Indiana Department of Natural Resources

Division of Forestry

Community & Urban Forestry

(CUF)

Sample Urban Statewide Inventory
SUSI Project

An analysis of Indiana's urban forests

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Executive Summary

Indiana's street trees comprise a valuable resource that works around the clock to provide environmental and economic benefits to communities. Taking a proactive approach to street tree management will sustain the structure, function, and value of the resource for years to come. However, proactive maintenance of this resource can be costly, and communities in Indiana have fallen slightly behind with the required maintenance tasks. If left unattended, the benefits afforded by Indiana's street trees will never be fully realized or sustainable, and priority maintenance concerns may create unwelcome liability issues. Furthermore, numerous planting sites throughout Indiana's communities remain vacant, representing untapped potential for increased benefits to Indiana and its citizens.

In 2008, Indiana Department of Natural Resources (DNR), Division of Forestry, Community and Urban Forestry (CUF) commissioned a study to assess the status of Indiana's street tree resource via a sample statewide inventory and analysis. The Sample Urban Statewide Inventory (SUSI) project utilized the U.S. Forest Service's i-Tree Street Tree Resource Analysis Tool for Urban Forest Managers (STRATUM) application to capture forest resource structure, function, and value in 23 communities across Indiana. The combination of street tree inventories and STRATUM analyses has provided the state of Indiana with scientifically reliable estimations of the resource composition present throughout Indiana.

Resource Structure

The SUSI project includes an estimated 326,788 publicly managed street trees among 23 communities. In order to gain an understanding of the benefits these trees provide and the management needs involved, an analysis of Indiana's street tree resource was performed. Species composition, stocking level, age distribution, condition, and canopy coverage can be used to characterize Indiana's resource as follows:

- There are over 243 distinct species of street trees growing throughout the state of Indiana. The predominant street tree species are *Acer saccharinum* (silver maple, 18%); *Acer saccharum* (sugar maple, 7%); *Acer platanoides* (Norway maple, 5%); *Fraxinus pennsylvanica* (green ash, 5%); and *Acer rubrum* (red maple, 4%).

- Municipal-maintained streets in Indiana are 52% stocked with trees.

- The age structure of Indiana's street trees is relatively balanced, with slightly more trees considered young than mature. Silver maple, Indiana's top performing species in terms of benefits provided, is lacking a suitable replacement in size and structure.

- The majority of street trees in Indiana are in good or better functional condition (58%), with 26% of trees classified as fair. Trees in poor condition are 14% of the inventory, while trees that are dead or dying make up 2% of the population.

- In Indiana, the canopy cover of the estimated street tree population is 5,778 acres, or approximately 1% of the SUSI communities' total land area.

Resource Function and Value

According to STRATUM's calculations of annual gross benefits per community, the cumulative value provided by all SUSI community street trees is approximately $30 million annually. Indiana's street trees conserve and reduce energy consumption, reduce carbon dioxide levels, improve air quality, mitigate stormwater runoff, and provide other benefits associated with aesthetics, increased property values, quality of life, and community pride. Indiana's street trees are providing communities with substantial benefits such as:

- Of the environmental benefits, stormwater management encompasses 31% of the total benefit; energy conservation contributes 12% of the total benefit; 4% of the benefit is from air quality improvements; and 1% of the benefit is from carbon dioxide sequestration. The less-tangible, yet equally significant, benefits providing increased property values and social benefits contribute 52% of the total annual benefits.
- The estimated total annual benefit associated with the SUSI communities' street trees is approximately $30 million. Using media values, Indiana's street tree benefits total approximately $79 million when taking into consideration all 567 Indiana communities. Calculated median value benefits for Indiana's towns is approximately $53,000 per year. For Third Class Cities, the median value of benefits received is approximately $180,000 per year, $775,000 per year for Second Class Cities, and $6.6 million per year for First Class Cities.
- Considering median values, Indiana communities investing their street tree population's health and public safety receive a positive return for every dollar in management. Towns receive $1.74 for every dollar invested in street tree management; Third Class Cities receive $1.17 for every management dollar; Second Class Cities receive $2.26 per management dollar; and First Class Cities receive $5.55 for every dollar invested in the street tree population.

Resource Management

Indiana's street tree resource is rich in the benefits it provides to communities. However, maintaining this resource requires constant attention and commitment. To maximize the benefits of Indiana's resource and ensure sustainability, the following proactive management practices should be implemented:

- Sustain the existing street tree resource through comprehensive tree maintenance programs, including new tree establishment and cyclical pruning. Develop replacement plans for the poor and dead/dying trees by replacing them with large-growing trees where appropriate. For those trees that are cyclically maintained, the associated costs to manage them may become less by encouraging safe and healthy trees.
- Reduce dependence on silver maple benefits through careful species selection to achieve greater species diversity and to help guard against catastrophic losses.
- Achieve an appropriate age distribution by planting new trees to improve long-term resource sustainability. Maintaining the flow of benefits provided by a community's street tree resource will require a continued commitment to planting trees, thus keeping an uneven balance of tree age heavily concentrated in young trees.

- Promote tree plantings to expand the extent of the resource and increase canopy cover. Focus on large-growing trees where planting site conditions are conducive to supporting growth. Select species and match them to existing site conditions to avoid conflicts with infrastructure, thereby maximizing benefits and minimizing maintenance costs.

- Increase funding for urban forestry planning, design, management, and maintenance to ensure the street tree canopy is kept healthy, well maintained, safe, and enhanced by well-planned planting projects.

Introduction

Socially, economically, and environmentally, trees are an important feature in Indiana's communities and should be maintained as an integral component of the municipal infrastructure. Research indicates that healthy street trees can mitigate adverse impacts of the urban environment. Specifically, urban trees can help slow and reduce stormwater runoff, improve poor air quality, reduce energy consumption, and regulate increased temperatures from urban heat islands. Healthy urban trees increase real estate values, provide neighborhood residents with a sense of place, and foster psychological health. Street trees are also associated with other benefits, such as increasing community attractiveness for tourism and business. A community is made more enjoyable by its street trees, making it a better place to live, work, and play, while mitigating the communities' environmental impact.

Report Goals

Indiana's street trees soften the harsh lines created by buildings in many parts of the urban landscape and provide a green sanctuary in the developed hardscape, greatly contributing to the "livability" of each community statewide. This summary report utilizes data from the 2008 SUSI project in conjunction with an economic model known as i-Tree's STRATUM application to establish baseline information on the value that street trees provide to communities statewide.

STRATUM is an urban forest management tool developed by a team of researchers at the USDA Forest Service, Pacific Southwest Research Station's Center for Urban Forest Research in Davis, California. This tool is a component of their software suite called i-Tree. Other i-Tree tools used in this project include Sample Street Segment Generator and the STRATUM/MCTI PDA Utility. The purpose of STRATUM is to enable any community to assess its street tree resource by calculating structure, function, and value, thus defining future management needs. Municipal managers can accurately develop policy, set priorities, and make informed management decisions about each community's urban forest using this i-Tree tool.

In an era of ever-increasing environmental awareness and responsibility, there is a need to establish the ways in which Indiana communities are addressing their impact on the environment. Statewide, each community's street tree resource represents a large part of Indiana's overall effort to improve the environment—an effort solidified by CUF's commitment to continue with a statewide assessment and compare results with a study from years before. The purpose of this report is to provide information concerning the structure, function, and value of the street tree resource so state officials, municipal managers, and citizens alike can make informed decisions about support and management priorities. Information is provided to accomplish the following:

- Assess the health and condition of Indiana's street trees via a sample statewide inventory and analysis of the findings.
- Gain insight on the changes in Indiana's street trees over time by comparing this 2008 analysis to the study completed in 1992.
- Describe the current structure of the street tree resource and establish benchmarks for future management decisions.
- Detail management expenditures for Indiana's publicly managed street trees and provide critical baseline information for evaluating program cost-efficiency.

- Quantify the value of the environmental benefits of Indiana's street trees and highlight the relevance and relationship of the resource to local quality of life issues, such as environmental and psychological health and economic development.
- Describe the current management challenges for street tree maintenance and assist decision-makers in assessing and justifying the level of funding and type of management program appropriate for Indiana's street trees.
- Create a study that is replicable by other states.

Methodology

Summary

The methodology of project setup, data collection, and project analysis are provided to give total understanding of the inventory process used by Davey Resource Group (Davey) in conducting the SUSI project. The inventory includes 23 communities scattered throughout Indiana. During the summer of 2008, Davey conducted sample inventories in 16 communities and obtained the latest inventory database from 7 other communities. In communities with sample inventories, tree data were collected providing information concerning the species composition, relative age, health, and maintenance recommendations for their street tree population. Available planting sites were also recorded for the assessment of street tree distribution and stocking level. In communities with existing inventories, the most up-to-date dataset was formatted according to STRATUM requirements. The data from all 23 inventories, sample and existing, were imported into STRATUM (version 3.4) for the analysis of each community's forest resource structure, function, and value. STRATUM (version 3.4) is i-Tree's tree population assessment and benefits modeling application. The inventory data, STRATUM project files, and STRATUM analysis reports are included on the 4 CD-ROMs, of which are divided by community class type.

The SUSI project consists of three stages: project setup, data collection, and project analysis.

Project Setup

Twenty of the 23 communities in this project are part of an earlier study by the National Urban Forest Council. In 1992, the American Forest Association, U.S. Forest Service, and State Foresters designed a national survey of 413 cities to prove a trend in urban forest conditions throughout North America. Jim Kielbaso of Michigan State University chose the communities for Indiana determined by population classes. It was CUF's full intention to use the same 20 communities in this 2008 statewide sample inventory. Sample inventory data collection was conducted where full street tree inventories did not exist. There are 16 sample inventories included in this 2008 project. Additionally, there are 7 pre-existing, complete street tree inventories included in this 2008 project. Four of the largest communities have updated, complete street tree inventories. These 4 complete inventories kept project costs manageable, since they would have involved the most fieldwork. In addition to the original 20 communities, 3 additional communities with existing, complete inventories were added to round out the 23 participating communities. Table 1 lists all 23 communities from the smallest population to the largest population and notes their type of inventory.

Table 1. Communities of the Sample Urban Statewide Inventory

Community	Inventory Type	Population	% Sample Targeted
Newburgh	Sample	3,088	12
Brookville	Sample	3,100	12
Fort Branch	Sample	3,500	12
Upland	Sample	3,758	10
Greendale	Existing, Complete	4,500	100
Rushville	Sample	5,995	6
Cedar Lake	Sample	9,279	6
Kendallville	Sample	10,199	6
Washington	Sample	11,380	6
Madison	Existing, Complete	12,579	100
Peru	Sample	12,994	6
Beech Grove	Sample	14,880	6
East Chicago	Sample	32,414	6
Mishawaka	Sample	49,057	6
Anderson	Sample	57,300	5
Lafayette	Sample	60,459	5
Bloomington	Existing, Complete	61,063	100
Muncie	Existing, Complete	67,430	100
Gary	Sample	102,746	5
South Bend	Sample	107,789	5
Evansville	Existing, Complete	120,582	100
Fort Wayne	Existing, Complete	250,000	100
Indianapolis	Existing, Complete	860,454	100

Sample Inventories

In 16 communities, Davey performed sample data collection specifically designed for use in STRATUM (version 3.4). Each community's sample inventory provides the necessary information based on its sample percentage to calculate an estimate of the street tree resource's structure, function, and value. Sample sizes were determined by the community's population size. A minimum of 30 street segments were needed to establish a sample. A 5%–12% sample of street segments was calculated in each community. The following is a breakdown of the sampling percentages:

- Communities with a population of <3,500 have a sample size that is 12% of the total street miles.
- Communities with a population between 3,500 and 5,500 have a sample size of 10%.
- Communities with a population between 5,500 and 50,000 have a sample size of 6%.
- Communities with a population between 50,000 and 150,000 have a sample size of 5%.
- Communities with a population >150,000 have a sample size of 3%.

The random samples for each community were generated using i-Tree's Sample Street Segment Generator (version 9) to match the needed target-sampling rate plus an additional amount of backup samples. TIGER/line data were used to create each community's random street segment sample. All streets were included in the sampling process, so as not to exclude streets maintained by each city or town. A full procedural explanation can be found in Appendix B of the i-Tree (version 2.1) Software Suite User's Manual. To aid in fieldwork, street maps were created illustrating sample line segments and backup line segments for each community. All sample inventory maps for each community have been included on 4 CD-ROMs of which are divided by community class type. Each community's sample data collection was completed using i-Tree's STRATUM/MCTI PDA Utility (version 2.1.2). By using the i-Tree utility database format, all data fields and data values are automatically formatted for input into STRATUM (version 3.4).

Existing Inventories

CUF acquired seven existing, complete inventories to increase the number of communities, cost-effectively represent Indiana's larger communities, and increase the geographical distribution of the sample. Due to STRATUM's limits in database recognition and organization, existing inventories were converted into STRATUM (version 3.4) format. All inventory databases were converted to Access™ database files. This procedure is found in Appendix D of the i-Tree (version 2.1) Software Suite User's Manual.

STRATUM Population Assessment and Benefits Model

STRATUM is used to assess and manage community forests. With STRATUM, cities and urban forest managers can accurately quantify the benefits of urban forests and understand the economic impact of managing an urban forest.

Specifically, STRATUM is a tool that quantifies the benefits of street trees and compares them directly with the costs of urban forestry programs to produce accurate net benefit values. It is a statistically valid, financially sound, and defensible cost-benefit analysis tool for urban forestry that may be used with complete or sample inventories in a community.

Inventory data from the SUSI inventory project was entered into the STRATUM model by Davey to assess and quantify the beneficial functions of Indiana's street tree resource and to place a dollar value on the annual environmental benefits they provide. The analysis was performed to determine and quantify these benefits:

- Energy Consumption Savings—The energy savings that trees provide can be attributed to shading, the cooling effect of transpiration, and wind reduction. These key factors reduce the amount of radiant energy absorbed in buildings and other hardscapes, cooling the air around buildings in the summer and helping retain heat during cold winter months. The energy savings is realized by lower cooling and heating costs for any type of building.
- Carbon Sequestering—Carbon dioxide (CO_2) is used during a tree's photosynthesis process to produce the natural building blocks necessary for tree growth. This process takes carbon dioxide from the atmosphere and holds it as woody and foliar biomass. This is referred to as carbon sequestration.
- Air Quality—The air quality of Indiana's urban environments greatly benefits from the presence of street and other public trees. Trees absorb gaseous pollutants in the

form of ozone (O_3) and nitrogen dioxide (NO_2). Reduction in ozone can also be attributed to the tree shading effect on hardscape surfaces and the transpiration process. Trees intercept volatile organic compounds (VOCs), sulfuric dioxide (SO_2), and small particulate matter (PM_{10}), such as dust, ash, dirt, pollen, and smoke, from the air. Trees also emit biogenic volatile organic compounds (BVOCs), an air pollutant that contributes to the formation of ozone, a process which the STRATUM model takes into account.

- Stormwater Mitigation—Indiana's street tree population reduces the volume of stormwater runoff in its neighborhoods and ultimately city-wide. This function and benefit is especially important in developed areas with increased quantities of impervious surfaces (roads, driveways, homes, parking areas) and in areas in close proximity to surface waters. A tree's surface area, especially the leaf surfaces, intercepts and stores rainfall. The root systems of trees increase soil infiltration, thereby decreasing runoff. Trees also reduce stormwater runoff by intercepting raindrops before they hit the ground, reducing soil compaction rates and improving soil absorptive properties. In addition, trees intercept suburban contaminants, such as oils, solvents, pesticides, and fertilizers, which are often part of stormwater runoff, reducing pollutant discharges into Indiana's vital waterways.
- Aesthetics and Other Public Values—It may seem difficult to place a dollar value on the benefit Indiana's street trees provide to the overall ambiance and well-being of its communities, but trees do improve real estate values and have positive impacts on human behavior, which can be quantified.

Data Collection

During the sample inventory of 16 Indiana communities, all sites along randomly selected street segments were individually identified, measured, examined, and recorded. Each segment was visited and data were collected for every public site (trees, stumps, and planting sites) along both sides of the street. If the street segment was not maintained by the city or town, the collector then recorded that segment as a *street with no public sites* and replaced that segment with the next chronological backup segment. Streets that were not considered city-maintained include: *alleys*, *paper streets*, *private streets*, *apartment complex roads*, *cemetery roads*, *U.S. highways*, and *interstate highways*. Recording all street types in the sample inventory kept each community's sample valid. However, recording these city non-maintained streets and replacing them with the next backup segment lead to an increase in sampling percentages for some communities compared to the original target sampling rate. Table 2 lists the actual sample percentages for each community after data collection was complete. Communities in this table are ordered by population size.

Table 2. Actual Community Sample Percentages

Community	Total Number of Street Segments	Target Number of Sample Street Segments	% Sample Targeted	Actual Number of Street Segments Sampled	Actual % Sampled
Newburgh	298	35	12	38	13
Brookville	585	70	12	112	19
Fort Branch	457	54	12	68	15
Upland	316	31	10	42	13
Rushville	506	30	6	38	8
Cedar Lake	845	50	6	51	6
Kendallville	1,059	63	6	90	8
Washington	2,047	122	6	169	8
Peru	1,121	67	6	82	7
Beech Grove	770	46	6	62	8
East Chicago	1,091	65	6	77	7
Mishawaka	4,854	291	6	449	9
Anderson	5,357	268	5	321	6
Lafayette	4,089	204	5	242	6
Gary	5,899	294	5	357	6
South Bend	12,931	646	5	964	7

Each inventory was conducted using a Trimble® Recon™ handheld data collection unit loaded with i-Tree's MCTI/STRATUM PDA Utility (version 2.1.2) as the inventory collection tool. The configuration for this collection utility is explained in the i-Tree (version 2.1) Software Suite User's Manual, section 3.2. The TIGER/line data used to generate the sample did not include right-of-way information. This information was gathered from each community before collection began. Some communities had GIS programs and others had printed city/town/county plat books. Each street segment's right-of-way was influenced by the information found in the community records, but was ultimately determined in the field by the experienced data collector's knowledge of reading in-field right-of-way indicators.

During the course of a single community's sample inventory, daily data files were merged into one final database. Upon completion of each community's inventory, the collector and project manager completed thorough quality control measures to assure the quality of data and consistency between data collectors. Specific data field definitions used during collection are provided in Appendix A. Inventory data fields were replicated from the 1992 national sample inventory and arranged to fit the required format for STRATUM (version 3.4). Data were recorded for the following street tree variables, which are described in further detail below:

- Tree ID
- Zone
- Street Segment
- City Managed
- Species Code
- Land Use
- Location Site
- DBH
- Maintenance Recommendation
- Maintenance Priority Task
- Sidewalk Damage
- Wire Conflict
- Condition of Wood
- Condition of Leaves
- Grow Space Size
- Utility Compatibility
- Observations

Tree ID

Each site was assigned a unique number to distinguish one record from another record.

Zone

The locations of each sample street segment within each community's *Central Business District*, *Urban Residential*, *Suburban Residential*, and *Rural* areas were identified. However, when importing a community's database into STRATUM (version 3.4), the zone areas were not complete with the information needed for the application to estimate area sample size. The TIGER/line data did not provide the needed information. Thus, all recorded zones in sample communities were assigned the same numeric code and were not able to be part of this analysis as they were in the 1992 study.

Street Segment

A street segment is a numeric code used to identify a street segment line within a community where the tree is located. Each street segment has a unique number referenced by the TIGER/line ID (TLID).

City Managed

This data field distinguishes inventory sites as public or private. Private trees were not included in sample inventories.

Species Code

All trees are identified by genus and species. The identification of trees by botanical names ensures the correct scientific identification of each tree species. STRATUM (version 3.4) uses alphanumeric codes consisting of the first two letters of the genus name and the first two letters of the species name followed by two optional letters or numbers to distinguish two species with the same four-letter code. Codes for available planting sites were entered as AVPS and given a large (L), medium (M), or small (S) code for the size tree best suited for that space. Codes for stumps were entered as *STUMP* for no plating space and no replacement tree, *STUMPL* for replacement with a large-growing tree, *STUMPM* for replacement with a medium-growing tree, and *STUMPS* for replacement with a small-growing tree. Streets with no public trees or planting sites are recorded with a species code of *XXXX*, which includes town/city non-maintained streets.

Land Use

Land use describes the type of parcel at the direct location of each site. Land use types include S*ingle-Family Residential*, *Multi-Family Residential*, *Industrial/Large Commercial*, *Park/Vacant/Other*, and *Small Commercial*.

Location Site

Location site describes the kind of site where the tree is growing or space for a tree to exist. These site descriptions include *Front Yard*, *Planting Strip*, *Cutout*, *Median*, *Other Maintained Location*, *Other Un-maintained Location*, and *Backyard*.

DBH

Diameter at breast height (DBH) is a standard forestry measurement taken at 4.5 feet above the ground. Each tree and stump diameter was measured with a 25-inch reach Biltmore® Cruiser™ stick. The measurement was read to the nearest inch and recorded in one of the nine size classes. When a tree had multiple stems, the largest diameter stem was measured and DBH class was recorded.

Maintenance Recommendation

Recommended maintenance is collected to provide basic information for the community's tree management needs. This information is based on the urgency of need for maintenance. The categories are *Young Tree* (*Routine*), *Young Tree* (*Immediate*), *Mature Tree* (*Routine*), *Mature Tree* (*Immediate*), and C*ritical Concern* (*Hazard*).

Maintenance Priority Task

A task describes the highest priority work to perform on each tree. Trees recommended for *Removal* are dead or have a serious structural defect that cannot be remedied and present an elevated risk to the public. Trees with recorded pruning tasks of *Clean*, *Raise*, *Reduce*, or *Stake/Train* are categorized based on the presence of potentially high-risk conditions in the canopy and/or to improve the health and longevity of the tree. *Treat/Pest Disease* was recorded when signs or symptoms of insects, disease, or nutrient deficiencies were present and detrimental to the tree's longevity. Where a tree needs no maintenance, *None* was recorded.

Sidewalk Damage

Tree roots that caused lifting of sidewalk pavement were indicated by *High*, *Medium*, *Low*, and *None.* These categories describe the amount of sidewalk lift caused by tree roots.

Wire Conflict

Overhead utility lines that interfere with the canopy of a tree or are present above a planting site were recorded. Values for recording utility line occurrence are *No Lines*, *Present and Not Conflicting*, and *Present and Conflicting*.

Condition of Wood and Leaves

Condition indicates the current state of a tree's functional health. Crown development, trunk condition, major branch structure, twig growth rate, insects/diseases, root condition, leaf size, and leaf color, among others, are considered. Tree conditions were recorded as *Excellent*, *Good*, *Fair*, *Poor*, or *Dead or Dying*.

Grow Space Size

Customized by using STRATUM's OtherOne data field, grow space is the shortest dimension (width in feet) of each location site. All *planting strips*, *cutouts*, and *medians* have an associated grow space size. Only where a Location Site recorded as *front yard*, *other maintained*, *other un-maintained*, or *backyard* and two impermeable surfaces lay on opposite sides of the tree within the canopy dripline was the width between the two surfaces measured and recorded. If there were no grow space restrictions, *Open/ Unrestricted* was the recorded value.

Utility Compatibility

Tree suitability for species growing under power lines was recorded by *Compatible Species* and *Incompatible Species*. *None* was recorded for sites with no overhead utilities and planting sites with overhead utilities. Utility compatibility is a data field customization using STRATUM's OtherTwo category.

Observations

General observations concerning tree health, structure, and location have been recorded for each tree in the inventory using STRATUM's OtherThree data field. All problems are only associated with trees rated as fair, poor, or dead as adapted from the 1992 U.S. Forest assessment inventory. Observations include *Poor Maintenance* (*young trees*), *Poor Pruning*, *Root and/or Trunk Damage*, *Utility Conflicts*, *Deadwood*, *Cavity/Decay, Poor Soil*, *Limited Root Space*, and I*nsect/Disease/Nutrient Deficiency*. *None* means no observation was recorded.

Project Analysis

The 23 databases for the SUSI project were imported in STRATUM (version 3.4), once sample data collection and existing inventory formatting were complete. STRATUM combines the results of each community's street tree inventory with reference city benefit-cost modeling data to produce information concerning resource structure, resource function, and resource value. For a detailed description of how STRATUM (version 3.4) handles tree sampling, tree growth modeling, and calculations of annual benefits, refer to the *Indianapolis, Indiana Municipal Forest Resource Analysis* (Peper, *et al*., 2008) and the *Lower Midwest Community Tree Guide* (Peper, *et al*., 2009).

Before importing a database into STRATUM (version 3.4), the community must be assigned to a climate zone. There are 16 STRATUM climate zones across the United States and 3 that stretch across Indiana. STRATUM (version 3.4) regionalizes its output calculations by using data specific to each climate zone. The three climate zones in Indiana are the Lower Midwest, Midwest, and Northeast Climate Zones (Appendix B). To calculate forest resource benefits, STRATUM (version 3.4) associates the local community data of urban forest structure with a climate zone's reference city model for urban forest structure. The Lower Midwest reference city is Indianapolis, Indiana. The Midwest reference city is Minneapolis, Minnesota and the Northeast reference city is New York, New York. Associating local community data to these reference city models will allow STRATUM (version 3.4) to estimate tree functions for that community. Table 3 alphabetically lists the 23 communities and the corresponding climate zones that were used.

Table 3. SUSI Community Climate Zones

Community	Climate Zone	Reference City
Anderson	Lower Midwest	Indianapolis, IN
Beech Grove	Lower Midwest	Indianapolis, IN
Bloomington	Lower Midwest	Indianapolis, IN
Brookville	Lower Midwest	Indianapolis, IN
Cedar Lake	Midwest	Minneapolis, MN
East Chicago	Northeast	New York, NY
Evansville	Lower Midwest	Indianapolis, IN
Fort Branch	Lower Midwest	Indianapolis, IN
Fort Wayne	Midwest	Minneapolis, MN
Gary	Northeast	New York, NY
Greendale	Lower Midwest	Indianapolis, IN
Indianapolis	Lower Midwest	Indianapolis, IN
Kendallville	Midwest	Minneapolis, MN
Lafayette	Midwest	Minneapolis, MN
Madison	Lower Midwest	Indianapolis, IN
Mishawaka	Northeast	New York, NY
Muncie	Lower Midwest	Indianapolis, IN
Newburgh	Lower Midwest	Indianapolis, IN
Peru	Midwest	Minneapolis, MN
Rushville	Lower Midwest	Indianapolis, IN
South Bend	Northeast	New York, NY
Upland	Midwest	Minneapolis, MN
Washington	Lower Midwest	Indianapolis, IN

Creating a STRATUM (version 3.4) project file requires a complete or sample inventory, inventory information, and project definitions. After importing a community's sample inventory database, Davey entered the total number of street segments for that community's project file. STRATUM then extrapolates the actual sample population by calculating the segments sampled and total number of segments. This step is not necessary for complete inventories. All species codes not recognized in STRATUM were matched to a generic tree type according to the community's assigned STRATUM climate zone. STRATUM (version 3.4) calculates benefits associated with these species based on the assigned tree type, such as Broadleaf Deciduous Large or Coniferous Evergreen Small.

Additional input information is needed to define each community and their costs for street tree maintenance. CUF solicited each community for urban forestry program information via a community questionnaire. The Municipal Cost Survey is based on information required for STRATUM (version 3.4) to calculate each community's cost-benefit ratio. All 23 communities provided specific information and program costs. All SUSI community Municipal Cost Surveys can be found on the 4 CD-ROMs of which are divided by community class type.

Benefit modeling in this study compares inventory data to the results from reference cities to obtain estimations of annual benefits. Annual benefits are estimated for one year. This "snapshot" analysis uses computer-simulated growth rate modeling to account for associated annual benefits. For STRATUM's five modeled benefits, annual resource units were determined on a per-tree basis. Resource units are measured as MWh of electricity save per tree; MBtu of natural gas conserved per tree; lbs. of atmospheric CO_2 reduced per tree; lbs. of NO_2, PM_{10}, and VOCs reduced per tree; cubic feet of stormwater runoff reduced per tree; and square feet of leaf area added per tree to increase property values. Prices were assigned to each resource unit using economic indicators of society's willingness to pay for the environmental benefits trees provide. STRATUM's default benefit prices for the three climate zones were used for all SUSI community project files (Tables 4, 5, and 6). For a detailed description of default benefit prices and how the magnitudes of benefit prices are calculated, refer to the *Indianapolis, Indiana Municipal Forest Resource Analysis* (Peper, *et al*., 2008).

Table 4. Lower Midwest Benefit Prices Used in this Analysis

Benefits	Price	Unit	Source
Electricity	$.0639	$/Kwh	STRATUM default- Lower Midwest
Natural Gas	$0.973	$/Therm	STRATUM default- Lower Midwest
CO_2	$0.00334	$/lb	STRATUM default- Lower Midwest
PM_{10}	$0.99	$/lb	STRATUM default- Lower Midwest
NO_2	$0.82	$/lb	STRATUM default- Lower Midwest
SO_2	$1.50	$/lb	STRATUM default- Lower Midwest
VOC	$0.30	$/lb	STRATUM default- Lower Midwest
Stormwater Interception	$0.0062	$/gallon	STRATUM default- Lower Midwest
Average Home Resale Value	$135,400	$	STRATUM default- Lower Midwest

Table 5. Midwest Benefit Prices Used in this Analysis

Benefits	Price	Unit	Source
Electricity	$.0759	$/Kwh	STRATUM default- Midwest
Natural Gas	$0.98	$/Therm	STRATUM default- Midwest
CO2	$0.0075	$/lb	STRATUM default- Midwest
PM10	$2.84	$/lb	STRATUM default- Midwest
NO2	$3.34	$/lb	STRATUM default- Midwest
SO2	$2.60	$/lb	STRATUM default- Midwest
VOC	$3.75	$/lb	STRATUM default- Midwest
Stormwater Interception	$0.0271	$/gallon	STRATUM default- Midwest
Average Home Resale Value	$128,000	$	STRATUM default- Midwest

Table 6. Northeast Benefit Prices Used in this Analysis

Benefits	Price	Unit	Source
Electricity	$.1401	$/Kwh	STRATUM default- Northeast
Natural Gas	$1.408	$/Therm	STRATUM default- Northeast
CO_2	$0.00334	$/lb	STRATUM default- Northeast
PM_{10}	$8.31	$/lb	STRATUM default- Northeast
NO_2	$4.59	$/lb	STRATUM default- Northeast
SO_2	$3.48	$/lb	STRATUM default- Northeast
VOC	$2.31	$/lb	STRATUM default- Northeast
Stormwater Interception	$0.008	$/gallon	STRATUM default- Northeast
Average Home Resale Value	$291,000	$	STRATUM default- Northeast

This summary of project setup, data collection, and project analysis concludes the Methods description for Indiana's SUSI project. Community sample maps, databases, and project files are provided as deliverables to CUF in completion of SUSI data collection and analysis. In addition to these pieces of work, Davey created four one-page analysis summaries targeted towards urban forest stewards involved in community urban forestry programs. The sections to follow will report on the analysis provided by STRATUM (version 3.4), concluding with a brief discussion of the results including highlights of future resource management needs.

Resource Structural Results

The extent of the data collected for this project includes 17,776 street trees and planting sites inventoried during sample data collection and 7 complete, updated inventories including 277,317 street trees and planting sites. Upon creating 23 STRATUM project files for each SUSI community, Indiana's street tree resource structure, functions, and values were captured. All SUSI communities are representative communities to Indiana. STRATUM estimates that there are 326,788 trees along the city- and town-maintained streets of the communities involved in this project. The combination of street tree inventories and STRATUM analyses has provided the state of Indiana with scientifically reliable estimations of the species composition, species importance, stocking levels, age distribution, tree condition, and canopy cover present in SUSI communities and throughout the state. Where appropriate, Davey has provided comparisons between the 1992 study results as well as between Indiana's community classes. Community classifications are based on the Indiana Association of Cities and Towns and U.S. Census Bureau. They include Towns (undefined due to governing body), Third Class City (population less than 35,000), Second Class City (population 35,000 to 250,000), and First Class City (population 250,000 and over). A map of SUSI community towns and cities has been provided in Appendix A.

Street Tree Numbers

Indiana's street tree population is dominated by broadleaf-deciduous trees (92% of the total estimate). Broadleaf-deciduous trees usually have larger canopies than coniferous street trees, and because most of the benefits provided by trees are related to leaf surface area, broadleaf trees usually provide the highest level of benefits. Rounding out the estimate population, coniferous trees make up the remaining 8% and broadleaf evergreen trees consist of less than 1% of the total population estimate for the 23 sample communities.

Species Composition

The inventoried street tree population is composed of 243 tree species and the family *Aceraceae* (maple) comprises 35% of the estimated population. Figure 1 shows species population estimates based on structural data from the tree inventories and STRATUM analyses. Ten species comprise 59% of the estimated population and *Acer saccharinum* (silver maple) comprises 18% of Indiana's street tree population. In comparison to the data from 1992, the family of maple and the species silver maple still are the largest population in the survey. Appendix D provides species distributions for all 23 SUSI communities.

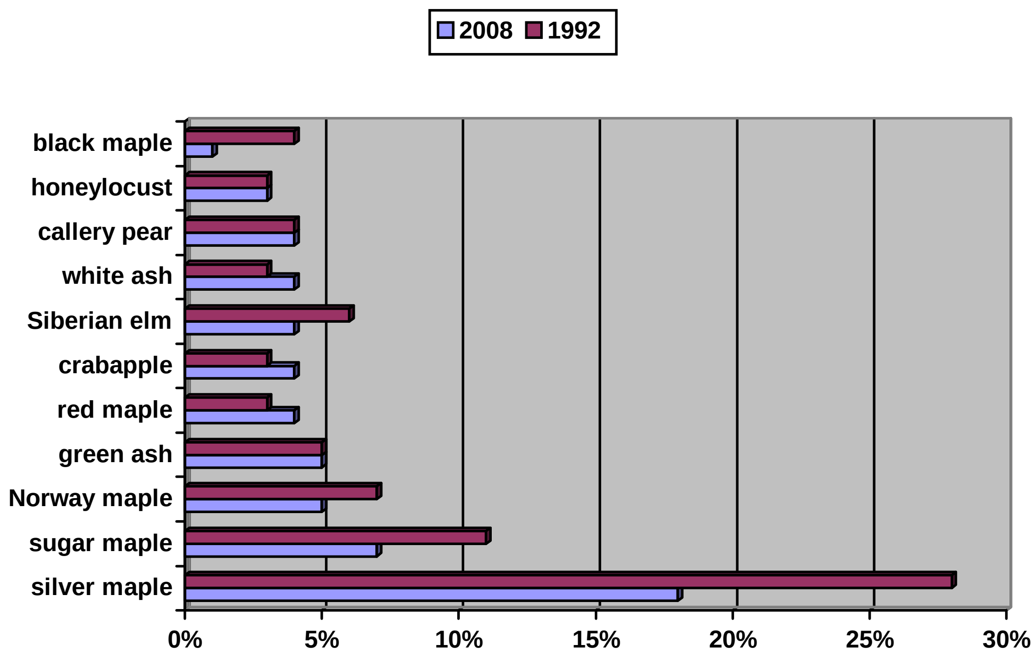


Figure 1. Indiana's Distribution of Street Trees by Species

In addition to this species composition breakdown, it is also important to examine the genus populations. Figure 2 shows Indiana's top six street tree population distributions by genus groupings. The predominant genus is *Acer* (maple, 35%); followed by *Fraxinus* (ash, 10%); *Ulmus* (elm, 6%); *Quercus* (oak, 5%); *Malus* (apple/crabapple, 4%); and *Pyrus* (pear, 4%). It is recommended that no single species should account for more than 10% of the total population and no single genus should account for more than 20% of the total population. Individually, most communities in Indiana exceed this industry guideline.

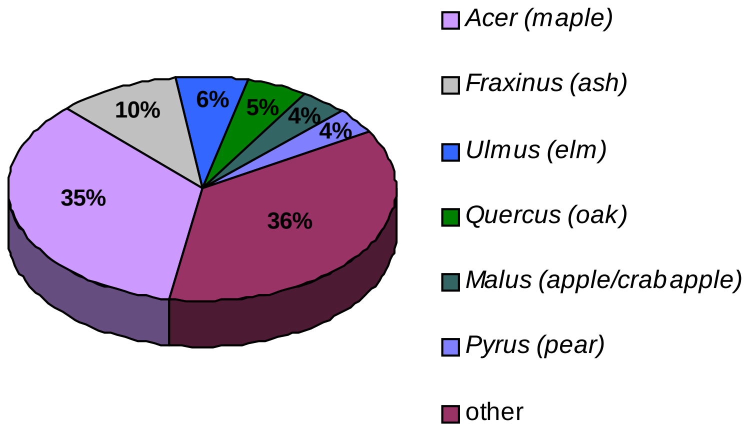


Figure 2. Indiana's Distribution of Street Trees by Genus

The threat of *Agrilus planipennis* (emerald ash borer (EAB)) makes species diversity and distribution not only imperative throughout the state, but also important from community to community. Emerald ash borer is an extremely destructive invasive species that is native to Asia. It was first discovered in Detroit, Michigan in the summer of 2002, and only attacks trees in the genus *Fraxinus* (ash). Ash accounts for approximately 10% of Indiana's estimated street tree population. Because EAB has already been recorded in 23 counties throughout the state, communities should monitor for this pest and be prepared to act immediately if EAB is detected within the community's urban forest.

Species Importance

STRATUM calculates the importance of any one species in a street tree inventory by assigning each species an Importance Value (IV). Importance values enable urban forest managers to indicate which trees have the greatest functional capacity within a community. Importance Value can be taken a step further to forecast the loss of benefits should a catastrophic event eliminate a single species.

Of the 23 communities involved in the sample inventory, silver maple is consistently one of the top five species of which Indiana communities rely heaviest on the functional capacity. Silver maple's high species importance (IV = 25) is due to its maturity, greater size, broader leaf area, and prevalence among Indiana's street trees. In fact, silver maple constitutes 30% of estimated leaf area and 27% of the estimated tree canopy in Indiana. Comparing the importance of silver maple to sugar maple (IV = 8), which also has a high presence in Indiana's street tree population, the statewide functional capacity of sugar maple is much lower. Sugar maple constitutes 9% of estimated leaf area and 7% of the estimated tree canopy in Indiana. Importance value forecasts approximately a quarter of loss in provided benefits due to the functional capacity of silver maple that would occur if this species were eliminated from the population. Appendix E provides IVs for all 23 SUSI communities.

Stocking Level

Currently, there are an estimated 172,661 planting sites along the municipally maintained streets of 21 SUSI communities. The Evansville and Muncie inventories did not contain planting site information. The inventory data from 21 communities presents a stocking level of approximately 52% for the state of Indiana. Compared to the stocking level in 1992 (36%), Indiana has more trees on its streets now. In providing a breakdown between community classes, median values show that there is a balance in stocking levels between towns, small communities, and medium communities.

- Towns have a stocking level median of 60%,
- Third Class City has a stocking level of 51%,
- Second Class City has a stocking level of 52%, and
- First Class City has a stocking level of 96%.

Of the 172,661 planting sites, an additional breakdown based on tree size due to available growing space provides the following numbers: 37% are for small-growing trees, 14% are for medium-growing trees, and 46% are for large-growing trees. Three percent of these planting sites are described as undefined due to complete inventories that did not assign a tree size to the planting site. Appendix F summarizes available planting sites and stocking levels for 21 SUSI communities.

Calculating trees per capita is another important measure of tree stocking. The 23 SUSI communities have a total human population of 1,864,546 and inventory estimates indicate there are 326,788 trees. This equates to a street trees per capita of 0.18, or approximately 1 tree for every 6 people.

Relative Age Distribution

The distribution of ages within a tree population influences present and future costs as well as the flow of benefits. An uneven-aged population allows managers to allocate annual maintenance costs uniformly over many years and assures continuity in overall tree canopy cover.

Indiana has a relatively balanced age distribution, with 28% of street trees considered young (<6-inch DBH), 23% established trees (6- to 12-inch DBH), 30% maturing trees (12- to 24-inch DBH), and 19% mature trees (>24-inch DBH). An ideal street tree population has an uneven age distribution, with higher percentages of young trees than mature trees to minimize fluctuations in functional benefits over time. As trees mature and begin to decline, a tree population skewed towards young trees will ensure that a flow of benefits continues to exist. Figure 3 shows Indiana's street tree age distribution as it compares to a more ideal distribution.

Relative age should also be considered between species (Figure 3). Silver maple, which makes up most of Indiana's street tree population and is heavily relied upon for the benefits provided by species, is represented in the population as 41% mature (>24-inch DBH) or maturing (12- to 24-inch DBH), with 51% established (6- to 12-inch DBH) and 8% young (<6-inch DBH). If young trees of similar size and structure are not planted to replace the function of the existing silver maples, benefits may be disrupted for future generations. Muncie's data were not included in the age distribution calculations of overall and silver maple populations. The inventory did not allow an analysis of this community's data with the other communities because DBH was collected in other specific ranges. Appendix G displays the relative age distributions for 23 SUSI communities.

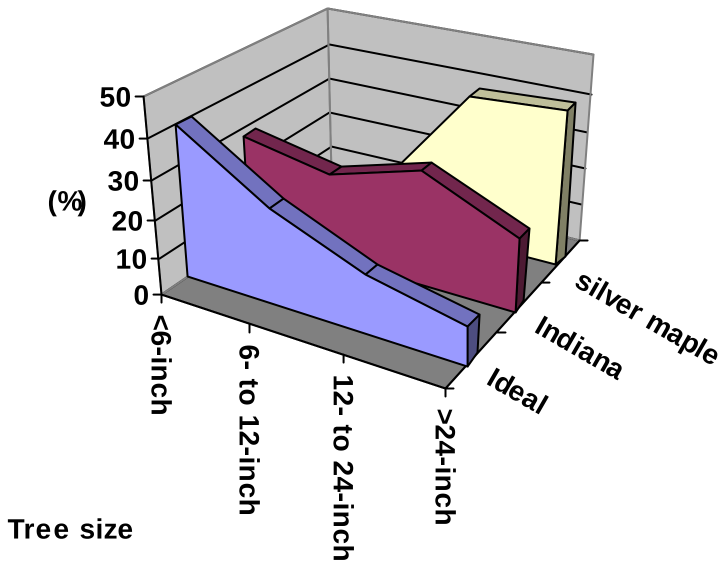


Figure 3. Relative Age Distribution Compared to Ideal Age Distribution

Tree Condition

Tree condition indicates both how well trees are managed and how well they perform given site-specific conditions. The majority of Indiana's street trees (36%) are in good condition. Figure 4 shows an improvement in the functional condition of Indiana's street trees from 1992 to 2008. When trees are performing at their peak, as are the 58% of trees classified as good and excellent, the benefits they provide will be maximized. Trees in fair condition account for 26% of the estimated population, poor condition accounts for 14% of the population, and 2% of street trees are dead or dying. Full inventory populations were not analyzed here due to differences between sample and complete inventory data collection definitions for condition. Appendix H displays the conditions for 16 SUSI communities.

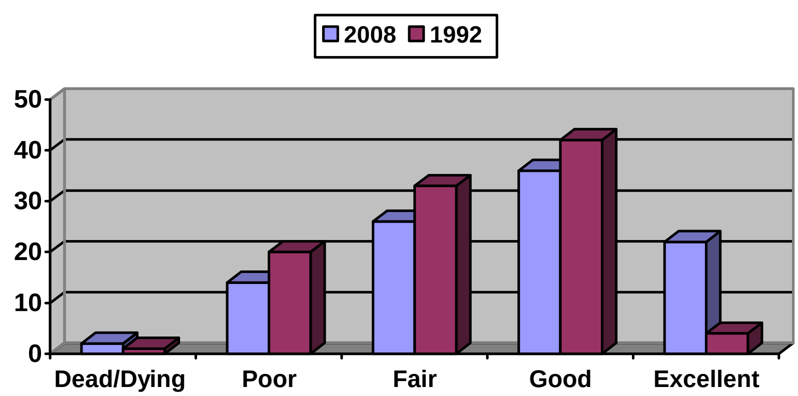


Figure 4. Condition Rating of Indiana's Street Trees

Figure 5 shows the distribution of observations for trees with a condition of fair, poor, or dead/dying. These data were collected from the sample inventories only. Deadwood is the most frequent observation resulting in 31% of the trees in fair, poor, and dead/dying condition. Compared to data from the 1992 study, root and trunk damage was the most frequently occurring with results of 39% of the condition rating.

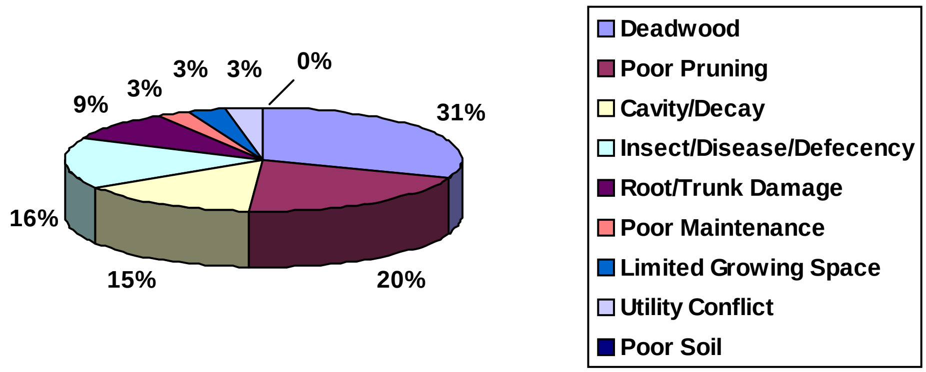


Figure 5. Observations Associated with Street Trees Rated in Conditions Fair, Poor, Dead/Dying

Canopy Cover

Leaf surface area directly correlates with the benefits of street trees. The greater the leaf surface area exhibited by a tree, the greater the benefits a particular tree is likely to provide the community. In other words, trees with large leaves and spreading canopies tend to produce the most benefits. The more large-growing, mature trees there are, the greater the canopy cover and more benefits provided.

Of the SUSI communities, the estimated street tree canopy covers approximately 5,891 acres of the total land area of 541,439 acres (846 square miles), or 1% of total canopy cover. Table 7 shows how the median values of canopy cover vary between community classes. While some communities may be understocked in terms of tree numbers, young in relative age distribution, or primarily consisting of small-growing trees, others may contain large amounts of open space or obstacles that hinder planting such as inadequate growing spaces. Indiana communities should strive to improve their stocking level by planting additional trees. Maximizing the space available and planting the right species in the right site will help maximize canopy cover and minimize maintenance, leading to greater benefits in the community. Appendix I displays the canopy cover for 23 SUSI communities.

Table 7. Indiana Community Class Distribution of Street Tree Canopy Cover

Community	Acres	Percent of Total Canopy
Town		
Fort Branch	7	0.19
Newburgh	17	2.63
Brookville	12	0.48
Upland	14	0.55
Cedar Lake	40	0.78
Median Value		**0.55**
Third Class City		
Washington	52	1.64
Madison	31	0.54
Greendale	4	0.13
Beech Grove	24	0.92
Peru	64	2.01
Kendallville	55	1.43
Rushville	28	0.72
East Chicago	84	0.87
Median Value		**0.90**
Second Class City		
Anderson	243	1.06
Bloomington	164	1.28
Evansville	197	0.73
Fort Wayne	801	1.14
Gary	942	2.94
Lafayette	156	0.94
Mishawaka	122	1.12
Muncie	245	1.53
South Bend	732	2.93
Median Value		**1.14**
First Class City		
Indianapolis	1,857	0.72

Costs of Managing Indiana's Street Trees

Investing in Indiana's street trees is well worth the cost. Trees provide numerous economic, environmental, psychological, and social benefits to communities statewide. In 2008, all 23 SUSI communitys' total related expenditures for street trees were approximately $6.1 million, on average approximately 0.32% of each community's collective total municipal budget of $1.8 trillion. The median percentages per community class distribution are: 2% for Towns, 1% for Third Class City, and less than 1% for Second and First Class Cities. Appendix J presents all SUSI community costs for street tree expenses.

Tree Planting and Establishment

Street tree planting, on average, accounts for 7% of the total street tree related expenditures. Ensuring that the benefits of Indiana's street trees are available for future generations requires quality nursery stock, proper planting techniques, and adequate follow-up care. In 2008, 16 SUSI communities allocated approximately $385,049 toward planting new trees. Seven of the 23 communities have no money budgeted towards planting trees. Of the total expenditures for tree-related services and based on median values, Towns budget approximately 1% towards tree planting, Third Class Cities budget less than 1%, Second Class Cities budget approximately 4%, and First Class Cities budget approximately 9% towards planting street trees.

Maintenance

Pruning, removals, and litter cleanup, on average, accounts for 57% of the total street tree related expenditures. Removals account for approximately 23% of total expenditures, while pruning accounts for 20%. Approximately 13% of total expenditures are attributed to litter and storm clean-up. In 2008, 20 communities allocated approximately $3.3 million toward the maintenance of street trees. Three of the 23 SUSI communities have no money budgeted towards tree maintenance. Of the total expenditures for tree-related services and, based on median values, Towns budget approximately 34% towards tree maintenance, Third Class Cities budget approximately 56%, Second Class Cities budget approximately 67%, and First Class Cities budget approximately 71% towards street trees maintenance.

Administration

On average, approximately 9% of total expenditures for managing street trees in 2008 can be attributed to administration costs. These costs include forestry personnel salaries, clerical staff, summer help, supplies, training, inspection, and membership fees. Nine SUSI communities do not have administration costs budgeted, suggesting a lack of in-house technical expertise in those communities.

Additional Tree Related Expenditures

Expenditures related to additional expenses that street tree programs absorb include pest management, irrigation, inspection/service, infrastructure repair, and liability/claim. On average, this amount is approximately 27% of the total expenditures related to street trees.

Resource Function and Value Results

Street trees provide a host of benefits to the State of Indiana. Street trees conserve energy, reduce carbon dioxide levels, improve air quality, and mitigate stormwater runoff. In addition, trees provide numerous economic, psychological, and social benefits. However, the intent of this project is to determine whether the benefits of Indiana's street trees outweigh the cost of maintaining them. Appendix J presents all SUSI communities' net annual benefits and associated benefit-cost ratios.

This study uses tree inventory data collected in 23 communities across Indiana and i-Tree's STRATUM model to assess and quantify the beneficial functions of Indiana's street tree resource and to place a dollar value on the annual benefits they provide. Of the 23 SUSI communities involved in this project, street trees are providing approximately $30 million of functional benefits each year. By applying median values to all 567 Indiana communities, the annual benefits afforded by street trees are nearly $79 million. There are 452 Towns, 95 Third Class Cities, 19 Second Class Cities, and 1 First Class City. Table 8 shows the breakdown in statewide median benefit values for Indiana's four community types. Additionally, tangible, statewide environmental benefits quantified in this project include environmental services that conserve energy ($9.7 million, 12%), manage stormwater ($24.1 million, 31%), improve air quality ($2.8 million, 4%), and sequester carbon dioxide ($1.1 million, 1%). Less-tangible, but equally significant, the statewide benefits provided through aesthetics and social benefits and increased property values are estimated at $41 million (52%) per year to Indiana communities.

Table 8. STRATUM Analysis Results for Total Annual Benefits per Community Class in the State of Indiana

Community	Energy ($)	CO_2 ($)	Air Quality ($)	Stormwater ($)	Aesthetic/Other ($)	Total ($)	Most Beneficial Species (% of Population)
Town							
Fort Branch	2,379	294	827	7,997	7,492	18,989	silver maple (17.4)
Newburgh	5,064	816	1,919	19,223	26,120	53,143	Siberian elm (13.5)
Brookville	4,165	520	1,419	13,777	16,842	36,723	sugar maple (30.0)
Upland	24,874	3,859	4,311	36,780	30,962	100,785	silver maple (47.2)
Cedar Lake	79,795	10,497	12,908	99,033	81,640	283,872	white oak (25.1)
Median Total	**-**	**-**	**-**	**-**	**-**	**$53,143**	
Third Class City							
Washington	17,329	2,343	6,060	59,472	74,026	159,230	silver maple (21.7)
Madison	56,889	7,037	9,874	73,952	52,849	200,601	sugar maple (26.2)
Greendale	1,318	210	479	4,674	7,747	14,428	sugar maple (15.6)
Beech Grove	8,030	1,308	2,825	26,077	46,366	84,606	silver maple (43.2)
Peru	117,102	16,725	20,374	166,161	130,002	450,364	silver maple (42.4)
Kendallville	106,942	14,864	17,416	133,058	120,546	392,826	sugar maple (33.4)
Rushville	9,544	1,337	3,209	31,918	40,094	86,101	silver maple (32.7)
East Chicago	229,073	5,153	42,069	57,863	206,605	540,763	silver maple (35.8)
Median Total	**-**	**-**	**-**	**-**	**-**	**$179,916**	
Second Class City							
Anderson	78,894	12,051	28,164	273,541	344,669	737,319	silver maple (27.6)
Bloomington	56,710	8,473	20,158	178,382	315,342	579,066	red maple (18.1)
Evansville	63,923	9,315	22,341	213,437	253,475	562,491	sugar maple (11.0)
Fort Wayne	1,735,844	228,716	279,642	1,753,736	1,932,828	5,930,764	silver maple (20.6)
Gary	2,551,378	59,189	469,741	643,761	1,960,004	5,684,074	silver maple (48.1)
Lafayette	315,864	41,821	51,113	356,696	337,422	1,102,914	silver maple (26.1)
Mishawaka	337,914	7,997	61,717	85,177	282,048	774,853	silver maple (33.5)
Muncie	78,527	11,811	27,570	266,774	313,597	698,279	silver maple (27.4)
South Bend	1,963,658	46,974	361,937	515,911	1,614,325	4,502,804	silver maple (23.9)
Median Total	**-**	**-**	**-**	**-**	**-**	**$774,853**	
First Class City							
Indianapolis	604,779	98,303	218,873	2,044,185	3,642,008	6,608,147	silver maple (16.7)

Communities in this project represent a broad range of human population sizes, demographics, urban forestry expertise, and program budgets. They also represent a broad range of urban tree resource extent and benefits. According to Table 8, the median value of benefits for Indiana's Towns is approximately $53,000 per year. For Third Class Cities, the median value of benefits received is approximately $180,000 per year, $775,000 per year for Second Class Cities, and $6.6 million per year for First Class Cities. Due to the species population dimension (including population, leaf surface area, and canopy cover), silver maple is shown providing the most benefit to the majority of SUSI communities. All totaled, silver maple contributes approximately $7.9 million, or 27% of the SUSI communities' total annual benefits. It may be obvious that the larger the community, the more trees that community has and, thus, greater benefits are received. However, any community can work to maximize the benefits afforded by its street tree resource through increased planting and proactive management. These numbers highlight the importance of trees in Indiana cities and towns and serve as a reminder of the worthwhile investment in community forestry programs.

Net Benefits and Benefit-Cost Ratio (BCR)

Indiana receives substantial benefits from its street trees; however, communities must also consider the cost of maintaining their resource. Applying a benefit-cost ratio (BCR) is a useful way to evaluate the public investment in street trees. Specifically in this analysis, BCR is the ratio of the cumulative benefits provided by the community's street trees, expressed in monetary terms, compared to the costs associated with their management, also expressed in monetary terms.

Table 9 provides BCR information broken into town and city classes. Considering median values, the following are returns earned by Indiana communities investing in their street tree populations' health and public safety:

- Towns receive $1.74 for every dollar invested in street tree management,
- Third Class Cities receive $1.17 for every management dollar,
- Second Class Cities receive $2.26 per management dollar, and
- First Class Cities receive $5.55 for every dollar invested in the street tree population.

These returns are somewhat predictable in that smaller communities, such as Towns and Third Class Cities, typically invest little in the planting and maintenance of their street tree population, and larger communities typically invest more in the planting, pruning, removal, and general maintenance of their street tree population and receive greater overall benefits in return.

Table 9. STRATUM Analysis Results for Annual Benefits, Net Benefits, and Cost for Public Trees

Community	Canopy Cover (Acres)	Gross Benefits ($)	Program Costs ($)	Net Benefit ($)	Benefit-Cost Ratio
Town					
Fort Branch	7	18,989	2,350	16,639	8.08
Newburgh	17	53,142	43,900	9,242	1.21
Brookville	12	36,723	31,025	5,698	1.18
Upland	14	100,786	500	100,286	201.57
Cedar Lake	40	283,873	163,000	120,873	1.74
Median Totals	-	-	-	-	**1.74**
Third Class City					
Washington	52	159,230	213,400	-54,170	0.75
Madison	31	200,601	17,880	182,721	11.22
Greendale	4	14,428	34,200	-19,772	0.42
Beech Grove	24	84,606	647,220	-562,614	0.13
Peru	64	450,364	0	450,364	0.00
Kendallville	55	392,826	11,507	381,319	34.14
Rushville	28	86,102	54,000	32,102	1.59
East Chicago	84	540,763	179,000	361,763	3.02
Median Totals	-	-	-	-	**1.17**
Second Class City					
Anderson	243	737,318	155,700	581,618	4.74
Bloomington	164	570,111	261,968	308,143	2.18
Evansville	84	562,491	269,965	292,526	2.08
Fort Wayne	801	5,872,011	674,000	5,198,011	8.71
Gary	942	5,684,075	0	5,684,075	0.00
Lafayette	156	1,102,915	487,000	615,915	2.26
Mishawaka	122	774,853	185,000	589,853	4.19
Muncie	245	698,279	645,000	53,279	1.08
South Bend	732	4,497,703	504,896	3,992,807	8.91
Median Totals	-	-	-	-	**2.26**
First Class City					
Indianapolis	1,857	6,608,147	1,191,048	5,417,099	5.55

The gross benefit a community receives is dependent on the street tree population's extent and canopy size. Canopy cover is the total amount of leaf area provided by the street tree population and influenced by the population's size and overall maturity. Canopy cover is the ultimate factor contributing to the gross benefits trees provide, referenced in Table 9. To maximize canopy cover, a community must increase its total tree population, manage its existing street trees to reach full maturity, and focus on planting the largest-growing trees suitable for each site. These basic program objectives will result in an increase in gross benefits that street trees provide to the community. Proactive street tree management does come at an increased cost in community investment. However, if a community's urban forestry program sets its primary goal to increase canopy cover by planting and maintaining street trees for health and safety, the end result will be a positive return on that investment. As illustrated in Table 9, the investment in urban trees is definitely paid back to Indiana communities.

Discussion

When cared for properly, Indiana's street trees are worth the investment. This summary has provided statistically valid, financially sound, and defensible cost-benefit analysis concerning Indiana's street tree resource. Citizens of Indiana can take comfort in knowing that the benefits produced by maintaining street trees outweigh the costs. In fact, for every $1 spent on street tree management, street trees pay back an average net value of $1.74 to Towns, $1.17 to Third Class Cities, $2.26 to Second Class Cities, and $5.55 to First Class Cities in benefits returned to the community. Unfortunately, street trees can become a burden to any municipality if neglected. As trees grow larger and mature, those that are not adequately maintained become increasingly more costly to manage and may create liability issues. Meanwhile, valuable benefits are not fully achieved, lessening opportunities to encourage a safe, healthy, and more enjoyable environment in which to live. Stakeholders involved in Indiana urban forestry can use this information to seek increased funding, improve tree conditions, and promote tree plantings and urban forestry activities.

Implementing proactive tree management programs, including new tree establishment and cyclical pruning programs, is the first step to ensure that benefits produced by a community's street trees surpass the cost of managing them. Currently, 58% of Indiana's street trees are considered to be in good and excellent functional condition. Trees in fair condition account for 26% of the population, with 14% as poor, and 2% as dead or dying. Indiana communities should strive to eliminate all dead and dying trees, replace poor conditioned trees, and actively maintain large-growing species that provide the most benefits. Optimizing the space available for trees by filling available planting sites and reaching higher stocking levels will help maximize canopy cover and associated benefits. Indiana's streets are approximately 52% stocked with trees. Planting large-growing trees in areas with no obstructions should be a priority. Planting the right tree in the right location is key to minimizing unnecessary maintenance costs. For example, areas with overhead utilities present should be planted with small-growing trees only. In addition to filling available planting sites, replacing over-utilized species, such as silver maple and other maples, with a greater mix of large-growing trees will help improve species distribution and reduce the impact of species- and genus-specific pests or disease. Silver maple constitutes 18% of the estimated population and the genus *Acer* (maple) comprises 34% of the population. Planting other large-growing trees that perform well as street trees will result in a more sustainable flow of benefits for future generations. The existing maples, especially silver maple, are driving much of the benefits afforded by Indiana's street trees, making a strong case for maintaining those that are in fair or better condition.

Indiana's street trees are a valuable resource. The estimated amount of street trees in this study return an annual gross benefit of $30 million to SUSI communities and a further estimate of $79 million statewide. Indiana communities see a return on their investment spent on management. However, budgets from each SUSI community's 2008-year show, on average, street tree expenditures approximately 0.32% of the municipal budget. As a result, this statewide sample inventory and STRATUM analysis suggests that there is justification for more attention and funding for urban forestry planning, design, management, and maintenance. Planning for greener and healthier communities can begin by including urban forestry in all community project discussions and considering creative ways to ensure the public tree canopy is kept healthy, well-maintained, safe, and enhanced by well-planned planting projects.

Appendix A
SUSI Data Field Definitions

Street Tree Inventory Data Field Definitions

Data will be collected on pentablet field computers using the data attributes listed below, according to the STRATUM/MCTI PDA Utility configuration for i-Tree, as explained in the *i-Tree Sofwater Suite v1.2 User Manual*.

1) **TreeId:** a unique number assigned to each tree within the Community in order to distinguish trees.

2) **Zone:** an alphanumeric code or name that represents the management area or zone that the tree is located in within a particular city. If no zones or areas are associated with inventoried trees, 1 is entered for each record. Up to 20 zones can be defined.

3) **StreetSeg:** a numeric code (must be a positive integer) to identify the street segment within a city where the tree is located. If TIGER/Line files have been used to create a sample inventory, the Tiger Line ID (TLID) is the StreetSeg. For full inventories, 0 (zero) is entered for each record.

4) **CityManaged:** a numeric code to distinguish trees owned by the city (1) and those privately planted and managed (2). If private trees were not included, 1 should be entered for each record.

5) **SpCode:** An alphanumeric code consisting of the first two letters of the genus name and the first two letters of the species name followed by two optional letters or numbers to distinguish two species with the same four-letter code. Additional codes for available planting sites or empty planting basins may be entered [e.g., AVPS (available planting site) or EMBA (empty basin)].

6) **LandUse:** A numeric code to describe the type of area where the tree is growing. The default values are as follows:

   1 = Single-family residential
   2 = Multi-family residential (duplex, apartments, condos)
   3 = Industrial/large commercial
   4 = Park/vacant/other (agricultural, riparian areas, greenbelts, park, etc.)
   5 = Small commercial (minimart, retail boutiques, etc.)

7) **LocSite:** a numeric code to describe the kind of site where the tree is growing. The default values are as follows:

   1 **=** Front yard
   2 **=** Planting strip
   3 **=** Cutout (tree root growth restricted on all four sides by hardscape within dripline)
   4 **=** Median
   5 **=** Other maintained locations
   6 **=** Other un-maintained locations
   7 **=** Backyard

8) **DBH:** A numeric entry for the diameter at breast height [4.5 ft. (1.37 m.) above the ground].

9) **MtncRec:** A numeric code to describe the recommended maintenance for the tree. The default values are as follows:

   1 = None – Tree does not need immediate or routine maintenance.
   2 = Young tree (routine) – Tree is less than 18 ft. tall and in need of maintenance; health or longevity of tree is not compromised by deferring maintenance for up to five years.
   3 = Young tree (immediate) – Tree is less than 18 ft. tall and in need of maintenance; deferring maintenance beyond one year would compromise health or longevity of tree.
   4 = Mature tree (routine) – Tree is more than 18 ft. tall and in need of maintenance; health or longevity of tree is not compromised by deferring maintenance for up to five years.
   5 = Mature tree (immediate) – Tree is more than 18 ft. tall and in need of maintenance; deferring maintenance beyond one year would compromise health or longevity of tree.
   6 = Critical concern (hazard) – Tree should be inspected without delay.

10) **PriorityTask:** A numeric code to describe the highest priority task to perform on the tree. The default values are as follows:

   1 = None – Tree does not need maintenance.
   2 = Stake/train – Staking or training needed to encourage a straight trunk, strong scaffold branching, or eliminate multiple leaders, crossing branches, and girdling ties. Includes removing or replacing stakes and ties to prevent damage to tree bole.
   3 = Clean – Crown needs cleaning to remove dead, diseased, damaged, poorly attached, or crossing branches to increase health or longevity of tree.
   4 = Raise – Crown should be raised by removing lower branches from the tree trunk to eliminate obstructions or clearance issues.
   5 = Reduce – Crown should be reduced/thinned by pruning to reduce tree height, spread, overcrowding, wind resistance, or an increase of light penetration.
   6 = Remove – Tree is dangerous, dead, or dying, and no amount of maintenance will increase longevity or safety.
   7 = Treat pest/disease – Insects, pathogens, or parasites are present and detrimental to tree longevity; treatment should be given to maintain longevity.

11) **SwDamg:** A numeric code to describe the amount of sidewalk damage. The default values are as follows:

   1 = None – Sidewalk heaved less than ¾ inch, requiring no remediation.
   2 = Low – Sidewalk heaved ¾ to 1½ inches, requiring minor grinding or ramping.
   3 = Medium – Sidewalk heaved 1½ to 3 inches, requiring grinding or ramping and/or replacement.
   4 = High – Sidewalk heaved more than 3 inches, requiring complete removal and replacement.

12) **WireConflict:** A numeric code to describe utility lines that interfere with or are present above a tree. The default values are as follows:

1 = No lines – No utility lines within vicinity of tree crown.
2 = Present and not conflicting – Utility lines occur within vicinity of tree crown, but crown does not presently intersect wires.
3 = Present and conflicting – Utility lines occur and intersect with tree crown.
4 = Street light conflicting – Street light and tree canopy conflict exists.

13) **CondWood:** A numeric code to describe the health of the tree's wood (its structural health) as per adaptation of the 1993 IN statewide urban forest assessment report:

1 = Dead – Dead.
2 = Poor – Dieback greater than 40% of small branches; 3 or more major branches dead; more than 50% of trunk circumference dead, decayed, and/or hollow.
3 = Fair – Dieback 20-40% of small branches; 1 or 2 large branches dead; 20-50% of trunk circumference dead; fruiting bodies may be present.
4 = Good – Dieback less than 20% of small branches; less than 20% of trunk circumference with dead bark.
5 = Excellent – Dieback 0 – 5% of small branches; trunk sound and solid.

14) **CondLvs:** A numeric code to describe the health of the tree's wood (its structural health) as per adaptation of the 1993 IN statewide urban forest assessment report.

1 = Dead– Dead.
2 = Poor – Great reduced in size or sparse and chlorotic.
3 = Fair – Reduced in size; showing major deficiency symptoms.
4 = Good – Slightly reduced size; showing minor deficiency symptoms.
5 = Excellent – Normal for species in size and color.

15) **OtherOne (Size of Growing Space):** A numeric code to describe the size of the growing space:

1 = 0 – 4 feet
2 = 4 – 6 feet
3 = 6 – 10 feet
4 = 10 – 20 feet
5 = 20 – 30 feet
6 = 30 – 40 feet
7 = 40 – 50 feet
8 = Open/Unrestricted Growing Space

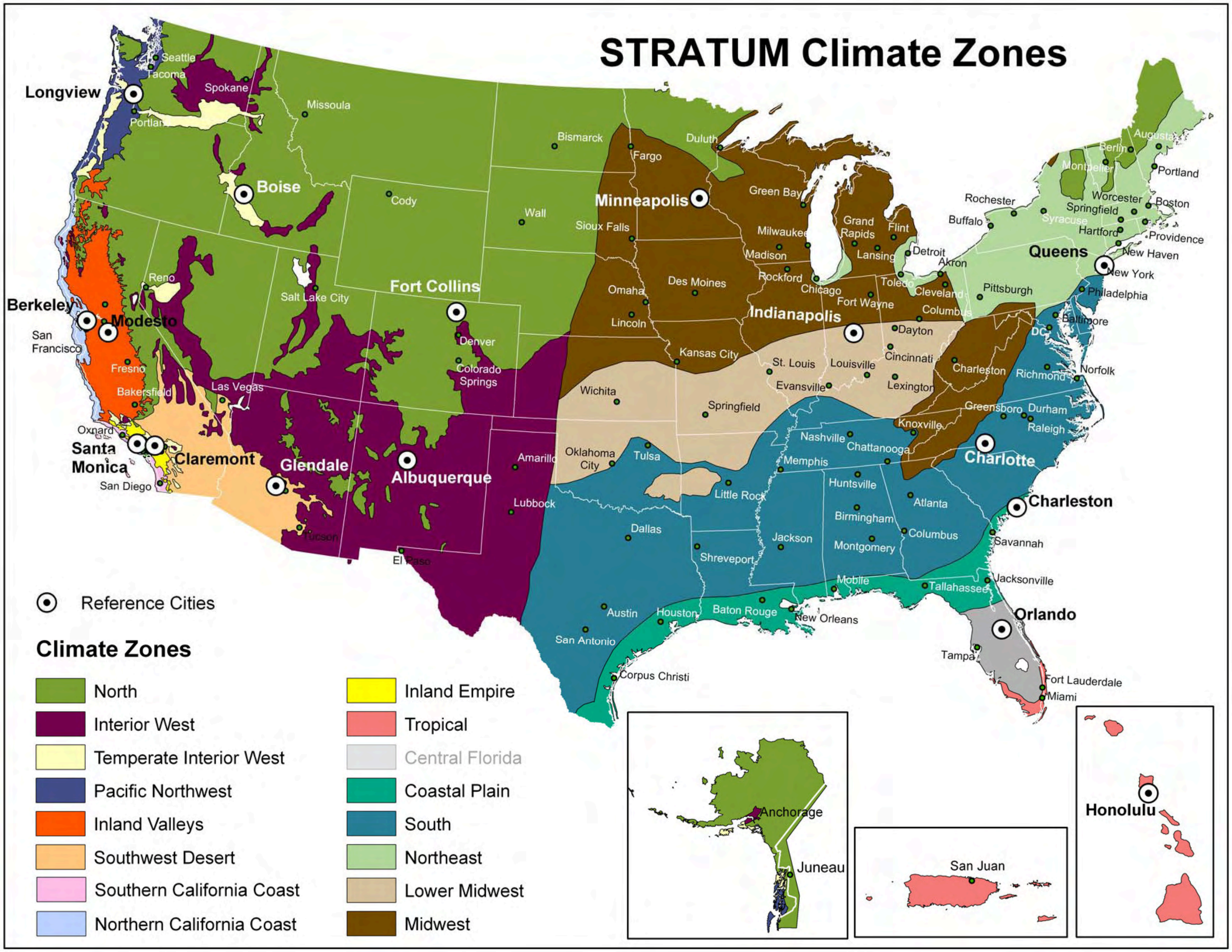
16) **OtherTwo (Utility Compatability) :** A numeric code describing the suitability of the inventoried species growing under power lines as defined by local utility partners.

1 = Compatible Species
2 = Incompatible Species
3 = N/A

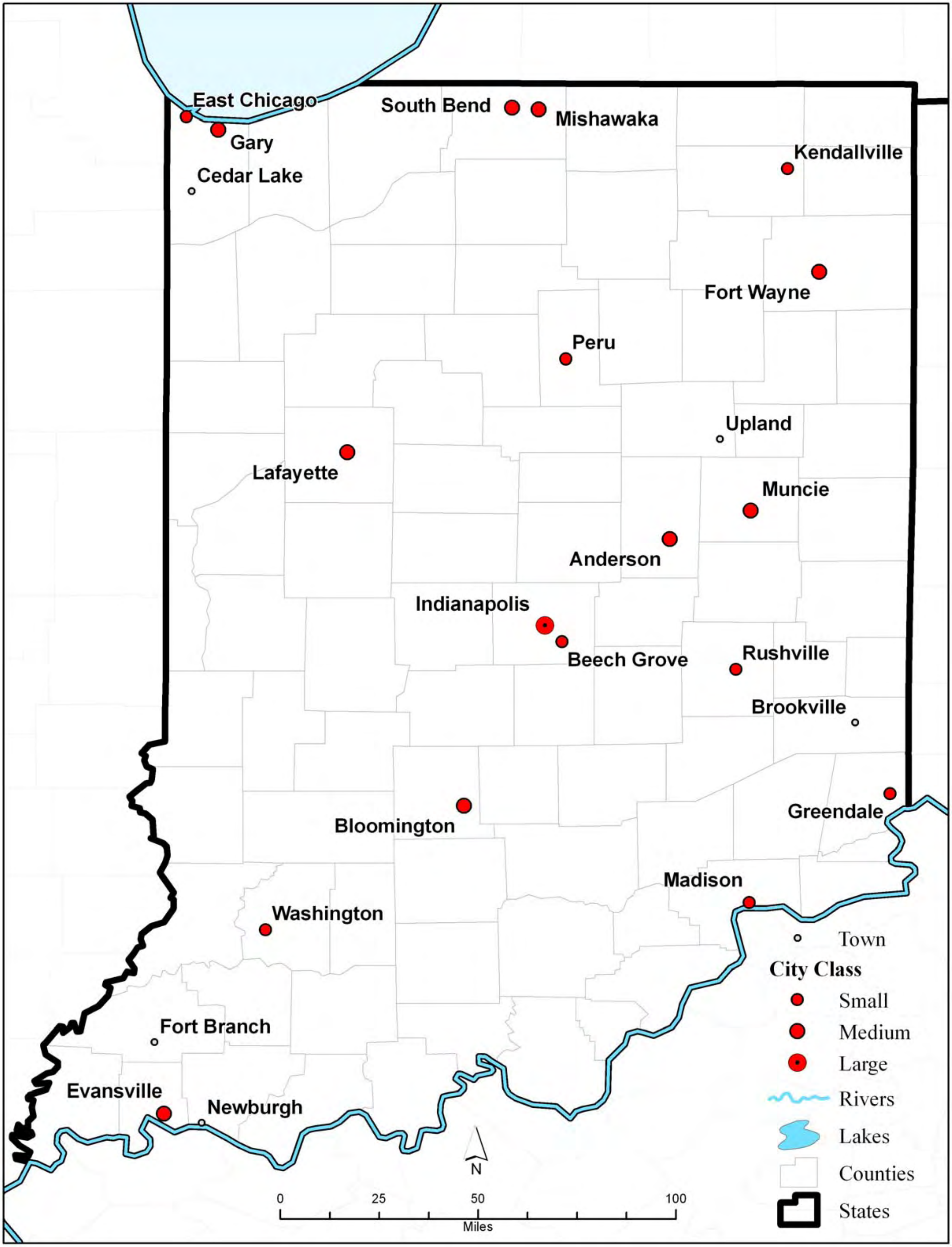
17) **OtherThree (Problem):** A numeric code describing the primary problem with trees rated as Fair, Poor, or Dead.

1 = Micellaneous (to be defined by field crews)
2 = Poor Maintenance (young trees)
3 = Poor Pruning
4 = Root/Trunk Damage
5 = Utility Conflict
6 = Deadwood
7 = Poor Soil
8 = Limited Growing Space
9 = Insect/Disease

Appendix B
STRATUM Climate Zones Map


STRATUM Climate Zones
Reference Cities
Climate Zones
North
Interior West
Temperate Interior West
Pacific Northwest
Inland Valleys
Southwest Desert
Southern California Coast
Northern California Coast
Inland Empire
Tropical
Central Florida
Coastal Plain
South
Northeast
Lower Midwest
Midwest
Longview
Seattle
Tacoma
Portland
Spokane
Missoula
Boise
Berkeley
San Francisco
Modesto
Fresno
Bakersfield
Reno
Las Vegas
Salt Lake City
Oxnard
Santa Monica
San Diego
Claremont
Glendale
Tucson
Albuquerque
El Paso
Cody
Fort Collins
Denver
Colorado Springs
Bismarck
Wall
Sioux Falls
Fargo
Duluth
Minneapolis
Omaha
Lincoln
Des Moines
Kansas City
Wichita
Oklahoma City
Tulsa
Amarillo
Lubbock
Dallas
Austin
San Antonio
Houston
Corpus Christi
Springfield
Little Rock
Shreveport
Baton Rouge
New Orleans
Jackson
Memphis
Nashville
Chattanooga
Huntsville
Birmingham
Montgomery
Mobile
Atlanta
Columbus
Tallahassee
Jacksonville
Savannah
Charleston
Charlotte
Orlando
Tampa
Fort Lauderdale
Miami
Green Bay
Milwaukee
Madison
Rockford
Chicago
Grand Rapids
Lansing
Flint
Detroit
Toledo
Akron
Cleveland
Fort Wayne
Indianapolis
Columbus
Dayton
Cincinnati
Louisville
St. Louis
Evansville
Lexington
Knoxville
Charleston
Greensboro
Durham
Raleigh
Richmond
Norfolk
DC
Baltimore
Philadelphia
Pittsburgh
Buffalo
Rochester
Syracuse
Queens
New York
New Haven
Hartford
Springfield
Worcester
Providence
Boston
Portland
Montpelier
Berlin
Augusta
Anchorage
Juneau
San Juan
Honolulu

Appendix C
Indiana SUSI Communities Map



East Chicago
South Bend
Mishawaka
Gary
Kendallville
Cedar Lake
Fort Wayne
Peru
Upland
Lafayette
Muncie
Anderson
Indianapolis
Beech Grove
Rushville
Brookville
Greendale
Bloomington
Madison
Washington
Town
City Class
Small
Medium
Large
Fort Branch
Rivers
Evansville
Newburgh
Lakes
N
Counties
0
25
50
100
Miles
States