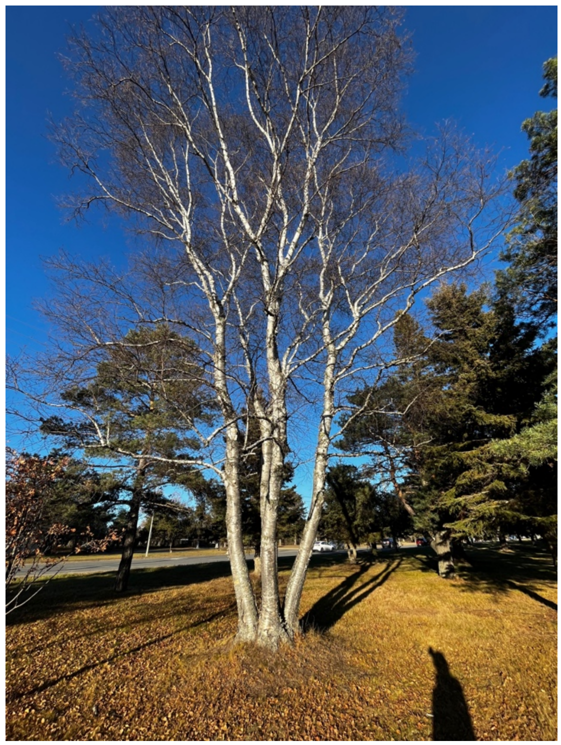
ECONOMIC COST ANALYSIS OF THE BRONZE BIRCH BORER ON THE THUNDER BAY CAMPUS OF LAKEHEAD UNIVERSITY

By

Kai Meekis (1159194)



Faculty of Natural Resource Management

Lakehead University

Thunder Bay, Ontario

April 22, 2024

ECONOMIC COST ANALYSIS OF THE BRONZE BIRCH BORER ON THE THUNDER BAY CAMPUS OF LAKEHEAD UNIVERSITY

By

Kai Meekis

1159194

An undergraduate thesis submitted in partial fulfillment of the requirements for the Degree of Honours Bachelor of Forestry

Faculty of Natural Resources Management

Lakehead University

April 2024

A CAUTION TO THE READER

This HBScF thesis has been through a semi-formal process of review and comment by at least two Natural Resource faculty members. It is made available for loan by the Faculty of Natural Resources Management for the purpose of advancing the practice of professional forestry.

The reader should be aware that the opinions and conclusions expressed in this document are those of the student and do not reflect opinions of the supervising faculty members or the Faculty of Natural Resources Management.

ABSTRACT

Meekis, K. 2024. Economic Risk Analysis of the Bronze Birch Borer on the Thunder Bay Campus of Lakehead University. H.B.Sc.F. thesis, Faculty of Natural Resources Management, Lakehead University, Thunder Bay, Ontario 34 + vii Pp.

Keywords: Birch, *Agrilus anxius*, Bronze Birch Borer, Urban Forests

Urban forests serve many purposes to a city, from parks to street trees to crown cover in downtown cores. Trees in urban environments are more prone to stress and pathogen due to the environment in which they live. Birch trees specifically make up a percentage of the urban trees in Thunder Bay and are easily affected by the Bronze Birch Borer. The Bronze Birch borer is a small beetle that can kill the tree by creating galleries of eggs in the cambium. Each of these trees are associated with a value based on tree quality and location factors, as well as their yearly contributions. The research done for this paper will cover only the birch trees planted on the Lakehead University, to find the most cost-effective solution to the effects of the Bronze Birch Borer. 65 birch trees were inventoried with a total value of $103,954 and a combined yearly contribution value of $732.54. A cost analysis between full treatment, partial treatment, and no treatment management options was done for a 20-year management plan. The most cost-effective option proved to be the partial treatment option, and the most expensive being the no treatment option. No treatment was not only the most expensive due to the high price of tree and stump removal, but the value of the trees is also completely lost.

ACKNOWLEDGEMENTS

I would like to thank Dr. Leonard Hutchison for his help and guidance while completing this project and for Dr. Wang for acting as my second reader. I would also like to thank Tim Nosworthy from Rutter Urban Forestry for his contribution of cost data.

CONTENTS

TABLE OF FIGURES

INTRODUCTION AND OBJECTIVE

The bronze birch borer is a species in the genus *Agrilus* and is native to North America. The first reports of the bronze birch borer being the cause of the death of many birch trees in North America came in the 1920's and 30's and still to this day has quite the effect on stressed birch trees (Katovich *et al.* 2000). The bronze birch borer attacks all birch trees but favors some species more than others, commonly attacked *Betula* species are paper birch (*Betula papyrifera*, Marshall) gray birch (*Betula populifolia,* Marshall), sweet birch (*Betula lenta,* Linn.), and yellow birch (*Betula alleghaniensis,* Britt.). Paper birch is a birch species that is most common in Thunder Bay, which makes the bronze birch borer a real threat to the birch population. *Agrilus anxius* (Gory) affects the tree by larvae feeding on the phloem and the cambium in the bark that eventually create zig zag galleries. These behaviors cause the efficiency in the transport tissue in the tree to be significantly reduced (Katovich *et al.* 2000). The effects can cause death and decline in birch species quickly. For this reason, I am creating a plan for Lakehead University to be able to manage the planted birch species on campus. This study will consist of different options with different cost values to choose from. A full treatment option, partial treatment option and no treatment option will be analyzed. These insects are directly related to the emerald ash borer but with some distinguishing factors. Although, the D-shaped exit hole are the same the galleries are different, the EAB create s-shaped galleries while the bronze birch borer creates more sporadic zig zag shaped galleries.

Trees are very valuable to urban environments; Lakehead University has many birch trees on campus, but the value of these trees is not yet known. The literature studied will be broken up into four sections, urban forestry, the bronze birch borer, paper birch trees, and TreeAzin®. The area of study consists of many areas of the campus, the main areas with birch trees are, around the Bora Laskin Building, by the resident's buildings, and in the Centennial Building courtyard. Lakehead has invested in the aesthetic appearance by planting many trees around campus, so for the purpose of this study, only ornamental, planted, birch trees will be studied. This study will be calculating the value of these trees using the basic method (Hutchison. 2023). Trees also make annual contributions to the school; these contributions must also be taken into consideration when making management decisions.

LITERATURE REVIEW

Urban Forestry

Urban forestry is a side of the forest industry that not many people think about. The public tends to not fully understand the importance of urban forestry and how it constantly contributes to us. While ecosystems thrive in forests outside of cities, urban areas have less tree cover and more barriers to overcome to have a strong ecosystem. "Urban forests are an integral component of cities, towns, and communities because they provide critical ecosystem services to continuously increasing urban populations" (Parajuli *et al*. 2022). Urban forestry itself can be defined as the science of managing trees and forest resources in and around urban community ecosystems for the physiological, sociological, economic, and aesthetic benefits trees provide society (Konijnendijk *et al.* 2005). Some urban forestry practices include planting trees and enhancing urban forest quality through proper tree maintenance (Yang *et al.,* 2023). Urban foresters work to model urban areas to benefit as much as possible from trees and other vegetation. Urban forests provide social benefits by promoting physical exercise through recreational areas, (Mytton *et al.,* 2012) and promoting social interaction and a sense of community (Kuo, 2003). The need to focus on the urban forest and how cities can contribute to the ecosystem has only gotten larger because of the need to mitigate climate change. (Campbell *et al.,* 2022) For all these reasons, urban forestry is only becoming more important and therefore management should be more heavily considered.

Urban forestry in Thunder Bay officially started in 1996 when Shelley Vescio was hired as an urban forestry consultant. (Thompson, 2016) Now the department has three members as well as an urban arborist who manages and plans the city's tree cover. Vescio states that during her time as an urban forester in Thunder Bay the biggest challenge was the public's attitude towards trees and that more recently, she has noticed a shift to people caring more about the urban environment. This is a huge step in the right direction for the city, and because of this, more management and urban planning will be done. Although the city is going in the right direction, the past methods of planting monocultures in the city has led decline in many urban tree species including paper birch. (Davey Resource Group, 2011)

Bronze Birch Borer

The Bronze Birch Borer (BBB) is a beetle in the family Buprestidae, a family also known as metallic wood borers. The adult beetle is about a centimetre long with a bronzy metallic iridescence on its back. The insect prefers direct sunlight and can be found crawling on the side of the birch tree stems facing the sun in late May and early July (Gibb and Sadof, 2017). The BBB became a key pest of ornamental landscapes and the urban forest when birch trees became widely planted as a high value street tree in urban environments. (Muilenburg and Herms, 2012) The BBB can be identified easily because of some distinct characteristics. To identify the presence of BBB a zig-zag pattern can be seen in the bark (Katovich *et al.,* 2000) (Figure 1). Another way to identify the presence of the borer are D-shaped exit holes can be seen in the bark of the tree (Figure

Figure 1: Zig-Zag pattern created by the Bronze Birch Borer. (Montana State University)

This occurs because the larvae of the beetle feed on the connective tissue of the tree underneath the bark. The tree then grows callus tissue over the wounds the larvae create, this tissue then creates visible bulges in the bark. Although these are the specific signs of the insect, the first sign of BBB in a tree is dieback starting from the crown of the tree and slowly making its way down the tree as the issue progresses (Gibb and Sadof, 2017).

How these beetles effect birch trees so much is through their life cycle. The life cycle starts when adults lay eggs in crevasses in the bark of the trees. From there, the larvae hatch and for the next one to two years feed on the cambium and phloem of the tree (Katovich *et al.,* 2000). They eat in zig-zag patterns that create galleries and scar tissue that goes back and forth up the tree. As the conductive tissue is full of larvae and is being destroyed in the areas where the larvae have been, the tree can no longer transport the necessary nutrients, and this is what causes dieback and eventually tree mortality. After the larvae are done feeding, they emerge as adults creating the D-shaped holes that can be used to identify their presence (Figure 2). These beetles are prone to outbreaks and due to their large native range have the ability to destroy entire birch populations (Muilenburg and Herms, 2012). This issue has inspired the management of birch trees in urban areas to respond to the effects of this pest.

Figure 2: Bronze Birch Borer and the D-shaped exit holes. (Steven Katovich, Bugwood.org)

Birch Trees – Betula

Birch trees are a hardwood species that are native to the study area of Thunder Bay. For this study, paper birch or *Betula papyrifera* will be the focus as these were the trees that were inventoried. The native range of paper birch not only includes Thunder Bay, but it also spreads across North America (Bressette, 2014) (Figure 3). The large natural distribution of this species makes the research done in this study relative for

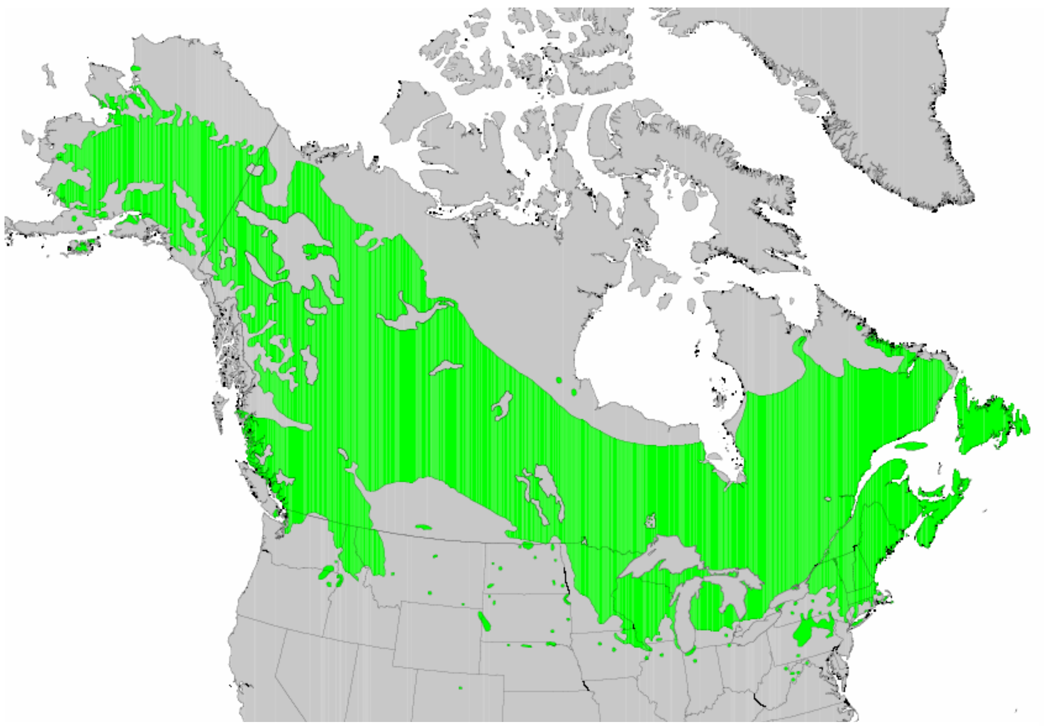


Figure 3: Native range of Paper Birch trees (Elbert L. Little, Jr., Atlas of United States Trees.)

many different areas other than just in Thunder Bay. Birch trees are easy to identify due to their distinct bark characteristics. Birch trees have smooth resinous usually white bark, that is marked by horizontal pores called lenticels (Farrar, 1995). The bark also peels horizontally in thin sheets, this is the easiest way to identify a paper birch tree. This characteristic also made these trees very historically important, as it was used to make things like baskets, canoes, and wigwams (Lines, 1984). All trees contribute to the environment they reside in, but birch have been found to have benefits to the soil. Birch trees have a positive influence on soil nutrients, biological turnover intensity, soil microorganisms, and enzymatic activity (Jonczak *et al.,* 2020). Due to the egg-shaped or triangular leaves (Farrar, 1995) birch trees can also minimise energy and heat costs for nearby buildings from shading and acting as a wind barrier. (I-Tree n.d.) Birch trees are a beautiful hardwood species that hold lots of value and historic importance, therefore management should be considered so that Lakehead can continue to benefit from the tree's contributions.

TreeAzin

TreeAzin is a brand of insecticide that is used to treat metallic wood borers of the genus *Agrilus* (Thompson, 2013). TreeAzin was first developed solely to combat the deadly effects of the Emerald Ash Borer in 2003 but was later approved by the Canadian government to treat Bronze Birch Borer as well, with an injection of 5ml/cm of DBH (Tim Nosworthy personal communication). TreeAzin was based off the chemical compounds known as azadirachtins that are found in the seeds of the neem tree that prevent insects from eating them (Thompson, 2013). Extensive research was done to determine the best way to administer the treatment, and it was determined that injection in the base of the tree so that the chemical could be transported through the conductive tissue of the tree was the best way to treat a tree (Thompson, 2013). Since the chemical compound is fully organic, it does not pose imminent risk to the environment and has low mammalian toxicity (Mordue and Blackwell, 1993). Although this seems like a perfect solution, there are still some drawbacks of azadirachtin-based insecticides. Barbosa (2015) found that chronic exposure to azadirachtin could cause reproduction issues and a change in behaviour in bumble bees under laboratory conditions. These compounds are also irritating to humans, causing harm to the skin and stomach if digested (Bond *et al.,* 2012). These effects are considered minor, and the use of the pesticide has been cleared by many companies and governments.

MATERIALS AND METHODS

To start the research, data needed to be collected. The data collected included diameter measurements at breast height around the Lakehead University campus. Data was collected by walking the campus and measuring every planted birch tree. The tree being “planted”, or “ornamental” is very key in this study because there are many naturally occurring birch trees in the forested areas by the river. Another reason that those naturally occurring trees are not an area of study is because the focus here is on urban forestry and management plans for urban environments. While determining DBH, pictures were taken of the tree to be able to determine a health class for the tree. Pictures included anything that would negatively impact the tree, and from the picture a location analysis could be done. This data was put into a large table so that calculations could be made from these numbers. The table had 4 inputs, tree number, DBH (cm), condition rating, location rating. The DHB was measured using a diameter tape provided by the school. The condition rating was a number from 1 to 5, with 0 being dead and 5 being perfect. This condition rating was used for both Basic method calculations and I-tree benefits calculator values. Some of the factors that condition was based on was, dead branches, dieback, presence of disease, insect attack, missing bark, large wounds with visible rot inside, root damage, and large frost cracks. Location ratings were given as a decimal from 0.0 to 1 to be easily converted into a percent. The rating was based on obstructions above the tree, distance to buildings, and distance to other trees.

Next, the economic value of yearly contributions the trees give were calculated using the I-tree calculator. I-tree benefits calculator is a peer-reviewed software site developed in 2006 by the USDA Forest Service that provides tree analysis and assessment (i-Tree n.d). The program determines values for the following outputs, carbon stored, air pollution removed, stormwater mitigated, energy savings provided, and emissions reduced (i-Tree n.d). With this information the program then assigns an American dollar value to the benefits the tree gives back.

Another large table was created with all the inputs needed for the program to determine these values. The calculator needed, DBH, a health rating, sun exposure, and if it was within 60 ft from a building. If so, a drop-down menu would show up with another set of values. These values were, building vintage, distance from building, and the aspect relative to the closest section of the building. This table can be found in the appendices. Health ratings were based on the ratings given to the tree during the initial data collection as a value from 0-5. This was done because the calculator had 5 different options, from dead to excellent which corresponded with the initial data collection. Sun exposure was simply three options, full sun, partial sun, and shade. The building vintage data was between 1950 - 1980 for the initial built buildings on campus or after 1980 for the newer additions that were made to the campus. Distance from the building and aspect were inputted using google maps.

How the value of the tree was determined was by using the "basic method" (Hutchison, 2023). This formula considers three main factors, species rating, condition rating, and a location rating. The condition value was taken from the initial data collection by converting the value out of 5 to a percent by dividing the value by 5. The species value has already been determined and you can find it publicly. The location value considers, contribution, placement, and site, each given a rating out of 100, then averaged to find the final location value. This value was also taken from the initial data collection, that is already in a percent value. Once these numbers are calculated a base cost must be determined by accessing someone who sells the same tree that one would be replacing. The value of the replacement tree was based on values from Uxbridge Nurseries 2014 price list. The largest tree available was 6 cm DBH and cost $135. After finding the largest transplantable tree size and cost, determine the cost per cm squared for the largest transplantable tree, then multiply that cost by the area value of the tree being replaced. This will give you a base cost that you can now multiply out the values determined above. Finally, this value will be rounded to the nearest hundred. To make this process more realistic, trees were split into DBH classes and an average value of DBH, health, and location were calculated for the trees within each class.

Treatment methods were found through Rutter Urban Forestry. The main three methods that were analysed were a full insecticide treatment, a partial treatment, and no treatment. The no treatment method would be a full removal of the birch trees and the associated costs of doing so. Full insecticide treatment would be, using a Treeazin treatment plan for all trees. Finally, a partial treatment plan consists of treating high value trees and removing the rest. These trees include trees larger than 31cm with a health rating of at least 3.5.

To determine which treatment plan should be implemented a cost analysis was done between the options. As explained above trees give back to the area with yearly contributions. Therefore, to properly analyse these benefits, the dollar value they give back must be subtracted from the total cost of operations for each treatment plan. Most urban forest management plans and forest management plans in general are 20-year plans, this research considers costs for each management option over a twenty-year period. This is done by considering the initial costs of tree and stump removal in year one for no treatment, partial treatment, and full treatment. Then the cost of treatment for year one is multiplied by ten because the treatment injection happens in two-year cycles and is added to the two options with treatment. For the no treatment option those bi-yearly charges will not be included. The economic benefit that the trees give back will be subtracted from the total values in the full treatment and partial treatment options.

RESULTS

Figure 4 shows a visual representation of diameter class distribution for the 65 trees inventoried. The diameter class 31-40 cm had the most trees, with 20 trees in the class. On the opposite side of the spectrum, the diameter class with the least number of trees was the 0-10 cm diameter class, where only two trees fell in this class. The average DBH for the whole range was 34.43 cm.

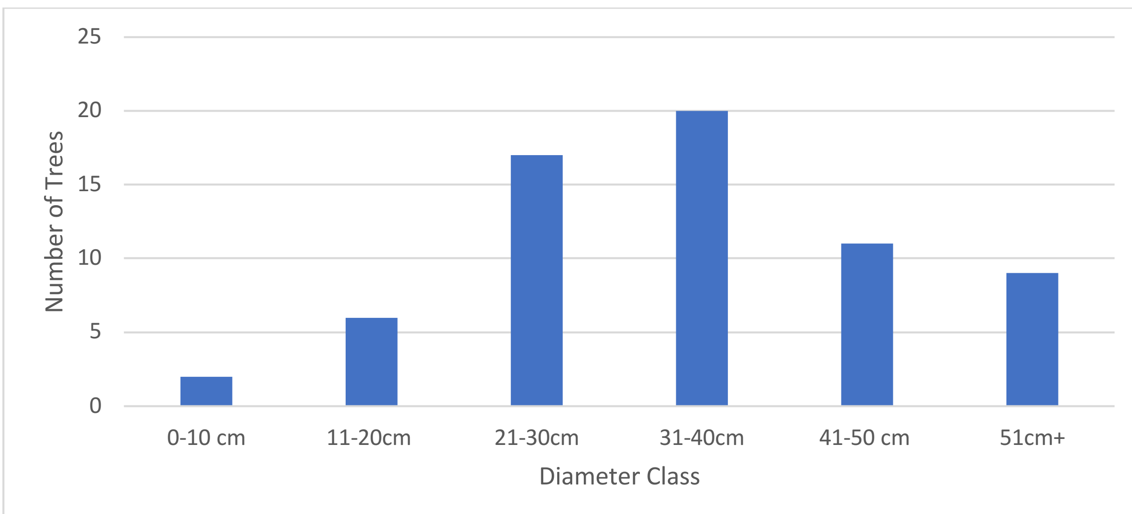


Figure 4: Diameter class distribution of the inventoried birch trees.

Figure 5 displays the distribution of health class ratings for the 65 inventoried birch trees. Most of the trees on campus were relatively healthy as most trees fell in the 3.1-4 health class. This class was significantly larger than the rest with 33 trees in the class. Fortunately for Lakehead, the class with the least number of trees was the lowest health rating of 1.1-2. This health class only contained 4 trees. The lowest health rating on the scale was 0-1, and this section was designated to dead trees. Lakehead campus did not have any fully dead trees. The average health rating for all inventoried trees was 3.42.

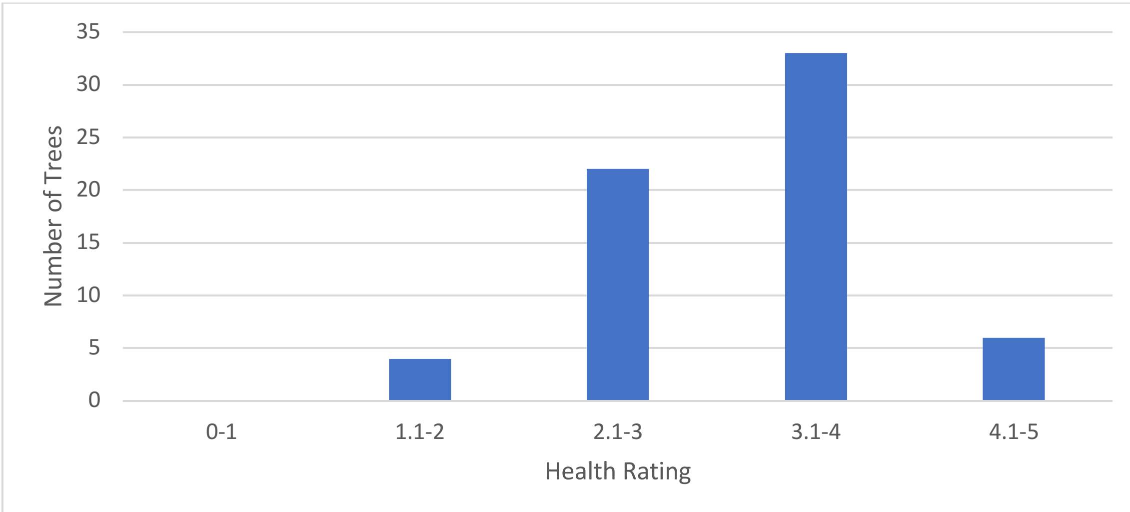


Figure 5: Health class distribution of 65 inventoried birch trees.

Table 1 shows the data used for the basic method calculations. The full calculation breakdown for each DBH class can be found in the appendices. The condition and location values are an average value from the trees in each of the associated DBH classes. The species value for birch is 59% and expressed as a decimal for calculation purposes. This value is outlined in the Ontario Supplement to Guide for Appraisal 10th edition (International Society of Arboriculture. 2020). The largest transplantable tree (LTT) was 6 cm DBH and cost \$135. (Worsley, 2014) To determine the resulting data, the individual tree value that was calculated was multiplied by the number of trees in that class. The DBH class with the most value was the 51cm + Class, which was valued at \$32,400. The smallest being the 0-10 class, valued at only \$54. The total value of all birch trees on the property is \$103,954.

Table 1. Input and Output Values of the Basic Method Calculations.

Tree dbh class (cm)	Number of Trees	Condition Value	Location Value	Species Value	DBH (cm)	DBH LTT (cm)	cost LT T ($)	Tree area constant	Value of Each Tree ($)	Total Value of Trees ($)
0-10	2	0.8	0.85	0.59	4.25	6 cm	135	0.7854	27	54
11-20	6	0.76	0.71	0.59	16.92	6 cm	135	0.7854	300	1800
21-30	17	0.74	0.82	0.59	25.77	6 cm	135	0.7854	900	15300
31-40	20	0.64	0.80	0.59	35.57	6 cm	135	0.7854	1400	28000
41-50	11	0.64	0.85	0.59	44.6	6 cm	135	0.7854	2400	26400
51+	9	0.68	0.82	0.59	54.21	6 cm	135	0.7854	3600	32400
Total										103954

Table 2 shows the breakdown of each of the values the I-Tree calculates. The program outputs data in USD, so the table also shows the conversion to Canadian dollars at the current conversion rate. The total value the birch trees on campus give back yearly is 732.54 dollars.

Table 2. I-Tree Benefit Results Over 1 Year.

	CO_2 Sequestered	Storm Water	Air Pollution	Energy Usage	Avoided Energy Emissions	Total
USD	$99.88	$0.56	$1.76	$350.87	$89.55	$542.62
CAD	$134.84	$0.76	$2.38	$473.67	120.89	$732.54

Table 3 states the prices or removal by DBH class. This information was provided by Tim Nosworthy of Rutter Urban Forestry located here in Thunder Bay. For each class a range was given, but for the purpose of this study the value used will be right in the middle of the range.

Table 3. Price of removal of Birch Trees for Three DBH Ranges.

DBH (cm)	Price of Removal ($)
<20	400
21-30	600
31-40	1500
40+	2150

Table 4 displays the cost to remove the stump and prep the area with topsoil and grass seed. The cost was provided by Tim Nosworthy of Rutter Urban Forestry at $5.51 per cm diameter of stump. An estimate of the diameter of the stump was determined by adding ten percent to the average DBH of each diameter class. The total cost to remove all the stumps is $13,564.52.

Table 4. Price for Stump Removals

Tree dbh class (cm)	Number of Trees	DBH (cm)	Price of Stump Removal ($)	Stump Diamter (cm)	Price to Remove Stump ($)	Totals ($)
0-10	2	4.25	5.51	4.675	25.76	51.52
11-20	6	16.92	5.51	18.612	102.55	615.31
21-30	17	25.77	5.51	28.347	156.19	2655.26
31-40	20	35.57	5.51	39.127	215.59	4311.80
41-50	11	44.6	5.51	49.06	270.32	2973.53
51+	9	54.21	5.51	59.631	328.57	2957.10
Total						13564.52

Table 5 shows the cost breakdown for the dollar amount needed to treat all of the birch trees with TreeAzin. The cost value of $6.50 per cm DBH was given from Tim Nosworthy. The average DBH value within the DBH classes was used to have a dollar value for treating all the trees within the DBH range. They were added for a total of $14, 547 for a full treatment.

Table 5. Price of TreeAzin Treatment.

DBH Class	Average DBH Value	Number of Trees	Cost Per Tree	Cost for all trees
0-10	4.25	2	27.63	55.25
11-20	16.92	6	109.98	659.88
21-30	25.77	17	167.51	2847.59
31-40	35.57	20	231.21	4624.10
41-50	44.6	11	289.90	3188.90
51+	54.21	9	352.37	3171.29
Totals				14547.00

Table 6 displays the full cost analysis for the management options proposed. The most expensive option being no treatment, at $96,764.52. The cheapest option is full treatment, at $13,814.46. Partial treatment removed all trees that were lower that 31 cm DBH and all trees with a health rating of 3.5. The remaining trees were treated with TreeAzin. I-Tree annual contributions for the year were subtracted from the costs.

Table 6. Price breakdown for year one from three treatment options.

	Cost of Removal ($)	Cost of Stump Removal ($)	Cost of Treatment ($)	i-Tree Annunal Contributions ($)	Total Cost ($)
100% Treatment	0	0	14547	732.54	13814.46
Partial Treatment	49250	7634.37	5644.54	150.34	62378.57
No Treatment	86400	13564.52	0	0	99964.52

Table 7 outlines the costs moving forward for a 20-year management window. There is no cost associated with the no treatment option as the only costs are the initial year one costs. TreeAzin injections happen every two years, therefore treatment costs were multiplied by ten for the 20-year period. The 20-year contribution I-Tree values were subtracted from costs to finalize the total costs for the two treatment options. Over twenty years the partial treatment option is cheaper than the 100% treatment option.

Table 7. Summary of costs for each treatment option for a 20-year management plan.

Level of Treatment	Year One Costs ($)	I-Tree 20 Year Contributions ($)	20 year Forecasted Costs ($)
100% Treatment	14547	12,437.60	133032.4
Partial Treatment	62528.91	3614.24	109715.53

DISCUSSION

The diameter and health classes were analysed and put into a visual format to be easily viewed and compared. These two graphs told us that most of the trees fell somewhat in the middle of both ranges. This tells us that most of the trees fall into a similar age category as well. With more than half of the trees within 21-40 cm DBH and with 3.1-4 health ratings this makes sense that a lot of these trees were planted at the same time and are probably about 60 years old (Abdurrazaque, 2024).

It was determined that the total monetary value of the 65 birch trees inventoried was $103,954. This is a significant amount of money, and this does not include the yearly benefits that these trees will contribute over the years to come. As shown in Table 2 trees can benefit economically in many ways. When trying to decide on a management option it is important to take this into consideration. For the no treatment option all this value will be lost and on top of that the cost to remove all these trees is extremely high at $96,764.52 in year one. This option proves to be the most expensive right away and no further contributions can be made from these trees. For these reasons the no treatment option should not be considered for Lakehead University.

Initially, the 100% treatment option is by far the most cost-efficient method of management for Lakehead to choose as it is only around $14,000 compared to the $60,000 and almost $100,000 other options. The reason that this option is so much cheaper is because of the expensive upfront costs of removing a tree and its stump. Removal proved to be the most expensive part of this whole study, and without it the 100% treatment option is a clear winner. Although, once 20-years goes by the cost of treatment for all the trees every two years starts to creep up and surpasses the cost of the partial treatment method. Looking at all the data and giving input for a 20-year urban forest management plan for Lakehead University, the partial treatment option is what would be the most cost-effective way to retain the healthy, high value trees on campus and continue to benefit from the birch tree's annual contributions.

This study was done with data collected on site and cost values given by a local arborist company that would be the company responsible for the work being done to these trees. There are realities to tree removal and other costs that are not accounted for. To start, tree removal is a very hard process to create an exact cost reference for because the price is affected by much more than just DBH. Tree removal costs can be affected by site access, distance to chipper, and use of a bucket truck compared to a climber. (Tim Nosworthy pers. comm.) The cost removal values given were a range for three DBH classes. The three classes were 21-30cm DBH at $400-800, then 31-40 cm at 800-1300. Finally, anything above 40cm was $1300-3000. For the study, the cost value in the middle of each range was used to try and consider all possible options in the range. For trees under 21 cm the lowest price of $400 was used to calculate the eight trees that were less than 21cm. This method works to estimate costs, but cost may vary in a real-life application.

Comparing this study to others found an interesting result. Other similar studies for ash trees on campus and birch trees in Vickers Park found that 100% treatment was always the cheapest option. After some more analyzing neither study did not do more than a 6-year treatment plan. This would make sense that there would not be enough time for the treatment to catch up to the initial cost of removal of the partial treatment option. When looking even further, it is also clear that the insecticide treatment plans are much cheaper than the one used in this study. This could be from inflation, or simply the use of different products. This could also be because the use of TreeAzin was just approved by the Canadian government as a treatment option for bronze birch borer and has a recommended dose of 5ml per cm every two years (Tim Nosworthy pers. comm.). After analysing the data collected in this study and results of others, more than just these three options should be considered to have the best management option. For example, to reduce the cost of treatment, only trees showing signs of bronze birch borer could be treated, or a health check before the injection schedule could occur to prevent unnecessary injections. This is great data to see what options would be the cheapest, but for an actual management plan there are ways to maintain a healthy urban forest and also keep costs lower than what is calculated here.

Another important detail can be considered but has been left out of this study is the growth of trees and how they contribute over the 20-year plan. I-Tree values are great, and they have provided a good input for how trees contribute to urban environments. The flaw with fully relying on this data for the 20-year calculations, is that each one of the trees will grow over time and continue to contribute more and more the larger they grow. Another consideration is when these trees grow larger and if they are removed due to disease, or becoming hazardous, the monetary value of the tree will increase, and more losses will happen. This study assumes that the trees left in the partial treatment plan will continue to thrive because they were selected due to their high health condition, but this may not always be the case and the study does not account for that loss. Finally, the benefits of newly planted trees within the 20-year plan are also not considered. The trees will only be saplings and have little benefit in the first couple of years, but throughout the course of the 20-year management plan these trees will have significant contribution. In fact, since data collection there have already been some birch trees planted around the new gym that are not considered in the study.

CONCLUSION

Trees in the urban forest are a very important aspect to having a strong and happy community. This is especially important in areas of high traffic and high stress, such as a university campus. The bronze birch borer has the potential to destroy a part of this urban forest and therefore measures should be taken to mitigate this. This study has shown just how important these trees are both in economic value and environmental contributions. The study has also shown that a total removal is very expensive and should not be considered. Retaining as much of the urban forest is key and doing this in the most cost-effective way over a 20-year management plan has proven to be a partial treatment plan. Doing this removes the small and low-quality trees and treating the high value birch trees on campus.

Personally, to create a more well-rounded management plan, more specific analysis needs to be done to each tree to save costs on unnecessary removals and unnecessary injection costs. I do believe that the partial treatment is still the best option, but there are some variables that can be tweaked to reduce costs further. This will make it easier for Lakehead University to maintaining the strong and healthy urban forest that student and professors need to thrive. There are some real-world variables in the study that are extremely difficult to account for by doing a general data analysis. Although, this information gives Lakehead a great idea of what to expect in the future if the school is to consider managing the birch trees on campus.

LITERATURE CITED

Abdurrazaque, M. (2024, January 18). *Tree age calculator - how old is a tree?*. Omni Calculator. https://www.omnicalculator.com/biology/tree-age

Barbosa, W. F., De Meyer, L., Guedes, R. N., and Smagghe, G. (2015). Lethal and sublethal effects of azadirachtin on the bumblebee *Bombus terrestris* (*Hymenoptera: Apidae*). Ecotoxicology 24: 130–142 doi: 10.1007/s10646-014-1365-9

Bond, C., Buhl, K., Stone, D. (2012). *Neem Oil General Fact Sheet*; National Pesticide Information Center, Oregon State University Extension Services. http://npic.orst.edu/factsheets/neemgen.html.

Bressette, D. K. (2014, June 23). *Paper Birch, Betula papyrifera*. Native Plants PNW. https://nativeplantspnw.com/paper-birch-betula-papyrifera/

Campbell, L. K., Svendsen, E. S., Johnson, M. L., & Plitt, S. (2022). Not by trees alone: Centering community in urban forestry. Landscape and Urban Planning, 224, 104445

Davey Resource Group. (2011) Urban Forest Management Plan. City of Thunder Bay, Ontario. 222 Pp.

Farrar, J.L. (1995) Trees in Canada. Fitzhenry & Whiteside Ltd., Markham, Ontario. 502 Pp.

Gibb, T., Sadof C. (November, 2017) Bronze Birch Borer, Landscape and Ornimental. Department of Entomology. Purdue University. Bronze Birch Borer (purdue.edu)

Hutchison L. (2023) Urban Forestry Lab Manual. Lakehead University., Thunder Bay Ontario.

I-Tree. (n.d.). *What is i-Tree?* https://www.itreetools.org/about

International Society of Arboriculture. (2020). The guide for plant appraisal (10th ed.). Council of Tree and Landscape Appraisers, 170 pp.

Jonczak, J., Jankiewicz, U., Kondras, M., Kruczkowska, B., Oktaba, L., Oktaba, J., & Sut-Lohmann, M. (2020). The influence of birch trees (Betula spp.) on soil environment–A review. Forest Ecology and Management, 477 118486.

Katovich, S. A., Munson, A. S., Ball, J., & McCullough, D. (2000). Bronze birch borer. US Department of Agriculture Forest Service, State and Private Forestry, Northeastern Area, Forest Insect and Disease Leaflet, 111

Konijnendijk, C. C., Ball, R., Benedikz, T., Campana, R. J., Campanella, T. J., Duinker, P. N., Edwards, K. K., Fernow, B. E., Forrest, M., Groninger, J. W., Harris, R. W., Haynes, R. W., Johnston, M., Jorgensen, E., Kinney, J. P., & Koch, J. (2005, December 27). *Defining urban forestry – a comparative perspective of North America and Europe*. Urban Forestry & Urban Greening. 4(3-4): 93-103)

Kuo, Frances E. (2003). Social Aspects of Urban Forestry. The role of arboriculture in a healthy social ecology. Journal of Arboriculture. 29(3): 148-155.

Lines, R. (1984). Man's use of birch—past and present. Proceedings of the Royal Society of Edinburgh. Section B. Biological Sciences, 85(1–2): 203–213. doi:10.1017/S0269727000004000

Mordue, L. A. J., and Blackwell, A. (1993). Azadirachtin: an update. J. Insect. Physiol. 39: 903–924. doi: 10.1016/0022-1910(93)90001-8

Muilenburg, V. L., & Herms, D. A. (2012). A review of bronze birch borer (Coleoptera: Buprestidae) life history, ecology, and management. Environmental Entomology : 41(6), 1372-1385.

Mytton, O. T., Townsend, N., Rutter, H., & Foster, C. (2012). Green space and physical activity: an observational study using Health Survey for England data. Health & Place, 18(5): 1034–1041. https://doi.org/10.1016/j.healthplace.2012.06.003

Økland, B., Haack, R. A., & Wilhelmsen, G. (2012). Detection probability of forest pests in current inspection protocols–A case study of the bronze birch borer. Scandinavian Journal of Forest Research, 27(3), 285-297.

Parajuli, R., Chizmar, S., Hoy, M., Joshi, O., Gordon, J., Mehmood, S., … & Buntrock, L. (2022). Economic contribution analysis of urban forestry in the northeastern and midwestern states of the United States in 2018. Urban Forestry & Urban Greening, 69, 127490

Thompson, D. G. (2013). TreeAzin®-a natural systemic insecticide for use against the emerald ash borer in Canada. Canadian Forest Service, Great Lakes Forestry Centre Frontline – TreeAzin® – a natural systemic insecticide for use against the emerald ash borer in Canada (lac-bac.gc.ca)

Thompson, J. (2016) City Forester Leaves. Tbnewswatch.com, City forester leaves - TBNewsWatch.com

Worsley, H. (2014). *Uxbridge Nurseries 2014 Price list* .

Yang, J., Wang, C., Xu, C., & He, X. (2023). Thirty years of urban forestry research and practices in China. Urban Forestry & Urban Greening, 86: 128031

APPENDICES

Calculations for DBH class 0-10 cm.

Betula papyfera:	Paper Birch		
Tree Area Constant	Dbh (cm)	Species value (%)	SV
0.7854	4.25	59	0.59
Condition Value (CV)	Location Value (LV)	Dbh (cm) Largest Transplantable Tree (LTT)*	Cost of LTT ($)
0.8	0.85	6	135

BASIC METHOD		
Cross-sectional Area of the actual tree: (Tree Area constant)x(dbh)²=	14.19	cm²
Cross-sectional area of LTT (Tree Area constant)x(dbh)²=	28.2744	cm²
Cost/cm² (Cost of LTT)/(CrossXArea of LTT)=	4.77	$/cm²
Value of tree (CrossXArea of Actual Tree)x(Cost)=	67.73	$
Species Value (Value of Tree)x(SV)=	39.96	$
Condition Value (Value of Tree)x(CV)=	31.97	$
Location Value (Value of Tree)x(LV)=	27.18	$
Final Appraised Value of the Paper Birch (rounded to the nearest hundred)	**0**	**$**

Calculations for DBH class 11-20 cm.

Betula papyfera:	Paper Birch		
Tree Area Constant	Dbh (cm)	Species value (%)	SV
0.7854	16.92	59	0.59
Condition Value (CV)	Location Value (LV)	Dbh (cm) Largest Transplantable Tree (LTT)*	Cost of LTT ($)
0.76	0.71	6	135

BASIC METHOD		
Cross-sectional Area of the actual tree: (Tree Area constant)x(dbh)²=	224.85	cm^2
Cross-sectional area of LTT (Tree Area constant)x(dbh)²=	28.2744	cm^2
Cost/cm² (Cost of LTT)/(CrossXArea of LTT)=	4.77	$/cm²
Value of tree (CrossXArea of Actual Tree)x(Cost)=	1073.57	$
Species Value (Value of Tree)x(SV)=	633.41	$
Condition Value (Value of Tree)x(CV)=	481.39	$
Location Value (Value of Tree)x(LV)=	340.98	$
Final Appraised Value of the Paper Birch (rounded to the nearest hundred)	**300**	**$**

Calculations for DBH class 21-30 cm.

Betula papyfera:	Paper Birch		
Tree Area Constant	Dbh (cm)	Species value (%)	SV
0.7854	25.77	59	0.59
Condition Value (CV)	Location Value (LV)	Dbh (cm) Largest Transplantable Tree (LTT)*	Cost of LTT ($)
0.74	0.82	6	135

BASIC METHOD		
Cross-sectional Area of the actual tree: (Tree Area constant)x(dbh)²=	521.58	cm²
Cross-sectional area of LTT (Tree Area constant)x(dbh)²=	28.2744	cm²
Cost/cm² (Cost of LTT)/(CrossXArea of LTT)=	4.77	$/cm²
Value of tree (CrossXArea of Actual Tree)x(Cost)=	2490.35	$
Species Value (Value of Tree)x(SV)=	1469.31	$
Condition Value (Value of Tree)x(CV)=	1087.29	$
Location Value (Value of Tree)x(LV)=	895.41	$
Final Appraised Value of the Paper Birch (rounded to the nearest hundred)	**900**	**$**

Calculations for DBH class 31-40 cm.

Betula papyfera:	Paper Birch		
Tree Area Constant	Dbh (cm)	Species value (%)	SV
0.7854	35.57	59	0.59
Condition Value (CV)	Location Value (LV)	Dbh (cm) Largest Transplantable Tree (LTT)*	Cost of LTT ($)
0.64	0.8	6	135

BASIC METHOD		
Cross-sectional Area of the actual tree: (Tree Area constant)x(dbh)²=	993.71	cm²
Cross-sectional area of LTT (Tree Area constant)x(dbh)²=	28.2744	cm²
Cost/cm² (Cost of LTT)/(CrossXArea of LTT)=	4.77	$/cm²
Value of tree (CrossXArea of Actual Tree)x(Cost)=	4744.59	$
Species Value (Value of Tree)x(SV)=	2799.31	$
Condition Value (Value of Tree)x(CV)=	1791.56	$
Location Value (Value of Tree)x(LV)=	1428.77	$
Final Appraised Value of the Paper Birch (rounded to the nearest hundred)	**1400**	**$**

Calculations for DBH class 41-50 cm.

Betula papyfera:	Paper Birch		
Tree Area Constant	Dbh (cm)	Species value (%)	SV
0.7854	44.6	59	0.59
Condition Value (CV)	Location Value (LV)	Dbh (cm) Largest Transplantable Tree (LTT)*	Cost of LTT ($)
0.64	0.85	6	135

BASIC METHOD		
Cross-sectional Area of the actual tree: (Tree Area constant)x(dbh)²=	1562.29	cm²
Cross-sectional area of LTT (Tree Area constant)x(dbh)²=	28.2744	cm²
Cost/cm² (Cost of LTT)/(CrossXArea of LTT)=	4.77	$/cm²
Value of tree (CrossXArea of Actual Tree)x(Cost)=	7459.35	$
Species Value (Value of Tree)x(SV)=	4401.01	$
Condition Value (Value of Tree)x(CV)=	2816.65	$
Location Value (Value of Tree)x(LV)=	2406.96	$
Final Appraised Value of the Paper Birch (rounded to the nearest hundred)	**2400**	**$**

Calculations for DBH class 51+ cm.

Betula papyfera:	Paper Birch		
Tree Area Constant	Dbh (cm)	Species value (%)	SV
0.7854	54.21	59	0.59
Condition Value (CV)	Location Value (LV)	Dbh (cm) Largest Transplantable Tree (LTT)*	Cost of LTT ($)
0.68	0.82	6	135

BASIC METHOD		
Cross-sectional Area of the actual tree: (Tree Area constant)x(dbh)²=	2308.07	cm²
Cross-sectional area of LTT (Tree Area constant)x(dbh)²=	28.2744	cm²
Cost/cm² (Cost of LTT)/(CrossXArea of LTT)=	4.77	$/cm²
Value of tree (CrossXArea of Actual Tree)x(Cost)=	11020.22	$
Species Value (Value of Tree)x(SV)=	6501.93	$
Condition Value (Value of Tree)x(CV)=	4421.31	$
Location Value (Value of Tree)x(LV)=	3610.74	$
Final Appraised Value of the Paper Birch (rounded to the nearest hundred)	**3600**	**$**

I-Tree Benefits 20 Year Results

MyTree Benefits

i-Tree

Tree Collection Totals, *()*

Serving Size: 64 trees

Expected over 20 years:	$12,437.60
Carbon Dioxide Uptake	**$2,632.70**
Carbon Sequestered[1]	67,457.16 lbs
CO_2 Equivalent[2]	247,342.93 lbs
Storm Water Mitigation	**$13.71**
Runoff Avoided	1,534.66 gal
Rainfall Intercepted	4,711,219.99 gal
Air Pollution Removal	**$40.78**
Carbon Monoxide	188.91 oz
Ozone	8,485.3 oz
Nitrogen Dioxide	929.53 oz
Sulfur Dioxide	487.74 oz
$PM_{2.5}$	184.04 oz
Energy Usage[3]	**$7,768.24**
Electricity Savings	61,568.89 kWh
Heating Fuel Savings	550.34 MMBtu
Avoided Energy Emissions	**$1,982.17**
Carbon Dioxide	174,775.41 lbs
Carbon Monoxide	1,123.91 oz
Nitrogen Dioxide	522.67 oz
Sulfur Dioxide	5,538.37 oz
$PM_{2.5}$	237.59 oz

Benefit estimates are based on USDA Forest Service research and are meant for guidance only. Visit www.itreetools.org to learn more.

See the Project Menu for currency conversions.

+ Read the fine print.

I-Tree Benefits 1-Year

MyTree Benefits

Tree Collection Totals, *()*

Serving Size: 64 trees

Estimated this year:	$542.62
	Annual values:
Carbon Dioxide Uptake	**$99.88**
Carbon Sequestered[1]	2,559.29 lbs
CO_2 Equivalent[2]	9,384.05 lbs
Storm Water Mitigation	**$0.56**
Runoff Avoided	63.2 gal
Rainfall Intercepted	194,017.87 gal
Air Pollution Removal	**$1.76**
Carbon Monoxide	7.85 oz
Ozone	362.39 oz
Nitrogen Dioxide	39.91 oz
Sulfur Dioxide	20.77 oz
$PM_{2.5}$	8.06 oz
Energy Usage Per Year[3]	**$350.87**
Electricity Savings	2,896.07 kWh
Heating Fuel Savings	24.03 MMBtu
Avoided Energy Emissions	**$89.55**
Carbon Dioxide	7,888.24 lbs
Carbon Monoxide	51.7 oz
Nitrogen Dioxide	23.63 oz
Sulfur Dioxide	250.62 oz
$PM_{2.5}$	11.14 oz
	Values are totals to date:
Carbon Dioxide Uptake[4]	**$2,492.92**
Carbon Storage[4]	63,875.64 lbs
CO_2 Equivalent[2, 4]	234,210.69 lbs

Benefit estimates are based on USDA Forest Service research and are meant for guidance only. Visit www.itreetools.org to learn more.

See the Project Menu for currency conversions.

+ Read the fine print.