URBAN FOREST MANAGEMENT: EVALUATING THE BENEFITS AND OPTIONS FOR REPLACING DECLINING URBAN ASH TREES, AND VALUE-ADDED POTENTIAL OF URBAN TREES.

by

Jobanpreet Kaur

Student number: 1092290

An Undergraduate Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Honours Bachelor of Environmental Management

Faculty of Natural Resources Management

Lakehead University

April 20th, 2023

URBAN FOREST MANAGEMENT: EVALUATING THE BENEFITS AND OPTIONS FOR REPLACING DECLINING URBAN ASH TREES, AND VALUE-ADDED POTENTIAL OF URBAN TREES.

by

Jobanpreet Kaur

Student number: 1092290

An Undergraduate Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Honours Bachelor of Environmental Management

Faculty of Natural Resources Management

Lakehead University

April 20th, 2023

--------------------------- -----------------------------

Dr. Mathew Leitch Ryan Wilkie

Thesis Supervisor Second Reader

LIBRARY RIGHTS STATEMENT

Date: __April 20th 2023 ___

A CAUTION TO THE READER

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

The reader should be aware that the opinions and conclusions expressed in this document are those of the student and do not necessarily reflect the opinions of the thesis supervisor, the faculty or Lakehead University.

ABSTRACT

Keywords: ash trees, costs, environmental benefits, social benefits, tree maintenance urban forestry, urban forest management, urban trees, value-added potential.

This thesis investigates the benefits and options for replacing declining urban ash trees, as well as the value-added potential of urban trees more broadly. The study aims to provide insights into the selection of suitable tree species for urban areas, considering their ecological, social and economic benefits. The research methodology involved a literature review of various peer-reviewed articles, government sites and books to assess the survival rate of different tree species and their growth patterns in urban areas. The study also analyzed the value-added potential of selected tree species in terms of ecosystem services, such as carbon sequestration, air quality improvement, and aesthetic value. The study also analyzed the approaches used by different cities to replace ash trees and suggested new species to plant. The findings indicate that urban trees have significant value-added potential, beyond their ecological benefits. The research suggests that a diverse mix of tree species should be considered in urban tree-planting programs to improve the resilience and sustainability of urban ecosystems. The results of this study can help urban planners, landscape architects, and policymakers to make informed decisions regarding the selection and management of tree species in urban areas.

ACKNOWLEDGEMENTS

I would like to thank God for giving me the strength, wisdom, and perseverance to complete this thesis. Almighty's divine grace has sustained me during difficult times and given me hope and inspiration to keep going. Additionally, I would like to express my deepest gratitude to my thesis supervisor Dr. Mathew Leitch and my thesis' second reader Mr. Ryan Wilkie for their guidance, support and encouragement throughout this research project. Their insightful comments, valuable feedback, and constructive criticism have helped me improve this work's quality.

I would also like to acknowledge the support of my family and my best friend Parveet, who have provided me with emotional support, motivation, and understanding during my studies. Their love, patience, and encouragement have been essential in helping me achieve this milestone.

Finally, I would like to express my appreciation to all my classmates for their intellectual engagement, lively discussions, and collaborative work during my studies.

Thank you all for your invaluable support and encouragement.

Table of contents

TABLES

FIGURES

1. INTRODUCTION

The importance of trees is very well known to everybody and how they help sustain nature as well as human life. An urban forest is a concept of improving the green infrastructure in towns and cities to maintain a healthy urban ecosystem. There are many benefits associated with urban trees such as they help in the reduction of GHG (Green House Gas) emissions by sequestering carbon, decreasing stormwater runoff by absorbing more rainwater, reduce heat by cooling the rooftops (Wolf et al. 2020). City streets, towns, and suburbs have street trees growing in the public right-of-way (Berland et al. 2019). It is well known that street trees constitute a small portion of the overall urban forest in many cities (Nowak et al. 2001), but they are still a prominent component targeted by municipalities and nonprofit organizations (NPOs) for their public engagement efforts (Galenieks 2017). Sustainability efforts at the local level are critical to addressing global environmental challenges and among local sustainability initiatives is urban greening, an activity that involves introducing, conserving, or maintaining vegetation in urban areas (Eisenman et al. 2019). Young (2011) and Nguyen et al. (2017) cite examples of cities setting ambitious tree canopy cover goals. Municipal foresters and tree-planting advocates increasingly emphasize ecosystem services in tree-planting programs (Young 2013). In addition to shading buildings to reduce air conditioning use (Ko 2018) and managing stormwater (Berland et al. 2017), urban trees provide many benefits to society.

This paper is going to explore the benefits and options for replacing declining urban ash trees (*Fraxinus spp.*), as well as the value-added potential of urban trees. This study is important because it is going to provide an in-depth insight into the growth and survival mechanisms of different tree species suitable for urban environments. A lot of ash trees in Canada are dying due to the Emerald Ash Borer's (EAB) (*Agrilus Planipennis*) invasion so it is important to understand what other trees could replace ash trees and could also provide value-added products after they die. The data would be collected by looking at different literature sources and would then be used to conclude what new tree species would be suitable to plant in those areas.

Different literature sources such as books, peer-reviewed journals and web sources were used to write this paper; all of these are cited in the literature cited section. These sources explained what urban forestry is, why it is important, what trees are well suited to urban environments, and what are the benefits and potential problems.

2. OBJECTIVES

There are two main objectives of this study. The first objective was to assess the need for the replacement of ash trees in urban areas of Canada and discuss urban tree benefits. The second objective of this study was to further analyze the value-added potential of selected tree species, including the use of dead trees for various wood products and other potential economic benefits.

3. LITERATURE REVIEW

It is very crucial to have an organized and systematic understanding of the growth potential of individual tree species as they relate to their local growing environment (Peper et al. 2014). A quantitative understanding of tree growth and mature size will help you choose the right tree for the right place without damaging structures, paying for tree maintenance, or even removing mature trees that are in good shape (Peper et al. 2014). To communicate information about the growth of different tree species, municipal and extension offices publish documents that explain how they grow qualitatively, and subjectively, such as the growth rate and height of trees (Peper et al. 2014). Urban sites are limited in their ability to apply these documents because tree dimensions do not only depend on species but also on specific site conditions and environmental factors (Peper et al. 2014). It is important to understand more precisely how trees grow to make informed decisions regarding the spacing and placement of the trees concerning the anthropogenic structures, according to Stoffberg et al. (2008). Nevertheless, the problem with urban forestry lies more in the need for additional data which can lead to more precise growth estimations (Peper et al. 2014).

Different growth equations have been developed for forest stands, power laws have been developed to determine plant structure, and growth theories that could be used to anticipate the change in the dynamics of forest trees over time (Peper et al. 2014). However, various studies say that open-grown trees and managed trees grow differently from each other (Zeng 2003), which emphasizes the need to conduct more studies that focus specifically on open-grown trees. Main examples of open-grown trees would be municipal trees, especially the ones that grow along roadsides and boulevards (Peper et al. 2014). Arborists and urban forest managers would greatly benefit if more equations were developed to measure tree dbh (diameter at breast height), height, canopy closure etc. as this would allow them to predict the tree management strategies, cost of their maintenance, and best management practices to sustainably manage the urban forests (Peper et al. 2014).

The prediction of how trees grow in urban settings has been done through different studies in different countries such as the United States, South Africa, and Denmark but no models have been developed for the urban forests of Canada. The equations that work for one species in one growing site do not work for the trees growing in other regions of the country because of the different growing site conditions and length of the growing season (Peper et al. 2014)

3.1 URBAN FORESTRY

Urban forestry is a multidisciplinary field that focuses on the dynamics of urban greenspaces involving tree stands and individual tree species (Konijnendiik et al. 2006). It is not easy to study the dynamics of an urban forest because of its complexity. An urban site is prone to different levels of stress and pressures such as changing urban demands, less growing space, and high levels of pollution (Konijnendiik et al. 2006). The concept of urban forestry is gaining international recognition because of the benefits it provides.

3.1.1 URBAN FORESTRY IN NORTH AMERICA

The establishment of urban forestry in North America mainly started in the 1970s and 1980s but there was no proper definition or name given to this field as is the case today (Konijnendiik et al. 2006). Words like ‘shade’ or ‘ornamentals’ were used whenever there was a discussion about urban trees (Konijnendiik et al. 2006). Defining urban forestry has always been a challenge and therefore several different definitions have been developed throughout US history. Urban forests are an everchanging concept not only in the US but in other countries as well because the environment in which the urban trees emerge change from time to time and require new management techniques and plans. A lot of variation can be noticed in urban areas when structural gradients change from urban to rural and the one thing that remains common throughout these visualizations are the trees, which are considered the smallest unit of the forest (Konijnendiik et al. 2006). The term urban forestry was first launched in Canada in 1965 by an ecologist named Jorgensen and he defined urban forestry as “a special branch of forestry that is focused on growing and managing trees for their potential contribution to the physiological, social, and economic well-being of an urban ecosystem (Jorgensen 1986).” Ontario is the only province in Canada that has its urban forestry legislation and according to the Professional Foresters Act of 2000 urban forests are very important as they are not just street trees or on private yards, but they are a benefit to the public in many ways (Konijnendiik et al. 2006).

3.1.2 URBAN FORESTRY IN EUROPE

Europe has always been very active with its urban forest management and has a rich history of conserving and managing urban greenspaces. When industrialization boomed in Europe there was an increase in the urban population, and this was the time when urban forestry gained recognition. Being a diverse continent, Europe had difficulty translating the concept of urban forests to people (Konijnendiik et al. 2006). Also, town forestry was more familiar which was simply conserving and managing woodlands only, however, urban forestry has a broader scope which does not include just woodlands but also groups of trees or single trees (Konijnendiik et al. 2006). British National Urban Forestry Unit (NUFU 1999) described urban forestry as “an urban forest which comprises of all the trees and woods in an urban area be it parks, yards, streets, offices or existing woodlands.”

3.1.3 URBAN FOREST MANAGEMENT

The urban population in Canada, which is mostly concentrated in cities, depends on urban forests to enhance their quality of life (van Wassenaer et al. 2000). In recent years, there has been growth in the number of urban forest management plans (UFMPs) (Ordonez and Duinker 2013). UFMPs have become essential records that outline the management of urban forests and this presents an opportunity to analyze current urban forest management practices in Canada by referring to these important documents (Ordonez and Duinker 2013).

Over the past few decades, there has been an increase in research on urban forests and this has enhanced our comprehension of urban forests while also questioning the conventional motivations behind their management, which are primarily the aesthetic and environmental benefits of trees, as well as the challenges of growing trees in the city (Ordonez and Duinker 2013). Public opinion studies in North America have identified aesthetics as the primary concern for planting trees (Hull 1992), while urban planners focus on climate benefits (Arnfield 2003). However, there is now a more comprehensive set of benefits associated with urban forests that go beyond these two factors (Ordonez and Duinker 2013). Urban trees are now also being planted for air pollution, nature conservation, human health, and property value among other valuable aspects (Tyrvainen et al. 2005). The values of urban forests serve as a significant driving force for their management, and since ecosystem management reflects our perception of nature, the need for a broader range of values must justify the creation of a UFMP (Ordonez and Duinker 2013).

Urban forest challenges in North America have been historically characterized by two key concerns: the loss of trees and the lack of tree diversity (Ordonez and Duinker 2013). Some attribute the loss of trees to the rising effects of urbanization, which creates harsh environmental conditions for the trees that remain (Carreiro 2008). Additionally, the fragmented ownership of trees poses a challenge to effective management and control. In Canada, policies before the 1990s often focused on removing publicly owned trees, resulting in an increase in private ownership of trees (Kenney and Idziak 2000). As a result, tree bylaws have become a popular tool for protecting trees, but their effectiveness is still up for debate (Conway and Urbani 2007). The unequal distribution of trees can also contribute to their loss and impact on accessibility and social equity (Heynen et al. 2006).

Regarding tree diversity, problems with age and species diversity are common in North American urban forests (Ordonez and Duinker 2013). Some Canadian cities are dominated by old trees, while others have mostly young trees (Town of Banff, 2008; Town of Ajax, 2011). Moreover, urban tree selection has been heavily biased toward a few species, mostly European or native ones which are often vulnerable to diseases and pests. The potential impact of diseases like Dutch Elm Disease and Emerald Ash Borer, among others, is high in Canada (Karnosky 2009; Poland and McCullough 2006). Climate change may exacerbate these problems by making some species maladapted to their new environment (Yang 2009). To address these challenges, experts suggest planting species that are better adapted to the changing climate, as well as adopting long-term strategies to facilitate tree survival (Johnston 2004).

An urban forest management approach has evolved intending to increase canopy cover, species diversity, and tree size in urban areas. This approach provides a technical focus to address the issues of tree loss and diversity and promote environmental benefits. However, relying solely on these three goals may lead to unintended consequences and disregard ecological considerations, such as connectivity and representation of native tree species. Moreover, relying solely on technical steering committees may isolate other stakeholders from decision-making and worsen the legitimacy of urban forest programs. Therefore, modern urban forest management must have a purpose that goes beyond providing circumstantial benefits, broad principles that define management approaches, public participation, and appropriate documentation in the form of a UFMP approved by the city council. Urban trees are critical to urban planning and must be managed with a comprehensive and inclusive approach.

Ordonez and Duinker's (2013) study revealed that combating diseases and pests, lack of diversity, and deforestation resulting from development were common rationales for creating a UFMP. The scope of inventories differs among municipalities, with some possessing UFORE-type inventories, while others lack specific details. Generally, most steering committees comprised municipal staff, and public input was minimal. The documentation's nature also varies, with nearly half of the plans referring to their UFMP document as a strategy or framework for a plan. In terms of management principles, safeguarding, augmenting, and preserving the urban forest resource were typical, followed by enhancing community support.

According to Ordonez and Duinker (2013), the effectiveness of managing Canadian urban forests hinged on how we envision their futures. A review of planning documentation in Canadian urban forest management reveals that management could be considerably improved by addressing the lack of ecological, social, and economic management themes, including nativeness, naturalness, climate change, public participation and the use of economic incentives. Furthermore, a deeper comprehension of urban forest management as a learning process may compensate for vagueness, requiring robust implementation of adaptive management.

3.1.4 URBAN FOREST MAINTENANCE

Urban forest maintenance can be divided into six main components, which include the type of maintenance required, who will perform the maintenance activity, the intensity, frequency, and duration of the maintenance, as well as the extent of maintenance necessary (Hauer et al. 2015). These considerations are critical to ensure that the trees are healthy and provide optimal benefits throughout their life cycle, from immature to semimature, mature, and eventually senescent stages. During each stage, different maintenance activities may be required to enhance the benefits provided by the trees. Failure to perform maintenance activities can lead to reduced benefits, lower value tree populations, and increased costs in the long term (Hauer et al. 2015). It is essential to select the appropriate plant species for a site to prevent future conflicts and ensure optimal growth and longevity. As trees mature, their benefits increase and maintenance costs decrease (Hauer et al. 2015). Eventually, senescent trees may require trade-offs between maintenance costs and heritage or ecological value and retaining these trees may be justified even if they no longer provide monetary benefits (Hauer et al. 2015).

Table 1 shows the main elements of an urban forest maintenance routine, which are what type of maintenance activity is required, who is going to perform it, what intensity and frequency are needed, and the duration and extent.

Table 1: The main components of an urban forest maintenance routine (Source: Hauer et al. 2015).

Table 1. Key elements of an urban forest maintenance regime.

Element	Description	Examples
Type	The particular maintenance activity	Prune, mulch, stake
Who	Party physically performing maintenance activity	City tree crew, contracted certified arborist, nonprofit, adjacent home owner
Intensity	How much	Ten percent of the crown, 5 (18.93) or 15 (56.78) gallons (liters) of water
Frequency	How often	A four- or six-year pruning cycle, once per week
Duration	How long	For just the first growing season after transplanting, throughout a tree's life
Extent	What part of a tree or which trees	Branches below 14-foot (4.27 m) clearance level, all trees in a city, trees on heavily traveled road corridors, trees in a downtown area

3.2 BENEFITS OF TREES

According to Roy et al. (2012), trees offer various advantages to society. Many trees found in urban settings are a result of deliberate efforts to plant them. The initial expenses of planting and caring for these trees are investments made with the expectation of future benefits (Hauer et al. 2015). The upkeep of the trees is connected to their structure and function, which are essential to the health of the urban forest. Failure to maintain the trees can result in additional costs and issues, such as tree collapses, wastes, pests, obstructed intersections, and other problems (Hauer et al. 2015). Therefore, maintaining urban trees is necessary to prevent conflicts with other infrastructure. According to Hauer et al. (2015), a proactive approach to tree care, which involves systematic maintenance, is more effective than a reactive approach that responds only when crises arise.

Fig. 1 shows maintenance has a direct impact on the urban tree structure and this in turn affects the functions and benefits provided by trees. It also shows how benefits have a cost associated with them and this explains that there is a monetary value associated with each benefit that the trees provide.

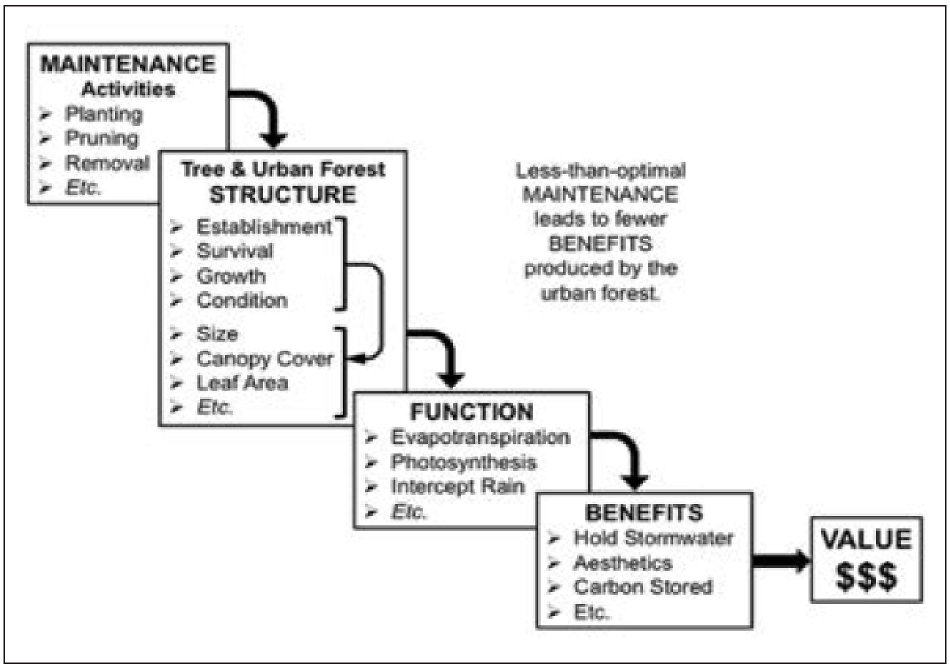

Fig 1: Shows how maintenance is responsible for an urban forest structure and affects the benefits provided by trees (Vogt et al. 2015).

3.2.1 ENVIRONMENTAL BENEFITS

According to Day et al. (2008) and Xiao et al. (1998), cities increasingly use green infrastructure such as trees to manage stormwater. The use of urban trees is particularly useful in addressing the challenges of impenetrable surfaces in urban areas (Donovan 2017). Stormwater from impervious surfaces quickly flows into the stormwater system, causing overflows and backups for residential and commercial customers (Villareal et al. 2004). This problem is more severe in communities with a combined sewer system (Donovan 2017). Trees can intercept rainwater before it enters the stormwater system, primarily if they are covering impenetrable surfaces (Donovan 2017).

Trees can also help reduce energy consumption by reducing summertime cooling costs, particularly if they are located to the west and south of a house (Donovan and Butry 2009). Additionally, trees can have a positive impact on public health through improved air quality, reduced stress, increased exercise, and improved social connections (Hystad et al. 2014). Trees in areas with high population density and air pollution are especially beneficial in improving air quality and public health (Daniels et al. 2000).

To maximize the benefits of trees in improving air quality and public health, planting them along freeways in residential areas is a good strategy (Daniels et al. 2000). The below-given figures (Figures 2, 3, 4) are well illustrated in Donovan (2017). These figures show how trees planted in urban areas help reduce stormwater runoff and improve public health.

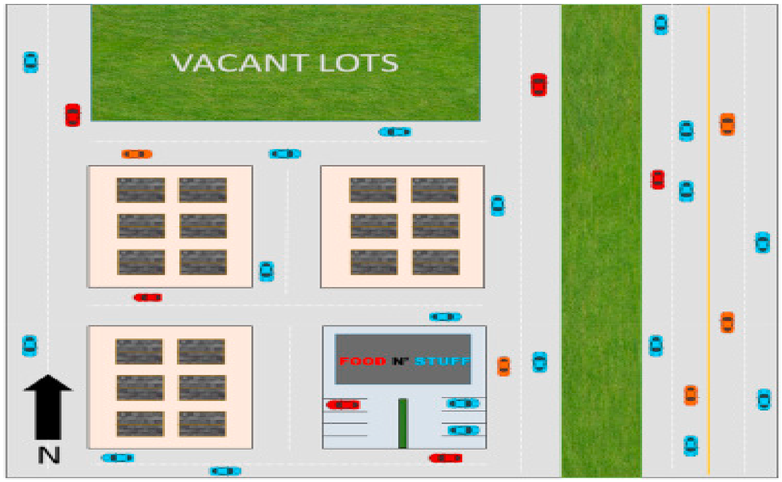

Figure 2: Represents urban areas with vacant spaces (no trees) (Donovan 2017)

Fig 3. Represents urban areas where trees are planted to decrease stormwater runoff and cooling costs (Donovan 2017).

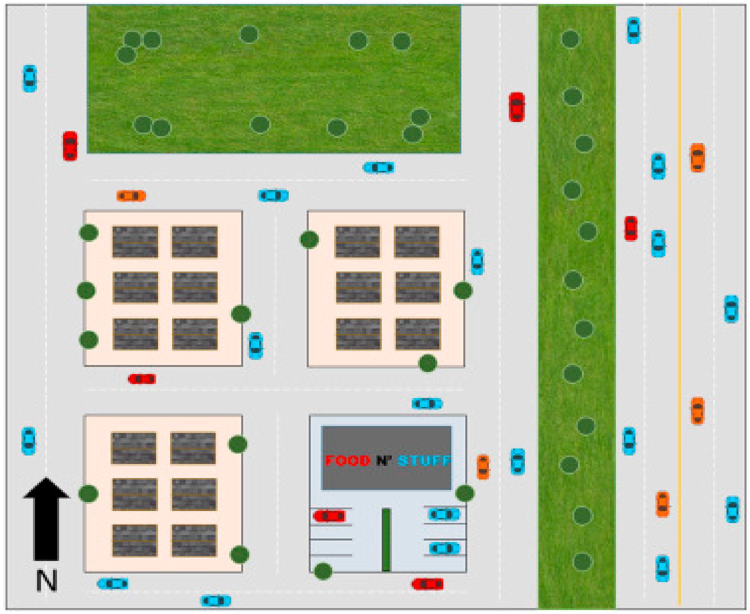

Fig 4: Trees planted to improve the health of the public (Donovan 2017)

Figure 5 represents the costs and benefits associated with an individual tree lifecycle. The solid lines show the benefits and costs of maintenance and the dashed lines are for without maintenance.

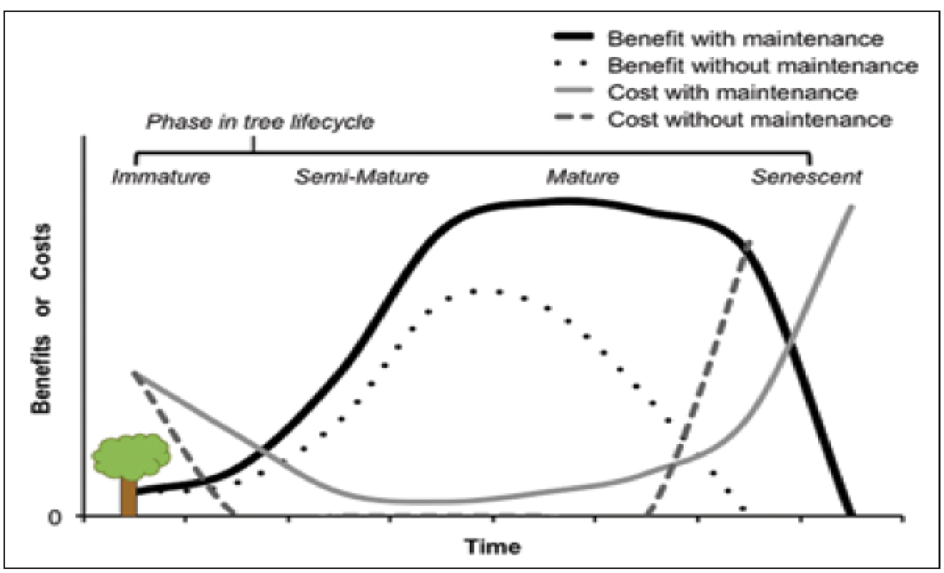

Fig 5: Costs and Benefits graph for an individual tree's lifecycle (Vogt et al. 2015)

3.2.2 HEALTH BENEFITS

To understand the impact of tree distribution on public health, it is useful to examine four mechanisms that connect trees to health: better air quality, lower stress, increased physical activity, and improved social connections (Hystad et al. 2014). Trees located in areas with high population density and air pollution will have the greatest impact on public health by ignoring air quality, as the relationship between air pollution and health is typically nonlinear (Daniels et al. 2000). Thus, planting trees along a busy road in a residential area would be an effective strategy to improve air quality and public health.

Research has shown that people who live in neighbourhoods with greater access to parks and green spaces tend to exercise more (Coombes et al. 2010; Hansmann et al. 2007). Studies have also found that increased greenness in neighbourhoods is associated with greater walkability and increased exercise (Frank et al. 2005; Lovasi et al. 2011). Therefore, parks and public rights of way are the ideal locations for planting trees to encourage physical activity. Studies have found that access to green space, such as parks, is associated with reduced stress (Hartig and Staats, 2006; Roe and Aspinall, 2011). This suggests that continuous areas of green space can help lower stress levels. Additionally, increased greenness around a person’s home has been linked to lower levels of the stress hormone cortisol (Ward Thompson et al. 2012). Some studies have also found that residential greenness is associated with improved health outcomes (Donovan 2017).

3.2.3 ECONOMIC BENEFITS

Urban forests have multiple economic benefits, including increasing property values, boosting real estate, improving consumer preference, and reducing costs by shading buildings and lowering surrounding temperatures (Tree Canada 2021). According to the TD Economics Report (2014), the combined value of urban forests in four Canadian cities i.e., Montreal, Vancouver, Halifax and Toronto, was $42 billion, and they provided $330 million in yearly environmental benefits. The report also revealed that cities earned between $1.88 and $12.70 in benefits for every dollar spent on tree maintenance, depending on the location. Tree valuation is critical because trees hold considerable monetary worth (Tree Canada 2021). To assess their value, the appraisal process considers species type, physical condition, location, and other factors listed in the established tree resources (Tree Canada 2021).

Calculating the benefits of trees is an important way to justify the allocation of resources to the urban forest in cities. Table 2, 3 and 4 represents the benefits of urban forests in three different cities namely Thunder Bay, Toronto and Vancouver, based on the available inventory data.

Table 2: Annual benefits of urban trees in Thunder Bay (TBUFMP 2011).

Benefit Category	Benefit Total ($)	Benefit per Tree ($)	Percent of Total Benefits
Stormwater	$552,362	$30	36%
Energy	$455,908	$25	29%
Aesthetic/Other	$403,056	$22	26%
Air Quality	$77,383	$4	5%
CO_2	$67,178	$4	4%
Total	$1,555,887	$85	100%

Table 3: Annual benefits of urban trees in Toronto (TD Economic Report 2014).

Benefit	$ value (millions)	$/tree
Wet-weather flow	$53.95	$5.28
Air quality	$19.09	$1.87
Energy savings	$6.42	$0.63
Carbon sequestration	$1.24	$0.12
Energy emission abatement	$0.58	$0.06
Total benefit	$81.29	$7.95
Cost benefit ratio	-	$1.35 - $3.20

Table 4: Annual benefits of urban trees in Greater Vancouver (TD Economic Report 2014).

Benefit	$ value (millions)	$/tree
Wet-weather flow	$96.43	$1.34
Air quality	$115.86	$1.61
Energy savings	$4.64	$0.16
Carbon sequestration	$7.21	$0.10
Total benefit	$224.15	$3.21
Cost benefit ratio	-	$4.59

3.3 COSTS OF TREES

To assess the costs of neglecting trees, one must consider the expenses and benefits incurred throughout the tree's lifespan under various maintenance scenarios (Vogt et al. 2015). These costs may include direct expenses associated with providing and maintaining urban trees, costs resulting from infrastructure interference, and costs inferred from environmental externalities (Vogt et al. 2015). In addition, different types of trees and planting situations have varying costs. Maintenance-related expenses start at planting and continue throughout the tree's useful life until its removal (Vogt et al. 2015).

Maintenance costs can vary depending on the species, location, and stage of the tree's life (McPherson 2003). These expenses may include purchasing the tree, modifying infrastructure, installing the tree, and maintenance activities such as pruning, mulching, watering, and pest management (Vogt et al. 2015). The cost of removing dead branches or the entire tree during senescence could be significant (Vogt et al. 2015). These maintenance expenses drive the theoretical costs throughout the tree's life cycle and different levels of maintenance at different points in time may affect subsequent maintenance needs (Table 5).

Table 5: Different types of costs associated with urban tree maintenance (Vogt et al. 2015).

Type of cost	Examples
Direct costs (of provisioning and maintaining trees)	Planting, pruning, watering, other types of maintenance
Infrastructure interference costs	Pavement and sewer repair, blockage of signs, tree-initiated power outages
Externality-related costs	Emissions of biogenic VOCs, release of carbon dioxide during decomposition, allergies due to pollen release, leaf/debris clean-up
Opportunity costs	Space for trees cannot be used for parking, bike lanes, etc.

3.4 ASH AS AN URBAN TREE

Trees planted in urban areas go through a lot of stress and often attract tree pests and diseases (MacFarlane and Meyer 2005). In recent decades, Ash trees replaced the American elms (*Ulmus americana* L.) killed by Dutch elm disease and became the most popular street tree (MacFarlane and Meyer 2005). A green ash plant, for example, can handle drought stress and tolerate salt as well as a wide range of soil pH conditions (McComb 1949). The species occupy a variety of natural environments because of its ecological amplitude, including riparian flats in Montana across the eastern U.S. (MacFarlane and Meyer 2005). Because of this natural stress tolerance, green ash thrives in urban settings (MacFarlane and Meyer 2005). Trees in urban areas also need to tolerate alkalinity due to calcium leachate from concrete gathering in tree root pits, causing a high pH (MacFarlane and Meyer 2005). All these high-stress tolerance properties make ash a suitable tree for urban planting.

Figure 6 shows the annual benefits provided by an individual ash tree by the type of distribution. Property value benefit is the highest of all the other benefits provided by ash trees.

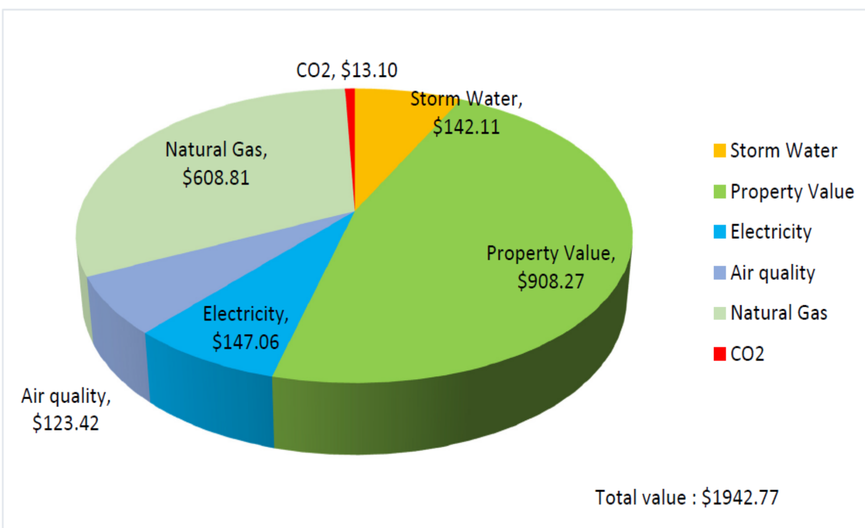

Fig. 6: Annual benefits of a single ash tree categorized by type of distribution (Arbab et al. 2022).

3.4.1 EMERALD ASH BORER

The emerald ash borer (EAB) is a type of beetle that bores into the wood and is found in the United States (Flower et al. 2018). It originally came from Asian countries such as China, Japan, and Korea, and was most likely brought to the U.S. through shipping materials from Asia (Haack 2006). The EAB attacks all types of ash trees in the United States and Canada, and since it was first identified near Detroit and has since spread throughout the U.S. and Canada due to the beetle's ability to fly and human transportation (Arbab et al. 2022). The infestation is spreading across the Midwest and Northeastern states of the U.S. (Arbab et al. 2022).

The fully grown larvae of the EAB make holes in the outer sapwood of ash trees and create twisted pathways in the inner tissue where sap flows, which eventually causes the trees to die quickly because the transportation of sap between the roots and shoots is disturbed (Flower et al. 2018). When EABs interfere with sap flow, the amount of water used by the trees is reduced by 80%, leading to a decrease in the size and mass of leaves (Flower et al. 2018). This decrease in leaf size and mass results in reduced photosynthesis and changes in the CO_2 levels inside the leaves (Arbab et al. 2022). Consequently, the number of carbohydrates stored in the leaf tissue decreases, which further damages the inner tissue that moves water and nutrients (Arbab et al. 2022).

3.4.2 TREATMENT

Herms et al. (2009) listed numerous insecticides that are available to treat ash trees threatened by the EAB and those will be discussed in this paragraph. Controlling insects that feed under the bark with insecticides has always been difficult. Therefore, selecting the appropriate insecticide product and application method is crucial for the effective control of EAB, ensuring that the product is applied at the right rate and time.

It is best to start using insecticides while the ash trees are still relatively healthy. Most people don’t detect canopy thinning or dieback until the tree’s vascular system has already suffered serious harm from the EAB. Although an effective insecticide may stop further damage, it cannot reverse the damage that has already occurred, and it takes time for the trees to recover.

Depending on the severity of the damage and the control methods employed, trees can recover from low to moderate EAB damage (Herms et al. 2009). Herms et al.’s (2009) study also said that effective control requires optimal timing, targeting two life stages of EAB: adult beetles and young larvae, and systemic insecticide applications should be performed in advance for proper absorption and distribution of the insecticide within the tree to ensure adult beetles and very young larvae encounter the toxin. Thorough coverage is critical for achieving successful control. Non-systemic cover sprays, which are less commonly used, should be applied to foliage to target adult beetles, as well as the trunk and branches to help control newly hatched larvae (Herms et al. 2009). Insecticides that can effectively control EAB fall into four categories: (1) systemic insecticides applied as soil injections or drenches; (2) systemic insecticides applied as trunk injections; (3) systemic insecticides applied as lower trunk sprays, and (4) protective cover sprays that are applied to the trunk, main branches, and foliage (Herms et al. 2009).

Table 6 presents a list of insecticide options that have been tested in multiple university trials for controlling EAB, but the inclusion of a particular product mustn't indicate endorsement by the authors or consistent effectiveness in controlling EAB. Additionally, certain products may not be approved for use everywhere.

Table 6: List of insecticide options to control EAB (Herms et al. 2009).

Insecticide Formulation	Active Ingredient	Application Method	Recommended Timing
Products Intended for Sale to Professional Applicators			
Merit® (75WP, 75WSP, 2F)	Imidacloprid	Soil injection or drench	Early to mid-spring or mid-fall
Safari ™ (20 SG)	Dinotefuran	Soil injection or drench	Mid- to late spring
Transect ™ (70WSP)	Dinotefuran	Soil injection or drench	Mid- to late spring
Xylam® Liquid Systemic Insecticide	Dinotefuran	Soil injection or drench	Mid- to late spring
Xytect™ (2F, 75WSP)	Imidacloprid	Soil injection or drench	Early to mid-spring or mid-fall
Azasol™	Azadirachtin	Trunk injection	Mid- to late spring after trees have leafed out
Imicide®	Imidacloprid	Trunk injection	Mid- to late spring after trees have leafed out
TREE-äge™	Emamectin benzoate	Trunk injection	Mid- to late spring after trees have leafed out
TreeAzin®	Azadirachtin	Trunk injection	Mid- to late spring after trees have leafed out
Safari™ (20 SG)	Dinotefuran	Systemic bark spray	Mid- to late spring after trees have leafed out
Transect (70 WSP)	Dinotefuran	Systemic bark spray	Mid- to late spring after trees have leafed out
Zylam® Liquid Systemic Insecticide	Dinotefuran	Systemic bark spray	Mid- to late spring after trees have leafed out
Astro®	Permethrin	Preventive trunk, branch, and foliage cover sprays	Two applications at 4-week intervals; first spray should occur at 450-550 degree days (50°F, Jan. 1); coincides with black locust blooming
Onyx™	Bifenthrin		
Tempo®	Cyfluthrin		
Sevin® SL	Carbaryl		
Products Intended for Sale to Homeowners			
Bayer Advanced™ Tree & Shrub Insect Control	Imidacloprid	Soil drench	Early to mid-spring
Optrol ™	Imidacloprid	Soil drench	Early to mid-spring
Ortho Tree and Shrub Insect Control Ready to Use Granules®	Dinotefuran	Granules	Mid- to late spring

3.4.3 ASH MORTALITY

The analysis conducted by Knight et al. (2013) on yearly surveys of ash trees in stands infested by EAB revealed that complete stand mortality can occur within 6 years. Shaded trees and trees initially exhibiting dieback had the most rapid mortality, and trees in hydric and xeric sites survived longer than trees in mesic sites (Knight et al. 2013). Trees in sites with a low density of ash trees died more rapidly than trees in high-density ash sites, suggesting that rapid host mortality may result from the concentration of insects on a few trees in areas with low host density (Knight et al. 2013).

Also, with the rise of accidental introductions and climate change, the issue of invasive insect pests has become more common (Knight et al. 2013). It is crucial to understand that both the biology of the insect and the host can play a significant role in determining the direction of the relationship between host density and host mortality (Knight et al. 2013). Reducing host density may not always prevent the remaining host trees from succumbing to the pest. (Knight et al. 2013).

3.5 OTHER URBAN TREES

Understanding the traits of different tree species is crucial because planting them in unsuitable locations can cause unforeseen issues. Some tree species resist pollution better than others, like the London plane, which has thrived in city environments due to its ability to shed bark and cleanse pollutants (Willis and Petrokofsky 2017). The effectiveness of removing particulate matter (PM) from the air varies greatly between species, with elm, magnolia, ash, holly, and certain climbing vines performing better than others (Willis and Petrokosfy 2017). Coniferous trees such as Scots pine are more efficient at capturing PM than broad-leaved deciduous trees like the linden tree (Willis and Petrokofsky 2017).

A study done by Conway and Vander Vecht (2015) included answers from different participants when asked about the characteristics of different urban forest management facilities (Table 7). There are landscape architects, NPOs, garden centers and nurseries, which influence the decision-making process related to urban forest management. Also, each actor has a list of what they think is the most planted or commonly sold urban tree. It must be noted that few participants of this study only provided genera-level tree information.

Table 7: Functions performed by various landscape architects, NPOs, retail garden centers and nurseries, and Toronto Urban Forestry for managing urban trees in Toronto (Conway and Vander Vecht 2015).

Basic characteristics of landscape architects, NPOs, retail garden centers and nurseries, and Toronto Urban Forestry.

Actor	Number of respondents (response rate)	Clients or planting areas	Experience
Landscape architects	50 (45%)	Residential – 56% Commercial – 42% Government – 38% Institutional – 34% Other – 12%	20 years or more – 56% 10–20 years – 22% Less than 10 years – 22%
NPOs	2 (100%)	One primarily residential; One primarily in parks and natural areas	Residential NPO started 1996; Parks and natural areas NPO started 1991
Retail garden centers and nurseries	12 (60%)	Primarily private residents; also landscapers, contractors, developers	Unknown/varied
Toronto Urban Forestry	N/A	Responsible for all municipal tree planting on streets, parks, natural areas and other public property.	N/A

Also, each actor had a list of what they think is the most planted or commonly sold urban tree. It must be noted that few participants of this study only provided genera-level tree information (Table 8). The most common trees include species of maple trees, walnuts, basswood, and Ginkgo.

Table 8: The list of popular tree species for planting or selling by these four actors (Conway and Vander Vecht 2015).

Landscape architects	NPOs	Retail garden centers and nurseries	Urban forestry
Acer	*Acer rubrum*	*Acer*	*Acer × fremanii*
Amelanchier	*Acer saccharinum*	*Betula*	*Celtis occidentalis*
Fagus	*Acer saccharum*	*Buxus*	*Ginkgo biloba*
Ginkgo	*Acer × freemanii*	*Cercis*	*Gleditsia triacanthos inermis*
Gleditsia	*Carpinus caroliniana*	*Cornus*	*Gymnocladus dioicus*
Quercus	*Celtis occidentalis*	*Euonymus*	*Tilia americana*
Tilia	*Cercis canadensis*	*Fagus*	*Tilia cordata*
	Julgans nigra	*Hydrangea*	*Ulmus japonica × wilsoniana*
	Ostrya virginiana	*Syringa*	
	Populus balsamifera	*Taxus*	
	Populus deltoids	*Thuja*	
	Populus tremuloides		
	Liriodendron tulipifera		
	Quercus rubra		
	Quercus macrocarpa		
	Thuja occidentalis		

Table 9 shows the top 10 urban tree species in the city of Thunder Bay. According to the Thunder Bay Urban Forest Management Plan (TBUFMP) (2011), species diversity remains an issue in urban tree management because a high percentage of certain tree species could make them susceptible to some exotic pests, and could cause a lot of damage. To prevent such losses, it is recommended to increase the diversity of the urban forest by adhering to best management principles that suggest that no more than 20% of a single genus and 10% of single species (TBUFMP, 2011). However, due to Thunder Bay's harsh climatic conditions, there could be potential challenges in diversifying the urban forest (TBUFMP, 2011). Thus, it recommended planting maples selectively, based on their historical importance. Also, an improved planting program should be implemented that incorporates other species (TBUFMP, 2011). Additionally, the management plan advises avoiding planting ash until the threat of EAB is eliminated.

Table 9: Thunder Bay's top 10 urban tree species (TBUFMP 2011).

Scientific Name	Common Name	Number	Percentage of Street Trees
Fraxinus pennsylvanica	green ash	4,661	26%
Acer saccharinum	silver maple	3,245	18%
Tilia americana	American basswood	1,440	8%
Betula papyrifera	paper birch	1,406	8%
Tilia species	linden	1,197	7%
Picea glauca	white spruce	772	4%
Malus 'hybrid (Spring Snow' or 'Pink Spire')	crabapple	732	4%
Fraxinus nigra	black ash	537	3%
Acer negundo 'Baron'	Manitoba maple	502	3%
Ulmus americana	American elm	383	2%
Total		14,875	81%

Table 10 provides a list of acceptable tree species and cultivars that can be planted as ornamental trees on boulevards and in parks in the City of Winnipeg (City of Winnipeg 2023). Planting of any other species or cultivar not included in the list would still be considered if written permission is given by the City Forester or an authorized representative. All the planted trees in the city are required to meet the standards outlined in the recent edition of the Canadian Nursery Stock Standard issued by the Canadian Nursery Landscape Association (City of Winnipeg 2023). The City of Winnipeg's urban forest management strategy plan has made a note that due to the severe threat posed by EAB, *Fraxinus* species and cultivars will not be taken into account for planting until notice is provided.

Table 10: Some acceptable tree species and cultivars for planting on boulevards and parks in the city of Winnipeg (City of Winnipeg 2023).

Species/cultivar name	Common Name	Special note
Acer negundo 'Baron'	Baron Manitoba maple	Seedless cultivar of Manitoba maple
Acer saccharinum	silver maple and various cultivars	
Quercus macrocarpa	bur oak	
Populus x canadensis 'Prairie Sky'	Prairie Sky poplar	Parks and green spaces only; seedless
Populus deltoides	Cottonwood	Parks and green spaces only; seedless cultivars available
Salix pentandra	laurel leaf willow	Better suited to parks and green spaces
Tilia americana	basswood / American linden and various cultivars	
Ulmus americana	American elm	
Ulmus americana 'Brandon'	Brandon American elm	
Ulmus americana 'Lewis and Clark'	Prairie Expedition elm	DED tolerant
Ulmus x 'Morton Glossy'	Triumph hybrid elm	DED tolerant
Ulmus pumila	Siberian elm	Limited use

Large Sized Trees (mature height 15 m or greater) – Coniferous

Species/cultivar name	Common Name	Special note
Larix siberica	Siberian larch	Parks and green spaces only
Picea glauca 'Densata'	Blackhills white spruce	Parks and green spaces only
Picea pungens	Colorado spruce – multiple cultivars	Parks and green spaces only
Pinus sylvestris	Scots pine	Parks and green spaces only

3.6 PROBLEMS

There are a few disadvantages of planting trees in cities which should always be considered while making urban tree/forest management decisions (Willis and Petrokosfy 2017). Certain tree species cause various issues such as airborne pollen leading to allergies in humans and the release of biogenic volatile compounds (BVOCs) contributing to ozone formation (Willis and Petrokosfy 2017). The most potent allergen sources belong to the orders Fagales, Lamiales, Proteales, and Pinales, including common urban trees like birch, ash, mesquite, plane, and cypress (Willis and Petrokosfy 2017). This raises concerns about the trade-offs between the benefits and potential problems of large-scale tree-planting initiatives in major cities like New York and London (Willis and Petrokosfy 2017). These initiatives often overlook the production of BVOCs by street trees and the potential for all tall trees and dense vegetation to limit air circulation and trap particulate matter (PM) at street level (Willis and Petrokosfy 2017).

While there are clear advantages to planting trees in cities, understanding the trade-offs requires detailed knowledge of the tree species and their suitability for the urban environment (Willis and Petrokosfy 2017). Ecological tolerances must also be considered, and diversity is crucial when selecting new candidates for urban tree planting (Willis and Petrokosfy 2017). Furthermore, rare, threatened and endangered species should also be considered, as demonstrated by the successful revitalization of Ginkgo biloba populations (Willis and Petrokosfy 2017).

3.7 VALUE-ADDED SERVICES

Trees have after-life value-added potential which means that even if the life cycle of a tree ends, it still could be useful for a variety of purposes. One common use of dead trees is to preserve biodiversity, for example, the white-backed woodpecker, threatened species of saproxylic beetles, and bat species richness are higher in forests with more deadwood (Tillon et al. 2016). Many birds and mammals also use deadwood and large old trees as nesting and roosting habitats (Lindenmayer and Ough 2006).

Moreover, private house owners could use wood from dead trees as firewood, and municipalities or local industries could chip the deadwood and use it as fuel to create heat and energy. Also, many dead tree materials such as dead branches, dead leaves and twigs could act as a natural soil fertilizer to add all the nutrients back to the soil. Urban trees, be they park trees or street trees, provide so many Non-Timber forest products (NTFPs) such as fruits, nuts, medicinal benefits, seedlings and decorative green materials (IATP 2000). These products are used for personal and economic gains, and add to the economy of the country for example, a study done in Baltimore City showed that there are several different collectors (nurseries, NPOs and public agencies) of these Non-Timber products who buy these products directly from the house owners or the municipalities and assign a dollar value to those products (IATP 2000).

Also, several groups of independent businesses work together with local arborists to identify trees that are eligible for removal and turn them into valuable products (Gordon 2019). Local mills process the logs into lumber, which can be sold or turned into furniture, flooring, and other high-value products (Gordon 2019). In 2016, the Wisconsin Urban Wood (WUW) experimented with selling wood through an online auction to increase profits (Gordon 2019). They also use the wood for other purposes, such as bedding for animals, bioenergy, and playgrounds (Gordon 2019). The Baltimore Wood Project is another example of urban wood waste utilization in which the wood is sorted by quality and repurposed for local users (Gordon 2019).

Moreover, cities and towns often need to remove trees for various reasons such as damage caused by natural disasters, insect infestations, construction projects etc (Bratkovich 2002). In these circumstances, urban trees become liabilities, and the cost associated with their removal can add to the financial burden for municipalities (Bratkovich 2002). To alleviate some of these challenges, municipalities are exploring different ways of utilizing the removed trees. “Recycling urban trees can generate a range of wood products including sawlogs for high-quality furniture, pulpwood for paper products, fuelwood for heating, wood chips for landscaping products, and unique specialty items such as burls and branch crotches for woodworking" (Bratkovich 2002). Entrepreneurs who are capitalizing on utilizing street, yard, and park trees for traditional wood products are realizing that is a cost-effective solution (Bratkovich 2002).

4. CONCLUSION

Urban trees play a significant role in maintaining the health and well-being of people and urban areas. Different literature sources showed that the survival rate and value-added potential of different tree species vary in urban settings, especially in a country like Canada where the climate is not the same in every province. Some tree species such as London Plane, Maple species, Oak species, Basswood, and Ginkgo have the potential to grow better than ash trees. Also, this review highlighted the benefits of urban trees, including improving air and water quality, reducing stormwater runoff, mitigating the urban heat island effect, and providing wildlife habitat. Urban trees can also increase property values, reduce energy costs, and improve the overall appearance of an urban environment.

However, there are various challenges related to urban trees, such as the emission of VOCs and allergens, pest attacks and diseases, and infrastructure issues. These challenges can be addressed by selecting the right tree species and implementing good urban forest management practices. To ensure that the sustainability of urban trees is maintained, urban planners and policymakers should consider a combination of tree species, taking into consideration the specific site requirements and conditions, and the needs of the community. There is a scope for future research to better understand the survival rate and value-added potential of different tree species in urban settings. By prioritizing the selection of appropriate tree species and with proper urban forest management, both the present and future generations could benefit and enjoy the urban environment

5. LITERATURE CITED

Alexander, C. and B. DePratto. 2014. The value of urban forests in cities across Canada. Special Report – TD Economics. Retrieved from https://www.td.com/document/PDF/economics/special/UrbanForestsInCanadianCities.pdf

Arbab, N., J. Grabosky & R. Leopold. 2022. Economic assessment of urban ash tree management options in New Jersey. Sustainability. 14(4):2172.

Arnfield, A. J. 2003. Two decades of urban climate research: a review of turbulence, exchanges of energy and water, and the urban heat island. International Journal of Climatology: A Journal of the Royal Meteorological Society. 23(1): 1-26.

Berland, A., L.A. Roman and J. Vogt. 2019. Can field crews telecommute? Varied data quality from citizen science tree inventories conducted using street-level imagery. Forests. 10(4): 349.

Berland, A., S.A. Shiftlett, W.D. Shuster, A.S. Garmestani, H.C. Goddard, D.L. Hermann and M.E. Hopton. 2017. The role of trees in urban stormwater management. Landscape urban planning. 162:167-177.

Bratkovich, S.M. 2002. Utilizing municipal trees – Ideas across the country. Retreived from https://www.woodweb.com/knowledge_base/Utilizing_Municipal_Trees.html

Carreiro, M. M. 2008. Introduction: the growth of cities and urban forestry. Ecology, planning, and management of urban forests: International perspectives. 3-9

City of Winnipeg. 2023. Acceptable tree species for planting on city-owned properties. Retrieved from https://www.winnipeg.ca/sites/default/files/2023-01/PW-Recommended_Tree_Species_0.pdf

Conway, T. M. & J. Vander Vecht. 2015. Growing a diverse urban forest: Species selection decisions by practitioners planting and supplying trees. Landscape and Urban Planning. 138:1-10.

Conway, T.M. and L. Urbani. 2007. Variations in municipal urban forestry policies: A case study of Toronto, Canada. Urban Forestry and Urban Greening. 6(3):181-192.

Coombes, E., A.P. Jones and M. Hillsdon. 2010. The relationship of physical activity and overweight to objectively measured green space accessibility and use. Social Science and Medicine. 70:816–822.

Daniels, M.J., F. Dominici, J.M. Samet and S.L. Zeger. 2000. Estimating particulate-matter-mortality dose-response curves and threshold levels: an analysis of daily time-series for the 20 largest US cities. American Journal of Epidemiology. 152: 397–406.

Day, S. D., Dove, J. E., Bartens, J., & Harris, J. R. (2008). Stormwater management that combines paved surfaces and urban trees. In GeoCongress 2008: Geosustainability and Geohazard Mitigation (pp. 1129-1136).

Donovan, G.H. and D.T. Butry. 2009. The value of shade: estimating the effect of urban trees on summertime electricity use. Energy Build. 41:662–668.

Eisenman, T.S., G. Charkina, S.P. Jariwala, P. Kumar, G.S. Lovasi, D.E. Pataki, K.R. Weinberger and T.H. Whitlow. 2019. Urban trees, air quality, and asthma: an interdisciplinary review: Landscape and urban planning. 187: 47-59.

Elmqvist, T., X. Bai, N. Frantzeskaki and D. Maddox. (Eds). 2018. The urban planet: knowledge towards sustainable cities. Cambridge University Press.

Flower, C. E., D.J. Lynch, K.S. Knight & M.A. Gonzalez-Meler. 2018. Biotic and abiotic drivers of sap flux in mature green ash trees (Fraxinus pennsylvanica) experiencing varying levels of emerald ash borer (Agrilus planipennis) infestation. Forests. 9(6):301.

Frank, L.D., T.L. Schmid, J.F. Sallis, J. Chapman and B.E. Saelens. 2005. Linking objectively measured physical activity with objectively measured urban form. American Journal of Preventive Medicine. 28:117–125.

Galenieks, A. 2017. Importance of urban street tree policies: A comparison of neighbouring Southern California cities. Urban Forestry and Urban Greening. 22:105-110.

Gordon, J. S. 2019. Waste not, want not–Using urban wood-waste to benefit communities. University of Georgia. Warnell School of Forestry and Natural Resources. Retrived from: https://bugwoodcloud.org/resource/files/18643.pdf

Haack, R. A. 2006. Exotic bark-and wood-boring Coleoptera in the United States: recent establishments and interceptions. Canadian Journal of Forest Research. 36(2):269-288.

Hansmann, R., S. Hug and K. Seeland. 2007. Restoration and stress relief through physical activities in forests and parks. Urban Forestry and Urban Greening. 6:213–225.

Hartig, T. and H. Staats. 2006. The need for psychological restoration as a determinant of environmental preferences. Journal of Environmental Psychology. 26:215–226.

Hauer, R. J., J.M. Vogt and B.C. Fischer. 2015. The cost of not maintaining the urban forest. Arborist News. 24(1): 12-17.

Herms, D. A., D.G. McCullough, D.R. Smitley, C.S. Sadof, R.C. Williamson, R. C & Nixon, P. L. 2009. Insecticide options for protecting ash trees from emerald ash borer. North central IPM center bulletin, 12.

Heynen, N., H.A. Perkins and P. Roy. 2006. The political ecology of uneven urban green space. Urban Affairs Review. 42(1):3-25.

Hull, R.B. 1992. How the public values urban forests. Journal of Arboriculture. 18(2):98-101.

Hystad, P., H.W. Davies, L. Frank, J. Van Loon, U. Gehring, L. Tamburic and M. Brauer. 2014. Residential greenness and birth outcomes: evaluating the influence of spatially correlated built-environment factors. Environmental Health Perspect. 122(10):1095–1102.

Institute for Agriculture and Trade Policy. 2000. Urban Non-Timber Forest Products provide benefits to residents and add economic value to the urban forest. Retrieved from: https://www.iatp.org/news/urban-non-timber-forest-products-provide-benefits-to-residents-and-add-economic-value-to-the-ur

Johnston, M. 2004. Impacts and adaptation for climate change in urban forests. In 6th Canadian Urban Forest Conference October. 19-23pp.

Jorgensen, E. 1986. Urban forestry in the rearview mirror. Arboricultural Journal. 10(3):177-190.

Karnosky, D.F. 2009. Dutch elm disease: A review of the history, environmental implications, control, and research needs. Environmental Conservation. 6(4):311-322.

Kenney, W.A. and C. Idziak. 2000. The state of Canada's municipal forests – 1996 to 1998. Forestry Chronicle. 76(2):231-234.

Knight, K. S., J.P. Brown & R.P. Long. 2013. Factors affecting the survival of ash (Fraxinus spp.) trees infested by emerald ash borer (Agrilus planipennis). Biological Invasions. 15:371-383.

Ko, Y. 2018. Trees and vegetation for residential energy conservation: A critical review for evidence-based urban greening in North America. Urban Forestry & Urban Greening. 34:318-335.

Konijnendiik, C.C., R.M. Ricard, A. Kennedy and T.B. Randrup. 2006. Defining urban forestry- a comparative perspective of North America and Europe. Urban forestry and urban greening. 4(3-4):93-103.

Lindenmayer, D.B. and K. Ough. 2006. Salvage logging in the montane ash eucalupt forests of the Central Highlands of Victoria and its potential impacts on biodiversity. Conservation Biology. 20:1005-15.

Lovasi, G.S., J.S. Jacobson, J.W. Quinn, K.M. Neckerman, M.N. Ashby-Thompson and A. Rundle. 2011. Is the environment near home and school associated with physical activity and adiposity of urban preschool children? Journal of Urban Health 88:1143–1157.

MacFarlane D.W. and S.P. Meyer. 2005. Characteristics and distribution of potential ash tree hosts for emerald ash borer. Forest Ecology and Management. 213(1):15–24. https://doi.org/10.1016/j.foreco.2005.03.013

McComb, A. L. 1949. Some fertilizer experiments with deciduous forest tree seedlings on several Iowa soils. Agricultural Experiment Station, Iowa State College of Agriculture and Mechanic Arts. 407pp.

McPherson, E. G. 2003. A benefit-cost analysis of ten street tree species in Modesto, California, US. Journal of Arboriculture, 29(1):1-8.

Middel, A., N. Chhetri, N. & R. Quay, R. 2015. Urban forestry and cool roofs: Assessment of heat mitigation strategies in Phoenix residential neighborhoods. Urban Forestry & Urban Greening. 14(1):178-186.

National Urban Forestry Unit (Great Britain). 1999. Trees & Woods in Towns & Cities: How to Develop Local Strategies for Urban Forestry: a Guide. National Urban Forestry Unit.

Nguyen, V. D., L.A. Roman, D.H. Locke, S.K. Mincey, J.R. Sanders, E.S. Fichman, M. Duran-Mitchell and S.L. Tobing. 2017. Branching out to residential lands: Missions and strategies of five tree distribution programs in the US. Urban Forestry & Urban Greening. 22:24-35.

Nowak, D.J., M.H. Noble, S.M. Sisinni and J.F. Dwyer. 2001. People and trees: assessing the US urban forest resource. Journal of Forestry. 99(3):37-42.

Ordonez C. and P.N. Duinker. 2013. An analysis of urban forest management plans in Canada: Implications for urban forest management. Landscape and Urban Planning. 116:36-47.

Peper, P. J., Alzate, C. P., McNeil, J. W., & Hashemi, J. (2014). Allometric equations for urban ash trees (Fraxinus spp.) in Oakville, Southern Ontario, Canada. Urban forestry & urban greening. 13(1):175-183.

Poland, T.M. and D.G. McCullough. 2006. Emerald Ash Borer: Invasion of the urban forest and the threat to North America's ash resource. Journal of Forestry. 104(3):118-124.

Roe, J. and P. Aspinall. 2011. The restorative benefits of walking in urban and rural settings in adults with good and poor mental health. Health Place. 17:103–113.

Stoffberg, G.H., M. W. Van Rooyen, M.J. Van der Linde and H.T. Groeneveld. 2008. Predicting the growth in tree height and crown size of three street tree species in the City of Tshwane, South Africa. Urban Forestry and Urban Greening. 7(4): 259-269.

Thompson, C. W., J. Roe, P. Aspinall, R. Mitchell, A. Clow, & D. Miller. 2012. More green space is linked to less stress in deprived communities: Evidence from salivary cortisol patterns. Landscape and urban planning. 105(3): 221-229.

Tillon, L., C. Bouget, Y. Paillet & S. Aulagnier. 2016. How does deadwood structure temperate forest bat assemblages? European Journal of Forest Research. 135(3):433-449.

Town of Ajax. 2011. In urban forest innovations Inc. and Beacon Environmental Ltd. (Eds.). Town of Ajax urban forest management plan 2011-2015 (final draft). ON, Canada. Town of Ajax. 130pp.

Town of Banff. 2008. In Tesera Systems Inc. (Ed.). Town of Banff urban forest management plan. Cochrane, AB, Canada: Town of Banff. 121pp. Retrieved from: https://www.banff.ca/322/Strategic-Plan

Tree Canada. 2021. Economic value and appraisal of trees. Canadian Urban Forest Compendium. Retrieved from https://treecanada.ca/resources/canadian-urban-forest-compendium/22-economic-value-appraisal-of-trees/

Tyrväinen, L., S. Pauleit, K. Seeland & S. De Vries. 2005. Benefits and uses of urban forests and trees. Urban forests and trees: A reference book. 81-114.

Ulmer, J. M., K.L. Wolf, K. L., D.R. Backman, R.L. Tretheway, C.J. Blain, J.P. O'Neil-Dunne & L.D. Frank. 2016. Multiple health benefits of urban tree canopy: The mounting evidence for a green prescription. Health & place. 42:54-62.

Urban Forest Management Plan for the City of Thunder Bay. 2011. Prepared by: Davey Resource Group. Retrieved from https://www.thunderbay.ca/en/city-hall/resources/Documents/Urban-Forest-Management-Plan.pdf

van Wassenaer, P.J.E., L. Schaeffer and W.A. Kenney. 2000. Strategic planning in urban forestry: A 21st century paradigm shift for small town Canada. Forestry Chronicle. 76(2):241-246.

Villarreal, E.L., A. Semadeni-Davies and L. Bengtsson. 2004. Inner city stormwater control using a combination of best management practices. Ecological Engineering 22(4-5):279–298.

Vogt, J., R.J. Hauer, & B.C. Fischer. 2015. The costs of maintaining and not maintaining the urban forest: A review of the urban forestry and arboriculture literature. Arboriculture & Urban Forestry. 41(6): 293-323.

Willis, K. J., & Petrokofsky, G. (2017). The natural capital of city trees. Science. 356(6336):374-376.

Wolf, K.L., S.T. Lam, J.K. McKeen, G.R. Richardson, M. van den Bosch and A.C. Bardekjian. 2020. Urban trees and human health: A scoping review. International journal of environmental research and public health. 17(12):4371.

Woodall, C.W., D.J. Nowak, G.C. Liknes and J.A. Westfall. 2010. Assessing the potential for urban trees to facilitate forest tree migration in the eastern United States. Forest Ecology and Management. 259(8):1447-1454.

Xiao, Q., E.G. McPherson, J.R. Simpson and S.L. Ustin. 1998. Rainfall interception by Sacramento's urban forest. Journal of Arboriculture. 24:235–244.

Yang, J. 2009. Assessing the impact of climate change on urban tree species selection: A case study in Philadelphia. Journal of Forestry. 107(7):364-372.

Young, R. F. 2011. Planting the living city: Best practices in planning green infrastructure—results from major us cities. Journal of the American Planning Association. 77(4):368-381.

Young, R. F. 2013. Mainstreaming urban ecosystem services: a national survey of municipal foresters. Urban Ecosystems. 16(4):703-722.

Zeng, B. 2003. Aboveground biomass partitioning and leaf development of Chinese subtropical trees following pruning. Forest Ecology and Management. 173(1-3): 135-144.