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Assessing Ecosystem Service Values Provided by Urban Trees

Burncoat and Greendale Worcester, Massachusetts

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ABSTRACT

Ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life. Ecosystems provide society with services that stretch far beyond just raw materials. Ecological economists assign monetary values to these services in order to estimate the economic value of an ecosystem. A study of the Burncoat and Greendale areas of Worcester, highlights the importance of urban trees by accurately assessing ecosystem services for the past, present, and future.

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Introduction

In 1997, an ecological economist, Robert Costanza, estimated the total value of the earth's ecosystem services at $33 trillion dollars a year. At that time, this number was equivalent to more than twice the Gross National Product (GNP) of every country in the world (Costanza, 1997). If this sounds revolutionary, it is because it is.

Until recent years, economists and ecologists were generally known to support conflicting ideologies when it came to the ecosystem. Economists were thought to promote any ideal that could catalyze economic growth, and that ecosystems were only a source of raw materials through which goods and services could be provided for capitalism. Ecologists, however, believed that the ecosystem helps to sustain economic growth by providing ecosystem services. "In recent years, a merging ideology of these two conflicting ideals has created a hybrid concept, known as the "ecological economist" ("Costing the Earth", 1998, p.426).

Ecosystems provide society with services that stretch far beyond just raw materials. Dailey (1997) defines ecosystem services as the "conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life (p. 3). Examples of ecosystem services include: air filtration, climate regulation, waste treatment, aesthetics, and recreational expenses (see Table 1). Ecological economists assign monetary values to these services in order to estimate the economic value of an ecosystem.

In summary, Ecosystem services are any service that the ecosystem is providing to society that would otherwise need replacing. One perfect example of this is wetlands and wastewater treatment plants. Wetlands provide the storage, retention, and filtration of water sources. Without wetlands, wastewater treatment plants need to be built to compensate.

After the Asian Longhorned Beetle (ALB), an invasive species of insect, infested the Burncoat and Greendale areas of Worcester, Massachusetts, thousands of trees were removed. After the removals began, people began to suddenly realize the value of their urban trees, both aesthetic and otherwise. Several residents discussed the value of trees in connection with neighborhood beauty, and how trees gave their neighborhood a 'country feel' in the city. They also said how the loss of trees has transformed their neighborhood image into an 'industrial park' (Schroeder, 1989).

This study examines Burncoat and Greendale to assess the value of urban trees in another way – in terms of ecosystem services. We sought to measure these services and provide our analysis in plain language so that a variety of stakeholders could understand the results. For example, community members and policy makers need to be made aware of how crucial it is that this situation is dealt with. People need to be made aware of the importance of urban trees in their community and, in conjunction; educated decisions need to be made with regard to tree re-plantings in the future.[1]

Table 1: Ecosystem Services of Concern

Ecosystem Service	Value Provided
Air Filtration	Reduction in: Carbon Monoxide, Particulate Matter, Nitrogen Dioxide, Sulfur Dioxide, Volatile Organic Compounds
Climate Regulation	Reduction in Electricity and Natural Gas Use
Waste Treatment	Reduction in Waste Water
Aesthetics	Increase in Median Home Resale Value
Recreational Expenses	Decrease in Municipal Budget

This study complements previous work on urban tree cover in Worcester. For example in 2005 and 2006, researchers from the United States Department of Agriculture (USDA) and the University of Massachusetts-Amherst developed an inventory and website called "TreeKeeper". This inventory was taken before the trees were removed starting in December of 2008. Last fall, researchers from WPI, UMass Amherst, and the Department of Conservation and Recreation (DCR) evaluated the publics' perception of urban trees in Burncoat and Greendale. This study sought to capture public perspectives about the tree removals and if/how they were off setting the value of trees through other means (e.g. blinds, air conditioners, etc…).

Our project takes a longitudinal approach to evaluate ecosystem services in the ALB-affected area by extending the work of the USDA and DCR to focus on all trees, rather than just street trees. We measured values before the trees were removed, assessed the diminished values after the trees were removed, and, finally, projected into the future values that the trees provide for the neighborhood. The information gained from this study has a far-reaching set of effects, extending to the community organizations, city, state, and federal governments, as well as schools and individual landowners. Our study complements previous studies in that it measures the actually monetary value of these trees. Subsequently, these two studies can be synthesized to understand the perception of tree value versus their real ecosystem service value. Moreover, these studies can be used to inform policy makers and the public about the value of urban trees, and ways of optimizing that value through educational outreach programs. Our study can help community members understand ecosystem services and the benefits associated with urban trees.

[1] There are certain ecosystem service benefits that can be represented in monetary value and others that pertain to the community's well being. This study looks at the monetary benefits organized in Table 1.

To appropriately assess the changes in ecosystem services in the Burncort and Greendale area, this study employed three sections of analysis. The first section described was created from past data. The past value assessed includes the ecosystem services provided by the trees before they were removed. By analyzing the past value, members of the community will be able see the substantial economic effect that the beetles have caused to Burncoat and Greendale. The second section mentioned was for the current ecosystem services. This simply included all of the value that the trees still remaining provide. The final section was for the future of Burncoat and Greendale. Since the federal and state government had already started to replant trees, a longitudinal analysis of the ecosystem services provided over time had to be performed. We now turn to the background chapter of our report.

Background

The goal of this project was to accurately assess the value of ecosystem services provided by the trees for the past, present, and future in Burncoat and Greendale. Although there have been several ecosystem service projects completed in Worcester, none are quite like this. Our project took a longitudinal approach to evaluate ecosystem services in the ALB-affected area by extending the work of the USDA and DCR to focus on all trees, rather than just street trees. We measured values before the trees were removed, assessed the diminished values after the trees were removed, and, finally, projected into the future values that the trees will provide for the neighborhood. Map 1 and Map 2 consist of two aerial photographs representing this study’s area of concern. Each photograph contains a zoomed in portion representing the same region. Both of these regions were highlighted in yellow. The top image is showing a before aerial photograph of Burncoat and Greendale taken in April of 2005, while the bottom image is showing an after photograph of the same region in April of 2009. One can clearly see the significant difference in canopy cover and the amount of trees present from one photograph to the next.

Map 1: Aerial Photograph of Study Area: April of 2005

Map 2: Aerial Photograph of Study Area: April of 2009

An ecosystem services evaluation has many benefits for both the government and the community. Because of the ALB infestation, according to the USDA, there have been over 25,000 trees removed since December of 2008. In an effort to rectify this problem, the local, state, and federal governments have dedicated funds to remove and replace the trees with new, non-host trees. The findings from this study could present a positive opportunity for the City of Worcester and non-profit organizations, such as the Worcester Tree Initiative (WTI), to replant the trees more effectively to maximize ecosystem service output. For example, if the results of this study show a trend that trees being replanted a certain amount of feet away from a building are having the most economic benefit, then organizations like the WTI and the DCR will be able to plan their re-plantings accordingly.

There are other benefits, too. With an economic value of the past, present, and future ecosystem services as benchmarks, different groups can "… justify their decisions, not only in terms of benefits to the natural environment, but also in terms of fiscal accountability and public support" (King & Mazzotta, 2000). Thus if the value of the services are calculated accurately, partners in the replanting effort could help property owners understand the past and current value of the ecosystem. This research could thus contribute to developing appropriate educational outreach materials to empower people to make these decisions. For example, if this report shows substantial evidence of money lost annually, people will begin to recognize the necessity of the replanting effort. This information could then be used to figure out if the future values, after the replanted trees have grown, will be sufficient to get Burncoat and Greendale back to 'ground zero'.

In the next section, we will discuss the tools and approaches for assessing ecosystem service values. There are several useful programs based on different algorithms to calculate the ecosystem service values provided in a given region. Which of them would be the most beneficial to this study was the important question at hand.

Tools for Assessing the Value of Urban Trees

Several programs exist that analyze and assess the value of urban trees. After conducting general research and looking at industrial standards for ecosystem services, it became necessary to narrow it down to three professional strength programs. Two of the programs were specific branches of one main domain program called i-Tree. I-Tree is split into several narrower programs, but those of highest interest to this study were i-Tree Eco and i-Tree Streets. The i-Tree suite is maintained by the USDA Forest Service in cooperation with other public and private entities. The other program suite called to for comparison is called CITYgreen. CITYgreen was designed by a private group called American Forests.

Overview of i-Tree Suite

The program suite that is in the public domain and offers robust features is called i-Tree. I-Tree is a state-of-the-art, peer-reviewed software suite from the USDA Forest Service that provides urban forestry analysis and benefit assessment tools (I-Tree, 2009). The i-Tree program was released in August of 2006 by the USDA Forest Service. The newest version of i-Tree offers the following urban forest assessment applications: i-Tree Eco, based on UFORE, and i-Tree Streets, previously known as STRATUM. I-Tree Eco provides a broad picture of the entire urban forest. It was designed to use field data along with local hourly air pollution and meteorological data to quantify urban forest structure, environmental effects, and value to communities. On the other hand, i-Tree Streets focuses on the benefits provided by a municipality's street trees. It is a street tree management and analysis tool for urban forest management that uses tree inventory data to quantify the dollar value of annual environmental and aesthetic benefits. These benefits include energy conservation, air quality improvement, CO2 reduction, storm water interception, and property value increase. It makes use of a sample or complete inventory to quantify and put a dollar value on the street trees' annual environmental and aesthetic benefits (I-Tree, 2009).

i-Tree Eco

I-Tree Eco is one of the modules included in the i-Tree suite. It is not a small utility program but rather an in-depth program to estimate ecosystem services. i-Tree Eco is based on the UFORE model, which stands for urban forest effects. I-Tree Eco is a tool that allows users to input data on the entire urban forest and estimate the ecosystem services that the resource provides to the community.

<u>I-Tree Eco has four major components:</u>

- Statistically based sampling and data collection protocols allow for estimation of totals and variation related to urban forest structure and population effects.
- An efficient way to enter in data by an application based on a PDA.
- "A central computing engine that makes scientifically sound estimates of the effects of urban forests based on peer-reviewed scientific equations to predict environmental and economic benefits. (i-Tree Eco, 2009)"
- "Summary reports that include charts, tables, written report, and mapping tool that allows you to display several basic urban forest data without having access to GIS software and skills. (i-Tree Eco, 2009)"

The i-Tree Eco program has two methods of entering in data, one is to do so manually and the other is to use their PDA program to automatically upload information. Once there is data for the program to analyze, they are merged with local hourly weather and air pollution concentration data (i-Tree Eco, 2009). This data makes it possible to calculate structural and functional information using a series of scientific equations and algorithms built into the program (Nowak, 2003). The i-Tree Eco program is designed to provide accurate estimates of the following (i-Tree Eco, 2009)":

- Urban forest structure (e.g., species composition, number of trees, tree density, tree health, etc.), analyzed by land-use type.
- Hourly amount of pollution removed by the urban forest, and associated percent air quality improvement throughout a year. Pollution removal is calculated for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide and particulate matter.
- Hourly urban forest volatile organic compound emissions and the relative impact of tree species on net ozone and carbon monoxide formation throughout the year.
- Total carbon stored and net carbon annually sequestered by the urban forest.
- Effects of trees on building energy use and consequent effects on carbon dioxide emissions from power plants.
- Compensatory value of the forest, as well as the value of air pollution removal and carbon storage and sequestration.
- Tree pollen allergenicity index.

i-Tree Eco provides one of the most in depth reports for ecosystem services. The report generated is very technical, detailed, and extensive. This report would be very useful when conducting an evaluation of ecosystem services for a research or scientific company. The complicated results on the report provided by i-Tree Eco would be difficult to represent to the community. This is because the report shows the services of the trees instead of the values associated with those services.

i-Tree Streets

The second major program of i-Tree is an adaptation from the STRATUM model called i-Tree Streets. I-Tree Streets STRATUM, which stands for Street Tree Management Tool, is a tool for inventory and analysis concerning tree management and street tree issues. Streets can use existing or newly sampled information to show a makeup of the street tree population for the given information. Streets can also analyze environmental benefits and contrast them with maintenance costs pertaining to the trees. (Federal Labs, 2009)

I-Tree Streets uses tree growth and benefit models for predominant urban tree species in 16 national climate zones. Users import data collected in a sample or complete inventory and enter community specific information like program management costs, city population, and price of residential electricity. I-Tree Streets uses this data to customize a benefit-cost analysis (i-Tree Streets, 2009).

i-Tree Streets uses this information to calculate the following:

- Structure (species composition, extent and diversity)
- Function (the environmental & aesthetic benefits trees afford the community)
- Value (the annual monetary value of the benefits provided and costs accrued)
- Management needs (evaluations of diversity, canopy cover, planting, pruning, and removal needs). Reports consist of "…graphs, charts, and tables that managers can use to justify funding, create program enthusiasm and investment, and promote sound decision-making. With Streets, users can answer the most important question related to their tree program: Do the accrued benefits of street trees outweigh their management costs? (i-Tree Streets, 2009)"

i-Tree Streets provides an easily understandable report of ecosystem services. The report provided by this program was designed so that it may be understood by everybody. This report is useful when being presented to a group of people who may not know much about ecosystem services. The report takes the calculated ecosystem service values and an input of local resource costs, and will provide a cost-benefit analysis in dollar value. This type of report tends to catch more attention from the people who may not have much background regarding ecosystem services.

CITYgreen

CITYgreen was created by American Forests, a nonprofit organization concerned with trees and urban forestry. CITYgreen is software designed to make it easy to quantify benefits provided by tree canopy cover. Using programmed formulas, it can calculate tree benefits from data stored in a GIS layer (Geographic Information System) (i-Tree Streets, 2009; International Society of Agriculture, 2001).

CITYgreen can provide an analysis of the ecological benefits of tree cover based on land cover data provided by the user. The source of the data can be obtained in several different ways, including satellite imagery or aerial photography. In order for it to work the image needs to be in color with a resolution of 4 meters or better so that all of the cover features of each tree can be identified. This information "…needs to be classified into different cover features, such as tree canopy, open space, impervious surfaces, water, etc., before the software can analyze the information. (CITYgreen, 2009)"

Some downsides to CITYgreen are that it is not an image-processing application (CITYgreen, 2009). It has issues after digitizing an image. It works by superimposing green circles over trees and some error is often introduced. This is because the image of the tree canopy may be obscured by the circles drawn. If the circles overlap the edge of the area being analyzed, then they will not be counted by CITYgreen. This becomes more of a problem when a large numbers of trees are along the edge of the study area. CITYgreen also does not calculate the area present in each of the land cover classes. It requires the user to collect and enter field inventory information to do these calculations (i-Tree Streets, 2009; International Society of Agriculture, 2001). CITYgreen only works with Windows-based computers that have ArcGIS installed. It is not a stand-alone software package or a tree inventory software application (CITYgreen, 2009).

The Programs in Practice: Case Studies from the Field

Conceptually, each of these programs has their own benefits and constraints. In order to understand what these programs are all about, examples of each used in the real world needed to be taken into consideration. Rather than simply discussing the elements of each program, this section looks at how each of the programs were used in past studies while providing feedback about how the results were obtained and utilized.

i-Tree Eco: Case Studies

I-Tree Eco was used in many different places, including: Atlanta, Baltimore, Brooklyn, Calgary, Jersey City, New York City, Philadelphia, Syracuse, and Toronto. In these places, i-Tree Eco was used to analyze the entire area within city limits. American Forests conducted a Regional Ecosystem Analysis of all these cities to determine how the landscape has changed over time and to calculate the impact of the changes in community management costs.

One of the major partners and users of the i-Tree programs, Davey Resource Group, set out to help different cities collect data and use i-Tree to analyze their urban forestry. In one study, they used i-Tree Eco to show the value of ecosystem services to different cities:

> "In 2007, Davey used existing street and public property tree inventories and i-Tree Eco to characterize the public urban forest and quantify ecosystem services within the cities of Bellevue, Covington, Florence, Fort Thomas, and Newport in Boone, Campbell, and Kenton Counties in Northern Kentucky. i-Tree Eco was used to perform the following analyses: urban forest

structure; pollution removal and associated percent of annual air quality improvement and economic value; total carbon stored and net carbon annually sequestered by the urban forest and current economic value; compensatory, or appraised, value of the public urban forest; threat level of exotic insect pests to the urban forest; and future projections of benefits if the urban forest population was increased by 5%, 10%, and 15%." (Davey Resource Group 2009)

Davey Resource Group used i-Tree Eco to broadly analyze all of the urban forestry in these cities. This is similar to our study in that they also used the suite to come up with future projections based on population increase; however, they focused much of their efforts on non-monetarily measurable ecosystem service values.

i-Tree Streets: Case Studies

The key use of i-Tree Streets is to get an urban forest benefits model on a street tree inventory. Many public and private organizations have used this software to help understand the costs of streets tree management as an investment. The benefits street trees provide are the return on the management dollar.

One of these examples had taken place in Pittsburgh, Pennsylvania, where the Davey Resource Group and the non-profit Friends of the Pittsburgh Urban Forest decided to apply i-Tree Streets to the City's street tree inventory. Since Friends of the Pittsburgh Urban Forest played a prominent role in the maintenance, planning, and budgeting of the City of Pittsburgh's urban forestry program, they already had the data to apply this model. Davey's senior urban forester used the model to complete a comprehensive Municipal Forest Resource Analysis Report. The report quantifies "the benefits Pittsburgh's street trees provide the City and expresses those benefits in dollar value. This effort resulted in the City having state-of-the-art structural and cost-benefit information about the City's urban forest" (Davey Resource Group 2009).

The City of Chattanooga has the benefit of a well-established and proactive urban forest management program. The City decided to apply the urban forest benefits model, i-Tree Streets, "to a statistically significant sampling of its entire street tree forest to determine the costs of management and quantify the benefits urban forests provide the City." (Davey Resource Group 2009) In 2008, Davey's senior urban foresters used the model, generated the calculations, and completed a comprehensive Municipal Forest Resource Analysis Report.

When considering the condition of Worcester over the last few years, especially Burncoat and Greendale, providing the city with a state-of-the-art benefit analysis regarding its urban forest would be extremely useful. The results from i-Tree Streets can help raise the awareness to policy makers and community members of the importance of urban trees. It can also educate the community so that people can make informed decisions about tree re-plantings to optimize the resulting ecosystem service value provided.

CITYgreen: Case Studies

CITYgreen 3.0 software was tested by the International Society of Agriculture running under ArcView® GIS 3.2 to determine how it "might be used for evaluating progress toward urban forestry goals". They used it to calculate canopy cover of a given area using a digital photo taken from a satellite and created a schematic drawing of the project site. The tree canopy was digitized by superimposing green circles over the trees.

They used only the "single tree method" where just one circle is used for each individual tree. They had the option of digitizing groups of trees as a single polygon but they chose not to do this because "several of the analyses that CITYgreen provides cannot be run on groups of trees". Plus, the single tree method was faster anyway, and it directly produced a GIS layer that could be manipulated and analyzed. It gave each tree a unique identifier number by the program.

Although the method was fast and simple, they noted some disadvantages. A certain amount of error was introduced when superimposing circles over the trees, mostly because the image of the tree canopy was obscured by the circles drawn. If the canopy circles overlap the edge of the project area, CITYgreen does not count it. It was a problem if a large number of trees were along the perimeter of the project area. The user could not modify the sizes of the circles representing the trees through direct data entry. This was because the data for each tree in the database was calculated from the digitized image when the analysis functions were run.

With this method, the canopy cover for their image of one of their example project areas was approximately 17.38 percent. However, by using either image analysis or dot grid counts on the same image they found it to be about 21 percent. They said that the CITYgreen method of digitizing tree canopy is more likely to have error unless the canopies were very distinct and spread apart. The alternate method for digitizing tree canopies by CITYgreen requires drawing polygons around each canopy. Not only is this extremely slow, but CITYgreen treats polygon representations of canopies as a single tree, which can ultimately cause problems (International Society of Agriculture, 2001).

It is evident that CITYgreen would not provide the analysis of Burncoat and Greendale's urban forest that this study intended. While calculations regarding canopy cover can be helpful for many applications, the process is much too rigorous for the little relevant information it would provide. What would be beneficial to this study, however, is a canopy cover calculation of both Map 1 and Map 2, located in the background section of this report. Due to time constraints however, this canopy cover analysis will have to hold for future work.

Value Analysis

After researching and reviewing how each program was used in other studies and organizations in the past, it came time to decide which was best for our purposes. In order to ensure that the best choice was made, specific criteria were created and a comprehensive value analysis based on those criteria was performed. The results are organized below in Table 2.

Table 2: Breakdown of Comprehensive Value Analysis

Criteria (Weight 1-10)	i-Tree Streets (Rating 1-5)	i-Tree Eco (Rating 1-5)	CITYgreen (Rating 1-5)	Totals 1) Streets 2) Eco 3) CityGreen
Accuracy (10)	Peer-Reviewed (5)	Peer-Reviewed (5)	Aerial Photos can be analyzed inaccurately (4)	1) 10*5 = 50 2) 10*5 = 50 3) 10*4 = 40
Relevancy (9)	Business-like, Monetary Outputs (5)	Ecosystem Benefits, Less Monetary Output (3)	Can't be used unless using Aerial Photos or GIS data. (2)	1) 9*5 = 45 2) 9*3 = 27 3) 9 * 2 = 18
Credibility (8)	Professionally Used, Backed by USDA , Many Prior Case Studies (5)	Professionally Used, Backed by USDA, Many Prior Case Studies (5)	Professionally Used, Closed Source Model, Private Support (4)	1) 8*5 = 40 2) 8*5 = 40 3) 8 * 4 = 32
Ease of Use (5)	Very user friendly (5)	Very user friendly (5)	More difficult but have training sessions (4)	1) 5*5 = 25 2) 5*5 = 25 3) 5*4 = 20 **TOTAL:** **Streets: 160** Eco: 142 CITYgreen: 110

After a thorough value analysis was performed, a program that accurately assesses ecosystem service values needed to be chosen out of the three available options up for consideration. In order to ensure that the correct choice was made for this study's purposes, it needed to first be determined what criteria was most important. After much thought, the criteria was narrowed down to accuracy, ease of use, credibility, and relevancy.

After much research, accuracy and relevancy were the most important criteria for this study. The goals of this project were to accurately assess ecosystem service values and to inform the community about the importance of urban trees. Without accurate results, this would not be feasible. In order to inform the community about the importance of urban trees, this study needed to ensure that the results provided by the program were in terms that everyone could understand. To relate to the community and to political figures, the results output by the program needed to be a benefit analysis in monetary value.

The last two criteria, credibility and ease of use, were chosen to ensure that the program chosen was tailored to the project limitations and time constraints. This study needed to be performed in seven weeks; therefore, a program with less of a learning curve was needed. After looking at the different case studies, credibility became an evident factor in this value analysis. If the program used in this study was not credible, how could our results be trusted?

The programs that were compared and contrasted based on the criteria described above were i-Tree Eco (UFORE), i-Tree Streets (STRATUM), and CITYgreen. After careful analysis, CITYgreen seemed to be the first ruled out because it only works really well with substantial arcGIS data. Due to a seven-week time constraint, CITYgreen scored low in ease of use. I-Tree Eco also did not strike us as the best choice because it seemed to be a broader program that gives an overall view of ecosystem services, rather than concrete economic values. Without concrete economic values, it would be difficult to raise awareness to policy makers and community members about the importance of urban trees. As a result, i-Tree Eco scored poorly in relevancy. Through a thorough value analysis shown in Table 2, it had become evident that i-Tree Streets was the best program for the purposes of this study. I-Tree streets seemed business and economically oriented. This program could provide the necessary results to collaborate ecosystem service data into something that the community could relate too. The results needed to be an accurate, monetary value that could clearly describe the past, present, and future states of the ecosystem services provided in Burncoat and Greendale.

Methodology

In order to accomplish the goals previously described, a large spectrum of data needed to be collected from many credible sources. This chapter describes our data needs and the process by which that data was collected.

Data Required for i-Tree Streets

I-Tree Streets takes a wide variety of inputs in order to output an accurate and useful report. According to i-Tree Streets these inputs can be classified into three main sections including: inventory data, community data, and benefit data. Each one of these categories can be broken down further depending on how much data is available and how specific that data is. The more specific the input data is, the more accurate the results will be. The data required for i-Tree Streets has been organized and displayed in Table 3.

Table 3: Breakdown of Data Required for i-Tree Streets

Data	
Inventory	• Number of Street Trees • Genus of Tree (%) • Species of Tree (%) • Relative Age Distribution • Condition of Trees • Importance Value

Community	• Municipal Budget
	  ○ Annual Planting
	  ○ Annual Pruning
	  ○ Annual Tree and Stump Removal
	  ○ Annual Pest and Disease Control
	  ○ Annual Establishment/Irrigation
	  ○ Annual price of repair/mitigation of infrastructure damage
	  ○ Annual price of litter/storm clean up
	  ○ Average annual litigation and settlements due to tree-related claims
	  ○ Annual expenditure for program administration
	  ○ Annual expenditure for inspection/answer service requests
	  ○ Other annual expenditures
	• Population
	• Total land area
	• Average street width
	• Average sidewalk width
	• Total linear miles of street

Benefit	• Electricity Prices • Natural Gas Prices • Carbon Dioxide Reduction • Particulate Matter Reduction • Nitrogen Dioxide Reduction • Sulfur Dioxide Reduction • Volatile Organic Compounds Reduction • Storm Water Interception • Median Home Resale Value

Inventory Data Explained

Inventory data is the data associated with the trees. It consists of the number of trees, percentage of species, percentage of genus, relative age distribution, importance value, etc. (see Table 3) The inventory taken can be a complete inventory or a sample inventory. In a complete inventory, information about each tree in the area of interest is required. A sample inventory only requires the information on approximately 6% of the trees to accurately represent the entire population. For purposes of this study, a complete tree inventory was appropriate. The percentage of species is also crucial if i-Tree Streets is to provide a useful benefit analysis. How can one analyze a city's urban forest without knowing what type of tree was providing which ecosystem services? Also, the relative age distribution must accurately reflect the tree inventory, otherwise i-Tree Streets will output an inaccurate total ecosystem service value. I-Tree Streets must be able to estimate, within reason, the sizes of these species of tree with regard to their DBH (Diameter Breast Height) classes. The importance value is important as well and is calculated by i-Tree Streets, but the user first needs to input the leaf area and canopy cover of the trees to get accurate results.

Community Data Explained

Community data is all of the local resource data associated with the community. This data consists of the municipal budget, population, total land area, average street width, average sidewalk width, and total linear miles of streets. In order to get more accurate results, the municipal budget can be broken down and input into smaller sections. Some of these sections include annual planting, pruning, and tree/stump removal. The municipal budget can be broken down into the following: the cost of annual planting, annual pruning, annual tree and stump removal, annual pest and disease control, annual establishment/irrigation, annual price of repair/mitigation of infrastructure damage, annual price of litter/storm clean up, average annual litigation and settlements due to tree-related claims, annual expenditure for program administration, annual expenditure for inspection/answer service request, and all other annual expenditures. This way the program is better able to see exactly where money is being saved. For example, if the city of Worcester is spending $2,000 annually on urban tree maintenance, then i-Tree Streets needs to be able to subtract that from the total ecosystem services provided.

Benefit Data Explained

Benefit data is all of the local resource costs associated with benefits gained by urban trees. This data consists of electricity prices, natural gas prices, storm water interception, etc (see Table 3). This data set is to acquire output values of dollar amount saved and gasses reduced. The program has some pre-selected default values for the Northeast. These default values include carbon monoxide, particulate matter, nitrogen dioxide, sodium dioxide, and volatile organic compounds. The rest of the data depends heavily on the area of study; therefore, these values are not pre-selected by i-Tree Streets. These values include electricity prices, natural gas prices, storm water interception, and the median home resale value.

Data Collection Methods from Credible Sources

It is clear now that i-Tree Streets required many different types of input data before it was able to output an accurate and useful report. We also needed to ensure that all of the data collected was from credible sources; otherwise, the merit of this study would be compromised. To gather all of the necessary information for this project, many different data collection approaches and data resources were called upon. Some of the information is more confidential and harder to gain access to, while other data can be out of date because of the time commitment and labor required to gather it. Table 4 organizes all of the credible sources called upon for this study.

Table 4: Breakdown of Data Required for i-Tree Streets and Credible Sources

Data		Sources
Inventory	• Number of Street Trees • Genus of Tree (%) • Species of Tree (%) • Relative Age Distribution • Condition of Trees • Importance Value	**Past**: Worcester's TreeKeeper (Gained Access from the Urban Forestry of City of Worcester) **Current** - Comparing Removed Trees to the database of TreeKeeper (List from the DCR and Urban Forestry) **Removals and Re-plantings** – Projected removals and replanting for the Burncoat and Greendale area from (List from WTI, DCR, APHIS)
Community	• Municipal Budget	Budget Office Department of Public Works
	• Population	US Census 2000 http://factfinder.census.gov
	• Total land area • Average street width • Average sidewalk width • Total linear miles of street	MassGIS www.mass.gov/mgis/
Benefit	• Electricity Prices	National Grid
	• Natural Gas Prices	NStar
	• Carbon Dioxide Reduction • Particulate Matter Reduction • Nitrogen Dioxide Reduction • Sulfur Dioxide Reduction • Volatile Organic Compounds Reduction • Storm Water Interception	i-Tree Streets defaults for Northeast
	• Median Home Resale Value	Worcester's Assessor Office

Sources: Community Data

A majority of the community data was publically accessible. One problem with the state and the city's information was that there wasn't one unified source to gather the information from. The information was spread amongst several different departments and only certain people could gain access to the data required.

One important question regarding this project was, "What exactly defines a tree as a Street Tree?" This project is about the ecosystem services provided by those trees, so before moving forward and collecting data, the exact definition of a "street tree" needed to be determined. The Department of Public Works is the department that takes care of the trees in the city of Worcester; therefore, the administrative assistant was contacted. The information that was provided included a formal three-page document called "An Ordinance Relative to the Protection of Public Trees". This document applied to all of the trees in Worcester. When researching necessary data, these definitions were used to make sure that the correct information was being gathered. The most important passage of the document has been attached in the Appendix of this report.

This project focused on the ecosystem services provided by urban trees; therefore, it makes sense that i-Tree Streets asked for specific information found in the municipal budget. This information was gathered from The Department of Public Works, the city's budget department. In order to calculate a past, current, and future value from i-Tree Streets, separate budget information from several different years was required.

The budget information gathered from the city was very useful in calculating the values for the past, current, and future ecosystem services. The budget included all of the money needed by the city to take care of the trees themselves. Some information included the actual re-plantings, the clean up, and even the pruning of the trees. This included almost all of the budget information required by i-Tree Streets. The 2010 municipal budget included projected budgets for the next five years. That information was used to make an accurate estimate for the future ecosystem service values provided.

Sources: GIS Layers

GIS layers were an extremely important asset to this study and were collected from a variety of different sources. A civil engineering professor at WPI, Suzanne LePage, gave us access to the GIS layers in WPI's existing database. The second source was the MassGIS website where full GIS layers of the entire city were available to download for free. In order to substantiate the layers from these other two sources, additional layers were collected from the city of Worcester as well. The GIS Analyst at City Hall provided the most recent and accurate layers available.

In order to collect the proper data from these GIS layers a program called ArcView was needed. This program is expensive, so we needed to acquire access through the school's ArcView licenses. Arcview can take GIS layers and organize them in order to access the data required for i-Tree more readily. Using GIS, information such as street and sidewalk width were now able to be gathered and organized efficiently. One example of how this program was so helpful is that we were able to take the width of all of the sidewalks in Worcester and isolate only them. Once isolated, the data could then be transferred into a useful database program such as Excel or Access. This way it could be easily manipulated to gather the exact information required for i-Tree.

Sources: Inventory Data

The most important data collected was all of the tree inventory data. It was also the most time consuming to collect because of its poor accessibility. There were three different types of inventory data needed to fulfill the goals of this study. These three separate inventories included one for the past, present, and future. The past inventory consisted of all of the trees that were in the area before the beetle infestation occurred. The current inventory consisted of all of the trees not cut down or anticipated for removal. Lastly, the future inventory consisted of all of the trees re-planted or projected for re-planting.

The past inventory data was available without actually going out and surveying the trees in these areas. "`A report on the status of Street Trees in Worcester, Massachusetts", released on October 2008, provided a great deal of necessary information for our past model. This report used data from the Worcester's TreeKeeper website, which the city uses to archive and manage information related to its street trees. This inventory was collected by The Worcester Department of Public Works and Parks in 2005 and 2006. This inventory was taken before any of the trees were removed from the area. There was restricted access to the information on the TreeKeeper's website; therefore, we submitted a formal request to Brian Breveleri to gain access. Brian is the City Forester of Worcester. With read-only access to this website, we now had information about the street trees all over Worcester.

The present tree inventory was created using a list of tree removals provided by the DCR. Basically, the past tree inventory was taken and trimmed down to exclude all of the trees on that removal list. This was the only way to accurately represent the current amount of trees in Burncoat and Greendale without going and individually assessing the trees with field work.

Similar to the present tree inventory, the future inventory was created using a list of tree re-plantings provided by the WTI and DCR. All of the tree re-plantings were simply added onto the present tree inventory to accurately represent the future. Since the re-plantings are categorized by species, with a bit of tree research, we were able to project five, ten, and fifteen years into the future.

Key Findings

After all of the extensive research and data collection, it finally came time to get some results. I-Tree Streets output a comprehensive benefit analysis in terms of monetary value for the past, present, and future. Multiple benefit analyses were output, one with regard to the full tree inventory, and one with regard to the street tree inventory. First, the difference between the results for the full tree and street tree inventories will be examined. Then, the value lost, and later gained with regard to each inventory will be presented and explained in detail. Finally, it will be shown how our project goals are associated with these findings.

Street Tree Inventory and Full Tree Inventory

Street Tree Inventory Described

The street tree model will give an accurate ecosystem service value for the past and present. One important and critical point of this model is that it will only be covering the street trees in the Burncoat and Greendale area. Street trees are the public trees, which are maintained by the Department of Public Works & Parks, located between the road and the end of the sidewalk. From this model there will be two distinct results; one that represents the past value and another that represents the current value. The past value was calculated from the inventory taken from 2005 and 2006, by the Davey Resource Group. The present value was calculated by simply taking the past inventory and then removing from it all of the trees on the street tree removal list provided by the DCR.

Full Tree Inventory Described

Unlike the street tree inventory, the full tree inventory includes every single tree that was removed. This list is comprised of both public and private trees. Public trees include street trees and park trees, while private trees include any tree that is located on private land. The full tree model, like the street tree model, will give an accurate value of ecosystem services lost, and later gained, in the area. Overall, the data provided by this inventory output two different values. The first value was calculated using the full list of removed trees provided by the DCR, so that the results would accurately reflect the total value lost. The next value was calculated using the list of replanted trees provided by DCR and WTI, so that the results would accurately reflect the value gained.

Why Two Separate Inventories?

It may not be entirely clear why there ended up being two different models for this project. The goal of this project was to accurately assess the value of ecosystem services for the past, present, and future in the Burncoat and Greendale areas. By using both the street tree and full tree models, this project was able to show a complete assessment of ecosystem services. The results from the street tree model include the values provided by the street trees that are still left; whereas, the full tree inventory is only showing the difference in overall value lost, and later gained.

Breakdown of the Ecosystem Service Values Provided by Urban Trees

The next category is the benefit prices shown in Table 5. These values are key values that i-Tree Streets uses to produce a benefit analysis. In Table 5, you can clearly see that five different groups make up the total ecosystem service value provided by the trees. These five groups include: energy, CO_2, air quality, stormwater interception, and aesthetics. The energy value was calculated using the electricity and natural gas prices. The next group, CO_2, was calculated by how much it costs to offset a pound of carbon dioxide from the atmosphere. The next four gasses (PM_{10}, NO_2, SO_2, VOC) are all grouped together to create the air quality value. The air quality value was calculated similarly to that of the carbon dioxide value. The storm-water interception was calculated by the amount of money it takes for a gallon of water to be treated at a wastewater treatment plant. The last value is the aesthetic value. This value was determined with regard to the average home resale value of the homes in Burncoat and Greendale. All of these values that i-Tree Streets provides represent the money being saved every year in the community because of urban trees.

Table 5: Ecosystem Service Benefits

Ecosystem Service Benefits
Electricity ($/Kwh)
Natural Gas ($/Them)
CO_2 ($/lb)
PM_{10} ($/lb)
NO_2 ($/lb)
SO_2 ($/lb)
VOC ($/lb)
Storm-Water Interception ($/gallon)
Average Home Resale Value ($)

Street Tree Inventory

Due to the removals of street trees in Burncoat and Greendale, the ecosystem service value provided has dropped by $119,692 a year. This drop happened over the past four years starting from December of 2005. This value was calculated by simply subtracting the total present value from that of the past. This "total value" includes the value saved with regard to energy, CO_2, air quality, storm-water interception, and aesthetics. To explain the reasoning behind the total value lost, the next two sections will go into detail about the process by which the past and present ecosystem service values were formulated.

Street Tree Inventory: Past

The ecosystem services that the past street tree inventory was providing is valued at $484,167 a year adjusted for inflation[2]. In Appendix A, there is a summary of the tree inventory that was input into i-Tree Streets for the past street tree model. The next three tables show other important information that was required for i-Tree Streets. They are split into two categories, city information and benefit prices.

Table 6: Past – City Information

City Information	
Total Municipal Budget	$478,199,000
Population	19,111
Total Land Area (sq mi)	1.46
Average Sidewalk Width (ft)	5.22
Total Linear Miles of Streets (mile)	46.01
Average Street Width (ft)	29

Table 6 is an overview of the city information that set the stage for i-Tree Streets to calculate different values for this region. Keep in mind that all of this information only pertains to the Burncoat and Greendale areas of Worcester. The population value used comes for the United States census taken in 2000. This population count may be almost ten years old; however, this is the most accurate and credible source obtainable. The total land area, average sidewalk width, total linear miles of streets, and average street width, were calculated out by hand using the GIS layers provided by MassGIS. The storm-water interception was the only price that was not available locally; therefore, Boston's storm-water interception needed to be used.

Table 7: Past – Benefit Prices

Benefit Prices	
Electricity ($/Kwh)	0.1167
Natural Gas ($/Them)	1.46
CO_2 ($/lb)	.0033
PM_{10} ($/lb)	8.31
NO_2 ($/lb)	4.59
SO_2 ($/lb)	3.48
VOC ($/lb)	2.31
Storm-Water Interception ($/gallon)	.0063
Average Home Resale Value ($)	$182,926

[2] To account for inflation, since $1.00 in 2005 is worth approximately $1.10 today according to the United States Department of Labor, we simply increased the total past value by 10%.

Table 8: Past – Total Annual Benefits

Burncoat & Greendale

Total Annual Benefits of All Trees By Species ($)

2/26/2010

Species	Energy	CO_2	Air Quality	Stormwater	Aesthetic/Other	Total ($)	Standard Error	% of Total $
Norway maple	155,199	5,346	29,345	28,275	99,564	317,729	(±0)	72.2
Red maple	19,794	372	3,637	4,055	6,390	34,248	(±0)	7.8
Sugar maple	15,453	397	2,714	3,631	8,224	30,420	(±0)	6.9
Pin Oak	5,801	172	1,052	1,164	3,945	12,134	(±0)	2.8
Silver maple	7,692	178	1,534	1,959	2,125	13,488	(±0)	3.1
Northern red oak	3,858	111	747	909	1,380	7,004	(±0)	1.6
OTHER STREET	13,247	325	2,523	2,763	6,272	25,129	(±0)	5.7
Total	221,044	6,901	41,552	42,755	127,900	440,152	(±0)	100.0

The $440,152 lost each year was the most important part of the past street tree model, but how this value associates with the multitude of species and types of benefits is the interesting part. Table 8 organizes the different categories that made up the total annual benefits. I-Tree Streets gave information about the top six species of tree and then combined the other less notable trees to the "OTHER STREET" row. To better understand and analyze this information, the next three figures compare the values based on population, total value provided annually per species, and total value provided annually per tree.

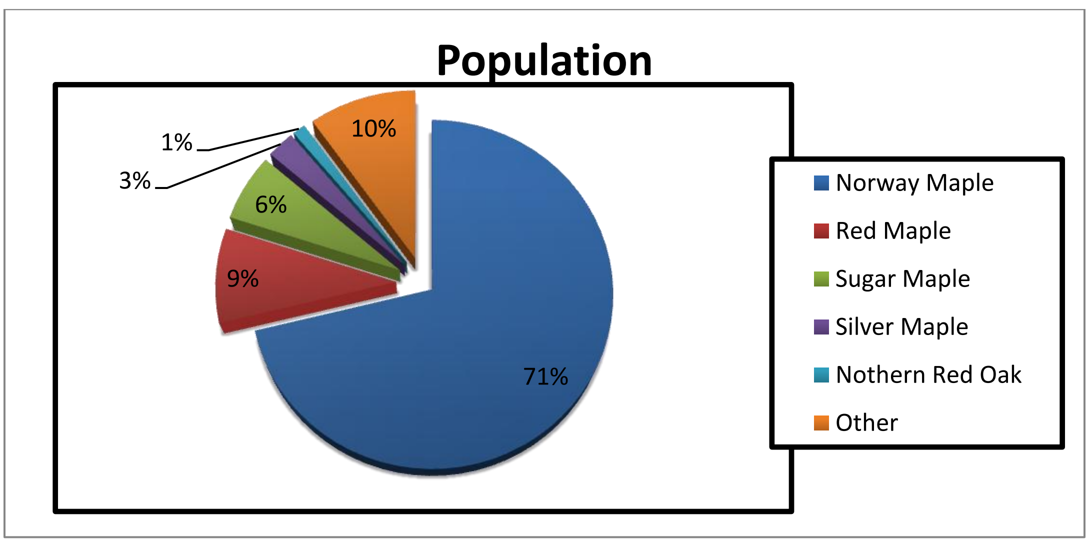


Figure 1: Past – Population

Figure 1 shows the population of street trees before the removals in Burncoat and Greendale. The large majority of the trees removed happened to be the Norway Maple. The Norway maple made up roughly 71% of the total street tree population, which consisted of approximately 2,000 street trees. This is more than likely because the Norway Maple is one of the preferred host trees of the Asian Long-Horned Beetle.

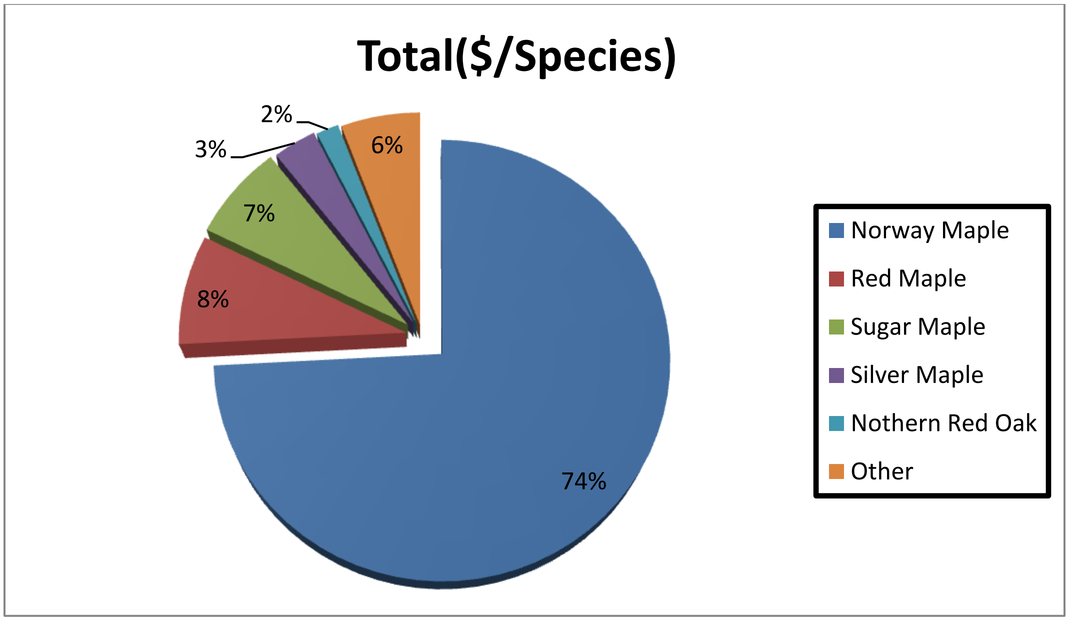


Figure 2: Past – Total Value Provided Annually per Species

Figure 2 shows more about how each of the species contributed to the overall ecosystem service value. It was apparent from the previous figure that the Norway Maple was the most abundant; therefore, it could have been expected that it also accounts for approximately 74% of the total value provided. The Northern Red Oak, which had the smallest population of the top six, jumped from 1% in population to providing 2% of the total value. The next bar graph will help determine which species of tree was actually providing the most value.

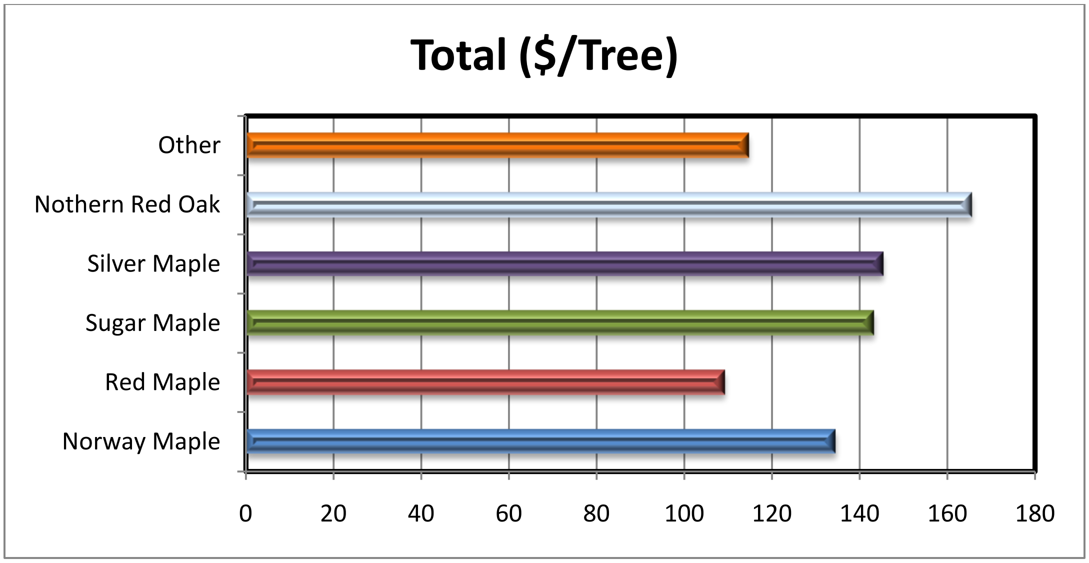


Figure 3: Past – Total Value Provided Annually per Tree

Since there was a huge population difference between the different species of street trees, Figure 3 shows the total value in a different format. This chart displays the total value provided annually by one tree in each species. We were able to create this figure by taking the value provided by each species and then dividing that number by the corresponding population of just those trees. Even though the population included a heavy mix of Norway Maples, one can see that the Northern Red Oak still provides more ecosystem service value per tree.

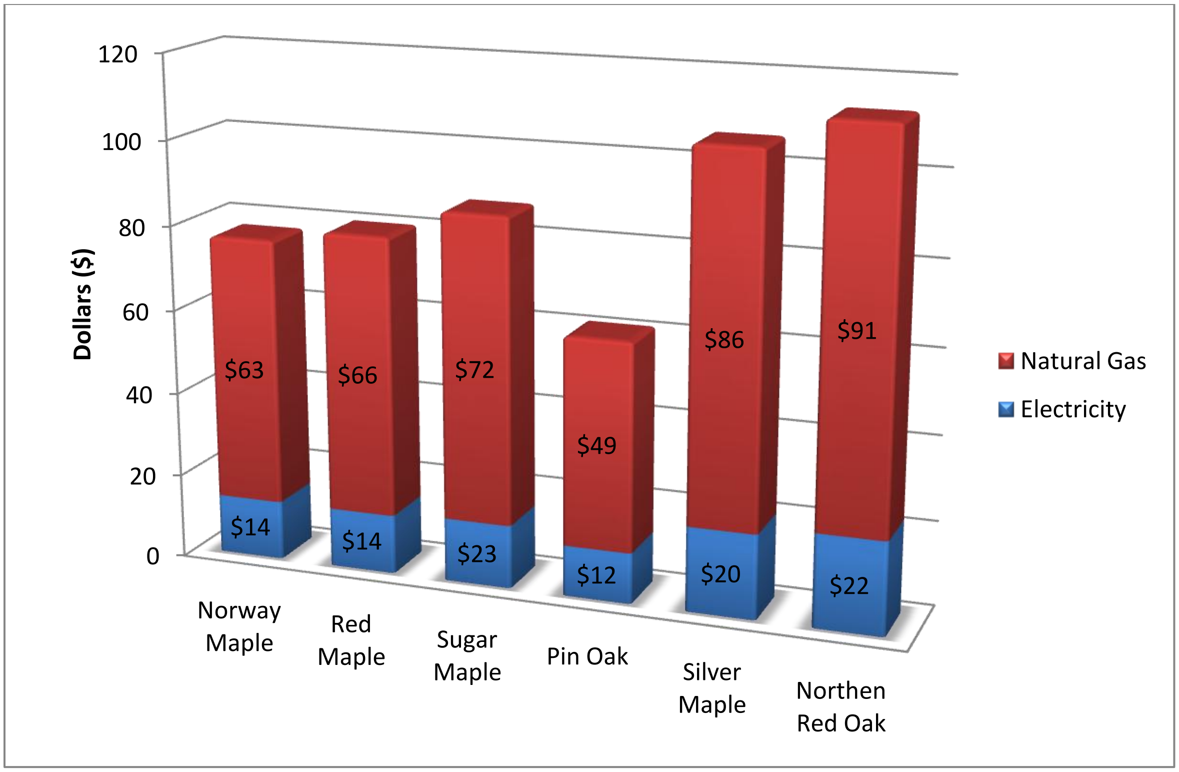


Figure 4: Past – Energy Savings

One of the project's major objectives was to show the community something that they could relate to, monetary value. This way they would be able to get a better grasp on what the information was trying to show. One of the groups that i-Tree Streets creates for energy savings has to do with how a tree can save money on electricity and natural gas. The figure above shows how much money one tree of each species can save someone on electricity and natural gas. The full break down of the energy cost for the past street tree model can be found in Appendix A. As one can see, the Northern Red Oak had the best average on both the natural gas and electricity savings.

Street Tree Inventory: Present

The current ecosystem services provided by public street trees in Burncoat and Greendale are valued at $364,475 a year. That means that these street trees are providing almost $120,000 less each year. The process by which this value was calculated is very similar to that of the past street tree model. However, instead of using tree inventory data and local resource costs from 2005, this model used current information. The street tree inventory that was used for the current value can be found in Appendix B. The other information needed for this model has been organized into Table 9 and Table 10. Some of the information stayed constant from the past street tree model since most of the city information does not change very much in five years. The Benefit Prices, on the other hand, are current prices provided by the suppliers.

Table 9: Present – City Information

City Information	
Total Municipal Budget	$491,165,675
Population	19,111
Total Land Area (sq mi)	1.46
Average Sidewalk Width (ft)	5.22
Total Linear Miles of Street (mile)	46.01
Average Street Width (ft)	29

Table 10: Present – Benefit Prices

Benefit Prices	
Electricity ($/Kwh)	0.0883
Natural Gas ($/Them)	0.7703
CO_2 ($/lb)	.0033
PM_{10} ($/lb)	8.31
NO_2 ($/lb)	4.59
SO_2 ($/lb)	3.48
VOC ($/lb)	2.31
Storm-water Interception ($/gallon)	.0063
Average Home Resale Value ($)	$219,336

As you may notice, the electricity and natural gas prices both went down since 2005. When collecting this information for the past five years, there ended up being a lot of fluctuation between the prices for electricity and natural gas. For this model, the current electricity and natural gas prices were used, but since they change randomly month to month, no noticeable trend was found.

Table 11: Present – Total Annual Benefits

Burncoat & Greendale

Total Annual Benefits of All Trees By Species ($)

2/26/2010

Species	Energy	CO_2	Air Quality	Stormwater	Aesthetic/Other	Total ($)	Standard Error	% of Total $
Norway maple	86,795	5,249	28,839	27,761	117,250	265,893	(±0)	73.0
Red maple	11,085	367	3,586	4,000	7,530	26,568	(±0)	7.3
Sugar maple	8,614	390	2,667	3,568	9,691	24,931	(±0)	6.8
Pin oak	3,326	172	1,052	1,164	4,730	10,444	(±0)	2.9
Silver maple	4,270	173	1,494	1,910	2,476	10,324	(±0)	2.8
Northern red oak	2,209	111	747	909	1,654	5,630	(±0)	1.5
OTHER STREET	7,555	325	2,523	2,763	7,520	20,686	(±0)	5.7
Total	123,855	6,787	40,908	42,074	150,851	364,475	(±0)	100.0

To understand where the $364,475 a year comes from, i-Tree Streets created a summary table (see Table 11) with the total annual benefits of all the trees by species. Similar to the past street tree model, the values are split into five different groups and organized by species. These five categories help create the total ecosystem service value. To help understand some of the broad information shown in the table, we have created charts that go into specific information regarding the $364,475 provided annually.

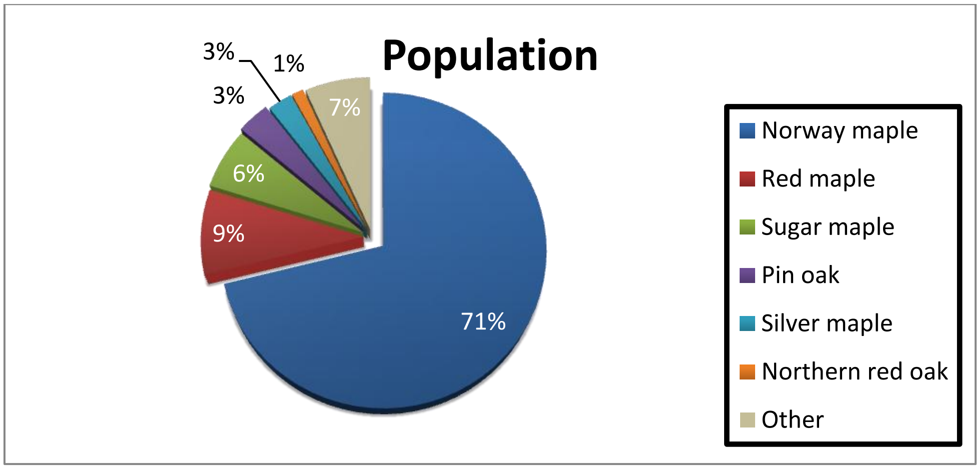


Figure 5: Present – Population

Figure 5 shows the current population of street trees. This population will change in the future due to planned tree removals by the Department of Conservation and Recreation. The biggest difference in population from past to present in the street tree model was the Norway Maples. The Norway maple, which still has the largest population for current street trees, was the main tree taken down since December 2008. Figure 6 shows how this affected the total ecosystem service value per species.

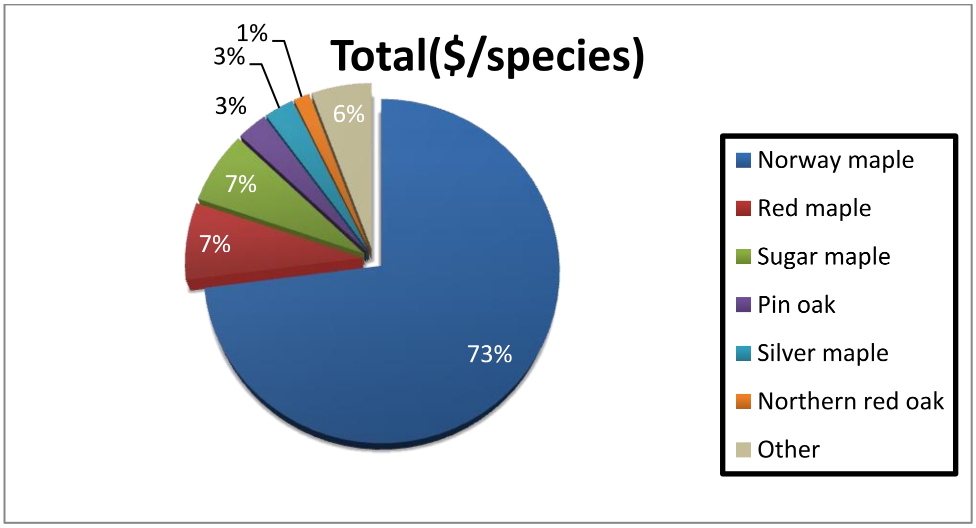


Figure 6: Present – Total Value Provided Annually per Species

The distribution for dollar per species is very similar to that of the past street tree model. Comparing both the value provided per species (Figure 6) and the value provided per tree (Figure 5) to the same figures in the past model (Figure 1 & Figure 2), you can tell that the trees still offer a fairly similar amount of value, just much less.

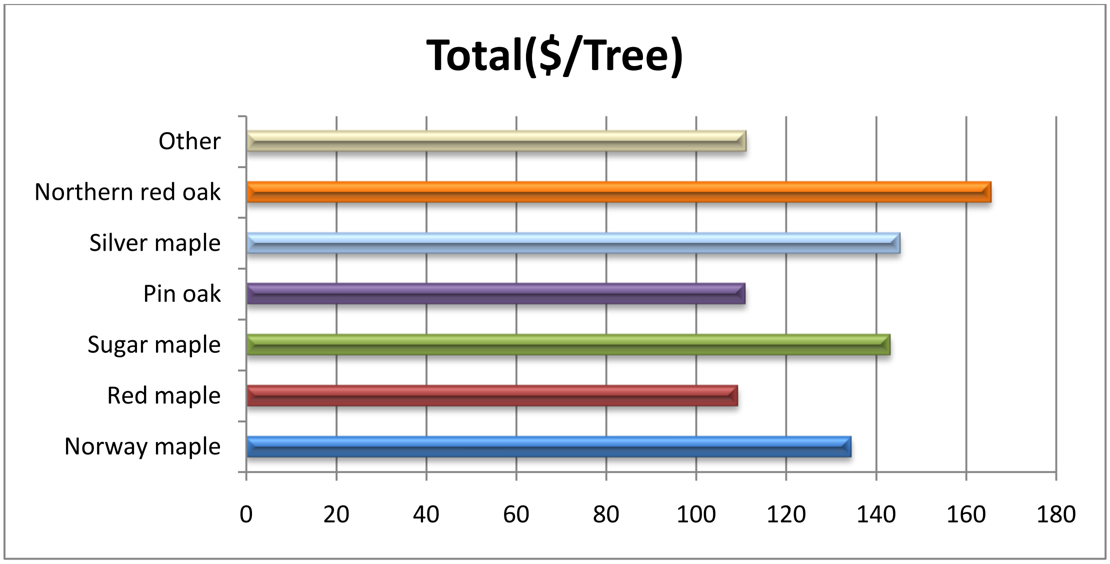


Figure 7: Present – Total Value Provided Annually per Tree

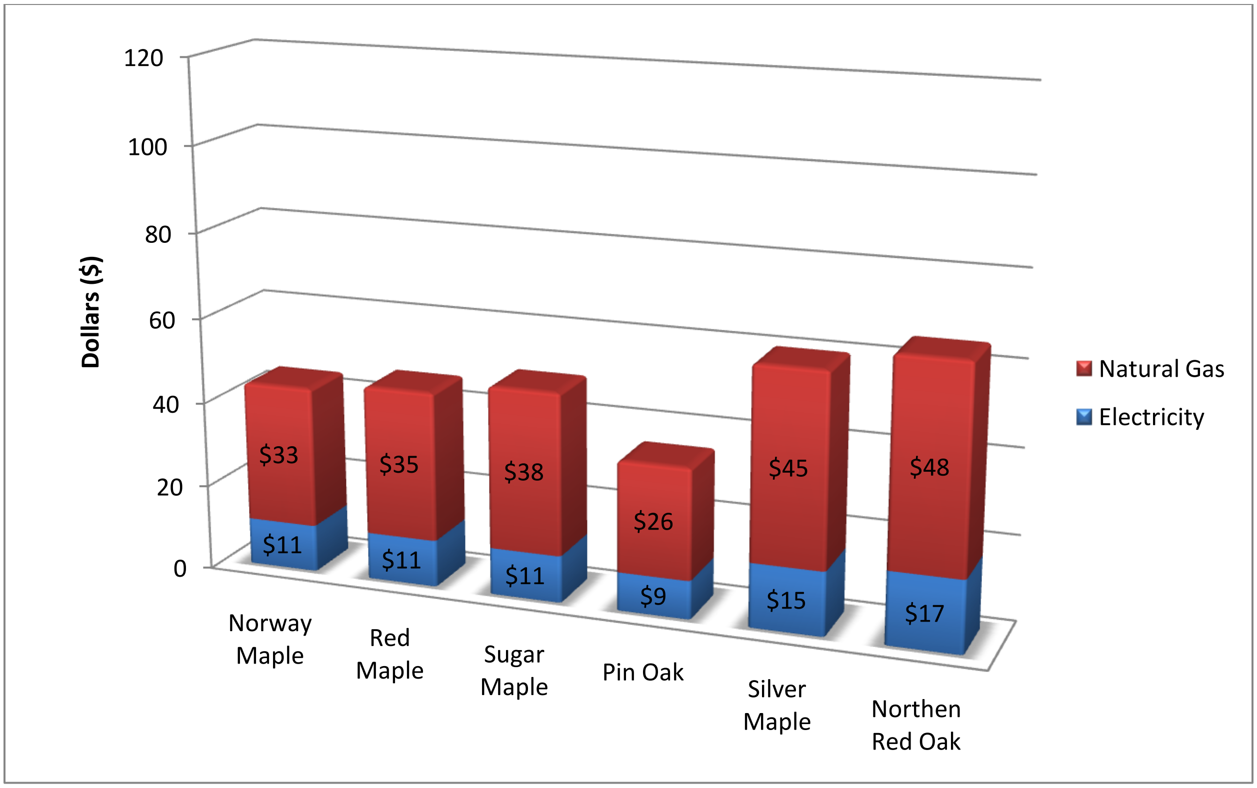


Figure 8: Present – Energy Savings

Out of the five groups that contribute to the total ecosystem service value, energy showed the greatest change in value from the past to the present for street trees. To get a more accurate view on how the removals effect, the energy per tree is shown in Figure 8. This chart is scaled the same as it was in the past street tree model to clearly highlight the reduced amount of energy savings. Although the majority of the 2,000 removed street trees were Norway Maples, all of the species were greatly affected in terms of energy savings. The highest savings is around $60 from the Northern Red Oak; whereas, in the past model the highest was around $120 annually.

The Burncoat and Greendale community is losing almost $120,000 a year in ecosystem service value. This is a scary trend to have, especially knowing that this model only pertains to public street trees. It would be foolish to ignore this loss of ecosystem services. To emphasize the significant value lost in these neighborhoods; this study also calculated a total value lost with regard to all removed trees, both public and private.

Full Tree Inventory

Removals

The total value lost due to the tree removals in Burncoat and Greendale is $628,178 a year. Unlike the street tree model, this model consists of all private and public tree removals. From all of the lists gathered, there were 8,593 of the approximately 25,000 trees removed in the area. The species of trees in this inventory included the following: Maple, Norway Maple, Red Maple, Black Maple, White Poplar, Birch, Gray Birch, Elm, Ash, White Ash, and several others. Every tree in this inventory was already removed; therefore, this truly represents value lost. Many of these trees were old and took decades to grow. Most of the removed trees cannot be replanted because they are one of the preferred hosts of the Asian Long-horned beetle. This section will go into detail about the process by which the removed trees were formatted to input into i-Tree Streets.

To create this model, we took the lists of the removed trees provided by the DCR, and then formatted them for i-Tree Streets. A summary of this inventory is attached in Appendix C. The end result was the total annual benefits of all the removed trees. This total value was the $628,178 a year mentioned earlier. Like the street tree model, i-Tree Streets required the same input of city information and benefit prices shown in Table 12 and Table 13.

Table 12: Removals and Re-plantings – City Information

City Information	
Total Municipal Budget	$491,165,675
Population	19,111
Total Land Area (sq mi)	1.46
Average Sidewalk Width (ft)	5.22
Total Linear Miles of Streets (mile)	46.01
Average Street Width (ft)	29

Table 12 shows an overview of the city information that set the stage for i-Tree Streets to calculate different values for Burncoat and Greendale specifically. This data is the same as the city information used for the present street tree model; again, coming from the same credible sources described in the methodology section of this report.

Table 13: Removals and Re-plantings – Benefit Prices

Benefit Prices	
Electricity ($/Kwh)	0.1167
Natural Gas ($/Them)	1.46
CO_2 ($/lb)	.0033
PM_{10} ($/lb)	8.31
NO_2 ($/lb)	4.59
SO_2 ($/lb)	3.48
VOC ($/lb)	2.31
Storm-Water Interception ($/gallon)	.0063
Average Home Resale Value ($)	$227,000

Table 13 shows the Benefit Prices associated with removed trees. Again, this data is the same as the Benefit Prices for the present street tree model. For more information regarding these Benefit Prices, refer to the present street tree model section of this report.

Table 14: Removals – Total Annual Benefits

Burncoat & Greendale

Total Annual Benefits of All Trees By Species ($)

2/26/2010

Species	Energy	CO_2	Air Quality	Stormwater	Aesthetic/Other	Total ($)	Standard Error	% of Total $
Norway maple	99,897	2,943	17,746	15,717	79,592	215,895	(±0)	34.4
Maple	49,974	1,364	8,589	7,317	40,373	107,617	(±0)	17.1
White poplar	30,703	529	4,214	3,132	40,679	79,257	(±0)	12.6
Birch	10,421	204	1,613	1,942	20,403	34,583	(±0)	5.5
Elm	15,447	371	2,611	2,717	27,913	49,059	(±0)	7.8
Ash	17,171	331	2,989	2,824	15,114	38,429	(±0)	6.1
Red maple	13,947	262	2,436	2,735	10,637	30,017	(±0)	4.8
Black Maple	3,411	67	548	652	7,041	11,719	(±0)	1.9
White ash	5,738	119	1,046	1,006	3,775	11,684	(±0)	1.9
Gray birch	1,492	29	233	273	3,144	5,172	(±0)	0.8
OTHER STREET	19,912	455	3,496	4,029	16,856	44,747	(±0)	7.1
Total	268,114	6,673	45,521	42,343	265,527	628,178	(±0)	100.0

The grand total of $628,178 a year lost in ecosystem service value is by far the most important key finding of this study. Table 14 shows the breakdown of the benefit analysis for removed trees. For removals, i-Tree Streets output information with regard to the top ten species and then, once again, combined the other less notable trees into the "OTHER STREET" row. These next three figures organize the values based on population, total value provided annually per species, and total value provided annually per tree.

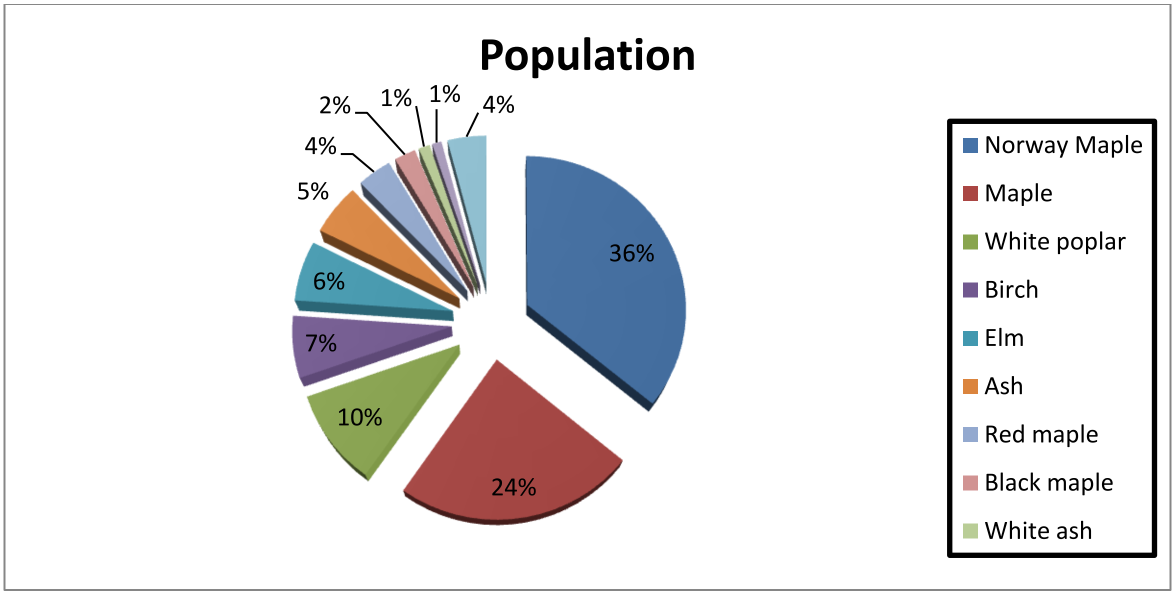


Figure 9: Removals – Population

I-Tree Streets gives a population breakdown of the corresponding tree inventory input into the program. Figure 5 shows the population of the removed trees. Here you can see that the Norway Maples consisted of approximately 36% of all the removed trees, while the White Ashes were only 1%. It will become clear later as to why the White Ash is mentioned here.

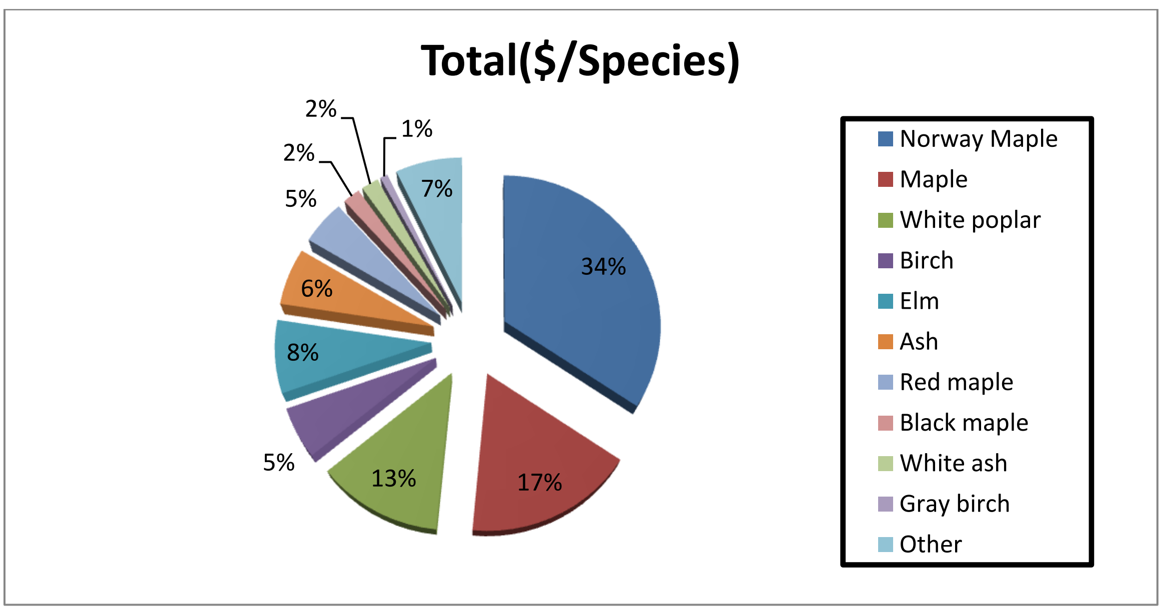


Figure 10: Removals – Total Value Lost Annually per Species

Figure 6 shows which species of removed trees were providing the most ecosystem services. Looking at the benefits per species, one can see that the Norway Maples in the area provided 34% of the total ecosystem service value. This is not surprising, considering they make up 36% of the total population. The White Ash, however, provides 2% of the total ecosystem service value while it only makes up 1% of the total population of removed trees.

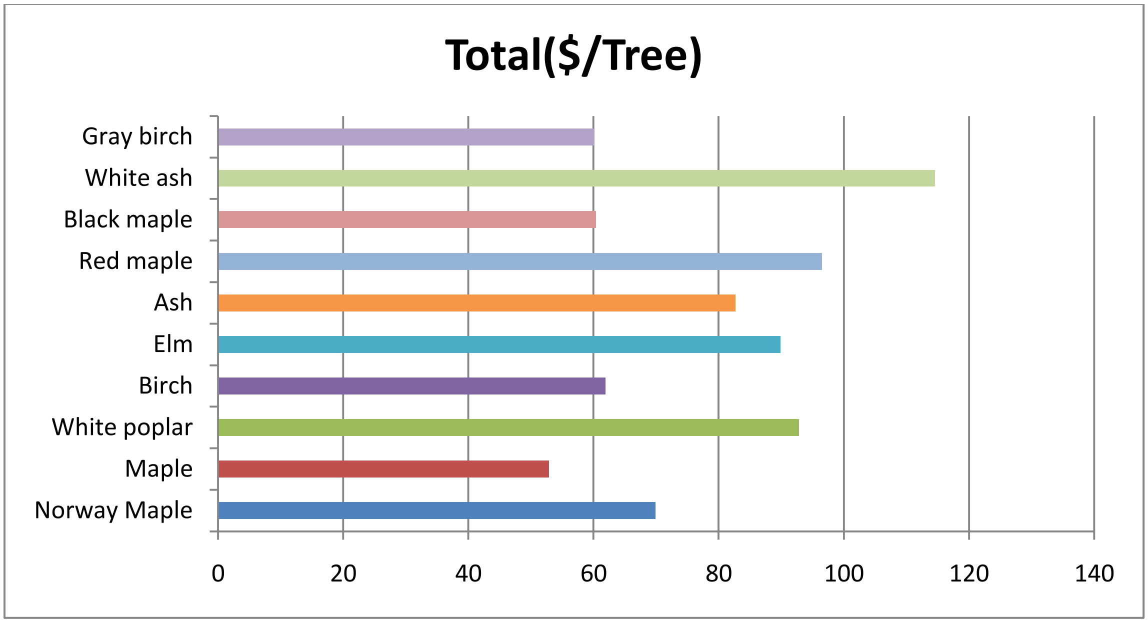


Figure 11: Removals – Total Value Lost Annually per Tree

Why is this so? Figure 11 helps in answering this question. The bar graph below shows the total value provided annually per removed tree. It shows the value provided each year by a single removed tree in each species. Looking at the graph, one can see that the White Ash is providing almost $120 a year in ecosystem service value, while the Norway Maple was only providing approximately $70. It is clear now as to why the White Ash only made up 1% of the population, but provided 2% of the total ecosystem service value.

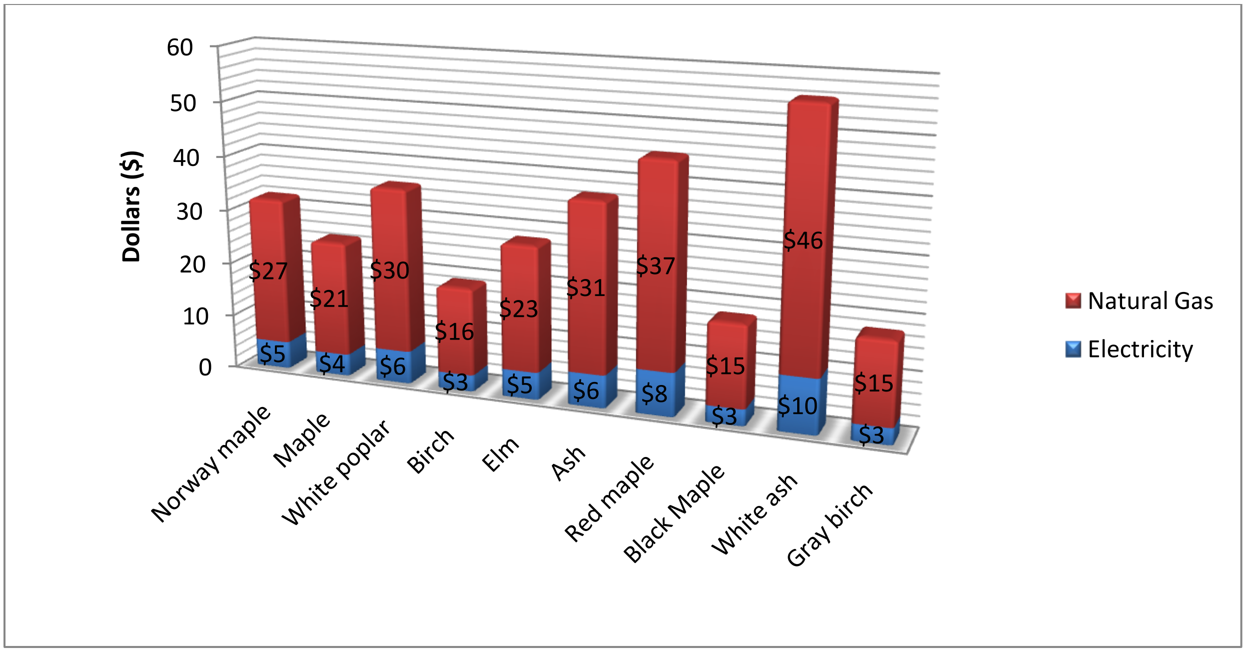


Figure 12: Removals – Energy Savings

Figure 12 shows the electricity and natural gas savings of individual removed trees. Looking again at the Norway maple and the White ash, one can see how much more the White ash provides with regard to energy. It has twice as much electricity savings and its natural gas savings alone are even more than the entire energy savings provided by the Norway Maple. This goes to show that the only reason the Norway maple had the highest benefit in ecosystem services was because it was the most removed tree. A full report of all the energy savings with regard to tree removals in Burncoat and Greendale can be found in Appendix C.

The model of tree removals is the most important section of this study. It shows just how valuable the removed trees were to the Burncoat and Greendale community. It highlights how much money is being lost every year and it reiterates the importance of urban trees. We hope that these results will help catalyze future tree re-plantings in an effort to, one day, gain back the value lost. It will take many decades for Burncoat and Greendale to regain the almost $630,000 lost each year in ecosystem services. Hopefully, this study can be used to make the replanting process more effective and efficient.

Re-plantings

The total ecosystem service value provided by the replanted trees in Burncoat and Greendale is only $31,679 a year. This number was calculated with only regard to the nearly 2,000 trees replanted by the city of Worcester, the DCR, and the Worcester Tree Initiative. This means that almost $600,000 a year is lost in ecosystem service value. Yes, the value provided by these replanted trees will rise as they mature; however, it has become evident that their value will never reach the value that the removed trees were providing.

This study has shown the substantial ecosystem service value lost due to tree removals in Burncoat and Greendale. In an effort to compensate for the lost value, the DCR and WTI have both started a replanting effort. Currently, the tree re-plantings have successfully compensated for approximately $31,679 of the $628,178 annually. Keep in mind that all of the replanted trees are still "whips". Meaning that they are all less than 3 inches in DBH. The summary inventory of replanted trees from the DCR and WTI is attached in Appendix D of this report.

Table 15: Re-plantings – Total Annual Benefits

Burncoat & Greendale

Total Annual Benefits of All Trees By Species ($)

3/4/2010

Species	Energy	CO_2	Air Quality	Stormwater	Aesthetic/Other	Total ($)	Standard Error	% of Total $
Sweetgum	46	2	3	15	1,487	1,552	(±0)	4.9
Kousa dogwood	253	7	62	41	779	1,142	(±0)	3.6
Kwanzan cherry	244	7	60	40	749	1,099	(±0)	3.5
Japanese tree lilac	240	6	59	39	737	1,081	(±0)	3.4
Apple	161	5	40	27	673	906	(±0)	2.9
Black tupelo	89	5	21	21	4,246	4,382	(±0)	13.8
Littleleaf Linden	42	3	9	12	3,213	3,279	(±0)	10.4
White oak	357	9	85	72	2,256	2,779	(±0)	8.8
Sargent cherry	180	5	44	29	553	811	(±0)	2.6
Dawn redwood	497	12	79	27	2,397	3,012	(±0)	9.5
Northern red oak	67	2	14	20	1,361	1,464	(±0)	4.6
Crabapple	84	2	21	14	351	472	(±0)	1.5
Callery pear	50	2	13	15	1,053	1,133	(±0)	3.6
Honey Locust	80	2	19	10	1,723	1,834	(±0)	5.8
Plum	89	2	22	15	273	401	(±0)	1.3
Swamp white oak	150	4	36	30	950	1,170	(±0)	3.7
English oak	38	1	8	11	765	823	(±0)	2.6
Black oak	36	1	7	10	723	778	(±0)	2.5
Common Linden	8	1	2	2	620	633	(±0)	2.0
Ginkgo	9	0	2	2	87	100	(±0)	0.3
Common pear	17	1	4	5	357	384	(±0)	1.2
Scarlet oak	79	2	19	16	499	614	(±0)	1.9
OTHER STREET	150	5	37	30	1,609	1,830	(±0)	5.8
Total	2,965	85	664	505	27,460	31,679	(±0)	100.0

There were a wide range of species that were replanted by both the DCR and the WTI. The WTI had only moderate control of the species being replanted. They left the choice in the hands of community members after they first went through a quick training session on how to properly care for a tree. Looking at Table 15, one can clearly see that aesthetics made up the overwhelming majority of all ecosystem service value provided by the replanted trees. If you look at the total aesthetic value for all the species, you can see that it makes up approximately 86% of the total annual benefits provided. The second most ecosystem services provided by replanted trees were in energy savings; however, this still only accounts for about 9% of the total. Figure 13 shows the most popular species of replanted trees.

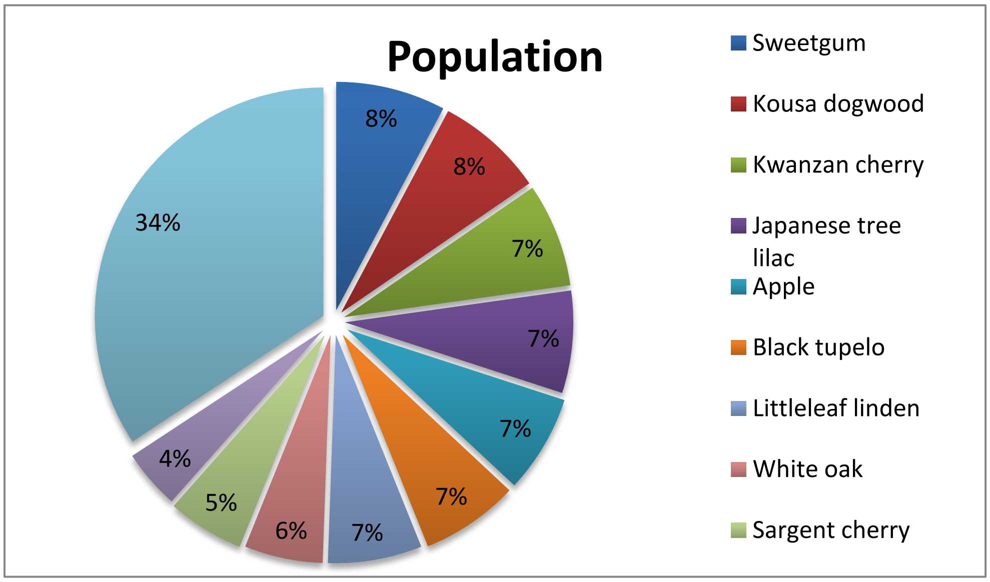


Figure 13: Re-plantings – Population

The ten most planted species are somewhat evenly distributed. This tells us that the community, as a whole, did not really have a favorite type of tree to plant. The fact that the "other" category (light blue) makes up approximately 34% of the total population also points to this conclusion.

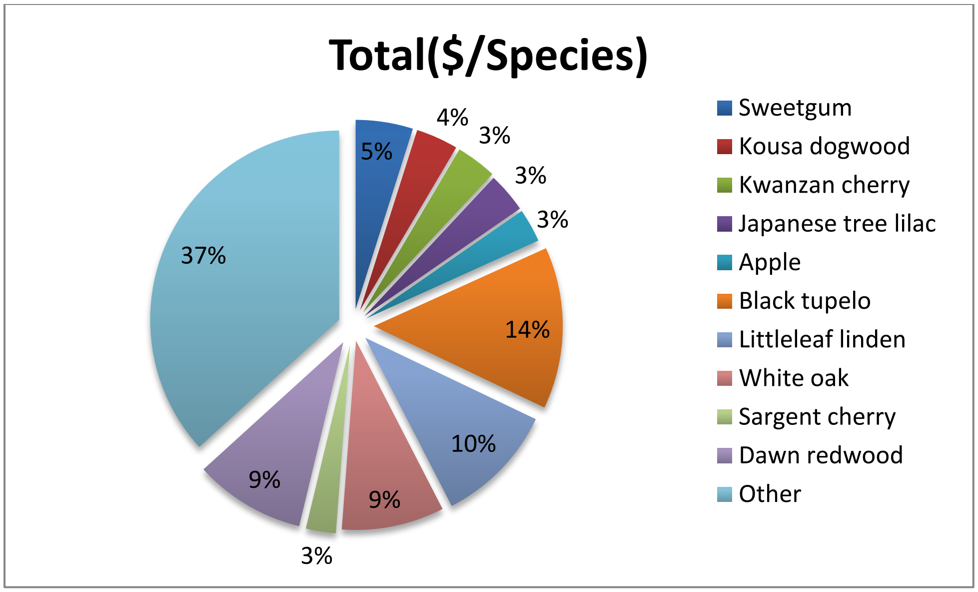


Figure 14: Re-plantings – Total Value Gained Annually per Species

As shown in Figure 13, the Sweetgum and Kousa Dogwood were the most abundantly replanted trees. This is evident, yet they still do not provide nearly enough to make up a majority of the total ecosystem service value. Why is this? Figure 15 displayed below helps answer that question.

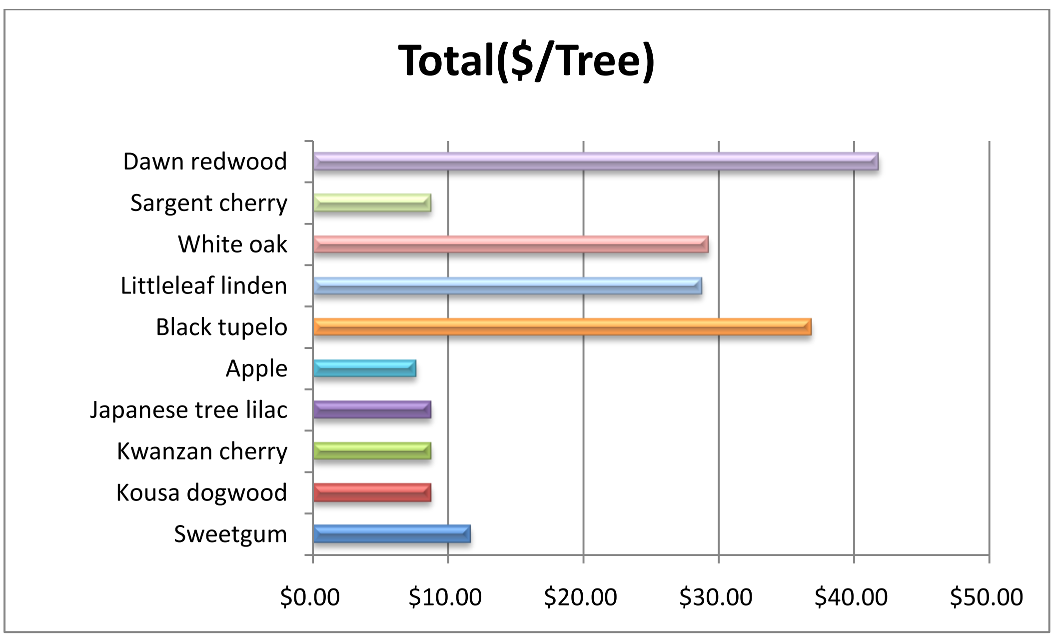


Figure 15: Re-plantings – Total Value Gained Annually per Tree

Figure 15 shows the total value provided annually per tree. This highlights that these pretty, ornamental trees just are not providing enough ecosystem service value. Even though the values of all trees are very low, some species are better than others. For example, The Dawn redwood provides around $40 per tree. When compared to the most abundantly replanted tree, the Sweetgum, the Dawn Redwood still provides about $30 more annually.

A breakdown of energy savings of the replanted trees is displayed below to highlight the fact that if uneducated tree re-plantings keep happening, the value gained will never compensate for the tree removals in Burncoat and Greendale.

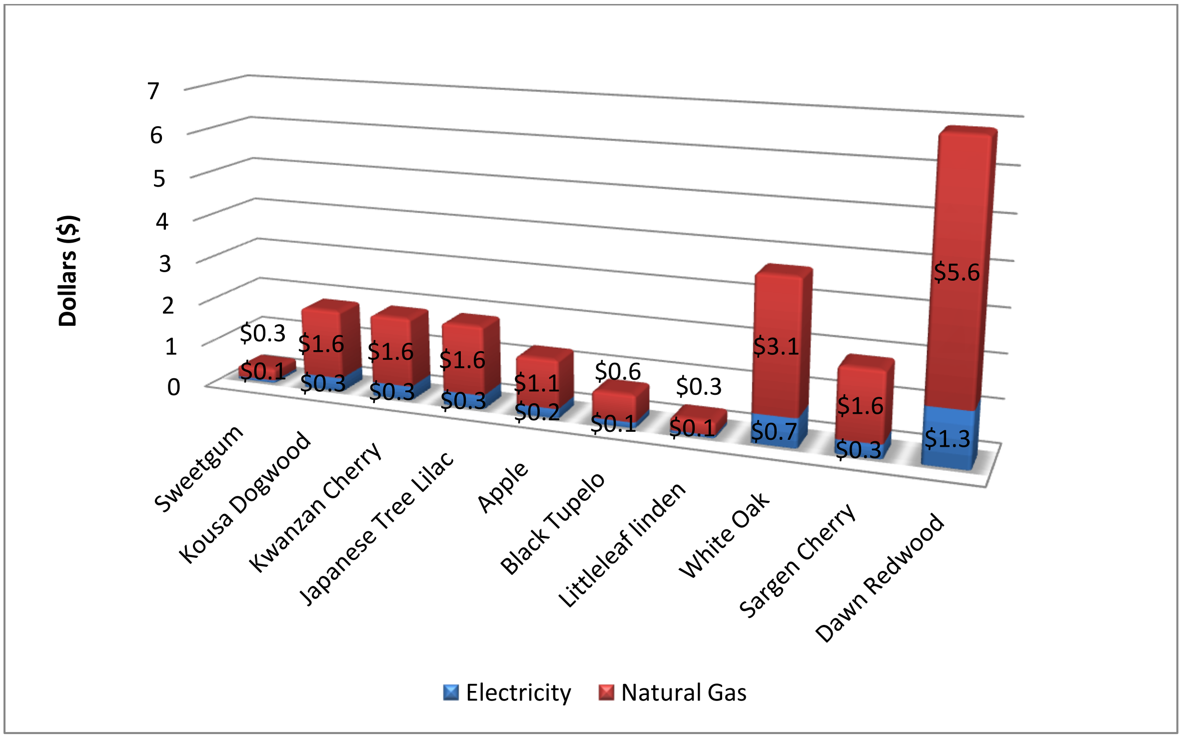


Figure 16: Re-plantings – Energy Savings

As one can see in Figure 16, the highest energy savings per tree is around $7 annually, provided by the Dawn Redwood. It provides approximately $5.60 a year in natural gas savings and $1.30 a year in energy savings. Keep in mind that all these trees are still young and will grow to provide more savings, but either way, you can clearly see the significant differences in the energy savings from specie to specie. The Sweetgum does not even provide $1.00 in energy savings. It is evident that the community has been choosing ornamental trees based on aesthetic value rather than ecosystem service benefits. This is not the way to go about the replanting strategy if the ecosystem in Burncoat and Greendale is ever to get back to where it was before the ALB infestation.

Benefits Comparison: Removals vs. Re-plantings

This section will analyze the difference in the values of ecosystem services provided by the removed and replanted trees in Burncoat and Greendale. It will outline which services are more predominant in each inventory and make suggestions on why the values are so different. Before going too in depth, the fact that the replanted trees are not at the same maturity levels as the removed trees must be taken into consideration. This is going to make a slight difference in the comparison. The next figure, however, will show that even at the same maturity levels, the replanted values will never reach what they were before the tree removals.

Figure 17 shows the comparison of percentages of total ecosystem service values. The inner ring represents the removals and the outer ring represents the re-plantings. Looking at the inner circle, you can see that 43% of the total ecosystem service values were being provided in energy savings. Now looking at the outer ring, the value of the energy savings diminishes to 9%. Another point to be made is that the majority of ecosystem service value provided by the replanted trees comes from aesthetic value. This suggests that most of the replanted trees in the area are being chosen because of how they look, not because of the ecosystem services that they will be providing.

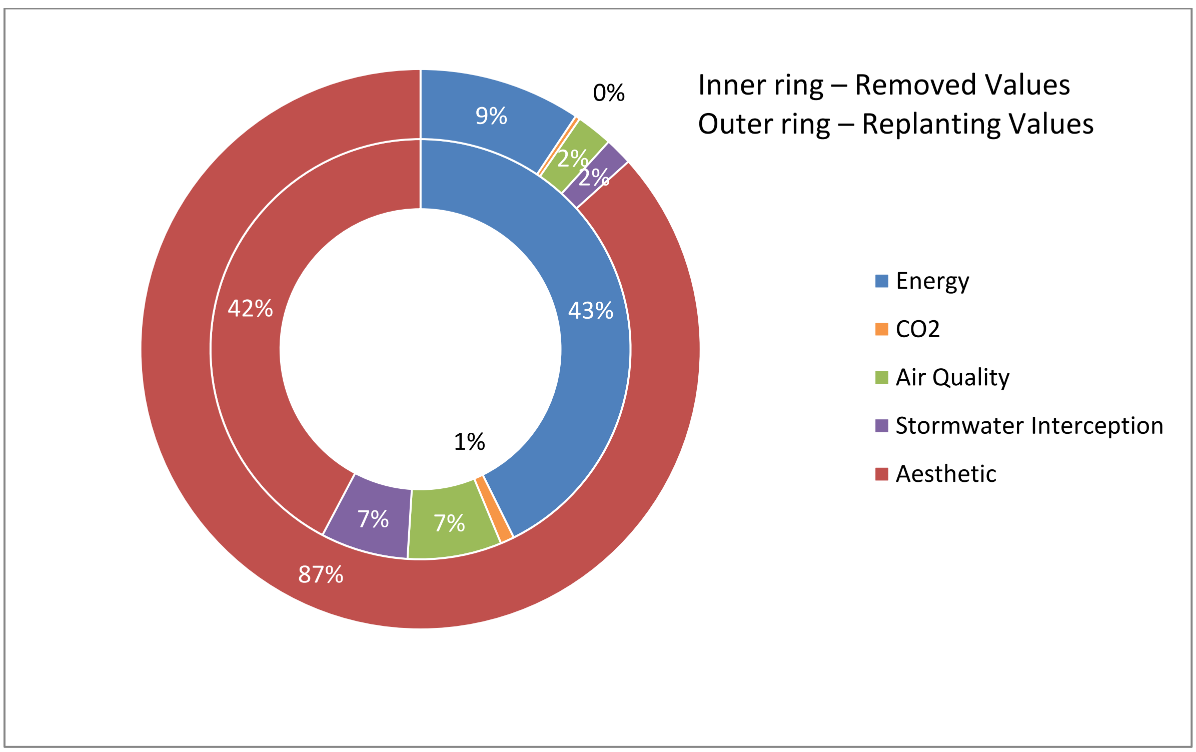


Figure 17: Removals & Re-plantings – Total Annual Benefits

Figure 18 and Figure 19 display the comparison of three different trees in Burncoat and Greendale. The first species of tree selected is the Norway maple, which was selected as a benchmark or "control group". This species was selected because it is the preferred host of the Asian Long Horned Beetle and was the most removed tree in the area. The second tree selected was the Sweetgum, which was selected because it is currently the most abundantly replanted tree in the area. Lastly, the Dawn Redwood was selected because it is the tree with the best ecosystem service values currently being replanted. In order to analyze these three species accurately, we inputted them into the program at a constant maturity level. To do this, we researched the maximum growth of each of these species and then input each of the DBH values for each tree at 80% of their maximum value. This assures that the trees are compared on an equal level and makes our results more credible. By looking at the figures below, it is evident that even the Dawn Redwood will not supply the same ecosystem service values that the Norway maple had been providing before they were removed. Keep in mind that the Norway maple was not providing the most ecosystem service value per tree for the removal model, yet still has greater values than the Sweetgum and Dawn Redwood. This information backs up the conclusion that, if people do not start selecting trees based on the ecosystem service values that they provide, then the replanting values will never reach or surpass the value lost.

Figure 18: Tree Comparison – Energy, CO2, Air Quality, Stormwater Interception

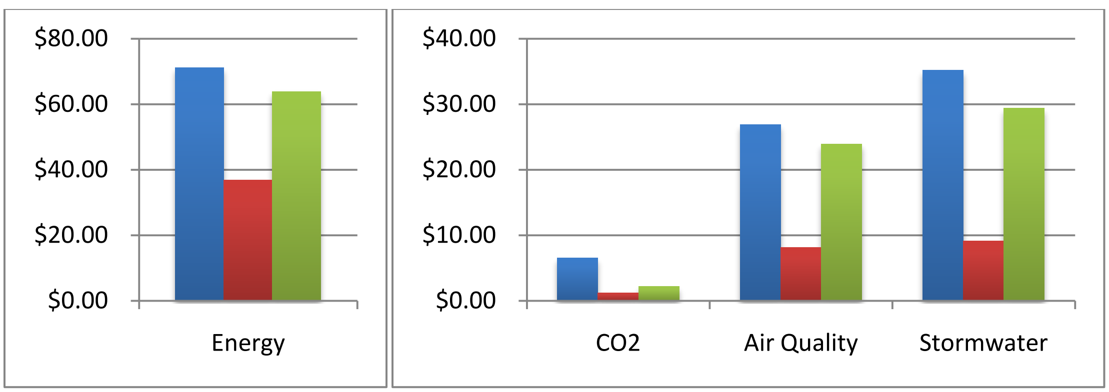
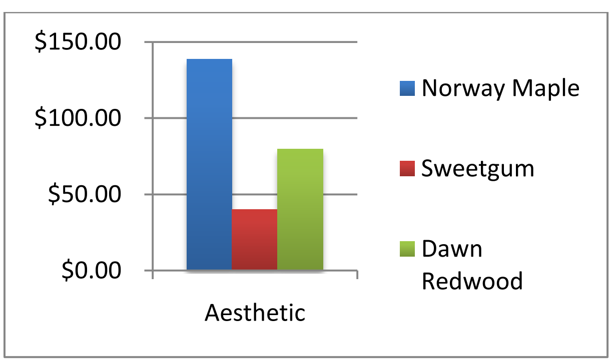


Figure 19: Tree Comparison – Aesthetic Value



The Big Picture

This study set out to accurately assess ecosystem service values for the past, present, and future in the Burncoat and Greendale areas of Worcester. In doing this, we hoped to accomplish two additional long-term goals. The first was to raise the awareness to policy makers and community members about the importance of urban trees, and the second was to educate members of the community about ecosystem services so that they can make informed decisions about tree re-plantings. By ensuring that people make informed decisions, organizations such as the DCR and WTI can maximize the ecosystem service value gained. Table 16 organizes the important findings associated with our project goals.

Table 16: Summary of Key Findings

Key Findings: Summary of Results	
Street Tree Inventory: Past Value	$484,167 / yr
Street Tree Inventory: Present Value	$364,475 / yr
Street Tree Inventory: Net Loss	**$119, 692/ yr**
Full Tree Inventory: Removals	$628,178 / yr
Full Tree Inventory: Re-plantings	$31,679 / yr
Full Tree Inventory: Net Loss	**$596,499 / yr**

Before summarizing the key findings, it needs to be made clear that approximately 25,000 trees have been removed in Burncoat and Greendale. This study only assesses the ecosystem services of approximately 8,700 of those 25,000 trees. The street tree inventory consisted of approximately 2,000 street trees, and the full tree inventory consisted of about 8,700 private and public trees.

As one can see, the Burncoat and Greendale areas have a total net loss of $119,692 a year from just the street tree removals, and a total of $596,499 a year from all tree removals – both public and private. The presentation of these net losses clearly accomplishes our project goal of raising the awareness to the community about the importance of urban trees.

The previous section regarding re-plantings and total annual benefits helps to educate people so that they can make informed decisions regarding tree re-plantings. It is clear that ornamental trees like the Sweetgum are not an effective choice. This study has made it evident that replanting trees which provide more ecosystem service value, such as the Dawn Redwood, is a necessity. The ecosystem of Burncoat and Greendale is in dire need of assistance. If used and distributed properly, this report can help Worcester get back to where it was in terms of ecosystem service value.

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Appendix A: Street Trees – Past

Past – Aesthetic

Burncoat & Greendale

Annual Aesthetic/Other Benefits of All Trees by Species

2/26/2010

Species	Total ($)	Standard Error	% of Total Trees	% of Total $	Avg. $/tree
Norway maple	99,564	(N/A)	71.2	77.9	49.61
Red maple	6,390	(N/A)	8.8	5.0	25.87
Sugar maple	8,224	(N/A)	6.3	6.4	46.46
Pin Oak	3,945	(N/A)	3.3	3.1	41.96
Silver maple	2,125	(N/A)	2.6	1.7	29.12
Northern red oak	1,380	(N/A)	1.2	1.1	40.58
OTHER STREET TREES	6,272	(N/A)	6.6	4.9	33.72
Total	127,900	(N/A)	100.0	100.0	45.39

Past – Air Quality

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Burncoat & Greendale

Annual Air Quality Benefits of All Trees by Species

2/26/2010

Species	Deposition (lb)				Total Depos. ($)	Avoided (lb)				Total Avoided ($)	BVOC Emissions (lb)	BVOC Emissions ($)	Total (lb)	Total ($)	Standard Error	% of Total Trees	Avg. $/tree
	O_3	NO_2	PM_{10}	SO_2		NO_2	PM_{10}	VOC	SO_2								
Norway maple	1,384.8	598.7	679.9	227.2	15,545	2,045.3	132.4	78.4	1,051.9	14,330	-229.4	-530	5,969.2	29,345	(N/A)	71.2	14.62
Red maple	169.8	73.3	84.7	28.4	1,919	259.5	16.8	10.0	132.7	1,815	-42.2	-98	733.0	3,637	(N/A)	8.8	14.72
Sugar maple	134.8	58.3	66.2	22.1	1,513	200.0	13.0	7.7	100.7	1,394	-83.4	-193	519.3	2,714	(N/A)	6.3	15.34
Pin Oak	52.3	22.6	26.1	8.7	591	80.4	5.2	3.0	43.6	570	-47.2	-109	194.6	1,052	(N/A)	3.3	11.19
Silver maple	77.7	33.6	38.2	12.8	873	103.1	6.7	3.9	54.0	725	-27.6	-64	302.2	1,534	(N/A)	2.6	21.01
Northern red oak	40.8	17.6	20.4	6.8	461	53.0	3.4	2.0	28.5	375	-38.8	-90	133.7	747	(N/A)	1.2	21.97
OTHER STREET TREES	124.3	53.0	61.3	20.2	1,393	177.5	11.5	6.8	92.9	1,249	-51.6	-119	495.8	2,523	(N/A)	6.6	13.56
Total	1,984.6	857.1	976.7	326.3	22,295	2,918.6	188.9	111.8	1,504.2	20,459	-520.3	-1,202	8,347.9	41,552	(N/A)	100.0	14.75

Past – Benefits Per Tree

Burncoat & Greendale

Annual Benefits of All Trees by Species ($/tree)

2/26/2010

Species	Energy	CO_2	Air Quality	Stormwater	Aesthetic/Other	Total ($)	Standard Error
Norway maple	77.33	2.66	14.62	14.09	49.61	158.31	(N/A)
Red maple	80.14	1.51	14.72	16.42	25.87	138.66	(N/A)
Sugar maple	87.30	2.24	15.34	20.51	46.46	171.86	(N/A)
Pin Oak	61.71	1.83	11.19	12.39	41.96	129.08	(N/A)
Silver maple	105.37	2.44	21.01	26.83	29.12	184.77	(N/A)
Northern red oak	113.47	3.27	21.97	26.72	40.58	206.01	(N/A)
OTHER STREET	71.22	1.75	13.56	14.85	33.72	135.10	(N/A)

Past – CO_2 Benefits

Burncoat & Greendale

Annual CO_2 Benefits of All Trees by Species

2/26/2010

Species	Sequestered (lb)	Sequestered ($)	Decomposition Release (lb)	Maintenance Release (lb)	Total Released ($)	Avoided (lb)	Avoided ($)	Net Total (lb)	Total Standard ($) Error	% of Total Trees	% of Total $	Avg. $/tree
Norway maple	1,049,123	3,462	-119,133	-31,900	-498	721,891	2,382	1,619,981	5,346 (N/A)	71.2	77.5	2.66
Red maple	43,294	143	-17,539	-3,955	-71	91,040	300	112,841	372 (N/A)	8.8	5.4	1.51
Sugar maple	65,073	215	-10,503	-3,294	-46	69,118	228	120,393	397 (N/A)	6.3	5.8	2.24
Pin Oak	31,936	105	-8,689	-1,170	-33	29,920	99	51,997	172 (N/A)	3.3	2.5	1.83
Silver maple	25,403	84	-6,954	-1,621	-28	37,050	122	53,877	178 (N/A)	2.6	2.6	2.44
Northern red oak	18,189	60	-3,318	-691	-13	19,542	64	33,723	111 (N/A)	1.2	1.6	3.27
OTHER STREET	49,464	163	-12,110	-2,687	-49	63,794	211	98,461	325 (N/A)	6.6	4.7	1.75
Total	1,282,481	4,232	-178,245	-45,318	-738		3,407	2,091,274	6,901 (N/A)	100.0	100.0	2.45

Past – Complete Population

Worcester

Complete Population of All Trees

2/26/2010

Species	DBH Class (in) 0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total Standard Error
Broadleaf Deciduous Large (BDL)										
Norway maple	11	7	85	546	821	390	108	29	10	2,007
Sugar maple	0	0	1	11	75	70	16	3	1	177
Pin Oak	0	0	14	54	19	5	2	0	0	94
Silver maple	1	0	2	5	15	13	16	14	7	73
Northern red oak	0	1	2	6	3	7	8	5	2	34
White ash	0	1	0	6	7	4	2	3	0	23
White oak	0	2	0	2	4	3	5	2	2	20
American basswood	0	0	0	2	3	3	8	1	1	18
Black cherry	0	0	2	4	4	0	1	0	0	11
Black locust	0	2	0	3	2	2	0	0	0	9
Scarlet oak	0	0	1	3	1	2	0	0	1	8
Sycamore maple	0	0	2	3	1	1	0	0	0	7
American elm	0	1	1	2	1	0	0	1	0	6
Green ash	0	0	1	1	1	2	0	0	0	5
Paper birch	0	0	2	0	1	0	0	0	0	3
Eastern cottonwood	0	0	1	2	0	0	0	0	0	3
Shagbark hickory	0	0	0	0	1	1	0	0	0	2
Quaking aspen	0	0	0	2	0	0	0	0	0	2
River birch	0	0	1	0	0	0	0	0	0	1
Pignut hickory	0	0	0	1	0	0	0	0	0	1
European beech	0	0	0	0	0	0	0	0	1	1
Honeylocust	0	0	0	0	1	0	0	0	0	1
Tmarack	0	0	0	0	1	0	0	0	0	1
London planetree	0	0	1	0	0	0	0	0	0	1
Total	**12**	**14**	**116**	**653**	**961**	**503**	**166**	**58**	**25**	**2,508 (±NaN)**
Broadleaf Deciduous Medium (BDM)										
Red maple	3	5	15	49	99	54	17	4	1	247
Littleleaf linden	0	1	0	4	7	3	3	0	0	18
European white birch	0	2	5	0	0	0	0	0	0	7
Boxelder	0	0	0	2	0	1	0	0	0	3
Northern catalpa	0	0	0	0	2	0	0	0	0	2
White mulberry	0	0	0	1	0	0	0	0	0	1
Total	**3**	**8**	**20**	**56**	**108**	**58**	**20**	**4**	**1**	**278 (±NaN)**
Broadleaf Deciduous Small (BDS)										
Crabapple	2	0	3	2	0	0	0	0	0	7
Cherry plum	0	2	1	2	0	1	0	0	0	6
Callery pear	0	5	1	0	0	0	0	0	0	6
American mountain ash	0	0	1	1	0	0	0	0	0	2
Japanese maple	0	0	1	0	0	0	0	0	0	1
Total	**2**	**7**	**7**	**5**	**0**	**1**	**0**	**0**	**0**	**22 (±NaN)**
Broadleaf Evergreen Large (BEL)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0 (±NaN)**
Broadleaf Evergreen Medium (BEM)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0 (±NaN)**
Broadleaf Evergreen Small (BES)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0 (±NaN)**
Conifer Evergreen Large (CEL)										
Balsam fir	0	1	0	1	0	1	0	0	0	3
Norway spruce	0	0	0	1	0	1	0	0	0	2
Blue Spruce	0	0	0	2	0	0	0	0	0	2
Eastern white pine	0	0	0	1	0	0	0	0	0	1
Total	**0**	**1**	**0**	**5**	**0**	**2**	**0**	**0**	**0**	**8 (±NaN)**
Conifer Evergreen Medium (CEM)										
Eastern red cedar	0	0	1	0	0	0	0	0	0	1

Worcester

Complete Population of All Trees

2/26/2010

	DBH Class (in)									
Species	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total Standard Error
Eastern hemlock	0	0	1	0	0	0	0	0	0	1
Total	**0**	**0**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**2 (±NaN)**
Conifer Evergreen Small (CES)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0 (±NaN)**
Palm Evergreen Large (PEL)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0 (±NaN)**
Palm Evergreen Medium (PEM)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0 (±NaN)**
Palm Evergreen Small (PES)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0 (±NaN)**
Grand Total	**17**	**30**	**145**	**719**	**1,069**	**564**	**186**	**62**	**26**	**2,818 (±0)**

Past – Energy

Burncoat & Greendale

Annual Energy Benefits of All Trees By Species

2/26/2010

Species	Total Electricity (MWh)	Electricity ($)	Total Natural Gas (Therms)	Natural Gas ($)	Total ($)	Standard Error	% of Total Trees	% of Total $	Avg. $/tree
Norway maple	239.7	27,970	87,143.2	127,229	155,199	(N/A)	71.2	70.2	77.33
Red maple	30.2	3,527	11,141.5	16,267	19,794	(N/A)	8.8	9.0	80.14
Sugar maple	22.9	2,678	8,749.8	12,775	15,453	(N/A)	6.3	7.0	87.30
Pin Oak	9.9	1,159	3,179.4	4,642	5,801	(N/A)	3.3	2.6	61.71
Silver maple	12.3	1,436	4,285.2	6,256	7,692	(N/A)	2.6	3.5	105.37
Northern red oak	6.5	757	2,123.8	3,101	3,858	(N/A)	1.2	1.8	113.47
OTHER STREET TREES	21.2	2,472	7,380.3	10,775	13,247	(N/A)	6.6	6.0	71.22
Total	342.7	39,999	124,003.3		221,044	(N/A)	100.0	100.0	78.44

Past – Stored Carbon

Burncoat & Greendale

Stored CO2 Benefits of All Trees by Species

2/26/2010

Species	Total Stored CO2 (lbs)	Total ($)	Standard Error	% of Total Trees	% of Total $	Avg. $/tree
Norway maple	18,011,397	59,438	(N/A)	71.2	70.7	29.62
Red maple	1,394,207	4,601	(N/A)	8.8	5.5	18.63
Sugar maple	2,142,925	7,072	(N/A)	6.3	8.4	39.95
Pin Oak	490,664	1,619	(N/A)	3.3	1.9	17.23
Silver maple	1,445,458	4,770	(N/A)	2.6	5.7	65.34
Northern red oak	634,427	2,094	(N/A)	1.2	2.5	61.58
OTHER STREET	622,427	4,528	(N/A)	6.6	5.4	24.35
Total	25,491,292	84,121	(N/A)	100.0	100.0	29.85

Past – Stormwater

Burncoat & Greendale

Annual Stormwater Benefits of All Trees by Species

2/26/2010

Species	Total rainfall interception (Gal)	Total ($)	Standard Error	% of Total Trees	% of Total $	Avg. $/tree
Norway maple	4,487,749	28,275	(N/A)	71.2	66.1	14.09
Red maple	643,542	4,055	(N/A)	8.8	9.5	16.42
Sugar maple	576,310	3,631	(N/A)	6.3	8.5	20.51
Pin Oak	184,783	1,164	(N/A)	3.3	2.7	12.39
Silver maple	310,904	1,959	(N/A)	2.6	4.6	26.83
Northern red oak	144,208	909	(N/A)	1.2	2.1	26.72
OTHER STREET TREES	438,483	2,763	(N/A)	6.6	6.5	14.85
Total	6,785,978	42,755	(N/A)	100.0	100.0	15.17

Past – Total Annual Benefits

Burncoat & Greendale

Total Annual Benefits of All Trees By Species ($)

2/26/2010

Species	Energy	CO_2	Air Quality	Stormwater	Aesthetic/Other	Total ($)	Standard Error	% of Total $
Norway maple	155,199	5,346	29,345	28,275	99,564	317,729	(±0)	72.2
Red maple	19,794	372	3,637	4,055	6,390	34,248	(±0)	7.8
Sugar maple	15,453	397	2,714	3,631	8,224	30,420	(±0)	6.9
Pin Oak	5,801	172	1,052	1,164	3,945	12,134	(±0)	2.8
Silver maple	7,692	178	1,534	1,959	2,125	13,488	(±0)	3.1
Northern red oak	3,858	111	747	909	1,380	7,004	(±0)	1.6
OTHER STREET	13,247	325	2,523	2,763	6,272	25,129	(±0)	5.7
Total	221,044	6,901	41,552	42,755	127,900	440,152	(±0)	100.0

Appendix B: Street Tree –Present

Present – Aesthetic

Burncoat & Greendale

Annual Aesthetic/Other Benefits of All Trees by Species

2/26/2010

Species	Total ($)	Standard Error	% of Total Trees	% of Total $	Avg. $/tree
Norway maple	117,250	(N/A)	71.1	77.7	59.34
Red maple	7,530	(N/A)	8.8	5.0	30.99
Sugar maple	9,691	(N/A)	6.3	6.4	55.70
Pin oak	4,730	(N/A)	3.4	3.1	50.32
Silver maple	2,476	(N/A)	2.6	1.6	34.88
Northern red oak	1,654	(N/A)	1.2	1.1	48.65
OTHER STREET TREES	7,520	(N/A)	6.7	5.0	40.43
Citywide total	150,851	(N/A)	100.0	100.0	54.30

Present – Air Quality

Burncoat & Greendale

Annual Air Quality Benefits of All Trees by Species

2/26/2010

	Deposition (lb)				Total	Avoided (lb)				Total	BVOC	BVOC	Total	Total	Standard	% of Total	Avg.
Species	O_3	NO_2	PM_{10}	SO_2	Depos. ($)	NO_2	PM_{10}	VOC	SO_2	Avoided ($)	Emissions (lb)	Emissions ($)	(lb)	($)	Error	Trees	$/tree
Norway maple	1,360.5	588.1	668.0	223.2	15,272	2,010.6	130.1	77.1	1,034.0	14,087	-225.1	-520	5,866.7	28,839	(N/A)	71.1	14.59
Red maple	167.6	72.4	83.6	28.0	1,893	255.7	16.6	9.8	130.7	1,789	-41.7	-96	722.6	3,586	(N/A)	8.7	14.76
Sugar maple	132.4	57.3	65.0	21.7	1,487	196.5	12.8	7.6	99.0	1,370	-82.0	-189	510.3	2,667	(N/A)	6.3	15.33
Pin oak	52.3	22.6	26.1	8.7	591	80.4	5.2	3.0	43.6	570	-47.2	-109	194.6	1,052	(N/A)	3.4	11.19
Silver maple	75.8	32.7	37.2	12.4	850	100.4	6.5	3.8	52.6	706	-27.0	-62	294.4	1,494	(N/A)	2.6	21.05
Northern red oak	40.8	17.6	20.4	6.8	461	53.0	3.4	2.0	28.5	375	-38.8	-90	133.7	747	(N/A)	1.2	21.97
OTHER STREET TREES	124.3	53.0	61.3	20.2	1,393	177.5	11.5	6.8	92.9	1,249	-51.6	-119	495.8	2,523	(N/A)	6.7	13.56
Citywide total	1,953.6	843.7	961.5	321.2	21,948	2,874.0	186.0	110.1	1,481.3	20,146	-513.3	-1,186	8,218.0	40,908	(N/A)	100.0	14.73

Present – CO_2 Benefits

Burncoat & Greendale

Annual CO $_2$ Benefits of All Trees by Species

2/26/2010

Species	Sequestered (lb)	Sequestered ($)	Decomposition Release (lb)	Maintenance Release (lb)	Total Released ($)	Avoided (lb)	Avoided ($)	Net Total (lb)	Total Standard ($) Error	% of Total Trees	% of Total $	Avg. $/tree
Norway maple	1,029,514	3,397	-117,240	-31,349	-490	709,658	2,342	1,590,583	5,249 (N/A)	71.1	77.3	2.66
Red maple	42,629	141	-17,207	-3,900	-70	89,701	296	111,223	367 (N/A)	8.8	5.4	1.51
Sugar maple	63,946	211	-10,336	-3,237	-45	67,923	224	118,296	390 (N/A)	6.3	5.8	2.24
Pin oak	31,936	105	-8,689	-1,170	-33	29,920	99	51,997	172 (N/A)	3.4	2.5	1.83
Silver maple	24,713	82	-6,814	-1,580	-28	36,090	119	52,409	173 (N/A)	2.6	2.6	2.44
Northern red oak	18,189	60	-3,318	-691	-13	19,542	64	33,723	111 (N/A)	1.2	1.6	3.27
OTHER STREET	49,464	163	-12,110	-2,687	-49	63,794	211	98,461	325 (N/A)	6.7	4.8	1.75
Citywide total	1,260,392	4,159	-175,713	-44,614	-727		3,355	2,056,693	6,787 (N/A)	100.0	100.0	2.44

Present – Energy Benefits

Burncoat & Greendale

Annual Energy Benefits of All Trees By Species

2/26/2010

Species	Total Electricity (MWh)	Electricity ($)	Total Natural Gas (Therms)	Natural Gas ($)	Total ($)	Standard Error	% of Total Trees	% of Total $	Avg. $/tree
Norway maple	235.6	20,804	85,668.3	65,990	86,795	(N/A)	71.1	70.1	43.92
Red maple	29.8	2,630	10,977.2	8,456	11,085	(N/A)	8.8	9.0	45.62
Sugar maple	22.6	1,991	8,597.6	6,623	8,614	(N/A)	6.3	7.0	49.51
Pin oak	9.9	877	3,179.4	2,449	3,326	(N/A)	3.4	2.7	35.39
Silver maple	12.0	1,058	4,170.4	3,212	4,270	(N/A)	2.6	3.5	60.15
Northern red oak	6.5	573	2,123.8	1,636	2,209	(N/A)	1.2	1.8	64.97
OTHER STREET TREES	21.2	1,870	7,380.3	5,685	7,555	(N/A)	6.7	6.1	40.62
Total	337.5	29,804	122,097.0	94,051	123,855	(N/A)	100.0	100.0	44.58

Present – Stormwater Benefits

Burncoat & Greendale

Annual Stormwater Benefits of All Trees by Species

2/26/2010

Species	Total rainfall interception (Gal)	Total ($)	Standard Error	% of Total Trees	% of Total $	Avg. $/tree
Norway maple	4,406,183	27,761	(N/A)	71.1	66.0	14.05
Red maple	634,815	4,000	(N/A)	8.8	9.5	16.46
Sugar maple	566,319	3,568	(N/A)	6.3	8.5	20.51
Pin oak	184,783	1,164	(N/A)	3.4	2.8	12.39
Silver maple	303,208	1,910	(N/A)	2.6	4.5	26.91
Northern red oak	144,208	909	(N/A)	1.2	2.2	26.72
OTHER STREET TREES	438,483	2,763	(N/A)	6.7	6.6	14.85
Total	6,677,998	42,074	(N/A)	100.0	100.0	15.15

Present – Complete Population

Worcester

Complete Population of All Trees

2/26/2010

Species	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total Standard Error
	DBH Class (in)									
Broadleaf Deciduous Large (BDL)										
Norway maple	11	7	85	546	821	390	108	29	10	2,007
Sugar maple	0	0	1	11	75	70	16	3	1	177
Pin Oak	0	0	14	54	19	5	2	0	0	94
Silver maple	1	0	2	5	15	13	16	14	7	73
Northern red oak	0	1	2	6	3	7	8	5	2	34
White ash	0	1	0	6	7	4	2	3	0	23
White oak	0	2	0	2	4	3	5	2	2	20
American basswood	0	0	0	2	3	3	8	1	1	18
Black cherry	0	0	2	4	4	0	1	0	0	11
Black locust	0	2	0	3	2	2	0	0	0	9
Scarlet oak	0	0	1	3	1	2	0	0	1	8
Sycamore maple	0	0	2	3	1	1	0	0	0	7
American elm	0	1	1	2	1	0	0	1	0	6
Green ash	0	0	1	1	1	2	0	0	0	5
Paper birch	0	0	2	0	1	0	0	0	0	3
Eastern cottonwood	0	0	1	2	0	0	0	0	0	3
Shagbark hickory	0	0	0	0	1	1	0	0	0	2
Quaking aspen	0	0	0	2	0	0	0	0	0	2
River birch	0	0	1	0	0	0	0	0	0	1
Pignut hickory	0	0	0	1	0	0	0	0	0	1
European beech	0	0	0	0	0	0	0	0	1	1
Honeylocust	0	0	0	0	1	0	0	0	0	1
Tmarack	0	0	0	0	1	0	0	0	0	1
London planetree	0	0	1	0	0	0	0	0	0	1
Total	**12**	**14**	**116**	**653**	**961**	**503**	**166**	**58**	**25**	**2,508 (±NaN)**
Broadleaf Deciduous Medium (BDM)										
Red maple	3	5	15	49	99	54	17	4	1	247
Littleleaf linden	0	1	0	4	7	3	3	0	0	18
European white birch	0	2	5	0	0	0	0	0	0	7
Boxelder	0	0	0	2	0	1	0	0	0	3
Northern catalpa	0	0	0	0	2	0	0	0	0	2
White mulberry	0	0	0	1	0	0	0	0	0	1
Total	**3**	**8**	**20**	**56**	**108**	**58**	**20**	**4**	**1**	**278 (±NaN)**
Broadleaf Deciduous Small (BDS)										
Crabapple	2	0	3	2	0	0	0	0	0	7
Cherry plum	0	2	1	2	0	1	0	0	0	6
Callery pear	0	5	1	0	0	0	0	0	0	6
American mountain ash	0	0	1	1	0	0	0	0	0	2
Japanese maple	0	0	1	0	0	0	0	0	0	1
Total	**2**	**7**	**7**	**5**	**0**	**1**	**0**	**0**	**0**	**22 (±NaN)**
Broadleaf Evergreen Large (BEL)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0 (±NaN)**
Broadleaf Evergreen Medium (BEM)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0 (±NaN)**
Broadleaf Evergreen Small (BES)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0 (±NaN)**
Conifer Evergreen Large (CEL)										
Balsam fir	0	1	0	1	0	1	0	0	0	3
Norway spruce	0	0	0	1	0	1	0	0	0	2
Blue Spruce	0	0	0	2	0	0	0	0	0	2
Eastern white pine	0	0	0	1	0	0	0	0	0	1
Total	**0**	**1**	**0**	**5**	**0**	**2**	**0**	**0**	**0**	**8 (±NaN)**
Conifer Evergreen Medium (CEM)										
Eastern red cedar	0	0	1	0	0	0	0	0	0	1

Worcester

Complete Population of All Trees

2/26/2010

Species	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total Standard Error
	DBH Class (in)									
Eastern hemlock	0	0	1	0	0	0	0	0	0	1
Total	**0**	**0**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**2 (±NaN)**
Conifer Evergreen Small (CES)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0 (±NaN)**
Palm Evergreen Large (PEL)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0 (±NaN)**
Palm Evergreen Medium (PEM)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0 (±NaN)**
Palm Evergreen Small (PES)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0 (±NaN)**
Grand Total	**17**	**30**	**145**	**719**	**1,069**	**564**	**186**	**62**	**26**	**2,818 (±0)**

Present – CO_2 Benefits

Burncoat & Greendale

Stored CO2 Benefits of All Trees by Species

2/26/2010

Species	Total Stored CO2 (lbs)	Total ($)	Standard Error	% of Total Trees	% of Total $	Avg. $/tree
Norway maple	17,657,369	58,269	(N/A)	71.1	70.5	29.49
Red maple	1,379,378	4,552	(N/A)	8.8	5.5	18.73
Sugar maple	2,106,420	6,951	(N/A)	6.3	8.4	39.95
Pin oak	490,664	1,619	(N/A)	3.4	2.0	17.23
Silver maple	1,414,708	4,669	(N/A)	2.6	5.7	65.75
Northern red oak	634,427	2,094	(N/A)	1.2	2.5	61.58
OTHER STREET	622,427	4,528	(N/A)	6.7	5.5	24.35
Total	25,055,180	82,682	(N/A)	100.0	100.0	29.76

Present – Total Annual Benefits

Burncoat & Greendale

Total Annual Benefits of All Trees By Species ($)

2/26/201

Species	Energy	CO_2	Air Quality	Stormwater	Aesthetic/Other	Total ($)	Standard Error	% of Total $
Norway maple	86,795	5,249	28,839	27,761	117,250	265,893	(±0)	73.0
Red maple	11,085	367	3,586	4,000	7,530	26,568	(±0)	7.3
Sugar maple	8,614	390	2,667	3,568	9,691	24,931	(±0)	6.8
Pin oak	3,326	172	1,052	1,164	4,730	10,444	(±0)	2.9
Silver maple	4,270	173	1,494	1,910	2,476	10,324	(±0)	2.8
Northern red oak	2,209	111	747	909	1,654	5,630	(±0)	1.5
OTHER STREET	7,555	325	2,523	2,763	7,520	20,686	(±0)	5.7
Total	123,855	6,787	40,908	42,074	150,851	364,475	(±0)	100.0

Appendix C: Full Tree Inventory – Removals

Removals – Aesthetic

Burncoat & Greendale

Annual Aesthetic/Other Benefits of All Trees by Species

2/26/2010

Species	Total ($)	Standard Error	% of Total Trees	% of Total $	Avg. $/tree
Norway maple	79,592	(N/A)	36.0	30.0	25.76
Maple	40,373	(N/A)	23.7	15.2	19.82
White poplar	40,679	(N/A)	9.9	15.3	47.63
Birch	20,403	(N/A)	6.5	7.7	36.50
Elm	27,913	(N/A)	6.4	10.5	51.12
Ash	15,114	(N/A)	5.4	5.7	32.50
Red maple	10,637	(N/A)	3.6	4.0	34.20
Black Maple	7,041	(N/A)	2.3	2.7	36.29
White ash	3,775	(N/A)	1.2	1.4	37.01
Gray birch	3,144	(N/A)	1.0	1.2	36.56
OTHER STREET TREES	16,856	(N/A)	4.1	6.4	48.30
Total	265,527	(N/A)	100.0	100.0	30.90

Removals – Air Quality

Burncoat & Greendale

Annual Air Quality Benefits of All Trees by Species

2/26/2010

Species	Deposition (lb)				Total Depos. ($)	Avoided (lb)				Total Avoided ($)	BVOC Emissions (lb)	BVOC Emissions ($)	Total (lb)	Total ($)	Standard Error	% of Total Trees	Avg. $/tree
	O_3	NO_2	PM_{10}	SO_2		NO_2	PM_{10}	VOC	SO_2								
Norway maple	811.6	350.9	398.5	133.2	9,111	1,282.2	83.3	49.8	639.2	8,917	-121.9	-282	3,626.8	17,746	(N/A)	36.0	5.74
Maple	387.4	167.5	190.2	63.6	4,349	630.9	41.1	24.7	308.4	4,368	-55.5	-128	1,758.3	8,589	(N/A)	23.7	4.22
White poplar	142.8	60.0	68.8	21.9	1,580	382.1	24.9	15.0	183.4	2,634	0.0	0	899.1	4,214	(N/A)	9.9	4.93
Birch	70.1	30.3	35.0	11.7	792	127.6	8.4	5.1	60.0	876	-23.4	-54	324.6	1,613	(N/A)	6.5	2.89
Elm	111.6	45.2	53.0	17.1	1,219	199.7	13.0	7.7	100.4	1,391	0.0	0	547.6	2,611	(N/A)	6.4	4.78
Ash	131.9	55.4	63.6	20.3	1,459	220.2	14.3	8.5	109.6	1,531	0.0	0	623.8	2,989	(N/A)	5.4	6.43
Red maple	110.5	47.7	55.1	18.4	1,249	180.2	11.7	7.0	90.5	1,255	-29.6	-68	491.6	2,436	(N/A)	3.6	7.83
Black Maple	24.1	10.4	12.0	4.0	273	42.4	2.8	1.7	20.4	293	-7.7	-18	110.2	548	(N/A)	2.3	2.82
White ash	47.2	19.8	22.8	7.3	522	75.0	4.9	2.9	38.2	524	0.0	0	218.0	1,046	(N/A)	1.2	10.26
Gray birch	10.1	4.4	5.1	1.7	115	18.4	1.2	0.7	8.7	126	-3.2	-7	47.0	233	(N/A)	1.0	2.71
OTHER STREET TREES	161.6	68.8	78.7	25.9	1,801	259.8	16.8	10.0	132.0	1,815	-52.1	-120	701.4	3,496	(N/A)	4.1	10.02
Total	2,009.1	860.5	982.7	325.0	22,469	3,418.5	222.4	133.0	1,690.8	23,730	-293.4	-678	9,348.5	45,521	(N/A)	100.0	5.30

Removals – CO_2 Benefits

Burncoat & Greendale

Annual CO_2 Benefits of All Trees by Species

2/26/2010

Species	Sequestered (lb)	Sequestered ($)	Decomposition Release (lb)	Maintenance Release (lb)	Total Released ($)	Avoided (lb)	Avoided ($)	Net Total (lb)	Total Standard ($) Error	% of Total Trees	% of Total $	Avg. $/tree
Norway maple	555,316	1,833	-80,151	-21,991	-337	438,555	1,447	891,729	2,943 (N/A)	36.0	44.1	0.95
Maple	251,701	831	-38,440	-11,485	-165	211,504	698	413,281	1,364 (N/A)	23.7	20.4	0.67
White poplar	47,848	158	-9,513	-3,650	-43	125,764	415	160,450	529 (N/A)	9.9	7.9	0.62
Birch	28,719	95	-5,683	-2,451	-27	41,153	136	61,739	204 (N/A)	6.5	3.1	0.36
Elm	58,059	192	-11,481	-3,092	-48	68,865	227	112,350	371 (N/A)	6.4	5.6	0.68
Ash	34,376	113	-6,315	-3,069	-31	75,200	248	100,192	331 (N/A)	5.4	5.0	0.71
Red maple	30,468	101	-10,388	-2,905	-44	62,100	205	79,275	262 (N/A)	3.6	3.9	0.84
Black Maple	9,123	30	-1,842	-822	-9	13,968	46	20,427	67 (N/A)	2.3	1.0	0.35
White ash	13,289	44	-2,380	-995	-11	26,202	86	36,116	119 (N/A)	1.2	1.8	1.17
Gray birch	4,063	13	-820	-350	-4	5,949	20	8,842	29 (N/A)	1.0	0.4	0.34
OTHER STREET	65,496	216	-14,541	-3,768	-60	90,582	299	137,770	455 (N/A)	4.1	6.8	1.30
Citywide total	1,098,460	3,625	-181,553	-54,578	-779		3,827	2,022,170	6,673 (N/A)	100.0	100.0	0.78

Removals – Complete Population

Worcester Page 1 of 2

Complete Population of All Trees

2/26/2010

Species	DBH Class (in) 0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total Standard Error
Broadleaf Deciduous Large (BDL)										
Norway maple	689	827	700	383	288	135	47	16	5	3,090
White poplar	277	336	172	40	13	14	1	0	1	854
Elm	88	207	179	46	10	11	2	1	2	546
Ash	72	151	136	66	20	13	4	0	3	465
White ash	3	24	27	26	13	5	1	2	1	102
Sugar maple	4	13	7	6	19	20	6	7	3	85
Cottonwood	8	14	14	17	6	2	2	1	1	65
American elm	8	17	12	10	3	2	3	0	0	55
Silver maple	0	6	3	2	7	4	6	4	6	38
Bigtooth aspen	3	13	3	0	1	0	0	0	0	20
Paper birch	3	4	4	5	0	0	0	0	0	16
London planetree	3	4	6	0	0	0	0	0	0	13
Quaking aspen	0	2	3	0	0	0	0	0	0	5
Black birch	0	1	2	0	0	0	0	0	0	3
Sycamore maple	1	0	1	0	0	0	0	0	0	2
Horsechestnut	0	0	1	0	0	0	0	1	0	2
River birch	0	0	1	1	0	0	0	0	0	2
Northern hackberry	1	0	0	0	0	0	0	0	0	1
Green ash	0	0	0	0	1	0	0	0	0	1
Sycamore	0	0	1	0	0	0	0	0	0	1
Linden	0	0	1	0	0	0	0	0	0	1
Siberian elm	1	0	0	0	0	0	0	0	0	1
Total	**1,161**	**1,619**	**1,273**	**602**	**381**	**206**	**72**	**32**	**22**	**5,368 (±NaN)**
Broadleaf Deciduous Medium (BDM)										
Maple	470	778	447	164	107	44	18	5	4	2,037
Birch	116	284	125	19	10	4	0	1	0	559
Red maple	37	62	86	54	35	22	5	6	4	311
Black Maple	64	84	30	9	2	2	2	1	0	194
Gray birch	34	24	23	3	1	1	0	0	0	86
Slippery elm	0	1	4	2	1	0	0	0	0	8
European white birch	0	4	1	0	0	0	0	0	0	5
Pussy Willow	0	1	2	1	0	0	0	0	0	4
Paperbark Maple	1	2	0	0	0	0	0	0	0	3
Katsua Tree	0	0	0	1	0	0	0	0	0	1
Willow	0	0	0	0	0	0	0	0	1	1
Weeping willow	0	0	0	0	0	1	0	0	0	1
Goat willow	0	0	0	0	1	0	0	0	0	1
Black willow	0	0	0	0	0	1	0	0	0	1
Total	**722**	**1,240**	**718**	**253**	**157**	**75**	**25**	**13**	**9**	**3,212 (±NaN)**
Broadleaf Deciduous Small (BDS)										
American mountain ash	1	3	5	2	0	1	0	0	0	12
Japanese maple	0	1	0	0	0	0	0	0	0	1
Total	**1**	**4**	**5**	**2**	**0**	**1**	**0**	**0**	**0**	**13 (±NaN)**
Broadleaf Evergreen Large (BEL)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0 (±NaN)**
Broadleaf Evergreen Medium (BEM)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0 (±NaN)**
Broadleaf Evergreen Small (BES)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0 (±NaN)**
Conifer Evergreen Large (CEL)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0 (±NaN)**
Conifer Evergreen Medium (CEM)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0 (±NaN)**

Worcester

Complete Population of All Trees

2/26/2010

Species	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total Standard Error
	DBH Class (in)									
Conifer Evergreen Small (CES)										
Total	0	0	0	0	0	0	0	0	0	0 (±NaN)
Palm Evergreen Large (PEL)										
Total	0	0	0	0	0	0	0	0	0	0 (±NaN)
Palm Evergreen Medium (PEM)										
Total	0	0	0	0	0	0	0	0	0	0 (±NaN)
Palm Evergreen Small (PES)										
Total	0	0	0	0	0	0	0	0	0	0 (±NaN)
Grand Total	1,884	2,863	1,996	857	538	282	97	45	31	8,593 (±0)

Removals – Energy Benefits

Burncoat & Greendale

Annual Energy Benefits of All Trees By Species

2/26/2010

Species	Total Electricity (MWh)	Electricity ($)	Total Natural Gas (Therms)	Natural Gas ($)	Total ($)	Standard Error	% of Total Trees	% of Total $	Avg. $/tree
Norway maple	145.6	16,992	56,834.9	82,905	99,897	(N/A)	36.0	37.3	32.33
Maple	70.2	8,195	28,641.4	41,779	49,974	(N/A)	23.7	18.6	24.53
White poplar	41.8	4,873	17,707.6	25,830	30,703	(N/A)	9.9	11.5	35.95
Birch	13.7	1,594	6,050.9	8,826	10,421	(N/A)	6.5	3.9	18.64
Elm	22.9	2,668	8,760.6	12,779	15,447	(N/A)	6.4	5.8	28.29
Ash	25.0	2,914	9,774.2	14,258	17,171	(N/A)	5.4	6.4	36.93
Red maple	20.6	2,406	7,911.9	11,541	13,947	(N/A)	3.6	5.2	44.85
Black Maple	4.6	541	1,967.3	2,870	3,411	(N/A)	2.3	1.3	17.58
White ash	8.7	1,015	3,237.8	4,723	5,738	(N/A)	1.2	2.1	56.26
Gray birch	2.0	230	865.1	1,262	1,492	(N/A)	1.0	0.6	17.35
OTHER STREET TREES	30.1	3,510	11,244.2	16,402	19,912	(N/A)	4.1	7.4	57.05
Total	385.1	44,938	152,996.1	223,175	268,114	(N/A)	100.0	100.0	31.20

Removals – Stored CO_2 Benefits

Burncoat & Greendale

Stored CO2 Benefits of All Trees by Species

2/26/2010

Species	Total Stored CO2 (lbs)	Total ($)	Standard Error	% of Total Trees	% of Total $	Avg. $/tree
Norway maple	8,380,236	27,655	(N/A)	36.0	49.2	8.95
Maple	3,483,814	11,497	(N/A)	23.7	20.4	5.64
White poplar	451,671	1,491	(N/A)	9.9	2.7	1.75
Birch	292,186	964	(N/A)	6.5	1.7	1.72
Elm	622,009	2,053	(N/A)	6.4	3.7	3.76
Ash	575,851	1,900	(N/A)	5.4	3.4	4.09
Red maple	777,781	2,567	(N/A)	3.6	4.6	8.25
Black Maple	128,393	424	(N/A)	2.3	0.8	2.18
White ash	267,936	884	(N/A)	1.2	1.6	8.67
Gray birch	43,532	144	(N/A)	1.0	0.3	1.67
OTHER STREET	919,069	6,686	(N/A)	4.1	11.9	19.16
Total	17,049,607	56,264	(N/A)	100.0	100.0	6.55

Removals – Stormwater

Burncoat & Greendale

Annual Stormwater Benefits of All Trees by Species

2/26/2010

Species	Total rainfall interception (Gal)	Total ($)	Standard Error	% of Total Trees	% of Total $	Avg. $/tree
Norway maple	2,494,564	15,717	(N/A)	36.0	37.1	5.09
Maple	1,161,276	7,317	(N/A)	23.7	17.3	3.59
White poplar	497,161	3,132	(N/A)	9.9	7.4	3.67
Birch	308,164	1,942	(N/A)	6.5	4.6	3.47
Elm	431,258	2,717	(N/A)	6.4	6.4	4.98
Ash	448,180	2,824	(N/A)	5.4	6.7	6.07
Red maple	434,143	2,735	(N/A)	3.6	6.5	8.80
Black Maple	103,454	652	(N/A)	2.3	1.5	3.36
White ash	159,600	1,006	(N/A)	1.2	2.4	9.86
Gray birch	43,300	273	(N/A)	1.0	0.6	3.17
OTHER STREET TREES	639,520	4,029	(N/A)	4.1	9.5	11.55
Total	6,720,620	42,343	(N/A)	100.0	100.0	4.93

Removals – Total Benefits

Burncoat & Greendale

Total Annual Benefits of All Trees By Species ($)

2/26/2010

Species	Energy	CO_2	Air Quality	Stormwater	Aesthetic/Other	Total ($)	Standard Error	% of Total $
Norway maple	99,897	2,943	17,746	15,717	79,592	215,895	(±0)	34.4
Maple	49,974	1,364	8,589	7,317	40,373	107,617	(±0)	17.1
White poplar	30,703	529	4,214	3,132	40,679	79,257	(±0)	12.6
Birch	10,421	204	1,613	1,942	20,403	34,583	(±0)	5.5
Elm	15,447	371	2,611	2,717	27,913	49,059	(±0)	7.8
Ash	17,171	331	2,989	2,824	15,114	38,429	(±0)	6.1
Red maple	13,947	262	2,436	2,735	10,637	30,017	(±0)	4.8
Black Maple	3,411	67	548	652	7,041	11,719	(±0)	1.9
White ash	5,738	119	1,046	1,006	3,775	11,684	(±0)	1.9
Gray birch	1,492	29	233	273	3,144	5,172	(±0)	0.8
OTHER STREET	19,912	455	3,496	4,029	16,856	44,747	(±0)	7.1
Total	268,114	6,673	45,521	42,343	265,527	628,178	(±0)	100.0

Appendix D: Full Tree Inventory – Re-plantings

Re-plantings – Aesthetic

Burncoat & Greendale

Annual Aesthetic/Other Benefits of All Trees by Species

3/4/2010

Species	Total ($)	Standard Error	% of Total Trees	% of Total $	Avg. $/tree
Sweetgum	1,487	(N/A)	7.8	5.4	11.18
Kousa dogwood	779	(N/A)	7.7	2.8	5.95
Kwanzan cherry	749	(N/A)	7.4	2.7	5.95
Japanese tree lilac	737	(N/A)	7.2	2.7	5.95
Apple	673	(N/A)	7.0	2.5	5.65
Black tupelo	4,246	(N/A)	7.0	15.5	35.68
Littleleaf linden	3,213	(N/A)	6.7	11.7	28.19
White oak	2,256	(N/A)	5.6	8.2	23.75
Sargent cherry	553	(N/A)	5.4	2.0	5.95
Dawn redwood	2,397	(N/A)	4.2	8.7	33.30
Northern red oak	1,361	(N/A)	3.7	5.0	21.26
Crabapple	351	(N/A)	3.6	1.3	5.65
Callery pear	1,053	(N/A)	3.6	3.8	16.99
Honeylocust	1,723	(N/A)	3.3	6.3	30.22
Plum	273	(N/A)	2.7	1.0	5.95
Swamp white oak	950	(N/A)	2.3	3.5	23.75
English oak	765	(N/A)	2.1	2.8	21.26
Black oak	723	(N/A)	2.0	2.6	21.26
Common Linden	620	(N/A)	1.3	2.3	28.19
Ginkgo	87	(N/A)	1.2	0.3	4.12
Common pear	357	(N/A)	1.2	1.3	16.99
Scarlet oak	499	(N/A)	1.2	1.8	23.75
OTHER STREET TREES	1,609	(N/A)	5.9	5.9	15.93
Total	27,460	(N/A)	100.0	100.0	16.03

Re-plantings – Air Quality

Burncoat & Greendale

Annual Air Quality Benefits of All Trees by Species

3/4/2010

Species	Deposition (lb) O_3	Deposition (lb) NO_2	Deposition (lb) PM_{10}	Deposition (lb) SO_2	Total Depos. ($)	Avoided (lb) NO_2	Avoided (lb) PM_{10}	Avoided (lb) VOC	Avoided (lb) SO_2	Total Avoided ($)	BVOC Emissions (lb)	BVOC Emissions ($)	Total (lb)	Total ($)	Standard Error	% of Total Trees	Avg. $/tree
Sweetgum	0.4	0.2	0.2	0.1	5	0.9	0.1	0.0	0.4	6	-3.3	-8	-1.0	3	(N/A)	7.8	0.02
Kousa dogwood	2.5	1.1	1.2	0.4	28	5.1	0.3	0.2	2.1	34	0.0	0	12.9	62	(N/A)	7.6	0.47
Kwanzan cherry	2.4	1.0	1.2	0.4	27	4.9	0.3	0.2	2.0	33	0.0	0	12.4	60	(N/A)	7.4	0.47
Japanese tree lilac	2.3	1.0	1.2	0.4	26	4.8	0.3	0.2	2.0	32	0.0	0	12.2	59	(N/A)	7.2	0.47
Apple	1.7	0.7	0.8	0.3	19	3.2	0.2	0.1	1.3	21	0.0	0	8.4	40	(N/A)	6.9	0.34
Black tupelo	0.9	0.4	0.4	0.1	10	1.8	0.1	0.1	0.7	12	-0.2	-1	4.3	21	(N/A)	6.9	0.18
Littleleaf linden	0.4	0.2	0.2	0.1	5	0.9	0.1	0.0	0.4	6	-0.4	-1	1.7	9	(N/A)	6.7	0.08
White oak	3.6	1.6	1.8	0.6	41	7.4	0.5	0.3	3.2	50	-2.7	-6	16.3	85	(N/A)	5.5	0.89
Sargent cherry	1.8	0.8	0.9	0.3	20	3.6	0.2	0.1	1.5	24	0.0	0	9.2	44	(N/A)	5.4	0.47
Dawn redwood	0.7	0.3	0.4	0.1	8	10.4	0.7	0.4	4.6	70	0.0	0	17.6	79	(N/A)	4.2	1.09
Northern red oak	0.7	0.3	0.3	0.1	7	1.3	0.1	0.1	0.6	9	-1.1	-3	2.3	14	(N/A)	3.7	0.22
Crabapple	0.9	0.4	0.4	0.2	10	1.7	0.1	0.1	0.7	11	0.0	0	4.4	21	(N/A)	3.6	0.34
Callery pear	0.6	0.2	0.3	0.1	6	1.0	0.1	0.0	0.4	7	0.0	0	2.7	13	(N/A)	3.6	0.21
Honeylocust	0.7	0.3	0.4	0.1	8	1.6	0.1	0.1	0.7	11	-0.1	0	3.8	19	(N/A)	3.3	0.32
Plum	0.9	0.4	0.4	0.1	10	1.8	0.1	0.1	0.7	12	0.0	0	4.5	22	(N/A)	2.7	0.47
Swamp white oak	1.5	0.7	0.8	0.3	17	3.1	0.2	0.1	1.3	21	-1.1	-3	6.9	36	(N/A)	2.3	0.89
English oak	0.4	0.2	0.2	0.1	4	0.8	0.1	0.0	0.3	5	-0.6	-1	1.3	8	(N/A)	2.1	0.22
Black oak	0.3	0.1	0.2	0.1	4	0.7	0.0	0.0	0.3	5	-0.6	-1	1.2	7	(N/A)	2.0	0.22
Common Linden	0.1	0.0	0.0	0.0	1	0.2	0.0	0.0	0.1	1	-0.1	0	0.3	2	(N/A)	1.3	0.08
Ginkgo	0.1	0.0	0.0	0.0	1	0.2	0.0	0.0	0.1	1	0.0	0	0.4	2	(N/A)	1.2	0.10
Common pear	0.2	0.1	0.1	0.0	2	0.3	0.0	0.0	0.1	2	0.0	0	0.9	4	(N/A)	1.2	0.21
Scarlet oak	0.8	0.3	0.4	0.1	9	1.6	0.1	0.1	0.7	11	-0.6	-1	3.6	19	(N/A)	1.2	0.89
OTHER STREET TREES	1.6	0.7	0.8	0.3	18	3.0	0.2	0.1	1.3	20	-0.9	-2	7.2	37	(N/A)	5.9	0.36
Total	25.5	11.0	12.6	4.2	287	60.4	4.0	2.5	25.5	405	-11.9	-28	133.7	664	(N/A)	100.0	0.39

Re-planting – CO_2 Benefits

Burncoat & Greendale

Annual CO_2 Benefits of All Trees by Species

3/4/2010

Species	Sequestered (lb)	Sequestered ($)	Decomposition Release (lb)	Maintenance Release (lb)	Total Released ($)	Avoided (lb)	Avoided ($)	Net Total (lb)	Total Standard ($) Error	% of Total Trees	% of Total $	Avg. $/tree
Sweetgum	422	1	-13	-152	-1	282	1	539	2 (N/A)	7.8	2.1	0.01
Kousa dogwood	797	3	-29	-150	-1	1,447	5	2,065	7 (N/A)	7.7	8.0	0.05
Kwanzan cherry	767	3	-28	-144	-1	1,391	5	1,987	7 (N/A)	7.4	7.7	0.05
Japanese tree lilac	755	2	-27	-142	-1	1,369	5	1,955	6 (N/A)	7.2	7.6	0.05
Apple	725	2	-37	-136	-1	879	3	1,431	5 (N/A)	7.0	5.5	0.04
Black tupelo	1,096	4	-41	-136	-1	498	2	1,417	5 (N/A)	7.0	5.5	0.04
Littleleaf linden	723	2	-19	-130	0	242	1	816	3 (N/A)	6.7	3.2	0.02
White oak	674	2	-23	-109	0	2,194	7	2,736	9 (N/A)	5.6	10.6	0.10
Sargent cherry	566	2	-21	-106	0	1,027	3	1,466	5 (N/A)	5.4	5.7	0.05
Dawn redwood	484	2	-6	-82	0	3,153	10	3,549	12 (N/A)	4.2	13.7	0.16
Northern red oak	424	1	-18	-73	0	377	1	709	2 (N/A)	3.7	2.7	0.04
Crabapple	378	1	-19	-71	0	458	2	745	2 (N/A)	3.6	2.9	0.04
Callery pear	399	1	-4	-71	0	269	1	593	2 (N/A)	3.6	2.3	0.03
Honeylocust	370	1	-18	-65	0	449	1	736	2 (N/A)	3.3	2.9	0.04
Plum	280	1	-10	-53	0	508	2	725	2 (N/A)	2.7	2.8	0.05
Swamp white oak	284	1	-10	-46	0	924	3	1,152	4 (N/A)	2.3	4.5	0.10
English oak	238	1	-10	-41	0	212	1	399	1 (N/A)	2.1	1.5	0.04
Black oak	225	1	-10	-39	0	200	1	377	1 (N/A)	2.0	1.5	0.04
Common Linden	140	0	-4	-25	0	47	0	158	1 (N/A)	1.3	0.6	0.02
Ginkgo	67	0	-2	-24	0	55	0	96	0 (N/A)	1.2	0.4	0.02
Common pear	135	0	-1	-24	0	91	0	201	1 (N/A)	1.2	0.8	0.03
Scarlet oak	149	0	-5	-24	0	485	2	605	2 (N/A)	1.2	2.3	0.10
OTHER STREET	665	2	-19	-115	0	874	3	1,405	5 (N/A)	5.9	5.4	0.05
Total	10,761	36	-372	-1,957	-8	17,431	58	25,863	85 (N/A)	100.0	100.0	0.05

Re-planting – Energy Benefits

Burncoat & Greendale

Annual Energy Benefits of All Trees By Species

3/4/2010

Species	Total Electricity (MWh)	Electricity ($)	Total Natural Gas (Therms)	Natural Gas ($)	Total ($)	Standard Error	% of Total Trees	% of Total $	Avg. $/tree
Sweetgum	0.1	8	48.7	37	46	(N/A)	7.8	1.5	0.34
Kousa dogwood	0.5	42	273.9	211	253	(N/A)	7.7	8.5	1.93
Kwanzan cherry	0.5	41	263.4	203	244	(N/A)	7.4	8.2	1.93
Japanese tree lilac	0.5	40	259.2	200	240	(N/A)	7.2	8.1	1.93
Apple	0.3	26	175.6	135	161	(N/A)	7.0	5.4	1.35
Black tupelo	0.2	15	96.8	75	89	(N/A)	7.0	3.0	0.75
Littleleaf linden	0.1	7	45.6	35	42	(N/A)	6.7	1.4	0.37
White oak	0.7	64	379.5	292	357	(N/A)	5.6	12.0	3.75
Sargent cherry	0.3	30	194.4	150	180	(N/A)	5.4	6.1	1.93
Dawn redwood	1.0	92	525.4	405	497	(N/A)	4.2	16.8	6.91
Northern red oak	0.1	11	73.2	56	67	(N/A)	3.7	2.3	1.05
Crabapple	0.2	13	91.5	70	84	(N/A)	3.6	2.8	1.35
Callery pear	0.1	8	54.2	42	50	(N/A)	3.6	1.7	0.80
Honeylocust	0.1	13	86.4	67	80	(N/A)	3.3	2.7	1.40
Plum	0.2	15	96.2	74	89	(N/A)	2.7	3.0	1.93
Swamp white oak	0.3	27	159.8	123	150	(N/A)	2.3	5.1	3.75
English oak	0.1	6	41.1	32	38	(N/A)	2.1	1.3	1.05
Black oak	0.1	6	38.9	30	36	(N/A)	2.0	1.2	1.05
Common Linden	0.0	1	8.8	7	8	(N/A)	1.3	0.3	0.37
Ginkgo	0.0	2	10.1	8	9	(N/A)	1.2	0.3	0.45
Common pear	0.0	3	18.4	14	17	(N/A)	1.2	0.6	0.80
Scarlet oak	0.2	14	83.9	65	79	(N/A)	1.2	2.7	3.75
OTHER STREET TREES	0.3	26	161.3	124	150	(N/A)	5.9	5.1	1.48
Total	5.8	511	3,186.2		2,965	(N/A)	100.0	100.0	1.73

Re-planting – Total Population

Worcester

Page 1 of 2

Complete Population of All Trees

3/4/2010

Species	DBH Class (in) 0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total Standard Error
Broadleaf Deciduous Large (BDL)										
Sweetgum	133	0	0	0	0	0	0	0	0	133
White oak	95	0	0	0	0	0	0	0	0	95
Dawn redwood	72	0	0	0	0	0	0	0	0	72
Northern red oak	64	0	0	0	0	0	0	0	0	64
Honeylocust	57	0	0	0	0	0	0	0	0	57
Swamp white oak	40	0	0	0	0	0	0	0	0	40
English oak	36	0	0	0	0	0	0	0	0	36
Black oak	34	0	0	0	0	0	0	0	0	34
Ginkgo	21	0	0	0	0	0	0	0	0	21
Scarlet oak	21	0	0	0	0	0	0	0	0	21
American basswood	17	0	0	0	0	0	0	0	0	17
Pin oak	8	0	0	0	0	0	0	0	0	8
Oak	7	0	0	0	0	0	0	0	0	7
Total	**605**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**605 (±NaN)**
Broadleaf Deciduous Medium (BDM)										
Black tupelo	119	0	0	0	0	0	0	0	0	119
Littleleaf linden	114	0	0	0	0	0	0	0	0	114
Common Linden	22	0	0	0	0	0	0	0	0	22
Eastern hophornbeam	13	0	0	0	0	0	0	0	0	13
Total	**268**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**268 (±NaN)**
Broadleaf Deciduous Small (BDS)										
Kousa dogwood	131	0	0	0	0	0	0	0	0	131
Kwanzan cherry	126	0	0	0	0	0	0	0	0	126
Japanese tree lilac	124	0	0	0	0	0	0	0	0	124
Apple	119	0	0	0	0	0	0	0	0	119
Sargent cherry	93	0	0	0	0	0	0	0	0	93
Crabapple	62	0	0	0	0	0	0	0	0	62
Callery pear	62	0	0	0	0	0	0	0	0	62
Plum	46	0	0	0	0	0	0	0	0	46
Common pear	21	0	0	0	0	0	0	0	0	21
Higan cherry	15	0	0	0	0	0	0	0	0	15
Eastern redbud	9	0	0	0	0	0	0	0	0	9
Dogwood	3	0	0	0	0	0	0	0	0	3
Total	**811**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**811 (±NaN)**
Broadleaf Evergreen Large (BEL)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0 (±NaN)**
Broadleaf Evergreen Medium (BEM)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0 (±NaN)**
Broadleaf Evergreen Small (BES)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0 (±NaN)**
Conifer Evergreen Large (CEL)										
White fir	16	0	0	0	0	0	0	0	0	16
Total	**16**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**16 (±NaN)**
Conifer Evergreen Medium (CEM)										
Northern white cedar	13	0	0	0	0	0	0	0	0	13
Total	**13**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**13 (±NaN)**
Conifer Evergreen Small (CES)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0 (±NaN)**
Palm Evergreen Large (PEL)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0 (±NaN)**
Palm Evergreen Medium (PEM)										

Complete Population of All Trees

3/4/2010

Species	DBH Class (in) 0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total Standard Error
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0 (±NaN)**
Palm Evergreen Small (PES)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0 (±NaN)**
Grand Total	**1,713**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1,713 (±0)**

Re-planting – Stored Carbon

Burncoat & Greendale

Stored CO2 Benefits of All Trees by Species

3/4/2010

Species	Total Stored CO2 (lbs)	Total ($)	Standard Error	% of Total Trees	% of Total $	Avg. $/tree
Sweetgum	566	2	(N/A)	7.8	3.2	0.01
Kousa dogwood	1,290	4	(N/A)	7.7	7.4	0.03
Kwanzan cherry	1,241	4	(N/A)	7.4	7.1	0.03
Japanese tree lilac	1,221	4	(N/A)	7.2	7.0	0.03
Apple	1,640	5	(N/A)	7.0	9.4	0.05
Black tupelo	1,829	6	(N/A)	7.0	10.4	0.05
Littleleaf linden	864	3	(N/A)	6.7	4.9	0.03
White oak	1,029	3	(N/A)	5.6	5.9	0.04
Sargent cherry	916	3	(N/A)	5.4	5.2	0.03
Dawn redwood	273	1	(N/A)	4.2	1.6	0.01
Northern red oak	803	3	(N/A)	3.7	4.6	0.04
Crabapple	855	3	(N/A)	3.6	4.9	0.05
Callery pear	855	3	(N/A)	3.6	4.9	0.05
Honeylocust	786	3	(N/A)	3.3	4.5	0.05
Plum	453	2	(N/A)	2.7	2.6	0.03
Swamp white oak	433	1	(N/A)	2.3	2.5	0.04
English oak	452	1	(N/A)	2.1	2.6	0.04
Black oak	427	1	(N/A)	2.0	2.4	0.04
Common Linden	167	1	(N/A)	1.3	1.0	0.03
Ginkgo	91	0	(N/A)	1.2	0.5	0.01
Common pear	289	1	(N/A)	1.2	1.7	0.05
Scarlet oak	227	1	(N/A)	1.2	1.3	0.04
OTHER STREET	377	3	(N/A)	5.9	4.7	0.03
Total	17,538	58	(N/A)	100.0	100.0	0.03

Re-planting – Stormwater

Burncoat & Greendale

Annual Stormwater Benefits of All Trees by Species

3/4/2010

Species	Total rainfall interception (Gal)	Total ($)	Standard Error	% of Total Trees	% of Total $	Avg. $/tree
Sweetgum	2,371	15	(N/A)	7.8	3.0	0.11
Kousa dogwood	6,561	41	(N/A)	7.7	8.2	0.32
Kwanzan cherry	6,311	40	(N/A)	7.4	7.9	0.32
Japanese tree lilac	6,210	39	(N/A)	7.2	7.8	0.32
Apple	4,329	27	(N/A)	7.0	5.4	0.23
Black tupelo	3,379	21	(N/A)	7.0	4.2	0.18
Littleleaf linden	1,897	12	(N/A)	6.7	2.4	0.10
White oak	11,451	72	(N/A)	5.6	14.3	0.76
Sargent cherry	4,658	29	(N/A)	5.4	5.8	0.32
Dawn redwood	4,270	27	(N/A)	4.2	5.3	0.37
Northern red oak	3,128	20	(N/A)	3.7	3.9	0.31
Crabapple	2,255	14	(N/A)	3.6	2.8	0.23
Callery pear	2,376	15	(N/A)	3.6	3.0	0.24
Honeylocust	1,625	10	(N/A)	3.3	2.0	0.18
Plum	2,304	15	(N/A)	2.7	2.9	0.32
Swamp white oak	4,821	30	(N/A)	2.3	6.0	0.76
English oak	1,759	11	(N/A)	2.1	2.2	0.31
Black oak	1,662	10	(N/A)	2.0	2.1	0.31
Common Linden	366	2	(N/A)	1.3	0.5	0.10
Ginkgo	306	2	(N/A)	1.2	0.4	0.09
Common pear	805	5	(N/A)	1.2	1.0	0.24
Scarlet oak	2,531	16	(N/A)	1.2	3.2	0.76
OTHER STREET TREES	4,730	30	(N/A)	5.9	5.9	0.30
Total	80,104	505	(N/A)	100.0	100.0	0.29

Re-planting – Total Benefits

Burncoat & Greendale

Total Annual Benefits of All Trees By Species ($)

3/4/2010

Species	Energy	CO_2	Air Quality	Stormwater	Aesthetic/Other	Total ($)	Standard Error	% of Total $
Sweetgum	46	2	3	15	1,487	1,552	(±0)	4.9
Kousa dogwood	253	7	62	41	779	1,142	(±0)	3.6
Kwanzan cherry	244	7	60	40	749	1,099	(±0)	3.5
Japanese tree lilac	240	6	59	39	737	1,081	(±0)	3.4
Apple	161	5	40	27	673	906	(±0)	2.9
Black tupelo	89	5	21	21	4,246	4,382	(±0)	13.8
Littleleaf linden	42	3	9	12	3,213	3,279	(±0)	10.4
White oak	357	9	85	72	2,256	2,779	(±0)	8.8
Sargent cherry	180	5	44	29	553	811	(±0)	2.6
Dawn redwood	497	12	79	27	2,397	3,012	(±0)	9.5
Northern red oak	67	2	14	20	1,361	1,464	(±0)	4.6
Crabapple	84	2	21	14	351	472	(±0)	1.5
Callery pear	50	2	13	15	1,053	1,133	(±0)	3.6
Honeylocust	80	2	19	10	1,723	1,834	(±0)	5.8
Plum	89	2	22	15	273	401	(±0)	1.3
Swamp white oak	150	4	36	30	950	1,170	(±0)	3.7
English oak	38	1	8	11	765	823	(±0)	2.6
Black oak	36	1	7	10	723	778	(±0)	2.5
Common Linden	8	1	2	2	620	633	(±0)	2.0
Ginkgo	9	0	2	2	87	100	(±0)	0.3
Common pear	17	1	4	5	357	384	(±0)	1.2
Scarlet oak	79	2	19	16	499	614	(±0)	1.9
OTHER STREET	150	5	37	30	1,609	1,830	(±0)	5.8
Citywide Total	2,965	85	664	505	27,460	31,679	(±0)	100.0