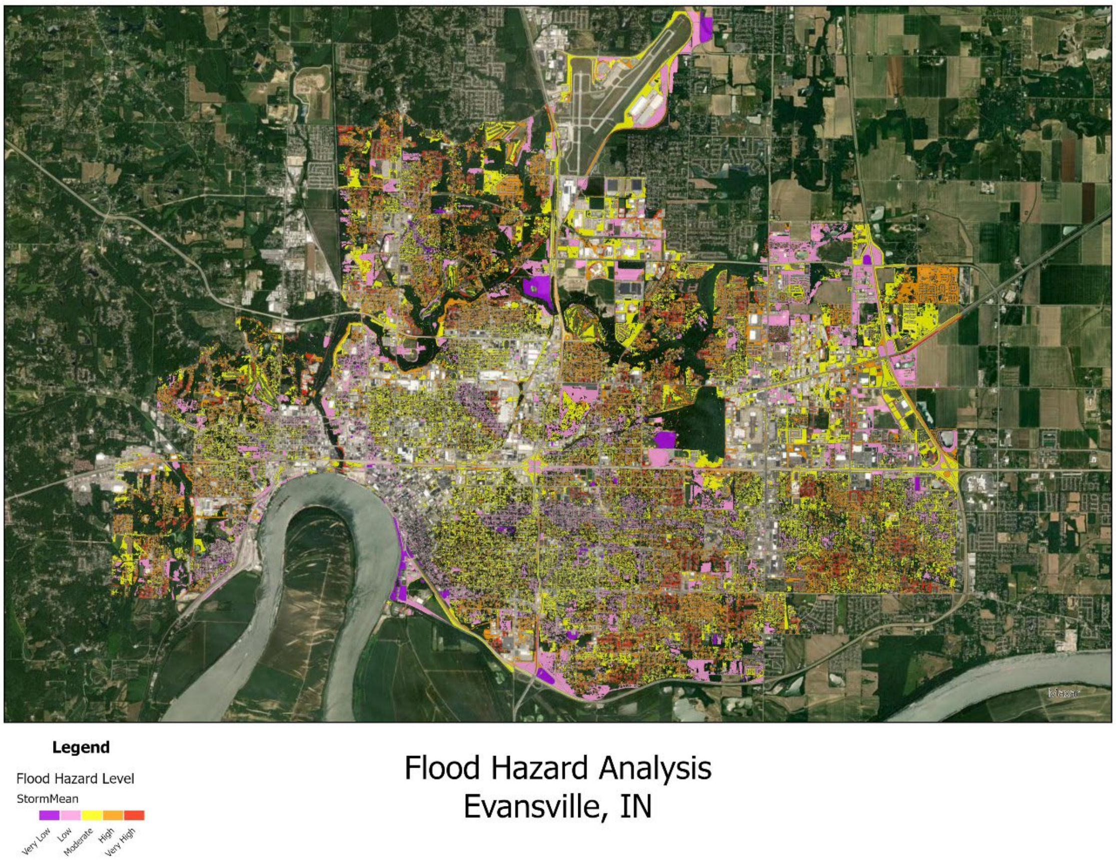


Figure 12. City of Evansville Flood Hazard Analysis

Priority Planting Areas in DACs

The maps below show the DACs as designated by the CEJST Screening Tool, and Priority Planting Areas within these census tracts. Methods used to create these maps can be found in Appendix B.

Priority Planting Area - Evansville, IN

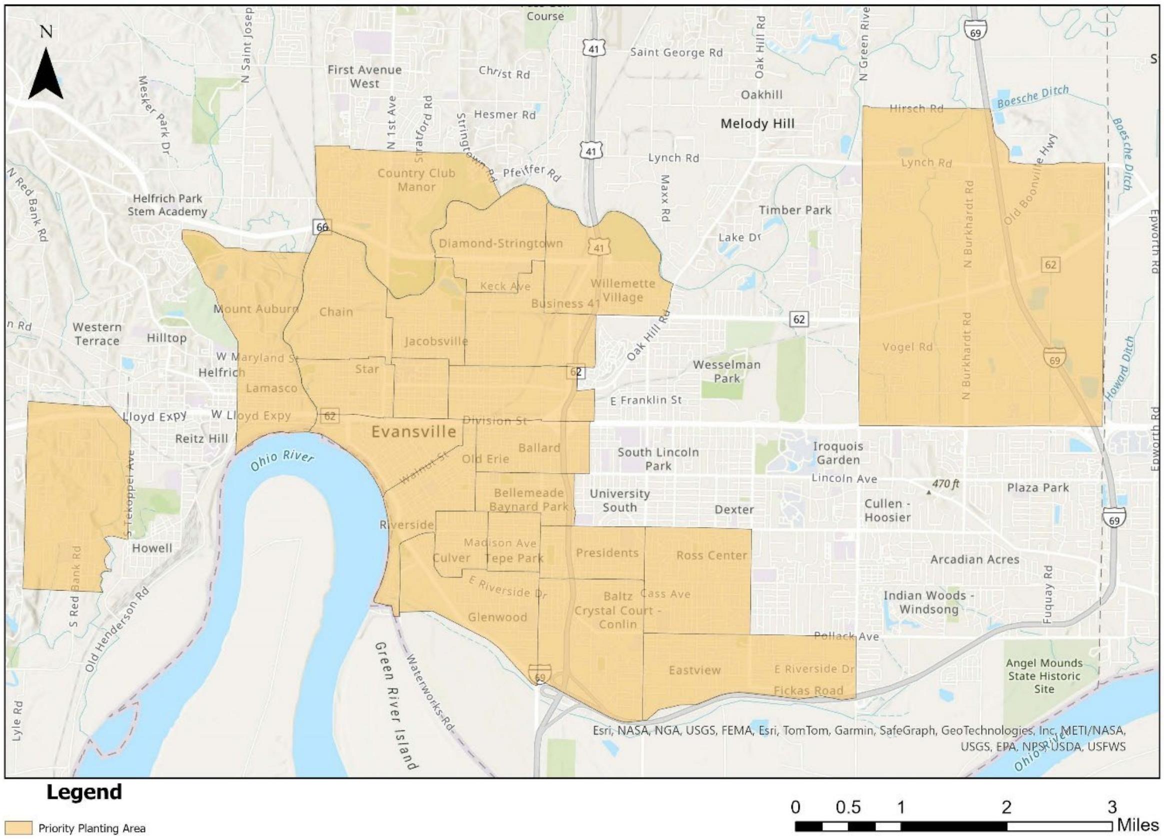


Figure 13. City of Evansville Priority Planting Areas (DACs)

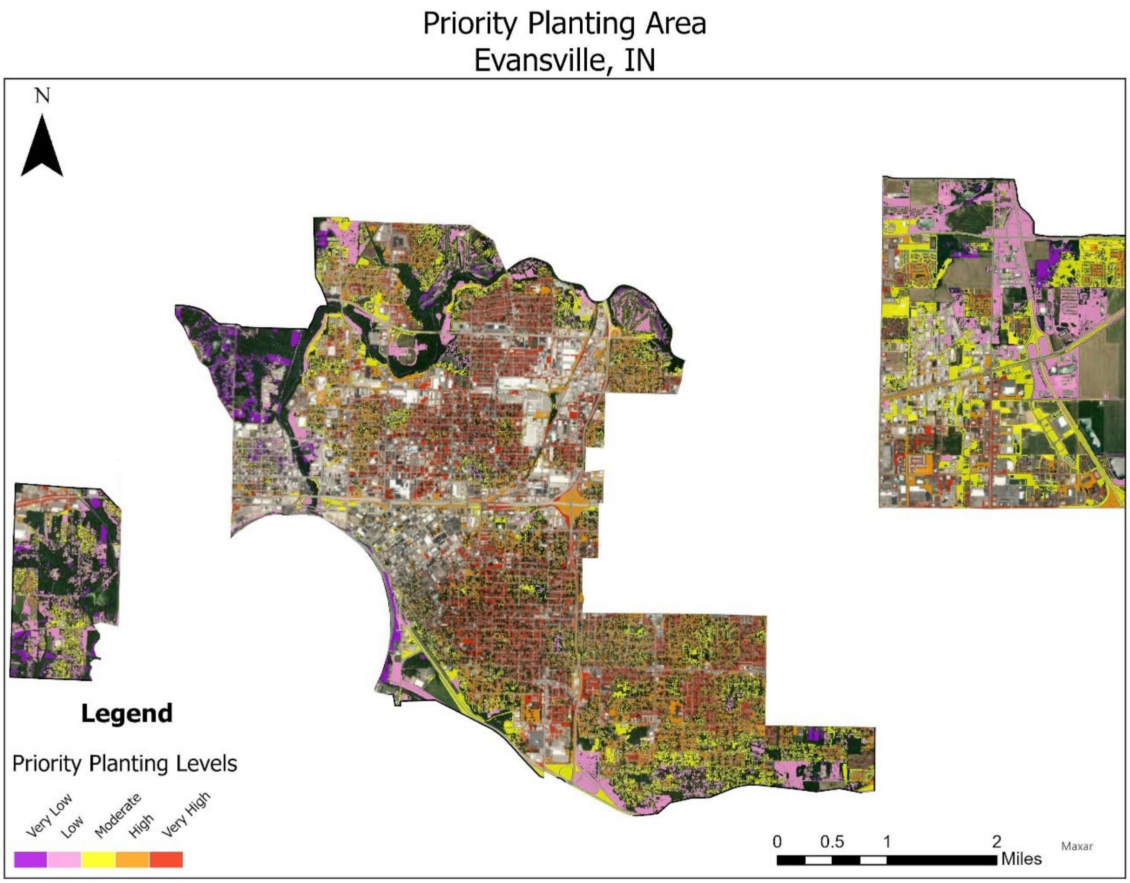


Figure 14. City of Evansville Priority Planting Analysis clipped to DACs

Planting sites for Fall 2024 plantings

The map below shows the sites chosen for the 100 trees to be planted in November 2024. The sites were selected based on data from the Priority Planting Analysis and through community engagement done throughout the summer of 2024.

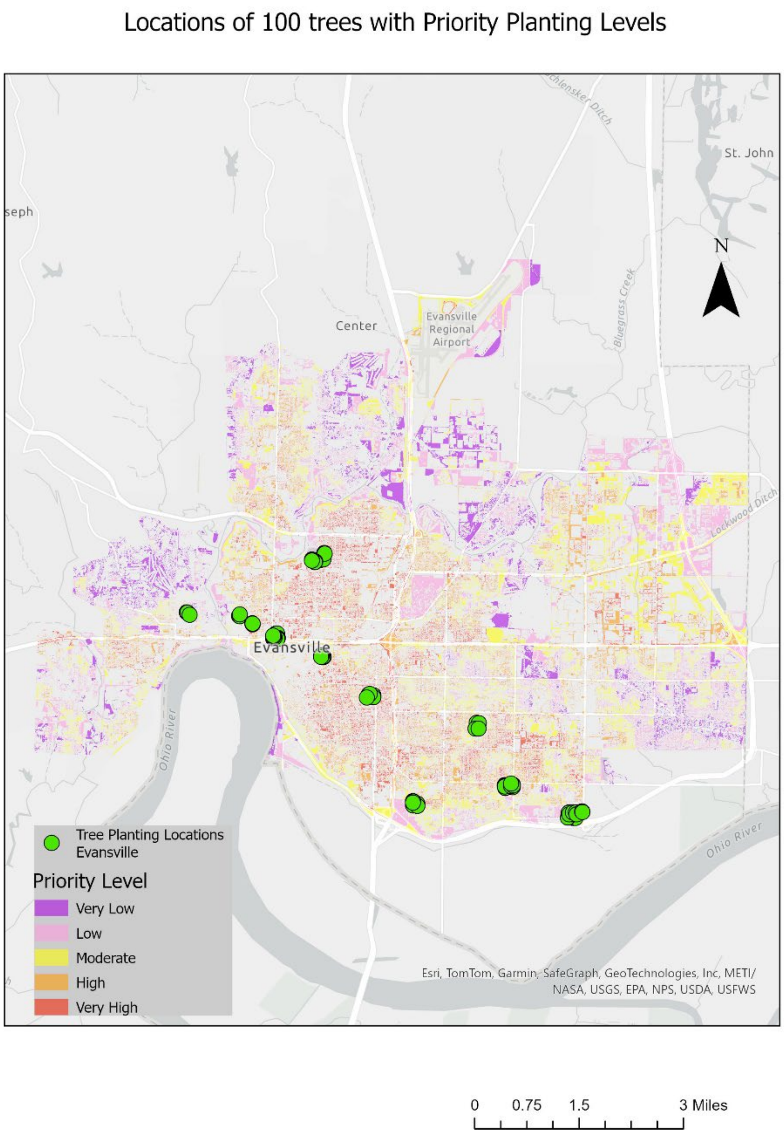


Figure 15. City of Evansville 100 Tree Planting Sites

November 2024 Tree Planting

Planting of the 100 trees is scheduled for November 2024. All are to be planted in sites chosen with community members, and all will be within higher priority planting areas in the DAC tracts in Evansville. All trees will be cared for over the next three years (2025, 2026,

2027) by a local contractor in collaboration with Davey Resource Group. Trees will be watered as needed during the summer months, inspected for condition and health, and will receive a pruning during the summer of 2027.

Future Considerations for UGI Planning

Tree Stewards/Stakeholders

The New Haven Neighborhood Association is interested in stewarding the 25 trees in their neighborhood. Their care for the trees would extend beyond the trees in their yard to the trees surrounding their neighborhood. Volunteers would do most of the work to maintain the trees in the fields adjacent to the neighborhood.

In public parks, the Evansville Parks Department and Urban Forestry Department will oversee and maintain the trees after the DRG period of maintenance concludes. Additionally, community members may help maintain new trees in parks near them.

Upcoming Projects/Grants

Evansville's urban forest has a new advocate—the Evansville Forest Alliance (EFA). The Evansville Forest Alliance comprises Wesselman Woods Nature Preserve (WW), the City of Evansville Arborist, the City of Evansville Climate Action Director, Community One, and the Indiana Department of Natural Resources (IDNR). The initiative is backed by a Community and Urban Forestry (CUF) grant through the Inflation Reduction Act. Trees planted through this initiative address disparities in tree benefits throughout the city. The EFA wants to address gaps in tree coverage in the city, while also prioritizing education, community engagement, and healthy tree management.

Discussion

The management of trees in an urban forest can be challenging. Local governments have to balance the recommendations of tree experts, the needs of residents, the pressures of local economics and politics, the concerns for public safety and liability, the physical aspects of trees, the forces of nature and severe weather, and the desires for all of these issues to be resolved. Local governments must carefully consider each specific issue and balance these pressures with a knowledgeable understanding of their current UTC. If balance is achieved, beauty will flourish, and the health of community trees and residents will sustain.

The national trend is urban forests are losing invaluable tree canopy. The UGI Cohort government study for the City of Evansville has an existing tree canopy cover of 24% with an attainable tree canopy of 51%. The preferred plantable area is equivalent to 8,277 acres. Plantable areas designated as Very High and High priority in the government's prioritized planting plan should be planted first.

If not planted or preserved, trees will be lost due to development, natural mortality, insects and diseases, and climate change. Reaching projected tree canopy potentials will require the UGI local governments to preserve all existing tree canopy while expanding the urban forest in designated preferred plantable areas. Further analyzing, establishing, planning, and setting out to achieve a tree canopy goal from a public and private perspective is the only way local governments will slow the loss of trees and tree canopy. If local governments want to sustain tree canopy, setting goals will help organize tree planting programs and direct tree preservation. Establishing realistic and achievable tree canopy goals will help capitalize on the economic, environmental, and social benefits trees provide to the community.

Many communities have set tree canopy goals, standards, or policies. Each UGI Cohort local government should consider setting a tree canopy goal that is attainable in a set period. The goal should be communitywide, and objectives can be more specific like public vs private lands or zoning land use based. To ensure goals are obtainable, utilize the results of the UTC assessment and the provided GIS tools to develop annual tree planting projects and tree preservation tactics. Increase public outreach efforts about the urban forest and the benefits it provides to the community using i-Tree Tools, a free software suite from the U.S. Forest Service and partners. This bolsters support of trees and an understanding of the importance for tree planting, maintenance, and preservation. Today, Indiana local governments and city partners need to make initiatives to help promote and sustain the urban tree canopy for the community and future generations to come.

Aftercare

Trees are essential in local communities, making tree care a wise investment for tree owners. Healthy trees increase property values, provide for wildlife, beautify surroundings, clean and lessen stormwater runoff, purify air, and save energy by providing shade in summer and protection in winter. Regular maintenance of new and established trees ensures trees remain healthy and structurally sound.

New Tree Maintenance

Irrigation - Trees require consistent, thorough watering for at least three years post-planting.

- Any newly planted trees that don't experience the equivalent of 1 inch of rainfall a week should be placed on a watering schedule.
- Know the soil texture at the planting location to understand its water-holding capacity.
- Establish a soil moisture monitoring protocol to ensure adequate water levels throughout the year.
    - The watering season for most trees mimics the growing season, approximately May 1 through October 31.
    - Deciduous trees need no supplemental water when leaves are not on trees, approximately November 1 through April 30.
    - Conifers and broadleaf evergreens should receive supplemental water throughout the fall and winter, approximately November 1 through April 30.

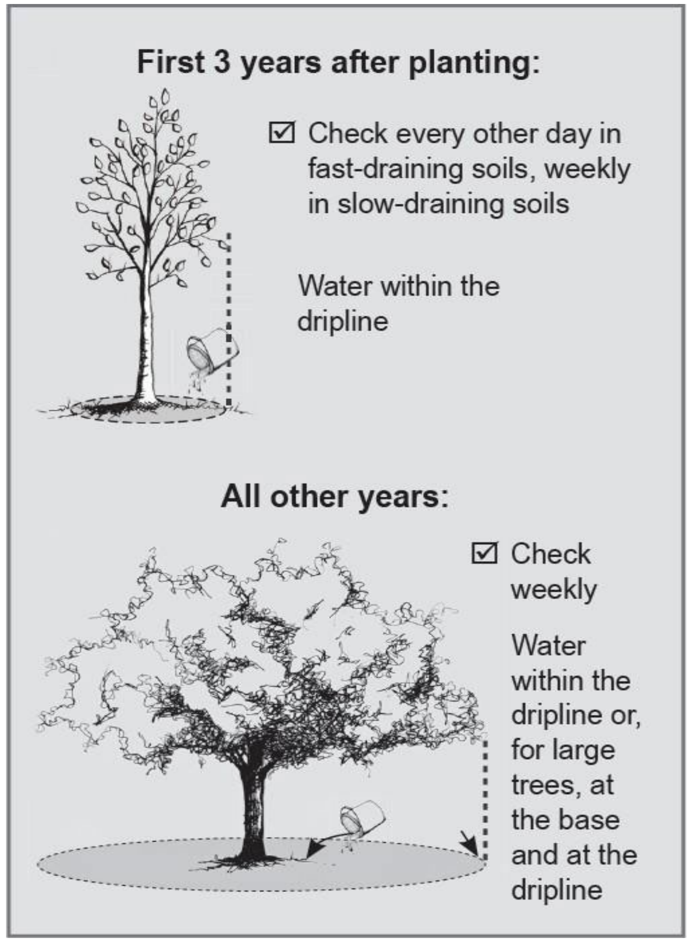


Figure 1: *First 3 years after planting: If the soil is dry, provide about 1-1/2 gallons of water per diameter inch of the trunk. Source: US Forest Service Tree Owner's Manual. www.treeownersmanual.info*

- Newly planted trees should receive a minimum of 1 inch of water per inch of caliper per week (Figure 1).
    - To offset the lack of water provided by rain or the water table at the site, newly planted trees should receive a minimum of 5 gallons of water per caliper inch at each watering.
    - Several methods of irrigation can effectively water trees in natural areas, including hand-watering, irrigation bags, soaker hoses, or bucket drip irrigation.
    - Tall-sided irrigation bags should be used only when trees are a minimum of 1.5 inches in caliper trees with branching starting above 3 feet.

Planting Circle Maintenance: Reduced environmental stresses, such as temperature extremes or weed competition, positively impact tree health.

- Keep the initial planting circle clear of vegetation and other debris by removing it by hand or cutting it with a string trimmer, careful not to strike the tree trunk.
- If mulch maintenance is attainable or desired, use natural wood chips or shredded bark, needles, or leaves free of any extraneous material such as soil, stones, and debris.
- Replenish mulch as needed to maintain a 2 to 3-inch deep layer around the tree, leaving 3 inches around the trunk clear from mulch. Do not use weed killer near small or thin-barked trees.

Tree Protection

- Rabbits and deer may browse on trees shorter than 3 feet tall.
    - Make a 4-inch wide and 32-inch tall wire cage to place around the tree (Figure 2).
    - Secure the cage to the ground with a stake.
    - Plastic tree guards are also effective.
- Voles, mice, and rabbits may damage stem cambium using wood to trim teeth.
    - Apply a repellent following labeled directions.

- Deer may damage stem cambium using the stem as an antler rub and beavers may damage stem cambium using wood to trim teeth or cut for use in dams.
    - Install loose-fitting 48-inch tall and minimum 4-inch diameter tree guards, made of wire or plastic mesh, around the tree trunk.
- All wildlife tree protection should be monitored seasonally and adjusted or removed as needed.
- Stakes installed at the tree's planting are typically removed after 1 year or one full growing season when they are capable of supporting themselves.

Tree Health

- The majority of all pruning should happen during leaf-off conditions and by a licensed arborist in accordance with ANSI A300 *Standard Practices for Trees, Shrubs, and Other Woody Plant Maintenance*.
- Large-growing trees should be pruned to maintain a central leader to 20 feet.
- Lateral branching should be retained to deter deer from using the stem as an antler rub.
- After the first growing season, trees may be pruned to remove any dead, diseased, damaged, or dying branches (Figure 3).
- After the third growing season, branches may be removed that are clustered together or are crossing.
- Tools used to prune shall be sharp and cleaned thoroughly with alcohol, hydrogen peroxide, or chlorine bleach before pruning.

- Treatment of cuts with wound dressing or paints should not be used.

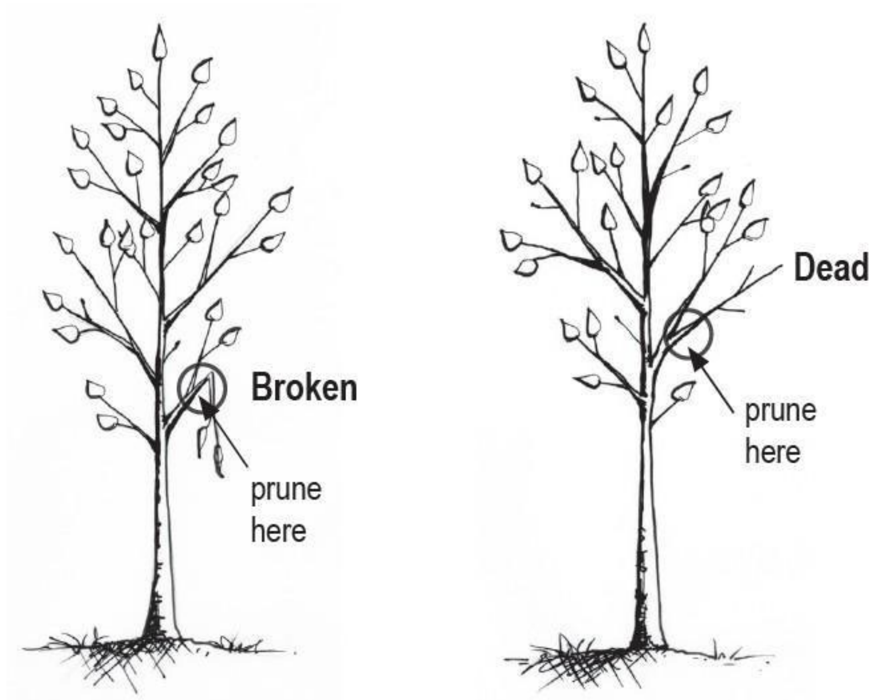


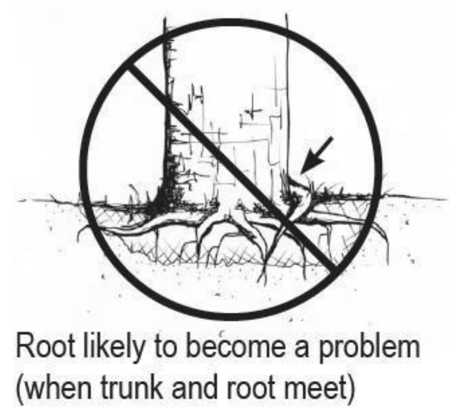
Figure 3: *Prune only branches that are broken or dead. You may also remove competing leaders if present. Most trees should have one central leader. If there are two or more leaders, choose which one you want to remain and remove the other(s). Source: US Forest Service Tree Owner's Manual. www.treeownersmanual.info*.

Established Tree Maintenance

Monitor Tree Health: When conducting routine checks of trees in an orchard, it's essential to diligently observe for any signs of distress or irregularities such as:

- *Visible Signs of Decay or Damage*: Look for areas of decay, cracks, splits, or wounds on the trunk, branches, or bark. These can indicate underlying issues such as fungal infections, pest infestations, or structural weaknesses.
- *Unusual Growth Patterns*: Keep an eye out for abnormal growth patterns such as excessive leaning, sudden changes in canopy density, or the presence of epicormic shoots (new growth from dormant buds on branches or trunks). These can signal stress or underlying health issues.
- *Presence of Pests or Pathogens*: Inspect for signs of pest infestations such as insect activity, chew marks, or the presence of larvae. Additionally, check for symptoms of diseases such as unusual lesions, discoloration, or wilting foliage.
- *Root Zone Issues*: Examine the area around the base of the tree for signs of root damage, soil compaction, or root girdling (roots circling the trunk). These issues can affect the tree's stability and nutrient uptake (Figure 4).
- *Abnormal Leaf Characteristics*: Look for abnormalities in leaf size, shape, color, or texture. This can include premature leaf drop, yellowing or browning of leaves, or unusual spotting or discoloration.

- *Structural Integrity*: Assess the overall structure of the tree, including the integrity of major branches and the main trunk. Pay attention to any signs of weakness, such as splits, that could indicate risk of failure.



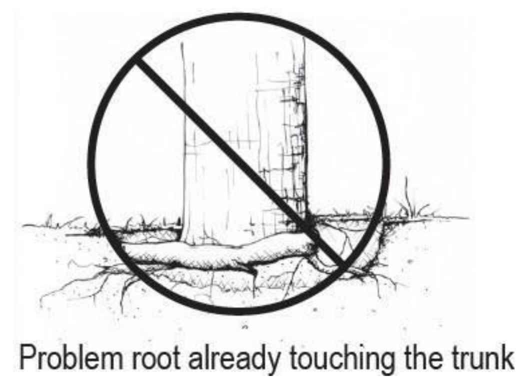


Figure 4: *Roots that encircle the trunk will likely cause health or safety problems later. Make sure that soil or mulch is never piled against the root collar. Source: US Forest Service Tree Owner's Manual.* *www.treeownersmanual.info.*

If any abnormalities are detected during the inspection, it's important to document them thoroughly and monitor them closely over time. Additionally, it's advisable to report these findings to a local tree care professional or certified arborist for further evaluation and advice on appropriate treatment options. Depending on the specific issues identified, treatment options may include pruning, pest or disease management, soil amendments, or other corrective measures aimed at preserving the health and safety of the tree

Glossary

bare soil land cover: The land cover areas mapped as bare soil typically include vacant lots, construction areas, and baseball fields.

canopy: Branches and foliage which make up a tree's crown.

canopy cover: As seen from above, it is the area of land surface that is covered by tree canopy.

geographic information systems (GIS): A technology that is used to view and analyze data from a geographic perspective. The technology is a piece of an organization's overall information system framework. GIS links location to information (such as people to addresses, buildings to parcels, or streets within a network) and layers that information to give you a better understanding of how it all interrelates.

impervious land cover: The area that does not allow rainfall to infiltrate the soil and typically includes buildings, parking lots, and roads.

i-Tree Canopy: The i-Tree Canopy tool allows users to easily photo-interpret Google aerial images of their area to produce statistical estimates of tree and other cover types along with calculations of the uncertainty of their estimates. A simple, quick, and inexpensive means for cities and forest managers to accurately estimate their tree and other cover types.

i-Tree Hydro: The i-tree Hydro tool is a desktop application that stimulates the effects of changes in urban tree cover and impervious surfaces on the hydrological cycle, including hourly stream flows, and water quality.

land cover: Physical features on the earth mapped from satellite or aerial imagery such as bare soils, canopy, impervious, pervious, or water.

open water land cover: The land cover areas mapped as water typically include lakes, oceans, rivers, and streams.

pervious land cover: The vegetative area that allows rainfall to infiltrate the soil and typically includes parks, golf courses, and residential areas.

possible UTC: The amount of land that is theoretically available for the establishment of tree canopy within the city boundary. This includes all pervious and bare soil surfaces.

preferred plantable area: The amount of land that is realistically available for the establishment of tree canopy within the city boundary. This includes all pervious and bare soil surfaces with specified land uses.

right-of-way (ROW): A strip of land generally owned by a public entity over which facilities, such as highways, railroads, or power lines, are built.

tree: A tree is defined as a perennial woody plant that may grow more than 20 feet tall. Characteristically, it has one main stem, although many species may grow as multi-stemmed forms.

tree benefit: An economic, environmental, or social improvement that benefited the community and resulted mainly from the presence of a tree. The benefit received has real or intrinsic value associated with it.

urban forest: All of the trees within a municipality or a community. This can include the trees along streets or rights-of-way, parks and greenspaces, and forests.

urban tree canopy assessment (UTC): A study performed of land cover classes to gain an understanding of the tree canopy cover, particularly as it relates to the amount of tree canopy that currently exists and the amount of tree canopy that could exist. Typically performed using aerial photographs, GIS data, or LIDAR.

Appendix A

Methodology and Accuracy Assessment

Davey Resource Group Canopy Height Modeling and Classification Methodology

Davey Resource Group utilized raster-based height modeling from LiDAR data in combination with an object-based image analysis (OBIA) semi-automated feature extraction method to process and analyze current high-resolution aerial imagery to identify tree canopy cover and land cover classifications. The use of imagery analysis is cost-effective and provides a highly accurate approach to assessing your community's existing tree canopy coverage. This supports responsible tree management, facilitates community forestry goal-setting, and improves urban resource planning for healthier and more sustainable urban environments.

Tree canopy was extracted from 2022 National Agricultural Imagery Program (NAIP) leaf-on, multispectral imagery. A digital surface model (DSM) was created by interpolating the maximum values of the first returns of each laser pulse across a 3-foot grid surface (raster). A speckled output was created because some pulses can entirely or partially pass-through tree canopy before detecting a return, so maximum focal statistics in a 3 by 3 rectangular grid window were applied to the DSM to create a smooth surface.

Another raster representing the elevations of solid surfaces which LiDAR does not penetrate - usually ground and buildings, but occasionally dense evergreens as well, was created by interpolating the minimum values of the last returns (which are also the first return in instances of single return). Mean focal statistics in a 3 by 3 cell window were applied to this raster. The last return raster was subtracted from the first return raster, creating a canopy height model (CHM) – a representation of the heights of objects with complex return structures above the ground. In addition to trees, this includes built structures such as power lines, poles, transmission towers, gantries, etc. The edges of buildings also appeared in the CHM as a result of different cell assignment and focal statistics types applied to the first and last return rasters. The heights of dense evergreens were underestimated due to the inability of LiDAR to penetrate to the ground for a proper base for height.

A constant raster of CHM cells with a height greater than 15 feet was created as a representation of tree canopy. Holes less than 500 square feet were filled to eliminate dubious small gaps while preserving discernable canopy gaps. This raster was then shrunk by 2 cells and expanded back by 2 cells. This process eliminated narrow or small features such as building edges, power lines, and poles.

Advanced image analysis methods were used to classify, or separate, the remaining land cover layers from the overall imagery. The semi-automated extraction process was completed using Feature Analyst, an extension of ArcGIS®. Feature Analyst uses an object-oriented approach to cluster together objects with similar spectral (i.e., color) and spatial/contextual (e.g., texture, size, shape, pattern, and spatial association) characteristics. The land cover results of the extraction process was post-processed and clipped to each project boundary prior to the manual editing process in order to create smaller, manageable, and more efficient file sizes. Secondary source data, high-resolution aerial imagery provided by each UTC city, and custom ArcGIS® tools were used to aid in the final manual editing, quality checking, and quality assurance processes (QA/QC). The manual QA/QC process was implemented to identify, define, and correct any misclassifications or omission errors in the final land cover layer.

A normalized digital elevation model (nDSM) was created by subtracting a DEM interpolated from ground-classified returns instead of last returns from the DSM. This surface provides more accurate tree canopy heights and includes the full heights of buildings as well. The nDSM was masked to the finalized tree canopy to provide a CHM capable of summarizing tree heights.

Classification Workflow

1. Prepare imagery for feature extraction (resampling, rectification, etc.), if needed.

2. Gather training set data for all desired land cover classes (impervious, bare soil). Water samples are not always needed since hydrologic data are available for most areas.
3. Extract canopy from LiDAR. Fill small holes and shrink and expand to remove building edges and power lines.
4. Edit and finalize canopy layer at 1:2000 scale. A point file is created to digitize-in small individual trees that will be missed during the extraction. These points are buffered to represent the tree canopy. This process is done to speed up editing time and improve accuracy by including smaller individual trees.
5. Extract remaining land cover classes.
6. Edit the impervious layer to reflect actual impervious features, such as roads, buildings, parking lots, etc. to update features.
7. Using canopy and actual impervious surfaces as a mask; input the bare soils training data and extract them from the imagery. Quickly edit the layer to remove or add any features. Davey Resource Group tries to delete dry vegetation areas that are associated with lawns, grass/meadows, and agricultural fields.
8. Assemble any hydrological datasets, if provided. Add or remove any water features to create the hydrology class. Perform a feature extraction if no water feature datasets exist.
9. Use geoprocessing tools to clean, repair, and clip all edited land cover layers to remove any self-intersections or topology errors that sometimes occur during editing.
10. Input canopy, impervious, bare soil, and hydrology layers into Davey Resource Group's Five-Class Land Cover Model to complete the classification. This model generates the pervious (grass/low-lying vegetation) class by taking all other areas not previously classified and combining them.
11. Thoroughly inspect final land cover dataset for any classification errors and correct as needed.
12. Perform accuracy assessment. Repeat Step 11, if needed.

Automated Feature Extraction Files

The automated feature extraction (AFE) files allow other users to run the extraction process by replicating the methodology. Since Feature Analyst does not contain all geoprocessing operations that Davey Resource Group utilizes, the AFE only accounts for part of the extraction process. Using Feature Analyst, Davey Resource Group created the training set data, ran the extraction, and then smoothed the features to alleviate the blocky appearance. To complete the actual extraction process, Davey Resource Group uses additional geoprocessing tools within ArcGIS®. From the AFE file results, the following steps are taken to prepare the extracted data for manual editing.

1. Davey Resource Group fills all holes in the canopy that are less than 30 square meters. This eliminates small gaps that were created during the extraction process while still allowing for natural canopy gaps.
2. Davey Resource Group deletes all features that are less than 9 square meters for canopy (50 square meters for impervious surfaces). This process reduces the amount of small features that could result in incorrect classifications and also helps computer performance.
3. The Repair Geometry, Dissolve, and Multipart to Singlepart (in that order) geoprocessing tools are run to complete the extraction process.
4. The Multipart to Singlepart shapefile is given to GIS personnel for manual editing to add, remove, or reshape features.

Accuracy Assessment Protocol

Determining the accuracy of spatial data is of high importance to Davey Resource Group and our clients. To achieve to best possible result, Davey Resource Group manually edits and conducts thorough QA/QC checks on all urban tree canopy and land cover layers. A QA/QC process will be completed using ArcGIS® to identify, clean, and correct any temporal discrepancies in LiDAR-derived tree canopy, misclassification or topology errors in the final land cover dataset. The initial land cover layer extractions will be edited at a 1:2000 quality control scale in the urban areas and at a 1:2500 scale for rural areas utilizing the most current high-resolution aerial imagery to aid in the quality control process.

Table 1. Land Cover Classification Code Values

Land Cover Classification	Code Value
Tree Canopy	1
Impervious	2
Pervious (Grass/Vegetation)	3
Bare Soil	4
Open Water	5

To test for accuracy, random plot locations are generated throughout the city area of interest and verified to ensure that the data meet the client standards. Each point will be compared with the most current NAIP high-resolution imagery (reference image) to determine the accuracy of the final land cover layer. Points will be classified as either correct or incorrect and recorded in a classification matrix. Accuracy will be assessed using four metrics: overall accuracy, kappa, quantity disagreement, and allocation disagreement. These metrics are calculated using a custom Excel® spreadsheet.

Land Cover Accuracy

The following describes Davey Resource Group's accuracy assessment techniques and outlines procedural steps used to conduct the assessment.

1. *Random Point Generation*—Using ArcGIS, 1,000 random assessment points are generated.

2. *Point Determination*—Each point is carefully assessed by the GIS analyst for likeness with the aerial photography. To record findings, two new fields, CODE and TRUTH, are added to the accuracy assessment point shapefile. CODE is a numeric value (1–5) assigned to each land cover class (Table 1) and TRUTH is the actual land cover class as identified according to the reference image. If CODE and TRUTH are the same, then the point is counted as a correct classification. Likewise, if the CODE and TRUTH are not the same, then the point is classified as incorrect. In most cases, distinguishing if a point is correct or incorrect is straightforward. Points will rarely be misclassified by an egregious classification or editing error. Often incorrect points occur where one feature stops and the other begins.

3. *Classification Matrix*—During the accuracy assessment, if a point is considered incorrect, it is given the correct classification in the TRUTH column. Points are first assessed on the NAIP imagery for their correctness using a "blind" assessment—meaning that the analyst does not know the actual classification (the GIS analyst is strictly going off the NAIP imagery to determine cover class). After all random points are assessed and recorded; a classification (or confusion) matrix is created. The classification matrix for this project is presented in Table 2. The table allows for assessment of user's/producer's accuracy, overall accuracy, omission/commission errors, kappa statistics, allocation/quantity disagreement, and confidence intervals (Figure 1 and Table 3).

	Classes	Tree Canopy	Impervious Surfaces	Grass & Low-Lying Vegetation	Bare Soils	Open Water	Row Total	Producer's Accuracy	Errors of Omission
Reference Data	Tree Canopy	227	3	12	0	0	242	93.80%	6.20%
	Impervious	2	398	24	0	0	424	93.87%	6.13%
	Grass/Vegetation	10	3	264	0	0	277	95.31%	4.69%
	Bare Soils	0	4	0	37	0	41	90.24%	9.76%
	Water	0	0	0	0	16	16	100.00%	0.00%
	Column Total	239	408	300	37	16	1000		
	User's Accuracy	94.98%	97.55%	88.00%	100.00 %	100.00 %		Overall Accuracy	94.20%
	Errors of Commission	5.02%	2.45%	12.00%	0.00%	0.00%		Kappa Coefficent	0.9152

Table 2. Classification Matrix

4. Following are descriptions of each statistic as well as the results from some of the accuracy assessment tests.

Overall Accuracy – Percentage of correctly classified pixels; for example, the sum of the diagonals divided by the total points ((227+398+264+37+16)/1,000 = 94.20%).

User's Accuracy – Probability that a pixel classified on the map actually represents that category on the ground (correct land cover classifications divided by the column total [227/239 = 94.98%]).

Producer's Accuracy – Probability of a reference pixel being correctly classified (correct land cover classifications divided by the row total [227/242 = 93.80%]).

Kappa Coefficient – A statistical metric used to assess the accuracy of classification data. It has been generally accepted as a better determinant of accuracy partly because it accounts for random chance agreement. A value of 0.80 or greater is regarded as "very good" agreement between the land cover classification and reference image.

Errors of Commission – A pixel reports the presence of a feature (such as trees) that, in reality, is absent (no trees are actually present). This is termed as a false positive. In the matrix below, we can determine that 5.02% of the area classified as canopy is most likely not canopy.

Errors of Omission – A pixel reports the absence of a feature (such as trees) when, in reality, they are actually there. In the matrix below, we can conclude that 6.20% of all canopy is classified as another land cover class.

Allocation Disagreement – The amount of difference between the reference image and the classified land cover map that is due to less than optimal match in the spatial allocation (or position) of the classes.

Quantity Disagreement – The amount of difference between the reference image and the classified land cover map that is due to less than perfect match in the proportions (or area) of the classes.

Confidence Intervals – A confidence interval is a type of interval estimate of a population parameter and is used to indicate the reliability of an estimate. Confidence intervals consist of a range of values (interval) that act as good estimates of the unknown population parameter based on the observed probability of successes and failures. Since all assessments have innate error, defining a lower and upper bound estimate is essential.

Confidence Intervals

Class	Acreage	Percentage	Lower Bound	Upper Bound
Tree Canopy	7,312.8	23.9%	23.6%	24.1%
Impervious Surfaces	12,187.1	39.8%	39.5%	40.1%
Grass & Low-Lying Vegetation	9,882.7	32.3%	32.0%	32.5%
Bare Soils	783.6	2.6%	2.5%	2.6%
Open Water	456.5	1.5%	1.4%	1.6%
Total	30,622.7	100.00%		

Statistical Metrics Summary	
Overall Accuracy =	94.20%
Kappa Coefficient =	0.9152
Allocation Disagreement =	4%
Quantity Disagreement =	2%

Accuracy Assessment

Class	User's Accuracy	Lower Bound	Upper Bound	Producer's Accuracy	Lower Bound	Upper Bound
Tree Canopy	95.0%	93.6%	96.4%	93.8%	92.3%	95.4%
Impervious Surfaces	97.5%	96.8%	98.3%	93.9%	92.7%	95.0%
Grass & Low-Lying Vegetation	88.0%	86.1%	89.9%	95.3%	94.0%	96.6%
Bare Soils	100.0%	100.0%	100.0%	90.2%	85.6%	94.9%
Open Water	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Appendix B

Prioritized Plantable Area Methodology

Evansville, Descriptions of steps taken to create maps

DACs

To create the Priority Planting Tracks Map, we first overlayed the Disadvantaged Communities (DAC) Tracts as defined by the Climate and Economic Justice Screening Tool to the City of Evansville. Then, we clipped those census tracts to the city boundary of Evansville. After clipping those to the city boundary, we added color, transparency, and outlines to use the DAC map for communication.

Priority Planting Analysis

The Priority Planting analysis aimed to identify optimal locations for tree planting within Evansville weighting various factors. The analysis identifies plantable areas and then ranks them with a weighted analysis. The ranking system is based on classes 0-4 representing priority levels from very low, to very high.

The first factors were used in a Stormwater Priority Planting Analysis. These factors include slope, soil erosion, soil permeability, distance to hardscape, distance to existing tree canopy, and floodplain proximity. Each layer was turned into a raster of classes 0-4 to be used in a weighting scheme. This scheme prioritized topography, stormwater paths, current canopy, and flooding potential to assess risk weighted with the class system.

The second analysis was a Heat Island Analysis. This used a layer for the average mean land surface temperature of June 2023, and June 2024, and then applied a similar ranking system to determine the hottest areas in the city. Trees reduce urban land surface temperatures, so the higher the land surface temperatures, the higher the priority.

The last analysis was a social equity analysis which used population density, per capita income, and college educational attainment to determine the most vulnerable communities. The demographic layers were selected because they each address different types of stress. Each was averaged in a mean and then divided by the number of demographic layers which was 3 to create a Social Equity Composite mean.

After the three analyses, there was an overall score between stormwater, heat islands, and social equity. To compute this, each mean from the stormwater analysis, urban heat island analysis, and social equity analysis were averaged to give a composite score. This composite score was ranked using the priority-level classes. After that, the priority planting levels were applied to a map and given distinct colors to represent and communicate priority in plantable areas.

Priority Planting Analysis Clipped to DACs

To clip the Priority Planting Analysis map to the disadvantaged communities tracts (DACs), the map created in the priority planting analysis was overlaid with the DACs map. After that, it was clipped to the outline of the DACs.

Appendix C

Summary of Assessed Local Government and Analyzed Geography Metrics

Geographic Unit	City of Warsaw	City of Richmond	City of Evansville	City of Elkhart
Census Block Groups	X	X	X	X
Census Tracts	X	X	X	X
Parcels	X	X	X	X
Subdivisions	X	X	X	X
Public vs Private	X	X	X	X
Rights-of-Way		X	X	
Zoning	X	X	X	X
Parks	X	X	X	X
Council Districts	X	X		X
Neighborhoods		X	X	
Voter Districts			X	X
Wards			X	