EOCENE ENVIRONMENTAL GROUP

JEFFERSONVILLE URBAN FORESTRY REPORT & WORK PLAN

APRIL 2025

Jeffersonville
INDIANA

Prepared For
CITY OF JEFFERSONVILLE

Prepared By
EOCENE ENVIRONMENTAL GROUP

Table of Contents

Appendices

Acknowledgements

Project Team

EOCENE ENVIRONMENTAL GROUP

- RICHARD HAUER, PH.D. | SUBJECT MATTER EXPERT
- MATT JOHNS | INVENTORY ARBORIST & CANOPY ANALYST
- SARAH LILLEY | CONSULTING URBAN FORESTER
- LIZ LINGO | PROJECT MANAGER
- PAOLA NANSEL | ASSISTANT CONSULTANT

CITY OF JEFFERSONVILLE

- CHAD REISCHL | PLANNING AND ZONING DIRECTOR
- ZACHARY GIUFFRE | PLANNER

Funding was provided by the Indiana Department of Natural Resources through the federal Inflation Reduction Act. The contents do not necessarily reflect the views or policies of the USDA Forest Service or Indiana DNR.

Disclaimer: Inventory data collected by Eocene Environmental Group is based on visual observations recorded at the time of inspection. Observations were made from the ground, without specialized equipment, and during standard weather conditions. Eocene is not responsible for conditions that were not visually observable at the time of inspection. Inventory data may not remain accurate after inspection due to tree growth, decline, and damage caused by environmental and anthropogenic factors. The provided tree risk ratings and maintenance recommendations are up to the client to act upon.

Introduction

The City of Jeffersonville recognizes that a healthy, well-managed urban forest is essential to community wellbeing and environmental sustainability. Trees and forests are vital to enhance quality of life, provide valuable ecosystem services, and contribute to the City's unique identity. The City has undertaken a comprehensive Urban Forestry Report and Work Plan Project to better protect and enhance its urban forest resources.

This project represents a significant investment in data collection, analysis, and planning to help Jeffersonville establish a resilient and diverse urban forest. Through this project, the City aims to make informed decisions regarding tree maintenance, planting, and long-term management. The project encompasses several key components:

- **Tree Canopy Assessment** to establish current tree coverage and analyze historical change from 2008 to determine if canopy cover has changed and why.
- **Tree Inventory** along streets and in public parks, providing valuable data on species diversity, tree health, and recommended maintenance.
- **Forest Assessment** to determine the health, diversity, and composition of the City's forested areas.
- **Eco-Benefit Study** to quantify the structural and environmental of inventoried trees.
- **Program Evaluation** to benchmark Jeffersonville against other comparable communities.
- **Work Plan** to help the City more efficiently and effectively manage its public tree maintenance.

Trees are an essential part of Jeffersonville, helping to make the City more livable and provide a sense of community. The City's trees offer numerous benefits, such as absorbing pollutants to improve air quality, providing shade to reduce urban heat islands, and filtering stormwater. Trees can increase property values, promote better physical and mental health, help calm traffic, and create more walkable neighborhoods. Well-maintained trees enhance the aesthetics of streets and public spaces, making residents feel a sense of belonging and pride in their community.

Jeffersonville's Urban Forestry Report presents the findings of these assessments and refines recommendations for management of the City's urban forest. By better understanding its tree resources, the City can maximize benefits while ensuring a sustainable and robust future urban forest.

Tree Canopy Assessment

A tree canopy assessment (TCA) provides a perspective of how much land within a geographic area is covered by tree canopy. Unlike a public tree inventory, a TCA accounts for private property trees' contributions to the urban forest resource. While a TCA tells Jeffersonville how much land is covered by trees, it does not relate the species, condition, or size of those trees. Instead, that information is ascertained through the tree inventory portion of the project.

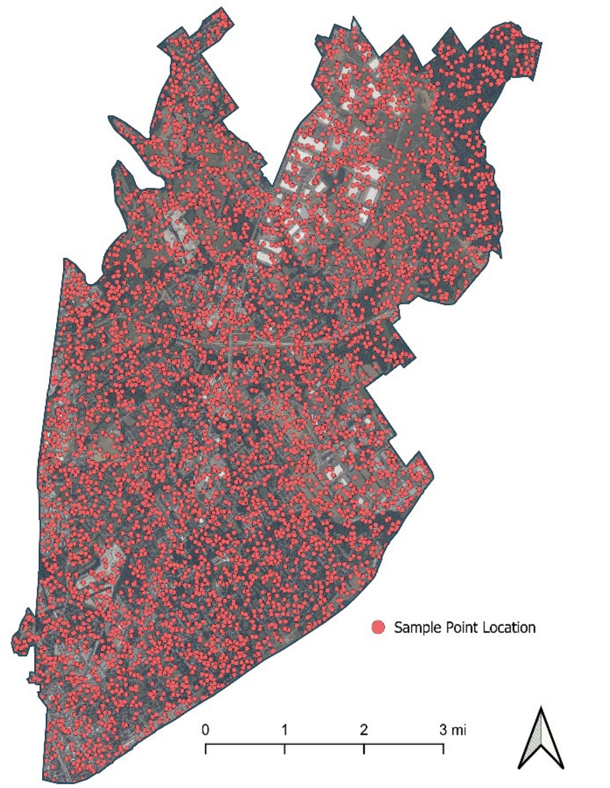


Figure 1. Sample point distribution in the project location.

Methodology

Jeffersonville's current and historical land cover was estimated through a sample point assessment (Figure 1). With this methodology, geospatial points are randomly generated and then classified by a reviewer. The points were classified as tree, grass, impervious surface, water, or bare soil. High-resolution aerial imagery from the National Agriculture Imagery Program (NAIP) was used.

To perform the current land cover analysis, 6,000 points were classified using the most current 2022 NAIP imagery with 60-centimeter accuracy. Historical tree canopy cover was assessed using 2016 and 2008 NAIP imagery with 1-meter resolution. Using the same sample point methodology, 3,000 points were classified for each historic time period. In addition to the City-wide TCA, the canopy assessment for each period was geographically disaggregated into census tracts and City planning districts.

Figure 2. Example land cover classes assessed for the project.

As a quality control accuracy assessment, a secondary evaluator classified a 10% sample of locations. By comparing how the two evaluators classify the land covers, we can determine the accuracy level of the primary evaluator. For this project, we exceeded the desired level of 95%, with tree canopy accuracy averaging 96.5% for the three time periods.

City-Wide Land Cover

A City-wide land cover analysis was conducted to determine the change in land covers over time (Figure 3), current land covers (Figure 4), and change in tree canopy from 2008 to 2022 (Figure 5). A summary of the findings for each time period is below.

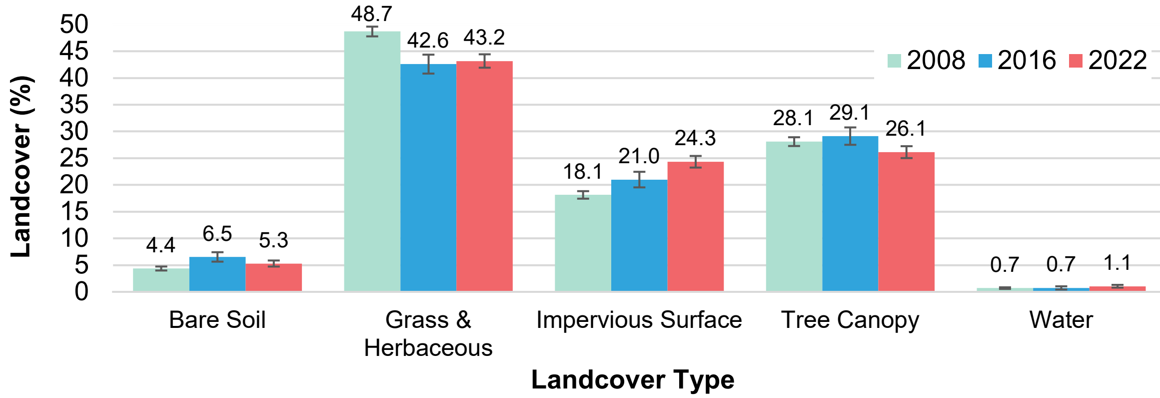


Figure 3. Comparison of percentage of land cover types for 2008, 2016, and 2022.

Historical (2008 and 2016): Jeffersonville's land cover analysis for 2008 shows the City comprised of 48.7% grass and herbaceous, 28.1% tree canopy, 18.1% impervious, 4.4% bare soil, and 0.7% water. In 2016, grass and herbaceous remained the most prominent classification, covering 42.6%. Tree canopy is the next most prominent classification with 29.1%, followed by impervious surfaces at 21.0%, bare soil at 6.5%, and water at 0.7%.

Current (2022): The current land cover, including tree canopy, for 2022 is shown in Figure 4. Grass and herbaceous (non-tree) vegetation accounted for over 43% of the total land cover in Jeffersonville. Tree canopy was the next most dominant land cover at 26.1%, with impervious surfaces (such as structures and roads) accounting for 24.3%. The City's two least dominant land covers were bare soil and water, comprising 5.3% and 1.1%, respectively.

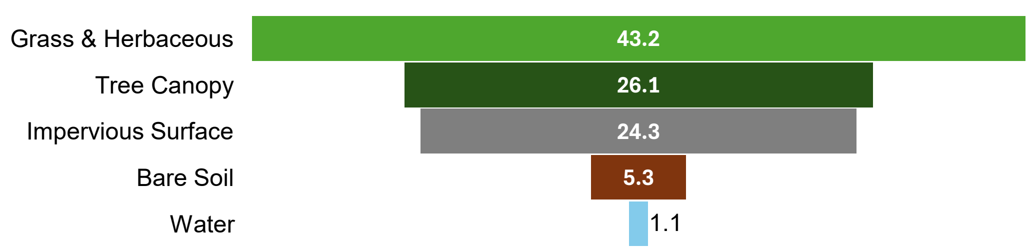


Figure 4. Distribution of land cover types in the project area.

Tree Canopy Change Comparison: From 2008 through 2022, there has been a downward trend in the percentage of tree canopy from 28.1% to 26.1% (Figure 5). There was a similar decrease in grass and herbaceous vegetation, from 48.7% in 2008 to 43% in 2022. Correspondingly, there was an increase in impervious surfaces, from 18.1% in 2008 to 26.1% in 2022. The most likely explanation for these changes is an increase in development, which has resulted in the loss of trees over time.

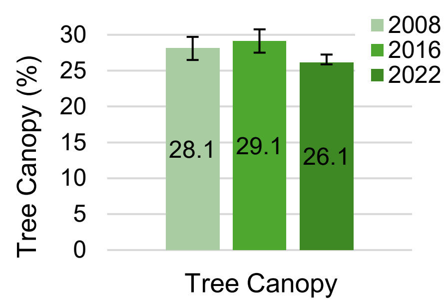


Figure 5. Tree canopy change comparison.

Planning District Canopy Cover

Tree canopy change was further analyzed at the planning district level. Land covers were assessed for each of the City's 11 districts over the three time periods (2008, 2016, and 2022) to evaluate change on a more local scale. Also, by determining areas with the lowest current canopy cover, the City can use that data to assist in future tree planting locations.

Historical (2008 and 2016): In 2008, the district with the lowest canopy cover was Port of Indiana (8.7%), with Downtown the second lowest (14.5%). The highest canopy cover was in the Oak Park district (38.5%); the second highest tree canopy cover was in River Ridge (34.4%). Other districts ranged from 20.9% canopy cover (Northwest Jeffersonville) to 33.6% cover (Lentzier Hills).

The increase in City-wide canopy cover from 2008 to 2016 is reflected in the individual neighborhoods. Downtown was the lowest district at 5.8%, and Port of Indiana was second lowest at 9.8%. Oak Park maintained the highest canopy cover (41.0%), and River Ridge was second highest (37.0%). While most districts (8 of 11) increased or maintained their canopy cover from 2008 to 2016, Downtown sharply declined from 12.6% to 5.8%. Part of this decrease can be attributed to construction of the Big Four Station Park. The 2008 aerial imagery shows mature tree cover in the future park area; however, the 2016 imagery reflects the new park with most of the mature trees removed.

Current (2022): The district with the lowest current canopy cover is Downtown at 12.6%; Port of Indiana is the second lowest canopy cover district with 14.7%. The district with the highest canopy cover is Oak Park at 37.2%, and River Ridge is the next highest at 31.8%. From 2016 to 2022, tree canopy decreased in 9 of the 11 districts; Port of Indiana and Downtown are the only districts that increased in canopy cover during that timeframe. The recent increase in the Downtown's canopy was likely influenced by the growth of new trees planted for the Big Four Station Park project.

Tree Canopy Change Comparison: From 2008 to 2022, tree canopy cover tends downward in all districts except Port of Indiana and Northwest Jeffersonville (Figure 6). The most notable decline was in the Vissing Park district, which went from 31.9% in 2008 to 21.7% in 2022. This equates to a loss of almost 32% of the Vissing Park district's canopy over 14 years. Reviewing aerial maps, this appears to be due to development of forested areas, including removal of mature trees in Vissing Park itself to construct park amenities.

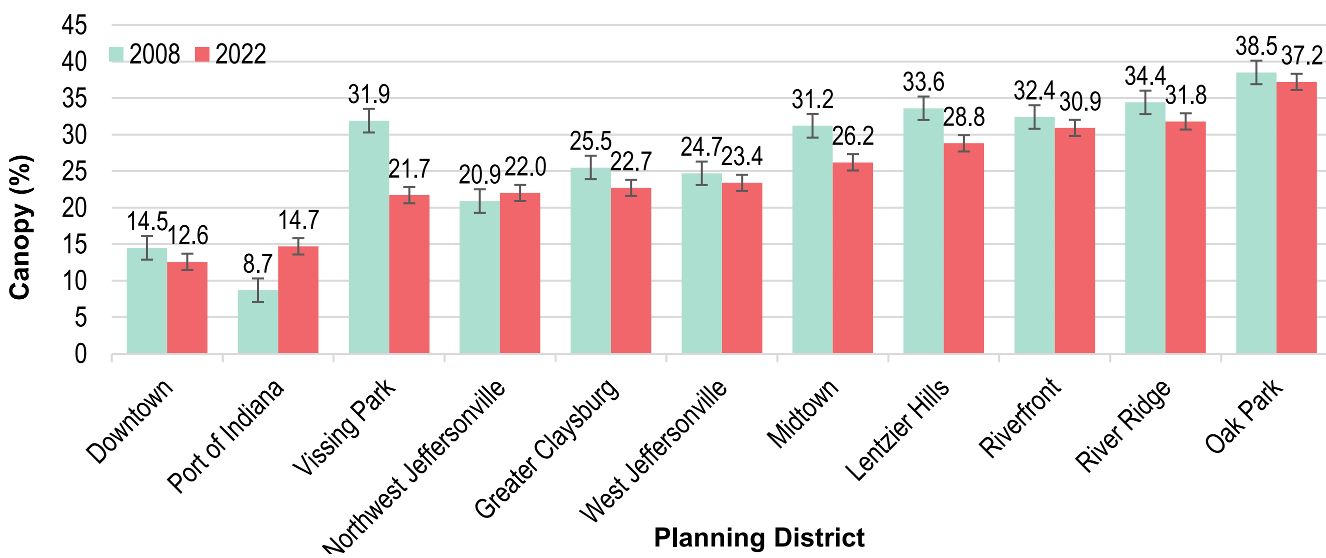


Figure 6. Percentage of tree canopy by planning district in 2008 compared to 2022.

Summary

There was a slight increase in City-wide tree canopy from 2008 to 2016 (28.1% to 29.1%) before the canopy decreased to 26.1% in 2022. The increase between 2008 and 2016 could be due to the expansion and growth of existing trees. In addition to development, emerald ash borer (EAB) likely played a role in the canopy decline from 2016 to 2022. EAB, an invasive beetle that infests and kills ash trees, has devasted ash tree populations across the country. According to official records, it was first discovered in Clark County, Indiana, in 2011 and nearby Jefferson County, Kentucky, in 2009 (EAB Network State Detection Table, n.d.). EAB damage typically peaks between 5 and 10 years after the initial date of detection (Sadof et al., 2017). This timeframe lines up with the corresponding decrease in canopy between 2016 and 2022.

Overall, canopy cover decreased from 28.1% in 2008 to 26.1% in 2022. This equals the loss of 420 acres of tree canopy, or an average annual loss of 30 acres. Since a majority of land within Jeffersonville is privately owned, the City cannot prevent continued tree canopy loss without addressing private property trees. While the City should lead by example and invest resources in its trees, public support and participation are critical to arrest the loss of tree canopy and its associated benefits.

Recommendations to Maintain and Increase Canopy Cover

- ✓ *Plant new trees while encouraging canopy growth of existing City trees*
- ✓ *Increase urban forest and tree public education resources (in-person trainings, expert lectures, guided tree walks)*
- ✓ *Establish partnerships (schools, non-profits, and other community-based groups)*
- ✓ *Explore tree planting and maintenance incentives or grants for private property*
- ✓ *Continue to complete canopy assessments as new imagery becomes available (approximately every 3-5 years)*

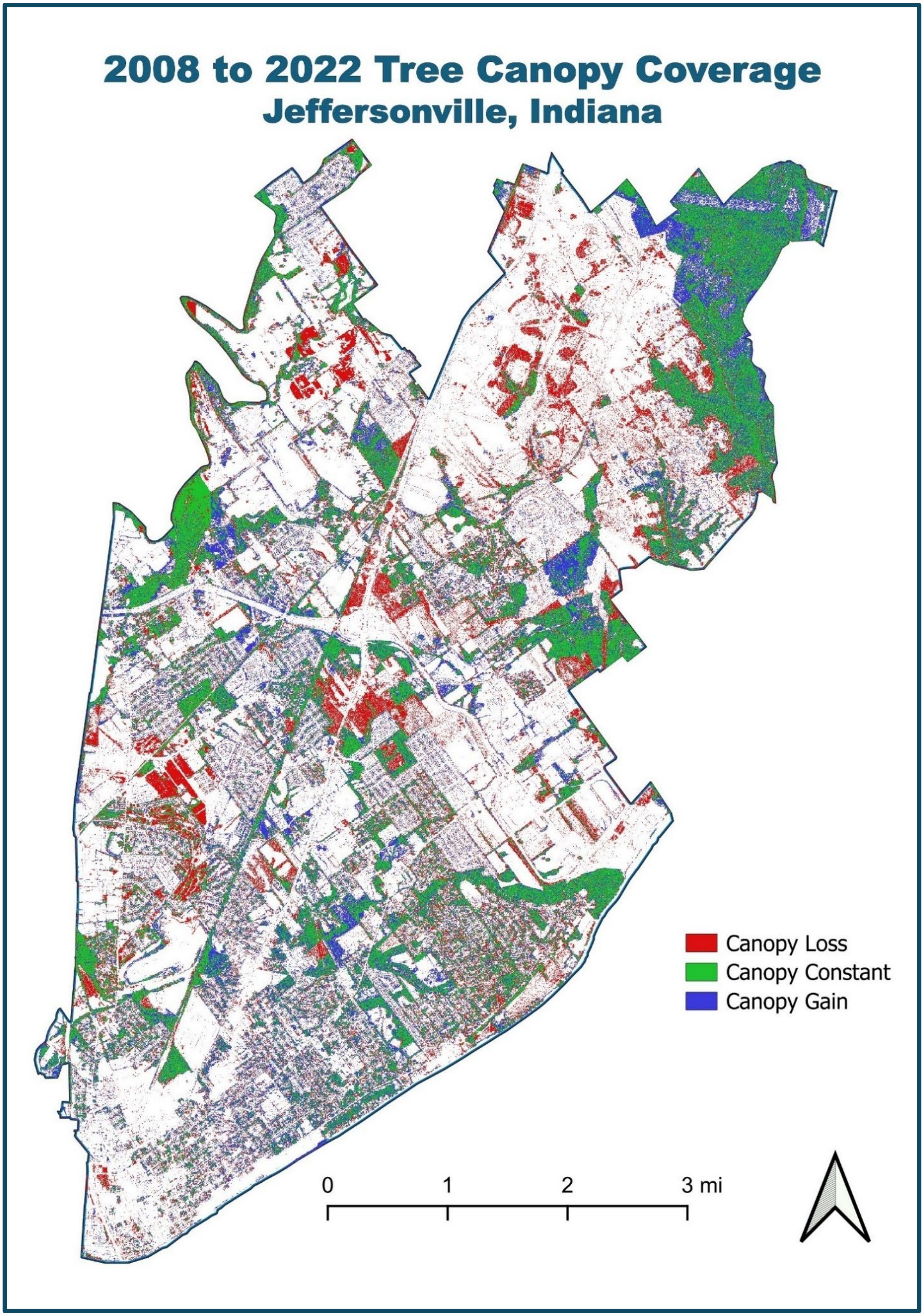


Figure 7. Map of project area depicting where tree canopy has been lost, gained, and remained constant from 2008 to 2016.

Tree Inventory Assessment

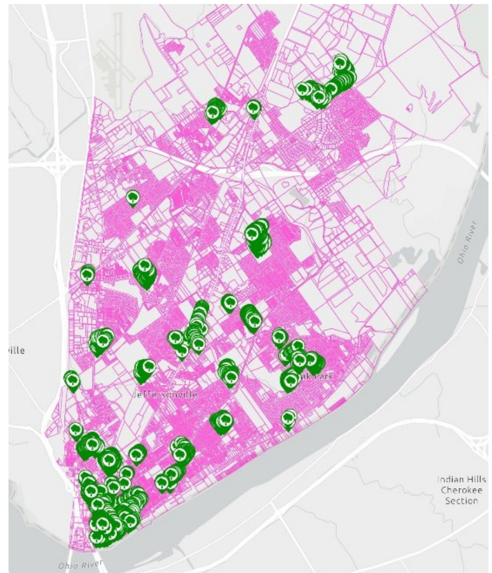


Figure 8. Map depicting distribution of inventoried trees.

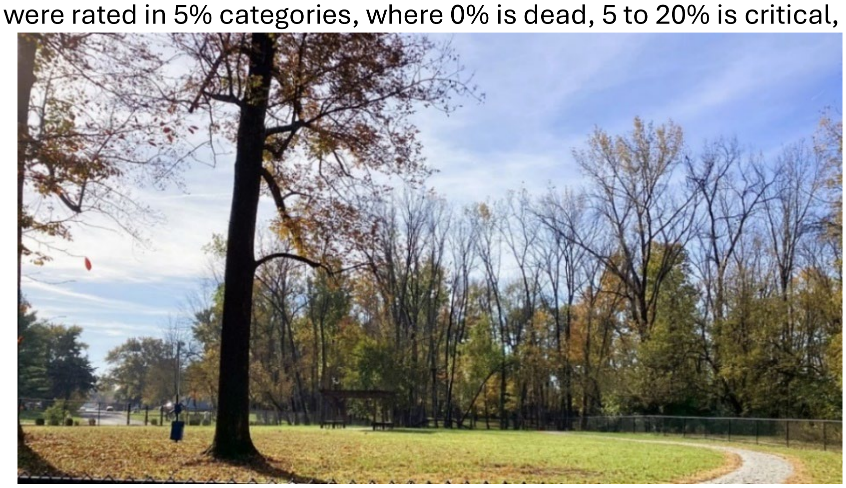
A tree inventory and assessment of public trees in parks and selected streets was conducted to systematically identify tree and site conditions. A public tree inventory provides valuable information on Jeffersonville's urban forest resource, such as the total number and distribution of trees. It also relates tree condition, size, and recommended maintenance. An accurate inventory can efficiently allocate resources and budget to prioritize maintenance recommendations. In turn, this increases the benefits trees provide the community.

For the City of Jeffersonville, Eocene Environmental Group collected data on a total of 3,024 trees located in selected parks, public locations, and street segments throughout the summer and fall of 2024. Attributes collected included tree species, size, location, condition, maintenance, and priority. A complete list of the attributes is located in Appendix A. All data was collected by an arborist certified by the International Society of Arboriculture (ISA), and an ISA Board Certified Master Arborist conducted onsite training, remote data checks, and quality control.

Methodology

The City provided a geographic information (GIS) file of parks, facilities, and streets to be inventoried, which was uploaded to our data collection and urban forest management software, FieldNote. The inventory arborist was equipped with a GPS-enabled iPad with FieldNote to collect tree inventory data. The inventory arborist collected data on maintained trees during the summer and fall of 2024. Tree attributes collected included species, size, condition, maintenance, and priority.

Tree diameter at 4.5 feet above the ground (DBH) was measured with a forester's diameter tape. Tree condition followed the Council of Tree and Landscape Appraisers (CTLA) guidance, which assigns a rating from 0 to 100%. For this inventory, trees were rated in 5% categories, where 0% is dead, 5 to 20% is critical, 25% to 40% is poor, 45% to 60% is fair, 65% to 80% is good, and 85% to 100% is excellent with few to no observable defects. The primary recommended tree maintenance action and corresponding maintenance priority were determined based on tree and site conditions. Damaged sidewalks, land use, and site type were also recorded for each tree. Further, additional notes were taken to record issues of concern.



Species Composition and Diversity

Jeffersonville's tree species were relatively diverse, with many new species recently planted. There were 117 unique species, 66 genera, and 41 families inventoried. The most prominent species were red maple (337, 11%), sweetgum (170, 6%), and Callery pear (118, 4%) (Figure 9). The top genera were *Acer* (maple), comprising 16.5% of the population; *Quercus* (oak), with 6.8%; and *Prunus* (cherry), with 6.5%. For families, *Rosaceae* (e.g., cherry) was 17.5% of the population; *Sapindaceae* (maple) made up 16.8%; and Fabaceae (e.g., honey locust) was 8.9%.

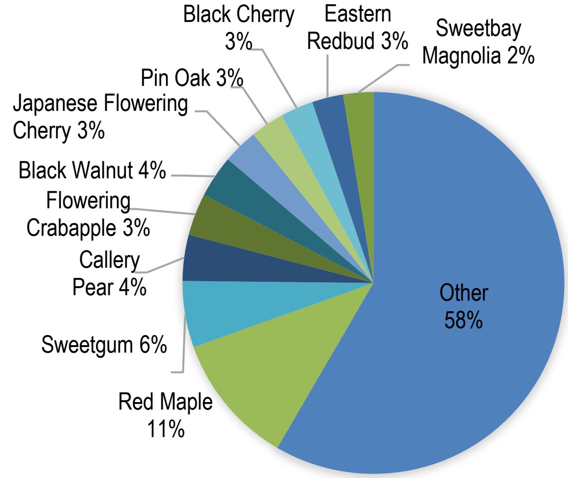


Figure 9. Species composition of inventoried trees.

Established metrics for species diversity call for tree composition to limit a single species, genus, and family to a maximum percentage. The most recent guidance is the 5-10-15 recommendation, stating that up to 5% of any species, up to 10% of any genus, and up to 15% of any family is ideal (Watson, 2017). Figure 10 uses a bar to illustrate the species, genus, and families exceeding these thresholds. This is the strictest standard benchmark, with others being 10-20-30 and 5-10-20 (Galle et al., 2021). While 5-10-15 may not be possible for all urban forests, it is a valuable metric and should be accounted for in planning, specifically planting.

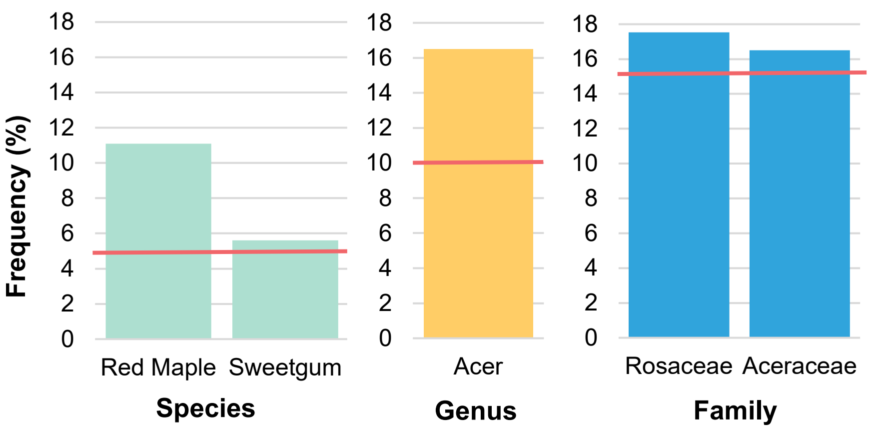


Figure 10. Species, genus, and families exceeding 5-10-15% diversity guidelines depicted by a bar at the percentage thresholds.

Age Distribution

Tree size, expressed as trunk diameter measured in inches, is often used to represent tree age. Jeffersonville's substantial number of small, young trees reflects a strong recent planting initiative, with over 50% of the inventoried trees' diameters measuring 6 inches or less. This is highlighted by Figure 11's reverse-J curve, which is considered ideal as it indicates the City's support of trees and new tree planting. This unequal age distribution is an essential goal of a sustainable urban forest, with a mix of young and old trees to maintain consistent canopy cover (Clark et al., 1997), balance ecosystem services, and increase resilience.

While the recent planting effort sets Jeffersonville on the right path to grow its urban forest, care must be taken to

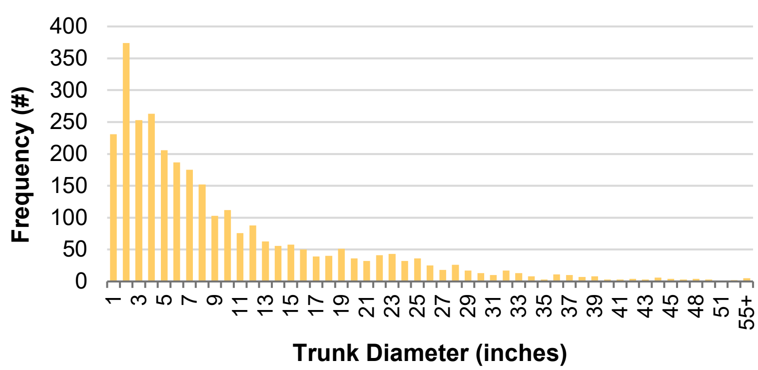


Figure 11. Size distribution of inventoried trees.

maintain the older trees while growing the young trees. While it is inevitable that trees age and develop defects or die, necessitating their removal, the next generation of trees must be adequately maintained to fill the gaps.

Condition

Tree condition is assessed based on the health and structure of the tree's roots, trunk, branches, twigs, foliage, and buds. In examining Jeffersonville's tree condition, almost 90% of trees were rated good or excellent (Figure 12). The City's overall average rating of 76% indicates a relatively healthy tree population. To increase the average rating, the City should continue to maintain existing and new trees as they are added. For example, by removing the 58 existing dead trees, Jeffersonville's rating will increase to over 77%.

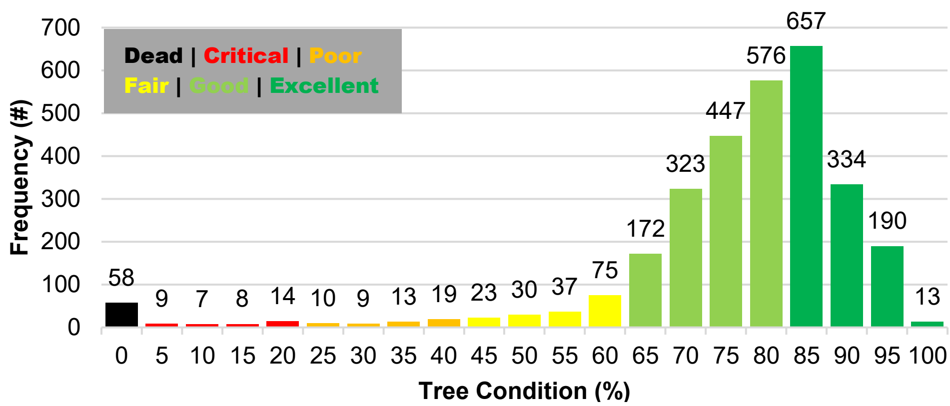


Figure 12. Tree condition of inventoried trees from 0-100% classified as dead, critical, poor, good, excellent.

Tree Maintenance and Priority

Tree maintenance recommendations collected as part of an inventory can be used to help develop a multi-year budget, increase public safety, increase overall tree health and longevity, and improve the overall aesthetics of a community. In Jeffersonville, 20.2% (611) of trees were recommended for maintenance, which included monitoring. Excluding monitoring from that total, 12.6% of trees required active maintenance such as pruning or removal. Active maintenance was further broken down into priority levels, with priority 1 being most important and priority 3 being least urgent. Monitoring was not assigned a maintenance priority level; instead, monitoring should be performed annually and after storms or other

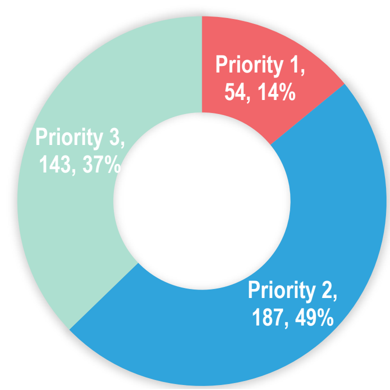


Figure 13. Maintenance priority level for trees with recommended maintenance.

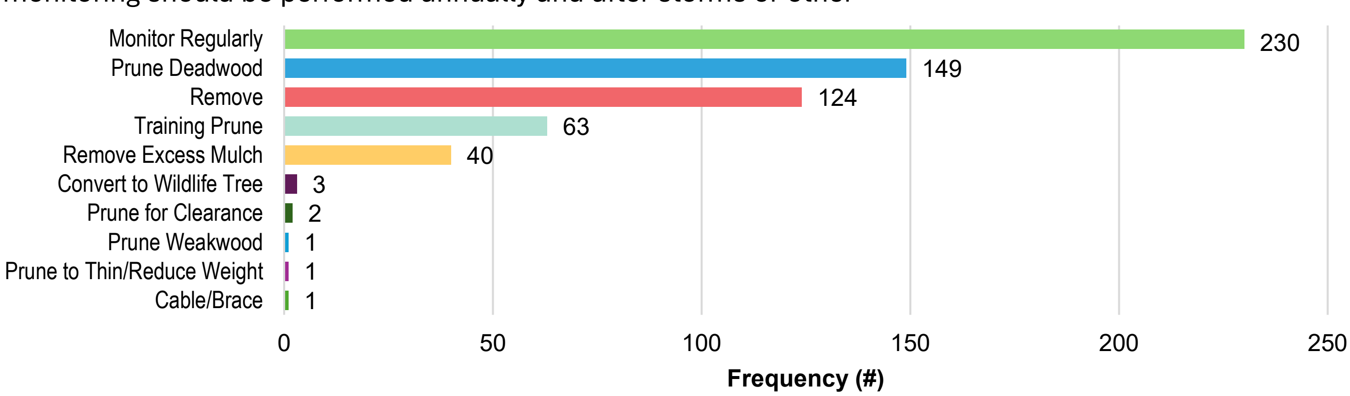


Figure 14. Counts of recommended maintenance types for inventoried trees.

significant weather events. As seen in Figure 13, the majority (86%) of priority assigned to maintenance tasks was Priority 2 or 3. The more urgent maintenance, priority 1, encompassed only 14%, or 54 trees. Of the 3,024 trees inventoried, those high priority trees account for only 1.8% of total trees. Similar to tree condition, this is an indicator of a maintained tree population.

Site Type

Of the 3,024 trees inventoried, the vast majority of trees (76%) were located in sites categorized as open (Figure 15). The most restrictive planting sites are typically bumpouts (2%) and tree pits (2%) surrounded by pavement on all sides. Trees growing in smaller, restricted spaces are more likely to outgrow their space, decline in health as they age, and potentially damage nearby sidewalks, curbs, and roadways. Jeffersonville's high percentage of open site types is conducive to future healthy tree growth and canopy expansion.

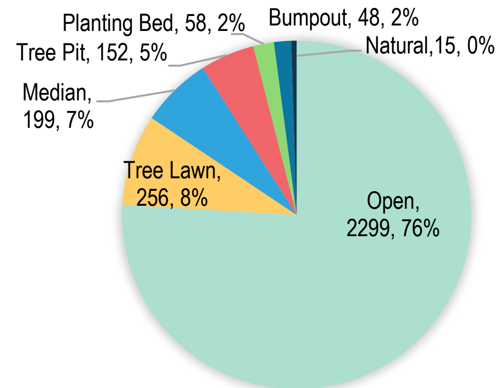


Figure 15. Percentage and number of site types associated with inventoried trees.

Sidewalk Damage

While damage to sidewalks is a frequent concern of cities nationwide, only 7 out of the 3,024 trees (0.2%) inventoried in Jeffersonville were adjacent to a cracked or lifted sidewalk. To ensure that the number remains low, Jeffersonville should continue to plant species that are appropriately sized for the space.

Table 1. Frequency of cracked and lifted sidewalks adjacent to inventoried trees.

Sidewalk Damage	Frequency (#)	Frequency (%)
Cracked	4	0.13
Lifted	3	0.10
None	3017	99.77

Land Use

As part of the tree inventory assessment, land use was classified to determine tree distribution amongst parks, facilities, residential sites, commercial use, vacant sites, and other locations. For Jeffersonville's inventory, the majority of trees surveyed were located in parks (73%), followed by facilities (15%), and residential (6%). Only 6% of the trees inventoried were located in commercial (2%), other (2%), and vacant (2%). Typically, parks and vacant spaces have the most open space for trees to grow, with commercial areas often being more constrictive and challenging for healthy tree growth and canopy. Additionally, if multiple departments within a municipality are responsible for tree care, this attribute can be used to assist in allocating staff and responsibilities.

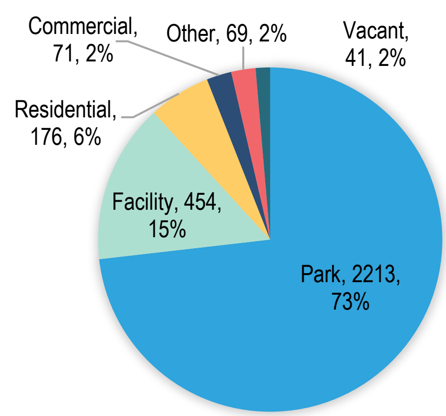


Figure 16. Percentage and number of land use types associated with inventoried trees.

I-Tree Eco-Benefits Assessment

Trees provide a multitude of services, including environmental, social, and aesthetic benefits. The i-Tree peer-reviewed suite of software, released by the USDA Forest Service in 2006, is considered one of the most effective and efficient methods to capture tree values. Using i-Tree Eco, tree benefits are quantified to associate a monetary value to Jeffersonville's tree population. The i-Tree value can then be balanced against the cost to plant and maintain City trees. However, it must be noted that i-Tree assessments do not account for all trees benefits, such as aesthetic, cultural, and mental health values. Additionally, a majority of inventoried trees were located in parks, so energy savings data related to nearby buildings was not collected.

Jeffersonville's 3,024 inventoried trees were analyzed using the most current version of i-Tree Eco (6.0.35). The replacement value of those trees was estimated at $6.26 million, based on the cost of replacing them with new trees of comparable value. Jeffersonville's trees also provide a carbon storage value of $546,000 and annual values of $17,140 (pollution removal, carbon sequestration, and storm water runoff avoidance). Since the City's tree population is young, those values will increase as the trees mature. A summary of i-Tree calculated values and descriptions is shown in Table 2. The full i-Tree Eco report (Appendix I) provides a more in-depth description of tree benefits and calculations.

Table 2. I-Tree eco-benefits summary by ecosystem metric.

Ecosystem Metric	i-Tree Measurement	I-Tree Value ($)	Description
Pollution Removal	1,357 pounds/year	2,820 annually	Quantity and value of air pollutants removed (ozone, carbon monoxide, nitrogen dioxide, particulate matter, and sulfur dioxide).
Carbon Storage	1,262 tons	546,000	Carbon stored in a tree over its lifetime and released when it dies.
Carbon Sequestration	26.39 tons	11,400 annually	Carbon sequestered as trees put on annual new growth, increases with the size and health of the tree.
Oxygen Production	70.36 tons		Creation of oxygen through photosynthesis.
Avoided Runoff	327,000 gallons/year	2,920 annually	Precipitation and associated pollutants enter waterways or are treated as wastewater. Trees intercept precipitation, promoting soil infiltration and storage.
Replacement Value		6,260,000	Cost to replace trees with the same species, size, and condition.

Summary

Overall, Jeffersonville's inventoried trees are healthy and in good condition. Although over 20% of the trees had a maintenance recommendation, most only needed ongoing monitoring. The City has a very young tree population, which indicates the potential for the canopy to expand over time as the trees grow. Conversely, trees are more likely to develop defects as they age that require maintenance. The City's tree species are also relatively diverse, with numerous inventoried species and only a few species, genus, and families exceeding the strictest diversity threshold.

Recommendations to Maintain the City's Tree Population

- ✓ *Undertake recommended maintenance as shown in the work plan*
- ✓ *Continue planting a variety of species and limit planting of those that exceed diversity thresholds*
- ✓ *Ensure preservation of mature trees to balance young tree population*
- ✓ *Provide adequate care to young trees to ensure healthy growth*
- ✓ *Update inventory as trees are removed or added*
- ✓ *Develop a tree inventory assessment and report every 5 to 10 years*

Forest Plot Assessment

While a public tree inventory studies individual trees and their contribution to the urban forest, it does not account for forested public land. A field-based assessment of those wooded areas explores forest health, structure, composition, and canopy cover. This increases understanding of the entirety of the urban forest, particularly when coupled with other sources of information such as a tree inventory.

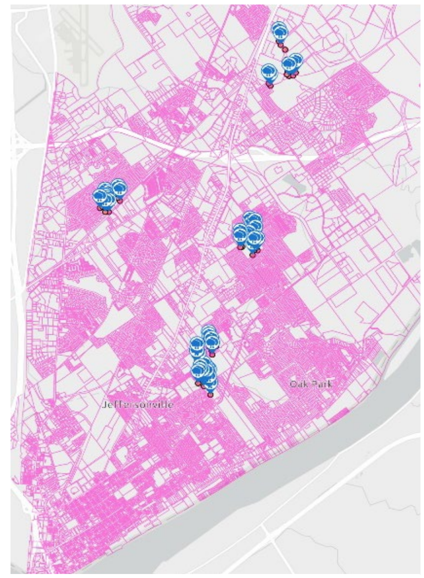


Figure 17. Map depicting forest plot distribution.

Methodology

An assessment of forested areas pre-determined by the City was conducted using randomized stratified sampling. A total of 50 plots 1/5 acre in size were assessed over approximately 90 acres of parkland. The center of each plot was located using an iPad with internal GPS. Similar to the tree inventory, the inventory arborist used FieldNote to collect the plot attributes. Data collected included species composition, dominant species, ground layer composition, invasive species rating, canopy cover, overall forest rating, and recommended maintenance. Descriptions of the forest plot attributes are in Appendix B.

Dominant Canopy Species

Sweetgum was the most dominant species in the canopy in 17 out of 50 plots (34%). Tulip tree dominated eight plots (16%), while sycamore was dominant in six plots (12%) (Figure 18). These three species comprised 62% of the dominant canopy trees assessed. These species are considered pioneer species, often associated with young, newer growth forests.

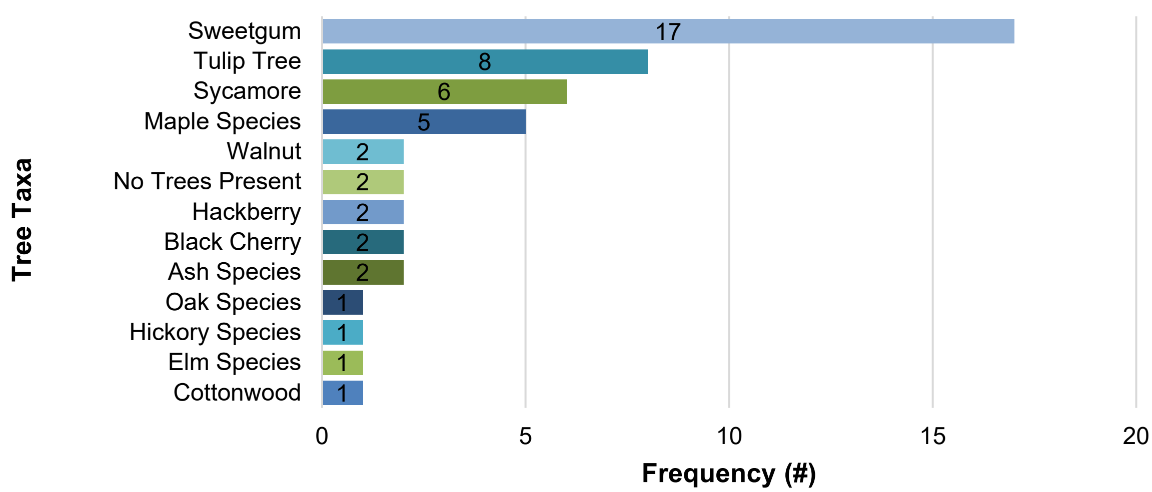


Figure 18. Frequency of dominant canopy tree species in forest plots.

Tree Composition and Diversity

The canopy layer and understory tree composition were assessed, with 29 different tree types noted. Sweetgum was the most frequently observed tree (Figure 19), found in the understory of 17 plots (34%) and canopy of 24 plots (48%). Maples were the next most frequent and were found in the understory of 13 plots (26%) and the canopy of 17 plots (34%). Hackberry was the third most observed, growing in 15 understory (30%) and 13 canopy (26%) plots. Other frequently observed trees were oaks, sassafras, ash, elm, and tulip tree. The understory and canopy of two plots (0.4%) consisted of mowed lawn and open space with no trees present. It is also worth noting that the invasive species Callery pear was found in the canopy of one plot and the understory of four plots.

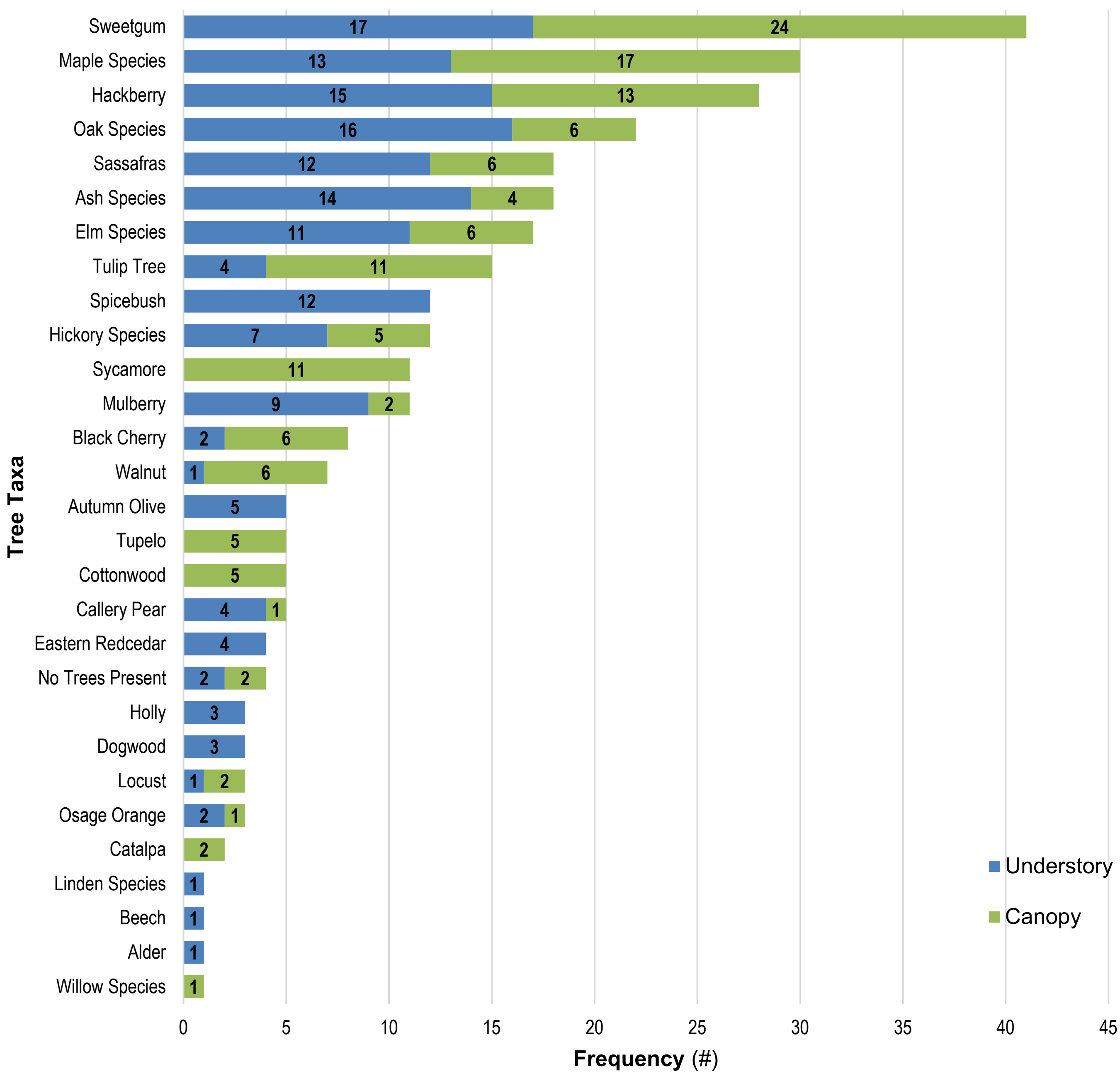


Figure 19. Frequency of trees found in the understory and canopy layer of forest plots.

Ground Layer Composition

The ground layer, consisting of tree seedlings, shrubs, herbaceous plants, and vines, is another component of a multilayered and diverse urban forest. The composition of this layer provides insight into the types of invasive species found in public forests. In fact, invasive honeysuckle (shrub and vine) was the most commonly found plant in the ground layer of Jeffersonville's forests, appearing in 47 of the 50 plots (94%). The other two most observed plants were invasive privet in 84% of plots and goldenrod in 36% of the plots. Honeysuckle and privet, both invasive plants, were found in all plots except the two mowed grass plots. Other plants found included blackberry, greenbrier, spicebush, viburnum, ash, buckthorn, and snakeroot.

Invasive Species Rating

Of the 50 surveyed plots, only two (4%) had a high level of invasive species proliferation. The majority of plots were rated as medium (25 plots, 50%) and low (21 plots, 42%); the remaining two plots (4%) had no invasive species and consisted of mowed grass (Figure 20). If these percentages were scaled to the City's 90 acres of woodland, it would equate to invasive species present in over 86 acres. Although that may seem like a high level of invasive species invasion, less than four acres would be considered to have a high level of invasive species.

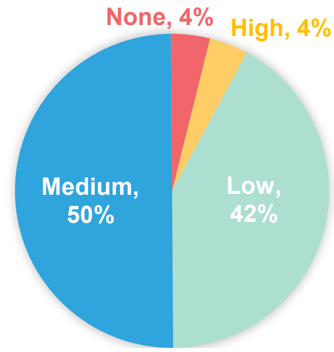


Figure 20. Invasive species ratings for forested plots.

Canopy Cover

Canopy cover for the 50 plots varied from 0% coverage (2 plots) to 95% (3 plots) (Figure 21). The most common canopy coverage percentages were 70%, 75%, and 80% (10, 7, 7 plots), representing almost 50% of the total plots surveyed. The average coverage of City forested areas was 62.8%. Based on the assessment of 90 acres of forested parkland, this equates to the preservation of nearly 57 acres of trees within the City. Although these forested park areas encompass only a fraction of Jeffersonville's total land, it is imperative that the City continues to protect and grow the canopy in these locations.

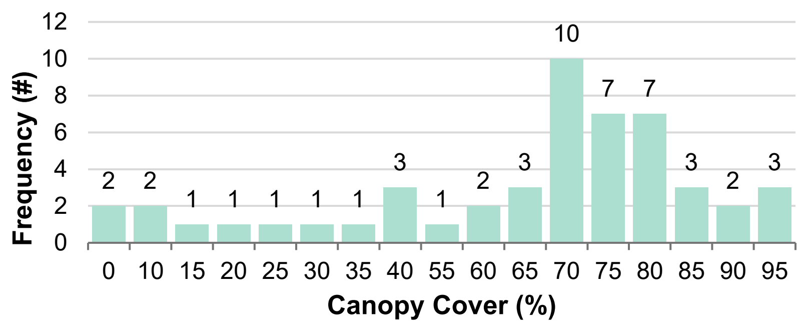


Figure 21. Canopy cover in forested plots.

Recommended Maintenance

For each plot, a primary maintenance option was recommended. While tree planting was recommended for 3 of the plots (6%), invasive species removal was recommended for 23 of the plots (46%). The remaining 24 plots had no recommended maintenance (Figure 22). However, as invasive species are removed, particularly in the plot with Callery pear in the canopy, gaps may be created in the corresponding forest layer that require replanting.

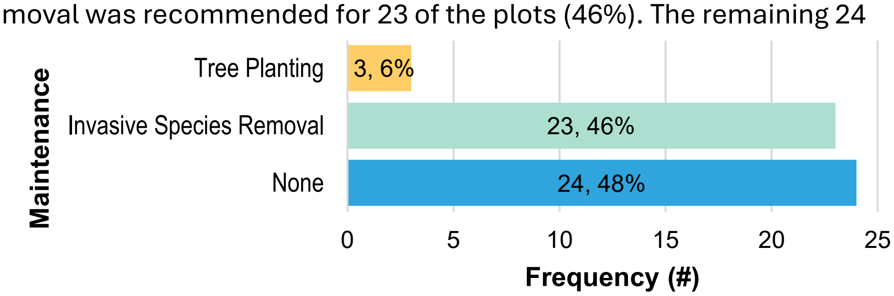


Figure 22. Frequency of recommended maintenance in forested plots.

Overall Forest Rating

For each sample plot assessed, the inventory arborist developed an overall forest rating from 1 to 5, with 5 being the highest quality forest. All collected data and observed conditions, such as species composition, invasive plant presence, canopy cover, and recommended maintenance, factor into this rating. Figure 23 shows that the most common rating was 3 (52%), followed by 4 (36%), with 1, 2, and 5 each making up 4% of the ratings. The overall forest score was 3.2, which represents a mid-value forest that can be characterized by the presence of invasive plants and may be lacking a canopy layer.

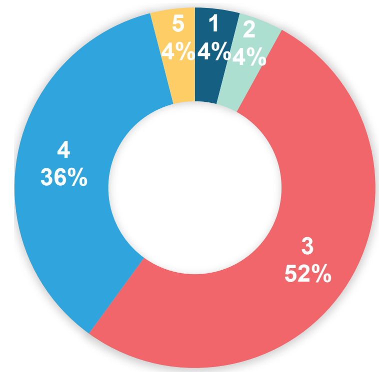


Figure 23. Comparison of overall forest rating in forested plots.

Summary

A city's natural resources, such as forested land, provide numerous benefits, including improved air and water quality, climate resilience, and increased public health. These benefits can be maintained or increased through proper inspections and maintenance of the City's forests. Overall, Jeffersonville's natural forested areas are in average condition, with a mix of native species in the canopy and understory. While the 5-10-15% species diversity guideline mentioned in the tree inventory section is important to consider in the context of urban forest management, natural wooded and forested areas generally have much lower diversity. While the lower tree diversity in Jeffersonville's forests is not necessarily a cause for concern, improving diversity to increase resilience should remain a goal when planting these areas.

Invasive species presence is often an indicator of forest health, as invasives can outcompete native vegetation, lower species diversity, and reduce wildlife habitat. Although not widespread in the canopy, invasive species were present in the ground layer of most plots surveyed. Without intervention, the proliferation and dominance of invasive species will increase in the plots. For example, invasive Callery pear in a plot understory may eventually become a canopy tree and possibly a dominant species in that plot.

Recommendations to Manage City Forests

- ✓ Initiate invasive species control intervention efforts using mechanical and chemical controls
- ✓ Plant native trees in areas lacking canopy with a focus on suitability and species diversity
- ✓ Implement a systematic monitoring and maintenance program to address invasive species or other issues
- ✓ Engage volunteers through new tree planting events

Conclusion and Recommendations

Conclusion

Jeffersonville's urban forest presents a complex picture of both opportunities and challenges. The presence of many young trees indicates a potential for canopy growth and increased tree benefits. However, the current state of operations being understaffed and underfunded for tree care poses a threat to the sustainability of the City's urban forest. The tree canopy assessment showed a loss of canopy cover, which is a clear indicator that immediate action is required to prevent further canopy loss.

Despite these challenges, the overall health of the forest remains average and the inventoried trees were in good condition. The inventory revealed a substantial tree replacement value with notable annual environmental values, emphasizing the economic importance of maintaining and enhancing this natural asset. In addition to those quantified benefits, trees also help increase human physical and mental health (Dhal, et al., 2025) and provide residents with a sense of community (Jennings & Bamkole, 2019).

To ensure a vibrant future for the health and expansion of Jeffersonville's urban forest, public participation is essential. Engaging with the community through tree care, tree planting, and education can help address limited resources. Through these collaborative efforts, Jeffersonville can establish the framework for a resilient, diverse urban forest that benefits both the environment and its residents.

Recommendations

Engage:

- ✓ *Establish partnerships with schools, non-profits, and/or other community-based groups*
- ✓ *Increase urban forest and tree public education through trainings, lectures, and guided tree walks*
- ✓ *Explore tree planting and maintenance incentives or grants for private property*
- ✓ *Host volunteer events such as tree plantings or an Arbor Day celebration*

Monitor and Assess:

- ✓ *Complete canopy assessments as new imagery becomes available (approximately every 3-5 years)*
- ✓ *Develop an assess and report on the public tree population every 5-10 years*
- ✓ *Implement a systematic tree and forest monitoring program*
- ✓ *Update inventory as trees are removed or added*

Grow and Maintain:

- ✓ *Undertake recommended maintenance as shown in the work plan*
- ✓ *Continue planting diverse tree species with a focus on "Right Tree, Right Place, Right Reason"*
- ✓ *Ensure preservation of mature trees*
- ✓ *Provide adequate care to young trees to ensure healthy growth*
- ✓ *Initiate invasive species control in forested areas*

Work Plan

Operational and Program Review

A study of Jeffersonville's urban forestry operations is essential to assessing the City's resource allocation to urban forestry. Jeffersonville's funding, tree maintenance activities, and staffing were benchmarked against comparable communities throughout the United States. Benchmarking information is based on a national assessment of municipal tree management throughout the United States (Hauer and Peterson, 2016). For the purpose of this review, the City's 2023 estimated census population of 51,235 people and its Midwest census geographic region were used. Comparisons are made nationally, population-based, and for the census region. Unless otherwise noted, all benchmark figures are based on Jeffersonville's population group. To account for price changes from the study date to current time, 2014 dollars were converted to 2025 (real) dollars using the U.S. Bureau of Labor Statistic's Consumer Price Index Inflation Calculator.

Community and Staff Profile

Table 3. Benchmark assessment of Jeffersonville's community and staff profile.

Benchmark	Jeffersonville's Current Situation
Street Tree Responsibility: 74% of Midwest communities were primarily responsible for street trees	■ Adjacent property owners primarily responsible
Years with a person responsible for tree care: 31 years; 33 years in the Midwest	■ No employee currently responsible for tree care
Staff qualification: 77% of communities had a certified arborist on staff	■ No certified arborist identified as on staff
Staff responsible for trees: arborist/forester located in Parks and Recreation Department	■ No arborist or forester; duties split between City departments
Staffing: 6.3 Full Time Equivalent (FTE) public employees involved in tree program, including managers	■ Unknown
Starting wage for city forester/forestry manager: $38.29 hourly wage in Midwest	■ No city forester on staff

Based on communities in the Midwest and those with similar populations, Jeffersonville is not adequately staffed to manage its urban forest. Tree management is currently divided between Parks, Streets, and Planning and Zoning. Ideally, all tree activities would be centered under an Urban Forestry department; however, a city arborist/forester is most commonly located in the Parks department. Jeffersonville does not have a public employee currently dedicated to managing the City's trees. It is vital for the City to fill this role, with one option being to train an existing employee as an arborist. The other option could be to hire a new staff member, either full-time or part-time, to fill this role. In terms of budgeting, the City should plan on a city forestry manager making approximately $38 per hour, or $79,000 annually. Further details on job titles and wages are available in Hauer and Peterson's 2016 published work, *Municipal Tree Care and Management in the United States*.

Tree Care Funding

Table 4. Benchmark assessment of Jeffersonville's tree care funding.

Benchmark	Jeffersonville's Current Situation
Public funding for trees (pruning, removals, education): 89% had specifically allocated funding; 88% in Midwest	■ Yes, funding is specifically allocated for tree care
Budget per public tree: nation-wide $50.93; Midwest $44.29	■ 3024 inventoried trees/$100,000 budget =$33.07
Forestry budget as a percentage of the total municipal budget: 0.53%	■ 0.07% of City budget allocated to forestry
Per capita forestry budget: $12.77	■ Currently accounted for spend is $1.83 per capita
Total expenditures on contracted tree care: $300,487; $265,644 (Midwest)	■ $63,650 Streets, $25,000 Parks, and $5,000 P&Z = $93,650

Although the City does allocate funding specifically for tree maintenance (including removals, pruning, and planting), the funding level is significantly lower than comparable communities. One limitation of the above benchmarking is that only select streets within the City limits were inventoried as part of this project. Based on visual observations, a more accurate number of public trees would be 4,000-4,500; this adjustment would decrease the budget to approximately $22-$25 per public tree. Another complicating factor is that most of the tree budget expenditures were based on contractor and tree cost budgets. It is reasonable to suspect that when including staff time, equipment purchases, and other incidental costs related to trees (i.e., leaf pick up), Jeffersonville's current situation may be more similar to the budgetary benchmarks.

Contractors and Volunteers

Table 5. Benchmark assessment of Jeffersonville's contractor and volunteer utilization.

Benchmark	Jeffersonville's Current Situation
Volunteer usage: 72% involve volunteers	■ Volunteers not utilized
Contractor use: 93% use contractors	■ Uses contractors
Most commonly contracted service: 88% of all respondents nationally contracted removals	■ Contracts out removals
Industry standards and accreditation: 80% use in contractor selection	■ Does not use for contractor selection

Jeffersonville is similar to other cities in that it commonly contracts out its tree removal work. Although utilizing contractors typically has a higher hourly cost than in-house staff, contractors have specific training and equipment to remove large trees efficiently and safely. However, it is also important for the City to maintain the flexibility of having internal staff to perform tree maintenance (watering, mulching, small tree pruning) as skill sets and time allow. Total reliance on contractors can be costly and time-consuming, and contractors often lack the ability to respond quickly to non-emergency issues. The lack of volunteers working with trees in the community is unusual for the City's population size. Volunteer groups can either be run through the City or as a non-profit partner. While partners can provide tree maintenance and planting help, they also can reach diverse segments of the community to expand the City's reach and engender interest in the urban forest.

Community Tree Populations

Table 6. Benchmark assessment of Jeffersonville's tree population.

Benchmark	Jeffersonville's Current Situation
Tree Inventory: 76% have a tree inventory	■ There is a current inventory
Canopy goal: 27% have or are developing a canopy goal	■ No current goal
Average per capita public trees: 0.43	■ 0.06 trees per capita

The City does have a current inventory but does not currently have a canopy goal. The City should maintain the inventory, updating it as trees are planted and removed. Canopy goals have become a standard way for cities to monitor their tree coverage, such as nearby Louisville's goal of 45% canopy coverage. However, one-size-fits-all canopy goals do not always account for the nuances of land use, community opinion, and other variances in a city. Metrics such as neighborhood-level canopy goals and the 3-30-300 rule (Konijnendijk, 2021) have become increasingly relevant, as they more accurately reflect the intricacies of urban forest management. For example, American Forests previously suggested a 15% canopy cover goal in downtown and industrial areas, 25% in light commercial and urbanized residential, and 50% in suburban residential (Hill et al., 2010). For an area like Jeffersonville's downtown planning district (12.6% current canopy cover), 15% may be a desirable level of canopy cover, whereas River Ridge (31.8% current canopy cover) may aim higher for 40-50%. The 3-30-300 rule states that everyone should be able to see 3 trees from their home, have 30% canopy cover in their neighborhood, and be within 300 meters (~330 yards) of a park or green space. This guideline goes beyond canopy cover by incorporating urban forest metrics that elevate human health and well-being.

Community and Staff Profile

Table 7. Benchmark assessment of Jeffersonville's community and staff profile.

Benchmark	Jeffersonville's Current Situation
Per capita public tree requests (complaints, pruning, etc.): 0.0101; 0.0095 in the Midwest	■ Unknown
Urban Forestry Website: 52% have a dedicated urban forestry website	■ A dedicated tree website exists
Arbor Day Tree City USA: 83% are Tree City USA	■ Not a Tree City USA
Reactive vs. systematic tree care: 59.5% scheduled/systematic tree care	■ Greater than 90% reactive/unscheduled tree care (complaints, storms, etc.)
Tree removal reasons: 46% of trees were declining /dead; 12.3% due to risk (all respondents)	■ Unknown
Tree inspections: 88% conduct tree inspections	■ Inspections not conducted

Tree requests are one metric that can be used to measure the public's engagement and satisfaction with city trees and maintenance. The City should track this to establish a baseline. The City's website is also a great resource to inform the public, and it should be regularly updated. Currently, Jeffersonville is not a Tree City USA through the Arbor Day program. It should be a priority in the upcoming year to ensure that the conditions to obtain Tree City status are met:

- Responsible Party: there must be a board, staff member, or department responsible to care for trees on public property. This can also include a parks or environmental citizen board.
- Tree Care Ordinance: Jeffersonville's current ordinance meets this requirement to guide planting, maintenance, and removal of trees on public property.

- Forestry Budget: there must be a budget of $2 per capita to care for public trees (includes staff, inspections, pruning, removal, planting, watering, etc.).
- Arbor Day Observance: the community must celebrate Arbor Day with a proclamation. Many communities center this around a tree planting event, but it can be as simple as reading the proclamation at a council meeting.

Jeffersonville's lack of inspections and focus on reactive tree care are a major concern for the urban forest. Reactive tree care relies on complaints and storms to drive maintenance. With this type of maintenance, trees are often only pruned or removed after they have developed critical safety issues or died. By establishing a tree care and inspection schedule, many issues can be prevented before they become critical. For example, a high risk tree near a playground may be discovered through an inspection and that issue mitigated through pruning; if not inspected and pruned, it may have fallen on playground equipment in a storm. Proactive tree care can also reduce public complaints and reduce staff time required to manage those complaints. Proactive maintenance has an overall positive effect on tree health, which in turn increases tree benefits to the public. Ultimately, proactive tree care will help the City save time and money and increase tree benefits and public satisfaction.

Operational and Program Review Summary

In terms of funding and staffing, Jeffersonville is below comparable communities. Nonetheless, the City possesses essential components, such as its inventory and website, which can be leveraged to align it with its peers. Many of the above urban forest benchmarks are interconnected and addressing a few strategic issues will improve the City's overall situation.

Key takeaways to set Jeffersonville on a more effective urban forest management path

- ✓ Become a Tree City USA: this addresses funding, maintenance, governance, and public engagement components of the urban forest.
- ✓ Move Towards Proactive Tree Care: establish tree maintenance and inspection schedules.
- ✓ Urban Forest Manager: hire or promote an individual to manage the City's trees (including maintenance and inspection schedules).

Maintenance and Inspection Cycle

All City maintained trees should be inspected on a five year interval by a qualified arborist, with a corresponding maintenance cycle. The five year scheduled maintenance cycle was cited as most desired by cities in Hauer and Peterson's study of municipal tree care (2016). Once the City completes all the priority tree work, they will be prepared to move into a proactive phase of management. By inspecting 1/5 of the tree population annually and specifying needed maintenance for those trees, the City can ensure appropriate inspection and maintenance. Aligning these inspection and maintenance timeframes will enable Jeffersonville to allocate resources more efficiently. Additionally, the City should have a complete tree population re-inspection and report done every five to ten years. As the City's urban forest program evolves over the next several years, this re-assessment and report will ensure that tree care priorities and goals remain supported by best practices and industry standards.

Work Plan Summary

To develop a work plan, cost and time estimates were developed and prioritized over the five years. This includes identified tree maintenance, tree planting, establishment of a pruning cycle, and a tree inspection timeframe. A separate work plan for the forested areas addresses invasive species removal, tree planting, maintenance, and inspections. Recommendations were based on public safety, maintenance to promote tree health and growth, and planting to increase canopy cover. Goals for Jeffersonville's work plan include:

- Tree Removal: To promote public safety, tree removals should occur first, with Priority 1 removals the most important task. Priority 1 trees are generally larger trees with a greater risk for injury and damage. Priority 2 removals present less public risk; Priority 3 removals are often small trees with lower risk.
- Tree Pruning and Support Systems: Tree pruning and when needed tree support systems (i.e., cabling) to mitigate critical safety concerns also represent a high priority. Priority 1 tree pruning often focuses on removing dead, dying, and damaged limbs. Priority 2 and 3 pruning can be related to tree health, promoting growth, or establishing and correcting structural concerns. Training pruning to help develop proper structure on young trees is critical to proactive tree care. It allows small issues to be corrected at a minor cost before they become significant issues.
- Tree Planting: Planting is an essential task to include in Jeffersonville's plan. At a minimum, the City should replace trees removed. Some municipalities codify replacement ratios, while others have a policy or procedure. However, attention must also be given to other factors, such as the potential canopy size of the new tree, existing tree condition, and species. Ultimately, Jeffersonville should ensure that new trees follow the principal of "Right Tree, Right Place, Right Reason".
- Invasive Species Removal: Invasive species represent a high threat to healthy forests. To protect and encourage healthy tree canopy, forested areas degraded by invasives should be addressed through chemical and/or mechanical control methods.
- Monitoring and Assessment: Ongoing monitoring of Jeffersonville's tree population is imperative to sustain a healthy urban forest and manage safety concerns. Trees that were recommended for monitoring should be inspected annually and after major weather events by a qualified arborist. All City maintained trees should be inspected on a five year interval. Forest restoration site should be inspected annually.

Year 1 (2025) is dedicated to resolving critical safety issues recommended as priority 1 maintenance. Year 2 is focused on Priority 2 work, with an emphasis on pruning and resuming replanting. Year 3 undertakes priority 3 work. All three years also include an annual inspection for the 230 trees recommended for monitoring during the inventory. While the cost for this monitoring is based on contracting a certified arborist to inspect the trees, this number could be significantly reduced using in-house staff. When the City is able to hire or promote an Urban Forester, this individual should be able to perform all inspections, as well as maintenance tasks such as training pruning and mulch removal. The City should aim to fund this position or promotion in the next fiscal year as a full or part-time role.

Starting in Year 4, the City should begin regularly assessing 1/5 of the tree population and developing removal and maintenance recommendations based on that assessment. At this point, the inspections should be completed in-house by the Urban Forester. If the 835 trees were inspected by an outside arborist, it would likely cost close to $10,500. Also in this year, the City will be caught up on replacing trees removed during Years 1-4. Year 5 continues systematic inspections and resulting work prescriptions. Notably, this is the first year that City tree planting is scheduled to outpace removals. This is a turning point at which Jeffersonville can start to grow their canopy. The trees estimated to be planted in excess of removals is meant primarily as a placeholder in this instance. Factors such as planting and canopy goals, community opinion, non-profit partners, and grant availability should help determine the annual number of trees planted.

Work Plan Tables

Table 8. Tree inventory work plan for a five-year period.

Year	Activity	Number of Trees	Contract Costs ($)	Comments
1 2025	Pruning- Priority 1	9	2,580	Includes debris removal
	Cable/Brace- Priority 1	1	700	Includes (1) cable
	Removal- Priority 1	44	30,365	Includes debris removal, stump grinding, and soil replacement
	Monitor	230	2,875	Estimated for outside contractor cost
	Totals	**284**	**36,520**	Appendix H contains cost assumptions

Year	Activity	Number of Trees	Contract Costs ($)	Comments
2 2026	Pruning- Priority 2	125	26,115	Includes debris removal
	Training Pruning- Priority 2	4	100	Includes debris removal
	Removal- Priority 2	57	18,115	Includes debris removal, stump grinding, and soil replacement
	Tree Planting (replace Y1 removals)	44	11,000	Includes new tree and mulch; does not include staff time
	Monitor	230	2,875	Estimated for outside contractor cost
	Totals	**460**	**58,205**	Appendix H contains cost assumptions

Year	Activity	Number of Trees	Contract Costs ($)	Comments
3 2027	Pruning- Priority 3	19	2,415	Includes debris removal
	Training Pruning- Priority 3	59	1,475	Includes debris removal
	Removal- Priority 3	23	2,704	Includes debris removal, stump grinding, and soil replacement
	Remove Mulch- Priority 3	40	1,200	Includes debris removal and new mulch
	Tree Planting (replace Y2+Y3 removals)	80	20,000	Includes new tree and mulch; does not include staff time
	Monitor	230	2,875	Estimated for outside contractor cost
	Totals	**451**	**30,669**	Appendix H contains cost assumptions

Year	Activity	Number of Trees	Contract Costs ($)	Comments
4 2028	Inspect 1/5 of City trees	605	N/A	Transition to City Forester inspections for approximately 50 hours
	Monitor	230	N/A	Transition to City Forester inspections for approximately 19 hours
	Pruning	30	6,090	Based on 5% recommended pruning from inventory. Cost estimate based on Y1-3 averages.
	Training Pruning	20	500	Minimal due to low planting over last 3 years
	Removals	91	37,583	Estimated at 3% annual mortality. Removal cost estimate based on Y1-3 averages.
	Planting (replace Y4 removals)	91	22,750	Includes new tree and mulch; does not include staff time
	Totals	**1,067**	**66,923**	Appendix H contains cost assumptions

Year	Activity	Number of Trees	Contract Costs ($)	Comments
5 2029	Inspect 1/5 of City trees	605	N/A	Urban Forester inspections (50 hours)
	Monitor	230	N/A	Urban Forester inspections (19 hours)
	Pruning	30	6,090	Based on 5% recommended pruning from inventory. Cost estimate based on Y1-3 averages.
	Training Pruning (trees planted in Year 3)	101	2,525	Includes debris removal
	Removals	91	37,583	Estimated at 3% annual mortality. Removal cost estimate based on Y1-3.
	Planting (replace Y5 removals + increase tree canopy/stocking)	125	31,250	Includes new tree and mulch; does not include staff time
	Totals	**1,182**	**77,448**	Appendix H contains cost assumptions

Table 9. Forest work plan for a five-year period.

Year	Activity	Number of Acres	Contract Costs ($)	Comments
1 2025	Invasive Species Removal	8.5	7,650	Includes manual/chemical removal
	Open Space Planting	1	700	Includes seedlings, tree tubes, and labor
	Monitoring + Ongoing Maintenance	9.5	950	Includes labor and herbicide
	YR1 Totals	N/A	**9,300**	Appendix H contains cost assumptions
2 2026	Invasive Species Removal	8.5	7,650	Includes manual/chemical removal
	Open Space Planting	1	700	Includes seedlings, tree tubes, and labor
	Monitoring + Ongoing Maintenance	19	1,900	Includes labor and herbicide
	Y2 Totals	N/A	**10,250**	Appendix H contains cost assumptions
3 2027	Invasive Species Removal	8.5	7,650	Includes manual/chemical removal
	Open Space Planting	1	700	Includes seedlings, tree tubes, and labor
	Monitoring + Ongoing Maintenance	28.5	2,850	Includes labor and herbicide
	YR3 Totals	N/A	**11,200**	Appendix H contains cost assumptions
4 2028	Invasive Species Removal	8.5	7,650	Includes manual/chemical removal
	Open Space Planting	1	700	Includes seedlings, tree tubes, and labor
	Monitoring + Ongoing Maintenance	38	3,800	Includes labor and herbicide
	YR4 Totals	N/A	**12,150**	Appendix H contains cost assumptions
5 2029	Invasive Species Removal	8.5	7,650	Includes manual/chemical removal
	Open Space Planting	1	700	Includes seedlings, tree tubes, and labor
	Monitoring + Ongoing Maintenance	47.5	4,750	Includes labor and herbicide
	YR5 Totals	N/A	**13,100**	Appendix H contains cost assumptions

References

Hauer, R. J., & Peterson, W. D. (2016). *Municipal Tree Care and Management in the United States: A 2014 Urban & Community Forestry Census of Tree Activities*. University of Wisconsin – Stevens Point.

Hauer, R. J., & Peterson, W. D. (2017). Effects of emerald ash borer on municipal forestry budgets. *Landscape and Urban Planning*, *157*, 98–105. https://doi.org/10.1016/j.landurbplan.2016.05.023

Jennings, Viniece & Bamkole, Omoshalewa. (2019). The Relationship between Social Cohesion and Urban Green Space: An Avenue for Health Promotion. *International Journal of Environmental Research and Public Health*. 16. 452. https://www.mdpi.com/1660-4601/16/3/452.

Galle, N. J., Halpern, D., Nitoslawski, S., Duarte, F., Ratti, C., & Pilla, F. (2021). Mapping the diversity of street tree inventories across eight cities internationally using open data. *Urban Forestry & Urban Greening*, 61, 127099. https://doi.org/10.1016/j.ufug.2021.127099.

Konijnendijk, C.C. (2021). *Promoting health and wellbeing through urban forests – introducing the 3-30-300 rule*. IUCN. https://iucnurbanalliance.org/promoting-health-and-wellbeing-through-urban-forests-introducing-the-3-30-300-rule.

Dhal, L., Gordon, J., Young, A., Subedi, M. R., Jennings, K., Lepine, L., Brandeis, T., & Dwivedi, P. (2024). Examining the impacts of urban tree structure and condition on adult depression in the United States. *Trees Forests and People*, 100734. https://doi.org/10.1016/j.tfp.2024.100734.

Pokorny, J., O'Brien, J., Hauer, R., Johnson, G., Albers, J., Bedker, P., & Mielke, M. (2003). *Urban Tree Risk Management: A Community Guide to Program Design and Implementation*. US Forest Service Research and Development. https://research.fs.usda.gov/treesearch/11070.

Nowak, David J. (2017). Urban forest sustainability in the United States. In: Ning, Z.; Nowak, D.; Watson, G., eds. *Urban Forest Sustainability*. Champaign, IL: International Society of Arboriculture. 2-11.

EAB Network State Detection Table. (n.d.). www.emeraldashborer.info; Michigan State University Dept. of Entomology, the Dept. of Forestry and MSU Extension. Retrieved February 17, 2025, from https://www.emeraldashborer.info.

Appendix A – Tree Inventory Attributes

Table A1. Description of attributes collected for Jeffersonville's tree inventory.

Data Attribute	Description
Tree Species Common Name	Common name of the species.
Tree Species, Genus, and Family	Botanical name including species, genus, and family.
i-Tree Code	Code assigned to tree species in i-Tree to calculate benefits.
Tree Diameter	Diameter (inches) of tree in accordance with ISA standards. Single stem trees are measured at 4.5 above ground level; multistem trees had each stem recorded individually with a master stem diameter calculated as the square root of all squared stem diameters.
Condition Rating	Tree health expressed as a percentage (0-100%) in accordance with CTLA Version 9.
Primary Maintenance Need	Recommended action based on tree condition in accordance with USDA Urban Tree Risk Management (Pokorny, 2003).
Maintenance Priority	Priority of recommended maintenance with Priority 1 being immediate, Priority 2 within 6 months, and Priority 3 within 1 year.
GPS Location	Latitude and longitude of tree location.
Street Address	Nearest parcel address or park name.
Site Type	Description of tree planting site including open, natural area, median, tree lawn, tree pit, bump out, planting bed (not between sidewalk and street).
Land Use	Description of the land use such as park, vacant, residential, commercial, public facility, other.
Sidewalk Damage	Notation of a damaged sidewalk adjacent to tree lifted, heaving, cracked 0.5 inches or greater
Comments	Any special notations about tree and site conditions not captured in above attributes.

Appendix B – Forest Plot Attributes

Table B1. Description of attributes collected for Jeffersonville's forest plot assessment.

Data Attribute	Description
GPS Location	Latitude and longitude of plot center.
Canopy Tree Species Composition	Description of all trees present in the canopy.
Dominant Canopy Species	Species most prevalent in the plot's canopy.
Understory Tree Species Composition	Description of all trees present in the understory.
Ground and Shrub Layer Composition	Description of plants comprising the ground layer.
Invasive Species Rating	Prevalence of invasive species ranked as none, low, medium, high.
Overall Forest Rating	Rating of the forest condition quality from 1-5, with 5 being a high value, healthy forest with multiple layers and 1 being a low value forest dominated by invasives with low canopy cover.
Recommended Maintenance	Recommended action including dead tree removal, invasive species removal, tree planting, and none.
Comments	Any additional information related to site conditions.

Appendix C – Land Cover Classifications

Table C1. Distribution of land cover classes in Jeffersonville based on NAIP imagery for the noted time frame.

Jeffersonville 2022 Total Area Land Classification						
Land Cover Type	**Land Cover Point Count**	**Land Cover (%)**	**Standard Error (%)**	**Confidence Interval (95%) ±**	**Lower**	**Upper**
Bare soil	318	5.3	0.29	0.57	4.73	5.87
Grass & Herbaceous	2591	43.2	0.64	1.25	41.93	44.44
Impervious Surface	1,460	24.3	0.55	1.09	23.25	25.42
Tree Canopy	1568	26.1	0.57	1.11	25.02	27.25
Water	63	1.1	0.13	0.26	0.79	1.31
Totals	**6,000**	**100.0**	N/A	N/A	N/A	N/A

Jeffersonville 2016 Total Area Land Classification						
Land Cover Type	**Land Cover Point Count**	**Land Cover (%)**	**Standard Error (%)**	**Confidence Interval (95%) ±**	**Lower**	**Upper**
Bare soil	196	6.5	0.45	0.88	5.65	7.42
Grass & Herbaceous	1,278	42.6	0.90	1.77	40.83	44.37
Impervious Surface	630	21.0	0.74	1.46	19.54	22.46
Tree Canopy	874	29.1	0.83	1.63	27.51	30.76
Water	22	0.7	0.16	0.31	0.43	1.04
Totals	**3,000**	**100.0**	N/A	N/A	N/A	N/A

Jeffersonville 2008 Total Area Land Classification						
Land Cover Type	**Land Cover Point Count**	**Land Cover (%)**	**Standard Error (%)**	**Confidence Interval (95%) ±**	**Lower**	**Upper**
Bare soil	131	4.4	0.37	0.73	3.64	5.10
Grass & Herbaceous	1,461	48.7	0.91	1.79	46.91	50.49
Impervious Surface	544	18.1	0.70	1.38	16.75	19.51
Tree Canopy	843	28.1	0.82	1.61	26.49	29.71
Water	21	0.7	0.15	0.30	0.40	1.00
Totals	**3,000**	**100.0**	N/A	N/A	N/A	N/A

Appendix D – Land Cover User & Producer QC

Table D1. Quality control accuracy assessment for landcover classifications in the project area.

Jeffersonville 2022 Entire Area User and Producer Outcome: Quality Control Initial Uncorrected Outcome

	Land Cover Type	User: Bare Soil	User: Grass & Herbaceous	User: Impervious Surface	User: Tree Canopy	User: Water	User: Grand Total	Producer Accuracy (%)
Producer	Bare soil	**37**	2	3			**42**	88.1
Producer	Grass & Herbaceous	1	**518**	9	20		**548**	94.5
Producer	Impervious Surface		6	**426**			**432**	98.6
Producer	Tree Canopy		16	6	**528**		**550**	96.0
Producer	Water					**30**	**30**	100.0
	Grand Total	**38**	**542**	**444**	**548**	**30**	**1602**	
	User Accuracy (%)	97.4	95.6	95.9	96.4	100.0		

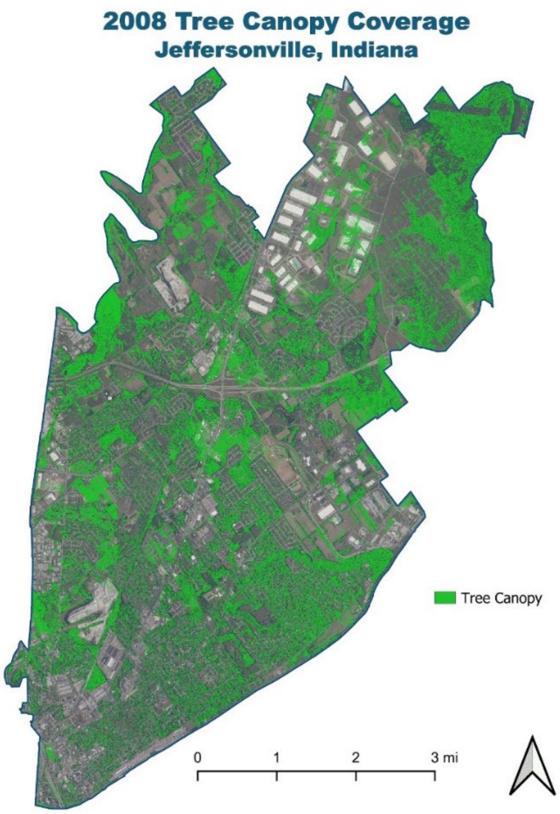
Jeffersonville 2016 Entire Area User and Producer Outcome: Quality Control Initial Uncorrected Outcome

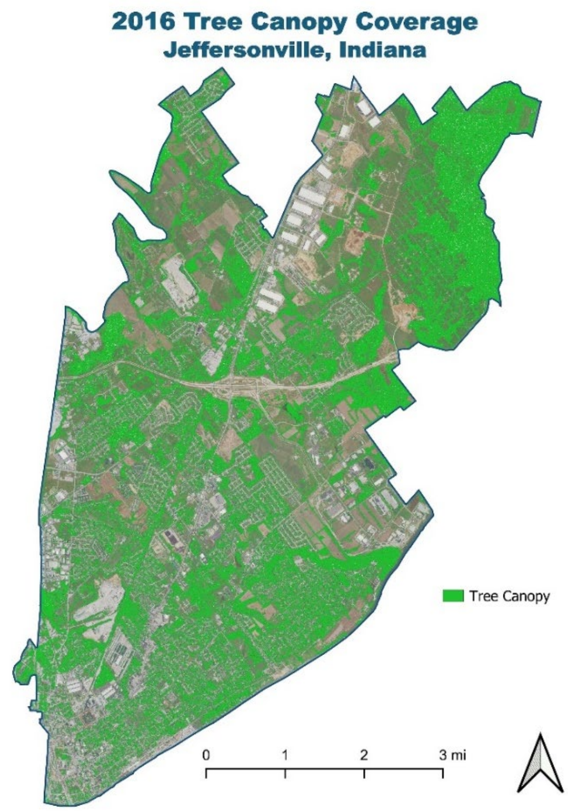
	Land Cover Type	User: Bare Soil	User: Grass & Herbaceous	User: Impervious Surface	User: Tree Canopy	User: Water	User: Grand Total	Producer Accuracy (%)
Producer	Bare Soil	**13**	2	1			**16**	81.3
Producer	Grass & Herbaceous		**130**		1		**131**	99.2
Producer	Impervious Surface			**55**	1		**56**	98.2
Producer	Tree Canopy		2		**91**		**93**	97.8
Producer	Water					**4**	**4**	100.0
	Grand Total	**13**	**134**	**56**	**93**	**4**	**300**	
	User Accuracy	100.0	97.0	98.2	97.8	100.0		

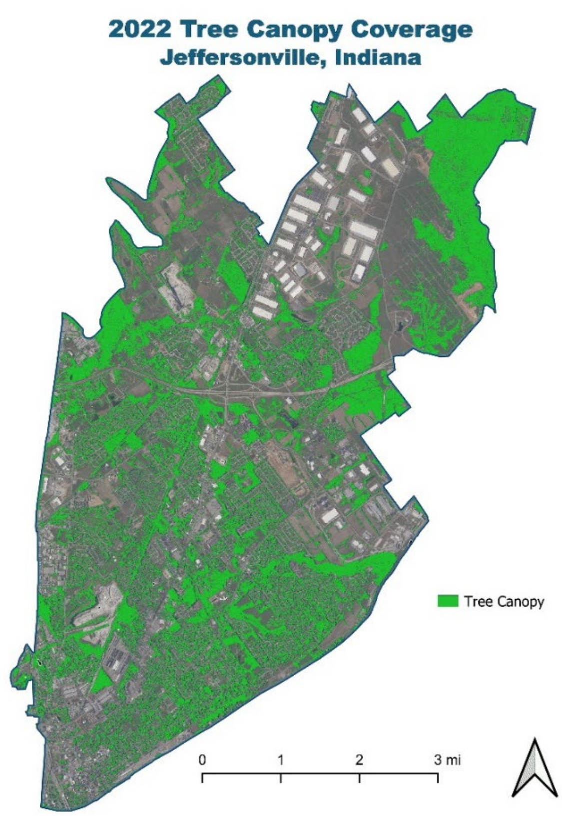
Jeffersonville 2008 Entire Area User and Producer Outcome: Quality Control Initial Uncorrected Outcome

	Land Cover Type	User: Bare Soil	User: Grass & Herbaceous	User: Impervious Surface	User: Tree Canopy	User: Water	User: Grand Total	Producer Accuracy (%)
Producer	Bare soil	**10**					**10**	100.0
Producer	Grass & Herbaceous		**145**	2			**147**	98.6
Producer	Impervious Surface		4	**44**			**48**	91.7
Producer	Tree Canopy		4		**87**		**91**	95.6
Producer	Water					**4**	**4**	100.0
	Grand Total (%)	**10**	**153**	**46**	**87**	**4**	**300**	
	User Accuracy	100.0	94.8	95.7	100.0	100.0		

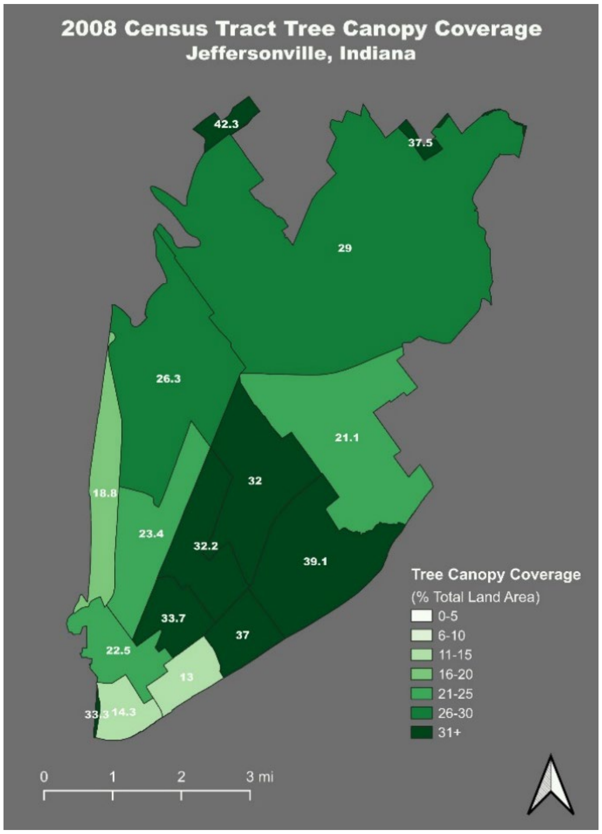
Appendix E – Tree Canopy Maps

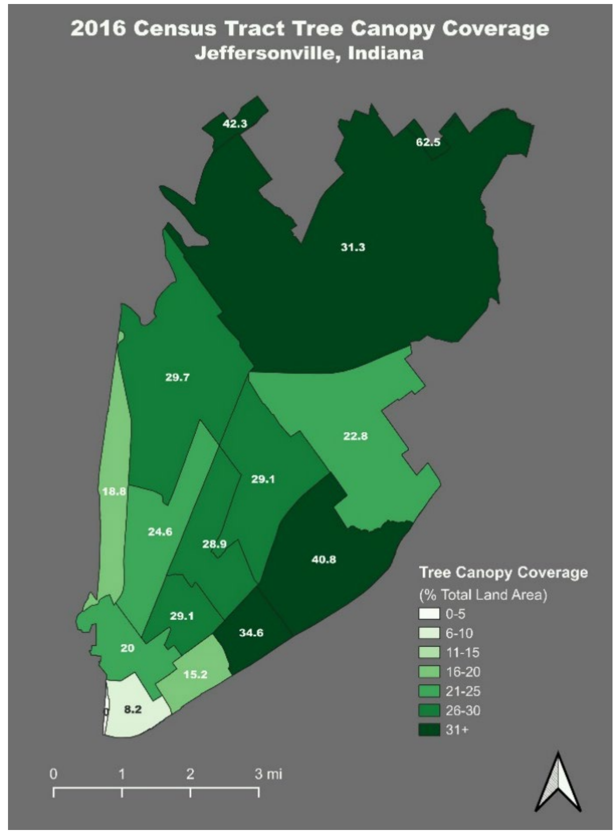


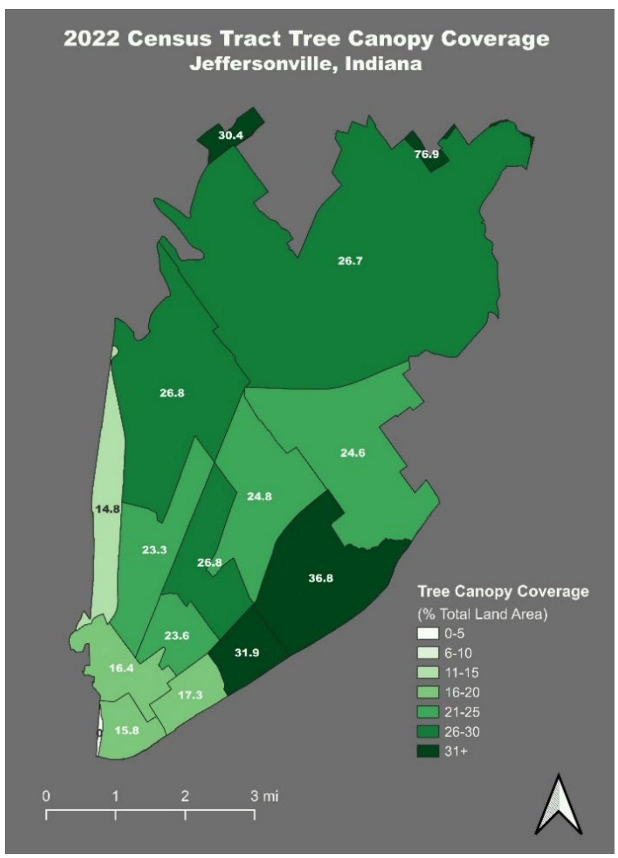




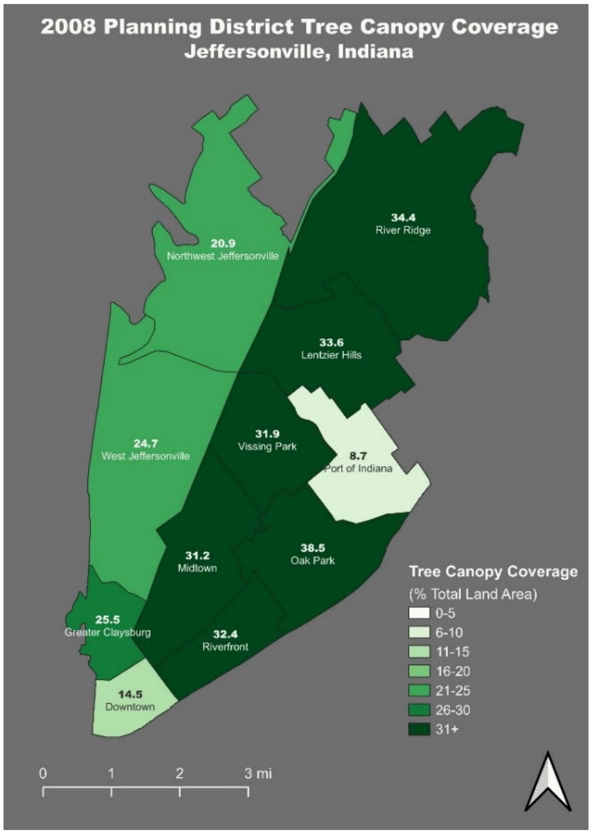
Appendix F – Tree Canopy By Census Tract

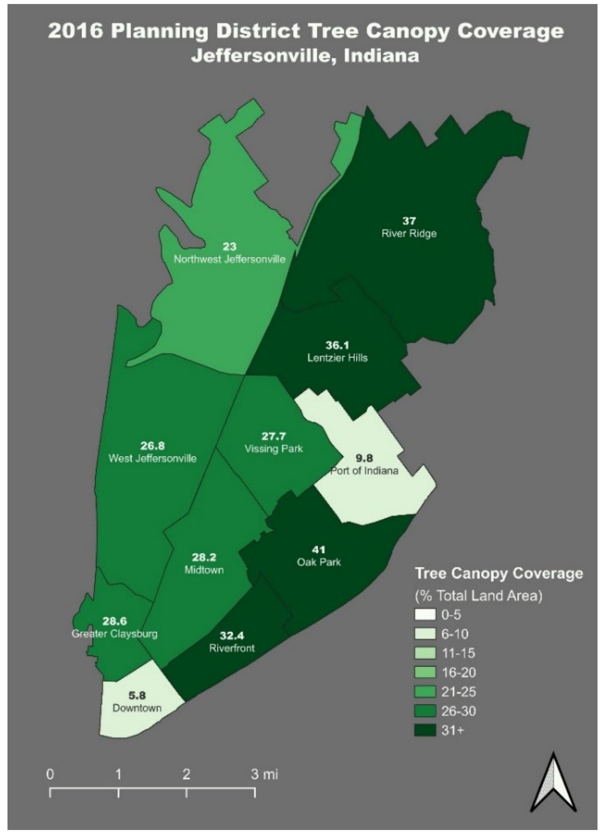


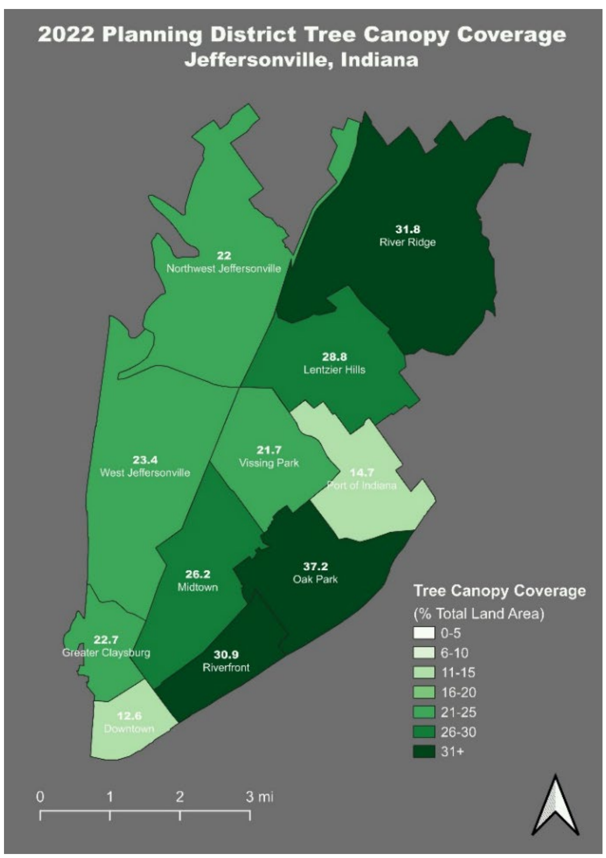




Appendix G – Tree Canopy By Planning District







Appendix H – Work Plan Cost Assumptions

Time estimates are based on workers already on site within the community. Debris removal assumes the material is disposed of within a community location.

Table H1. Assumptions used to develop time and cost estimates for proposed work.

Monitor: Time estimate based on a rate of inspecting a tree every 5 minutes or 12 trees per hour; this detail includes inspection for significant pest problems, significant tree risk by a limited visual assessment (e.g., dead trees, broken or dead branches > 2 inches), and identifying needed removal or pruning needs with priority ranking. Additional time required for basic or advanced tree risk assessment and beyond the scope of monitoring.
Pruning: Time estimate based on Churack et al. (1994) model. The diameter-based model for trees 4 inches or greater in trunk diameter generates a time estimate based on the size of tree (y = -15.12 + 6.0 * x; were y = time estimate in minutes, x = tree trunk diameter, and -15.12 is the y-intercept value which was excluded from the time estimate). Thus, a 6-minute estimate per diameter inch of tree trunk was used to project tree pruning needs. Pruning time for training pruning estimated at 0.25 hours per tree. A $100 per person hour rate is estimated for contracted pruning costs and debris removal.
Removal: Tree estimate based on Obrien et al. (1992) model. The time (people hours) per trunk diameter inch for removal increases by diameter class with 0”–12.5” = 0.19 hr/in, 12.6”–24.5” = 0.25 hr/in, 24.6”–30.5” = 0.31 hr/in, 30.6”–36.5” = 0.39 hr/in, and 36.6” or greater = 0.49 hr/in. Time estimates assume a three-person crew. For example, the removal time estimate for a 23-inch tree is 5.75 total hours (23 in * 0.25 hr/in = 5.75 people hours; for a 3-person crew would be an approximate 2-hour job). Removal costs estimated by the mean value for the Village of Ashwaubenon 2023 tree removal bids 1”–12” = $32.1/in, 13”–18” = $30.8/in, 19–24” = $32.7/in, 25–30” = $34.7/in, 31–36” = $38.9/in, 37–42” = $42.4/in, and 43” or greater = $43.8/in. These rates include tree removal, removal of debris, stump grinding, and back filling ground stump with soil. A mean $32.58/inch was used for 1” to 30” trees and a $41.71/in rate for 30” or greater trees.
Tree Planting: Estimated tree planting costs were based Jeffersonville’s estimated costs of $200 per tree plus $50 per tree for establishment (mulch and watering) for a total $250 per tree.
Invasive Species Removal: Estimated at $900 per acre including manual equipment, herbicides and labor.
Open Space Planting: Estimated at $700 per acre including seedlings, tree tubes, and labor.
Monitoring + Ongoing Maintenance: Estimated at $100 per acre including herbicides and labor.

References

Churack P.L, R.W. Miller, K. Ottman, and C. Koval (1994). Relationship Between Street Tree Diameter Growth and Projected Pruning and Waste Wood Management Costs. *Journal of Arboriculture*. 20(4):231–236

Hauer R. J. and Peterson W. D. (2016). *Municipal Tree Care and Management in the United States: A 2014 Urban & Community Forestry Census of Tree Activities*. Special Publication 16-1, College of Natural Resources, University of Wisconsin – Stevens Point.

O'Brien P.R, K.A. Joehlin, D. J. O'Brien, (1992). Performance Standards For Municipal Tree Maintenance. *Journal of Arboriculture*. 18(6):307–315.

Appendix I – i-Tree Eco Report

Summary

Understanding an urban forest's structure, function and value can promote management decisions that will improve human health and environmental quality. An assessment of the vegetation structure, function, and value of the Jeffersonville, Indiana urban forest was conducted during 2024. Data from 3024 trees located throughout Jeffersonville, Indiana were analyzed using the i-Tree Eco model developed by the U.S. Forest Service, Northern Research Station.

- Number of trees: 3,024
- Tree Cover: 22.1 acres
- Most common species of trees: Red maple, Sweetgum, Callery pear
- Percentage of trees less than 6" (15.2 cm) diameter: 49.9%
- Pollution Removal: 1357 pounds/year ($2.82 thousand/year)
- Carbon Storage: 1.262 thousand tons ($546 thousand)
- Carbon Sequestration: 26.39 tons ($11.4 thousand/year)
- Oxygen Production: 70.36 tons/year
- Avoided Runoff: 327.1 thousand gallon/year ($2.92 thousand/year)
- Building energy savings: N/A – data not collected
- Avoided carbon emissions: N/A – data not collected
- Replacement values: $6.26 million

Ton: short ton (U.S.) (2,000 lbs)
Monetary values $ are reported in US Dollars throughout the report except where noted.
Ecosystem service estimates are reported for trees.
With Complete Inventory Projects, oxygen production is estimated from gross carbon sequestration and does not account for decomposition. Oxygen production in Plot Inventory Projects is estimated from net carbon sequestration.

For an overview of i-Tree Eco methodology, see Appendix I. Data collection quality is determined by the local data collectors, over which i-Tree has no control.

Table of Contents

I. Tree Characteristics of the Urban Forest

The urban forest of Jeffersonville, Indiana has 3,024 trees with a tree cover of Red maple. The three most common species are Red maple (11.1 percent), Sweetgum (5.6 percent), and Callery pear (3.9 percent).

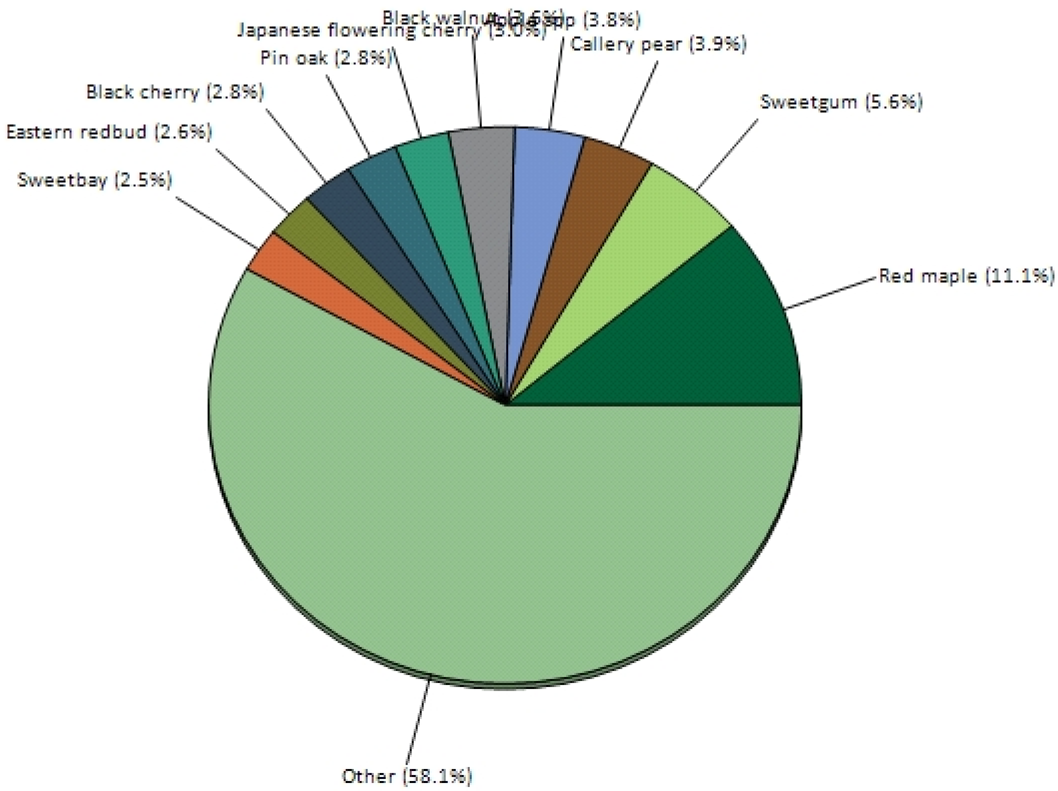


Figure 1. Tree species composition in Jeffersonville, Indiana

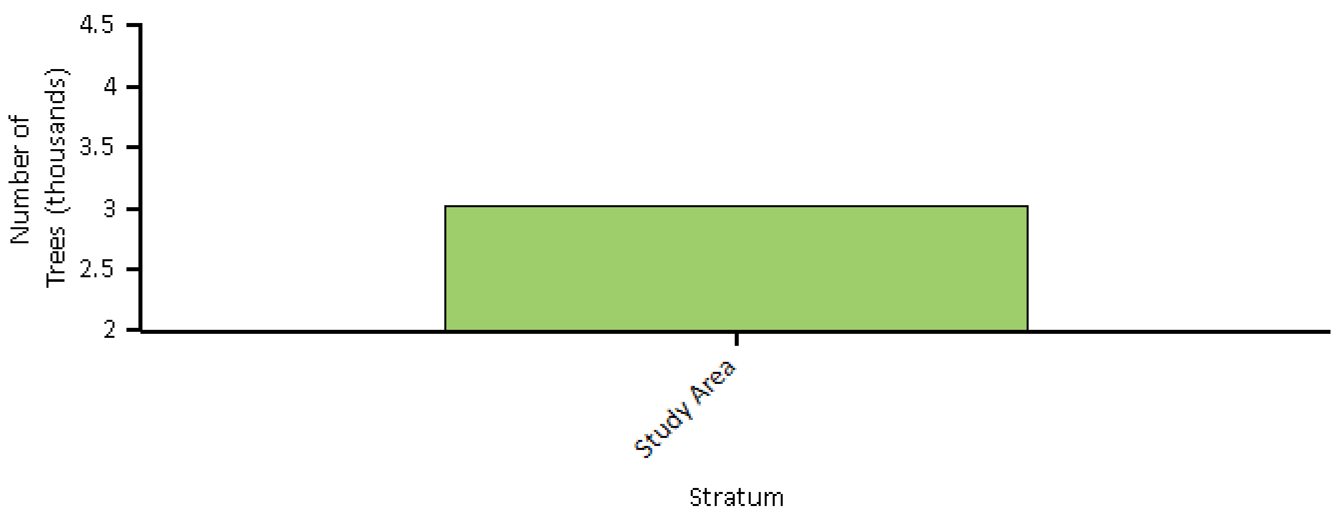


Figure 2. Number of trees in Jeffersonville, Indiana by stratum

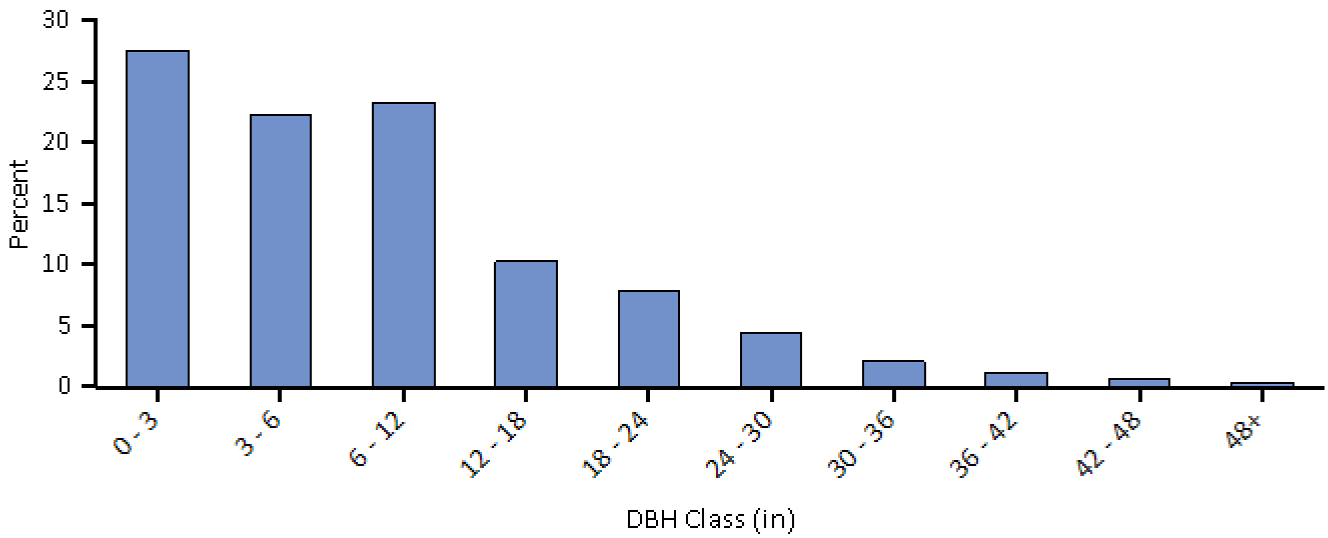


Figure 3. Percent of tree population by diameter class (DBH - stem diameter at 4.5 feet)

Urban forests are composed of a mix of native and exotic tree species. Thus, urban forests often have a tree diversity that is higher than surrounding native landscapes. Increased tree diversity can minimize the overall impact or destruction by a species-specific insect or disease, but it can also pose a risk to native plants if some of the exotic species are invasive plants that can potentially out-compete and displace native species. In Jeffersonville, Indiana, about 79 percent of the trees are species native to North America, while 68 percent are native to Indiana. Species exotic to North America make up 94 percent of the population. Most exotic tree species have an origin from COUNTRY (73 percent of the species).

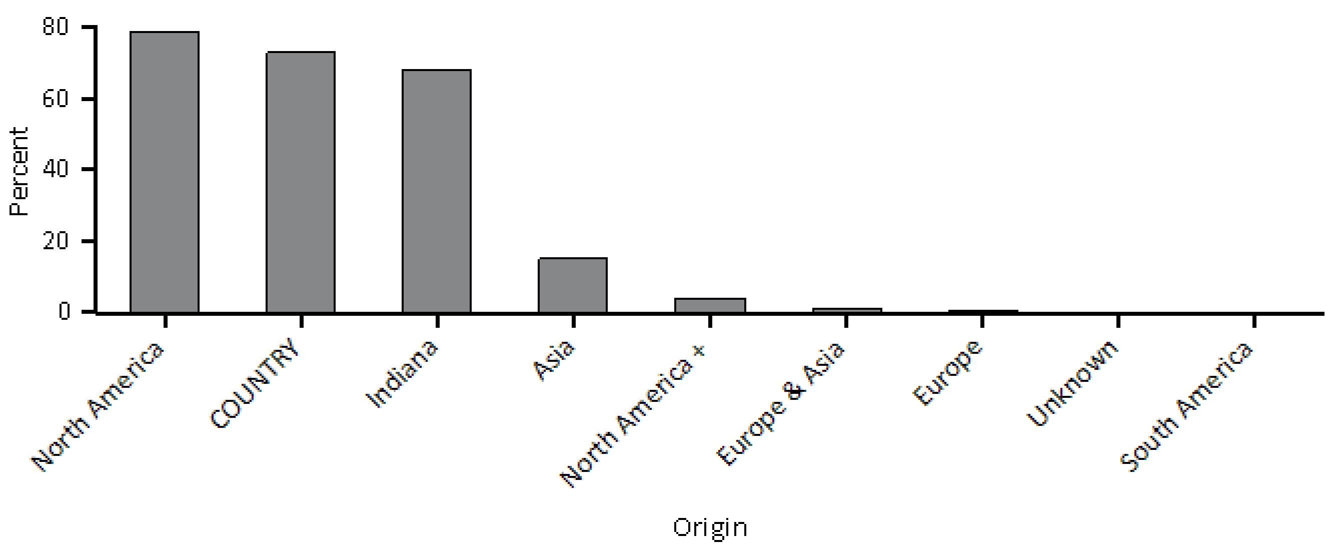


Figure 4. Percent of live tree population by area of native origin, Jeffersonville, Indiana

The plus sign (+) indicates the tree species is native to another continent other than the ones listed in the grouping.

Invasive plant species are often characterized by their vigor, ability to adapt, reproductive capacity, and general lack of natural enemies. These abilities enable them to displace native plants and make them a threat to natural areas. Eight of the 115 tree species in Jeffersonville, Indiana are identified as invasive on the state invasive species list (Indiana Cooperative Agricultural Pest Survey 2007). These invasive species comprise 8.7 percent of the tree population though they may only cause a minimal level of impact. The three most common invasive species are Callery pear (3.9 percent of population), Black locust (2.4 percent), and White mulberry (1.4 percent) (see Appendix V for a complete list of invasive species).

II. Urban Forest Cover and Leaf Area

Many tree benefits equate directly to the amount of healthy leaf surface area of the plant. Trees cover about 22.1 acres of Jeffersonville, Indiana and provide 112.3 acres of leaf area.

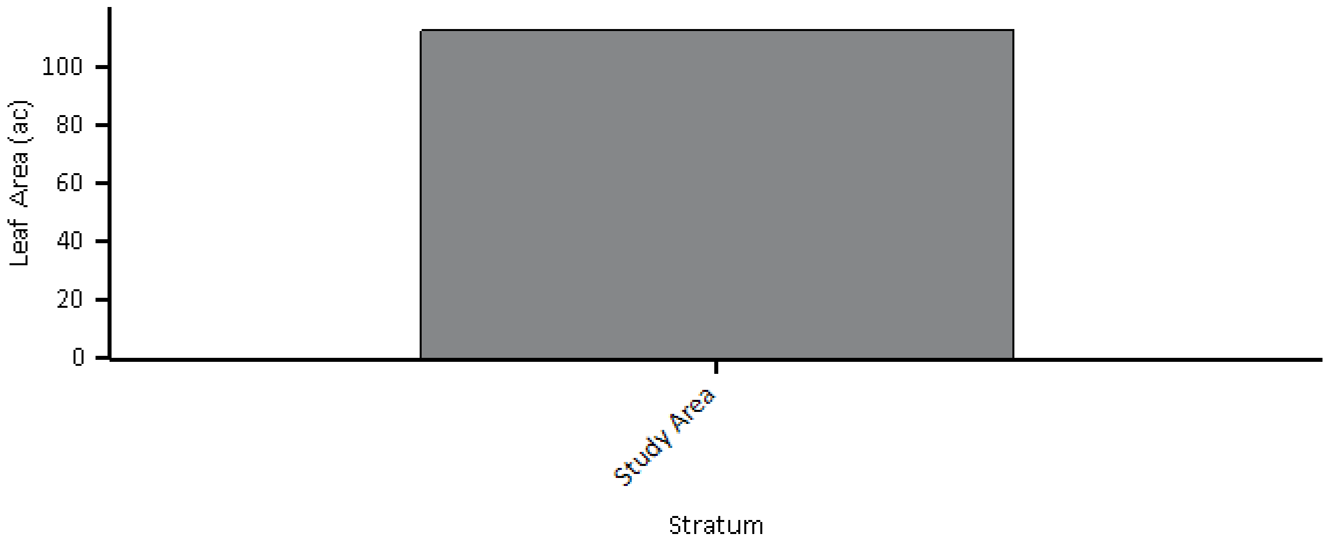


Figure 5. Leaf area by stratum, Jeffersonville, Indiana

In Jeffersonville, Indiana, the most dominant species in terms of leaf area are Sweetgum, Red maple, and Pin oak. The 10 species with the greatest importance values are listed in Table 1. Importance values (IV) are calculated as the sum of percent population and percent leaf area. High importance values do not mean that these trees should necessarily be encouraged in the future; rather these species currently dominate the urban forest structure.

Table 1. Most important species in Jeffersonville, Indiana

Species Name	*Percent Population*	*Percent Leaf Area*	*IV*
Red maple	11.1	12.1	23.3
Sweetgum	5.6	12.1	17.8
Pin oak	2.8	9.9	12.7
Tulip tree	2.1	7.2	9.4
Black walnut	3.6	3.9	7.4
Callery pear	3.9	3.5	7.4
Black cherry	2.8	4.1	6.9
American sycamore	2.0	4.4	6.4
Northern hackberry	2.4	3.6	6.0
Green ash	2.4	2.8	5.2

Common ground cover classes (including cover types beneath trees and shrubs) in Jeffersonville, Indiana are not available since they are configured not to be collected.

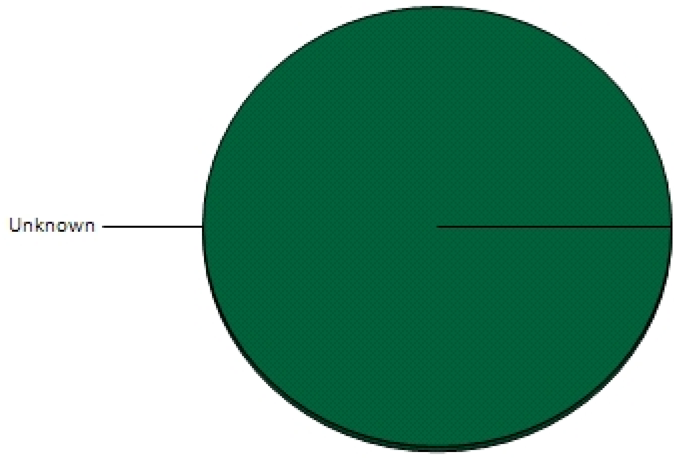


Figure 6. Percent of land by ground cover classes, Jeffersonville, Indiana

III. Air Pollution Removal by Urban Trees

Poor air quality is a common problem in many urban areas. It can lead to decreased human health, damage to landscape materials and ecosystem processes, and reduced visibility. The urban forest can help improve air quality by reducing air temperature, directly removing pollutants from the air, and reducing energy consumption in buildings, which consequently reduces air pollutant emissions from the power sources. Trees also emit volatile organic compounds that can contribute to ozone formation. However, integrative studies have revealed that an increase in tree cover leads to reduced ozone formation (Nowak and Dwyer 2000).

Pollution removal[1] by trees in Jeffersonville, Indiana was estimated using field data and recent available pollution and weather data available. Pollution removal was greatest for ozone (Figure 7). It is estimated that trees remove 1357 pounds of air pollution (ozone (O3), carbon monoxide (CO), nitrogen dioxide (NO2), particulate matter less than 2.5 microns (PM2.5), particulate matter less than 10 microns and greater than 2.5 microns (PM10*)[2], and sulfur dioxide (SO2)) per year with an associated value of $2.82 thousand (see Appendix I for more details).

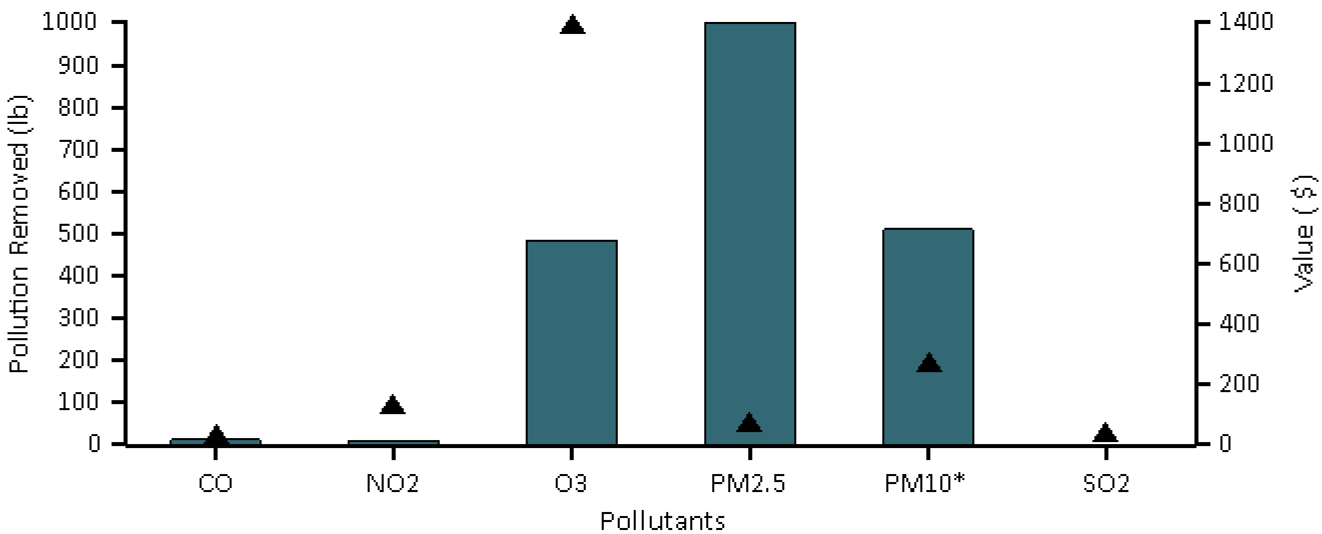


Figure 7. Annual pollution removal (points) and value (bars) by urban trees, Jeffersonville, Indiana

[1] PM10* is particulate matter less than 10 microns and greater than 2.5 microns. PM2.5 is particulate matter less than 2.5 microns. If PM2.5 is not monitored, PM10* represents particulate matter less than 10 microns. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

[2] Trees remove PM2.5 and PM10* when particulate matter is deposited on leaf surfaces. This deposited PM2.5 and PM10* can be resuspended to the atmosphere or removed during rain events and dissolved or transferred to the soil. This combination of events can lead to positive or negative pollution removal and value depending on various atmospheric factors (see Appendix I for more details).

In 2024, trees in Jeffersonville, Indiana emitted an estimated 1054 pounds of volatile organic compounds (VOCs) (567.1 pounds of isoprene and 486.9 pounds of monoterpenes). Emissions vary among species based on species characteristics (e.g. some genera such as oaks are high isoprene emitters) and amount of leaf biomass. Sixty percent of the urban forest's VOC emissions were from Pin oak and Sweetgum. These VOCs are precursor chemicals to ozone formation.[3]

General recommendations for improving air quality with trees are given in Appendix VIII.

[3] Some economic studies have estimated VOC emission costs. These costs are not included here as there is a tendency to add positive dollar estimates of ozone removal effects with negative dollar values of VOC emission effects to determine whether tree effects are positive or negative in relation to ozone. This combining of dollar values to determine tree effects should not be done, rather estimates of VOC effects on ozone formation (e.g., via photochemical models) should be conducted and directly contrasted with ozone removal by trees (i.e., ozone effects should be directly compared, not dollar estimates). In addition, air temperature reductions by trees have been shown to significantly reduce ozone concentrations (Cardelino and Chameides 1990; Nowak et al 2000), but are not considered in this analysis. Photochemical modeling that integrates tree effects on air temperature, pollution removal, VOC emissions, and emissions from power plants can be used to determine the overall effect of trees on ozone concentrations.

IV. Carbon Storage and Sequestration

Climate change is an issue of global concern. Urban trees can help mitigate climate change by sequestering atmospheric carbon (from carbon dioxide) in tissue and by altering energy use in buildings, and consequently altering carbon dioxide emissions from fossil-fuel based power sources (Abdollahi et al 2000).

Trees reduce the amount of carbon in the atmosphere by sequestering carbon in new growth every year. The amount of carbon annually sequestered is increased with the size and health of the trees. The gross sequestration of Jeffersonville, Indiana trees is about 26.39 tons of carbon per year with an associated value of $11.4 thousand. See Appendix I for more details on methods.

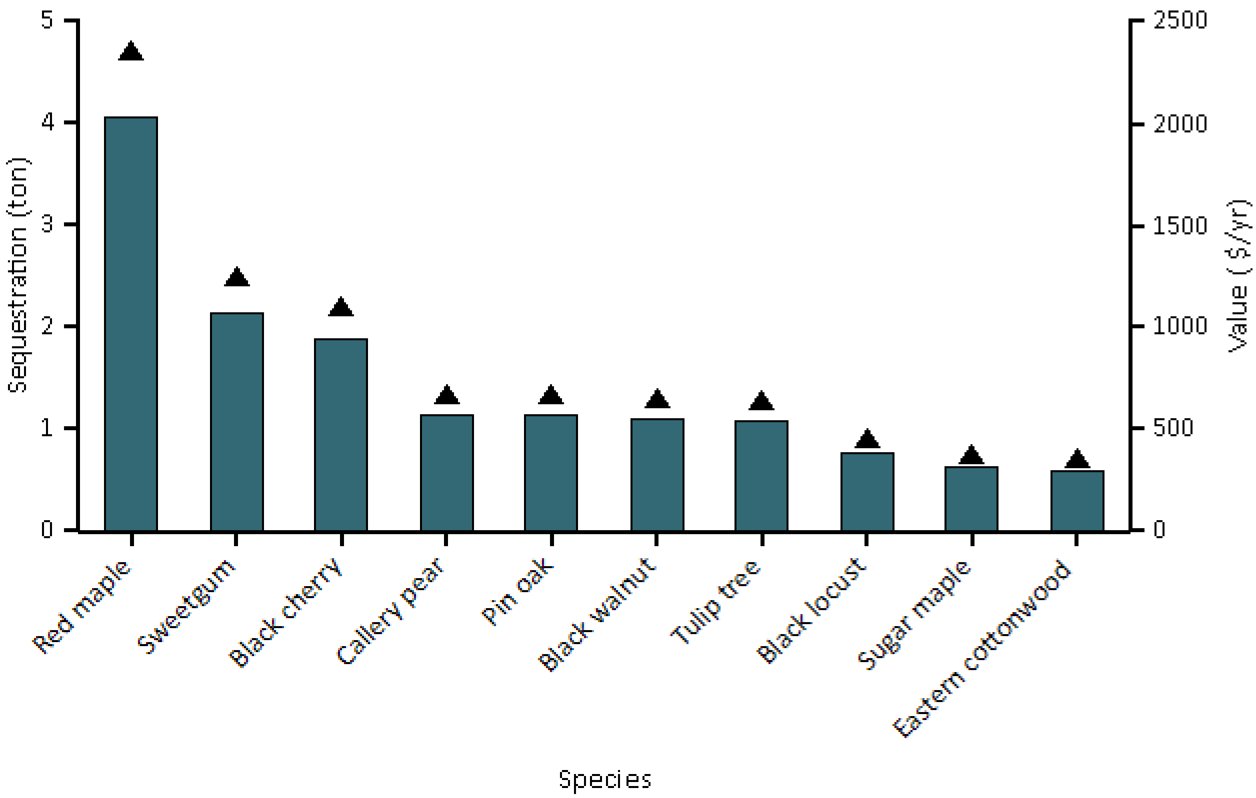


Figure 8. Estimated annual gross carbon sequestration (points) and value (bars) for urban tree species with the greatest sequestration, Jeffersonville, Indiana

Carbon storage is another way trees can influence global climate change. As a tree grows, it stores more carbon by holding it in its accumulated tissue. As a tree dies and decays, it releases much of the stored carbon back into the atmosphere. Thus, carbon storage is an indication of the amount of carbon that can be released if trees are allowed to die and decompose. Maintaining healthy trees will keep the carbon stored in trees, but tree maintenance can contribute to carbon emissions (Nowak et al 2002c). When a tree dies, using the wood in long-term wood products, to heat buildings, or to produce energy will help reduce carbon emissions from wood decomposition or from fossil-fuel or wood-based power plants.

Trees in Jeffersonville, Indiana are estimated to store 1260 tons of carbon ($546 thousand). Of the species sampled, Red maple stores and sequesters the most carbon (approximately 13.4% of the total carbon stored and 17.8% of all sequestered carbon.)

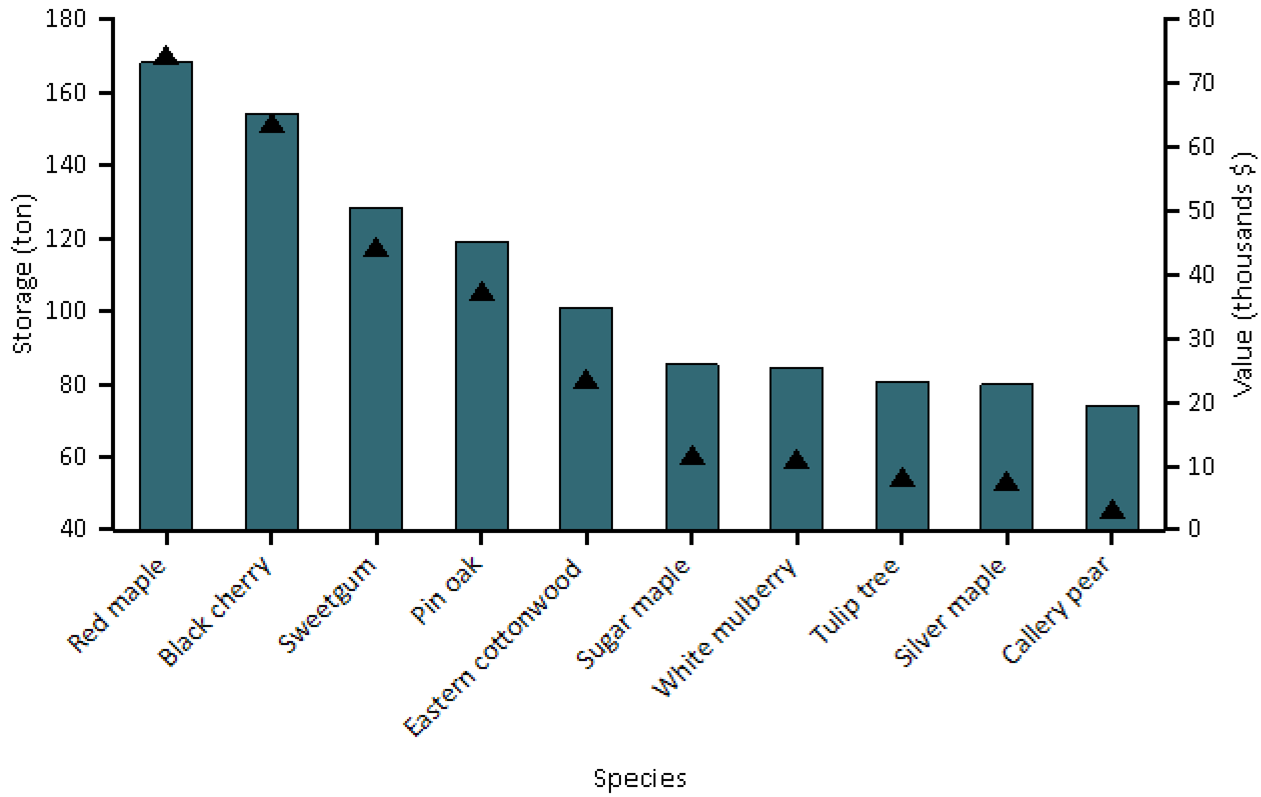


Figure 9. Estimated carbon storage (points) and values (bars) for urban tree species with the greatest storage, Jeffersonville, Indiana

V. Oxygen Production

Oxygen production is one of the most commonly cited benefits of urban trees. The annual oxygen production of a tree is directly related to the amount of carbon sequestered by the tree, which is tied to the accumulation of tree biomass.

Trees in Jeffersonville, Indiana are estimated to produce 70.36 tons of oxygen per year.[4] However, this tree benefit is relatively insignificant because of the large and relatively stable amount of oxygen in the atmosphere and extensive production by aquatic systems. Our atmosphere has an enormous reserve of oxygen. If all fossil fuel reserves, all trees, and all organic matter in soils were burned, atmospheric oxygen would only drop a few percent (Broecker 1970).

Table 2. The top 20 oxygen production species.

Species	*Oxygen (ton)*	*Gross Carbon Sequestration (pound/yr)*	*Number of Trees*	*Leaf Area (acre)*
Red maple	12.50	9,378.30	337	13.62
Sweetgum	6.58	4,937.69	170	13.64
Black cherry	5.81	4,355.31	84	4.64
Callery pear	3.52	2,643.57	118	3.95
Pin oak	3.52	2,642.61	86	11.06
Black walnut	3.40	2,549.06	108	4.35
Tulip tree	3.35	2,508.88	65	8.10
Black locust	2.36	1,772.41	72	2.12
Sugar maple	1.92	1,442.42	47	3.86
Eastern cottonwood	1.84	1,380.61	26	2.91
Silver maple	1.81	1,358.25	40	3.42
White mulberry	1.66	1,243.39	43	2.00
American sycamore	1.55	1,161.34	60	4.91
River birch	1.38	1,037.87	41	2.17
Honeylocust	1.30	971.92	66	1.15
Green ash	1.21	904.81	74	3.14
Apple spp	1.06	797.17	116	0.56
Alternateleaf dogwood	1.05	789.36	64	1.10
American elm	1.05	785.03	32	1.45
Japanese flowering cherry	1.01	755.51	90	0.46

VI. Avoided Runoff

Surface runoff can be a cause for concern in many urban areas as it can contribute pollution to streams, wetlands, rivers, lakes, and oceans. During precipitation events, some portion of the precipitation is intercepted by vegetation (trees and shrubs) while the other portion reaches the ground. The portion of the precipitation that reaches the ground and does not infiltrate into the soil becomes surface runoff (Hirabayashi 2012). In urban areas, the large extent of impervious surfaces increases the amount of surface runoff.

Urban trees and shrubs, however, are beneficial in reducing surface runoff. Trees and shrubs intercept precipitation, while their root systems promote infiltration and storage in the soil. The trees and shrubs of Jeffersonville, Indiana help to reduce runoff by an estimated 327 thousand gallons a year with an associated value of $2.9 thousand (see Appendix I for more details). Avoided runoff is estimated based on local weather from the user-designated weather station. In Jeffersonville, Indiana, the total annual precipitation in 2023 was 40.6 inches.

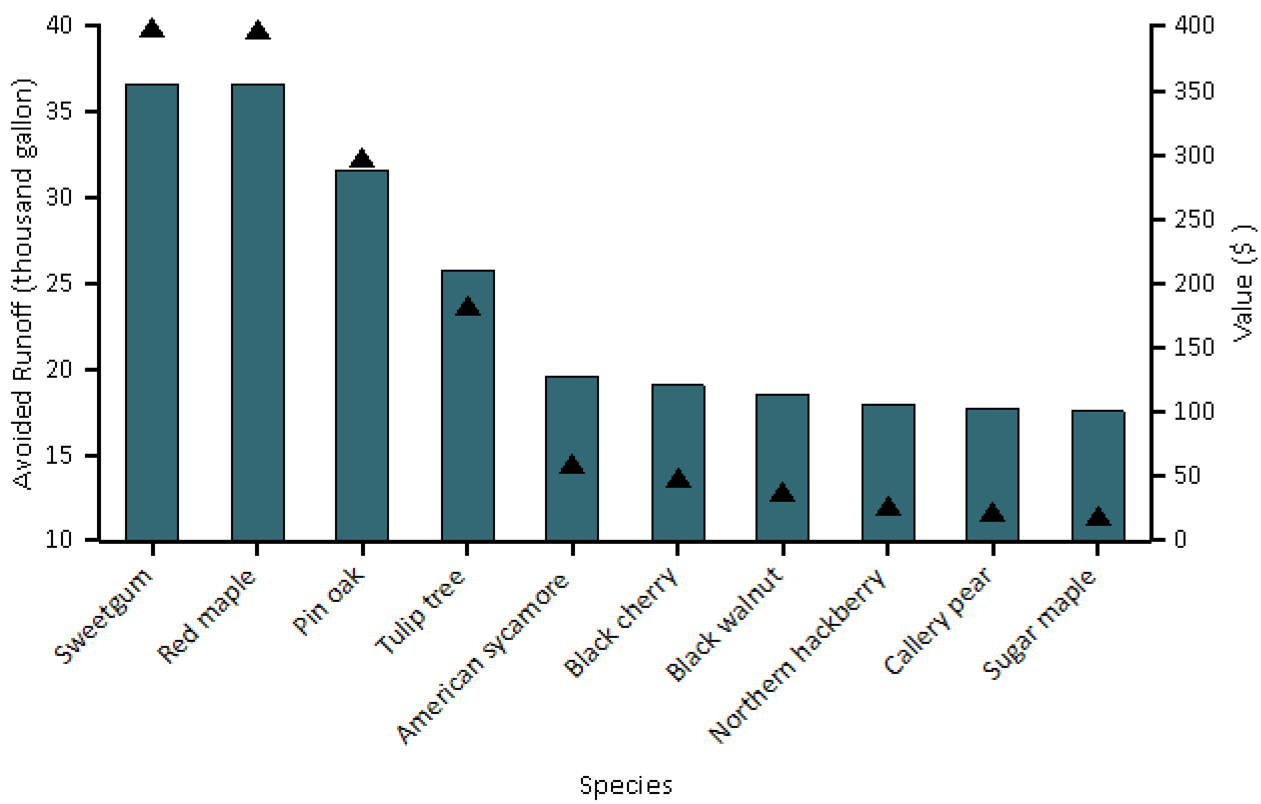


Figure 10. Avoided runoff (points) and value (bars) for species with greatest overall impact on runoff, Jeffersonville, Indiana

VII. Trees and Building Energy Use

Trees affect energy consumption by shading buildings, providing evaporative cooling, and blocking winter winds. Trees tend to reduce building energy consumption in the summer months and can either increase or decrease building energy use in the winter months, depending on the location of trees around the building. Estimates of tree effects on energy use are based on field measurements of tree distance and direction to space conditioned residential buildings (McPherson and Simpson 1999).

Because energy-related data were not collected, energy savings and carbon avoided cannot be calculated.

Table 3. Annual energy savings due to trees near residential buildings, Jeffersonville, Indiana

	Heating	*Cooling*	*Total*
MBTU[a]	0	N/A	0
MWH[b]	0	0	0
Carbon Avoided (pounds)	0	0	0

[a]MBTU - one million British Thermal Units

[b]MWH - megawatt-hour

Table 4. Annual savings [a]($) in residential energy expenditure during heating and cooling seasons, Jeffersonville, Indiana

	Heating	*Cooling*	*Total*
MBTU[b]	0	N/A	0
MWH[c]	0	0	0
Carbon Avoided	0	0	0

[b]Based on the prices of $126 per MWH and $9.26184002592696 per MBTU (see Appendix I for more details)

[c]MBTU - one million British Thermal Units

[c]MWH - megawatt-hour

[5] Trees modify climate, produce shade, and reduce wind speeds. Increased energy use or costs are likely due to these tree-building interactions creating a cooling effect during the winter season. For example, a tree (particularly evergreen species) located on the southern side of a residential building may produce a shading effect that causes increases in heating requirements.

VIII. Replacement and Functional Values

Urban forests have a replacement value based on the trees themselves (e.g., the cost of having to replace a tree with a similar tree); they also have functional values (either positive or negative) based on the functions the trees perform.

The replacement value of an urban forest tends to increase with a rise in the number and size of healthy trees (Nowak et al 2002a). Annual functional values also tend to increase with increased number and size of healthy trees. Through proper management, urban forest values can be increased; however, the values and benefits also can decrease as the amount of healthy tree cover declines.

Urban trees in Jeffersonville, Indiana have the following replacement values:

- Replacement value: $6.26 million
- Carbon storage: $546 thousand

Urban trees in Jeffersonville, Indiana have the following annual functional values:

- Carbon sequestration: $11.4 thousand
- Avoided runoff: $2.92 thousand
- Pollution removal: $2.82 thousand
- Energy costs and carbon emission values: $0

(Note: negative value indicates increased energy cost and carbon emission value)

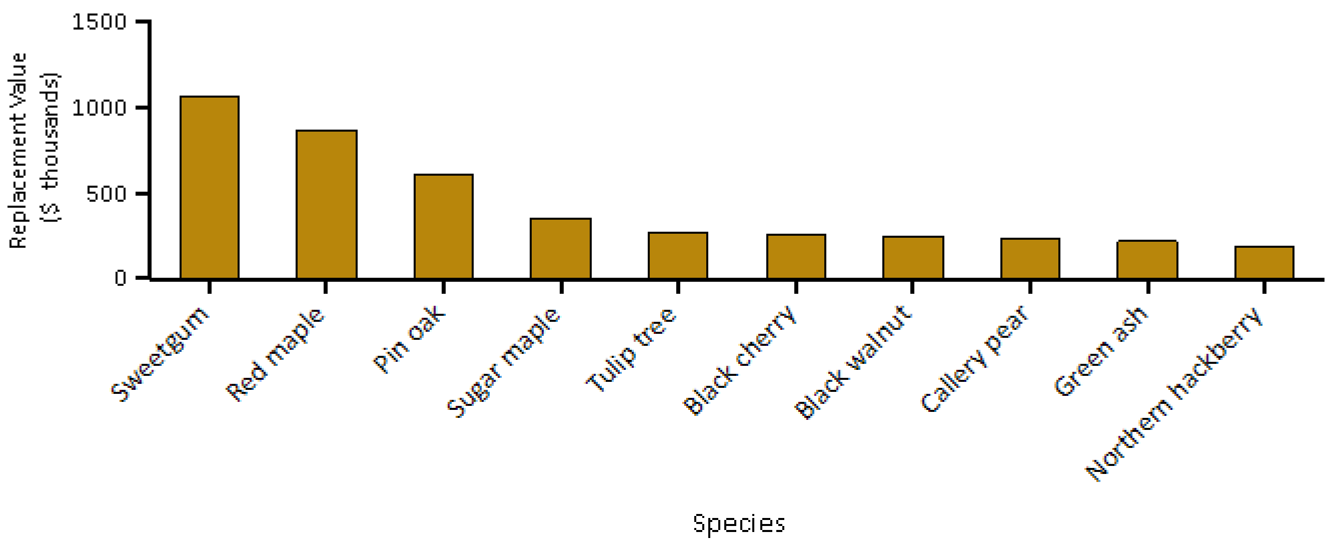


Figure 11. Tree species with the greatest replacement value, Jeffersonville, Indiana

IX. Potential Pest Impacts

Various insects and diseases can infest urban forests, potentially killing trees and reducing the health, replacement value and sustainability of the urban forest. As pests tend to have differing tree hosts, the potential damage or risk of each pest will differ among cities.Fifty-three pests were analyzed for their potential impact and compared with pest range maps (Forest Health Technology Enterprise Team 2014) for the conterminous United States to determine their proximity to Clark County. Nine of the fifty-three pests analyzed are located within the county. For a complete analysis of all pests, see Appendix VII.

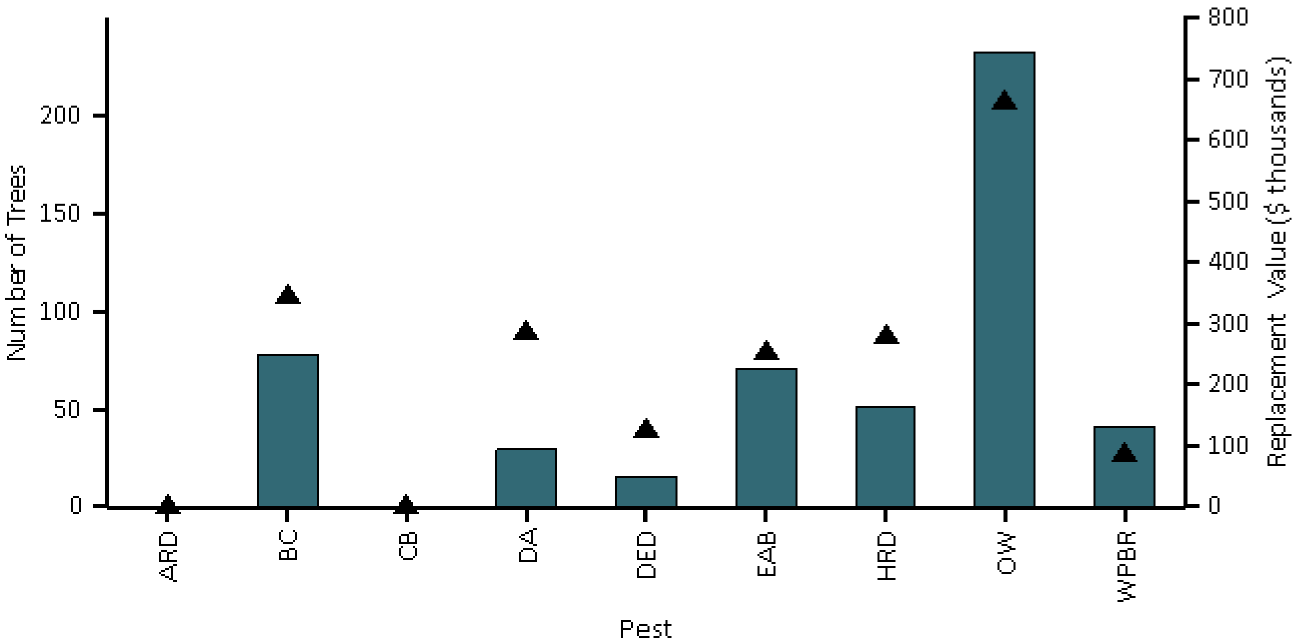


Figure 12. Number of trees at risk (points) and associated compensatory value (bars) for most threatening pests located in the county, Jeffersonville, Indiana

Armillaria Root Disease (ARD) poses a threat to 0.0 percent of the Jeffersonville, Indiana urban forest, which represents a potential loss of $0 in replacement value.

Butternut canker (BC) (Ostry et al 1996) is caused by a fungus that infects butternut trees. The disease has since caused significant declines in butternut populations in the United States. Potential loss of trees from BC is 3.6 percent ($250 thousand in replacement value).

The most common hosts of the fungus that cause chestnut blight (CB) (Diller 1965) are American and European chestnut. CB has the potential to affect 0.0 percent of the population ($0 in replacement value).

Dogwood anthracnose (DA) (Mielke and Daughtrey) is a disease that affects dogwood species, specifically flowering and Pacific dogwood. This disease threatens 2.9 percent of the population, which represents a potential loss of $94.1 thousand in replacement value.

American elm, one of the most important street trees in the twentieth century, has been devastated by the Dutch elm disease (DED) (Northeastern Area State and Private Forestry 1998). Since first reported in the 1930s, it has killed over 50 percent of the native elm population in the United States. Although some elm species have shown varying degrees of resistance, Jeffersonville, Indiana could possibly lose 1.3 percent of its trees to this pest ($48.4 thousand in replacement value).

Emerald ash borer (EAB) (Michigan State University 2010) has killed thousands of ash trees in parts of the United States. EAB has the potential to affect 2.6 percent of the population ($227 thousand in replacement value).

Heterobasidion Root Disease (HRD) poses a threat to 2.9 percent of the Jeffersonville, Indiana urban forest, which represents a potential loss of $163 thousand in replacement value.

Oak wilt (OW) (Rexrode and Brown 1983), which is caused by a fungus, is a prominent disease among oak trees. OW poses a threat to 6.8 percent of the Jeffersonville, Indiana urban forest, which represents a potential loss of $746 thousand in replacement value.

Since its introduction to the United States in 1900, white pine blister rust (Eastern U.S.) (WPBR) (Nicholls and Anderson 1977) has had a detrimental effect on white pines, particularly in the Lake States. WPBR has the potential to affect 0.9 percent of the population ($131 thousand in replacement value).

Appendix I. i-Tree Eco Model and Field Measurements

i-Tree Eco is designed to use standardized field data and local hourly air pollution and meteorological data to quantify urban forest structure and its numerous effects (Nowak and Crane 2000), including:

- Urban forest structure (e.g., species composition, tree health, leaf area, etc.).
- Amount of pollution removed hourly by the urban forest, and its associated percent air quality improvement throughout a year.
- Total carbon stored and net carbon annually sequestered by the urban forest.
- Effects of trees on building energy use and consequent effects on carbon dioxide emissions from power sources.
- Replacement value of the forest, as well as the value for air pollution removal and carbon storage and sequestration.
- Potential impact of infestations by pests, such as Asian longhorned beetle, emerald ash borer, spongy moth, and Dutch elm disease.

Typically, all field data are collected during the leaf-on season to properly assess tree canopies. Typical data collection (actual data collection may vary depending upon the user) includes land use, ground and tree cover, individual tree attributes of species, stem diameter, height, crown width, crown canopy missing and dieback, and distance and direction to residential buildings (Nowak et al 2005; Nowak et al 2008).

During data collection, trees are identified to the most specific taxonomic classification possible. Trees that are not classified to the species level may be classified by genus (e.g., ash) or species groups (e.g., hardwood). In this report, tree species, genera, or species groups are collectively referred to as tree species.

<u>Tree Characteristics:</u>

Leaf area of trees was assessed using measurements of crown dimensions and percentage of crown canopy missing. In the event that these data variables were not collected, they are estimated by the model.

An analysis of invasive species is not available for studies outside of the United States. For the U.S., invasive species are identified using an invasive species list (Indiana Cooperative Agricultural Pest Survey 2007)for the state in which the urban forest is located. These lists are not exhaustive and they cover invasive species of varying degrees of invasiveness and distribution. In instances where a state did not have an invasive species list, a list was created based on the lists of the adjacent states. Tree species that are identified as invasive by the state invasive species list are cross-referenced with native range data. This helps eliminate species that are on the state invasive species list, but are native to the study area.

<u>Air Pollution Removal:</u>

Pollution removal is calculated for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide, particulate matter less than 2.5 microns, and particulate matter less than 10 microns and greater than 2.5 microns. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

Air pollution removal estimates are derived from calculated hourly tree-canopy resistances for ozone, and sulfur and nitrogen dioxides based on a hybrid of big-leaf and multi-layer canopy deposition models (Baldocchi 1988; Baldocchi et al 1987). As the removal of carbon monoxide and particulate matter by vegetation is not directly related to transpiration, removal rates (deposition velocities) for these pollutants were based on average measured values from the literature (Bidwell and Fraser 1972; Lovett 1994) that were adjusted depending on leaf phenology and leaf area. Particulate removal incorporated a 50 percent resuspension rate of particles back to the atmosphere (Zinke 1967). Recent updates (2011) to air quality modeling are based on improved leaf area index simulations, weather and pollution processing and interpolation, and updated pollutant monetary values (Hirabayashi et al 2011; Hirabayashi et al 2012; Hirabayashi 2011).

Trees remove PM2.5 and PM10* when particulate matter is deposited on leaf surfaces (Nowak et al 2013). This deposited PM2.5 and PM10* can be resuspended to the atmosphere or removed during rain events and dissolved or transferred to the soil. This combination of events can lead to positive or negative pollution removal and value depending on various atmospheric factors. Generally, PM2.5 and PM10* removal is positive with positive benefits. However, there are some cases when net removal is negative or resuspended particles lead to increased pollution concentrations and negative values. During some months (e.g., with no rain), trees resuspend more particles than they remove. Resuspension can also lead to increased overall PM2.5 and PM10* concentrations if the boundary layer conditions are lower during net resuspension periods than during net removal periods. Since the pollution removal value is based on the change in pollution concentration, it is possible to have situations when trees remove PM2.5 and PM10* but increase concentrations and thus have negative values during periods of positive overall removal. These events are not common, but can happen.

For reports in the United States, default air pollution removal value is calculated based on local incidence of adverse health effects and national median externality costs. The number of adverse health effects and associated economic value is calculated for ozone, sulfur dioxide, nitrogen dioxide, and particulate matter less than 2.5 microns using data from the U.S. Environmental Protection Agency's Environmental Benefits Mapping and Analysis Program (BenMAP) (Nowak et al 2014). The model uses a damage-function approach that is based on the local change in pollution concentration and population. National median externality costs were used to calculate the value of carbon monoxide removal (Murray et al 1994).

For international reports, user-defined local pollution values are used. For international reports that do not have local values, estimates are based on either European median externality values (van Essen et al 2011) or BenMAP regression equations (Nowak et al 2014) that incorporate user-defined population estimates. Values are then converted to local currency with user-defined exchange rates.

For this analysis, pollution removal value is calculated based on the prices of $1,622 per ton (carbon monoxide), $1,366 per ton (ozone), $282 per ton (nitrogen dioxide), $69 per ton (sulfur dioxide), $59,839 per ton (particulate matter less than 2.5 microns), $7,623 per ton (particulate matter less than 10 microns and greater than 2.5 microns).

<u>Carbon Storage and Sequestration:</u>

Carbon storage is the amount of carbon bound up in the above-ground and below-ground parts of woody vegetation. To calculate current carbon storage, biomass for each tree was calculated using equations from the literature and measured tree data. Open-grown, maintained trees tend to have less biomass than predicted by forest-derived biomass equations (Nowak 1994). To adjust for this difference, biomass results for open-grown urban trees were multiplied by 0.8. No adjustment was made for trees found in natural stand conditions. Tree dry-weight biomass was converted to stored carbon by multiplying by 0.5.

Carbon sequestration is the removal of carbon dioxide from the air by plants. To estimate the gross amount of carbon sequestered annually, average diameter growth from the appropriate genera and diameter class and tree condition was added to the existing tree diameter (year x) to estimate tree diameter and carbon storage in year x+1.

Carbon storage and carbon sequestration values are based on estimated or customized local carbon values. For international reports that do not have local values, estimates are based on the carbon value for the United States (U.S. Environmental Protection Agency 2015, Interagency Working Group on Social Cost of Carbon 2015) and converted to local currency with user-defined exchange rates.

For this analysis, carbon storage and carbon sequestration values are calculated based on $433 per ton.

Oxygen Production:

The amount of oxygen produced is estimated from carbon sequestration based on atomic weights: net O2 release (kg/yr) = net C sequestration (kg/yr) × 32/12. To estimate the net carbon sequestration rate, the amount of carbon sequestered as a result of tree growth is reduced by the amount lost resulting from tree mortality. Thus, net carbon sequestration and net annual oxygen production of the urban forest account for decomposition (Nowak et al 2007). For complete inventory projects, oxygen production is estimated from gross carbon sequestration and does not account for decomposition.

Avoided Runoff:

Annual avoided surface runoff is calculated based on rainfall interception by vegetation, specifically the difference between annual runoff with and without vegetation. Although tree leaves, branches, and bark may intercept precipitation and thus mitigate surface runoff, only the precipitation intercepted by leaves is accounted for in this analysis.

The value of avoided runoff is based on estimated or user-defined local values. For international reports that do not have local values, the national average value for the United States is utilized and converted to local currency with user-defined exchange rates. The U.S. value of avoided runoff is based on the U.S. Forest Service's Community Tree Guide Series (McPherson et al 1999; 2000; 2001; 2002; 2003; 2004; 2006a; 2006b; 2006c; 2007; 2010; Peper et al 2009; 2010; Vargas et al 2007a; 2007b; 2008).

For this analysis, avoided runoff value is calculated based on the price of $0.01 per gallon.

Building Energy Use:

If appropriate field data were collected, seasonal effects of trees on residential building energy use were calculated based on procedures described in the literature (McPherson and Simpson 1999) using distance and direction of trees from residential structures, tree height and tree condition data. To calculate the monetary value of energy savings, local or custom prices per MWH or MBTU are utilized.

For this analysis, energy saving value is calculated based on the prices of $126.00 per MWH and $9.26 per MBTU.

Replacement Values:

Replacement value is the value of a tree based on the physical resource itself (e.g., the cost of having to replace a tree with a similar tree). Replacement values were based on valuation procedures of the Council of Tree and Landscape Appraisers, which uses tree species, diameter, condition, and location information (Nowak et al 2002a; 2002b). Replacement value may not be included for international projects if there is insufficient local data to complete the valuation procedures.

Potential Pest Impacts:

The complete potential pest risk analysis is not available for studies outside of the United States. The number of trees at risk to the pests analyzed is reported, though the list of pests is based on known insects and disease in the United States.

For the U.S., potential pest risk is based on pest range maps and the known pest host species that are likely to experience mortality. Pest range maps for 2012 from the Forest Health Technology Enterprise Team (FHTET) (Forest Health Technology Enterprise Team 2014) were used to determine the proximity of each pest to the county in which the urban forest is located. For the county, it was established whether the insect/disease occurs within the county, is within 250 miles of the county edge, is between 250 and 750 miles away, or is greater than 750 miles away. FHTET did not have pest range maps for Dutch elm disease and chestnut blight. The range of these pests was based on known occurrence and the host range, respectively (Eastern Forest Environmental Threat Assessment Center; Worrall 2007).

Relative Tree Effects:

The relative value of tree benefits reported in Appendix II is calculated to show what carbon storage and sequestration, and air pollutant removal equate to in amounts of municipal carbon emissions, passenger automobile emissions, and house emissions.

Municipal carbon emissions are based on 2010 U.S. per capita carbon emissions (Carbon Dioxide Information Analysis Center 2010). Per capita emissions were multiplied by city population to estimate total city carbon emissions.

Light duty vehicle emission rates (g/mi) for CO, NOx, VOCs, PM10, SO2 for 2010 (Bureau of Transportation Statistics 2010; Heirigs et al 2004), PM2.5 for 2011-2015 (California Air Resources Board 2013), and CO2 for 2011 (U.S. Environmental Protection Agency 2010) were multiplied by average miles driven per vehicle in 2011 (Federal Highway Administration 2013) to determine average emissions per vehicle.

Household emissions are based on average electricity kWh usage, natural gas Btu usage, fuel oil Btu usage, kerosene Btu usage, LPG Btu usage, and wood Btu usage per household in 2009 (Energy Information Administration 2013; Energy Information Administration 2014)

- CO2, SO2, and NOx power plant emission per KWh are from Leonardo Academy 2011. CO emission per kWh assumes 1/3 of one percent of C emissions is CO based on Energy Information Administration 1994. PM10 emission per kWh from Layton 2004.
- CO2, NOx, SO2, and CO emission per Btu for natural gas, propane and butane (average used to represent LPG), Fuel #4 and #6 (average used to represent fuel oil and kerosene) from Leonardo Academy 2011.
- CO2 emissions per Btu of wood from Energy Information Administration 2014.
- CO, NOx and SOx emission per Btu based on total emissions and wood burning (tons) from (British Columbia Ministry 2005; Georgia Forestry Commission 2009).

Appendix II. Relative Tree Effects

The urban forest in Jeffersonville, Indiana provides benefits that include carbon storage and sequestration, and air pollutant removal. To estimate the relative value of these benefits, tree benefits were compared to estimates of average municipal carbon emissions, average passenger automobile emissions, and average household emissions. See Appendix I for methodology.

Carbon storage is equivalent to:

- Amount of carbon emitted in Jeffersonville, Indiana in 2 days
- Annual carbon (C) emissions from 893 automobiles
- Annual C emissions from 366 single-family houses

Carbon monoxide removal is equivalent to:

- Annual carbon monoxide emissions from 0 automobiles
- Annual carbon monoxide emissions from 0 single-family houses

Nitrogen dioxide removal is equivalent to:

- Annual nitrogen dioxide emissions from 6 automobiles
- Annual nitrogen dioxide emissions from 3 single-family houses

Sulfur dioxide removal is equivalent to:

- Annual sulfur dioxide emissions from 120 automobiles
- Annual sulfur dioxide emissions from 0 single-family houses

Annual carbon sequestration is equivalent to:

- Amount of carbon emitted in Jeffersonville, Indiana in 0.0 days
- Annual C emissions from 0 automobiles
- Annual C emissions from 0 single-family houses

Appendix III. Comparison of Urban Forests

A common question asked is, "How does this city compare to other cities?" Although comparison among cities should be made with caution as there are many attributes of a city that affect urban forest structure and functions, summary data are provided from other cities analyzed using the i-Tree Eco model.

I. City totals for trees

City	*% Tree Cover*	*Number of Trees*	*Carbon Storage (tons)*	*Carbon Sequestration (tons/yr)*	*Pollution Removal (tons/yr)*
Toronto, ON, Canada	26.6	10,220,000	1,221,000	51,500	2,099
Atlanta, GA	36.7	9,415,000	1,344,000	46,400	1,663
Los Angeles, CA	11.1	5,993,000	1,269,000	77,000	1,975
New York, NY	20.9	5,212,000	1,350,000	42,300	1,676
London, ON, Canada	24.7	4,376,000	396,000	13,700	408
Chicago, IL	17.2	3,585,000	716,000	25,200	888
Phoenix, AZ	9.0	3,166,000	315,000	32,800	563
Baltimore, MD	21.0	2,479,000	570,000	18,400	430
Philadelphia, PA	15.7	2,113,000	530,000	16,100	575
Washington, DC	28.6	1,928,000	525,000	16,200	418
Oakville, ON , Canada	29.1	1,908,000	147,000	6,600	190
Albuquerque, NM	14.3	1,846,000	332,000	10,600	248
Boston, MA	22.3	1,183,000	319,000	10,500	283
Syracuse, NY	26.9	1,088,000	183,000	5,900	109
Woodbridge, NJ	29.5	986,000	160,000	5,600	210
Minneapolis, MN	26.4	979,000	250,000	8,900	305
San Francisco, CA	11.9	668,000	194,000	5,100	141
Morgantown, WV	35.5	658,000	93,000	2,900	72
Moorestown, NJ	28.0	583,000	117,000	3,800	118
Hartford, CT	25.9	568,000	143,000	4,300	58
Jersey City, NJ	11.5	136,000	21,000	890	41
Casper, WY	8.9	123,000	37,000	1,200	37
Freehold, NJ	34.4	48,000	20,000	540	22

II. Totals per acre of land area

City	*Number of Trees/ac*	*Carbon Storage (tons/ac)*	*Carbon Sequestration (tons/ac/yr)*	*Pollution Removal (lb/ac/yr)*
Toronto, ON, Canada	64.9	7.8	0.33	26.7
Atlanta, GA	111.6	15.9	0.55	39.4
Los Angeles, CA	19.6	4.2	0.16	13.1
New York, NY	26.4	6.8	0.21	17.0
London, ON, Canada	75.1	6.8	0.24	14.0
Chicago, IL	24.2	4.8	0.17	12.0
Phoenix, AZ	12.9	1.3	0.13	4.6
Baltimore, MD	48.0	11.1	0.36	16.6
Philadelphia, PA	25.1	6.3	0.19	13.6
Washington, DC	49.0	13.3	0.41	21.2
Oakville, ON , Canada	78.1	6.0	0.27	11.0
Albuquerque, NM	21.8	3.9	0.12	5.9
Boston, MA	33.5	9.1	0.30	16.1
Syracuse, NY	67.7	10.3	0.34	13.6
Woodbridge, NJ	66.5	10.8	0.38	28.4
Minneapolis, MN	26.2	6.7	0.24	16.3
San Francisco, CA	22.5	6.6	0.17	9.5
Morgantown, WV	119.2	16.8	0.52	26.0
Moorestown, NJ	62.1	12.4	0.40	25.1
Hartford, CT	50.4	12.7	0.38	10.2
Jersey City, NJ	14.4	2.2	0.09	8.6
Casper, WY	9.1	2.8	0.09	5.5
Freehold, NJ	38.3	16.0	0.44	35.3

Appendix IV. General Recommendations for Air Quality Improvement

Urban vegetation can directly and indirectly affect local and regional air quality by altering the urban atmosphere environment. Four main ways that urban trees affect air quality are (Nowak 1995):

- Temperature reduction and other microclimate effects
- Removal of air pollutants
- Emission of volatile organic compounds (VOC) and tree maintenance emissions
- Energy effects on buildings

The cumulative and interactive effects of trees on climate, pollution removal, and VOC and power plant emissions determine the impact of trees on air pollution. Cumulative studies involving urban tree impacts on ozone have revealed that increased urban canopy cover, particularly with low VOC emitting species, leads to reduced ozone concentrations in cities (Nowak 2000). Local urban management decisions also can help improve air quality.

Urban forest management strategies to help improve air quality include (Nowak 2000):

Strategy	*Result*
Increase the number of healthy trees	Increase pollution removal
Sustain existing tree cover	Maintain pollution removal levels
Maximize use of low VOC-emitting trees	Reduces ozone and carbon monoxide formation
Sustain large, healthy trees	Large trees have greatest per-tree effects
Use long-lived trees	Reduce long-term pollutant emissions from planting and removal
Use low maintenance trees	Reduce pollutants emissions from maintenance activities
Reduce fossil fuel use in maintaining vegetation	Reduce pollutant emissions
Plant trees in energy conserving locations	Reduce pollutant emissions from power plants
Plant trees to shade parked cars	Reduce vehicular VOC emissions
Supply ample water to vegetation	Enhance pollution removal and temperature reduction
Plant trees in polluted or heavily populated areas	Maximizes tree air quality benefits
Avoid pollutant-sensitive species	Improve tree health
Utilize evergreen trees for particulate matter	Year-round removal of particles

Appendix V. Invasive Species of the Urban Forest

The following inventoried tree species were listed as invasive on the Indiana invasive species list (Indiana Cooperative Agricultural Pest Survey 2007):

Species Name[a]	*Number of Trees*	*% of Trees*	*Leaf Area (ac)*	*Percent Leaf Area*
Callery pear	118	3.9	4.0	3.5
Black locust	72	2.4	2.1	1.9
White mulberry	43	1.4	2.0	1.8
Tree of heaven	10	0.3	0.5	0.4
Sawtooth oak	8	0.3	0.4	0.4
Siberian elm	7	0.2	0.5	0.5
Norway maple	4	0.1	0.0	0.0
Winged burningbush	2	0.1	0.0	0.0
Total	**264**	**8.73**	**9.58**	**8.54**

[a]Species are determined to be invasive if they are listed on the state's invasive species list

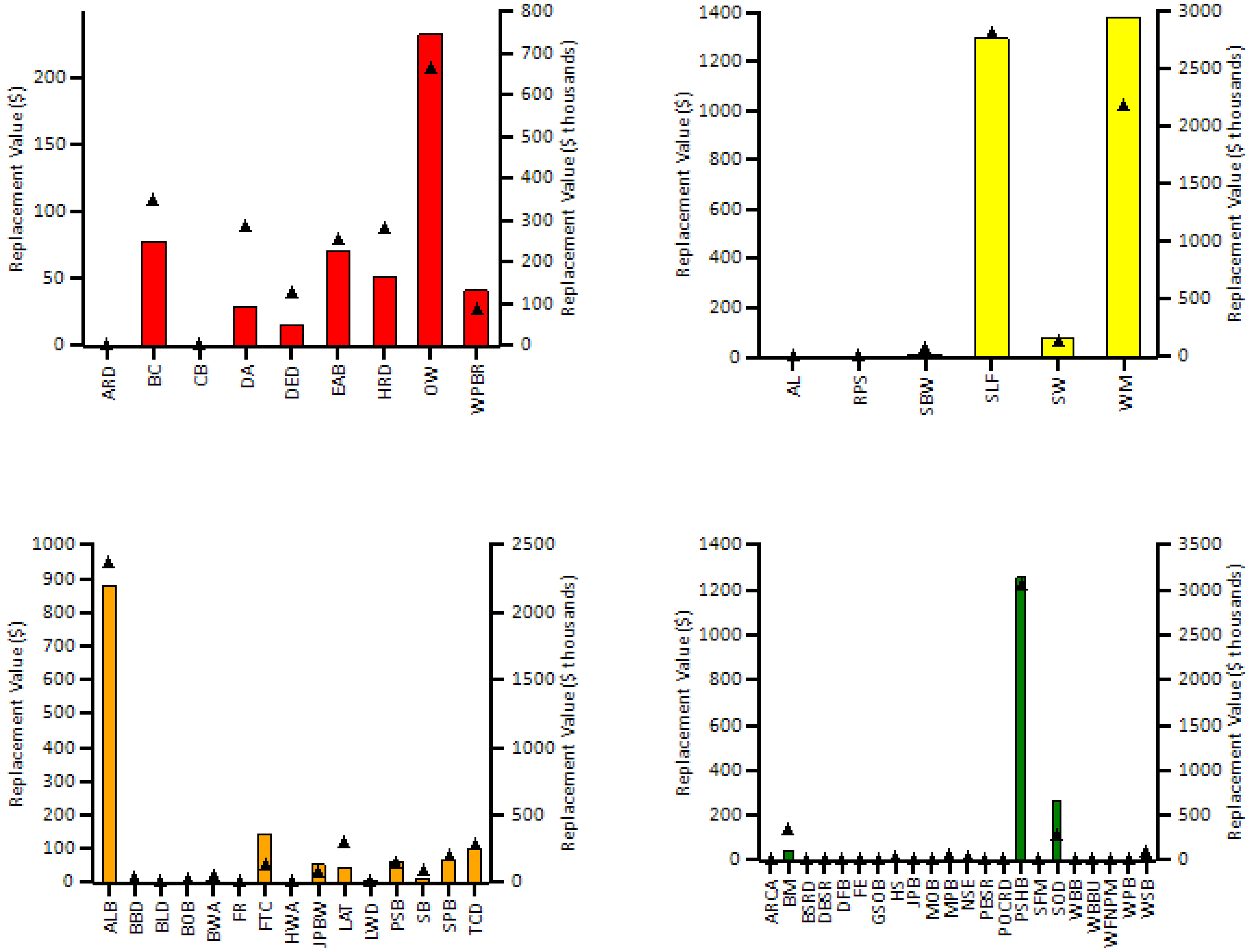
Appendix VI. Potential Risk of Pests

Fifty-three insects and diseases were analyzed to quantify their potential impact on the urban forest. As each insect/ disease is likely to attack different host tree species, the implications for {0} will vary. The number of trees at risk reflects only the known host species that are likely to experience mortality.

Code	Scientific Name	Common Name	Trees at Risk (#)	Value ($ thousands)
AL	Phyllocnistis populiella	Aspen Leafminer	0	0.00
ALB	Anoplophora glabripennis	Asian Longhorned Beetle	945	2,196.69
ARCA	Neodothiora populina	Aspen Running Canker	0	0.00
ARD	Armillaria spp.	Armillaria Root Disease	0	0.00
BBD	Neonectria faginata	Beech Bark Disease	9	1.81
BC	Sirococcus clavigignenti juglandacearum	Butternut Canker	108	250.16
BLD	Litylenchus crenatae mccannii	Beech Leaf Disease	0	0.00
BM	Euproctis chrysorrhoea	Browntail Moth	131	99.13
BOB	Tubakia iowensis	Bur Oak Blight	8	3.79
BSRD	Leptographium wageneri	Black Stain Root Disease	4	0.45
BWA	Adelges piceae	Balsam Woolly Adelgid	17	12.86
CB	Cryphonectria parasitica	Chestnut Blight	0	0.00
DA	Discula destructiva	Dogwood Anthracnose	89	94.12
DBSR	Leptographium wageneri var. pseudotsugae	Douglas-fir Black Stain Root Disease	0	0.00
DED	Ophiostoma novo-ulmi	Dutch Elm Disease	39	48.40
DFB	Dendroctonus pseudotsugae	Douglas-Fir Beetle	0	0.00
EAB	Agrilus planipennis	Emerald Ash Borer	79	227.18
FE	Scolytus ventralis	Fir Engraver	0	0.00
FR	Cronartium quercuum f. sp. Fusiforme	Fusiform Rust	0	0.00
FTC	Malacosoma disstria	Forest Tent Caterpillar	47	356.69
GSOB	Agrilus auroguttatus	Goldspotted Oak Borer	0	0.00
HRD	Heterobasidion irregulare/ occidentale	Heterobasidion Root Disease	87	162.51
HS	Neodiprion tsugae	Hemlock Sawfly	6	0.54
HWA	Adelges tsugae	Hemlock Woolly Adelgid	0	0.00
JPB	Dendroctonus jeffreyi	Jeffrey Pine Beetle	0	0.00
JPBW	Choristoneura pinus	Jack Pine Budworm	27	131.49
LAT	Choristoneura conflictana	Large Aspen Tortrix	114	112.32
LWD	Raffaelea lauricola	Laurel Wilt	2	11.04
MOB	Xyleborus monographus	Mediterranean Oak Borer	0	0.00
MPB	Dendroctonus ponderosae	Mountain Pine Beetle	17	12.86
NSE	Ips perturbatus	Northern Spruce Engraver	10	0.99
OW	Ceratocystis fagacearum	Oak Wilt	207	745.64
PBSR	Leptographium wageneri var. ponderosum	Pine Black Stain Root Disease	0	0.00
POCRD	Phytophthora lateralis	Port-Orford-Cedar Root Disease	2	0.13
PSB	Tomicus piniperda	Pine Shoot Beetle	57	155.50

Code	Scientific Name	Common Name	Trees at Risk (#)	Value ($ thousands)
PSHB	Euwallacea nov. sp.	Polyphagous Shot Hole Borer	1,217	3,142.44
RPS	Matsucoccus resinosae	Red Pine Scale	3	3.52
SB	Dendroctonus rufipennis	Spruce Beetle	35	24.34
SBW	Choristoneura fumiferana	Spruce Budworm	29	23.80
SFM	subalpine fir mortality summary	Subalpine Fir Mortality	0	0.00
SLF	Lycorma delicatula	Spotted Lanternfly	1,313	2,766.83
SOD	Phytophthora ramorum	Sudden Oak Death	105	668.10
SPB	Dendroctonus frontalis	Southern Pine Beetle	75	166.98
SW	Sirex noctilio	Sirex Wood Wasp	57	155.50
TCD	Geosmithia morbida	Thousand Canker Disease	108	250.16
WBB	Dryocoetes confusus	Western Bark Beetle	0	0.00
WBBU	Acleris gloverana	Western Blackheaded Budworm	0	0.00
WFNPM	western five-needle pine mortality summary	Western Five-Needle Pine Mortality	0	0.00
WM	Operophtera brumata	Winter Moth	1,016	2,950.22
WPB	Dendroctonus brevicomis	Western Pine Beetle	0	0.00
WPBR	Cronartium ribicola	White Pine Blister Rust	27	131.49
WSB	Choristoneura occidentalis	Western Spruce Budworm	29	23.80

In the following graph, the pests are color coded according to the county's proximity to the pest occurrence in the United States. Red indicates that the pest is within the county; orange indicates that the pest is within 250 miles of the county; yellow indicates that the pest is within 750 miles of the county; and green indicates that the pest is outside of these ranges.



Note: points - Number of trees, bars - Replacement value

Based on the host tree species for each pest and the current range of the pest (Forest Health Technology Enterprise Team 2014), it is possible to determine what the risk is that each tree species in the urban forest could be attacked by an insect or disease.

Spp. Risk	Risk Weight	Species Name	AL	ALB	ARCA	ARD	BBD	BC	BLD	BM	BOB	BSRD	BWA	CB	DA	DBSR	DED	DFB	EAB	FE	FR	FTC	GSOB	HRD	HS	HWA	JPB	JPBW	LAT	LWD	MOB	MPB	NSE	OW	PBSR
Red	22	Norway spruce											Orange											Red								Green			
Red	21	Eastern white pine																						Red				Orange							
Red	15	White spruce										Green												Red									Green		
Orange	10	Sugar maple		Orange																		Orange													
Orange	10	River birch		Orange																									Orange						
Orange	10	Yellow birch		Orange																									Orange						
Red	10	American elm		Orange													Red																		
Red	10	Bur oak									Orange																							Red	
Orange	10	Sitka spruce																							Green								Green		
Orange	10	Japanese black pine																																	
Red	9	Green ash		Orange															Red																
Red	9	Northern red oak								Green																								Red	
Orange	9	Blue spruce																																	
Red	9	Siberian elm		Orange													Red																		
Red	8	Black walnut						Red																											
Red	8	Pin oak																																Red	
Orange	8	Boxelder		Orange																															
Orange	8	Gray birch		Orange																									Orange						
Orange	8	Austrian pine																																	
Orange	8	Virginia pine																																	
Orange	7	Red maple		Orange																															
Orange	7	Silver maple		Orange																															
Red	7	White oak																																Red	
Red	7	Shumard oak																																Red	
Red	7	Southern red oak																																Red	
Orange	7	Norway maple		Orange																															
Orange	6	Apple spp		Orange						Green																									
Red	6	Swamp white oak																																Red	
Orange	6	Freeman maple		Orange																															
Red	6	Willow oak																																Red	
Orange	6	Japanese maple		Orange																															
Red	6	White ash																	Red																
Orange	6	London planetree		Orange																															
Red	6	Shingle oak																																Red	
Red	6	Overcup oak																																Red	
Red	6	Chinkapin oak																																Red	
Orange	6	Common chokecherry								Green																			Orange						
Red	6	Chestnut oak																																Red	
Orange	6	Trident maple		Orange																															
Red	5	Eastern red cedar																						Red											
Orange	5	Eastern cottonwood		Orange																															

Spp. Risk	Risk Weight	Species Name	AL	ALB	ARCA	ARD	BBD	BC	BLD	BM	BOB	BSRD	BWA	CB	DA	DBSR	DED	DFB	EAB	FE	FR	FTC	GSOB	HRD	HS	HWA	JPB	JPBW	LAT	LWD	MOB	MPB	NSE	OW	PBSR
	5	American beech																																	
	5	Sawtooth oak																																	
	5	Painted maple																																	
	5	Sassafras																																	
	4	Black cherry																																	
	4	Alternateleaf dogwood																																	
	4	Kousa dogwood																																	
	4	Flowering dogwood																																	
	4	Silky dogwood																																	
	4	White poplar																																	
	4	Cornelian cherry																																	
	3	Japanese flowering cherry																																	
	3	Northern hackberry																																	
	3	Tulip tree																																	
	3	American sycamore																																	
	3	Japanese zelkova																																	
	3	White mulberry																																	
	3	Tree of heaven																																	
	3	Amur maple																																	
	3	Rose-of-sharon																																	
	3	Paperbark maple																																	
	3	Ohio buckeye																																	
	2	Black locust																																	
	2	Black tupelo																																	
	2	American hornbeam																																	
	2	Pignut hickory																																	
	2	Shagbark hickory																																	
	2	Eastern hophornbeam																																	
	1	Sweetgum																																	
	1	Callery pear																																	
	1	Sweetbay																																	
	1	Honeylocust																																	
	1	Northern catalpa																																	
	1	Southern magnolia																																	
	1	Pecan																																	
	1	Goldenrain tree																																	
	1	Babylon weeping willow																																	
	1	Hinoki cypress																																	
	1	Witch hazel																																	
	1	Magnolia spp																																	

Spp. Risk	Risk Weight	Species Name	POCRD	PSB	PSHB	RPS	SB	SBW	SFM	SLF	SOD	SPB	SW	TCD	WBB	WBBU	WFNPM	WM	WPB	WPBR	WSB
	22	Norway spruce																			

Spp. Risk	Risk Weight	Species Name	POCRD	PSB	PSHB	RPS	SB	SBW	SFM	SLF	SOD	SPB	SW	TCD	WBB	WBBU	WFNPM	WM	WPB	WPBR	WSB
	21	Eastern white pine																			
	15	White spruce																			
	10	Sugar maple																			
	10	River birch																			
	10	Yellow birch																			
	10	American elm																			
	10	Bur oak																			
	10	Sitka spruce																			
	10	Japanese black pine																			
	9	Green ash																			
	9	Northern red oak																			
	9	Blue spruce																			
	9	Siberian elm																			
	8	Black walnut																			
	8	Pin oak																			
	8	Boxelder																			
	8	Gray birch																			
	8	Austrian pine																			
	8	Virginia pine																			
	7	Red maple																			
	7	Silver maple																			
	7	White oak																			
	7	Shumard oak																			
	7	Southern red oak																			
	7	Norway maple																			
	6	Apple spp																			
	6	Swamp white oak																			
	6	Freeman maple																			
	6	Willow oak																			
	6	Japanese maple																			
	6	White ash																			
	6	London planetree																			
	6	Shingle oak																			
	6	Overcup oak																			
	6	Chinkapin oak																			
	6	Common chokecherry																			
	6	Chestnut oak																			
	6	Trident maple																			
	5	Eastern red cedar																			
	5	Eastern cottonwood																			
	5	American beech																			
	5	Sawtooth oak																			
	5	Painted maple																			
	5	Sassafras																			
	4	Black cherry																			

Spp. Risk	Risk Weight	Species Name	POCRD	PSB	PSHB	RPS	SB	SBW	SFM	SLF	SOD	SPB	SW	TCD	WBB	WBBU	WFNPM	WM	WPB	WPBR	WSB
Red	4	Alternateleaf dogwood																			
Red	4	Kousa dogwood																			
Red	4	Flowering dogwood																			
Red	4	Silky dogwood																			
Yellow	4	White poplar								Yellow								Yellow			
Red	4	Cornelian cherry																			
Yellow	3	Japanese flowering cherry			Green					Yellow											
Orange	3	Northern hackberry																			
Yellow	3	Tulip tree			Green					Yellow											
Yellow	3	American sycamore			Green					Yellow											
Yellow	3	Japanese zelkova			Green					Yellow											
Yellow	3	White mulberry			Green					Yellow											
Yellow	3	Tree of heaven			Green					Yellow											
Orange	3	Amur maple																			
Orange	3	Rose-of-sharon																			
Orange	3	Paperbark maple																			
Orange	3	Ohio buckeye																			
Yellow	2	Black locust								Yellow											
Yellow	2	Black tupelo								Yellow											
Yellow	2	American hornbeam								Yellow											
Yellow	2	Pignut hickory								Yellow											
Yellow	2	Shagbark hickory								Yellow											
Yellow	2	Eastern hophornbeam								Yellow											
Green	1	Sweetgum			Green																
Green	1	Callery pear			Green																
Green	1	Sweetbay			Green																
Green	1	Honeylocust			Green																
Green	1	Northern catalpa			Green																
Green	1	Southern magnolia			Green																
Green	1	Pecan			Green																
Green	1	Goldenrain tree			Green																
Green	1	Babylon weeping willow			Green																
Green	1	Hinoki cypress	Green																		
Green	1	Witch hazel									Green										
Green	1	Magnolia spp			Green																

Note:
Species that are not listed in the matrix are not known to be hosts to any of the pests analyzed.

Species Risk:
- Red indicates that tree species is at risk to at least one pest within county
- Orange indicates that tree species has no risk to pests in county, but has a risk to at least one pest within 250 miles from the county

- Yellow indicates that tree species has no risk to pests within 250 miles of county, but has a risk to at least one pest that is 250 and 750 miles from the county
- Green indicates that tree species has no risk to pests within 750 miles of county, but has a risk to at least one pest that is greater than 750 miles from the county

Risk Weight:
Numerical scoring system based on sum of points assigned to pest risks for species. Each pest that could attack tree species is scored as 4 points if red, 3 points if orange, 2 points if yellow and 1 point if green.

Pest Color Codes:
- Red indicates pest is within Clark county
- Red indicates pest is within 250 miles county
- Yellow indicates pest is within 750 miles of Clark county
- Green indicates pest is outside of these ranges

References

Abdollahi, K.K.; Ning, Z.H.; Appeaning, A., eds. 2000. Global climate change and the urban forest. Baton Rouge, LA: GCRCC and Franklin Press. 77 p.

Baldocchi, D. 1988. A multi-layer model for estimating sulfur dioxide deposition to a deciduous oak forest canopy. Atmospheric Environment. 22: 869-884.

Baldocchi, D.D.; Hicks, B.B.; Camara, P. 1987. A canopy stomatal resistance model for gaseous deposition to vegetated surfaces. Atmospheric Environment. 21: 91-101.

Bidwell, R.G.S.; Fraser, D.E. 1972. Carbon monoxide uptake and metabolism by leaves. Canadian Journal of Botany. 50: 1435-1439.

British Columbia Ministry of Water, Land, and Air Protection. 2005. Residential wood burning emissions in British Columbia. British Columbia.

Broecker, W.S. 1970. Man's oxygen reserve. Science 168(3939): 1537-1538.

Bureau of Transportation Statistics. 2010. Estimated National Average Vehicle Emissions Rates per Vehicle by Vehicle Type using Gasoline and Diesel. Washington, DC: Burea of Transportation Statistics, U.S. Department of Transportation. Table 4-43.

California Air Resources Board. 2013. Methods to Find the Cost-Effectiveness of Funding Air Quality Projects. Table 3 Average Auto Emission Factors. CA: California Environmental Protection Agency, Air Resources Board.

Carbon Dioxide Information Analysis Center. 2010. CO2 Emissions (metric tons per capita). Washington, DC: The World Bank.

Cardelino, C.A.; Chameides, W.L. 1990. Natural hydrocarbons, urbanization, and urban ozone. Journal of Geophysical Research. 95(D9): 13,971-13,979.

Diller, J. D. 1965. Chestnut Blight. Forest Pest Leaflet 94. Washington, DC: U. S. Department of Agriculture, Forest Service. 7 p.

Eastern Forest Environmental Threat Assessment Center. Dutch Elm Disease. http://threatsummary.forestthreats.org/threats/threatSummaryViewer.cfm?threatID=43

Energy Information Administration. 1994. Energy Use and Carbon Emissions: Non-OECD Countries. Washington, DC: Energy Information Administration, U.S. Department of Energy.

Energy Information Administration. 2013. CE2.1 Fuel consumption totals and averages, U.S. homes. Washington, DC: Energy Information Administration, U.S. Department of Energy.

Energy Information Administration. 2014. CE5.2 Household wood consumption. Washington, DC: Energy Information Administration, U.S. Department of Energy.

Federal Highway Administration. 2013. Highway Statistics 2011.Washington, DC: Federal Highway Administration, U.S. Department of Transportation. Table VM-1.

Forest Health Technology Enterprise Team. 2014. 2012 National Insect & Disease Risk Maps/Data. Fort Collins, CO: U.S. Department of Agriculture, Forest Service. http://www.fs.fed.us/foresthealth/technology/nidrm2012.shtml

Georgia Forestry Commission. 2009. Biomass Energy Conversion for Electricity and Pellets Worksheet. Dry Branch, GA: Georgia Forestry Commission.

Heirigs, P.L.; Delaney, S.S.; Dulla, R.G. 2004. Evaluation of MOBILE Models: MOBILE6.1 (PM), MOBILE6.2 (Toxics), and MOBILE6/CNG. Sacramento, CA: National Cooperative Highway Research Program, Transportation Research Board.

Hirabayashi, S. 2011. Urban Forest Effects-Dry Deposition (UFORE-D) Model Enhancements, http://www.itreetools.org/eco/resources/UFORE-D enhancements.pdf

Hirabayashi, S. 2012. i-Tree Eco Precipitation Interception Model Descriptions, http://www.itreetools.org/eco/resources/iTree_Eco_Precipitation_Interception_Model_Descriptions_V1_2.pdf

Hirabayashi, S.; Kroll, C.; Nowak, D. 2011. Component-based development and sensitivity analyses of an air pollutant dry deposition model. Environmental Modeling and Software. 26(6): 804-816.

Hirabayashi, S.; Kroll, C.; Nowak, D. 2012. i-Tree Eco Dry Deposition Model Descriptions V 1.0

Indiana Cooperative Agricultural Pest Survey. 2007. Indiana's "Most Unwanted" Invasive Plant Pest List - FY 2007. IN: Purdue University, Purdue Extension Entomology. <http://www.extension.entm.purdue.edu/CAPS/downloads/IndianaInvasivePlantPestList.pdf>

Interagency Working Group on Social Cost of Carbon, United States Government. 2015. Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866. http://www.whitehouse.gov/sites/default/files/omb/inforeg/scc-tsd-final-july-2015.pdf

Layton, M. 2004. 2005 Electricity Environmental Performance Report: Electricity Generation and Air Emissions. CA: California Energy Commission.

Leonardo Academy. 2011. Leonardo Academy's Guide to Calculating Emissions Including Emission Factors and Energy Prices. Madison, WI: Leonardo Academy Inc.

Lovett, G.M. 1994. Atmospheric deposition of nutrients and pollutants in North America: an ecological perspective. Ecological Applications. 4: 629-650.

McPherson, E.G.; Maco, S.E.; Simpson, J.R.; Peper, P.J.; Xiao, Q.; VanDerZanden, A.M.; Bell, N. 2002. Western Washington and Oregon Community Tree Guide: Benefits, Costs, and Strategic Planting. International Society of Arboriculture, Pacific Northwest, Silverton, OR.

McPherson, E.G.; Simpson, J.R. 1999. Carbon dioxide reduction through urban forestry: guidelines for professional and volunteer tree planters. Gen. Tech. Rep. PSW-171. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 237 p.

McPherson, E.G.; Simpson, J.R.; Peper, P.J.; Crowell, A.M.N.; Xiao, Q. 2010. Northern California coast community tree guide: benefits, costs, and strategic planting. PSW-GTR-228. Gen. Tech. Rep. PSW-GTR-228. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA.

McPherson, E.G.; Simpson, J.R.; Peper, P.J.; Gardner, S.L.; Vargas, K.E.; Maco, S.E.; Xiao, Q. 2006a. Coastal Plain Community Tree Guide: Benefits, Costs, and Strategic Planting PSW-GTR-201. USDA Forest Service, Pacific Southwest Research Station, Albany, CA.

McPherson, E.G.; Simpson, J.R.; Peper, P.J.; Gardner, S.L.; Vargas, K.E.; Xiao, Q. 2007. Northeast community tree guide: benefits, costs, and strategic planting.

McPherson, E.G.; Simpson, J.R.; Peper, P.J.; Maco, S.E.; Gardner, S.L.; Cozad, S.K.; Xiao, Q. 2006b. Midwest Community Tree Guide: Benefits, Costs and Strategic Planting PSW-GTR-199. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA.

McPherson, E.G.; Simpson, J.R.; Peper, P.J.; Maco, S.E.; Gardner, S.L.; Vargas, K.E.; Xiao, Q. 2006c. Piedmont Community Tree Guide: Benefits, Costs, and Strategic Planting PSW-GTR 200. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA.

McPherson, E.G.; Simpson, J.R.; Peper, P.J.; Maco, S.E.; Xiao Q.; Mulrean, E. 2004. Desert Southwest Community Tree Guide: Benefits, Costs and Strategic Planting. Phoenix, AZ: Arizona Community Tree Council, Inc. 81 :81.

McPherson, E.G.; Simpson, J.R.; Peper, P.J.; Scott, K.I.; Xiao, Q. 2000. Tree Guidelines for Coastal Southern California Communities. Local Government Commission, Sacramento, CA.

McPherson, E.G.; Simpson, J.R.; Peper, P.J.; Xiao, Q. 1999. Tree Guidelines for San Joaquin Valley Communities. Local Government Commission, Sacramento, CA.

McPherson, E.G.; Simpson, J.R.; Peper, P.J.; Xiao, Q.; Maco, S.E.; Hoefer, P.J. 2003. Northern Mountain and Prairie Community Tree Guide: Benefits, Costs and Strategic Planting. Center for Urban Forest Research, USDA Forest Service, Pacific Southwest Research Station, Albany, CA.

McPherson, E.G.; Simpson, J.R.; Peper, P.J.; Xiao, Q.; Pittenger, D.R.; Hodel, D.R. 2001. Tree Guidelines for Inland Empire Communities. Local Government Commission, Sacramento, CA.

Michigan State University. 2010. Emerald ash borer. East Lansing, MI: Michigan State University [and others].

Mielke, M. E.; Daughtrey, M. L. How to Identify and Control Dogwood Anthracnose. NA-GR-18. Broomall, PA: U. S. Department of Agriculture, Forest Service, Northeastern Area and Private Forestry.

Murray, F.J.; Marsh L.; Bradford, P.A. 1994. New York State Energy Plan, vol. II: issue reports. Albany, NY: New York State Energy Office.

National Invasive Species Information Center. 2011. Beltsville, MD: U.S. Department of Agriculture, National Invasive Species Information Center. http://www.invasivespeciesinfo.gov/plants/main.shtml

Nicholls, T. H.; Anderson, R. L. 1977. How to Identify White Pine Blister Rust and Remove Cankers. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry

Northeastern Area State and Private Forestry. 1998. How to identify and manage Dutch Elm Disease. NA-PR-07-98. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry.

Nowak, D.J. 1994. Atmospheric carbon dioxide reduction by Chicago's urban forest. In: McPherson, E.G.; Nowak, D.J.; Rowntree, R.A., eds. Chicago's urban forest ecosystem: results of the Chicago Urban Forest Climate Project. Gen. Tech.

Rep. NE-186. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 83-94.

Nowak, D.J. 1995. Trees pollute? A "TREE" explains it all. In: Proceedings of the 7th National Urban Forestry Conference. Washington, DC: American Forests: 28-30.

Nowak, D.J. 2000. The interactions between urban forests and global climate change. In: Abdollahi, K.K.; Ning, Z.H.; Appeaning, A., eds. Global Climate Change and the Urban Forest. Baton Rouge, LA: GCRCC and Franklin Press: 31-44.

Nowak, D.J., Hirabayashi, S., Bodine, A., Greenfield, E. 2014. Tree and forest effects on air quality and human health in the United States. Environmental Pollution. 193:119-129.

Nowak, D.J., Hirabayashi, S., Bodine, A., Hoehn, R. 2013. Modeled PM2.5 removal by trees in ten U.S. cities and associated health effects. Environmental Pollution. 178: 395-402.

Nowak, D.J.; Civerolo, K.L.; Rao, S.T.; Sistla, S.; Luley, C.J.; Crane, D.E. 2000. A modeling study of the impact of urban trees on ozone. Atmospheric Environment. 34: 1601-1613.

Nowak, D.J.; Crane, D.E. 2000. The Urban Forest Effects (UFORE) Model: quantifying urban forest structure and functions. In: Hansen, M.; Burk, T., eds. Integrated tools for natural resources inventories in the 21st century. Proceedings of IUFRO conference. Gen. Tech. Rep. NC-212. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station: 714-720.

Nowak, D.J.; Crane, D.E.; Dwyer, J.F. 2002a. Compensatory value of urban trees in the United States. Journal of Arboriculture. 28(4): 194 - 199.

Nowak, D.J.; Crane, D.E.; Stevens, J.C.; Hoehn, R.E. 2005. The urban forest effects (UFORE) model: field data collection manual. V1b. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station, 34 p. http://www.fs.fed.us/ne/syracuse/Tools/downloads/UFORE_Manual.pdf

Nowak, D.J.; Crane, D.E.; Stevens, J.C.; Ibarra, M. 2002b. Brooklyn's urban forest. Gen. Tech. Rep. NE-290. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 107 p.

Nowak, D.J.; Dwyer, J.F. 2000. Understanding the benefits and costs of urban forest ecosystems. In: Kuser, John, ed. Handbook of urban and community forestry in the northeast. New York, NY: Kluwer Academics/Plenum: 11-22.

Nowak, D.J.; Hoehn, R.; Crane, D. 2007. Oxygen production by urban trees in the United States. Arboriculture & Urban Forestry. 33(3):220-226.

Nowak, D.J.; Hoehn, R.E.; Crane, D.E.; Stevens, J.C.; Walton, J.T; Bond, J. 2008. A ground-based method of assessing urban forest structure and ecosystem services. Arboriculture and Urban Forestry. 34(6): 347-358.

Nowak, D.J.; Stevens, J.C.; Sisinni, S.M.; Luley, C.J. 2002c. Effects of urban tree management and species selection on atmospheric carbon dioxide. Journal of Arboriculture. 28(3): 113-122.

Ostry, M.E.; Mielke, M.E.; Anderson, R.L. 1996. How to Identify Butternut Canker and Manage Butternut Trees. U. S. Department of Agriculture, Forest Service, North Central Forest Experiment Station.

Peper, P.J.; McPherson, E.G.; Simpson, J.R.; Albers, S.N.; Xiao, Q. 2010. Central Florida community tree guide: benefits, costs, and strategic planting. Gen. Tech. Rep. PSW-GTR-230. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA.

Peper, P.J.; McPherson, E.G.; Simpson, J.R.; Vargas, K.E.; Xiao Q. 2009. Lower Midwest community tree guide: benefits, costs, and strategic planting. PSW-GTR-219. Gen. Tech. Rep. PSW-GTR-219. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA.

Rexrode, C. O.; Brown, H. D. 1983. Oak Wilt. Forest Insect & Disease Leaflet 29. Washington, DC: U.S. Department of Agriculture, Forest Service. 6 p.

U.S. Environmental Protection Agency. 2010. Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards. Washington, DC: U.S. Environmental Protection Agency. EPA-420-R-10-012a

U.S. Environmental Protection Agency. 2015. The social cost of carbon. http://www.epa.gov/climatechange/EPAactivities/economics/scc.html

van Essen, H.; Schroten, A.; Otten, M.; Sutter, D.; Schreyer, C.; Zandonella, R.; Maibach, M.; Doll, C. 2011. External Costs of Transport in Europe. Netherlands: CE Delft. 161 p.

Vargas, K.E.; McPherson, E.G.; Simpson, J.R.; Peper, P.J.; Gardner, S.L.; Xiao, Q. 2007a. Interior West Tree Guide.

Vargas, K.E.; McPherson, E.G.; Simpson, J.R.; Peper, P.J.; Gardner, S.L.; Xiao, Q. 2007b. Temperate Interior West Community Tree Guide: Benefits, Costs, and Strategic Planting.

Vargas, K.E.; McPherson, E.G.; Simpson, J.R.; Peper, P.J.; Gardner, S.L.; Xiao, Q. 2008. Tropical community tree guide: benefits, costs, and strategic planting. PSW-GTR-216. Gen. Tech. Rep. PSW-GTR-216. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA.

Worrall, J.J. 2007. Chestnut Blight. Forest and Shade Tree Pathology.
http://www.forestpathology.org/dis_chestnut.html

Zinke, P.J. 1967. Forest interception studies in the United States. In: Sopper, W.E.; Lull, H.W., eds. Forest Hydrology. Oxford, UK: Pergamon Press: 137-161.