AN ECONOMIC ANALYSIS OF THE IMPACT OF THE BRONZE BIRCH BORER ON BIRCH TREES IN THUNDER BAY, ONTARIO

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An undergraduate thesis submitted in partial fulfillment of the requirements for the

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Faculty of Natural Resources Management

Lakehead University

April 2022

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Advisor Second Reader

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ABSTRACT

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Urban street trees provide many ecosystem services, environmental and economic benefits for residents, communities, cities, and municipalities. The economic benefits of trees are not easily quantified as they have no market value. Since 2011, the bronze birch borer, a specialist wood-boring beetle, has been a pest of birch trees in northern Ontario. A street tree inventory of streets east of Vicker's Park in Thunder Bay was completed to determine the economic value and annual contributions of the birch trees in this area. To determine the value of the trees, the basic method was used. To calculate annual contributions the i-Tree MyTree benefits calculator was used. The cost of removal and replacement were also determined. Using this data, and assuming all trees would become infested and killed, an economic analysis was completed to determine which of 100% treatment, partial treatment, or removal and replacement was most economically feasible. None of the examined scenarios yielded positive results, however, the most cost-effective solution was 100% treatment of the birch trees.

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INTRODUCTION

The bronze birch borer (BBB) (*Agrilus anxius* Gory) is a wood-boring species of beetle specific to birch trees (*Betula* spp.) (Slingerland 1906, Barter 1957, Carlson and Knight 1969). It is a recognized pest of ornamental and street trees, and large-scale outbreaks tend to follow stress events when trees have compromised defences (Barter 1957, Carlson and Knight 1969, Davey Resource Group 2011). Urban street trees provide many ecosystem services and benefits to communities and to the city. These ecosystem services include air purification, noise reduction, improved water quality, stormwater mitigation, decreased soil erosion, carbon sequestration, and increased property value (Alexander & DePratto 2014). Trees provide additional benefits including economic, psychological and wildlife habitat (Davey Resource Group 2011). The benefits that trees provide are translated into a dollar value with the use of modelling. It is important to determine the value of the ecosystem services and benefits that trees provide and compare that to the costs associated with managing and protecting against BBB.

There are still many birch trees planted along streets around Vicker's Park in Thunder Bay but the economic benefits these trees provide have not yet been determined. There also has not been a recent street tree inventory which includes the many birch removals across Thunder Bay. This study will determine the value of birch trees planted on streets east of Vicker's Park, and how much the trees generate each year for the City of Thunder Bay in terms of ecosystem services. This information can be useful for the city, as they can then determine how much money is spent on managing these trees each year and allow them to determine whether the trees are worth protecting and treating, or whether removal is more economically feasible. The research will take place on the streets adjacent to the east side of Vicker's Park. A quick evaluation of each tree will be completed, as well as diameter at breast height (DBH) and photos of the condition of each tree will also be taken. This data will be useful to determine the overall health of the tree. The focus of this study will be on the services that the birch trees provide and the cost of losing their annual benefits as well as the cost of removal and replacement trees.

LITERATURE REVIEW

BIRCH TREES – *BETULA*

Birch trees are part of the Betula family (Betulaceae) (Farrar 2017). Birch trees are susceptible to environmental stresses like drought, temperature, and light availability (Muilenburg and Herms 2012). White birch is an early successional, fast-growing, short-lived, shade-intolerant species which has been used as an ornamental street tree (Muilenburg and Herms 2012, Farrar 2017). There are 50 different species of birch worldwide with 10-12 of them being native to Canada (Farrar 2017). In Canada, these species can be divided into white birches and yellow birches, with white birch (*Betula papyrifera* Marsh.) being the most common species (Farrar 2017). Figure 1 outlines a white birch tree on Vickers Street South which was inventoried for this study.

Figure 1. White birch tree on Vickers Street South

Birch leaves are deciduous, alternately arranged on twigs and shoots (Farrar 2017). They are oval to triangular with prominent lateral veins arranged parallel along the midvein (Farrar 2017). Each of these veins ends in a sharp tooth with smaller intervening teeth (Farrar 2017). Birch trees are commonly identified by the thin papery sheets of bark they form and the prominent lenticels on the bark and twigs (Farrar 2017). The flowers and fruits of birches are borne in catkins on the tree, and exposure to light is highly important for the proper germination of this shade-intolerant species (Farrar 2017).

BRONZE BIRCH BORER

The bronze birch borer (BBB) is a specialist wood-borer of birch trees in Ontario (Slingerland 1906, Barter 1957, Carlson and Knight 1969). It is from the order Coleoptera, and the family Buprestidae, known as the metallic wood-boring beetles (Bright 1987). Prior to 2002, the BBB was known as the most economically and ecologically significant *Agrilus* species in North America (Carlson and Knight 1969). As shown in Figure 2, birch trees have a wide geographic distribution across North America, indicating the ability of BBB to tolerate many climatic conditions (Muilenburg and Herms 2012).

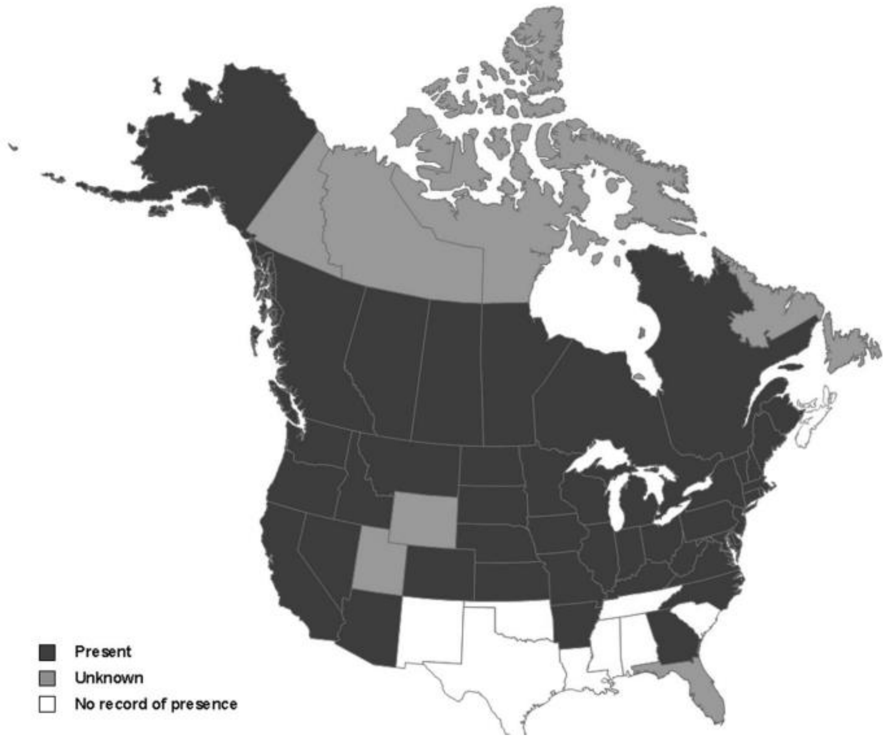

Figure 2. Bronze birch borer range in North America (Muilenburg and Herms 2012).

The BBB is known to colonize most species of birch, with some being more resistant than others (Carlson and Knight 1969). It is considered to be a secondary, opportunistic colonizer of birch which have been weakened by other stresses (Carlson and Knight 1969). Outbreaks are known to follow large-scale stress events when trees have a compromised resistance (Barter 1957, Carlson and Knight 1969).

The adult beetles are subcylindrical and have a coppery-bronze metallic colour (Barter 1957). They are 7-12 mm long with female beetles being larger than males (Barter 1957). Adult beetles live for 2-5 weeks, feeding on foliage to achieve their reproductive maturity (Barter 1957, Akers and Nielson 1990). It has been suggested that male beetles arrive on host birch trees prior to females (Barter 1965). When females arrive, the males ambush them and copulate (Barter 1965). Female beetles produce and oviposit oval-shaped, cream-colored eggs under flakes of the outer bark (Barter 1957). Two weeks later, when the eggs hatch, they immediately bore through the bark and begin feeding on the vascular tissues of the tree, as shown in Figure 3 (Barter 1957, Carlson and Knight 1969). The boring creates galleries in the vascular tissue which become filled with frass and interrupt the transportation of nutrients and water (Barter 1957, Carlson and Knight 1969). The larvae can infest trees of all sizes, including smaller branches and twigs (Barter 1957). When larval density is high, galleries have the potential to girdle the tree and cause death (Barter 1957).

Figure 3. Bronze birch borer pupa creating galleries the vascular tissue (BugWood Wiki 2010)

When trees are infested with BBB, there are many signs and symptoms that they may possess. Emerging adults create distinctive D-shaped holes 3-5 mm wide which can be seen in the bark (Barter 1957). Just under the bark, frass-filled galleries may be present in the vascular tissue (Barter 1957). Welts may also be seen externally on the tree where callus tissue builds up over galleries (Barter 1957). Since larvae can create galleries and girdle branches, branch dieback may be seen beginning in the upper crown and spreading downward, with foliage being thin or chlorotic (Barter 1957). Sprouting at the base of the trunk may also be seen externally, along with damage caused by woodpeckers excavating larvae (Anderson 1944, Barter 1957). Generally, it takes years for the trees to decline and die but when larval densities are high, death can occur fairly quickly (Barter 1957).

According to Hutchison (pers. comm.) the BBB has been present in Thunder Bay since the early 2000s. The city has experienced a shift in the composition of the urban forest due to climate change (Vescio pers. comm.). The city's birch trees became increasingly stressed due to consistent drought conditions present across the city over many years (Vescio pers. comm.). These conditions create the ideal environment for the BBB to thrive and attack the stressed birch trees (Carlson and Knight 1969). Since the first arrival of the beetle in the city, many birch trees have been infested and have succumbed to the attacks of the BBB.

URBAN FORESTRY

Urban forestry is the science of managing forest resources and trees in urban communities for the purpose of providing economic, physiological, sociological, and aesthetic benefits to society (Miller 1997). Urbanization is concentrating people, energy, and infrastructure into small areas to create a functioning society (Nowak 2006). This degrades the local and regional environment as infrastructure replaces the natural landscape (Nowak 2006). Urban vegetation can improve the environmental quality and help to counteract anthropogenic activity (Nowak 2006). Over the last 30 years, as urban forestry has evolved, the primary purpose of urban trees has changed from a purely aesthetic role to a role that also includes providing ecosystem services (Seamans 2013). Urban trees and forests provide many environmental, social, and economic benefits for society (Seamans 2013).

BENEFITS OF URBAN TREES

ENVIRONMENTAL BENEFITS

Street trees provide many environmental benefits including improving air quality, managing stormwater, sequestering carbon, enhancing biodiversity, and providing habitat for urban fauna (Mullaney *et al.* 2015). The extent to which trees provide benefits is dependent on the tree's species, overall structure, size and health, and physical placement (Mullaney *et al*. 2015).

Urban forests and street trees provide environmental services to cities by improving air quality. As urban sprawl continues, and more people are living in cities, air pollution is quickly becoming a significant environmental problem by affecting human health and damaging infrastructure and vegetation (Escobedo and Nowak 2009). Urban trees can be implemented as a strategy for reducing ozone levels through natural tree functions (Nowak 2006). Urban trees and shrubs have the potential to remove large amounts of pollution and therefore improve the environment and subsequently, human health (Nowak 2006). Urban trees can remove pollutants such as carbon monoxide (CO), carbon dioxide (CO_2), ozone, nitrogen dioxide (NO_2), particulates less than 10 microns (PM_{10}), and sulphur dioxide (SO_2). Trees can reduce air temperatures through shading, changing wind patterns, and evapotranspiration (Escobedo and Nowak 2009, Nowak 2006). Trees remove air pollutants by intercepting them in the air and through dry deposition on plant surfaces (Nowak 2006). Trees also reduce the energy consumption of buildings and therefore reduce emissions of power plants (Nowak 2006). Trees remove gases in the air by uptake through the leaf stomata, although some gases can also be removed by the plant surface (Nowak 2006). Carbon dioxide is taken up by leaves and is converted to oxygen through photosynthesis, while ozone and NO_2 are absorbed directly into the leaf tissue (Brack 2002). Trees also remove pollutants by intercepting the particles in the air (Nowak 2006). These particles are either absorbed into the tree or are retained on the surface of the tree where they are later shed off by rainwater (Nowak 2006, Brack 2002). Brack (2002) suggests larger trees a with higher leaf area index (LAI) tend to extract and store more gases from the atmosphere and can trap more pollutants. Larger trees can also cast more shade and decrease air temperatures (Brack 2002, Nowak 2006).

Urban forests and street trees also provide ecosystem services through stormwater mitigation. Management that relies on ecosystem processes can be a useful tool in achieving urban sustainability and creating a cost-effective stormwater management system (Bartens *et al*. 2009). As urbanization increases, there are more impervious surfaces which lead to increased runoff of stormwater (Bartens *et al.* 2009). This impairs water quality, threatens the water supply, and reduces the recharge of groundwater (Bartens *et al.* 2009). Increased runoff can also cause rapid fluctuations of streamflow which can degrade aquatic habitats and erode channels (Bartens *et al*. 2009). Urban trees and forests reduce stormwater runoff in urban areas (Bartens *et al.* 2009). Leaves and branches from urban trees intercept and absorb large amounts of rainfall

(Brack 2002, Mullaney *et al.* 2015). Trees temporarily store and slow water run-off before releasing it back into the atmosphere or allowing it to slowly infiltrate into the soil (Mullaney *et al.* 2015). Trees also channel water away from impervious surfaces and down stems through trunk flow, leading water into the soil below (Bartens *et al.* 2009). The stormwater benefits that urban trees provide depend on the physical size of the tree like the trunk diameter, canopy size and LAI (Mullaney *et al.* 2015). By intercepting rainfall, particulate matter from rain precipitates out and therefore does not end up in waterways (Brack 2002). By increasing canopy cover in urban areas, surface runoff is reduced and costs of stormwater mitigation in cities are decreased (Bartens *et al*. 2009).

Urban trees and forests provide environmental services through carbon sequestration and climate change mitigation. Urban areas are known to have higher climate variability when compared with rural environments due to the high presence of artificial surfaces and high levels of greenhouse gas (GHG) emissions and fossil fuel combustion (Nowak and Crane 2002). Global warming is a significant environmental issue causing increased surface air temperatures and leading to increased emissions of GHG (Parsa *et al*. 2019). Trees in urban areas can act as a sink for carbon dioxide by fixing carbon during photosynthesis and storing it as biomass (Nowak and Crane 2002). While urban areas are hotspots for GHG emissions, they also provide climate regulation by sequestering and storing carbon (Parsa *et al*. 2019). Parsa *et al*. (2019) suggest that urban forests and trees ability to sequester carbon are a useful tool in mitigating climate change on many scales. It reduces carbon emissions on the microscale and local microclimate by shading buildings and reducing energy demand (Parsa *et al.* 2019). At the city level, urban trees reduce solar radiation and decrease humidity, thereby decreasing energy demand and subsequently carbon emissions (Parsa *et al*. 2019). On a global scale, urban forests can act as a carbon sink by sequestering and storing large amounts of carbon as biomass (Parsa *et al*. 2019). Carbon sequestration ability is a function of the total tree cover in cities (Parsa *et al*. 2019). The amount of carbon stored in urban trees is large and it is therefore essential to maintain the current urban forest (Parsa *et al*. 2019). The ability of trees to sequester and store carbon depends on the tree species and DBH, where large trees can generally store 1000 times more carbon than smaller trees (Parsa *et al*. 2019). Urban forests can therefore help to reduce the atmospheric carbon dioxide levels (Nowak and Crane 2002). Improving forest cover in urban environments through tree planting and other strategies is an effective strategy in mitigating climate change (Parsa *et al*. 2019).

Urban trees provide ecosystem services by enhancing biodiversity and providing habitat for urban fauna (Savard *et al*. 1999). There is a rapid loss of biodiversity occurring across the globe and many species are at risk of extinction (Alvey 2006). Research shows that biodiversity plays a significant role in ecosystem functioning, so the loss of biodiversity is a key concern (Alvey 2006). There are many contributing factors to biodiversity loss in urban environments including human demand for certain species, rapid environmental fluctuations like climate change, habitat modification, and competition from non-native species (Alvey 2006). Preserving intact natural areas is key to maintaining biodiversity, but this is not always feasible in urban locations (Alvey 2006). Human population density, air and soil pollution, air temperature, soil compaction, and road density are significantly higher in urban areas compared with rural ones (Alvey 2006). As population density and infrastructure increase, natural habitat is lost over time which reduces the richness of plants, birds, insects, and mammals in urban areas (Alvey 2006). Street trees and parks enhance biodiversity by providing food, habitat, and landscape connectivity for urban fauna (Mullaney *et al*. 2015). The species and height of the tree influence the overall abundance and diversity of urban fauna (Mullaney *et al.* 2015). Small mammals need the ability to disperse between remnant patches of vegetation and the ability to live and persist in a patch long enough that they can reproduce (Dickman and Doncaster 1987). Street trees provide connectivity between urban forests and riparian strips in cities and provide a corridor for the dispersal of small mammals, birds, butterflies, moths, and beetles (Mullaney *et al*. 2015). Many cities and urban areas have a network of habitat fragments with greenways connecting them (Angold *et al*. 2006). These habitats are important for biodiversity and are valuable for their function as corridors to facilitate species dispersal (Angold *et al*. 2006). Greenways and wildlife corridors are an important part of urban landscape planning to allow plants and animals to move to different urban areas and preserve biodiversity (Angold *et al.* 2006). In urban ecosystems, habitat fragmentation occurs and fragments of natural vegetation may be too small or isolated to support wildlife (Savard *et al*. 1999). For this reason, the corridors that link parks and other green areas are important to enhance biodiversity by facilitating movement between (Savard *et al*. 1999).

ECONOMIC BENEFITS

Urban forests have direct economic benefits for individual residents, communities, municipalities, and local governments (Mullaney *et al*. 2015). The economic benefits that urban forests and streets trees provide do not all have a market value placed on them and are difficult to quantify (Mullaney *et al*. 2015). For the benefits of street trees to be understood by policy and decision-makers, the benefits need to be quantified and given a dollar value (Mullaney *et al*. 2015). The economic contribution of trees correlates with physical variables of the trees such as species, trunk diameter, and LAI (Mullaney *et al.* 2015). Street trees provide economic benefits through stormwater mitigation, energy savings from heating and cooling, and increasing property values and business income (Mullaney *et al*. 2015).

Street trees provide economic benefits by mitigating stormwater runoff (Mullaney *et al*. 2015). By intercepting rainfall and allowing it to slowly percolate into the soil or be released through evapotranspiration, urban trees can reduce stress on existing stormwater management infrastructure and eliminate the need for additional stormwater treatment systems (Mullaney *et al*. 2015). This leads to decreases in maintenance, replacement, and expansion costs (Mullaney *et al*. 2015). It also means there less damage caused by flooding in residential areas (Mullaney *et al*. 2015). Stormwater mitigation is a well-researched topic with all studies showing a significant reduction in management costs when street trees were present (Mullaney *et al*. 2015).

Street trees also provide economic benefits by increasing property values and business income (Mullaney *et al*. 2015). Greene *et al*. (2018) found there were higher residential property values observed where there was more urban tree cover present. Treescaping outside of businesses has also been found to increase business income by 20%. Mullaney *et al*. (2015) found that consumers are more likely to visit a retail development with street trees and they will spend 9% more on an item from an establishment with street trees, versus one that has none.

Lastly, city trees and parks provide economic benefits by reducing energy costs (Greene *et al*. 2018). Donovan and Butry (2009) suggest that by planting more urban shade trees, cities and municipalities can conserve energy use and reduce the need for heating and cooling. Trees provide cooling properties through evapotranspiration and by casting shade, therefore reducing air and surface temperatures (Greene *et al*. 2018). By planting trees outside of homes and businesses, the shade cast reduces the temperatures indoors thereby reducing the demand for energy (Pandit and Laband 2010). Energy savings are therefore provided by trees through their shading and cooling properties in the summer and wind-chill protection in the winter (Mullaney *et al*. 2015). Since energy used to cool houses during the warmest part of summer makes up a large part of the peak electrical load, savings from electricity use can be huge (Pandit and Laband 2010). It is important to note that dense shade, as opposed to moderate or light shade, is more effective in reducing summertime energy consumption and energy savings were maximized where trees had highly dense leaf canopies in the summer (Pandit and Laband 2010). Mullaney *et al*. (2015) found a 10% increase in tree cover reduced the energy use for heating in cooling by 5-10%, while Donovan and Butry (2009) found urban trees reduced seasonal cooling costs by 26-47%. Trees planted on the west-facing side of buildings were also more effective at reducing energy costs and reducing seasonal cooling costs by 10-50% (Pandit and Laband 2010). A reduction in energy use also leads to reduced emissions and therefore less costs to offset emissions (Mullaney *et al.* 2015).

MATERIALS AND METHODS

To determine the economic contributions of birch trees to the community of Thunder Bay and more specifically, around Vicker's Park, a tree inventory of the birch trees present on the streets east of Vicker's Park was completed. A map was created on MyMaps, a google feature, as shown in Figure 4. The map was entitled "BBB Tree Inventory" and can be found using the link provided. In creating the map, the first step was to update the data table with the column headings: name, address, diameter at breast height (DBH), health condition, and remarks. The tree names were given an alphanumerical value for each tree beginning with T1.

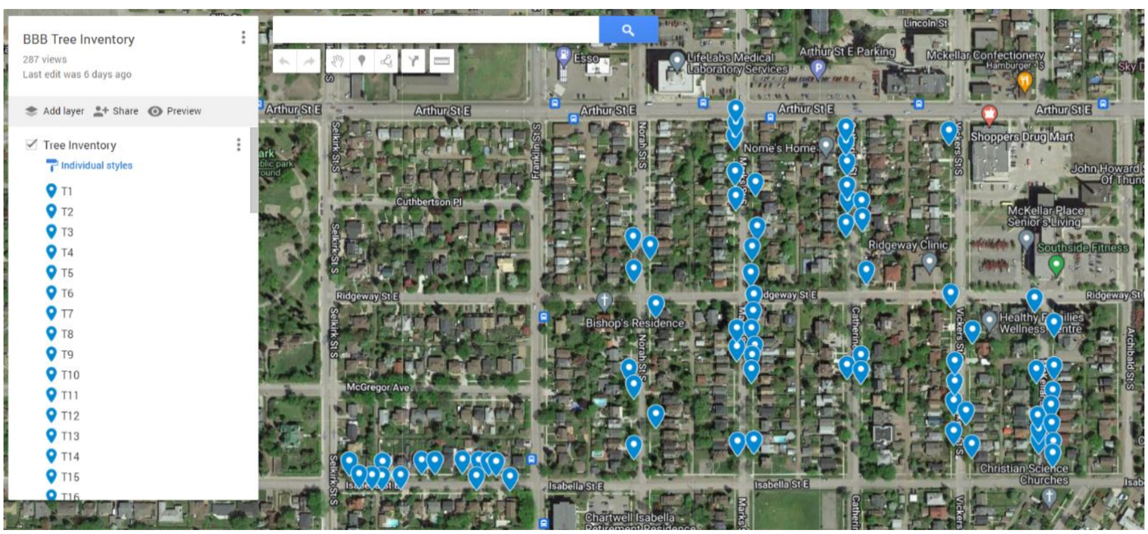

Figure 4. Bronze birch borer tree inventory map

The field data for the tree inventory was collected on October 14th, 2021. While completing the tree inventory and collecting data, one student assessed and recorded the name of the tree, the street address, the DBH, health condition, and any remarks. The data collected was recorded in the BBB Tree Inventory data table on MyMaps. A data point was created on the map for each birch tree that was visited. Photos of each tree were also taken which were added to the data point for additional reference information. The DBH was measured using a diameter tape. The overall health condition of the tree's roots, stem, scaffold branches, foliage, and twigs was rated on a scale of 0-5 with 0 being a dead stump and 5 being perfect health condition. Some factors included in the determination of health condition were the presence of disease, insect attack, decay, dieback or dead branches, injury, location, and site factors. The aspect and distance to buildings of each tree were also assessed and recorded.

I-TREE MY TREE BENEFITS CALCULATOR

To determine the economic contribution that birch trees have, a benefits calculator called i-Tree was used. I-Tree is a software which was developed by the USDA Forest Service (i-Tree n.d.). To complete this study, the i-Tree MyTree application was used to determine the benefits that street trees provide. The program required the species, health condition, sun exposure, distance to buildings, age of building, and the aspect of the tree to be inputted (i-Tree n.d.). The program then gives output measures for the amount of carbon stored, air pollution removed, stormwater mitigated, energy savings provided, and emissions reduced (i-Tree n.d.). Lastly, the program provided an American dollar value of the tree as determined by all of these benefits (i-Tree n.d.).

The i-tree MyTree application required a two-step process. Six inputs were required in step one including the assigned name of the tree, the location, the species, the overall condition rating, DBH, and sun exposure. The condition ratings used by MyTree were dead, critical, poor, fair, good, and excellent. Since the trees were given a number value rating on a scale of 1-5, each number range was given a corresponding condition as shown in Table 1. The inputs used by MyTree for sun exposure included full sun, partial sun and full shade. For the purpose of this tree inventory, the input full sun was used for each tree as none were competing for sunlight along the street. Step two of the application involved inputting information about nearby buildings. If there was a building nearby, the age of the building must be selected from the three options provided, before 1950, between 1950 and 1980 and after 1980. For the purpose of this tree inventory, the input between 1950 and 1980 was used as most of the houses were built during this time period. The distance to the building must also be selected from four options which were 0 – 6 m, 6 – 12 m, 12 – 18 m, and >18 m. Since the distance to the houses from the tree lawns was relatively similar throughout the neighborhood, the input 6 – 12 m was used for each of the trees. The last input needed was aspect. Through the MyTree application, the benefits of the trees could be calculated individually or all together. The benefits were provided by the application as a quantitative value and in American dollars.

Table 1. Condition and associated number rating

Condition	**Rating**
Excellent	4-5
Good	3-4
Fair	2-3
Poor	1-2
Critical	0-1

TREATMENT SCENARIOS

Three different treatment scenarios were assessed including no treatment, full treatment with systemic insecticides and partial treatment. In the no treatment scenario, all of the birch trees in the area would be removed and replaced with a resistant variety. With the full treatment scenario, all of the birch trees in the area would be treated to protect against bronze birch borer. Lastly, with the partial scenario, trees that are over 40 cm DBH with a condition rating of 3.5 or higher would be treated, while the remainder would be removed and replaced.

VALUE OF BIRCH TREES

The monetary value of the birch trees needs to be calculated in order to understand the economic risk. To calculate the value of the birch trees in this neighborhood, the basic method was used. This method involves inputs of DBH, condition rating, species value, and location value. In order for the condition values to be useful in this equation, they must be converted to a percent. The species value is outlined in the Ontario supplement to Guide for Appraisal 10th edition (International Society of Arboriculture 2020). Lastly, a location value needed to be determined based on the locations of trees observed. The location was given a value of 75% based on the size of tree lawns and proximity to houses and street lights which was consistent throughout the neighborhood. To calculate the value of the trees, they were first separated into six 10 cm increment DBH classes (10-20, 20.1-30, etc.). From there, the average DBH and condition values by DBH class could be calculated to determine the value of the average tree. This value was then multiplied by the number of birch trees in each class to calculate a total value for all the birch trees.

CALCULATIONS

The economic losses for each treatment scenario were then calculated and forecasted five years into the future. This was completed by multiplying the annual i-tree contributions and the treatment cost by four and adding that to the total cost for year one.

The tree value, removal and replacement costs remain the same, as they are one-time expenditures in year one.

RESULTS

Figure 5 outlines the diameter class distribution of all 79 inventoried birch trees. As shown, the 20.1-30 cm diameter class had the most trees with 22, while the class with the lowest number of trees recorded was 60.1-70 with only 2 trees. 78% of the trees surveyed fell within the 20.1-50 cm diameter range. The average DBH of the 74 surveyed birch trees was 35.5 cm.

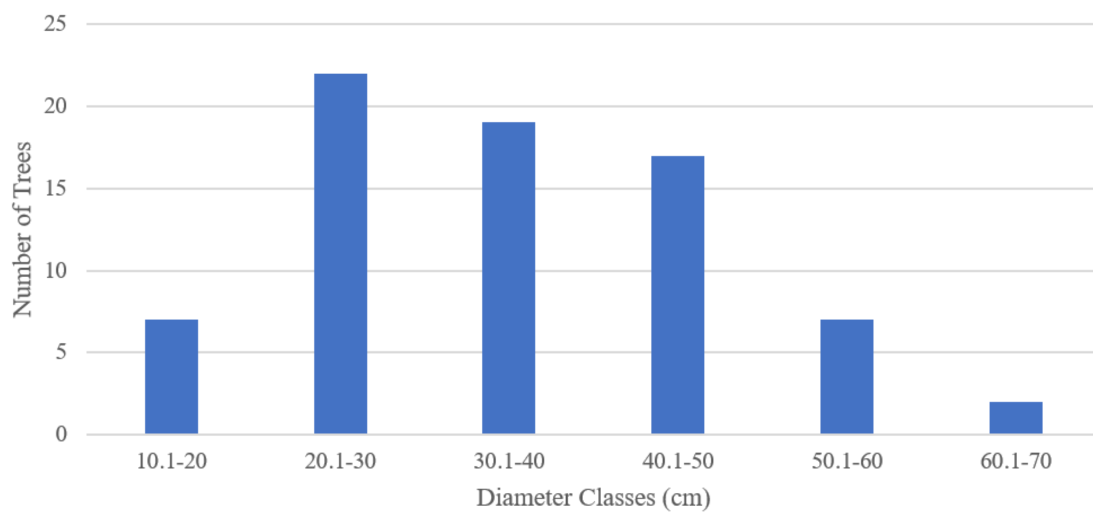

Figure 5. Diameter class distribution of the inventoried birch trees

Figure 6 outlines the condition class distribution of the 79 inventoried birch trees. The condition class with the highest number of trees was 2.1-3 with 29, while the 3.1-4 condition class was a close second with 28. The class with the lowest number of trees was the 0-1 condition class, where only 1 tree was identified. The average condition of all the inventoried trees was 3.2.

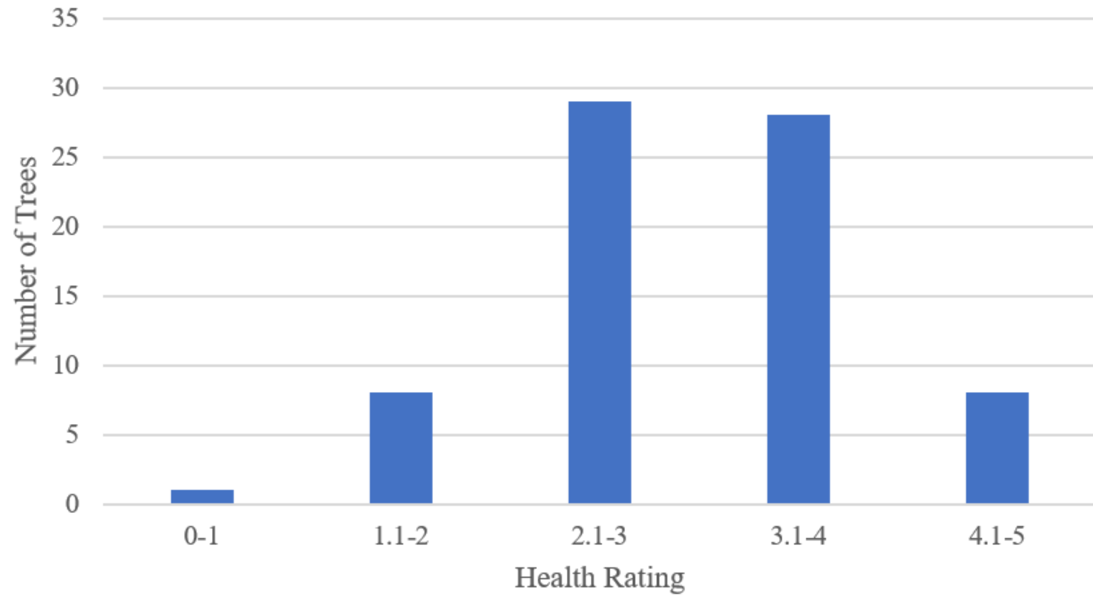

Figure 6. Condition class distribution of the inventoried birch trees

Table 2 displays the i-Tree MyTree annual benefits calculated for all trees inventoried. The i-tree program gives a total amount in US dollars so this was converted to Canadian dollars with the current exchange rate. As shown, the annual benefits contributed by the inventoried trees was $984.09 CAD.

Table 2. ITree MyTree annual benefits for all trees (n=79)

	CO_2 Sequestered	Storm Water	Air Pollution	Energy Usage	Avoided Energy Emissions	Sum
Total (USD)	$191.84	$0.64	$2.13	$472.11	$120.55	$787.27
Total (CAD)	$239.80	$0.80	$2.66	$590.14	$150.69	$984.09

Table 3 outlines the number of trees, average DBH and average health rating for each DBH class. This data was used in the basic method calculations to determine the value of each individual tree in each DBH class. The resulting values were then multiplied by the total number of trees in each class to determine a total value for all trees inventoried. As shown, the DBH class with the highest value for each individual tree was the 50.1-60 cm class with a value of $8,800 per tree, while the DBH class with the highest total value for all trees was the 40.1-50 cm class with a total value of $107,100. The total value of all trees inventoried was found to be $303,700.

Table 3. Input and output data for the basic method calculations

DBH Class (cm)	Number of Trees	Average DBH (cm)	Average Health Rating	Value of Each Tree ($)	Total Value of Trees ($)
10.1-20	7	17.1	2.7	700	4900
20.1-30	22	26.1	3.3	2,100	46,200
30.1-40	19	34.5	3.3	3,700	70,300
40.1-50	17	45	3.3	6,300	107,100
50.1-60	7	55.1	3.1	8,800	61,600
60.1-70	2	63.6	1.8	6,800	13,600
Total					303,700

Table 4 outlines the cost of tree removals by DBH class as provided by Vince Rutter of Rutter Urban Forestry.

Table 4. Price of removal used in calculations

DBH (cm)	Price of Removal
0-20	200
20 - 40	700
40+	1600

The systemic insecticide chosen to treat the birch trees is TREE-age, an ArborJet product. Table 5 outlines the cost to treat each tree in each DBH class and the cost of treatment for all trees in each DBH class as provided by ArborJet.

Table 5. Cost to treat birch trees with TREE-age systemic insecticide

DBH (cm)	Number of Trees	Cost Per Tree	Cost for All Trees
10 to 16	3	13	39
17 to 23	11	20.8	228.8
24 to 31	21	28.6	600.6
32 to 39	13	36.4	473.2
40 to 46	12	44.2	530.4
47 to 54	8	52	416
55 to 61	4	59.8	239.2
62 to 69	2	67.6	135.2

Table 6 summarizes the total cost the City of Thunder Bay would incur with all factors considered for the 100% treatment, partial treatment and complete removal and replacement according to the data collected. The 100% treatment scenario involves treating all trees, the partial treatment scenario involves treating 26 trees and removing and replacing the remainder of the trees, and the final scenario is removing and replacing all of the trees. Every scenario yields negative results, however, the 100% treatment scenario is the most economically friendly option, incurring the least costs in the short run.

Table 6. I-Tree MyTree calculations (in dollars)

	Cost of Removal	Cost to Replace	Cost of Treatment	I-Tree Annual Contributions	Total Cost
100% Treatment	0	0	2,662.40	984.09	-1,678.31
Partial Treatment	41,600	19,240	1,320.80	492.04	-64,983.80
No Treatment	71,700	38,480	0	0	-110,180

Table 7 displays the 5-year forecast for both treatment options where positive values indicate a benefit and negative values indicate a loss. These values were calculated based on the cost of treatment per year over the 5 years. There is no five-year forecast for the removal and replacement option as contributions of future trees cannot be calculated for. The most cost-friendly option in the five-year forecast is the 100% treatment scenario where costs are only incurred for the treatment of trees annually.

Table 7. Summary of costs for each treatment scenario for the five-year forecast

Level of Treatment	Total Cost	Five-Year Forecast
100% Treatment	-1,678.31	-8,391.55
Partial Treatment	-61,668.75	-64,983.80

DISCUSSION

The total value of the birch trees inventoried was found to be $303,700. Both the complete removal and replacement scenario and the partial treatment scenario require trees to be removed, which would mean all or some of this value would be lost. This is a significant economic loss to the city, and also means the loss of the benefits that the trees provide yearly. The trees provide yearly economic benefits through stormwater mitigation and energy savings and with the removal of the birch trees present there, the benefits will be lost and the cost to the city will increase.

The City of Thunder Bay will lose money with any of the three scenarios explored. The scenario that was the most cost-friendly was the 100% treatment option as there were no significant costs incurred for the removal and replacement of the trees. This also allows for the most benefits to be gained from the trees and the total value of the birch trees to remain and be recognized. The removal and replacement scenario incurred the highest costs, however, the trees would likely need to be removed and replaced in the long run when they become too large and hazardous or succumb to the BBB. With this scenario, the total value of the trees would be lost whereas with the partial treatment option, the value of trees with less than 40 cm DBH would be lost when the trees were removed. This opportunity cost was not included in the total cost and five-year forecast.

COST OF REMOVALS

The cost of tree removal is outlined in Table 4. The cost of removal is based on a diameter range where when a tree diameter is larger than 20 cm, the cost to remove increases by $500 and when a tree diameter is larger than 40 cm, the cost to remove increases by $900. This is a flaw of this study as in reality, each tree would be assessed and evaluated prior to removal based on size, location, and hazards. The cost difference between a tree with a DBH of 39 cm would be very similar to the cost of removal of a tree that has a DBH of 40 cm. All of the trees are also grown in the open along streets which would make removal easier and more cost-friendly. For these reasons, the cost of removal would likely be lower, resulting in less of an economic loss.

FUTURE CONTRIBUTIONS

As trees age and grow in size, they increase in value, and the annual benefits they contribute to the city increase. In the calculations for this study, this is not considered. The i-tree annual contributions are calculated based on the current status and value of each individual tree for this current year. The five-year forecast does not take into account the additional benefits that each tree will contribute as it ages and grows in size. Since each tree would be increasing in size and value, the economic losses over time would therefore be greater, suggesting the five-year forecast is not accurate.

A second factor not considered in the calculations is the value of the newly planted trees and the annual benefits they contribute. These trees will be low in value and have little annual benefits in the first year, however as they grow over time, these benefits will increase and reduce the economic loss to the city.

CONCLUSION

Through this study, the benefits that urban birch trees provide have been given a monetary value so these benefits can be recognized and included in the city's decision-making processes. An updated inventory of all trees in Thunder Bay and specifically in areas where birch trees are still present would be beneficial for the city to determine the impact that the BBB is having. The information collected and the associated analyses can be useful for the city, as they can then see how much money the trees generate for the city yearly and how much value these trees hold. This will allow them to determine whether the trees are worth protecting and treating, or whether removal is more economically feasible.

In my opinion, it makes the most sense economically to make an attempt to save the birch trees on the streets on the east side of Vicker's Park. The 100% treatment option was the most economically feasible option. This option assumes that all trees being treated would survive, which is not likely given the health condition and size of some of the trees. Some of the trees are small and in poor health due to additional factors, such as frost cracks, the presence of fungi and physical damage. For this reason, the investment in saving the trees could be lost by treating these trees. It would make the most sense to remove the trees of smaller size and in poor health to prevent the loss of investment and to decrease costs of removal and replacement in the future when the trees are larger and more hazardous. By treating the trees in good health and with DBH over 40 cm, these trees will remain and continue to provide benefits to the city, which maximizes economic gains.

Birch trees are becoming rarer along streets in Thunder Bay. The trees are not only beneficial in terms of the benefits they contribute to the city, but they beautify the neighbourhood and improve the physical and mental well-being of citizens. By saving the largest and most prosperous of the trees, these benefits would continue and be recognized as well.

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APPENDICES

APPENDIX I

Table #. Street tree inventory data with price of removal, treatment and replacement

Tree Name	DBH (cm)	Health Condition	Price of Removal	Price of Treatment ($/year)	Price of Replacement
T1	29.8	4.5	700	28.6	520
T2	15.8	2	200	13	520
T3	22	3.5	700	20.8	520
T4	32.3	3	700	36.4	520
T5	41.6	3.5	1600	44.2	520
T6	18.6	3	200	20.8	520
T7	20.2	3.5	700	20.8	520
T8	27.2	3	700	28.6	520
T9	23.3	2	700	20.8	520
T10	14.4	1	200	13	520
T11	29.6	2.5	700	28.6	520
T12	25.4	3	700	28.6	520
T13	25.2	2.5	700	28.6	520
T14	12.8	1.5	200	13	520
T15	20.2	4.5	700	20.8	520
T16	19.8	3	200	20.8	520
T17	27.2	2.5	700	28.6	520
T18	54.2	3.5	1600	52	520
T19	31.8	1.5	700	28.6	520
T20	56.1	3.5	1600	59.8	520
T21	39.4	3	700	36.4	520
T22	18.5	4	200	20.8	520
T23	58.8	3.5	1600	59.8	520
T24	65.2	1.5	1600	67.6	520
T25	55.2	3	1600	59.8	520
T26	27.7	2.5	700	28.6	520
T27	31.8	2.5	700	28.6	520
T28	54.2	2.5	1600	52	520
T29	42.6	3.5	1600	44.2	520
T30	29.2	3	700	28.6	520
T31	49.8	4	1600	52	520
T32	33.7	2.5	700	36.4	520

T33	29.8	2.5	700	28.6	520
T34	31.5	2.5	700	28.6	520
T35	42.6	3	1600	44.2	520
T36	45.5	2	1600	44.2	520
T37	36.8	3.5	700	36.4	520
T38	55.5	3	1600	59.8	520
T39	47.6	3.5	1600	52	520
T40	51.5	3	1600	52	520
T41	62	2	1600	67.6	520
T42	35.4	3.5	700	36.4	520
T43	35	4	700	36.4	520
T44	28.8	2.5	700	28.6	520
T45	35.5	3.5	700	36.4	520
T46	45.5	4	1600	44.2	520
T47	46.2	4	1600	44.2	520
T48	46.6	3.5	1600	44.2	520
T49	38.4	4	700	36.4	520
T50	31.8	3.5	700	28.6	520
T51	23.2	3	700	20.8	520
T52	41.5	2.5	1600	44.2	520
T53	40.4	3	1600	44.2	520
T54	36.4	3	700	36.4	520
T55	19.8	4.5	200	20.8	520
T56	21.5	4.5	700	20.8	520
T57	29.2	4.5	700	28.6	520
T58	31.3	4.5	700	28.6	520
T59	48.9	4	1600	52	520
T60	39.1	4.5	700	36.4	520
T61	28.8	2.5	700	28.6	520
T62	29.2	4	700	28.6	520
T63	30.2	5	700	28.6	520
T64	25.4	4	700	28.6	520
T65	22.4	3.5	700	20.8	520
T66	45.5	4	1600	44.2	520
T67	36.1	4	700	36.4	520
T68	42.8	3.5	1600	44.2	520
T69	48.2	3	1600	52	520
T70	47.6	1.5	1600	52	520

T71	42.2	3.5	1600	44.2	520
T72	32.6	3	700	36.4	520
T73	36.2	2.5	700	36.4	520
T74	28.8	3.5	700	28.6	520

APPENDIX II

White Birch - *Betula papyrifera* (10-20 cm diameter class)		
Tree area constant	0.7854	
DBH	17.1	cm
Species Value (SV)	0.59	
Condition Value (CV)	0.54	
Location Value (LV)	0.75	
DBH (cm) largest transpantable tree (LTT)	7	cm
Cost of LTT ($)	520	$
Basic Method		
Cross-sectional area of actual tree:		
(tree area constant) x (DBH)^2=		
(0.7854) x (34.5)^2=	229.66	cm^2
Cross-sectional Area of LTT:		
(tree area constant) x (DBH)^2=		
(0.7854) x (8.0)^2=	38.48	cm^2
Cost/cm^2		
(Cost of LTT)/(Cross sectional area of LTT)=		
(654)/(50.27)=	13.51	$/cm^2
Value of tree		
(Cross sectional area of actual tree)x(Cost)=		
(934.8) x (13.01)=	3103.13	$
Species Value		
(Value of tree) x (SV)=		
(12161.75) x (0.81)=	1830.84	$
Condition Value		
(value of tree) x (CV)=		
(9851.02) x (0.797)=	988.66	$
Location Value		
(Value of tree) x (LV)=		
(8462.02) x (0.8)=	741.49	$
Final appraised value of birch tree (10-20 cm) (rounded to nearest hundred)	700	$

APPENDIX III

White Birch - *Betula papyrifera* (20.1-30 cm diameter class)		
Tree area constant	0.7854	
DBH	26.1	cm
Species Value (SV)	0.59	
Condition Value (CV)	0.66	
Location Value (LV)	0.75	
DBH (cm) largest transpantable tree (LTT)	7	cm
Cost of LTT ($)	520	$
Basic Method		
Cross-sectional area of actual tree:		
(tree area constant) x (DBH)^2=		
(0.7854) x (34.5)^2=	535.02	cm^2
Cross-sectional Area of LTT:		
(tree area constant) x (DBH)^2=		
(0.7854) x (8.0)^2=	38.48	cm^2
Cost/cm^2		
(Cost of LTT)/(Cross sectional area of LTT)=		
(654)/(50.27)=	13.51	$/cm^2
Value of tree		
(Cross sectional area of actual tree)x(Cost)=		
(934.8) x (13.01)=	7229.17	$
Species Value		
(Value of tree) x (SV)=		
(12161.75) x (0.81)=	4265.21	$
Condition Value		
(value of tree) x (CV)=		
(9851.02) x (0.797)=	2815.04	$
Location Value		
(Value of tree) x (LV)=		
(8462.02) x (0.8)=	2111.28	$
Final appraised value of birch tree (20.1-30 cm) (rounded to nearest hundred)	2100	$

APPENDIX IV

White Birch - *Betula papyrifera* (30.1-40 cm diamater class)		
Tree area constant	0.7854	
DBH	34.5	cm
Species Value (SV)	0.59	
Condition Value (CV)	0.66	
Location Value (LV)	0.75	
DBH (cm) largest transpantable tree (LTT)	7	cm
Cost of LTT ($)	520	$
Basic Method		
Cross-sectional area of actual tree:		
(tree area constant) x (DBH)^2=		
(0.7854) x (34.5)^2=	934.82	cm^2
Cross-sectional Area of LTT:		
(tree area constant) x (DBH)^2=		
(0.7854) x (8.0)^2=	38.48	cm^2
Cost/cm^2		
(Cost of LTT)/(Cross sectional area of LTT)=		
(654)/(50.27)=	13.51	$/cm^2
Value of tree		
(Cross sectional area of actual tree)x(Cost)=		
(934.8) x (13.01)=	12631.22	$
Species Value		
(Value of tree) x (SV)=		
(12161.75) x (0.81)=	7452.42	$
Condition Value		
(value of tree) x (CV)=		
(9851.02) x (0.797)=	4918.60	$
Location Value		
(Value of tree) x (LV)=		
(8462.02) x (0.8)=	3688.95	$
Final appraised value of birch tree (30.1-40 cm)		
(rounded to nearest hundred)	3700	$

APPENDIX V

White Birch - *Betula papyrifera* (40.1-50 cm diameter class)		
Tree area constant	0.7854	
DBH	45	cm
Species Value (SV)	0.59	
Condition Value (CV)	0.66	
Location Value (LV)	0.75	
DBH (cm) largest transpantable tree (LTT)	7	cm
Cost of LTT ($)	520	$
Basic Method		
Cross-sectional area of actual tree:		
(tree area constant) x (DBH)^2=		
(0.7854) x (34.5)^2=	1590.44	cm^2
Cross-sectional Area of LTT:		
(tree area constant) x (DBH)^2=		
(0.7854) x (8.0)^2=	38.48	cm^2
Cost/cm^2		
(Cost of LTT)/(Cross sectional area of LTT)=		
(654)/(50.27)=	13.51	$/cm^2
Value of tree		
(Cross sectional area of actual tree)x(Cost)=		
(934.8) x (13.01)=	21489.80	$
Species Value		
(Value of tree) x (SV)=		
(12161.75) x (0.81)=	12678.98	$
Condition Value		
(value of tree) x (CV)=		
(9851.02) x (0.797)=	8368.13	$
Location Value		
(Value of tree) x (LV)=		
(8462.02) x (0.8)=	6276.09	$
Final appraised value of birch tree (40.1-50 cm)		
(rounded to nearest hundred)	6300	$

APPENDIX VI

White Birch - Betula papyrifera (50.1-60 cm diameter class)		
Tree area constant	0.7854	
DBH	55.1	cm
Species Value (SV)	0.59	
Condition Value (CV)	0.62	
Location Value (LV)	0.75	
DBH (cm) largest transpantable tree (LTT)	7	cm
Cost of LTT ($)	520	$
Basic Method		
Cross-sectional area of actual tree:		
(tree area constant) x (DBH)^2=		
(0.7854) x (34.5)^2=	2384.48	cm^2
Cross-sectional Area of LTT:		
(tree area constant) x (DBH)^2=		
(0.7854) x (8.0)^2=	38.48	cm^2
Cost/cm^2		
(Cost of LTT)/(Cross sectional area of LTT)=		
(654)/(50.27)=	13.51	$/cm^2
Value of tree		
(Cross sectional area of actual tree)x(Cost)=		
(934.8) x (13.01)=	32218.88	$
Species Value		
(Value of tree) x (SV)=		
(12161.75) x (0.81)=	19009.14	$
Condition Value		
(value of tree) x (CV)=		
(9851.02) x (0.797)=	11785.67	$
Location Value		
(Value of tree) x (LV)=		
(8462.02) x (0.8)=	8839.25	$
Final appraised value of birch tree (50.1-60 cm) (rounded to nearest hundred)	8800	$

APPENDIX VII

White Birch - *Betula papyrifera* (60.1-70 cm diameter class)		
Tree area constant	0.7854	
DBH	63.6	cm
Species Value (SV)	0.59	
Condition Value (CV)	0.36	
Location Value (LV)	0.75	
DBH (cm) largest transpantable tree (LTT)	7	cm
Cost of LTT ($)	520	$
Basic Method		
Cross-sectional area of actual tree:		
(tree area constant) x (DBH)^2=		
(0.7854) x (34.5)^2=	3176.91	cm^2
Cross-sectional Area of LTT:		
(tree area constant) x (DBH)^2=		
(0.7854) x (8.0)^2=	38.48	cm^2
Cost/cm^2		
(Cost of LTT)/(Cross sectional area of LTT)=		
(654)/(50.27)=	13.51	$/cm^2
Value of tree		
(Cross sectional area of actual tree)x(Cost)=		
(934.8) x (13.01)=	42926.11	$
Species Value		
(Value of tree) x (SV)=		
(12161.75) x (0.81)=	25326.40	$
Condition Value		
(value of tree) x (CV)=		
(9851.02) x (0.797)=	9117.50	$
Location Value		
(Value of tree) x (LV)=		
(8462.02) x (0.8)=	6838.13	$
Final appraised value of birch tree (60.1-70 cm)		
	6800	$

APPENDIX VIII

My Tree Benefits

Tree Collection Totals

Serving Size: 74 trees

Total benefits for this year:	$787.26
Carbon Dioxide (CO_2) Sequestered	**$191.84**
Annual CO_2 equivalent of carbon[1]	< 0.10 kg
Storm Water Runoff Avoided	**$0.64**
Runoff Avoided	269.86 L
Rainfall Intercepted	828,435.25 L
Air Pollution Removed Each Year	**$2.13**
Carbon Monoxide	241.11 g
Ozone	11,991.91 g
Nitrogen Dioxide	1,339.89 g
Sulfur Dioxide	681.36 g
$PM_{2.5}$	285.49 g
Energy Usage Per Year[2]	**$472.11**
Electricity Savings (A/C)	4,856.12 kWh
Fuel Savings (natural gas, oil)	21.58 MMBtu
Avoided Energy Emissions	**$120.55**
Carbon Dioxide	4,477.28 kg
Carbon Monoxide	2,125.01 g
Nitrogen Dioxide	849.93 g
Sulfur Dioxide	9,086.34 g
$PM_{2.5}$	519.17 g
CO_2 Stored To Date[3]	**$4,951.82**
Lifetime CO_2 equivalent of carbon[3]	197,479.94 kg

Benefits are estimated based on USDA Forest Service Research and are meant for guidance only.

[1] For large trees sequestration is overtaken by CO_2 loss with decay/maintenance.

[2] Positive energy values indicate savings or reduced emissions. Negative energy values indicate increased usage or emissions.

[3] Not an annual amount or value.

Visit www.itreetools.org to learn more.

MyTree 2.11.1

Powered by the i-Tree Engine