The 2007 Bloomington Street Tree Report: An Analysis of Demographics and Ecosystem Services

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Executive Summary

The 2007 Bloomington Street Tree Inventory was a project undertaken through a partnership with The School of Public and Environmental Affairs (SPEA) and the City of Bloomington Parks & Recreation Department, Urban Forestry Program ("Agreement for Undergraduate Student Interns in Urban Forestry" IU Grant Number 40-401-50). The project is useful for giving students urban forestry experience in collecting and analyzing real data, and it benefits the city by applying some of the best young minds to improving the practice of urban forestry in Bloomington. This report is hopefully the first of many that will result from this partnership, providing continuous refinement of our knowledge of the trees in this community and management recommendations on how to continue to cultivate this valuable resource.

In the time since the last street tree inventory of 1994, Bloomington's street tree population has grown considerably, with a net increase of over two thousand individual trees to 12,169 trees. The potential of Bloomington's street tree population has also grown through an aggressive search for unoccupied planting spaces. As it currently stands, with approximately 4,000 vacant spaces for potential street trees, there is room to expand the street tree population to over 16,000 trees.

The 2007 inventory revealed a number of trends, some of which are very positive and others that will need to be addressed before they become problematic. In addition to the growth in the street tree population since 1994, the percentage of trees whose condition was rated as either fair, poor, or dead/dying have all decreased, whereas the percentage with a good rating has increased by 28%. On the other hand, the street tree population has been decreasing in diversity with further concentrations of the most common species, Red Maple and Callery Pear (hence forth referred to as Flowering Pear). This may leave street tree cover in Bloomington vulnerable as potential threats that affect those species in particular could take a heavy toll on the population as a whole. Also, the inventory revealed a decrease in the percentage of trees in the smallest one- to six-inch diameter at breast height (DBH) class which may lead to a future loss of canopy cover if there are not adequate numbers of small trees that will grow and maintain a sustainable population of large trees over time.

This inventory included the first attempt to quantify the value of the ecosystem services that street trees provide for Bloomington. From the tree's ability to remove greenhouse gases such as carbon dioxide and other pollutants from the air, to their ability to slow storm water runoff and prevent erosion, the annual stream of ecosystem services is valued at over $400,000. This value is far more than what is spent on the program annually. As more data is collected in future updates to the inventory, it will be possible to accurately estimate the reduced energy consumption that street trees allow due to the effects of shading and wind-breaks. The additional value in direct energy savings and the reduced power plant emissions that occur as a result will likely push the value of ecosystem services to over $1 million annually.

In summation, Bloomington's street tree population is growing, healthy, and adds considerable value to this community. There are biological, managerial, and policy recommendations at the end of this report to help continue this trend. These recommendations include:

- Strive to follow the "10% Rule" by diversifying species in new plantings,
- Increase the proportion of young trees, particularly those that will grow into large trees with age,
- Plant "right tree, right place" and largest species where possible,
- Utilize GIS technology to reveal spatial relationships,
- Regularly re-inventory to keep abreast of changes and monitor progress toward goals
- Link Urban Forestry goals with broader City initiatives and planning documents, and
- Develop a street tree management plan for the city with measurable benchmarks so that future inventories can be used to assess progress on a periodic basis.

Through this ongoing effort, it is likely that Bloomington's Urban Forestry Program can continue to be a leader in the state of Indiana and perhaps a model that cities across the nation will look to when developing their urban forestry programs.

Introduction

In 1994 the first ever comprehensive inventory of the City of Bloomington's street tree population took place. This inventory led to the creation of the report, *Seeing the Forest and the Trees: The State of Bloomington's Urban Forest and a Plan to Improve It* (Banks, 1995). That report focused primarily on street tree demographic information, such as the number of each species, their condition, and maintenance needs. The 1995 report placed a value of $8.9 million on Bloomington's street trees and made a number of recommendations for improving the makeup of the population. This $8.9 million figure was calculated as the replacement value of the trees, or the cost of replacing each tree with a comparable specimen (Banks, 1995). In 2007 the replacement value has grown to over $11.3 million. The replacement value of trees is generally based upon International Society of Arboriculture median tree replacement value. Banks (1995) utilized ACRT's Tree Manager Software to compute the replacement value, while the 2007 replacement values were determined by The Street Tree Resource Analysis Tool for Urban-Forest Managers (STRATUM) software program developed in part by the US Forest Service. It is not clear whether the methods used to calculate the replacement values are comparable between the two measurements. However, an increase in replacement value is expected as there are more trees in 2007, and those trees that existed in the previous 1995 assessment have grown larger and thus more expensive to replace (Petitjean *et al*., 1997).

This, *The 2007 Bloomington Street Tree Report*, preceded by the 2006-2007 street tree inventory, provides not only updated tree demographic information, but an initial estimation of the value of street trees through the *ecosystem services* that they provide in improving the physical environment of the city. "Ecosystem services" is the term used to describe the benefits human populations derive from intact ecosystems (Bolund, 1999). The end product of these services can be valued in terms of the finished product, such as clean air, water, or flood prevention (Boyd and Banzhaf, 2007). Thus this report provides an estimate of value that is received by the community from street trees rather than just what it would cost to replace them. There is considerable additional value that street trees provide to the community that was not possible to calculate at the time this report was written. Future inventories that gather more information will allow for estimations of street tree contributions to property values and their effect on reducing energy consumption. In addition to the monetary savings that result in reduced energy consumption, the value of subsequent environmental benefits from reduced power plant emissions will also be calculable in terms of avoided carbon dioxide, nitrous oxides, sulfur oxides, volatile organic compounds, and particulate matter. The Street Tree Resource Analysis Tool for Urban-Forest Managers (STRATUM) software program was used to evaluate the ecosystem services that Bloomington's street tree population provides.

This report also makes recommendations to the Bloomington Tree Commission, Urban Forester, and Parks and Recreation Department regarding the planning and management of Bloomington's street trees. These recommendations are a result of the 2006-2007 street tree inventory and the subsequent analysis of the data collected. These recommendations are primarily based on biological concerns evident through comparison of 1994-95 and 2006-07 inventory data, and consideration of how such processes and analyses can be better integrated into Bloomington's city planning.

Therefore, while we may make recommendations to address issues raised herein, the main purpose of this report is to advise the Bloomington Tree Commission and Urban Forester in the creation of a formal Bloomington Street Tree Management Plan. The results presented here are intended to play a role in shaping that plan, but information and advice should also be sought from, among others, the Bloomington Environmental and Sustainability Commissions, City of Bloomington Public Works, Planning, and Parks Departments, and of course, the citizens of Bloomington.

A secondary purpose of this report is to demonstrate the economic return that the City of Bloomington reaps from its investment in a healthy urban forest. This return on investment is demonstrated through monetized estimates of the benefits that Bloomington's street trees provide for us. This information will better enable decision makers to appropriately budget for public trees, knowing their benefits to the community. For instance, oftentimes in applications for grants and other community improvement dollars, knowledge of the current situation and the impact those dollars will have can be a determining factor in whether or not funds are awarded. The information here is encouraged to be used to bolster proposals by the City of Bloomington or other community groups wishing to increase tree cover in Bloomington.

Explanation of the Inventory Process

Data collection for the most recent inventory began in November 2006. At this time paper data sheets were used to record information on a street tree's location by street address and where on the property each individual tree was located. Tree species, size as measured by trunk diameter at breast height (DBH), condition, and infrastructure conflicts were recorded. Field crews also attempted to identify new potential planting sites that were not included in the 1995 report. The number and spacing of new planting sites was based on the best judgment of the field crew after an initial training with Urban Forester, Lee Huss. Firm rules on determining a new site were not established recognizing that each site faces unique constraints and opportunities. A full discussion of data collection can be found in Appendix A.

Throughout the 2007 inventory, data from the 1994 inventory was used to guide the field workers on where to collect data. In this way, the trees that existed in the 1994 inventory have been accounted for. A number of these trees and their spaces were found to have been eliminated by new development, among other causes. Additional trees and spaces were found in neighborhoods that were either newly constructed or annexed since the 1994-1995 inventory and through close attention paid to potential tree spaces that were not previously identified in that inventory.

In March of 2007 data collection was facilitated by personal digital assistance (PDA) recorders. The PDA recorders made data collection considerably easier and quicker. The recorders used software included in the i-Tree suite of programs from which the Street Tree Resource Analysis Tool for Urban Forest Managers (STRATUM) software is also a component. This software was specifically designed for recording street tree inventory data in a format that was easy to use with STRATUM. The data recorders also eliminated the time-intensive and potentially error-producing process of entering field data into a database manually.

Street Tree Demographics

Tree Numbers

Urban foresters consider the total number of street (i.e. public) trees within a city through inventory analysis in order to better manage the natural resource; each individual tree or planting site is given a unique identification number for individualized care and maintenance that contributes to the overall health of the population. Secondarily, population statistics provide management insight regarding the current state of the street tree population which aids in the planning process (National Arbor Day Foundation, 2002).

It is important to remember that this report only refers to street trees (see Appendix A for definition). This does not include trees on private land, the Indiana University campus, or City parks. Street trees are generally thought to make up only a small portion of a city's total urban forest. While there are no published guidelines on what percentage street trees comprise of an urban forest, Nowak (personal communication) suggests from data he has reviewed for the Eastern United States that city street trees can comprise as little as 0.4% (Atlanta, GA) of the urban forest to 22% (Jersey City, NJ) with a mean of about 8%. American Forests reports, on average, urban areas are 20% street trees and 80% non-street trees, but McPherson (personal communication) suggests that there is great variation between cities and "that the relative percentage of street trees declines as you move out along the urban-rural gradient" for some cities such as Sacramento, CA, and just the opposite for other cities like Chicago, IL (McPherson, 1998).

The 2007 inventory data reveals that Bloomington's street tree population totals 12,169 trees with an additional 4,083 planting sites available. More than half of the trees of this grand total are classified as large broadleaf deciduous species by STRATUM, numbering 6,795 individuals. Examples of large broadleaf deciduous species include Red, Silver, and Sugar Maple,[4], as well as Northern Red Oak and Tulip Tree. There are 2,878 medium-sized (*e.g.*, Locust or Flowering Pear) and 1,458 small-sized (*e.g.*, Crabapple) broadleaf deciduous individuals. Only 35 individual trees are categorized as broadleaf evergreens (*e.g.*, Magnolia, Holly), but 646 large conifer evergreens (*e.g.*, White Pine, Eastern Hemlock) exist, along with 215 medium-sized (*e.g.*, Blue Spruce) and 104 small-sized (*e.g.*, Eastern Red Cedar) conifer evergreens. Clearly, the majority of the street tree population, 91.76%, is composed of broadleaf deciduous tree species.

The 1994 Bloomington street tree inventory revealed that the citywide street tree population at that time totaled 10,167 individual trees with 1,110 additional planting sites (Banks 1995). Thus, since 1994, Bloomington's street tree population has increased by 2,002 individual trees and 2,973 planting sites.

[4] We have used common names for all species within the report for readability. Scientific names for all species are given in Appendix B.

Species Richness and Diversity

Knowing the diversity of species among a given street tree population provides invaluable insight for management of the urban forest. Species richness is characterized through the shear number of species in existence, while species diversity describes the degree of variation among species in the population (World Resources Institute 2005). Theory in the field suggests the “Ten Percent Rule,” the concept that no one genus or species should compose more than ten percent of the urban tree population (Miller and Miller 1991). Although 10% is a rather arbitrary “rule of thumb”, it is a very useful communication device. This rule suggests the need for high species richness and diversity which guard against the inopportunity that perturbation events (pests, disease, storms— which affect various species differently) harm or kill a large portion of the population.

According to the 2007 inventory, the street tree population of Bloomington is composed of approximately 100 species (Appendix B). Red Maple composes the largest proportion of individuals, making up 16.9% of the citywide street tree population. The second most populous species, Flowering Pear, composes 10.2% of the population. Making up 8.2% of the population are Sugar Maples, followed by Pin Oaks which comprise 6.8%, and Silver Maples comprising 6.1% of the population.

Clearly the Red Maple population exceeds the “Ten Percent Rule.” Perhaps more important is recognition of the fact that three maple species are contained within the top five most populous species. Thus, the genus *Acer* makes up 31.2% of the street tree population. This genus greatly exceeds the “Ten Percent Rule,” and the vulnerability of the street tree population is heightened in the event of a pest, disease, or storm that is harmful to this specific genus.

Although, the 1994 inventory is somewhat lacking in the analysis of species diversity, it appears that the street tree population has not changed in diversification as suggested in one of the general urban forestry goals listed in the 1995 consultant’s inventory report (Banks 1995). Banks reported that the most populous species in 1994 were those of the Maple genus which made up nearly 30% of Bloomington’s street tree population. The 2007 data reveals a slight increase in the proportion of this genus to 31.2% of the citywide street tree population. Banks also reported that the most common small tree in 1994 was the Callery Pear (includes all Flowering Pears), making up 7% of the street trees. Again, 2007 inventory data reveals that flowering pears have increased in proportion, to 10.2% of the population. Clearly, species composition has continued to exceed the “Ten Percent Rule.” More importantly, however, this points to the importance of more frequent inventories allowing better monitoring of species diversity, as well as policy that allows urban forest managers the ability to direct developers regarding the tree species that they add to Bloomington’s street tree population.

Relative Age Distribution

The relative age of a tree population is best explained by graphing tree population by DBH class which suggests the relative age distribution of the street tree population. Urban foresters strive for sustainability by maintaining uneven-aged tree populations that are graphically represented by a reverse "J-shaped" curve (Figure 2). In other words, these managers attempt to maintain more trees in each subsequently smaller DBH class, maintaining "replacement populations" for older trees that die with age. The relative age-distribution of Bloomington's total street tree population does not follow the reverse "J-shaped" curve in the smallest, zero to six-inch DBH class. This class has a relatively lower population than optimal, making up only 26.7 % of the population. This proportion is too small in comparison to the next, six to twelve-inch DBH class which makes up 37.8% of the population, and from which there is, optimally, a proportionally smaller population of older trees (Figure 1). Additionally, age distribution for the top five most populous species follow the same pattern as the total population and can be found in Appendix C.

The 1995 report defined Bloomington's street tree population as relatively young with 64% of the trees having a DBH of less than ten inches (Banks 1995). Today, the same proportion of the street tree population, 64%, has a DBH of 12 inches or less, suggesting that the street tree population is still relatively young, or that small species (such as Flowering Pear) make up a large proportion of this relatively younger population (Appendix C). However, in 1994, the overall age distribution better graphically matched the optimal reverse "J-shaped" curve (Figure 2) than it does today (Figure 1). Given the state of the current relative age distribution, managers may want to increase the focus on planting and/or care of zero to six-inch DBH trees within the city in order to improve the proportions of young trees to older trees, and therefore improve the coffer of replacement trees for those that die with age. The diameter class is not the same for Figures 1 and 2 because of the differences in data handling, although the general shape of the curve communicates the same message. We suggest that Figure 1 should be how data is presented in all future reports.

Figure 1. 2007 Bloomington Street Tree Diameter (DBH) Distribution

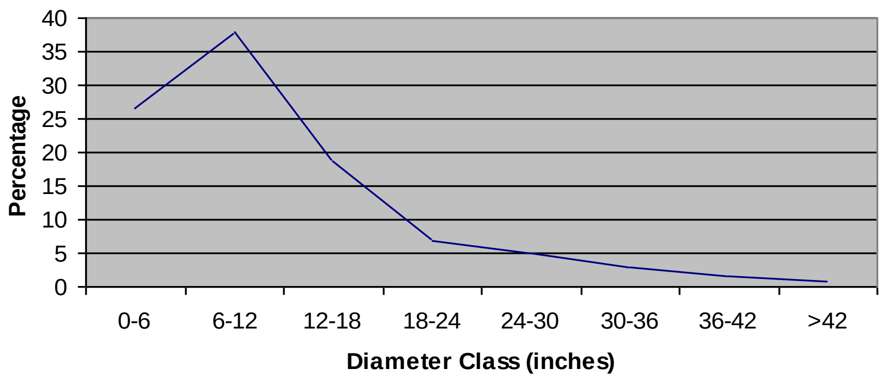
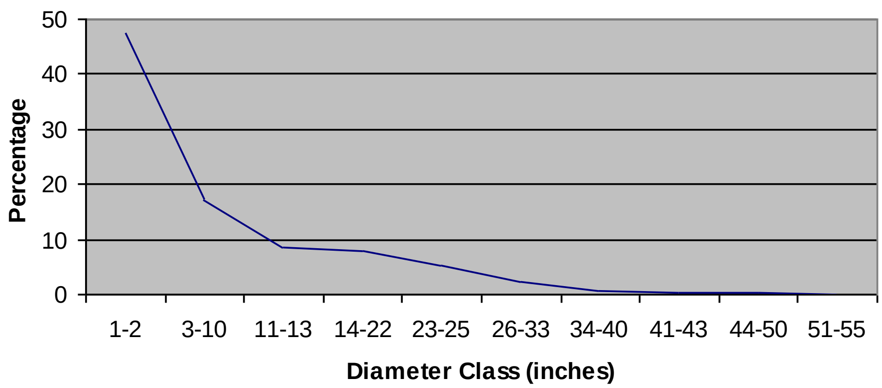


Figure 2. 1994 Bloomington Street Tree Diameter (DBH) Distribution (Banks 1995)



Condition

Consideration of the physical condition of street trees during an inventory helps urban forest managers to identify tree condition and maintenance needs, which in turn, helps determine benefits and costs, and avoid the costly litigation often associated with neglected hazard trees (The National Arbor Day Foundation, 2002). During the 2007 inventory, the conditions of Bloomington's street trees were rated by assignment to a category –"good," "fair," "poor," or "dead" for the overall tree condition (see Appendix A). We did not collect specific data on the condition of the wood of trees or the condition of the foliage. This is partially due to the fact that much of the data was collected during the winter when leaf condition was not observable and making a judgment on tree 'wood' condition was beyond the expertise of the field crew.

Of Bloomington's twenty most populous species of trees, the majority, 65.4% are in good condition, 27.1% are in fair condition, 6.9% are in poor condition, and only 0.6% are dead or dying (Table 1). Thus, 92.5% of Bloomington's street trees are in good or fair condition. Again, among the twenty most populous species, the Northern Pin Oak species has the highest proportion of individual trees that are rated in "good" condition and the lowest proportion of individuals rated as "poor." Conversely, among the city-wide street tree species, Silver Maple has the largest proportion, 19.3%, of poor and dead/dying trees. This species also has the lowest proportion of street trees that are rated in "good" condition. Since Silver Maples are some of the largest (oldest) trees in the city, it is not surprising that they are generally in poor condition. Thus, these statistics underscore general characterizations of these species which may point to species performance relevant for new plantings within the city (Chaney, 1993).

Species	Dead/Dying	Poor	Fair	Good
Red Maple	0.5	5.8	23.4	70.4
Flowering Pear	0.3	2.6	18.7	78.4
Sugar Maple	1.1	12.6	38.9	47.5
Silver Maple	0.8	18.5	54.2	26.5
Pin Oak	0.1	0.6	4.2	95
Green Ash	0.2	3.1	21.4	75.3
Crabapple	0.7	6.8	42.7	49.9
Sweetgum	0.5	1.5	14	84
White Ash	0.3	6.3	17.9	75.5
Eastern Redbud	0.6	13.8	32.1	53.5
Northern Red Oak	0.7	3	12.9	83.4
Ginkgo	0	1.7	20.1	78.2
Littleleaf Linden	0	7.1	23.2	69.6
Basswood	0.4	5.8	21.5	72.2
Eastern White Pine	1.1	3.2	23.2	72.6
Dogwood	0.6	10.5	44.2	44.8
Norway Maple	1.2	7.4	27	64.4
Tulip Tree	1	2.5	30.4	67.1
Other Pine Species	0.7	3.6	23	72.7
All Other Species	0.8	7.2	27.0	65.3
Citywide Total	0.6	6.9	27.1	65.4

Table 1. Condition of street trees by species (%) for 2007.

The 1994 inventory report utilized a similar condition ranking system but with three more condition categories: "critical" (for this analysis, collapsed into "dead/dying"), "very good," and "excellent" (for this analysis, collapsed into "good"). The 1994 inventory revealed that 78.6% of Bloomington's street trees were in good or fair condition (Banks, 1995). Therefore, overtime, these conditions have improved by nearly

14% to 92.5% of the street trees in "good" or "fair" condition by 2007. By another perspective, marked improvement is clear through the decrease in the proportion of "dead," "poor," and "fair" condition rankings and the large increase in "good" rankings over this time (Table 2). This improvement in tree condition appears to be the result of an aggressive street tree management program to remove trees of higher risk/hazard, which has resulted in a residual street tree population that is in very good condition.

	1994	2007	CHANGE
Dead/Dying	2.2	0.6	-1.6
Poor	9.7	6.9	-2.8
Fair	35.5	27.1	-8.4
Good	43.1	65.4	22.3

Table 2. Condition rating of street trees by percentage of total street tree population for 1994 (Banks, 1995) and 2007 inventories, and percentage change in condition between inventories.

Stocking

The 2007 inventory yields interesting results in consideration of the number of occupied *and* vacant planting sites for street trees within the city, and in comparison to 1994 inventory stocking data. The 2007 inventory reveals that of the city's 16,252 street tree sites, approximately 75% are stocked. The number of planted sites naturally corresponds with the grand total of street trees within Bloomington, at 12,169 sites. However, this inventory identified 4,083 unplanted sites. This number is subject to change at the discretion of the Urban Forester for various reasons including underground infrastructure conflicts, traffic safety concerns, and strategic planning that field crews were unaware of in the field when identifying new planting sites. These unplanted sites are a result of various factors including previously unrecognized locations in which street trees could be accommodated, site vacancy due to tree death and/or removal, and in many cases, new site locations in recently incorporated areas of the city. The majority of these unplanted sites are considered "small" planting sites meaning that they should only accommodate small tree species due to the confines of the space available (Table 3).

Planting site size (lawn width)	**Number of sites**
Large (8' or larger)	1,134
Medium (6' to 8')	928
Small (4' to 6')	1,892
Stumps/Undefined	289
Total	4,083

Table 3. Vacant planting site size distribution of 2007 street tree inventory.

Stumps and undefined spaces are treated separately here as they indicate that they are not ready to be planted immediately (stumps need to be removed first) or if a field crew member determined that a space was possible but did not conform to the definitions of a small, medium, or large space. In either case consultation with the Urban Forester would be needed before planting.

Attempts were made to identify the status of each planting site identified in the 1994 street tree inventory. A detailed analysis is impossible given that some of this original inventory was lost. However, some statistics can be deciphered. Between the inventory years, there were 258 of 1,110 empty sites that were planted. By contrast there were a total of 2,331 sites that previously had a tree, which are now vacant and may have been planted and subsequently failed in the interim.

The important revelation here is that, of previously inventoried (planted) spaces, there was a net loss of 2,331 trees. The implication is that while the city as a whole may have gained trees as they were planted in new areas of the city, planting efforts may need to be shifted back towards the core of Bloomington in order to maintain density and canopy cover in older areas of the city. Future use of GPS/GIS to geocode individual street tree sites throughout the city may better inform managers in monitoring the geographic stocking patterns that emerge over time.

Wire Conflicts

Urban Foresters must consider the size of unplanted sites to plant "the right tree in the right place" (The National Arbor Day Foundation, ND). A tree that grows to a height of 40 feet at maturity will not be well accommodated in a planting site over which a utility wire runs at 20 feet above ground. Thus, in an inventory of this nature, utility conflicts are often considered.

During the 2007 inventory, tree-wire potential conflicts were recorded citywide for individual trees. Citywide, the large majority of street trees, 10,972, are not located in locations with wires, whereas 1,197 street trees, 9.8% of the total population, are located within the presence of wires. In 1994, 10.5% of the city's street tree population was in the presence of utility wires (Banks, 1995). Therefore, over the past 13 years, managers have successfully decreased the percentage of street trees in the presence of wires by 0.7% to 9.8% of the total street tree population. Continued collaboration between the City's Urban Forester and the utility foresters should further reduce wire conflicts in the future.

Ecosystem Services, Return on Investment

In order to valuate the ecosystem services that Bloomington's street trees provide, we used the US Forest Service's Street Tree Resource Analysis Tool for Urban-Forest Managers (STRATUM) software program (www.itreetools.org/stratum.shtm). STRATUM estimates the provision of relevant ecosystem services based on the species and size of a tree and then translates that service into a monetary value. There can be competing notions of value when it comes to ecosystem services. One may think that markets like the Chicago Climate Exchange (www.chicagoclimatex.com) might be a good place to look for the price of a ton of CO_2, for example. The value of avoided pollution for markets is a function of the cost for industry to avoid those emissions. The true value of the ecosystem service would include the value of public health benefits for reduced sulfur dioxide, for example. In this analysis, the default values that STRATUM provides were used. It is possible that these values do not reflect the true value of each of these services specifically to Bloomington's context. Future initiatives could be taken to refine these values, and it is possible that future versions of STRATUM will have these values defined for this area more locally. The STRATUM default benefit values are found in Table 4.

Benefit Category	Price
Electricity ($/Kwh)	0.0759
Natural Gas ($/Therm)	0.098
Carbon dioxide – CO2 ($/lb)	0.0075
Particulate matter – (PM10) ($/lb)	2.84
Nitrogen dioxide – NO2 ($/lb)	3.34
Sulfur dioxide – SO2 ($/lb)	2.06
Volatile Organic Compounds - VOC ($/lb)	3.75
Stormwater ($/Gal)	0.271

Table 4. STRATUM default prices used for the 2007 inventory analyses

As with many first time endeavors, there is a learning curve between the earliest versions of a program and the version that finally fulfills its potential to its users; we feel such will be the case for STRATUM. The i-Tree software suite and the level of detail we are able to provide using this resource will increase significantly in the future. STRATUM was developed along with the other i-Tree programs through a peer review process and is published by the USDA Forest Service. STRATUM is designed to take basic measures of street trees, such as species and size measured by DBH and translate that into measures of the overall structure of the street tree population from which the many benefits of trees can be derived.

A brief explanation of how STRATUM works may help the reader to more completely understand the results presented here. For this version of STRATUM, the country was split up into 19 climate zones of relatively similar weather and species composition, similar to a map of plant hardiness zones. For each climate zone, a reference city was chosen where a detailed tree inventory took place. From those inventories, relationships were established between the DBH of certain common species and the size of the tree crown, the amount of leaf area, and growth rates, etc. By knowing these tree species parameters, estimates can be made of how much rainwater an individual tree will catch and slow down, preventing runoff, or how much pollution the tree filters from the air or how much carbon it sequesters, for example.

This introduces the first caveat of the limitations of this report as compared to what will be possible in the future. Due to the enormity of the task, only a limited number of the detailed reference city inventories have taken place. Currently the reference city for Bloomington is Minneapolis, Minnesota, which is arguably quite different in terms of climate and the related tree species that survive and grow well there. This difference is likely to produce conservative results for Bloomington if based on data from the cooler, drier climate of Minneapolis. In upcoming versions of STRATUM, our reference city will be Indianapolis (projected date is 2008-09), which will produce more accurate results.

A second caveat is that, as with any computer program, the results you get out are only as good as the data you input. Due to time constraints, data collection began before we had become completely familiar with STRATUM and the data it requires to perform all of its capabilities. For example, by recording a building type that each tree is nearest, STRATUM will provide estimates of the energy savings created by either shading in the summer or providing a windbreak in winter. In this inventory we did not collect the necessary data on buildings and the proximity of the trees to them to perform this analysis. However a pilot project of this type of analysis could be performed on smaller areas of interest, such as the downtown or individual neighborhoods. It is important to remember that those benefits are real and we hope to report them in the future when our capabilities are stronger.

Carbon Dioxide Reduction

It is well known that all plants take in carbon dioxide as part of their metabolism (photosynthesis) and store the carbon in the form of plant tissue. Woody plants such as trees store that carbon over the life of the tree, during which a considerable amount of carbon can accumulate. By estimating the size of each tree, STRATUM estimates the amount of carbon that is currently stored in Bloomington's street trees. Table 5 depicts stored carbon for the 20 most populous species and all street trees combined. A complete listing of all species sampled is presented in Appendix B – Population Summary for the 2007 Bloomington Street Tree Inventory.

Species	Total CO2 Stored (lbs)	Value ($)	% of Population	% of Value ($)	Average Value per Tree ($)
Red maple	3779522	28346	16.9	8.9	13.82
Flowering pear	2250774	16881	10.2	5.3	13.59
Sugar maple	6918689	51890	8.2	16.3	51.73
Pin oak	2586906	19402	6.8	6.1	23.32
Silver maple	11905329	89290	6.1	28.0	120.34
Green ash	1411010	10583	4.2	3.3	20.67
Crabapple	486831	3651	3.8	1.2	7.99
Sweetgum	1061944	7965	3.3	2.5	19.91
White ash	705988	5295	3	1.7	14.39
Eastern redbud	271073	2033	2.6	0.6	6.52
Northern red oak	240265	1802	2.2	0.6	6.65
Ginkgo	81848	614	2	0.2	2.56
Littleleaf linden	355573	2667	1.9	0.8	11.8
Basswood	745668	5593	1.8	1.8	24.97
Eastern white pine	230437	1728	1.6	0.5	9.10
Dogwood	123377	925	1.4	0.3	5.38
Norway maple	274265	2057	1.3	0.7	12.62
Tulip tree	1472238	11042	1.3	3.5	69.88
All Other pine species	231300	1735	1.1	0.5	12.48
All Other Street Trees	33199992	54895	20.3	17.2	22.25
Citywide total	42452348	318393	100	100	26.16

Table 5. Stored Carbon Dioxide in Bloomington Street Trees, 2007.

The amount of carbon stored by each species is a function of both the number of that species and the size of those trees. Clearly some species store more carbon than others on a tree by tree basis. Silver Maples, some of oldest and largest trees in the population, stand out in that they make up only 6.1% of the population but are holding 28% of the stored carbon.

In addition to the carbon dioxide stored, each year as trees grow they take more carbon dioxide out of the atmosphere and add to their mass. This process is known as carbon sequestration. In this case the benefit is a function of both number and size of trees in each species and the growth rate of that species. Similar trends emerge since those species that grow quickest become the largest trees, storing the most carbon. Table 6 depicts the amount of carbon sequestered annually (2007 basis) by each species and the value of that sequestration. In addition to the amount of carbon dioxide sequestered, STRATUM also estimates the amount of carbon dioxide that is released when dead trees and limbs removed from trees decompose.

Species	Sequestered (lbs)	Decomposition Release (lbs)	Maintenance Release (lbs)	Total Release (lbs)	Net Sequestered (lbs)	Value of Sequestered Carbon ($'s)	Avg Value Per Tree ($'s)
Red Maple	315,604	-18,142	-400	-18,542	297,062	$2,228	$1.09
Flowering Pear	305,410	-10,804	-242	-11,046	294,364	$2,208	$1.78
Sugar Maple	409,187	-33,210	-196	-33,406	375,781	$2,818	$2.81
Silver Maple	894,618	-57,146	-145	-57,291	837,327	$6,280	$8.46
Pin Oak	219,399	-12,417	-162	-12,579	206,820	$1,551	$1.86
Green Ash	142,477	-6,773	-100	-6,873	135,604	$1,017	$1.99
Crabapple	53,923	-2,337	-89	-2,426	51,497	$386	$0.85
Sweetgum	113,622	-5,097	-78	-5,175	108,447	$813	$2.03
White Ash	72,798	-3,389	-72	-3,461	69,337	$520	$1.41
Eastern Redbud	31,012	-1,301	-61	-1,362	29,650	$222	$0.71
Northern Red Oak	26,309	-1,153	-53	-1,206	25,103	$188	$0.69
Ginkgo	8,615	-393	-47	-440	8,175	$61	$0.26
Littleleaf Linden	58,121	-1,707	-44	-1,751	56,370	$423	$1.87
Basswood	75,866	-3,579	-44	-3,623	72,243	$542	$2.42
Eastern White Pine	18,175	-1,106	-37	-1,143	17,032	$128	$0.67
Dogwood	15,236	-592	-34	-626	14,610	$110	$0.64
Norway Maple	29,794	-1,316	-32	-1,348	28,446	$213	$1.31
Tulip Tree	86,862	-7,067	-31	-7,098	79,764	$598	$3.79
All Other Pine Species	13,377	-1,110	-27	-1,137	12,240	$92	$0.66
All Other Stree Trees	502,717	-35,133	-481	-35,614	467,103	$3,503	$1.42
Citywide Total	3,393,123	-203,771	-2,373	-206,144	3,186,979	$23,902	$38.60

Table 6. Annual CO_2 Sequestration by Bloomington Street Trees, 2007 basis.

Air Quality Improvement

In addition to sequestering carbon dioxide from the air, trees also clean the air of pollutants that are more directly harmful to humans. Pollutants from car emissions such as particulate matter have been linked to triggering heart attacks in at risk populations and ground level ozone (O_3) is related to increased incidence of asthma and other respiratory problems (Ewing *et al*., 2006).

By slowing air currents and acting directly as a filter, trees can remove those pollutants from the air we breathe. The main factor determining the efficiency of pollutant removal for a tree is the amount of leaf surface area it has. Trees with large canopies and a high amount of leaf area will remove more pollutants than smaller ones.

STRATUM uses data collected in the inventory and estimates both canopy size and leaf area to calculate the amount of air pollutants removed. Table 6 demonstrates the removal of air pollutants by Bloomington street trees. STRATUM also recognizes that trees release small amounts volatile organic compounds (VOC) as part of their normal respiration. This release is small compared to the amount of pollutants removed from the air; the health cost associated with those VOCs is accounted for in Table 7.

	Pollution Depostion (lb)								
Species	O3	NO2	PM10	SO2	Value of Deposition ($)	VOCs Released	Cost of VOCs ($)	Net Value ($)	Avg Value Per Tree ($)
Red Maple	326.6	55.7	161.3	14.5	$1,765	117	-439.00	1,326.00	0.65
Flowering Pear	128.8	22.2	73.7	5.7	$725	36.6	-137.00	588.00	0.47
Sugar Maple	239.4	40.7	124.3	10.6	$1,310	192.2	-721.00	589.00	0.59
Silver Maple	518.7	87.9	256.1	23	$2,801	275	-1,031.00	1,770.00	2.39
Pin Oak	141.2	24.6	75.3	6.3	$785	37.4	-291.00	494.00	0.59
Green Ash	40.7	6.5	23.6	1.8	$228	0	0.00	228.00	0.45
Crabapple	27.5	4.5	14.6	1.3	$151	0.2	-1.00	150.00	0.33
Sweetgum	31.5	5	18.3	1.4	$177	0	0.00	177.00	0.44
White Ash	35	5.6	18.2	1.6	$191	0	0.00	191.00	0.52
Eastern Redbud	15.2	2.5	8.1	0.7	$84	0.1	0.00	84.00	0.27
Northern Red Oak	14.1	2.4	8.4	0.6	$81	20.4	-76.00	5.00	0.02
Ginkgo	5.3	0.9	3.4	0.2	$31	2.3	-9.00	22.00	0.09
Littleleaf Linden	14.4	2.5	8.6	0.6	$82	8.5	-32.00	50.00	0.22
Basswood	22.2	3.6	12.6	1	$124	0	0.00	124.00	0.55
Eastern White Pine	28.4	5.6	24.6	3.5	$191	103.5	-388.00	-197.00	-1.04
Dogwood	6.4	1.1	3.6	0.3	$36	0	0.00	36.00	0.21
Norway Maple	15.8	2.7	8.7	0.7	$88	4.3	-16.00	72.00	0.44
Tulip Tree	44.8	7.2	22.1	2	$240	0	0.00	240.00	1.52
All Other Pine Species	24.1	4.8	20.4	3	$160	98.1	-368.00	-208.00	-1.50
All Other Street Trees	359.2	61.5	205.3	20.9	$2,031	250.4	-939.00	1,092.00	0.44
Citywide Total	2,040.50	347.5	1,091.20	99.7	$11,281	1,186.00	-4,448.00	6,833.00	0.56

Table 7. Air Pollution Removal by Bloomington Street Trees, 2007.

As previously stated , STRATUM can also calculate energy savings due to street trees shading buildings from the sun to keep them cool in the summer or by providing windbreaks that help keep buildings warm in the winter. In addition to the money saved directly from reduced energy usage, saving energy also results in fewer power plant emissions. The magnitude of benefits from avoided emissions such as carbon dioxide, nitrogen dioxide, sulfur dioxide, volatile organic compounds, and particulate matter from power plants dwarf those reported above from the trees cleaning the air directly. Preliminary estimates in STRATUM using a single building type across the entire city indicates more than $342,000 in energy savings for Bloomington businesses and residents per year and that the avoided air pollution benefits may be worth as much as an additional

$48,000 per year. Future inventories could include information on the relationship of each tree to nearby buildings so that the energy savings benefits can be calculated more accurately and included in the analysis.

Storm Water Interception

When a raindrop hits the ground, one of two things will happen. The water can either soak into the ground providing moisture to growing plants and replenishing groundwater supplies, or if there is too much water to soak in or it hits an impermeable surface, the water will become stormwater runoff. Trees act in a number of ways to reduce runoff volume. First, the crown of a tree will intercept rainfall allowing some of it to evaporate and never hit the ground while some will slowly fall from the tree at a rate that can be absorbed by the ground. Tree roots also increase the water holding capacity of soil and can slow stormwater runoff, again allowing more of it to infiltrate the soil. Rainfall interception by tree canopies also prevents erosion by reducing the impact of raindrops on the soil surface, thereby preserving the quality of surface water supplies (McPherson, 2006).

Again STRATUM uses the same methods described above to estimate canopy and leaf area and combines that with Midwestern climate data to estimate the amount of rainfall and thus the stormwater intercepted. Table 8 depicts this estimated benefit.

Species	Total Rainfall Interception (gal)	Total Value ($'s)	% of Population	% of Value	Average Value per Tree ($'s)
Red maple	1629460	44161	16.9	11.7	21.53
Flowering pears	967963	26234	10.2	6.9	21.12
Sugar maple	1943319	52668	8.2	13.9	52.51
Pin oak	871900	23630	6.8	6.2	28.4
Silver maple	3054852	82792	6.1	21.9	111.58
Green ash	496878	13466	4.2	3.6	26.3
Crabapple	127630	3459	3.8	0.9	7.57
Sweetgum	392295	10632	3.3	2.8	26.58
White ash	296254	8029	3	2.1	21.82
Eastern redbud	71680	1943	2.6	0.5	6.23
Northern red oak	103138	2795	2.2	0.7	10.31
Ginkgo	45023	1220	2	0.3	5.08
Littleleaf linden	134857	3655	1.9	1	16.17
Basswood	266508	7223	1.8	1.9	32.24
Eastern white pine	261414	7085	1.6	1.9	37.29
Dogwood	34614	938	1.4	0.3	5.45
Norway maple	106646	2890	1.3	0.8	17.73
Tulip tree	383692	10399	1.3	2.8	65.82
All Other pine species	216018	5855	1.1	1.6	42.12
All Other Street Trees	2554508	69232	20.3	18.3	28.06
Citywide total	13958649	378305	100	100	31.09

Table 8. Annual Stormwater Interception by Bloomington Street Trees, 2007

Other Benefits of Street Trees

Clearly street trees do much to improve the physical environment here in Bloomington, but there are a number of other less tangible benefits that urban trees provide. Retail business areas can reap a large benefit from having more trees, as consumer surveys reveal that people tend to shop longer and more often in areas that are well landscaped (Wolf, 2005). Trees also improve the value of residential property by as much as 7% depending on the size and number of trees. They also have been shown to have positive psychological effects, reducing levels of stress and thereby contributing to the overall health of those who maintain a visual connection with nature during stressful situations such as work or driving (McPherson, 2006).

STRATUM is capable of calculating those benefits, but again it requires that the type of property that each tree is located on is known. Preliminary estimates without specifying a property type yield aesthetic and related benefits at over $366,000 per year for Bloomington street trees. It is assumed that STRATUM uses a general default value that averages these benefits across property types to calculate this figure.

Return on Investment

A five year average (2002-2006) of costs shows the City of Bloomington annually spends $247,062 on urban forestry directly. That's $20.30 per tree or $3.57 per person in Bloomington. These costs are broken down in Table 9.

Category	Value
Planting	$41,099.00
Contracted Pruning	$34,503.00
Removal	$98,581.00
Administration	$66,025.00
Litter Removal	$471.00
Other Costs	$6,383.00
Total	**$247,062.00**
Cost Per Tree	**$20.30**

Table 9. Bloomington Annual Urban Forestry Expenses Average FY2002-2006

Category	Value
CO_2 Sequestration	$23,902.00
Pollution Removal	$6,833.00
Stormwater	$378,305.00
Total	**$409,040.00**
Benefit Per Tree	**$33.61**

Table 10. Annual Bloomington Street Tree Ecosystem Services, 2007 basis

The total value of ecosystem services that Bloomington's street trees provide as presented in Table 10 is $409,040 per year or $33.61 per street tree or $5.90 per person. When the benefits as calculated here are directly compared to the annual costs of the urban forestry program in Bloomington (Table 9), the net benefits total $161,978. The benefit-cost ratio for the urban forestry program is 1.66. That means that for every dollar spent on the program, Bloomington street trees yield $1.66 in benefits. This figure is conservative because urban forestry expenses go towards both street trees and park trees and cannot be separated, whereas the ecosystem services are only reported for street trees. Similar assessments of other cities' street tree populations have revealed benefits ranging from $1.37-$3.09 for every dollar invested (McPherson, et al., 2005).

While this number is positive and would indicate that more investment in Bloomington's street trees would be beneficial to the community, this number is skewed low. Being able to fully capture the value of Bloomington's street trees will show that they provide significantly more value to the community. Adding the benefit categories that have been omitted in previous tables and using generic calculations due to lack of Bloomington specific data (see earlier explanations for the Minneapolis specific model, building type-energy savings) , the net benefits jump to $939,985 per year with a benefit-cost ratio of 4.80. Again, that extra value would include street trees effect on property values, energy savings, and reduced air pollution that result from reduced energy use.

Species Importance Value

STRATUM produces a report generating “Importance Values” for the most abundant street trees species. The importance value takes into consideration the number of individual trees, and the subsequent leaf area and canopy cover for a given species; the value is calculated by averaging a given species’ proportion of the total number of trees, proportion of the total leaf area, and proportion of the total canopy cover. Thus, the importance value is effectively a percentage. Again, leaf area and canopy cover were not directly measured during the 2007 inventory, but are calculated by STRATUM utilizing a formula that takes into consideration the inventory’s direct measurements (such as DBH) and species-specific properties based on the reference city inventory data.

The highest importance value given to a single species is 15.5 for Silver Maple, followed by 13.8 for Red Maple, and 12.5 for Sugar Maple. These figures are certainly not surprising as these three species are in the top five most populous species as well as among the largest trees on average within the street tree population, and subsequently have a large proportion of the total leaf area and canopy cover. The other two species in the top five most populous species, Flowering Pear and Pin Oak, follow as the fourth and fifth “most important species,” with importance values of 8.0 and 6.4 respectively. Green and White Ash trees, which are at risk from Emerald Ash Borer (EAB) have an importance value of 6.2, ranking sixth among species.

The Importance Values “suggest a community’s reliance on the functional benefits of a particular species” (i-Tree Users Manual, 2007). Certainly Bloomington has become quite reliant on the Maple genus. This suggests that the Importance Value is most pertinent to managers as a planning tool, not to distinguish the most important species for future planting, but to distinguish those that might need to be avoided—those that the city has become too reliant upon in terms of diversification and for ecosystem services. Rather than having a very high importance value for only a few species, it seems that a well diversified city street tree population would present a list of similar importance values for many species.

Recommendations

Setting goals for the Bloomington's Urban Forestry Program are needed to provide an overall management strategy. Care must be taken when setting those goals, as they often conflict with one another. If for example, Bloomington wished to maximize ecosystem services as its main priority, planting of large fast growing species would be one way to achieve that. Species that fit that description, such as Silver Maple, provide benefits far in excess of other species, but they also are more costly. The Bloomington experience with Silver Maple is similar to many other communities in the Midwest. These fast growing trees with softer wood eventually result in large trees that are potentially hazardous because of their tendencies to become hollow and because of their softer wood more likely to be damaged in wind and ice storms (Chaney, 1993). Over time the direct cost to the Urban Forestry Program may become unsustainable. This strategy would also come at the expense of sacrificing diversity as only a small number of species would be selected for optimizing ecosystem services. Herein are biological, managerial, and policy recommendations to help inform the establishment of goals and how to achieve them.

Biological

In terms of species distribution, managers should strive to comply with the "Ten Percent Rule" in order to protect the street tree population and its ecosystem services from disturbance events that could potentially target specific species or genera. Clearly, the Maple genus and the flowering pear species exceed this limit. There are a number of ways in which this imbalance may be corrected over time, given the availability of necessary resources. Perhaps most simply, managers should avoid planting genera or species that violate or nearly violate this rule of thumb. In order to effectively monitor species and genera proportions, regular inventories must be conducted, as suggested below. Moreover, policy-makers must continue to institute strategies that give urban forest managers and city planners some form of control over the planting of all street trees—even those planted by developers.

Secondly, regarding relative age distribution, city managers should make an effort to increase the cohort of relatively young trees (one to six-inch DBH) in order to somewhat renew the "reverse j-shaped" curve that represents a more optimal age distribution of the street tree population. The small "dip" in the graphic representation of the relative age distribution of Bloomington's street trees will be practically indistinguishable within decades if managers begin to bolster numbers of young trees and focus care and management on new plantings today. Certainly, this may incur increased cost for the short term, but small budgetary adjustments are well worth the effort to ensure a continual stream of the ecosystem benefits that the city's street trees provide.

Thirdly, city managers should continue to adhere to the concept of "right tree right place" (The National Arbor Day Foundation, No Date). Following this rule of thumb provides multiple benefits. Conflicts with utility wires and street signs are minimized when planting spaces accommodate proportionally appropriate-sized species.

Moreover, when a planting site receives the largest species appropriate for its size, that planting site will deliver the most "bang for the buck" in ecosystem services, as STRATUM figures that species with the most canopy cover deliver the most benefits and therefore, have the highest importance values. The current wholesale cost of purchasing and planting an individual large or medium species costs the City of Bloomington approximately $200. If a goal were set to fill every large vacant space to maximize the potential for ecosystem services it would cost an additional $45,360. Spread over a time span of five years, an additional $9,000/year to the Urban Forester's planting budget would accomplish this task. Planting these vacant spaces in addition to the regular yearly plantings would help to address the concerns over the current age distribution as well.

Management

Further utilizing computer technology will also help to better manage the street tree population across the entire city. The records from this inventory will soon be converted for use with GIS by the City of Bloomington. In this way managers will be able to see on a map the spatial distribution of Bloomington's street trees and tree planting spaces. Areas of town with high concentrations of planting spaces could be identified for targeted planting efforts. Likewise areas that might be particularly susceptible to threats, such as Emerald Ash Borer could be identified and appropriate management steps could then be taken to reduce the potential for sudden losses of canopy cover in large areas.

In order to successfully integrate urban forestry into the broader goals of the city of Bloomington and to biologically maintain the city's street trees, the street tree inventory must be regularly updated. Some urban foresters choose to inventory the entire street tree population every five years, while others find that the budgetary consistency of inventorying a percentage of the population annually is more appropriate. Many variables, such as the budget and the ratio of urban forestry employees to street trees, must factor into such a decision. However, it is clear from this analysis that thirteen years between inventories is far too long. Important biological patterns and subsequent management requirements are increasingly difficult to discern as time between inventories increases. Personal communication with several experts[5] suggest that conducting a complete street tree inventory on a consistent five to 10 year cycle is critical. An alternative approach is to re-measure 10-20% of the street tree population per year on a regular cycle. Data from this type of inventory can be used to determine a "rolling average" for the re-measurement period.

Policy Integration

Linking urban forestry to wider goals and policies that Bloomington has set for itself is key to Bloomington realizing the maximum benefits that streets can provide. The

[5] Jennifer Gulick, Davey Resources; Pam Louks, Indiana Division of Forestry; Greg McPherson and David Nowak, US Forest Service.

importance of street trees is noted repeatedly in the Bloomington Growth Policies Plan (GPP). The GPP calls for increased tree cover and greenspace in the downtown area and promotes street trees as improvements to neighborhood spaces as well. Street trees are also recognized by the GPP for their contribution to the adoption of alternative transportation by making walking safer and buffering pedestrians from road spray, dust, and noise. The GPP also notes the desirability of large species that create beauty and shade which will entice walkers.

Other documents support increased street trees as well. The Downtown Vision and Infill Redevelopment Plan states that "Street trees should be considered an important component to any new and redevelopment project." The Unified Development Ordinance (UDO) recognizes the energy conservation benefits from shading and wind breaks in section a-5 of the Landscaping Standards for development. Also neighborhood plans such as the one for Green Acres includes many references to concerns over losing mature trees and the desirability of maintaining tree cover in that neighborhood.

The role of city planners in the development of Bloomington's urban forest also cannot be overlooked. It is believed that much of deviation from the ideal level of diversity among street trees is driven by private developers planting large numbers of certain species such as Red Maple and Flowering Pear trees. In addition to recent initiatives from the Planning Department emphasizing the use of native species, the results of this report could be used to better inform decisions on planting in specific areas to maximize diversity. Utilizing GIS technology and data collected in this project, a planner would easily be able to assess an area of proposed development with respect to the tree diversity in surrounding areas. In this way the risk of catastrophic loss from species specific threats can be mitigated at the outset of planting.

To provide better management, those recommendations could be linked with the street tree inventory to provide information on whether or not Bloomington is achieving its goals. Based on those planning documents, it would be possible for a street tree management plan to set benchmarks for certain areas that are defined in Bloomington's strategic planning efforts, such as for downtown or other important corridors. These benchmarks could be in terms of goals for canopy cover, number of trees per mile of street, or other metrics. Subsets of the inventory can be used to analyze the benefits of street trees in any area of interest including city council districts and individual neighborhoods.

Recommendation Summary

- Strive toward compliance with the 10% rule in species diversity,
- Increase the proportion of young trees, particularly those that will grow into large trees,
- Plant "right tree, right place" and largest species where possible,
- Utilize GIS technology to reveal spatial relationships,
- Regularly re-inventory to keep abreast of changes and monitor progress toward goals

- Link Urban Forestry goals with broader City initiatives and planning documents, and
- Develop a street tree management plan for the city with measurable benchmarks so that future inventories can be used to assess progress on a periodic basis.

Conclusion

The City of Bloomington is increasingly becoming known as a place where progressive and sustainable ideas flourish (Wann, 2007). Recent initiatives by the City of Bloomington such as joining the U.S. Mayors Climate Protection Agreement go hand in hand with increasing support for urban forestry in Bloomington which not only reduces energy consumption but also helps to sequester greenhouse gasses. Bloomington has annually maintained Tree City USA status with the National Arbor Day Foundation after becoming the first Tree City in Indiana in 1984 and is well known for having one of the top urban forestry programs in the state. This report is likely the first of many that will come from the School of Public and Environmental Affairs and the Indiana University community on the state of Bloomington's urban forest. Together with the City of Bloomington, we can further the tradition of excellence in urban forestry in this town, bringing together scientific analysis and recommendations that are practical and useful for decision makers in the community.

How does Bloomington wish to see itself in the future? If that vision includes cleaner air, cleaner water, less energy dependence, and a pleasant town where one can walk down the street in the cool shade of Bloomington's urban forest, then this important resource must be cultivated. The dynamic nature of the urban forest demands active participation in its development if long term goals are to be achieved. With continued planning and implementation, such participation will become increasingly easier. For now, a number of issues have been uncovered in this report to guide management in the near term. Species diversity is a continuing concern as the proportion of Maples and Flowering Pears continue to climb. Also, the age distribution shows some vulnerability in young trees that will be needed to replace the old.

Overall, Bloomington's street trees are doing quite well. The number of trees is growing and the condition of standing trees has improved significantly from the previous inventory. While our stocking rate seems to have decreased with the higher number of planting sites in this inventory compared to the previous one, this is largely due to the inventory teams aggressively seeking to identify new planting sites that were not previously recorded. The distribution of planting sites will need to be examined to ensure that the benefits provided by street trees are received equitably across the city by maintaining adequate tree cover in all areas of town, not just prominent places.

Bloomington's street trees yield positive benefits for every dollar invested in them. In terms of what we have been able to confidently and conservatively estimate here, street trees return $1.66 for each dollar invested. The benefits may actually approach $4.00 or higher for every dollar invested. As both STRATUM and our data are refined in future years, a more precise figure of those benefits can be estimated.

Finally we wish to acknowledge Bloomington's Urban Forester, Lee Huss. Lee has provided not only a great deal of support for this project, but his hard work and service is directly responsible for the high quality condition of Bloomington's street trees.

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CCX: http://www.chicagoclimatex.com/

STRATUM: http://www.itreetools.org/stratum.shtm

Fischer, B.C., M. Steinhoff, S.K. Mincey and L. Dye. 2007. The 2007 Bloomington street tree report: an analysis of demographics and ecosystem services. Bloomington Urban Forestry Report 01-07, 35p.

Appendices

Appendix A. Description of the 2007 Inventory Process and Definitions.

Street Trees are defined as trees that are located within the public right-of-way or the layout of a public road. The State of Indiana grants to the local municipalities the authority for street and public shade trees within their own geographical areas.

The City of Bloomington Unified Development Ordinance defines '**Street Trees**' as "trees lying on the real estate owned or controlled by the City, excluding the real estate owned or controlled as a public park except for an area fifteen (15) feet in depth from the pavement edge on either side of any paved through streets within the park."

Inventory crew volunteers used the following guidelines below to determine whether a particular tree should be counted as a street tree.

1. The tree is located between the curb and the sidewalk.
2. The tree is located within the sidewalk corridor.
3. On streets that do not have sidewalks, the tree is located within **_____** feet of a curb or pavement edge.
4. The tree is located on a traffic island or median strip.

If the tree is not located as described above, it is not considered a street tree. The following are generally **not** street trees:

- a tree located between the sidewalk and a house or building
- a tree located on the front yard of a property
- **Unless** it is within _____ feet of a road without a sidewalk, where there is a specific defined distance for an allowable public tree setback planting
- a tree that arches over the street
- **Unless** it is actually planted in one of the four types of locations described on the previous list (1-4)

Field Techniques/Data Collection

This section describes each data field that is included in the Bloomington i -Tree databases and how the data in each field was created. For categorical data fields, the i-Tree suite uses numeric categories for different values of tree condition or maintenance recommendations. Definitions for those categories are the defaults provided by i-Tree and are located here. However it is possible to change those definitions in future iterations of the inventory if the default values are not useful for the City Forester.

ID:

ID is the data base record number, and is created in each database as records are entered. This number may not always be unique to a specific tree or tree location. New databases that are created to do analyses on subsets of data, such as a particular zone, will be renumbered. The ID number is for the software only; it contains no information about a particular tree or planting space and may be ignored.

Location:

Location can be defined as any geographical area of interest that might want to be analyzed individually. For the Bloomington Inventory, we chose to define Location as established residential neighborhoods that are registered with the City. For areas not included in a neighborhood, the entry will denote non-neighborhood.

TreeID:

Tree ID is the unique number that corresponds to each data record. This number should really be thought more of as a tree site number. Over time many different trees or no trees may end up occupying a particular site. It is useful for the City Forester to maintain information about each planting site such as utility conflicts and the width of the tree lawn in order to make appropriate decisions about what tree should be planted in the future.

Zone:

Zones are defined in the i-Tree users manual to be particular management areas. Due to its relatively small size, Bloomington does not need separate management areas. We have chosen to use City Council districts for the Zone category. This will allow analysis to be performed on each individual district and will allow Council Members to better understand the how the condition of Bloomington's Urban Forest affects their district.

SpeciesCode:

Species Code is the code defined for each tree species in the i-Tree users manual Appendix D. Some tree species may not be found in the Midwest species list. Additional Species Codes may be found in other region's lists, often in the Piedmont list. Due to the limited number of species codes that are provided in the i-Tree users manual, it was occasionally necessary to group some less common varieties at the genus level. Empty tree spaces are coded as Planting Site Small (PSS, where Lawn Width is 4-6'), Planting Site Medium (PSM, where Lawn Width is 6-8'), and Planting Site Large (PSL, where Lawn Width is greater than 8').

CityTree:

City Tree denotes whether a tree is Street or Park Tree, coded as 1 or 2 respectively. As this inventory is of exclusively Street trees, all entries should be 1.

DBH:

The urban forestry tree measurement standard for size is the trunk diameter, measured at breast height. This measurement is usually abbreviated as DBH (all capital letters). Breast height is defined as 4.5 feet (4.5') above ground level. DBH will be estimated to a 2" class (2"=1.0-2.9", 4"= 3.0-4.9", etc.) with a Biltmore cruiser stick.

NOTE: The height at which the diameter is measure may have to be adjusted if an odd growth or interrupting object interferes with measuring at the 4.5' height. A tree that has a large root flare should be measured as any other tree. If the root flare extends as high as 4.5', then the diameter should be measured above it. The height at which the DBH is actually taken should then be entered in the Comments column.

LandUseCode:

Land use code describes the type of property that a tree is associated with. Options include: **1 =** single family residential, **2 =** multi-family residential, **3 =** Industrial/Large Commercial, **4 =** Park/Vacant/Other, **5 =** Small Commercial.

Land use codes are used by STRATUM in the estimation of energy savings caused by trees by assuming a building type that is associated with a particular land use designation. Land use codes are also used by STRATUM in the estimation of the effect on property values that STRATUM causes.

LocationCode:

Location code denotes in what type of site the tree is growing. Definitions are as follows: **1 =** Yard – In the case that a tree is located where the Public Right of Way extends into a private yard without a sidewalk, **2 =** Planting Strip – Where a tree is located in a strip of unpaved ground between the roadway and sidewalk, **3 =** Side walk or hard-scape cutout – Where a tree is located in a cutout opening in a continuous stretch of concrete, occasionally surrounded by a grate, **4 =** Street median – Where a tree is located in a grassy area dividing a roadway, **5 =** Other maintained locations, **6 =** Other un-maintained locations, **7 =** Backyard – Where a tree is located along the rear of a property, such as an alleyway.

Location codes are used by STRATUM in the estimation of energy benefits by assuming an average distance between a tree in each type of location to a building associated with that property.

Maint_Rec:

Maintenance recommendation is a numeric code to describe the recommended maintenance for the tree. Definitions are as follows: **1** = **None** – Tree does not need immediate or routine maintenance, **2** = **Small tree (routine)** – Tree is in need of maintenance and of a size that a maintenance task may be performed from the ground; health or longevity of tree is not compromised by deferring maintenance for up to five years, **3** = **Small tree (immediate)** – Tree is in need of maintenance and of a size that a maintenance task may be performed from the ground; deferring maintenance beyond one year would compromise health or longevity of tree, **4** = **Large tree (routine)** – Tree is in need of maintenance and of a size that a maintenance task requires the use of large equipment such as a cherry picker; health or longevity of tree is not compromised by deferring maintenance for up to five years, **5** = **Large tree (immediate)** – Tree is in need of maintenance and of a size that a maintenance task requires the use of large equipment such as a cherry picker; deferring maintenance beyond one year would compromise health or longevity of tree, **6** = **Critical concern (public safety)** – Tree should be inspected without delay.

Maint_Task:

Maintenance Task uses a numeric code that describes the highest priority task to perform on the tree. Definitions 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 = Plant** – Empty tree space should be planted with a new tree.

SidewalkDamage

Sidewalk damage is rated as being either none, low, medium, or high. Definitions from the i-Tree users Manual 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.

WireConflict

A numeric code to describe utility lines that interfere with or are present above a tree. Definitions 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, and crown is not likely to intersect utility lines in the next 3 years, **3** = **Present and conflicting** –

Utility lines occur and currently intersect with tree crown or will likely intersect within the next 3 years.

<u>ConditionWood / ConditionLeaves</u>

Each tree assigned to a category –Good, Fair, Poor or Dead. While there is some debate about the importance of collecting separate information about the condition of the wood of a tree and the condition of its leaves, we have chosen to rate the overall tree condition. This is partially due to the fact that much of the data was collected during the winter when leaf condition was not observable. In keeping with the i-Tree Users Manual, both fields will be rated the same for the single measurement when measuring overall tree condition. Definitions are as follows: **4 = Good (G) -** Full canopy, Minimal to no mechanical damage to trunk, No dieback of branches over 2" diameter, No suckering (root or water sprouts), Form is characteristic of species. **3 = Fair (F) -** Thinning canopy, New growth medium to low amount, or stunted, Significant mechanical damage to trunk, new or old, Insect/disease that is affecting tree, Form not representative of species, Premature fall coloring on foliage, Needs train pruning. **2 = Poor (P) -** Tree is declining, Visible dead branches over 2" diameter in canopy, Significant dieback of other branches, Severe mechanical damage to trunk, usually including decay from damage, New foliage small, stunted, or minimal amount, Needs priority pruning. **1 = Dead (D) -** No signs of life with new foliage, Bark may be beginning to peel, Default value for empty planting sites.

<u>Other 1</u>

In the Other 1 field, we have chosen to collect data on the "Lawn Width" for a planting site. i-Tree limits the number of categories of data for each field to ten, thus categories 1-9 correspond to lawn widths of 2-10 ft respectively and category 10 corresponds to a lawn that is greater than 10 ft wide; i.e. 1 = 2', 2 = 3', 3 = 4', 4 = 5', 5 = 6', 6 = 7', 7 = 8', 8 = 9', 9 = 10', and 10 = >10'

<u>Other 2</u>

Other 2 is used to identify "Tree Location", on what side of a property each tree is located, with respect to the side that corresponds to the street address of the property. Options are: **1 = Front, 2 = Right Side, 3 = Left Side, 4 = Rear.**

<u>Other 3</u>

Other 3 is used for "Location Order", to distinguish each tree or planting site from others on the same side of the property. Numbering begins at 1 on each property and increases in the direction of increasing address numbers.

<u>StreetName</u>

The name of the street of the property that a tree is associated with is on.

<u>StreetNumber</u>

The address number of the property a tree is associated with.

<u>SurveyorID</u>

The name of the surveyor taking the data.

<u>SurveyDate</u>

The date the data was collected.

Data Transformations to STRATUM format.

Data collection for the 2007 inventory began before consulting the protocols of the i-Tree program suite and the manner in which data was collected prior to 3/07 utilized the methods and definitions of previous Bloomington Street Tree Inventories. Thus some manipulation of the data was needed to conform to the STRATUM format. Three data fields are subject to these changes.

Maintenance

First the Maintenance Recommendation and the Maintenance Task fields give a finer level of detail than the previous method of recording maintenance needs did. Previously the options available included Routine Small and Routine Large for trees that did not pose any hazard and were in good health. There was no option for trees that did not require any maintenance. Three levels of Priority Pruning were available with level 3 as the lowest priority and 1 as the highest priority. Levels were based on the relative level of threat each tree posed, based on size of the tree and diameter of dead branches. A category of Train would be applied to young trees that needed training supports or pruning. Lastly trees could be slated for Removal.

Since there was no other way to define trees that did not require maintenance, the Routine Small and Large categories were the default value for these trees, while Priority ratings were given to trees that did require some sort of attention. Thus all trees rated as Routine Small and Large will be given the category of None for both the Maintenance Recommendation and Task.

Trees that were given a Priority rating previously will be given either the Young or Mature Tree Immediate rating with young trees defined as those whose maintenance needs could be accomplished by personnel on the ground. The vast majority of these priority rankings were based on dead branches in the crown, and a Maintenance Task of Clean will be given to those records unless a more appropriate task can be discerned from the field notes.

Trees that required training will be given a Young Tree Immediate Recommendation and Stake/Train as the task.

Trees coded for removal will be given either a Mature Tree Immediate or Critical Concern based on whether the reason for removal was due to being an undesirable species or a safety threat respectively. The task will remain Removal.

Utility Wire

Previous inventories only coded for the presence or absence of utility wires. With the new classification scheme we can differentiate between wires that are conflicting with a tree that may need to be pruned and wires that are present and might potentially conflict with a tree in the future. Since all we know for each of these entries is whether or not a wire is present, all wires will be classified as present but not conflicting. This represents the same level of information as was available in the old system, but avoids calling for pruning on trees that may not need it.

New Fields

New Fields such as Land Use, Location Code, and Sidewalk Damage will be given zero values as there is no record of any kind for those fields. These fields will be updated in future iterations of the inventory.

Appendix B. Population Summary for the 2007 Bloomington Street Tree Inventory.

Species	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
Red maple *Acer rubrum*	453	314	832	186	81	81	70	28	6	2051
Flowering pear *Pyrus species*	101	136	598	390	15	1	1	0	0	1242
Sugar maple Acer saccharum	42	66	311	174	159	157	73	17	4	1003
Pin oak Quercus *palustris*	145	130	181	253	65	33	22	4	1	832
Silver maple Acer *saccharinum*	45	15	55	101	110	151	119	85	61	742
Crabapple Malus species	47	70	378	66	4	1	0	0	0	566
Green ash *Fraxinus pennsylvanica*	36	85	206	142	30	5	4	0	4	512
Sweetgum *Liquidambar styraciflua*	67	49	128	104	40	11	1	0	0	400
White ash *Fraxinus americana*	75	70	175	28	4	4	7	2	3	368
Eastern redbud *Cercis canadensis*	49	66	163	32	2	0	0	0	0	312
Northern red oak *Quercus rubra*	57	87	107	14	4	0	1	1	0	271
Flowering Dogwood *Cornus florida*	36	64	145	7	1	0	0	0	0	253
Ginkgo *Ginkgo biloba*	73	54	105	4	3	1	0	0	0	240
Littleleaf linden *Tilia cordata*	12	35	145	36	7	0	1	0	0	226
Basswood species *Tilia species*	26	10	76	81	18	12	1	0	0	224
Eastern white pine *Pinus strobus*	4	2	75	82	21	3	3	0	0	190
Norway maple *Acer platanoides*	44	24	59	25	7	3	0	0	1	163
Tulip tree *Liriodendron tulipifer*	5	6	23	38	49	19	11	5	2	158
Pine species *Pinus species*	8	6	54	36	21	9	4	1	0	139
Spruce species *Picea species*	7	15	62	35	2	0	0	0	0	121
White oak *Quercus alba*	97	4	7	6	1	0	0	0	2	117
Honeylocust *Gleditsia triacanthos*	1	20	40	30	8	9	2	0	0	110
Black walnut *Juglans nigra*	3	1	17	20	24	20	7	2	0	94
Eastern red cedar *Juniperus virginiana*	2	7	56	18	4	1	0	0	0	88
Northern hackberry *Celtis occidentalis*	2	1	13	14	25	12	4	9	4	84
Hawthorn *Crataegus species*	8	31	40	1	1	0	0	0	0	81
American Elm *Ulmus americana*	25	9	25	8	4	1	3	4	1	80
Blue spruce *Picea pungens*	27	4	23	18	2	1	0	0	0	75
Japanese Zelkova *Zelkova serrata*	9	16	43	6	0	0	0	0	0	74
Arborvitae *Thuja species*	6	39	22	1	1	0	0	0	0	69
Elm species *Ulmus species*	7	0	21	18	8	6	3	1	3	67
Oak species *Quercus species*	27	7	16	5	8	2	0	0	0	65
Eastern hemlock *Tsuga canadensis*	7	21	17	9	4	0	0	0	0	58
Ash species *Fraxinus species*	3	3	11	22	11	2	3	1	1	57

Species	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
American sycamore *Platanus occidentalis*	0	0	3	14	11	13	4	6	5	56
Fir species *Abies species*	0	5	38	8	3	2	0	0	0	56
Black spruce *Picea mariana*	15	4	17	17	2	0	0	0	0	55
Black cherry *Prunus serotina*	3	1	13	25	5	3	3	0	1	54
Norway spruce *Picea abies*	1	3	16	17	8	2	2	0	0	49
Apple *Malus species*	1	4	22	9	3	0	0	0	0	39
Siberian elm *Ulmus pumila*	1	0	5	14	8	5	2	1	1	37
White mulberry Morus alba	4	1	17	8	4	3	0	0	0	37
Maple species *Acer species*	0	5	17	8	2	0	0	1	0	33
Plum *Prunus species*	2	5	13	6	5	1	1	0	0	33
Boxelder *Acer negundo*	0	0	6	10	6	7	2	0	0	31
American basswood *Tilia americana*	4	8	9	5	1	0	1	2	0	30
River birch *Betula nigra*	2	3	12	12	0	0	0	0	0	29
Black locust *Robinia pseudoacacia*	1	2	10	6	6	1	0	1	0	27
Chinkapin oak *Quercus muehlenbergii*	0	0	19	1	1	1	0	0	0	22
Mulberry species *Morus species*	0	1	6	7	2	5	1	0	0	22
Southern Magnolia *Magnolia grandiflora*	0	11	5	4	1	0	0	0	0	21
Japanese maple *Acer palmatum*	6	4	9	1	0	0	0	0	0	20
Scotch pine *Pinus sylvestris*	0	0	9	11	0	0	0	0	0	20
Birch species *Betula*	3	5	5	2	0	1	0	0	0	16
Serviceberry *Amelanchier arborea*	0	7	8	1	0	0	0	0	0	16
Shagbark hickory *Carya ovata*	0	0	6	5	1	1	0	1	0	14
Scarlet oak *Quercus coccinea*	3	7	4	0	0	0	0	0	0	14
English oak *Quercus robur*	0	0	11	2	0	0	0	0	0	13
Willow species *Salix*	1	2	3	3	1	2	0	0	0	12
Red pine *Pinus resinosa*	1	1	5	3	1	1	0	0	0	12
Kentucky coffeetree *Gymnocladus dioicus*	5	1	5	0	0	0	0	0	0	11
European hornbeam *Carpinus betulus*	3	1	4	3	0	0	0	0	0	11
Swamp white oak *Quercus bicolor*	2	1	8	0	0	0	0	0	0	11
Catalpa species *Catalpa species*	0	2	0	6	2	0	0	0	0	10
Tree of Heaven *Ailanthus altissima*	0	0	0	2	1	1	2	3	0	9
Cottonwood *Populus deltoides*	0	1	0	6	0	0	1	1	0	9
Sweetbay *Magnolia virginiana*	1	2	3	2	0	1	0	0	0	9
Beech species *Fagus species*	1	0	0	3	1	3	0	0	0	8
Sawtooth oak *Quercus acutissima*	3	0	5	0	0	0	0	0	0	8
Kwanzan cherry *Quercus*	2	1	3	2	0	0	0	0	0	8

Species	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
acutissima										
Hickory species *Carya species*	0	0	1	2	3	0	0	0	0	6
Paper birch *Betula papyrifera*	0	2	2	1	0	0	0	0	0	5
American Beech *Fagus grandifolia*	0	0	0	1	3	1	0	0	0	5
Persimmon *Diospyros virginiana*	0	0	1	4	0	0	0	0	0	5
Cherry plum *Prunus cerasifera*	2	0	3	0	0	0	0	0	0	5
Blackgum *Nyssa sylvatica*	0	0	1	2	1	0	0	0	0	4
Chinese chestnut *Castanea mollissima*	0	0	1	1	0	1	1	0	0	4
Eastern hophornbeam *Carpinus caroliniana*	0	0	2	2	0	0	0	0	0	4
European Beech *Fagus sylvatica*	0	0	2	1	0	0	0	0	0	3
Dawn Redwood *Metasequoia glyptostroboides*	0	0	0	1	0	2	0	0	0	3
Willow oak *Quercus phellos*	1	0	0	2	0	0	0	0	0	3
Mimosa *Albizia julibrissin*	2	1	0	0	0	0	0	0	0	3
Goldenrain Tree *Koelreuteria paniculata*	0	0	2	1	0	0	0	0	0	3
Holly *Ilex opaca*	0	1	2	0	0	0	0	0	0	3
Austrian pine *Pinus nigra*	0	1	2	0	0	0	0	0	0	3
Shumard oak *Quercus schumardii*	0	2	0	0	0	0	0	0	0	2
American hornbeam *Carpinus caroliniana*	2	0	0	0	0	0	0	0	0	2
Osage Orange *Maclura pomifera*	0	0	0	1	0	1	0	0	0	2
Bitternut hickory *Carya cordiformis*	0	0	1	0	0	0	0	0	0	1
Mockernut hickory *Carya tomentosa*	0	0	0	1	0	0	0	0	0	1
Black poplar Populus nigra	0	1	0	0	0	0	0	0	0	1
Swamp Chestnut oak *Quercus michauxii*	0	0	0	0	1	0	0	0	0	1
Baldcypress *Taxodium distichum*	0	0	0	0	0	1	0	0	0	1
Amur corktree *Phellodendron amurense*	0	0	0	0	0	1	0	0	0	1
Sassafras *Sassafras albidum*	0	0	1	0	0	0	0	0	0	1
Autumn Olive *Elaeagnus umbellata*	0	0	1	0	0	0	0	0	0	1
Witch Hazel *Hamamelis species*	0	0	1	0	0	0	0	0	0	1
Japanese lilac tree *Syringa reticulata*	0	0	1	0	0	0	0	0	0	1
Unknown species	19	5	16	5	1	0	1	0	0	47
Other Small Conifer	4	10	2	0	0	0	0	0	0	16
Other small broad	8	4	0	0	0	0	0	0	0	12
Other large Broad	1	0	0	2	0	0	0	1	0	5
Other medium broad	0	0	3	1	0	0	0	0	0	4
Other medium Conifer	0	3	5	3	1	0	0	0	0	12
Other large Conifer	0	0	1	0	0	0	0	0	0	1
Other pine species	0	0	0	1	0	0	0	0	0	1
Grand Total	1661	1575	4597	2266	827	605	361	177	100	12169

Appendix C. Top Five Species Diameter (DBH) Class Distributions

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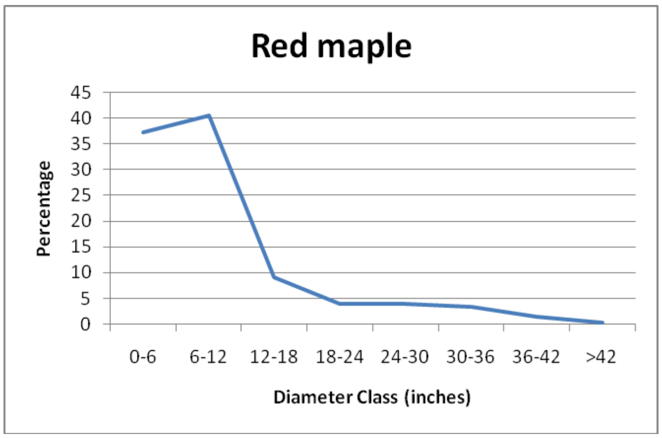

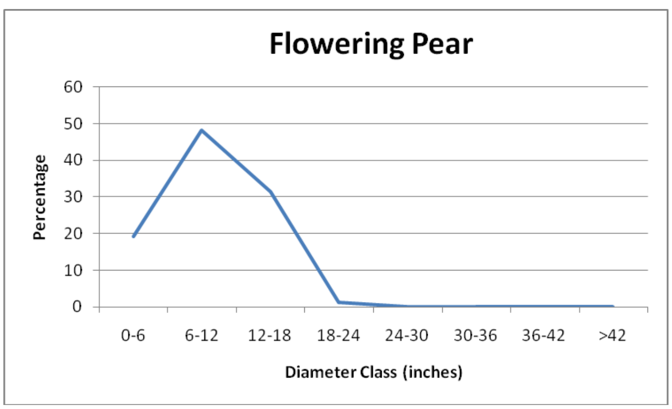

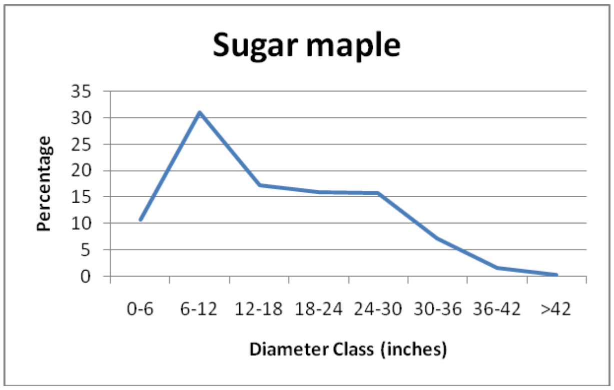
Sugar maple
Percentage
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30
25
20
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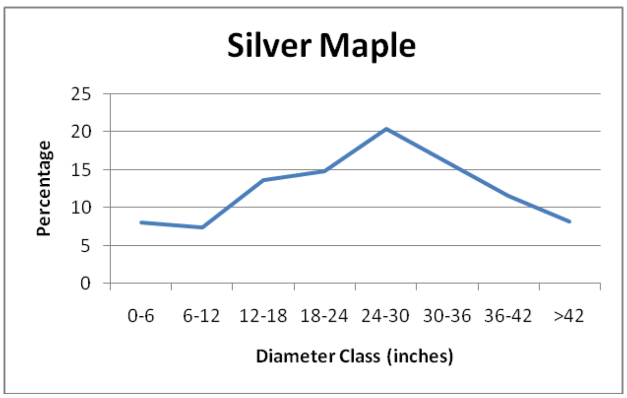
0-6
6-12
12-18
18-24
24-30
30-36
36-42
>42
Diameter Class (inches)


Silver Maple
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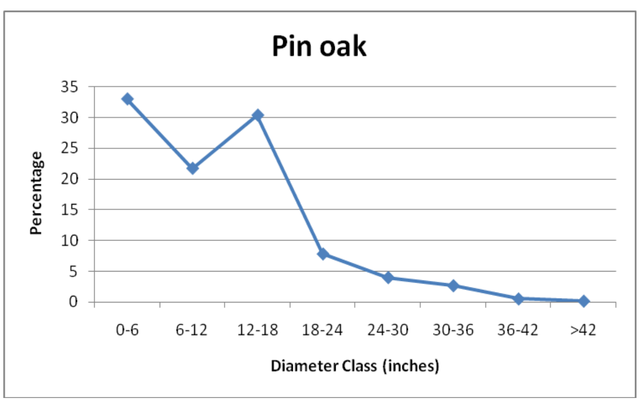
18-24
24-30
30-36
36-42
>42
Diameter Class (inches)


Pin oak
Percentage
35
30
25
20
15
10
5
0
0-6
6-12
12-18
18-24
24-30
30-36
36-42
>42
Diameter Class (inches)