

Growing Livability²⁰¹⁶

A Comprehensive Study of Oakville's Urban Forest

Acknowledgements

This project was a partnership between the Town of Oakville, the USDA Forest Service, BioForest Technologies Inc., KBM Resources Group, J. Ghent Planning, and Plan-It Geo.



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Executive Summary

The i-Tree software suite was used to conduct a quantitative analysis of the urban forest in the Town of Oakville, ON, in 2015. i-Tree Eco (formerly UFORE) was employed to conduct a plot-based sample inventory that was analyzed to quantify the structural attributes and the monetary values associated with the environmental services provided by Oakville's urban forest. A statistical change analysis was also conducted to track the significance of the changes that have occurred in Oakville's urban forest since a UFORE study was conducted there in 2005. i-Tree Storm was used to create a pre-storm assessment of street-side and adjacent trees in order to estimate the potential damage-related costs of a severe storm event. i-Tree Streets (formerly STRATUM) was employed to estimate the value of the annual environmental and aesthetic benefits provided by Oakville's

street trees. i-Tree Hydro was used to estimate the effects of changes in urban forest and impervious cover on stream flow in the East Sixteen Mile Creek watershed, in which Oakville is located. An urban forest canopy assessment was conducted to map land cover across the Town of Oakville south of Dundas Street, quantify the distribution of existing and potential urban forest canopy, and to track canopy change since 2005. The results of these assessments form the basis of recommendations made in this report to decision makers in urban forestry and urban planning in the Town of Oakville. Recommendations seek to enhance the growth potential and health of Oakville's urban forest and support the Town's efforts to increase livability and attain the goal of 40% urban forest canopy.

Oakville's Urban Forest: 2005-2015		
Feature	2005	2015
Number of Trees in Oakville	1.9 million	2 million
Top 3 Species by Leaf Area	Sugar maple, Norway maple, silver maple	Sugar maple, Norway maple, northern red oak
Top 3 Species by Population	Northern white cedar, sugar maple, white ash	Northern white cedar, sugar maple, European buckthorn
Average Urban Forest Canopy Cover	26.5% ¹	27.8%
Replacement Value of Oakville's Urban Forest	\$878 million ²	\$1.04 billion
Annual Carbon Sequestration ³	6,000 tonnes	5,940 tonnes
Carbon Storage	133,000 tonnes	148,000 tonnes
Criteria Pollutants Removed Annually ⁴	172 tonnes (\$1.12 million)	113 tonnes (\$668,000)
Annual Home Energy Savings	\$840,000	\$1.8 million
Trees In "Excellent" or "Good" Condition	76.8%	82.9%

¹ This figure represents a correction of the UFC value presented in 2005, 29.1%, which was an overestimation, due to limited technology and other factors at the time of analysis. See Section 4.2 for more information.

² Dollar figures for 2005 are presented in the amounts reported in 2005. After adjusting for inflation, \$878 million in 2005 is equivalent to \$1.04 billion in 2015 values.

³ For information on the value of carbon sequestration in 2005 and 2015, see Section 4.1.1.

⁴ The suite of criteria pollutants measured in 2005 includes PM10, which was not measured in 2015. See Section 4.1.1 for more information.



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- Urban forest cover: 27.8%⁵
- Total number of trees: 2 million
- Structural value of Oakville's urban forest: \$1.04 billion
- Carbon storage: 148,000 tonnes (Value of \$11.5 million)
- Carbon sequestration: 5,940 tonnes per year (Annual value of \$460,000)
- Pollution removal: 113 tonnes per year (Annual value of \$668,000)⁶
- Home energy savings: \$1.8 million/year
- Carbon emissions avoided as a result of home energy savings: 2,220 tonnes (Value of \$172,000)
- Percentage of trees under 15.3 cm DBH : 76.3% (1.5 million trees)⁷
- Percentage of trees over 76 cm DBH: 0.6% (12,000 trees)
- Total leaf area of trees: 135.2 km²
- Total leaf area of shrubs: 29.9 km²
- Land use with most carbon stored and sequestered: Woodlots, with 45% of carbon stored and 41% of carbon sequestered⁸
- Tree condition ratings in Oakville: Excellent or Good (82.9%), Poor or Fair (9.2%), Critical or Dying (1.4%), Dead (6.6%)
- Pre-storm estimate of major storm damage: \$7.13 million
- Street tree population: 95,770 (5% of the total tree population)
- Street tree condition: Good (95%), Fair (3%), Poor (1%), Dying/Dead (1%)
- Street tree benefit/cost ratio: 1.52
- Value of annual net benefits provided by street trees: \$4,039,554
- Average annual tree mortality rate: 5.3%

Oakville's Top 5 Species

<i>By Leaf Area</i>	<i>By Population</i>
1. Sugar maple	1. Northern white cedar
2. Norway maple	2. Sugar maple
3. Northern red oak	3. European buckthorn
4. Silver maple	4. White ash
5. Black walnut	5. Staghorn sumac

⁵ Based on point-sampling method (see Section 4.2.1)

⁶ While this figure appears to be a significant reduction from 2005 levels, it does not include PM10 data. See Section 4.1.1 for more information.

⁷ Diameter at breast height (See Glossary)

⁸ According to the 2015 Oakville Planning Department definition of Woodlots. See Appendix 1.



In recent years, the importance of the urban forest to human well-being has been more extensively examined, researched, and quantified than ever before. An abundance of scientific evidence confirms that urban forests provide many environmental, economic, and social benefits to communities, including air pollution removal, carbon sequestration, and home energy savings. The benefits provided by urban trees have been linked to improvements in human mental and physical health. However, urban forests continue to face multiple threats, such as invasive species, climate change, and limited funding, that make ongoing assessments crucial for developing successful management strategies.

In the years following the turn of the century, several Canadian cities, including Oakville, joined the movement to study their urban forests. In 2005, Oakville became the third Canadian municipality to complete a UFORE study, the results of which were published in the report *Oakville's Urban Forest: Our Solution to Our Pollution*.⁹ In 2015, Oakville became the first municipality in the world to conduct its own 10-year follow-up survey to track the changes its urban forest has undergone since the 2005 UFORE study. To this end, the Town of Oakville contracted a team of consultants¹⁰ to conduct a comprehensive assessment of its urban forest and how it has changed.

Since the 2005 urban forest study, the Town of Oakville has updated and enhanced several policies related to urban forest management. Oakville strengthened measures to conserve its urban forest by enacting a private tree by-law in 2008. A new comprehensive zoning by-law was adopted by the Town of Oakville in 2014 in order to better represent the existing uses of land in the Town. As a result of this reclassification of land uses, the distribution of urban forest across land use classifications has been altered from the distribution that existed in 2005. One benefit of this change has been an increase in the amount of land classified under "Woodlots", a classification that contains environmental zones with restricted development permissions. Appendix 1 contains definitions of the current land use classifications, which are used in this report.

The future well-being of Oakville's urban forest faces many challenges, some of which are due to damaging pest invasions, diseases, and abiotic stresses. Emerald ash borer (EAB, *Agrilus planipennis*), an invasive insect from Asia that feeds on and kills all native species of ash trees (*Fraxinus* spp.), was first detected in Oakville in 2008. Following that discovery, Oakville has been implementing a canopy conservation-based EAB management program, under which the Town has been proactively treating ash trees with TreeAzin® systemic insecticide in order to limit the damage caused by EAB and, where necessary, removing dead ash trees and ash trees

that did not qualify for treatment. The Town of Oakville has also instituted the Emerald Ash Borer Management Program to track the severity of infestation, and has engaged the public to raise awareness of the problem and encourage the treatment of privately owned trees. Under the Town's Canopy Replacement Program new trees are planted in active parks and in road allowances where EAB-killed ash trees have been removed. While many trees were lost in Oakville as a result of EAB, the damage to the tree canopy would have been much greater in the absence of these programs.

Oakville has also taken action to address other invasive forest insect pests. The Town's gypsy moth monitoring program surveys woodlots and streets and identifies areas where there is a high risk of defoliating damage by the invasive gypsy moth (*Lymantria dispar dispar*). The Town's Heritage Elm Recovery Program is aimed at protecting notable specimens of native elms (*Ulmus* spp.) by implementing preventive treatments against Dutch elm disease.

Abiotic factors have also had an effect on Oakville's urban forest in the past ten years. Oakville's urban forest experienced damage and canopy loss as a result of the ice storm on December 22, 2013. Approximately 11,000 municipal trees were damaged as a result of this event, 10% of which had to be removed. On average, Oakville forestry staff estimate 150 municipal trees are removed each year due to storm events. Furthermore, the pressures of Oakville's growing population have implications for the future of its urban forest. A growing human population creates additional demand for the benefits the urban forest provides. However, it also exerts increased stress on the urban forest. As more land is developed for employment, commercial, and residential purposes and density is intensified, there is potentially less room for trees and healthy forests to grow.

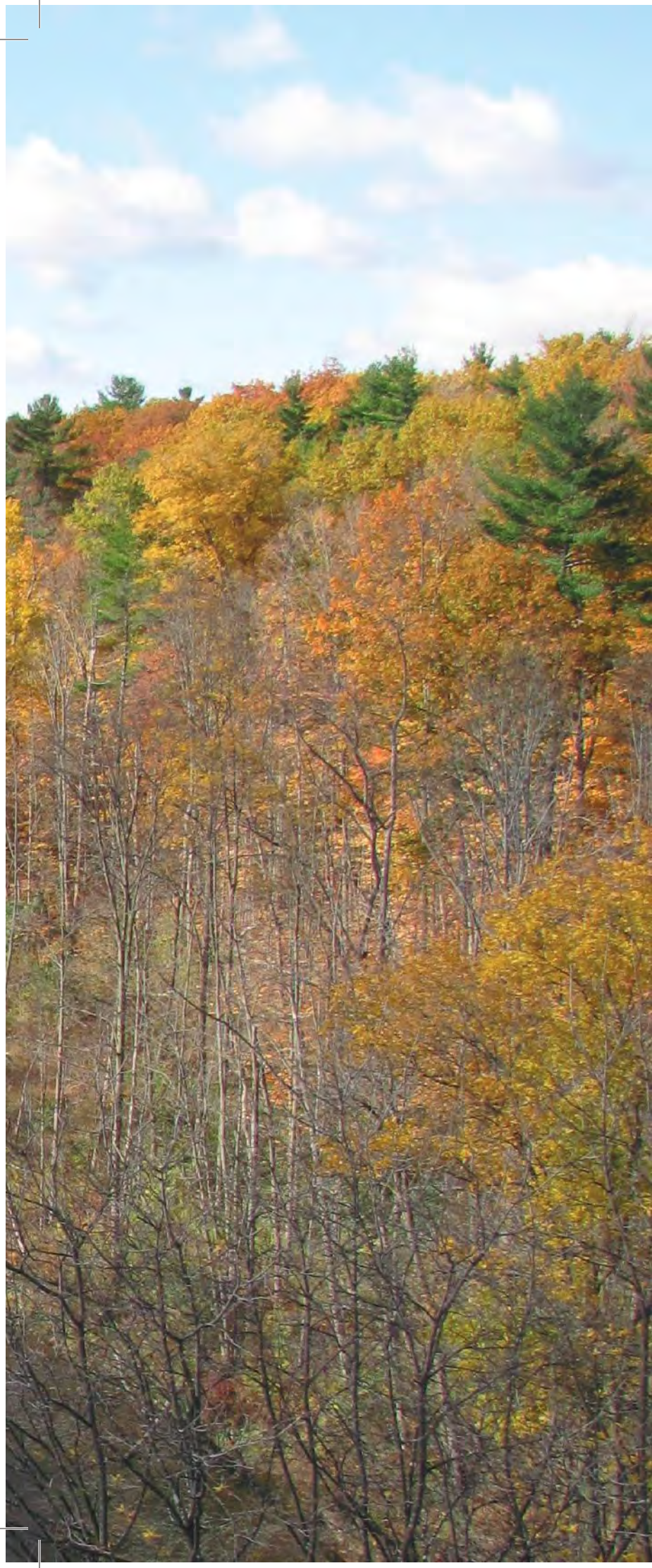
As a result of Oakville's response to the many challenges facing its urban forest, the Town has been recognized by the Canadian Forestry Association and the Society of Municipal Arborists, among others, for its leadership in municipal urban forest management. The support and involvement of Oakville's citizens also provides a significant boost to the stewardship efforts undertaken by the Town. Community groups such as Oakvillegreen Conservation Association work to promote environmental protection, hold tree planting events, and address other important urban forest-related goals. The Town's work has also been supported by the Canopy Club, a Town of Oakville initiative, and its proactive outreach to Oakville residents, as well as its tree planting events. While the future holds many challenges, Oakville's urban forest will be well served by cooperative stewardship, comprehensive assessments, and long-term investments in urban forest management.

⁹ <https://www.itreetools.org/resources/reports/Oakville's%20Urban%20Forest.pdf>

¹⁰ The consultant team was composed of staff from BioForest Technologies Inc., Plan-it Geo, J. Ghent Planning, KBM Resources Group, and USDA Forest Service.



3 | Project Purpose



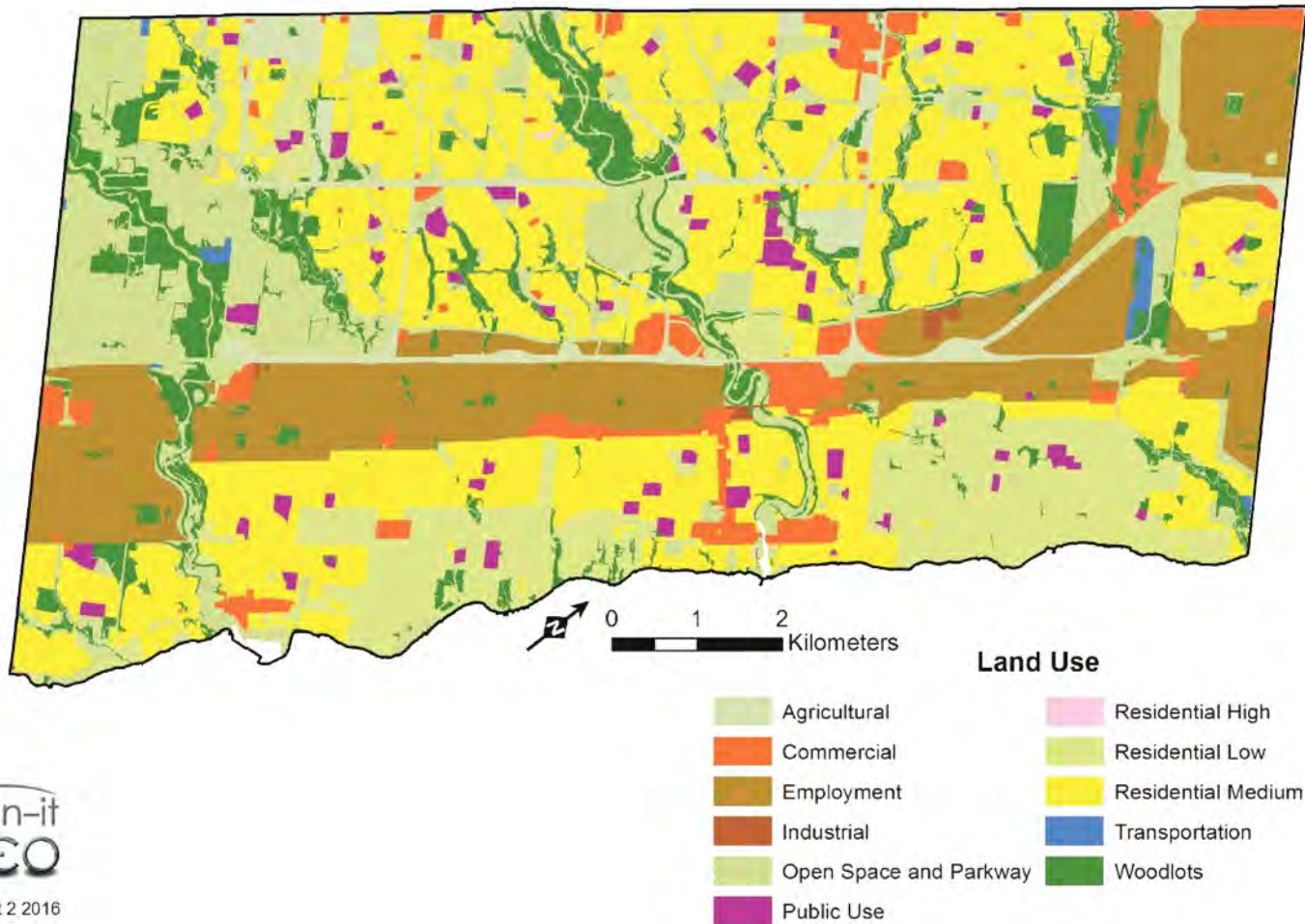
Since the 2005 UFORE study was conducted, Oakville and its urban forest have seen many changes. Periodic re-assessments of the urban forest provide insight into the changes that are taking place and the success of management strategies. These re-assessments allow Oakville's urban forest managers to make informed decisions and plan for the future. As such, the purpose of the 2015 urban forest study is threefold:

1. Undertake a comprehensive study of Oakville's urban forest as it exists in 2015 using state of the art technology and sound scientific methodologies
 - Employ the i-Tree suite of benefit assessment tools in combination with high resolution aerial imagery to assess:
 - Structural attributes
 - Environmental benefits
 - Economic value associated with urban forest structure and environmental benefits
 - Urban forest canopy
 - Potential planting opportunities
2. Compare the results of the 2015 urban forest study with the results gathered in the 2005 urban forest study, to assess the changes that have occurred over ten years
 - Conduct a statistical change analysis of the 2005 and 2015 project findings to quantify the significance of the changes
3. Evaluate the results and provide recommendations aimed at the enhancement of urban forest management strategies so that Oakville's urban forest resource may be conserved and remain resilient and healthy into the future

4 | Results

Figure 2: Land use distribution, 2005

Town of Oakville Urban Forest Canopy Assessment Land Use - 2005



August 2 2016

4.1 – i-Tree

i-Tree is a state-of-the-art software suite of urban forest benefit assessment tools developed by the United States Department of Agriculture (USDA) Forest Service and its partners. i-Tree may be used to quantify the economic and environmental benefits generated by the urban forest and to inform future management decisions. Each component of the i-Tree suite focuses on specific aspects of the urban forest, allowing users to perform assessments at multiple scales. i-Tree projects may be conducted individually, or may be combined for more in-depth analysis, as was the case for the 2015 comprehensive assessment of Oakville’s urban forest.

4.1.1 – i-Tree Eco

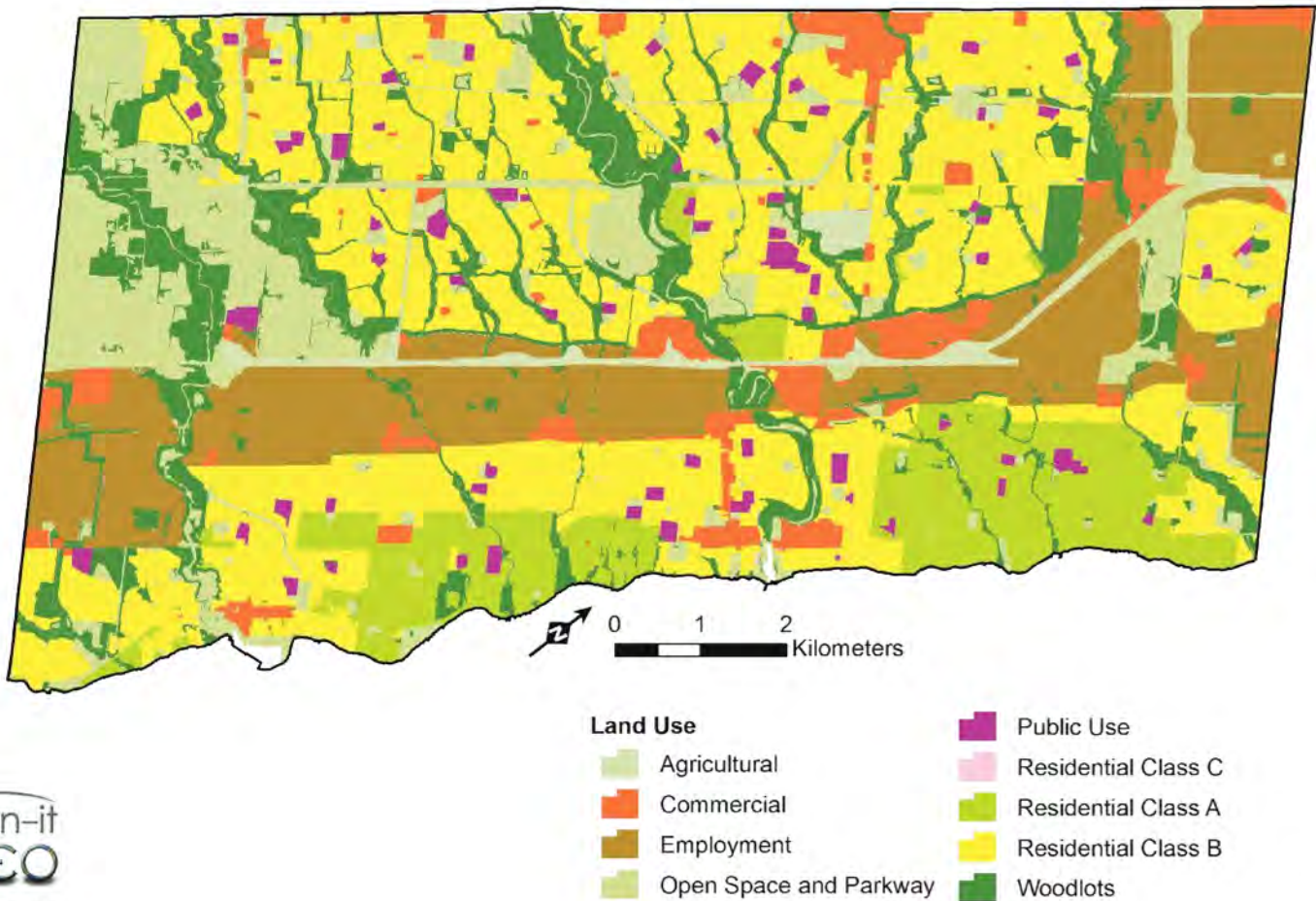
OVERVIEW & APPROACH

i-Tree Eco (formerly known as UFORE) combines field data with local hourly pollution data and meteorological data to quantify the structural attributes, environmental effects, and economic value provided by the urban forest.

Prior to the collection of data in the field, the study area (comprising the portion of Oakville south of Dundas Street) is stratified according to land use classification. Due to the new comprehensive 2014 zoning by-law mentioned in Section 2, there were slight changes to the distribution of land use classifications since the 2005 UFORE study. For example, the definition of Woodlots was updated to include additional natural areas,

Figure 3: Land use distribution, 2015

Town of Oakville Urban Forest Canopy Assessment
Land Use - 2015



August 2 2016

such as flood regulated lands. Some lands formerly zoned as Agriculture had been re-zoned to reflect current land uses, including Residential and Open Space/Parkway. As a result of these changes, some plots changed land use classification between 2005 and 2015. A comparison of land use distribution in 2005 and 2015 may be seen in Figures 2 and 3.

BioForest staff collected field data from a total of 372 plots, assessing 367 of the 372 plots that were measured in 2005, plus five new plots.¹¹ Staff recorded attributes of each tree within each 0.04 hectare plot, including:

- Tree height
- DBH
- Crown width
- Species
- Dieback (%)
- Missing canopy (%)
- Crown light exposure
- Distance and direction to nearby buildings

Shrubs were also recorded, as were general data about the plot, such as visual estimates of the tree and shrub cover, and ground cover composition.¹² Crews in 2015 navigated to plot centre using reference points established in 2005 and reassessed all trees measured by 2005 crews, noted which original trees had been removed, and measured all new trees within each plot.

USDA Forest Service staff then reviewed and compared field data gathered in 2005 and 2015 and conducted a statistical change analysis to measure the significance of the changes in the two data sets.

¹¹ Field crews were unable to access five original plots, due to lack of permission by private property owners.

¹² For more information on I-Tree Eco methodology, follow the link to the I-Tree Eco manual under Section 9 (Additional Resources).

RESULTS

Oakville currently has about 2 million trees, an increase from about 1.9 million in 2005, at a density of about 199 trees per hectare. In total, Oakville added about 167,200 trees to its tree population over ten years.

Oakville's trees have a structural value of about **\$1.04 billion**, which is equivalent to their value of \$848,000 in 2005, when adjusted for inflation. Oakville's trees perform environmental services whose combined annual value is equivalent to about **\$2.93 million**.

Table 1 shows the estimated changes to the tree population from 2005 to 2015, based on the data recorded in the UFORE/I-Tree Eco plots, which are sorted by the land use in which they are located. For the purposes of measuring change over ten years, land use classifications as they existed in 2005 are used here, in order to compare equivalent units. Based on the 2005 land use distribution, Open Space/Parkway, Residential Medium, and Agricultural land uses saw significant increases in their tree populations. Only the Commercial land use experienced a decline in its tree population. The influx of trees in the Agriculture classification may be largely attributed to the reclassification of 57.3% of its lands into other land uses, such as Open Space/Parkway, Residential, and Employment, where tree planting is more likely to occur.

Table 1: Population change (2005-2015) by land use in Oakville, using 2005 land use classifications.

Land use (2005 Definitions)	2005	Removals	Influx	2015	Difference
Employment/Industrial	94,200	33,500	75,300	136,000	41,800
Woodlots	884,700	316,800	357,500	925,400	40,700
Open Space/Parkway	274,800	178,300	217,800	314,300	39,500**
Residential Low	195,200	64,900	92,600	222,900	27,700
Residential Medium	377,600	171,200	182,900	389,300	11,800*
Agricultural	1,200	0	9,000	10,200	9,000*
Public Use	2,700	700	3,300	5,300	2,700
Commercial	19,000	9,800	3,800	13,000	-6,000
Town total	1,849,300	775,000	942,200	2,016,500	167,200**

* Significant difference ($\alpha = 0.1$) in species population between 2005 and 2015

** Significant difference ($\alpha = 0.05$) in species population between 2005 and 2015

Oakville's trees perform environmental services whose combined annual value is equivalent to about **\$2.93 million**.

Table 2: Average annual tree mortality rate, by 2005 land use classification.

Land use (2005 Definitions)	Avg. Ann. Mortality Rate (%)
Open Space/Parkway	9.9
Commercial	7.0
Residential Medium	5.9
Woodlots	4.3
Employment/Industrial	4.3
Residential Low	4.0
Public Use	3.0
Agricultural	0.0
Town total	5.3

Average annual tree mortality rates were calculated based on the numbers of trees recorded in 2005 that still existed in 2015, trees removed since 2005, and new trees recorded in 2015. **Oakville's average annual tree mortality rate was calculated as 5.3%.** Tree mortality was highest in the Open Space/Parkway land use, with a 9.9% average annual mortality rate. Staghorn sumac (*Rhus typhina*) had the highest average annual mortality rate among tree species, at 26.5%. The lowest average annual mortality rates were attributed to eastern hemlock (*Tsuga canadensis* – 0.3%), sugar maple (*Acer saccharum* – 0.6%), and northern red oak (*Quercus rubra* 0.6%).

Structural Attributes

Tree Population Dynamics and Leaf Area

Figure 4

Top 10 tree species in Oakville, according to importance value

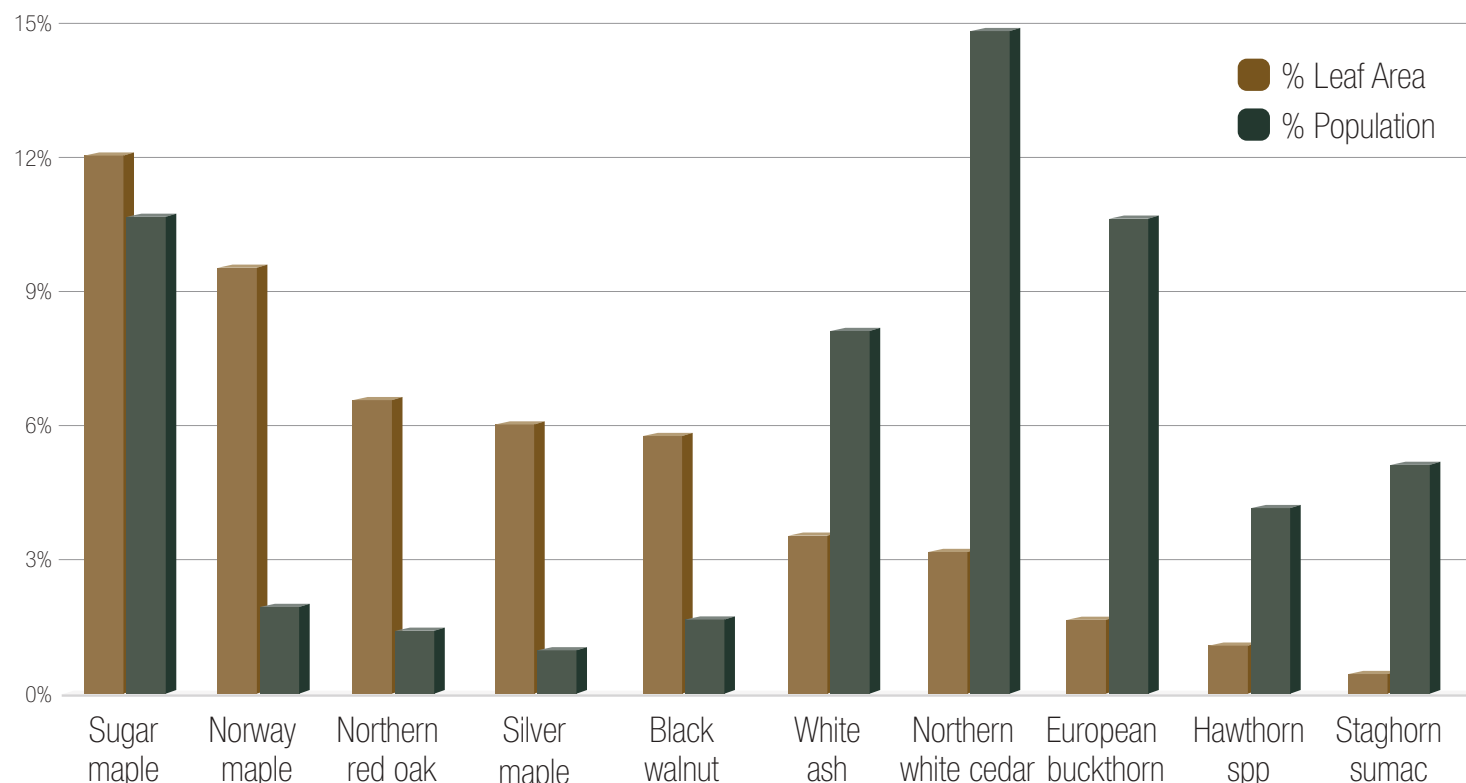


Figure 4 shows the top ten tree species in Oakville, according to Importance Value (IV), the sum of the population and relative leaf area of each species. While ranking tree species by population provides useful information on the number of trees on the landscape, a clearer picture of a tree species' contribution to environmental benefits may be gleaned by measuring its relative leaf area. Leaf area is the primary part of a tree's anatomy that filters pollution, releases oxygen, and casts shade, among other valuable benefits. Large, long-lived trees deliver the greatest amount of benefits per tree, due to their extensive leaf area and large quantity of woody tissue, which stores carbon.

As in 2005, sugar maple (*Acer saccharum*) scored the highest IV and held the top spot as Oakville's most important tree species. Sugar maple also ranked highest in total leaf area. Despite the impact of EAB, white ash (*Fraxinus americana*) remains an important species in Oakville, ranking fourth overall in IV. As in 2005, eastern white cedar (*Thuja occidentalis*) ranked as the most abundant tree species in 2015, likely due to its popular use in garden hedges. Eastern white cedar's population has increased significantly, with about 83,500 trees over 2005 population levels. Eastern white cedar was also ranked the most abundant species of shrub.¹³

One concerning development since the 2005 UFORE study is the population explosion of European buckthorn (*Rhamnus cathartica*), an invasive shrubby tree, which increased from 2% of the tree population in 2005 to 10.6% in 2015 (See Figure 4). This is equivalent to a population increase of about 192,000 buckthorn trees.

¹³ See Section 10 (Glossary) for i-Tree definitions of trees and shrubs.

Figure 5

Leaf area and leaf area density by land use

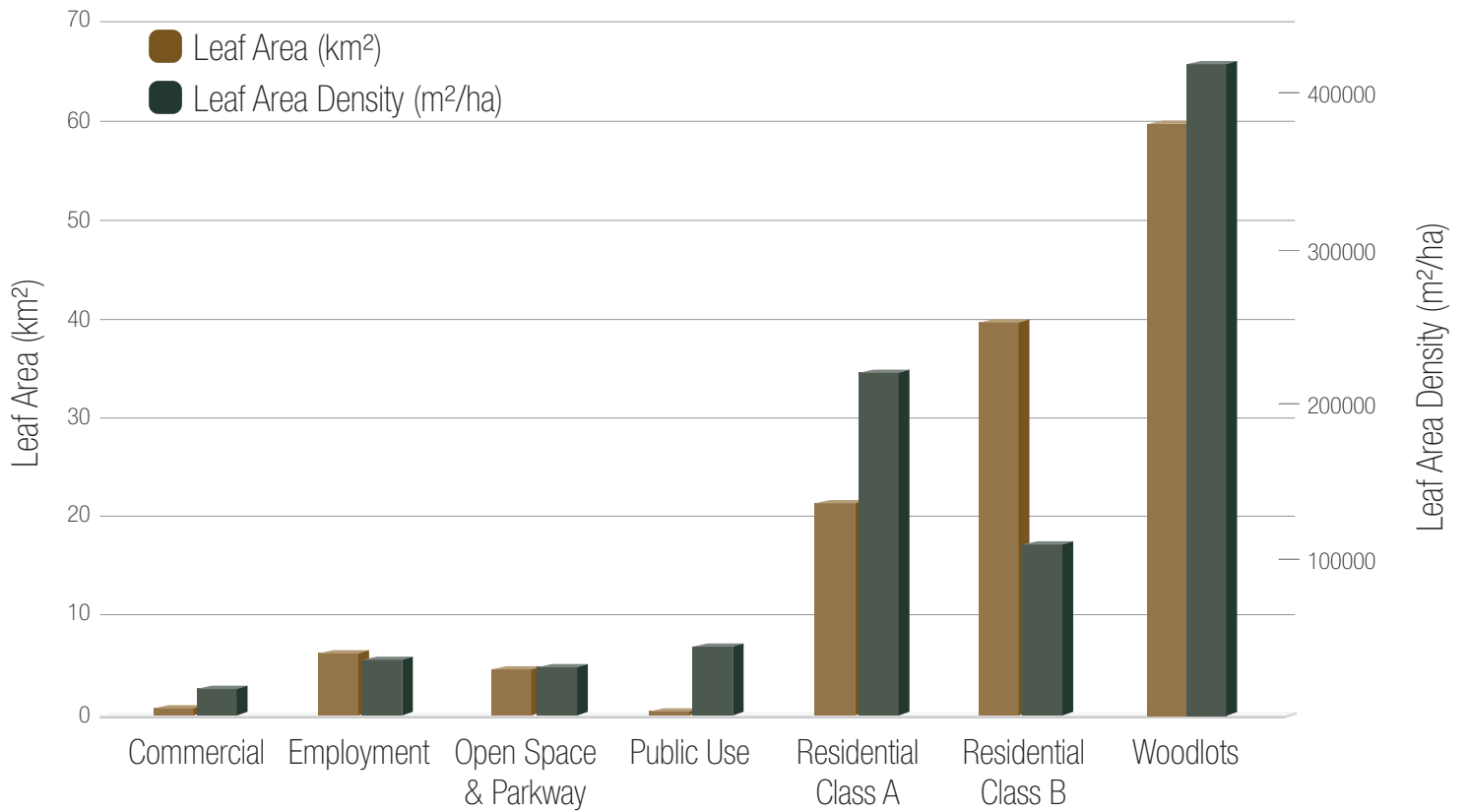
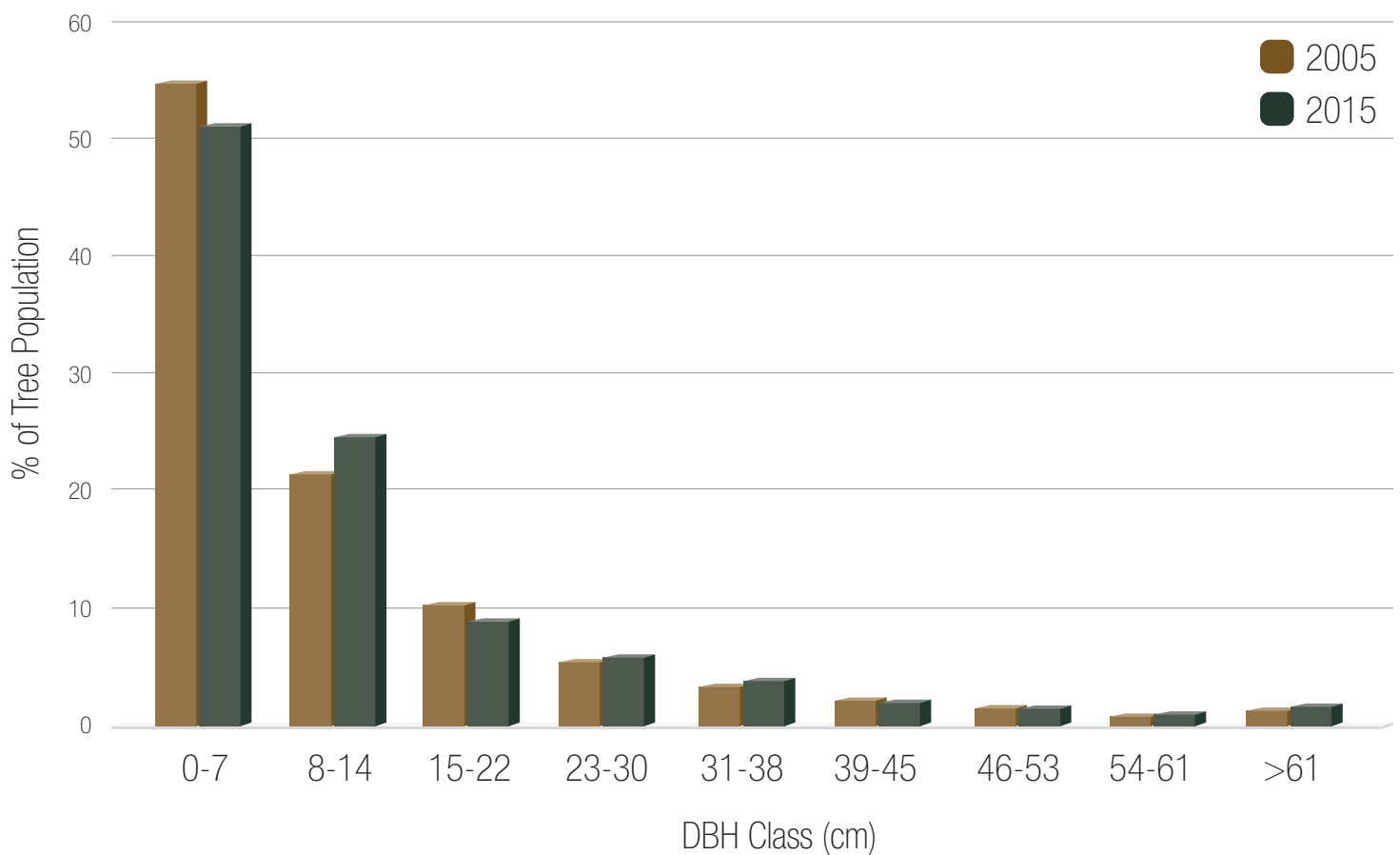


Figure 6

Tree population by diameter class, 2005 and 2015



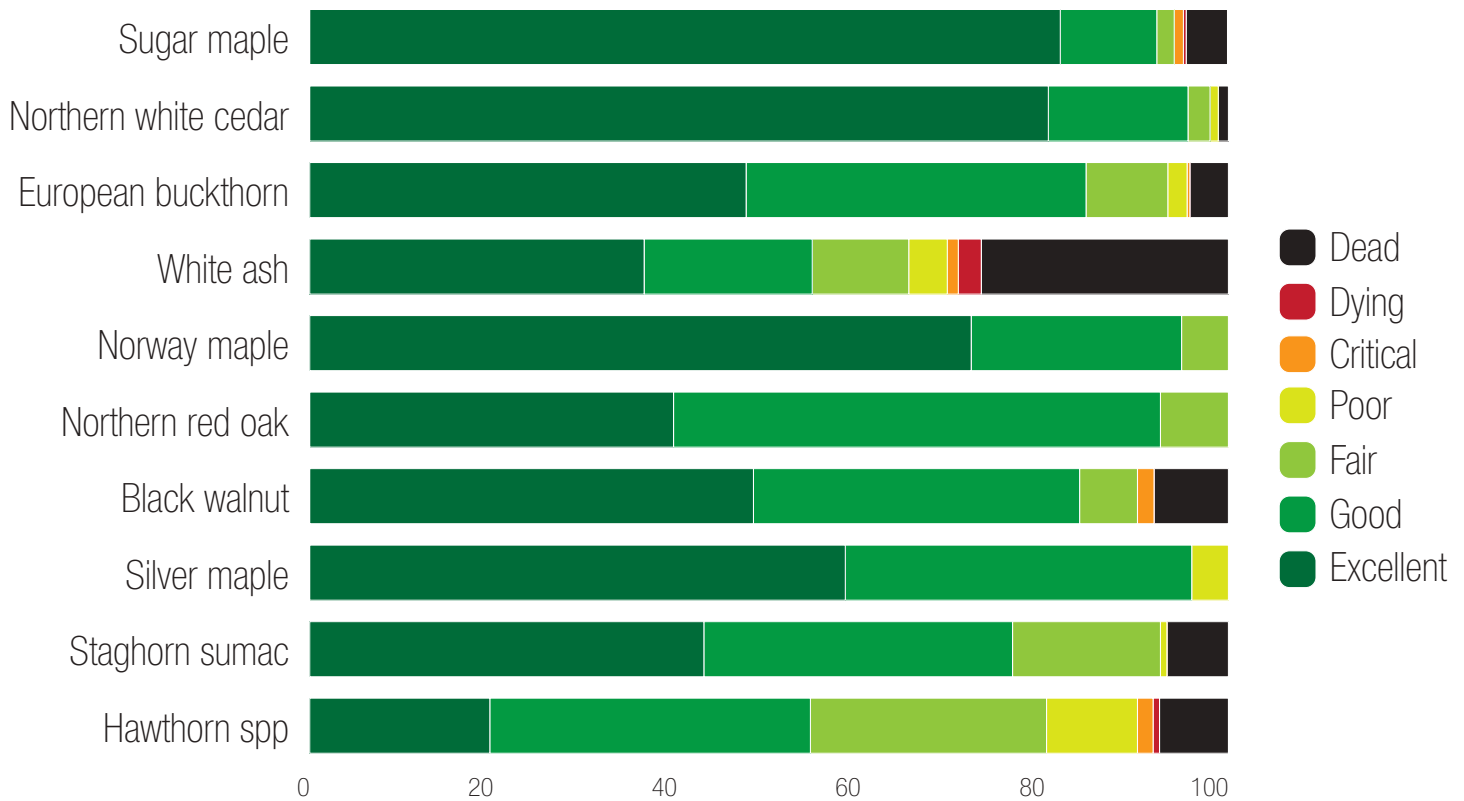
Oakville's urban forest contains a **total leaf area of 135.2 km²**. Woodlots contain a greater amount of leaf area than any other land use, but residential lands make a significant contribution to overall leaf area in Oakville (Figure 5). Woodlots contain the highest leaf area density, a measure of leaf area per unit of land area (in this case, square meters of leaf area per hectare of land). Residential Class B is the second highest ranking land use in terms of leaf area, but it has a relatively low leaf area density. This indicates that, while Residential Class B lands represent a large amount of leaf area, there is a relatively low concentration of leaf area per hectare of land in that classification.

The distribution of tree population by diameter class has changed little since 2005, although there has been a slight growth in the population of trees under 15 cm diameter at breast height (DBH) since 2005 (up to 76.3% from 76%). This figure includes immature trees that occur naturally in woodlots, but they do not skew the demographics dramatically. If Woodlot trees are removed from the analysis, 72.7% of Oakville's trees measure less than 15 cm DBH. The Town of Oakville's report following the 2005 UFORE study expressed a desire to eventually attain a goal of 10% large-diameter trees (i.e. trees larger than 76 cm in diameter). In 2005, the tree population in that diameter range was 0.5% and by 2015 it had risen to 0.6%, representing about 12,000 trees.

Urban Tree Health

Figure 7

Condition ratings of Oakville's top 10 tree species



In order to evaluate tree condition, all trees measured during the i-Tree Eco study were assessed for the level of die-back; in other words, the amount of dead branches occurring within the live crown. Approximately **83% of trees in Oakville were observed to be in either Excellent or Good condition**, which represents an increase from 2005, when 76.8% of trees were rated in Excellent or Good condition. Bearing in mind the relatively large amount of ecosystem services delivered by large-diameter trees (over 76.3 cm DBH), it should be noted that trees in this diameter class were generally found to be in Excellent or Good condition. Of the top ten tree species in Oakville, sugar maple and northern white cedar posted the highest proportion of trees in Excellent condition (Figure 7).

Ash species, including green/red ash (*Fraxinus pennsylvanica*) and white ash (*Fraxinus americana*) experienced moderately high dead tree counts (approximately 28% and 27%, respectively), most likely due to EAB.

Other invasive insect pests that pose a serious threat to Oakville's urban forest include Asian longhorned beetle (ALB, *Anoplophora glabripennis*) and gypsy moth (*Lymantria dispar dispar*), both of which can attack a range of tree species, but have preferred host genera. Asian longhorned beetle, which prefers maples (*Acer* spp.), potentially poses a greater degree of risk for the urban forest, as approximately 42% of Oakville's leaf area is susceptible to this pest. ALB has been detected in Vaughan (in 2003) and Mississauga (in 2013), making detection efforts for this pest in Oakville crucial. Oakville currently conducts annual surveys for the presence of ALB.

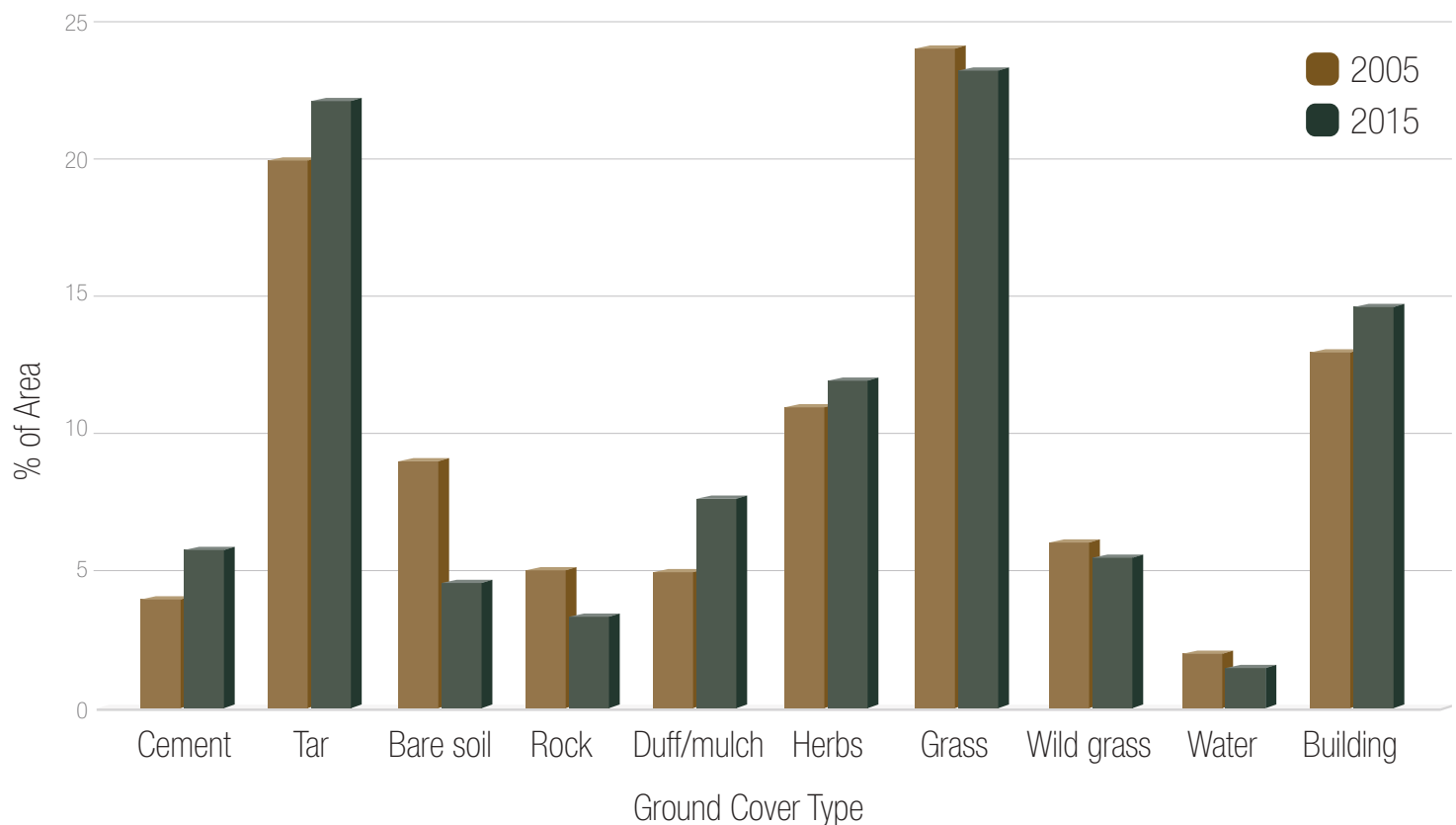
Table 3: Susceptibility of trees to major pests.

Pest	Known Host Population	Leaf Area of Host Population (% of Total)	Value of Trees (\$ million)
Dutch Elm Disease	36,600	1	8.3
Emerald Ash Borer	192,500	5.5	59.4
Gypsy Moth	409,000	23	325
Asian Longhorned Beetle	481,000	42	391

A comparison of the distribution of ground cover types observed by field crews in 2005 and in 2015 suggests that there may be less suitable tree habitat today than existed ten years ago (Figure 8). Total impervious ground covers are estimated to have risen from 37% of ground cover in 2005 to 42.5% in 2015.

Figure 8

Distribution of ground cover types in Oakville, 2005 and 2015



Environmental Services

Air Pollution¹⁴

Oakville's urban forest removes **113 tonnes of air pollution** annually, with an associated annual value of **\$668,295** (Figure 9). In 2005, Oakville's urban forest was estimated to have removed 172 tonnes of pollution annually. It should be noted that the 2005 figure includes 50 tonnes of particulate matter between 2.5 and 10 microns (PM10), a criteria pollutant that is no longer measured by i-Tree Eco, as the focus has shifted to smaller particulate matter (less than 2.5 microns, PM2.5) due to its more harmful effects on human health.

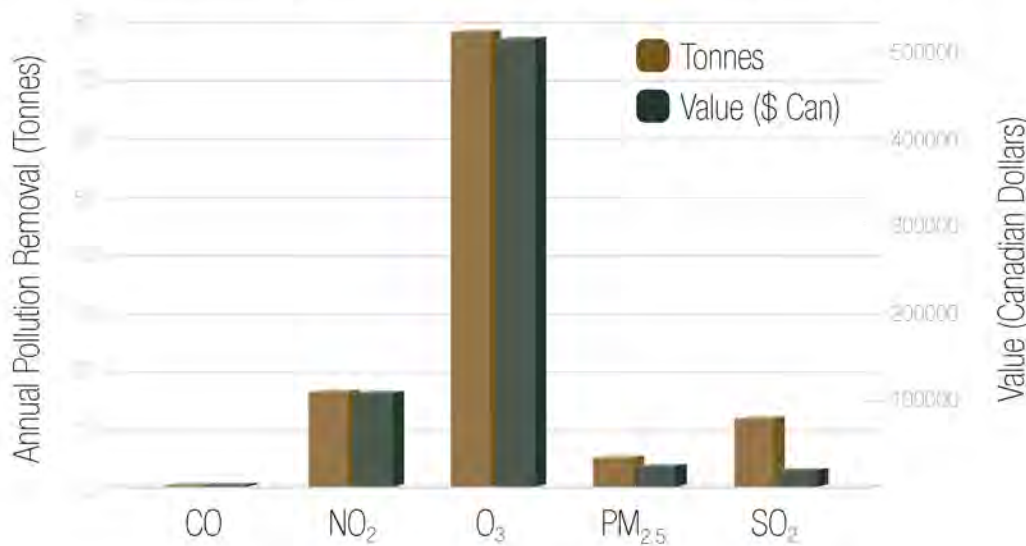
Table 4: Pollution removal by Oakville's urban forest, 2005-2015.

Criteria Pollutant	Tonnes (2005)	Tonnes (2015)
CO	3.5	0.35
NO ₂	21.2	16.3
O ₃	85.4	78.9
PM ₁₀	50	N/A
PM _{2.5}	N/A	5.2
SO ₂	11.9	12.1
Total	172	113

Oakville's urban forest removes 113 tonnes of air pollution annually, with an associated annual value of \$668,295.

Figure 9

Annual amounts of pollution removed by Oakville's urban forest, as measured in tonnes, and the associated annual value



¹⁴ The apparent declines in pollution removal as of 2015 are difficult to attribute to any single cause. Pollution monitoring is influenced by wind and weather, which can cause some variability in the data recorded at monitoring stations. Pollution emissions may also vary over time. For example, ozone levels recorded at the Oakville monitoring station were apparently lower in 2014 than in 2005. Any of the above factors could have influenced the pollution removal data presented in this study.

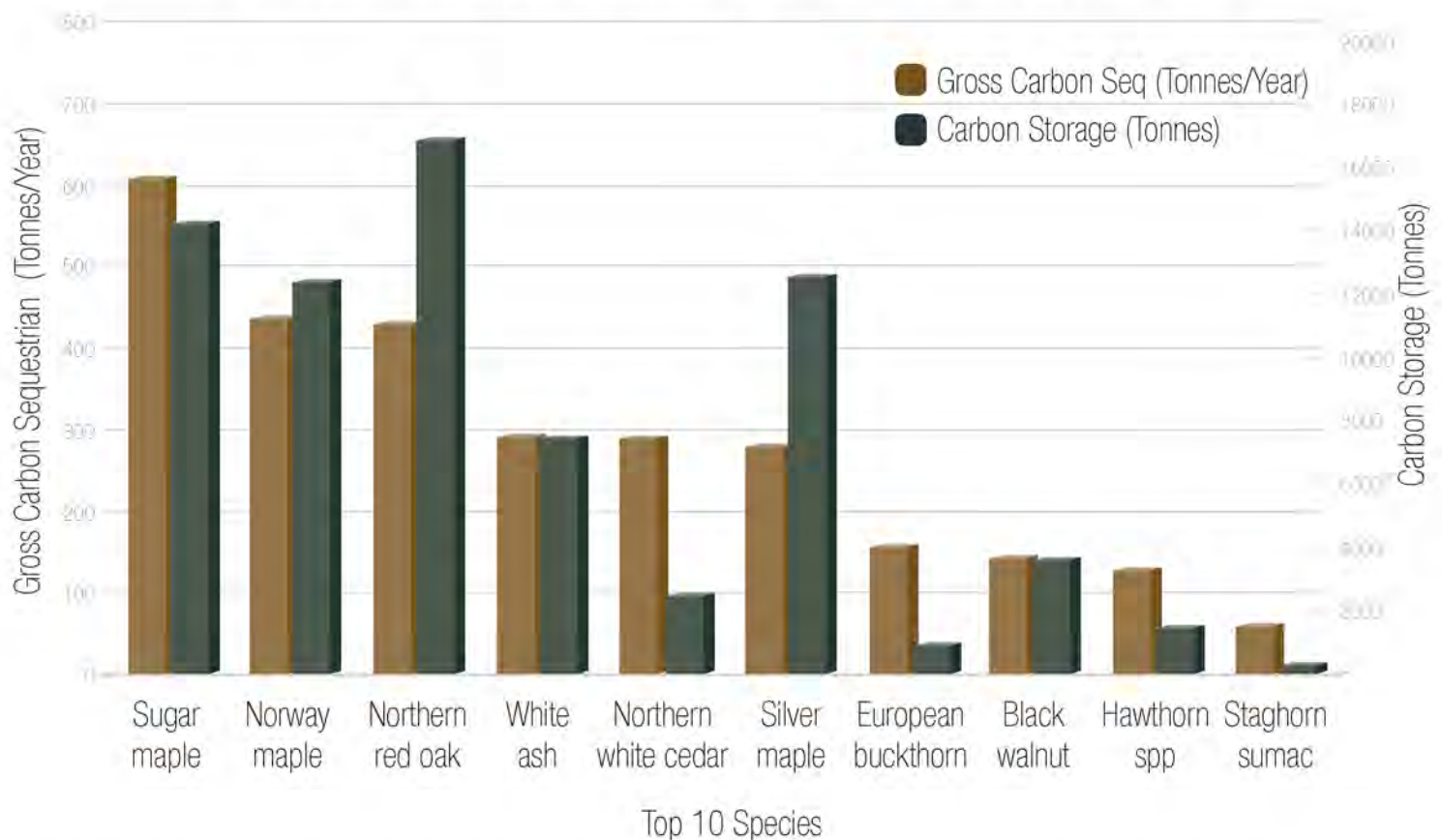
In Oakville, the total value of annual home energy savings provided by trees is \$1,799,582.¹⁵ As a result of these energy savings, about 2,200 tonnes of carbon emissions are avoided each year, with an additional value of \$171,828.

Carbon Mitigation

When properly placed on residential properties, trees help to lower home energy use, thereby reducing associated carbon emissions. In summer, trees that shade a residence contribute to lower cooling costs, and in winter, evergreen trees can help to block cold winds, thus lowering the cost of home heating. In both cases, these benefits are enhanced as the size and leaf area of the trees increase. In Oakville, the total value of annual home energy savings provided by trees is **\$1,799,582**.¹⁵ As a result of these energy savings, about **2,200 tonnes** of carbon emissions are avoided each year, with an additional value of **\$171,828**.

Figure 10

Carbon stored and sequestered by Oakville's top 10 tree species



Oakville's trees sequester about 5,943 gross tonnes of carbon (C) each year, with an associated annual value of \$460,000 (Figure 10). This represents a similar rate of annual carbon sequestration to 2005 levels, when Oakville's urban forest was estimated to sequester 6,000 tonnes of carbon each year.¹⁶ Oakville's trees store approximately 148,000 tonnes of carbon, with an associated value of \$11.5 million.¹⁷ This represents an increase from 2005, when the urban forest stored 133,000 tonnes of carbon. Of all the species in Oakville's urban forest, northern red oak (*Quercus rubra*) currently stores the most carbon (11.4%) and sugar maple (*Acer saccharum*) sequesters the most carbon each year (9.6%) (Figure 10).

¹⁵ Based on the prices of \$121 per MWH (Oakville Hydro) and \$10.45 per MBTU (Default value) (Canadian dollars).

¹⁶ In 2005, the value of annual carbon sequestration was reported as \$141,000. This value was based on a price of \$20.30 per tonne of carbon (UFORE methods: <https://www.treecools.org/econ/resources/UFORE%20Methods.pdf>)

¹⁷ Based on the carbon price of \$77 per tonne (\$Can).

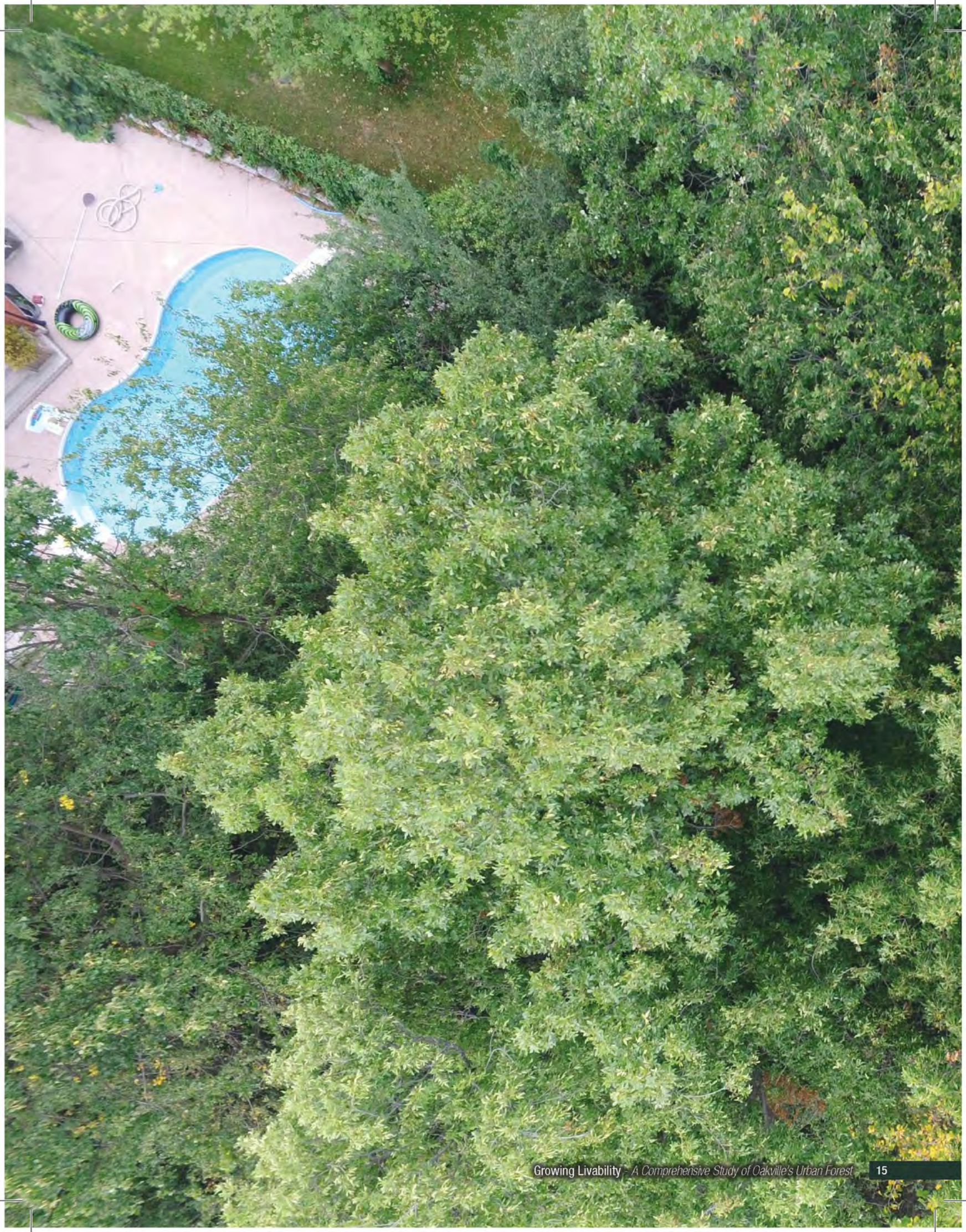




Photo Credit: Forestry Section, Parks and Open Space Department, Town of Oakville

4.1.2 – i-Tree Storm

i-Tree Storm is a storm preparedness utility that provides users with a standard method to assess damage to urban trees after a severe storm event. Users survey a sample of street segments immediately following a severe storm, to assess the damage that has occurred. Typically 30 street segments are surveyed within a municipality. Users may also perform a pre-storm survey to create a baseline sample and calculate time and cost requirements to inform storm-related contingency plans.

OVERVIEW & APPROACH

The rationale for conducting the Oakville i-Tree Storm assessment may be traced to December, 2013, when Oakville's urban forest was damaged by the ice storm that passed through southern Ontario. Approximately 11,000 municipal trees were damaged, 10% of which had to be removed.¹⁸ The total cost recovery submitted by Oakville to the Province of Ontario associated with this storm was approximately \$6.2 million, a figure that did not include the cost of staff salaries during the storm clean-up.¹⁹

In Oakville's Urban Forest Strategic Management Plan (2008) the Town was divided into three distinct Areas of Interest (AOIs) based on an approximation of the age-class of the urban forest (Immature – Intermediate – Mature) (See Figure 11). A sample of 30 street segments was surveyed in each AOI, in order to provide a larger sample. BioForest staff conducted a pre-storm assessment of trees located in the right of way (ROW) and within 15.24 m of the ROW in all 90 randomly selected street segments. Field data were entered into i-Tree Storm software, which calculated estimates of storm clean-up costs.²⁰

Town of Oakville i-Tree Storm Assessment Eligible Roads and Areas of Interest - 2015

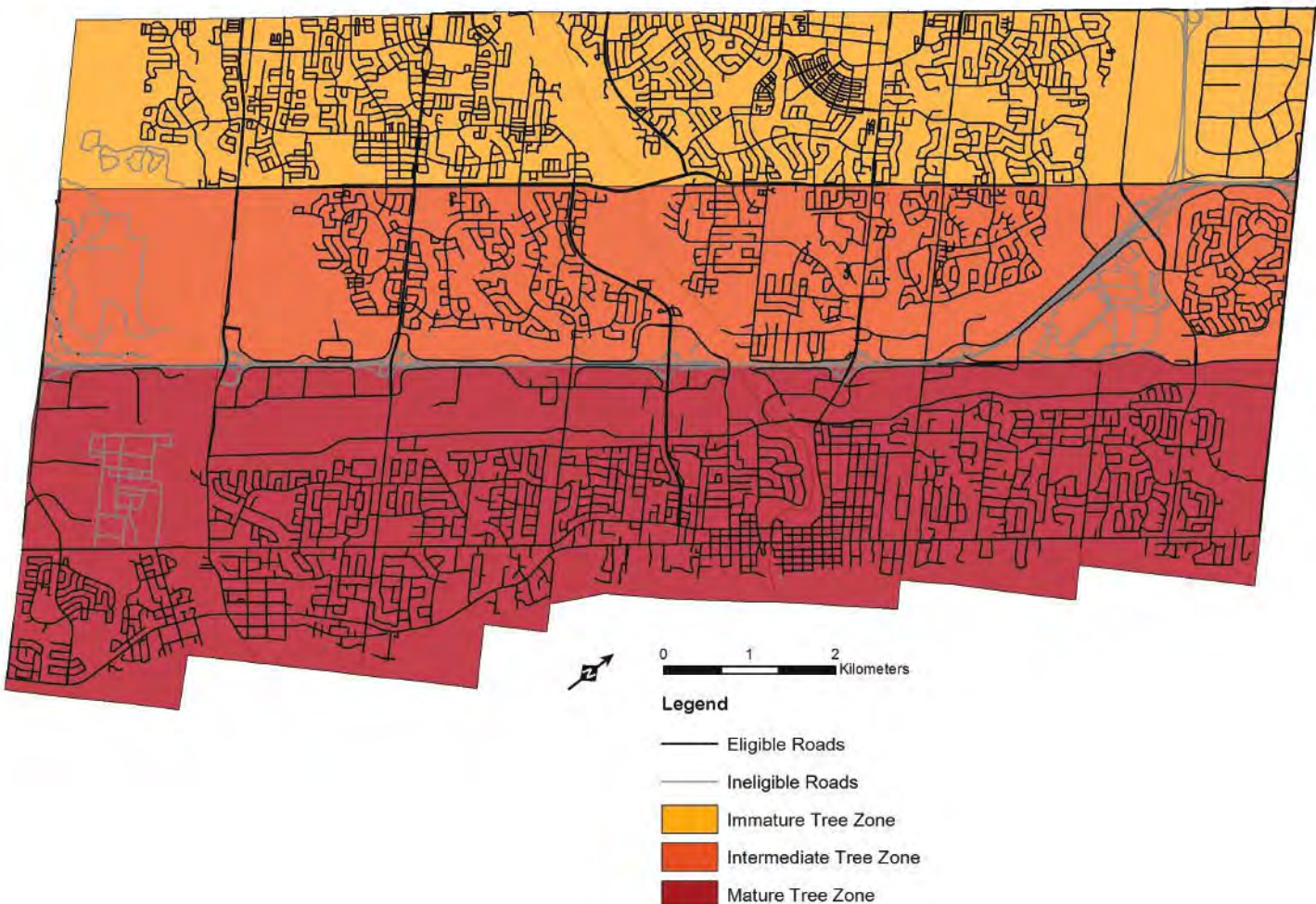


Figure 11: Map of the Town of Oakville showing the three Areas of Interest to be surveyed for i-Tree Storm.

¹⁸ CityWorks Database.

¹⁹ Finance Department, Town of Oakville.

²⁰ For more information on i-Tree Storm methodology, see the link to the i-Tree Storm manual under Section 9 (Additional Resources).

RESULTS

The overall Pre-Storm Estimates of Major Storm Damage for the three Areas of Interest are as follows²¹:

- **\$3,105,317 for the Mature Tree Zone**
- **\$2,279,016 for the Intermediate Tree Zone**
- **\$1,743,979 for the Immature Tree Zone**

The total Pre-Storm Estimate of Major Storm Damage for the Town of Oakville is **\$7,128,312**. It should be noted that this estimate closely parallels the cost recovery amount that Oakville submitted to the Province of Ontario in the aftermath of the 2013 ice storm.

4.1.3 – i-Tree Streets

Table 5: Summary of 2015 i-Tree Streets Results.

i-Tree Streets Results Summary	
Street Tree Population	95,770
Structural Value of Street Trees	\$201.6 million
Benefits Provided by Street Trees	\$11.9 million (Annual Value)
Street Tree Benefit-Cost Ratio	1.52
Carbon Stored by Street Trees (Tonnes)	63,295 (Value of \$605,908)
Air Quality Improvement by Street Trees	\$576,700 (Annual Value)
Aesthetic Benefits	\$7,436,922 (Annual Value)

OVERVIEW & APPROACH

i-Tree Streets (formerly known as STRATUM) uses street tree inventory data to quantify the benefits provided by street trees, including removal of air pollution, aesthetic benefits, and energy savings, and the dollar value of those benefits. The model also calculates a cost-benefit ratio, which demonstrates the extent of the return on a municipality's investment in street tree management. Stocking level, a measure of the area occupied by trees, is calculated based on the number of trees in the inventory and available planting locations. Results allow municipal urban forest managers to assess the effectiveness of their street tree management and identify areas where improvements may be made.

In 2015, BioForest staff conducted an i-Tree Streets analysis of Oakville's street tree population using the Town's pre-existing street tree inventory data. This inventory data was entered into i-Tree Streets software along with municipal budget information (including costs of tree pruning, removal, replacement, etc.) provided by the Town of Oakville.²²

RESULTS

Structural Attributes of Street Trees

Based on Oakville's current street tree inventory, there are 95,770 street trees that are actively managed by Oakville's Forestry Section, which is equivalent to about 5% of Oakville's total tree population. These trees have a structural value of approximately **\$201.6 million**.²³ Oakville's streets are nearly fully stocked; an estimated 97% of potential planting spots on Oakville's streets contain trees. There is approximately one street tree for every two Oakville residents.

Maples (*Acer* spp.) are the dominant genus in Oakville's street tree population; four of the ten most abundant species of street trees are maples (Norway maple (*Acer platanoides*), red maple (*Acer rubrum*), silver maple (*Acer saccharinum*), and sugar maple (*Acer saccharum*)). The remaining most abundant species of street trees include northern white cedar (*Thuja occidentalis* – the most abundant of all), Littleleaf linden (*Tilia cordata*), apple species (*Malus* spp.), honey locust (*Gleditsia triacanthos*), blue spruce (*Picea pungens*), and Broadleaf Deciduous Small unidentified species (an assortment of small stature, shrubby species).

The structural (woody) and functional (foliage) condition of Oakville's street tree resource is very good overall (**95% in "good" structural condition and 96% in "good" functional condition**). These numbers have direct implications for the capacity of Oakville' street trees to deliver benefits that are linked to tree functioning.

²¹ Pre-Storm Estimates are generated by i-Tree Storm in United States dollars (\$USD). For the purposes of this report, the values for these estimates were converted to Canadian dollars (\$CAD) using the exchange November 4, 2015, exchange rate of \$1 CAD = \$1.31 USD.

²² For more information on i-Tree Streets methodology, see the link to the i-Tree Streets manual under Section 9 (Additional Resources).

²³ Value estimates generated by i-Tree Streets are presented in United States dollars (\$USD). For the purposes of this report, the values for street tree benefits were converted to Canadian dollars (\$CAD) using the exchange November 4, 2015, exchange rate of \$1 CAD = \$1.31 USD.



Figure 12: Oakville's street trees provide approximately \$11,866,948 in benefits each year.

Street Tree Benefits

i-Tree Streets calculates the value of benefits delivered by street trees, including air pollution removal, energy savings, and aesthetic improvements. However, the benefits analyzed by the model may not necessarily be considered exhaustive, as there may be additional benefits that are difficult to quantify and thus may not be accounted for in this analysis.

Based on the outputs of the i-Tree Streets model, **Oakville's street trees are estimated to provide approximately \$11,866,948 in benefits each year.** After factoring in the costs associated with maintaining the street tree population (approximately \$7,827,396 per year²⁴), street trees deliver an estimated \$4,039,554 in annual net benefits. This equates to a benefit-cost ratio of 1.52; in other words, **Oakville's street trees return benefits equal to 152% of the costs required to maintain them.**

By shading buildings in the summer and blocking winds in the winter, Oakville's street trees provide approximately **\$3.08 million in annual energy savings.**²⁵ Norway maple (*Acer platanoides*) contributes more annual energy savings than any other species of street tree, at about \$435,420 each year.

As a result of these building energy savings and their natural carbon sequestration abilities, **street trees are estimated to remove a net total of about 7,586 tonnes of carbon dioxide each year.** The estimated value of this service is \$72,260. **Oakville's street trees are also estimated to store about 63,295 tonnes of carbon dioxide, with an associated value of \$605,908.** Among street trees, silver maple (*Acer saccharinum*) and Norway maple (*Acer platanoides*) account for the most carbon storage, with 11,764 tonnes and 10,066 tonnes stored, respectively.

Oakville's street trees provide annual air quality improvement benefits valued at about \$576,699, averaging about \$6.03 per tree each year. The total figure may be broken down as follows:

- Total annual value of pollution deposition by street trees: \$314,421
- Total annual value of avoided pollution emissions: \$295,576
- Negative annual value due to emission of 3,969 kg of biogenic volatile organic compounds (BVOCs) by street trees: -\$33,299.

Norway maple (*Acer platanoides*) provides more air quality improvement benefits than any other species of street tree, with a total annual value of \$79,786.

Street trees also play a valuable role in stormwater retention by intercepting rainfall and reducing overland flow of stormwater. **Oakville's street trees are estimated to intercept approximately 252,357 m³ of rainfall per year, with an associated annual value of \$701,744.** Norway maple (*Acer platanoides*) accounts for more stormwater runoff reduction than any other species of street tree, intercepting about 29,900 m³ of rainfall each year, with an associated annual value of \$83,184, or about \$7.21 per tree.

The largest share of the annual benefits provided by Oakville's street trees is represented by the values associated with aesthetic and related benefits.

These benefits account for approximately **\$7,436,922**, or 63% of the total annual value provided by street trees.

Implications for Street Tree Management

Street trees play an important role in residential, commercial, and employment areas and they represent an essential form of green infrastructure that is accessible to the public and that enhances the livability of the community.

Oakville is currently doing a very good job of managing its street tree resource, as evidenced by the positive outputs of the i-Tree Streets analysis. However, several key priorities must be addressed in order to maintain a healthy street tree population over the long term. While Norway maple delivers a large amount of benefits as a

species, its dominance among street trees presents some concerns for the long term. There is a need to even out the diversity of species over time so that other high-performing species of street tree, such as London planetree (*Platanus × acerifolia*), European beech (*Fagus sylvatica*), and eastern hophornbeam (*Ostrya virginiana*) may offer a relatively greater amount of benefits than they currently do. Reducing the dominance of Norway maple may also reduce the risk associated with pest attacks, particularly Asian longhorned beetle (*Anoplophora glabripennis*), which can result in large-scale single-species or single-genus tree losses.

The conservation of the ash component of Oakville's street tree population is an important investment. The ash trees on Oakville's streets currently have a replacement value of about \$15 million. However, where necessary, timely removals of ash trees that are dying from the effects of EAB infestation will minimize the risk associated with tree failure and will maintain the overall health of the street tree population. Where trees have been removed, it is important to continue the Town of Oakville's practice to plant replacement trees, in order to ensure a sufficient population of young trees that will continue to mature and increase the benefits they return to the community.

Oakville's street trees are estimated to provide approximately \$11,866,948 in benefits each year.

²⁴ Forestry Section, Parks and Open Space Department, Town of Oakville

²⁵ Note that this figure differs from the residential energy savings result in i-Tree Eco, which calculates the energy savings provided by trees to residential buildings only.

Preventive maintenance is key to insuring the long-term health and viability of the street tree population. Early intervention, as well as regular pruning and watering, will maximize the benefits street trees can provide throughout the course of their lives. These efforts will be assisted by ensuring that Oakville's tree inventory database is regularly updated. The main strengths of Oakville's street tree population are its health and diversity. Conserving these strengths by implementing measures to improve its noteworthy street trees will enable the Town of Oakville to further enhance the livability of its neighbourhoods.

4.1.4 – i-Tree Hydro

i-Tree Hydro models the effect of vegetative and impervious land cover on hydrology within a watershed. Users are able to quantify the impacts of simulated changes in land cover types on stream flow and water quality. The results allow urban forest managers and urban planners to make informed decisions with a view to the potential hydrologic impacts brought about by a growth or reduction of impervious area and tree canopy.

OVERVIEW & APPROACH

Staff of the United States Department of Agriculture (USDA) Forest Service, the Davey Institute, and the State University of New York (SUNY) conducted an i-Tree Hydro analysis of the East Sixteen Mile Creek watershed (Figure 13). Oakville is in a downstream location and is situated just southeast of the Omagh gauging station, represented by the red dot in Figure 13. Inputs to the model included: hourly weather data gathered from the weather station at the Region of Waterloo International Airport; tree and impervious cover estimates using 250 random points in Google Earth imagery; 2014 hourly stream flow data collected at “East Sixteen Mile Creek near Omagh” gauging station; and estimates of tree canopy leaf area index (LAI), based on the 2015 i-Tree Eco study of Oakville.²⁶ A total of 121 model scenarios were produced, with varying combinations of changes in impervious cover and tree cover. The results, which apply to the East Sixteen Mile Creek watershed as a whole, illustrate the extent to which changes to the landscape can have an impact on stream flow and water quality.

Environment Canada 02HB004

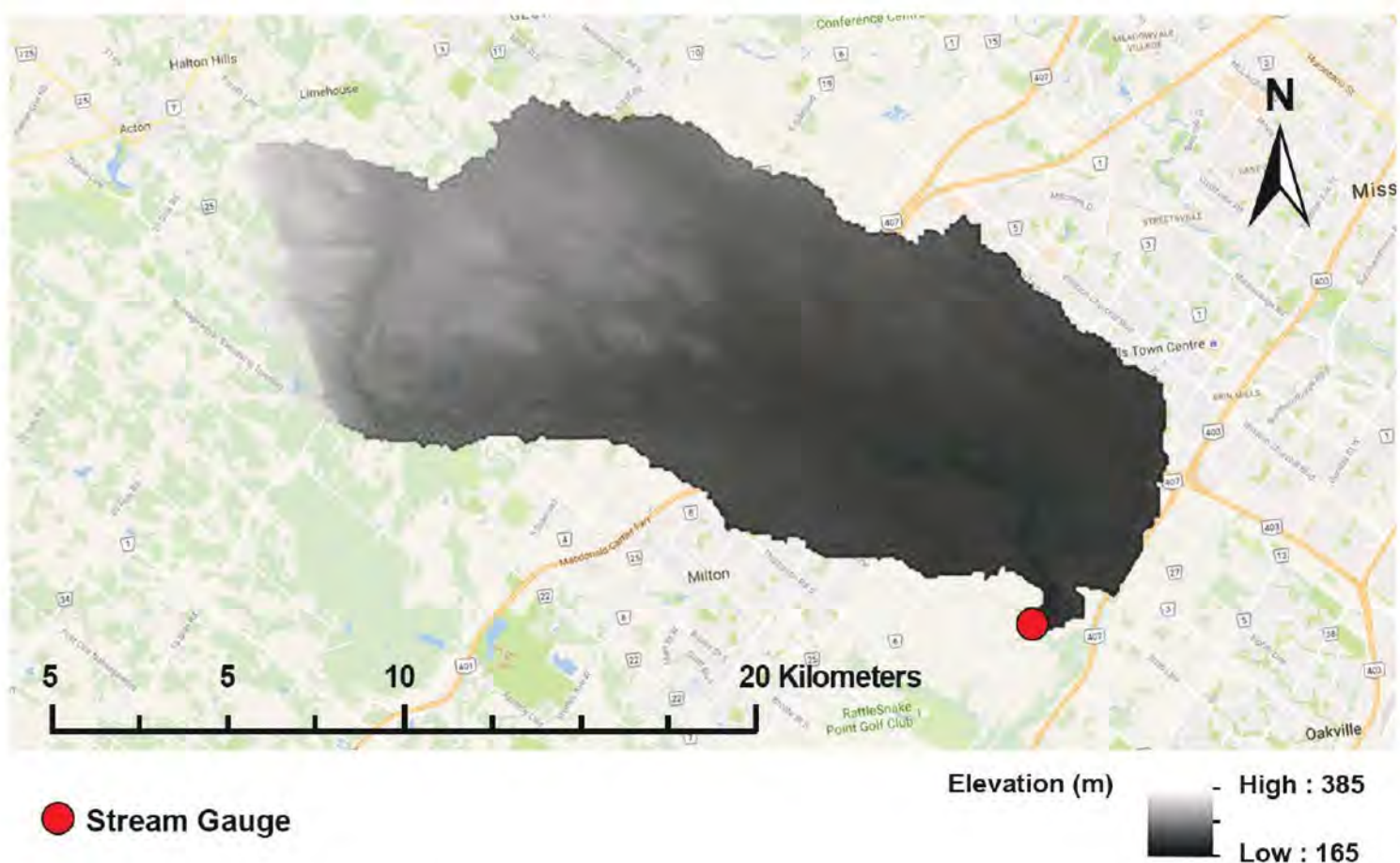


Figure 13: Digital Elevation Model (DEM) of East Sixteen Mile Creek Watershed. Oakville is located just southeast of the Omagh gauging station. This gauging station was the closest available source of hourly stream flow data.

²⁶ See Section 9 (Additional Resources) for links to further information on i-Tree Hydro protocol.



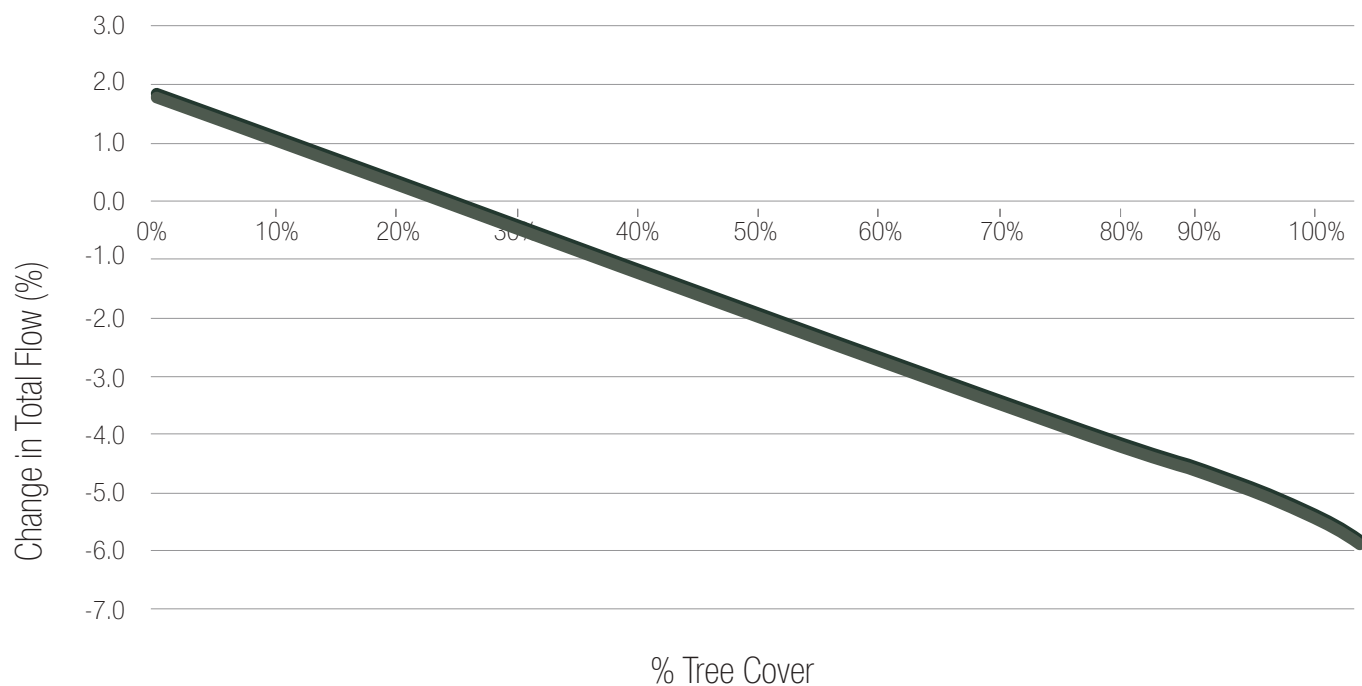
RESULTS

Tree Cover Effects

Increasing tree cover tends to reduce total flow in the East Sixteen Mile Creek watershed (Figure 14), with the loss of existing tree cover increasing total runoff during the 12-month simulation period by an average of 2.7% (597 thousand m³). Increasing canopy cover from 22.4% to 40.0% would reduce runoff (pervious and impervious area flow) by 1.7% (367 thousand m³) during the simulation period. Increasing tree cover reduces runoff generated from impervious areas and generally reduces runoff from pervious land.

Figure 14

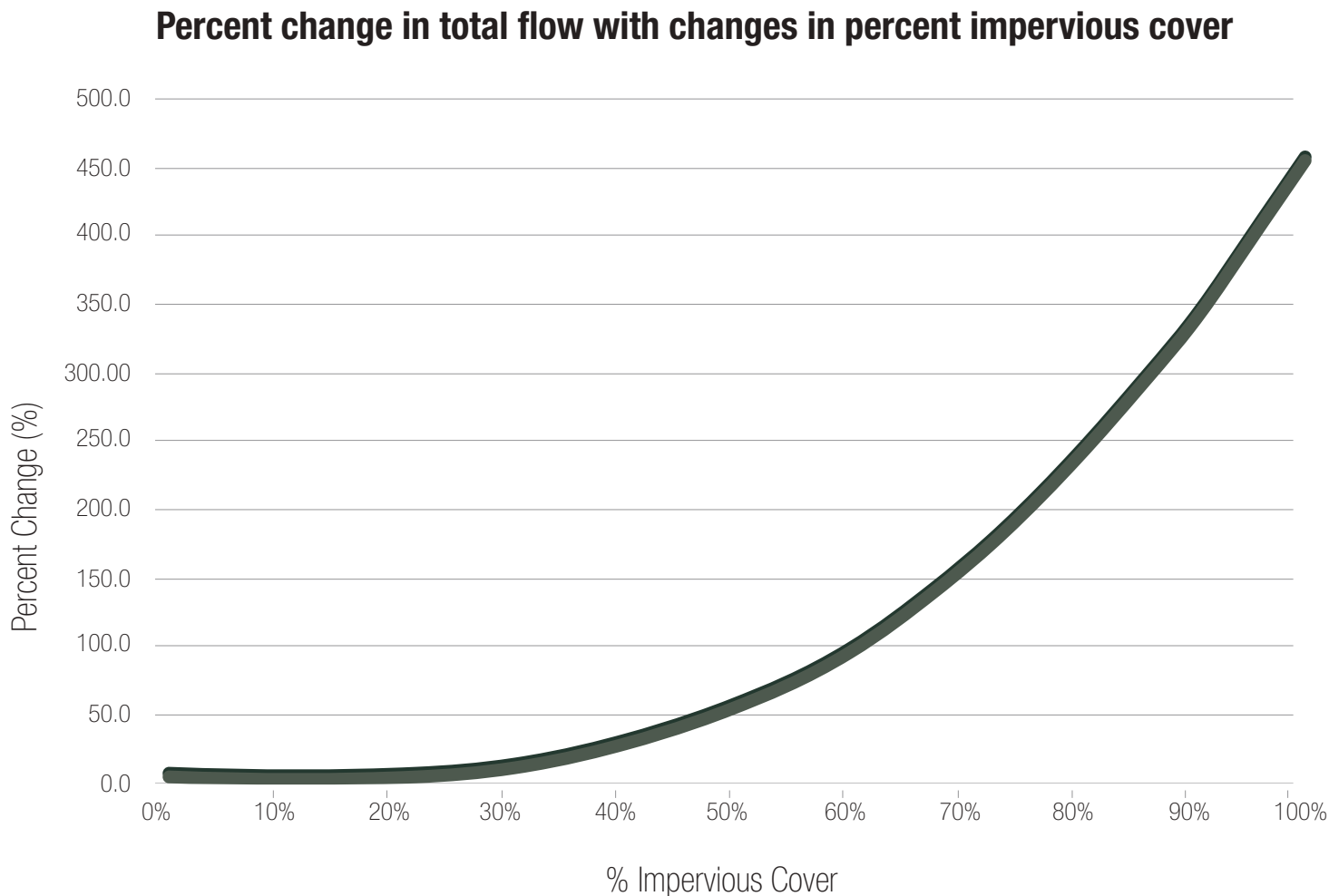
Percent change in total flow with changes in percent tree cover



Impervious Cover Effects

Increasing impervious cover tends to increase total flow in the East Sixteen Mile Creek watershed (Figure 15), with the loss of existing impervious cover decreasing total runoff during the 12-month simulation period by an average of 3.2% (698 thousand m³). Increasing impervious cover from 7.4% to 20% of the watershed would increase total runoff by 9.2% (2.0 million m³) during the simulation period (Figure 15). Increasing impervious cover reduces base flow and pervious runoff while significantly increasing runoff from impervious surfaces.

Figure 15



Increasing tree cover will reduce stream flow, but the dominant cover type influencing stream flow is impervious surfaces. Under current cover conditions, increasing impervious cover had a 25 times greater impact on flow relative to tree cover. Increasing impervious cover by 1% averaged a 1.92% increase in stream flow, while increasing tree cover by 1% averaged only a 0.08% decrease in stream flow.

Areas of tree canopies intercepted about 13.2% of the total rainfall, but as only 22.4% of this watershed is under tree cover, interception of total precipitation in the watershed by trees was only 3.0% (6.5 million cubic meters). Areas of grass/herbaceous cover intercepted about 3.1% of the total rainfall, but as only 68.0% of this watershed is under grass/herbaceous cover, interception of total precipitation in the watershed by grass/herbaceous cover was only 2.1% (4.6 million cubic meters). About 80.1% of total precipitation is estimated to re-enter the atmosphere through evaporation or evapotranspiration (including evaporation from interception) or go to ground water recharge.

Due to Oakville's downstream location within the East Sixteen Mile Creek watershed, the hydrologic effects stemming from expansion or loss of impervious or tree cover would be attributed to factors outside of the Town's control. Changes in impervious cover and urban forest canopy in areas upstream from Oakville would influence stream flow dynamics in Oakville. Nevertheless, it is important to note that the retention and expansion of urban forest canopy, and increases in impervious cover in Oakville still play a role in the local hydrology.

4.2 – Urban Forest Canopy Analysis

An urban forest canopy analysis was conducted by Plan-It Geo to examine the existing urban forest canopy (UFC) across several geographic boundaries and the change in UFC between 2005 and 2015. The results provide the Town with an update of UFC and assist in reviewing urban forest management goals.

4.2.1 – Overview and Approach

The overall urban forest cover reported in the 2005 study of Oakville’s urban forest was 29%; however, this figure was an overestimation. One task of the current study was to review the prior land cover classification data and assess its accuracy and use for comparison over the 10-year period.

It was determined that the overall accuracy of the 2005 urban forest cover study was 80% and not sufficient for measuring change. Several factors may be at play, including quality of the original satellite imagery (ex. clouds/haze), the remote sensing software used at the time, the analyst’s experience, and Quality Assurance/Quality Control (QA/QC) protocols used. Since 2005, advancements in technology and an extensive QA/QC process allow for more accurate measurements of urban forest canopy.

When finalizing the methods for the 2015 study, an alternative approach using high resolution aerial imagery and i-Tree Canopy software was used to produce a new estimate for 2005 and a more reliable change estimate over the 10 years. A new remotely-sensed analysis of land cover and UFC was also conducted but with emphasis placed on the statistical sampling approach as the Town’s official updated UFC % and other uses recommended for land cover mapping products. Tables 6 and 7 summarize the two approaches used in this study, and the benefits, limitations, and applications of each.

Table 6: Point-based sampling canopy analysis method (Method #1). This method was used to calculate the total urban forest canopy (UFC) for the Town of Oakville.

Method	Description	2005 Result (UFC) ²⁷	2015 Result (UFC)	Measure of Accuracy or Reliability	Benefits, Limitations, and Suggested Use / Application
1. Point-based sampling	Statistical approach of 2,800 random point locations assessed (tallied) for presence of canopy vs. non-canopy based on manual aerial imagery interpretation	26.5%	27.8%	0.84% standard error (SE)	<ul style="list-style-type: none"> • Benefits: most accurate estimate of town-wide Urban Forest Canopy (small standard error) • Limitations: this is a sample and cannot be broken down further spatially in GIS without loss of accuracy and SE • Application: use to compare trends or change over time towards canopy goal

Table 7: Satellite remote sensing canopy analysis method (Method #2). This method was used to identify potential plantable areas (PPAs) and produce land cover data.

Method	Description	2005 Result (UFC)	2015 Result (UFC)	Measure of Accuracy or Reliability	Benefits, Limitations, and Suggested Use / Application
2. Satellite remote sensing	Land cover classification (0.5 meter resolution imagery)	N/A	25.5%	Roughly 2.5% standard error (SE)	<ul style="list-style-type: none"> • Benefits: produces maps to spatially represent % UFC and planting potential • Limitations: lower overall accuracy (higher SE) and more time-intensive • Applications: use to identify potential plantable areas; the land cover data is also useful for other planning/modeling applications (land use, hydrology, etc.)

²⁷ 2005 figures represent the estimates for 2005 conditions calculated using 2015 technology. It was determined that the level of accuracy in the original remote sensing data was too low to properly review, so for the purposes of time and cost, attention was directed toward calculating an updated canopy cover using the point-based sampling method, which has a higher degree of accuracy.

Results show that Oakville has slightly increased its canopy coverage even in the face of ice storms, development, and EAB.



Vegetated Possible Planting Area



Impervious Possible Planting Area



Unsuitable for Planting

4.2.2 – Results

Utilizing the point sampling method (#1), 742 points were identified through aerial photo interpretation as urban forest canopy in 2005 for an average of 26.5% UFC. For 2015, 778 out of 2,800 sample locations were tallied as urban forest canopy for an average of **27.8% UFC**. This represents a **canopy increase of 1.3% between 2005 and 2015** within the study area. Results show that Oakville has slightly increased its canopy coverage even in the face of ice storms, development, and EAB.

Oakville's official 2015 canopy cover through this project is reported as 27.8% given the greater precision (lower standard error) of this method over the remote sensing land cover classification approach.

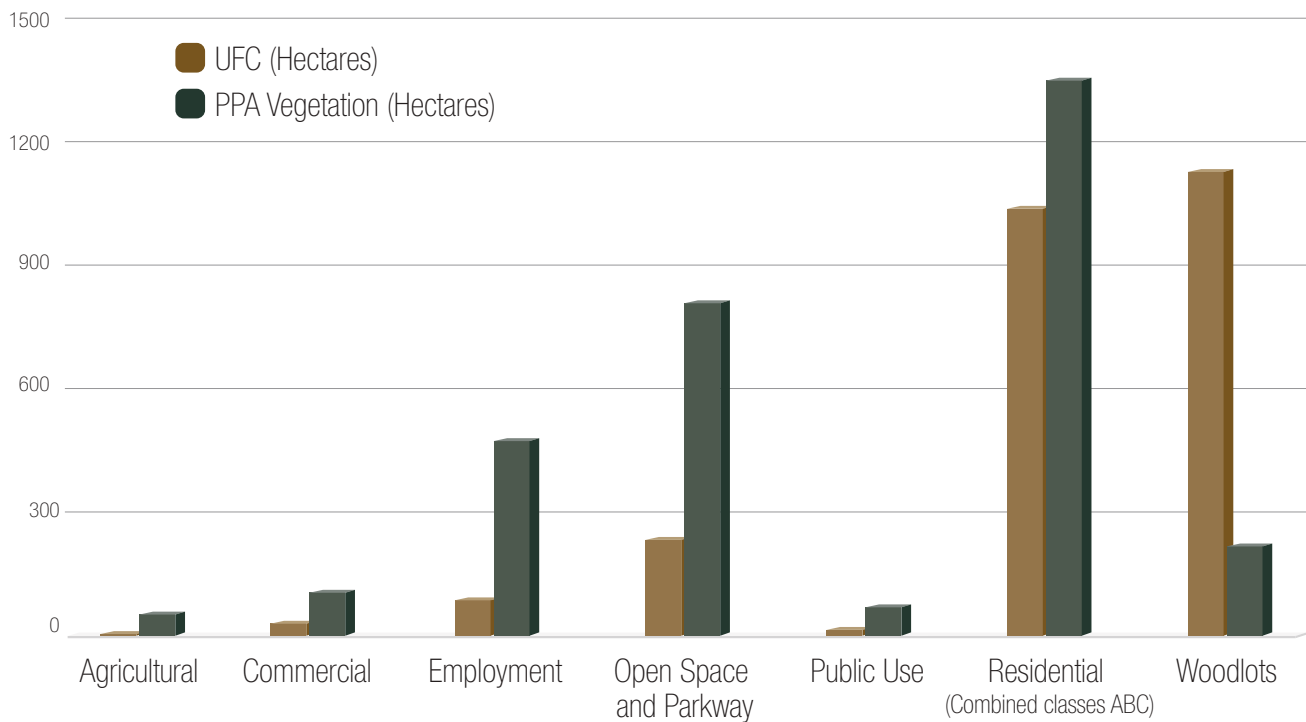
Based on the remote sensing land cover classification approach (#2),

Oakville averages **25.5%** urban forest canopy (based on total area in the study area including all land and water), **32%** grass and open space, and **40%** impervious surface area. The remaining land cover consists of water and bare soil. Dividing the impervious areas into more detailed classifications shows that 13% of the Town is covered by buildings and 8% by roads, leaving 19% classified as "other impervious", or non-building, non-road impervious surfaces such as parking lots, driveways, patios and sidewalks.

While the land cover data shows 32% of the Town is grass and open space, the amount of Vegetated Possible Planting Area (PPA-Veg) equals **31%** of the Town (3,089 hectares) after removing areas unsuitable for planting (ex. soccer fields, etc.). Non-building, non-road impervious areas cover **19%** of Oakville (1,881 hectares) offering additional planting opportunity (PPA-IA), while **24%** (2,346 hectares) has been identified as Unsuitable UFC.

Figure 16

Total Urban Forest Canopy and Vegetated Possible Planting Area in hectares, by land use classification



Land use often plays a huge role in the presence or absence of trees and forest canopy. This study assessed the amount and distribution of urban forest canopy (UFC) and Possible Planting Areas (Vegetation, Impervious, and Total PPA) data for seven land use classifications (after combining all residential classifications) (See Figure 16). Combining the residential classifications (class A, class B, and class C) shows that this land use contains nearly as much canopy as Woodlots (roughly 1,000 hectares each) and offers the most planting potential within the study area (roughly 1,300 hectares). Thus, residents of Oakville have a significant potential influence on the expansion or loss of Town-wide urban forest canopy over the long term.

Urban forest canopy (UFC) totals and Possible Planting Areas (Vegetation, Impervious, and Total PPA) metrics were generated for the Town's 2015 Land Use Areas (LUAs), which are consistent with the Land Use Schedules of the Livable Oakville Plan²⁸ (Figure 17). LUA West contains about 29% of Oakville's total urban forest canopy (the largest share). LUA West also holds the largest share of vegetated potential planting area (PPA Vegetation), at 37% (See Table 8).

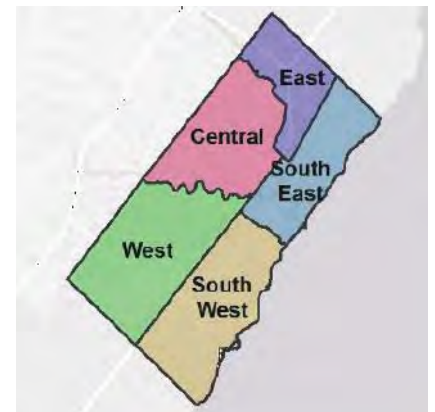


Figure 17: 2015 Land Use Areas

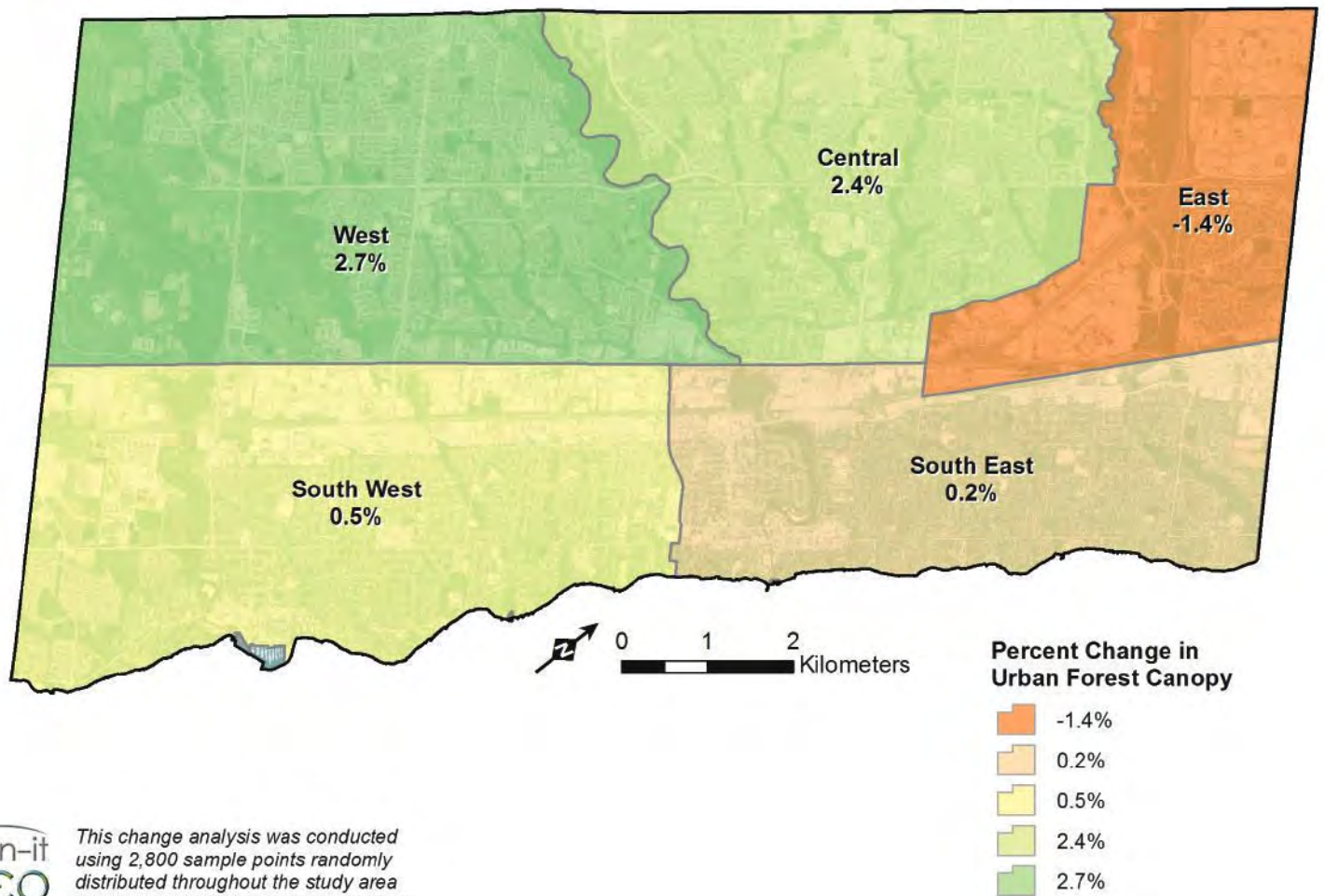
Table 8: Urban Forest Canopy Assessment Results by Land Use Area.

Land Use Area	Land Area (ha)	UFC (ha)	Dist. of UFC %	% PPA Vegetation	% PPA Impervious	% Total PPA
Central	2,054	563	22%	29%	17%	46%
East	1,135	136	5%	30%	29%	59%
South East	1,606	534	21%	26%	18%	44%
South West	2,379	573	23%	32%	22%	54%
West	2,677	733	29%	37%	14%	51%
Total	9,850	2,540	100%	31%	19%	50%

²⁸ 2009 Oakville Official Plan. See: <http://www.oakville.ca/townhall/livable-oakville-official-plan.html>

Figure 18: Percent change in urban forest canopy, 2005-2015, by Land Use Area.

Town of Oakville Urban Forest Canopy Assessment
Percent Change in Urban Forest Canopy (UFC) from 2005-2015
by Land Use Area

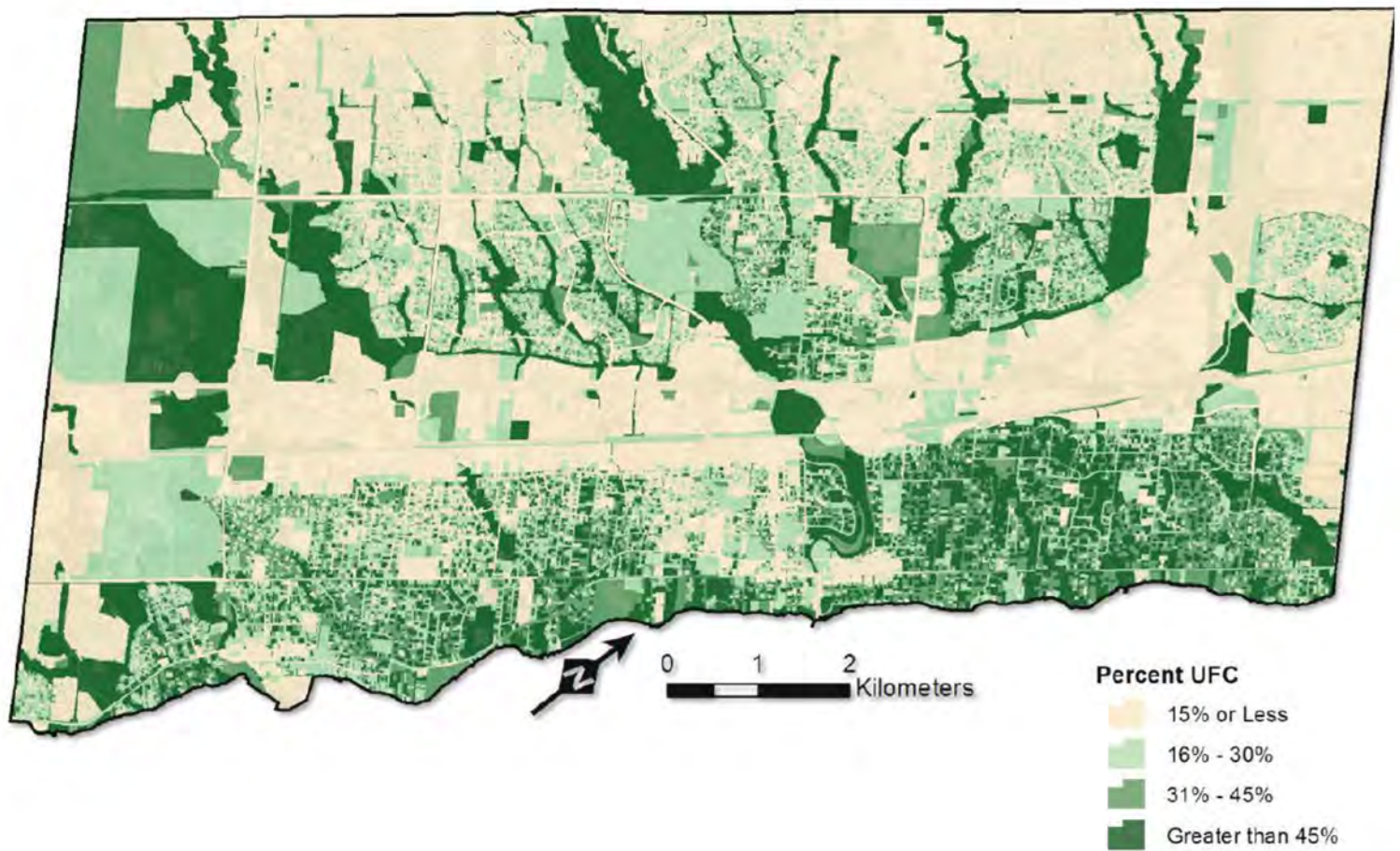


This change analysis was conducted using 2,800 sample points randomly distributed throughout the study area to identify the presence or absence of urban forest canopy.

May 3 2016

Figure 18 shows the percent change in urban forest canopy (UFC) from 2005-2015 by Land Use Areas. LUA West was observed to have the greatest increase in urban forest canopy, having increased in UFC by 2.7% from 2005-2015. LUA East was the only area to show a decline in urban forest canopy over those ten years, posting a 1.4% decline.

Figure 19: Percent urban forest canopy by parcel.



This study processed urban forest canopy (UFC) totals and Possible Planting Areas (Vegetation, Impervious, and Total PPA) data for all properties within the study area boundary. This included nearly 60,000 individual parcel records. Figure 19 shows the distribution of percent UFC by parcel. This data layer can be queried at the neighborhood level to quickly identify which properties have low UFC and high planting potential. Urban forest canopy expansion efforts can thus focus not only on areas of the Town that require additional UFC, but also on individual districts and neighbourhoods, allowing managers to direct efforts on a much finer scale.



5 | Discussion & Analysis: Implications for Oakville's Urban Forest

The results of this study on Oakville's urban forest demonstrate that, in the ten years since the 2005 UFORE study, many elements of Oakville's urban forest have undergone change. This section discusses the implications of the results derived from the i-Tree modules and the Urban Forest Canopy analysis, as well as an analysis of factors related to urban planning that may have an impact on the urban forest.

Figure 20: Urban forest health is enhanced by a diversity of tree species and age classes.

5.1 – Urban Forest Diversity

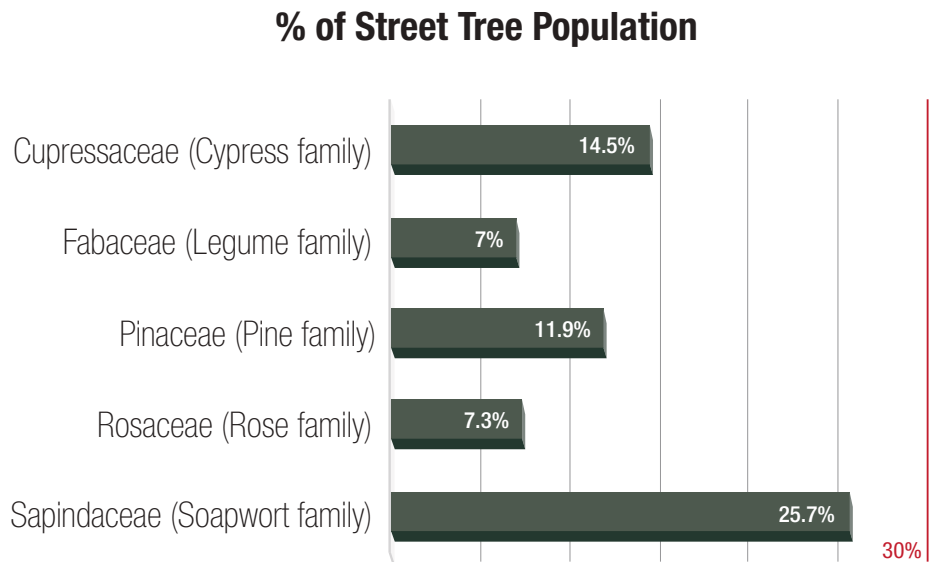
Species diversity is an important factor in ecosystem health. An urban forest with high species diversity is better equipped to absorb the effects of species-specific disease or pest outbreaks than an urban forest with lower species diversity. At the same time, the relatively high number of non-native species in land uses with higher species diversity entails a risk that one or more of these species may prove to be invasive, in which case they could pose a risk to the ecological integrity of nearby natural systems.

Maples dominate Oakville's urban forest, partly due to their use as planted, cultivated trees, but also because of forests and woodlots naturally dominated by sugar maple (*Acer saccharum*). While it is desirable to maintain these maple-dominated forests as parts of Oakville's ecological heritage, it is also important to be mindful of the risk entailed in having a single species or genus dominate a geographic area or land use classification. Sugar maple accounts for more than a quarter of the leaf area in Woodlots, while Norway maple dominates the leaf area of Residential and Employment land uses. Norway maple is also a dominant species among the street tree population. In the event of an invasive pest introduction, such as Asian longhorned beetle, which attacks a range of broadleaf trees but has a preference for maples, species distributions with a lack of diversity could lead to widespread damage and tree loss, with many harmful consequences.

In order to minimize canopy loss, Santamour (1990) recommends a standard of urban forest diversity that has become known as the 10-20-30 approach. According to this standard, an urban forest should be composed of no more than 10 percent of any single species, no more than 20 percent of any single genus, and no more than 30 percent of any single family. As natural forests and woodlots do not conform to this sort of distribution, this standard is primarily relevant to the diversity of cultivated trees.

For the most part, an assessment of the street tree population indicates that Oakville's streets largely conform to the 10-20-30 standard. None of the top

Figure 21: Top five families represented in Oakville's street tree population.



five families represented in Oakville's street tree population exceed the recommended diversity limits put forward by Santamour (Figure 21).

Of the top ten genera represented in Oakville's street trees (Figure 22), the maples (*Acer* spp.) exceed the recommended limit of 20% of the population. Comprising about 25% of the street tree population, maples are by far the most abundant genus of street trees in Oakville. Of the ten most abundant species in Oakville's street tree population (Figure 23), Norway maple (*Acer platanoides*) and northern white cedar (*Thuja occidentalis*) both exceed the recommended species population limit of 10%. The prevalence of northern white cedar is likely due to the extensive use of this species as hedging along private property boundaries, which effectively encroaches on the municipal right of way. The high population of Norway maple likely represents the legacy of past urban forest practices. While it remains well-suited to urban conditions, Norway maple's over-use and its potential invasiveness make it less desirable as planting stock in the present day.

Age class diversity is also an important factor in urban forest health. A community whose urban forest has a significant contingent of healthy, mature, large-diameter trees will reap the environmental benefits generated by those trees. However, it is also important to ensure that healthy, younger, small and medium diameter trees are sufficiently distributed so that there are enough young trees to take the place of the more mature ones when those trees eventually die, and to expand the urban forest canopy over time.

In the 2005 report *Oakville's Urban Forest: Our Solution to Our Pollution*, Oakville's forestry staff expressed a desire to set a tree population goal of 10% for large-diameter trees (those measuring over 76 cm DBH). Given that only 0.6% of the current urban forest population falls within that diameter range and 3.5% of its street trees measure 62 cm DBH and up, it seems more reasonable to confine this 10% population target to large-diameter street trees (measuring 62 cm DBH and up), rather than the urban forest as a whole. Reaching this goal will take time and will be dependent on the consistent application of routine street tree maintenance and tree protection to ensure the necessary component of the existing street tree population matures into healthy large-diameter trees.

Figure 22: Top ten genera represented in Oakville's street tree population.

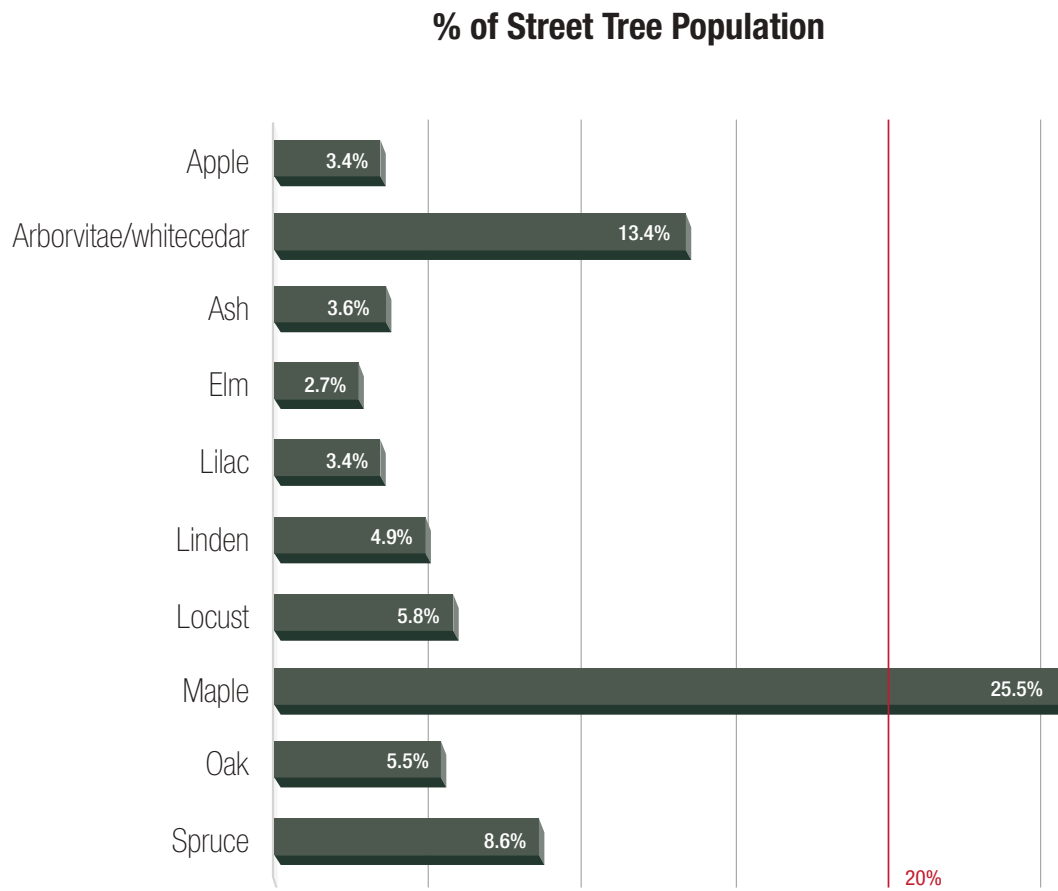
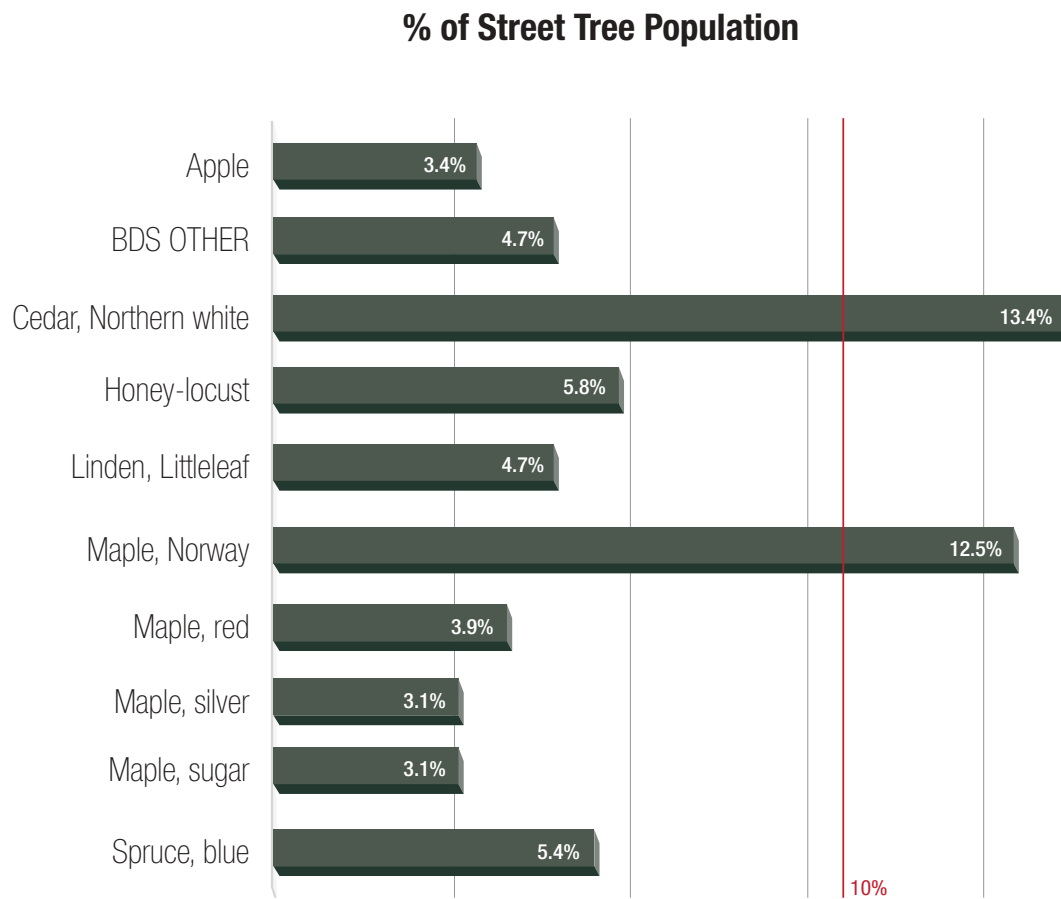


Figure 23: Top ten species represented in Oakville's street tree population.



5.2 – Invasive Species

Human activity has transported exotic species into ecosystems where some of those species are able to thrive with virtually no competition or predation. These invasive species of flora and fauna represent significant ecological threats and management challenges all over the globe. Oakville's experiences with invasive species are fairly typical of southern Ontario, but are nonetheless daunting challenges to overcome. Potential introductions of new invasive species threaten to cause great damage to Oakville's urban forest resource, but there are many strategies available that may assist in preventing or minimizing negative outcomes.



Figure 24: An Oakville woodlot with a declining ash canopy and heavy European buckthorn invasion in the understory.

5.2.1 – European buckthorn

European buckthorn populations have risen dramatically since the 2005 UFORE study. According to the results of the 2015 i-Tree Eco study, this species is now the third most abundant species of tree in Oakville, having increased from about 2% of stems in 2005 to 10.6% of stems in 2015.

The increased abundance of European buckthorn, a highly invasive shrubby tree native to Europe and Asia, represents a long-term management issue for the Town, as this species spreads rapidly and is difficult to control. There is some evidence to suggest that the spread of European buckthorn and other invasive plants has been assisted by the presence of earthworms, all of which are invasive in Ontario, in Oakville's woodlots. By changing soil characteristics, earthworms enable the spread of invasive species, while the presence of those species further alters the soil and makes it inhospitable for native plant growth (Frèlich *et al.*, 2006; Heneghan *et al.*, 2004; Knight *et al.*, 2007; Nuzzo *et al.*, 2009).

European buckthorn's impact is largely confined to woodlots and natural areas – in many ways the most significant component of Oakville's urban forest. That impact threatens the viability of that important resource and its attendant benefits. If European buckthorn continues to expand its population and distribution at the expense of native trees, Oakville's future urban woodlands could be characterized by understories dominated by European buckthorn and a gradually declining canopy of native trees. Over time, this will likely result in decreased overall species diversity, poor wildlife habitat, and unattractive aesthetics. The expansion of European buckthorn would likely also reduce the environmental services provided by Oakville's urban forest over time. While European buckthorn is abundant, its small size contributes relatively fewer environmental services than larger trees, which are capable of storing more carbon and intercepting more stormwater.

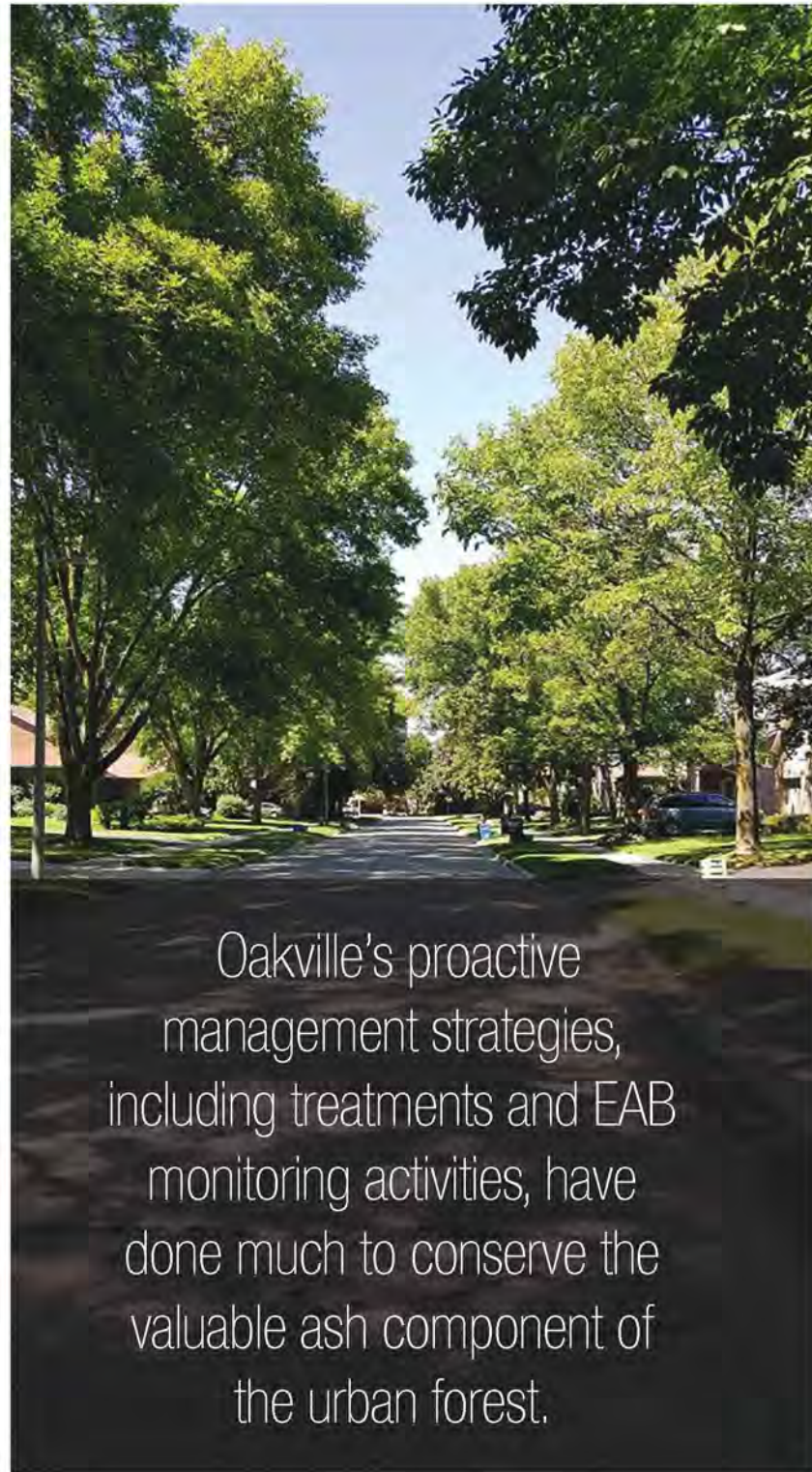
The Town of Oakville has conducted prescribed burns in small areas of Iroquois Shoreline Woods, in an effort to reduce European buckthorn in native oak habitat.²⁹ This and other strategies, such as removals and targeted applications of herbicides, may be necessary as components of a buckthorn management plan to reduce European buckthorn populations, where Town resources allow.

5.2.2 – Invasive Insects

Emerald ash borer (EAB, *Agrilus planipennis*) has infested and killed ash trees (*Fraxinus* spp.) across the Town since it was first detected in Oakville in 2008 and it is likely that EAB will continue to be a management issue for years to come. Oakville's proactive management strategies, including treatments and EAB monitoring activities, have done much to conserve the valuable ash component of the urban forest.

Asian longhorned beetle (ALB, *Anoplophora glabripennis*) has yet to be detected in Oakville, but it has appeared in nearby areas, making it a very real threat to Oakville's urban forest. This species was detected in Vaughan, ON, in 2003 and was declared eradicated in 2013, following a successful quarantine program. However, it was detected again in 2013 in Mississauga, near Toronto's Pearson International Airport, prompting the Canadian Food Inspection Agency (CFIA) to implement another quarantine program. Oakville's Urban Forest Health Monitoring Program

conducts detection surveys for this insect in Oakville. Trees that make up approximately 42% of the Town's leaf area are susceptible to infestation by ALB, which attacks a wide range of species, including birch (*Betula* spp.), poplar (*Populus* spp.), and willow (*Salix* spp.), with a preference for maple (*Acer* spp.). More than half of the amount of Oakville's leaf area that is susceptible to ALB is composed of the top three species of maple (sugar maple, Norway maple, and silver maple – amounting to about 27.6% of the total leaf area in Oakville).



Oakville's proactive management strategies, including treatments and EAB monitoring activities, have done much to conserve the valuable ash component of the urban forest.

²⁹ <http://www.oakville.ca/residents/prescribed-burn.html>

5.3 – Climate Change

Considering the array of benefits provided by Oakville's urban forest, it stands as a great asset in view of the predicted effects of climate change. However, those same effects also threaten to degrade and damage Oakville's urban forest resources. Urban forest planning that thoroughly accounts for urban forests' role in climate change, and the many uncertainties that accompany it, will help to insure the viability of the resource into the future.

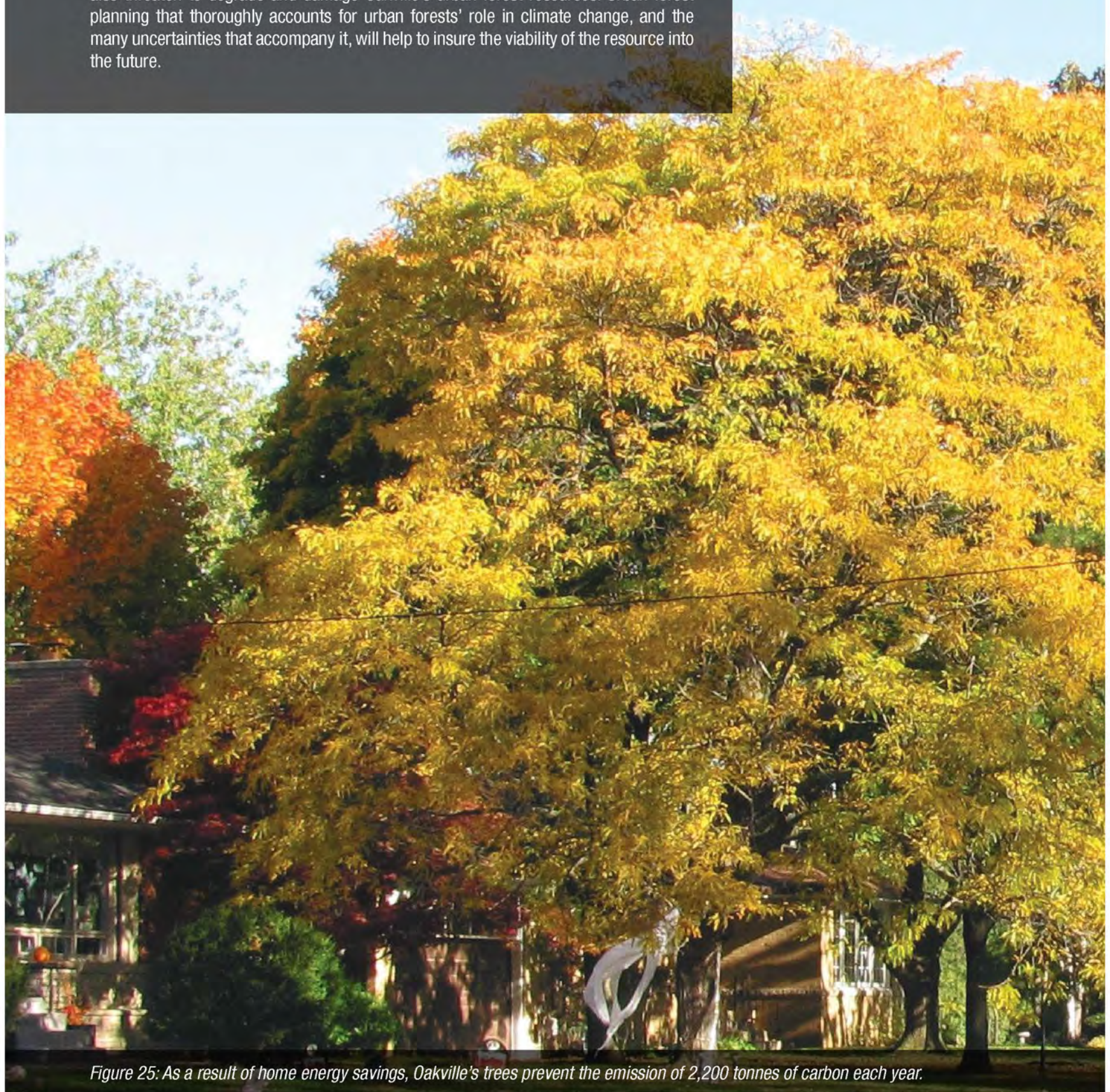
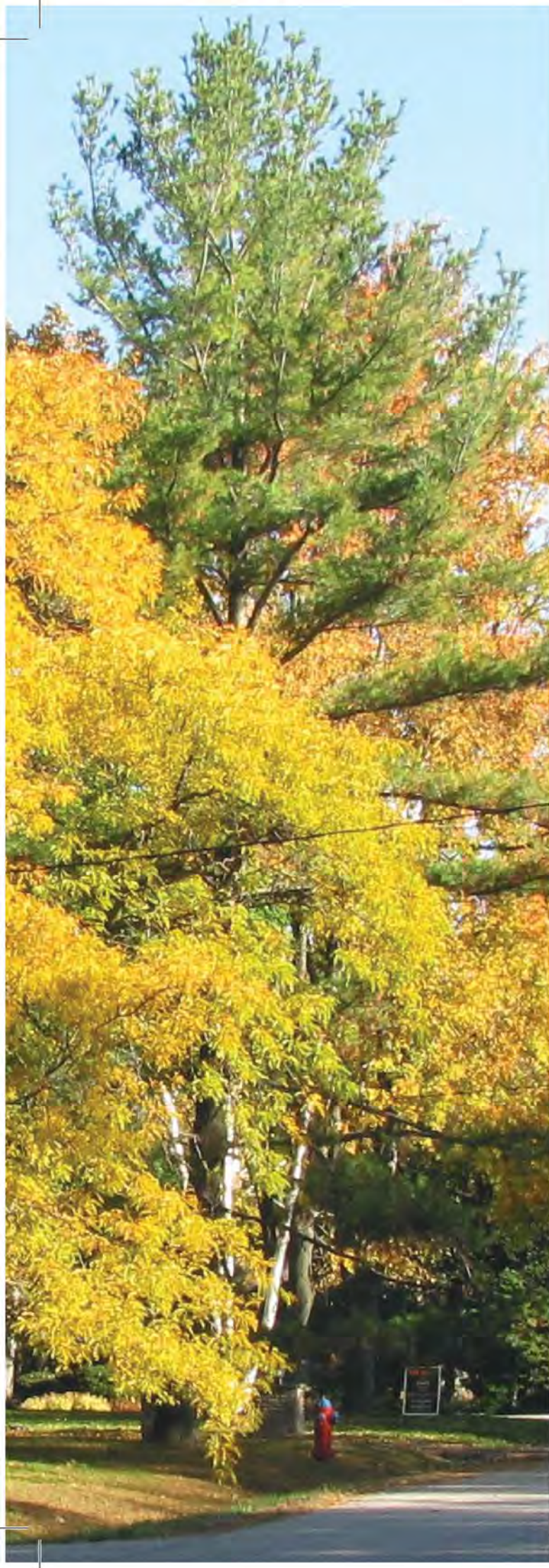


Figure 25: As a result of home energy savings, Oakville's trees prevent the emission of 2,200 tonnes of carbon each year.



5.3.1 – Carbon and Pollution Mitigation

The urban forest's role in relation to climate change produces significant benefits that are derived from its natural functioning (Nowak *et al.* 2013). When properly placed, trees assist in the reduction of carbon emissions by contributing to building energy savings. Oakville's urban forest currently prevents 2,200 tonnes of carbon emissions each year, as a result of residential building energy use savings. An increase in large stature trees in residential areas would enhance this capacity, as tree growth and expansion of the leaf area would provide more shade and buffering against the climatic factors that drive home energy consumption. By reducing home energy consumption, trees effectively reduce not only carbon emissions, but also pollution emissions that contribute to human health problems, and may also reduce incidents of heat stress (Rosenzweig *et al.* 2009, Solecki *et al.* 2005).

Oakville's trees sequester enough carbon in a year (5,940 tonnes) to equal the annual emissions of 3,900 automobiles, or 2,000 single-family homes. The amount of carbon currently stored by Oakville's trees equals about 148,000 tonnes, which represents an increase of 15,000 tonnes of carbon stored since 2005. The capacity of the urban forest to perform these services is contingent on the overall health and structural characteristics of its trees.

5.3.2 – Impacts of Climate Change on the Urban Forest

It is important to note the role that diseases and pests play and the potential for these processes to have a negative effect on the ability of the urban forest to deliver environmental services. Even slight increases in temperature during the growing seasons could lead to drought stress, particularly when magnified by the urban heat island effect, thus weakening trees' defenses against invading pathogens and pests (Arnfield, 2003; Dale *et al.*, 2001). Trees may be at even greater risk of further damage from other stresses and structural injuries, with some species being less tolerant of stress than others.

Another anticipated effect of climate change is an increase in the frequency and severity of storm events. Such events could cause significant structural damage to the urban forest in a relatively short period of time, leading to a reduction in the ecological services provided by trees and an increase in clean-up costs for the municipality and private citizens. The ice storm of December, 2013, which caused extensive damage in southern Ontario, stands as the most recent example of such an event. Approximately 11,000 Town-owned trees were damaged in Oakville during this event, about 1,100 of which had to be removed due to the severity of damage.³⁰

While Oakville's tree maintenance program accounts for the need to maintain trees to mitigate storm damage,³¹ the results of the i-Tree Storm project speak to the need for resource preparedness. Developing an action plan for post-storm surveys would maximize efficiency, cost-effectiveness, communications, and public safety in the event of large-scale storm damage to urban trees.

Furthermore, the i-Tree Hydro analysis demonstrated that changes in urban forest cover and impervious ground cover can influence local hydrology. Most importantly, this analysis shows that an increase in impervious ground cover will result in increases in overland stream flow, and the effect is compounded by losses in tree cover. Over time, this can place added stress on municipal grey infrastructure and result in higher costs to municipalities.

³⁰ Forestry Section, Parks and Open Space Department, Town of Oakville

³¹ <http://www.oakville.ca/residents/trees-maintenance.html>

5.4 – The Effects of Tree Mortality on Canopy Levels

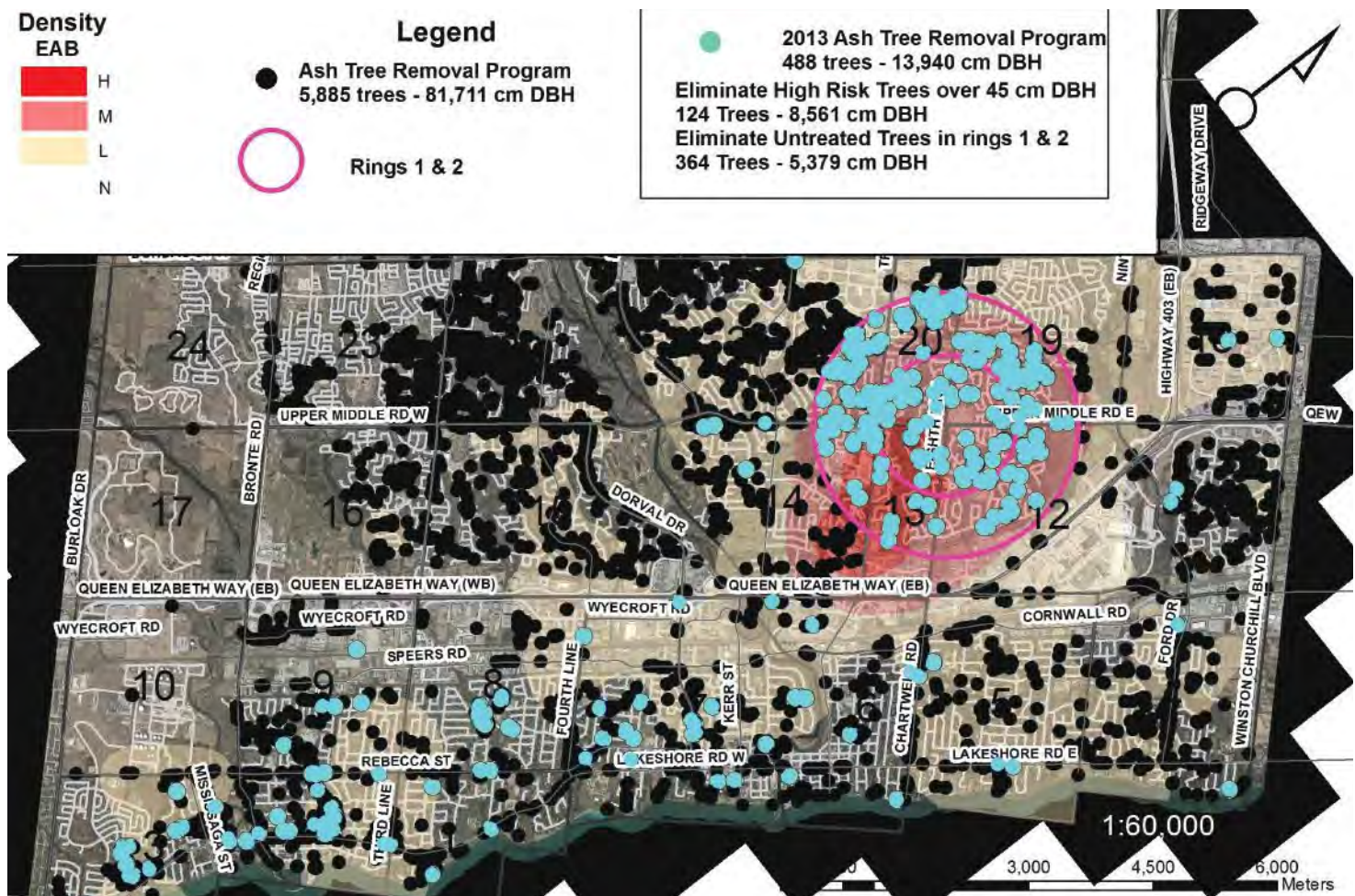
Despite the emphasis on city tree planting in recent decades, studies have found that overall canopy cover levels in major US cities have been declining (Nowak and Greenfield, 2012). Planting trees is not the most important factor influencing the growth or decline of urban forest canopy levels. Tree planting must be accompanied by measures to protect the existing urban forest and quantitative data that allows for action based on an informed view of the factors that are influencing change in the urban forest. Understanding how to achieve urban canopy targets ultimately requires a much better understanding of tree mortality and growth rates. However, little is known about actual mortality rates in urban forests. The importance and difficulty of predicting mortality rates are particularly critical when considering the potential impacts of climate change. These impacts can include effects from extreme weather events (e.g., ice storm, prolonged drought) and increased activity of invasive insect and other pests. As a result of the statistical change analysis performed using the 2005 UFORE and 2015 i-Tree Eco findings, Oakville's average annual tree mortality rate was calculated as 5.3%. As discussed below, there are multiple factors influencing tree mortality.

5.4.1 – The Impact of Emerald Ash Borer

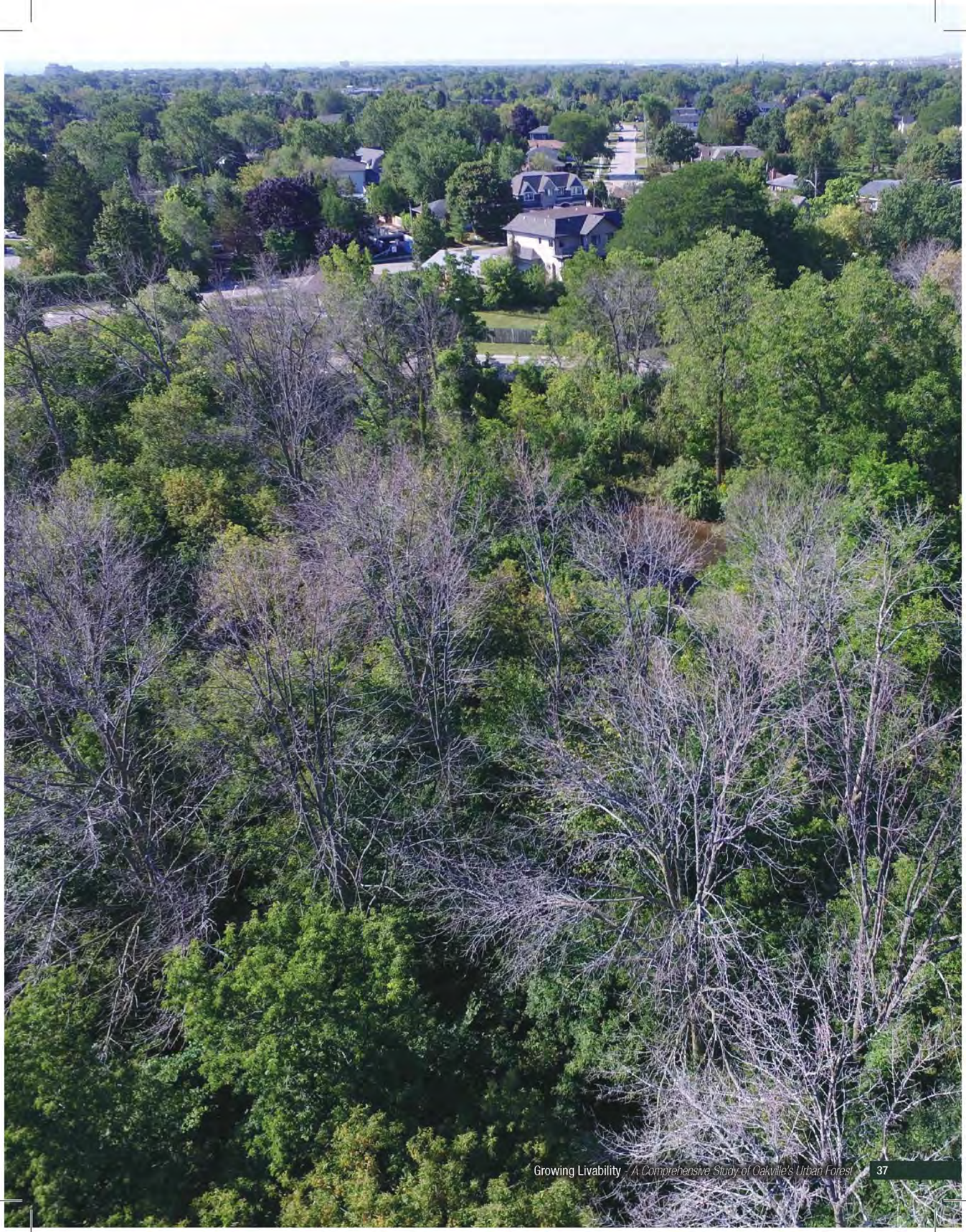
Approximately 7,150 ash trees killed or damaged by emerald ash borer (EAB) were removed by Oakville staff from 2011-2015, representing 0.4% percent of the town's total number of trees.³² Depending on the size of the trees removed and taking into consideration the impacts to the crown health/extent of the Town's ash population, the overall impact on tree canopy loss is likely considerably more than 0.4%. For example, ash trees in woodlots that were killed by EAB may have been left on site, unless they posed a hazard to the public, and not recorded in the above tally. Ash trees in Oakville's woodlots that have been eliminated, primarily by EAB, account for about 68% of the ash that was lost in Oakville's urban forest from 2005 to 2015.

Nevertheless, a comparison of Figure 26 with Figure 18 indicates that Oakville's urban forest canopy is increasing despite EAB-related tree mortality. LUA East experienced a decline and, although it is adjacent to areas with the most EAB-related tree removals, there are likely several reasons for the decline in that Land Use Area, including EAB.

Figure 26: Oakville ash tree removal program map.



³² This figure is a combination of treated ash trees that failed and untreated ash trees.



5.4.2 – Development and Urban Forest Canopy

Property development can potentially have a positive or negative impact on tree mortality and urban forest canopy. Development may result in deforestation, if conducted in areas where there is existing tree cover that is subsequently removed and replaced by impervious cover or turf. Development may also result in an increase in tree cover, if it is conducted in areas with little to no tree cover (ex. agricultural lands) and new trees are planted after development.

While an increase in building footprint as a result of development would reduce the amount of land area available for planting, Oakville requires a landscape plan and a canopy coverage plan as a component of the site plan approval process, which can help to mitigate impacts on the urban forest. However, site plan approval is not required for all forms of construction, such as in some low-density residential areas, except under certain conditions. In these areas, construction occurs through the building permit process. There is currently no formal process in place to make the link between building permit applications and the potential effects of development and building on Oakville's urban forest. More research is needed to determine the extent to which building and development may have an impact on changes to ground cover and tree mortality rates.

The percentage of impervious ground cover is relevant to tree canopy in Oakville as it affects several aspects of forest and watershed health. An increase in impervious ground cover has several negative impacts, as supported by the results of the i-Tree Hydro analysis (Section 4.1.4). An increase in impervious ground cover is related to increases in storm water runoff, while simultaneously reducing high quality, low cost plantable space for trees that could help mitigate the increase in runoff. Construction of new impervious area may also reduce existing canopy through tree removal.

The results of the i-Tree Eco study (Section 4.1.1) and the urban forest canopy assessment (Section 4.2) indicate that impervious cover has increased in Oakville since 2005. Currently, Oakville does not formally track changes in ground cover types across the municipality. As a result, there is no formal mechanism to track the effect of increases in impervious surfaces to potential reductions in tree canopy (e.g. tree removal to construct new parking lots). Projecting forward, Oakville can expect to see further increases in impervious ground cover unless aggressive solutions are implemented. This is a complex issue to resolve as the more impervious ground cover increases, the more trees are required to help mitigate the effects. Investments into engineered planting solutions and more aggressive integration of trees into impervious landscapes would help to address this issue. The ability to track the effect of development on urban forest cover would allow Oakville to gain greater insight into the extent to which development is having an effect on its urban forest.

5.4.3 – Tree Protection³³

Tree protection measures are an important means for a municipality to exert some control over the conservation of its urban forest. By regulating the removal of trees, tree protection by-laws can reduce rates of urban forest canopy loss, when they are effectively implemented. Oakville enacted its Private Tree Protection by-law (2008-156) in 2008 in order to support tree conservation on private property. This by-law regulates the removal of trees on private property between 20 and 76 cm DBH, excluding trees that are regulated by development approval processes, such as Building Permits and Site Plans. The Private Tree Protection by-law requires Oakville residents to obtain a permit to remove trees greater than 76 cm DBH, or to remove five or more trees between 20 and 76 cm DBH in a calendar year.

Table 9: Trees Removed and Replanted Under Oakville's Tree Removal Permit System.

Permit Applications	2011	2012	2013	2014	2015
Trees Removed	14	27	18	11	15
Trees Planted	52	27	18	22	27

Most tree removal permits are approved by Oakville Parks and Open Space on the condition that residents either replant trees on their property or provide funds to plant replacement trees elsewhere in the Town. Table 9 shows the number of trees removed as a result of Oakville's tree permit system from 2011 to 2015. In each year, the number of trees removed is met or exceeded by the number of trees planted to replace the removals.³⁴

Up to four private trees (20-76 cm DBH) may be removed in a calendar year by filing a notification with either Oakville's Forestry Section, Parks and Open Space Department, or Development Engineering Department. These removals do not require the planting of replacement trees. **Since 2012, a total of 4,633 private trees have been removed through tree removal notification forms submitted to Oakville's Forestry Section and Development Engineering Department. Of these, 3,556 trees were removed through non-development related processes in the Forestry Section, and 1,077 were removed through development related processes in the Development Engineering Department (Table 10). These numbers suggest that Oakville's citizens are removing more trees and thus are having a greater impact on its urban forest than development.**

³³ Data pertaining to tree protection was provided by Forestry Section, Parks and Open Space Department, Town of Oakville.

³⁴ Note that all figures pertaining to removed trees in Oakville exclude all hazardous and dead trees, and trees affected by EAB.

Table 10: Trees and Urban Forest Cover (m²) Removed by Tree Removal Notifications through Oakville's Departments of Forestry and Development Engineering, 2012-2015.

	2012	2013	2014	2015	Total
Forestry trees removed	907	863	952	834	3,556
Forestry m ² removed	41,442	39,754	45,727	40,773	167,696
Dev. & Eng. trees removed	236	280	335	226	1,077
Dev. & Eng. m ² removed	11,319	14,361	16,145	12,931	54,216
				Trees Removed	4,633
				Total m² Removed	222,989

Of the private trees removed through the Forestry department from 2012 to 2015, 65% have been in the 20-40 cm DBH size class (Table 11). While larger trees deliver more environmental services on a per-tree basis, removed trees in the 20-40 cm DBH class have effectively been prevented from delivering environmental services over the remainder of their life span. Furthermore, those trees have been removed without any compensation to the Town's urban forest, as no replanting was required.

Table 11: Trees Removed Through Removal Notifications and Approved Removal Permits via Oakville's Forestry Department, 2012-2015.

Category	Tree Classification	Total
1	Removed Trees 20-40 cm	2,303
2	Removed Trees 41-60 cm	914
3	Removed Trees 61-75 cm	264
4	Granted Removal Permits 76 cm+	75
	Total	3,556

Public trees, located on municipal property, are also protected by several by-laws:

- **By-law 2009-025** as amended authorizes and regulates the planting, care, maintenance and removal of trees on town property and ensures the sustainability of the urban forest

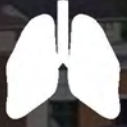
- **By-law 2003-021** as amended regulates site alterations within the town
- **By-law 1999-159** as amended prescribes rules and regulations for parks within the town

Several policies also protect trees during construction projects, when they may be vulnerable to damage by various types of equipment and activities. For example, Policy EN-TRE-001 enables the establishment of procedures to prevent damage or destruction of trees, provide for replacement of trees and optimize planting provisions and tree health for future arboricultural activities within the Town. Trees must also be protected during construction and developers are required to follow certain guidelines to this end.

Given the constraints placed on private property owners, it is apparent that Oakville's tree by-laws have prevented the loss of some of the Town's urban forest. However, a review of the Private Tree Protection by-law promises to deliver even greater protective measures for Oakville's trees. The revised Private Tree Protection by-law will be presented to Oakville Town Council in 2016, having been presented to the public through workshops and public consultations. It proposes to lower the DBH size of regulated trees from 20 cm to 15 cm.

In addition to the factors described above, changes in urban forest canopy may be influenced by storm events, survival rates of newly planted trees, and the effects of various biotic and abiotic agents (other than emerald ash borer, Asian longhorned beetle, and storm events). The implementation of a comprehensive tree mortality study would assist the Town of Oakville in identifying the primary drivers behind tree mortality that may be impeding more rapid expansion of urban forest canopy.

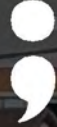
Access to urban greenspace has been linked to:



**Lower
asthma rates**



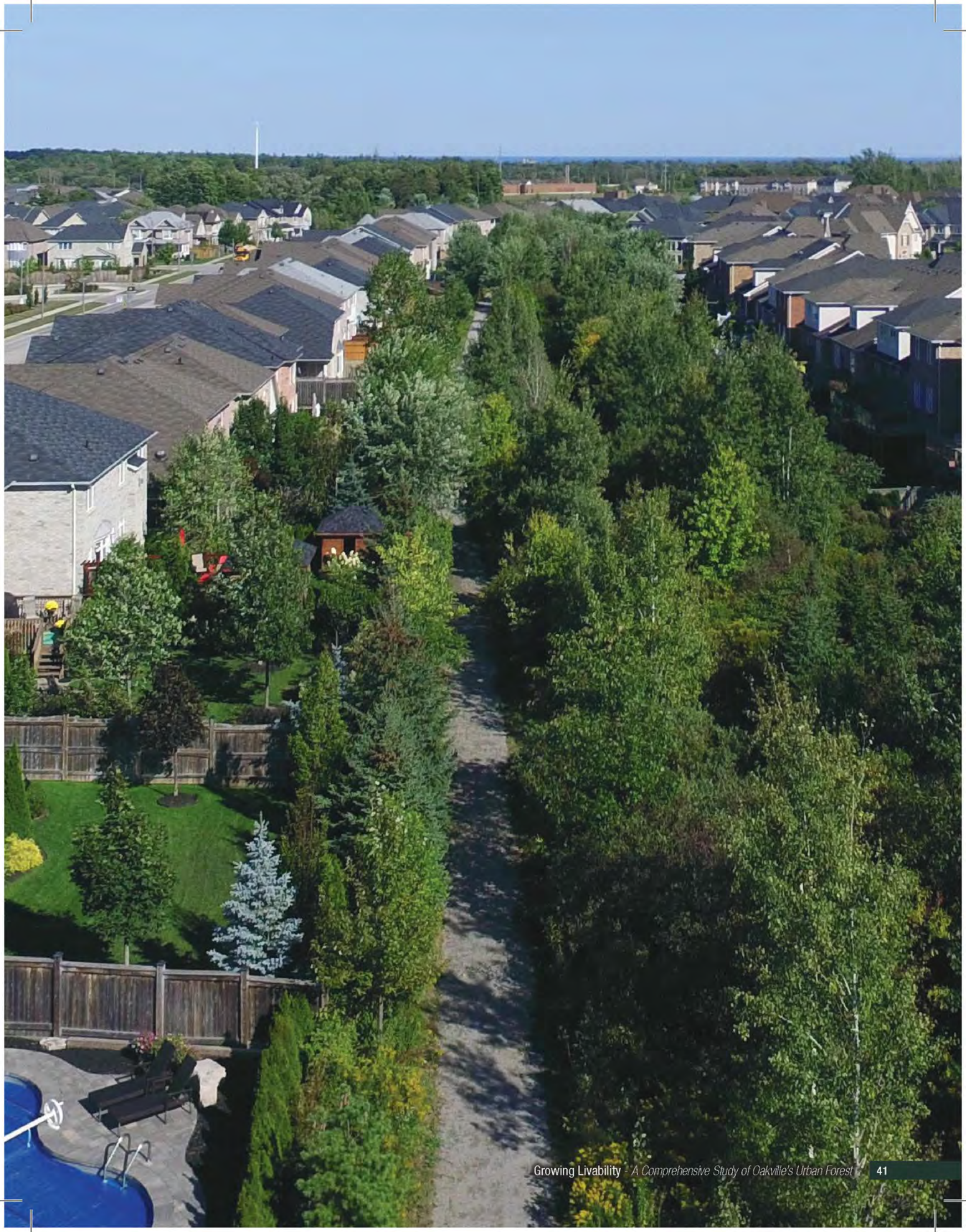
**Decreased
blood pressure**



**Sustained mental
health benefits**



**Stress
relief**



In addition to the value of the environmental, aesthetic, and other benefits provided by Oakville's urban forest, its structural value of \$1.04 billion represents a significant asset for the Town of Oakville and its residents.

5.5.1 – Understanding the Value of Oakville's Urban Forest

Given the many benefits provided by urban forests – some with financial value, others seemingly invaluable – it is in the best interests of all of Oakville's citizens to continue to invest in and conserve the Town's urban forest. Research continues to uncover connections between access to urban greenspace and improvements in physical and mental health, including lower asthma rates (Lovasi *et al.* 2008), sustained mental health improvements (Alcock *et al.* 2013), decreased blood pressure (Tsunetsugu *et al.* 2013), and stress relief (Tyrväinen *et al.* 2014). In short, the urban forest has a direct and powerful influence on the livability of neighbourhoods and communities.

By extension, a loss of urban forest cover can have negative effects on human well-being. A study by Donovan *et al.* (2015) found a correlation between tree loss in U.S. Midwestern counties infested with emerald ash borer and increased rates of mortality due to cardiovascular and lower-respiratory illness in post-menopausal women. Although emerald ash borer has contributed to some tree loss in Oakville, the Town's high standard of urban forest stewardship and its official commitment to increasing its tree canopy indicate that a long-term reduction in the Town's tree canopy due to EAB damage is unlikely.

While the Oakville i-Tree study does not have the ability to quantify the direct human health impacts of the urban forest, it is reasonable to conclude that the health and well-being of Oakville's residents is linked to some degree with the health and well-being of the Town's urban forest. Additional investments in Oakville's urban forest may assist in improving residents' health and quality of life and, conversely, may also help to prevent declines in health and quality of life, and avoid additional costs to the health care system.

In addition to the value of the environmental, aesthetic, and other benefits provided by Oakville's urban forest, its structural value of \$1.04 billion represents a significant asset for the Town of Oakville and its residents. However, this value and the value of the potential cost savings arising from reductions in health problems (due to urban forest benefits) are not readily accounted for using conventional means of asset reporting. As such, it may be difficult for forest

managers to justify additional costs for urban forest management. An understanding and recognition of the true value of Oakville's urban forest is integral to the development and implementation of future plans for the Town and its residents.

5.5.2 – Actions to Enhance the Urban Forest

It is imperative that the private sector and the public at large play an even greater role in efforts to expand Oakville's urban forest canopy. As the results of the i-Tree Streets analysis demonstrated (Section 4.1.3), the Town's street trees are near the maximum stocking level, which affords little opportunity to expand urban forest cover on the Town's streets. Private property owners therefore represent a significant influence on future urban forest outcomes. Barriers to success in increasing private tree planting may include lack of suitable planting space on some properties and lack of interest on the part of some landowners, who may be unwilling to bear the cost of tree planting and maintenance.

It is therefore important to publicly convey the message that trees provide economic and ecological benefits. Residential property owners have a particularly significant influence on the urban forest. As reported in the 2015 urban forest canopy study (Section 4.2), residential properties account for 1,300 hectares of possible plantable area, or about 41% of the total possible plantable area in Oakville. Where planting trees is impractical, other forms of green infrastructure may be more suitable, such as green roofs, rain gardens, and shrubs. Tree protection, such as Oakville's Private Tree Protection by-law, is a vital component of urban forest canopy expansion, as it exerts some control over the loss of existing urban forest canopy.

The creation of a **tree planting incentive program for private properties** may provide additional assistance in expanding tree cover on employment, commercial, and residential properties, and allow the Town of Oakville to make additional strides toward realizing its canopy goal of 40%. A targeted approach to addressing deficits of urban forest cover in specific areas of Oakville will help to ensure a more equitable distribution of urban forest and access to the benefits it provides. Other key priorities that may be addressed by urban forest canopy expansion include:

- Improving sustainability and minimizing the Town's ecological footprint
- Achieving sustainable building and community design
- Preserving, enhancing and protecting the Town's environmental features, natural heritage systems, and waterfronts

Periodic re-assessments of its urban forest will also allow Oakville to keep abreast of the changing conditions of its urban forest and address priority issues in a timely manner. These re-assessments should include analyses of urban forest cover and the use of a full suite of urban forest assessment tools, such as i-Tree, in periods of up to ten years. In order to ensure that the findings of such analyses are addressed in the execution of Oakville's Urban Forest Strategic Management Plan (UFSMP), it would be advantageous to integrate the findings and recommendations of this and future studies into periodic reviews of the UFSMP.

The results of the 2015 Oakville urban forest study demonstrate that Oakville's urban forest is a growing asset that continues to provide vital benefits to the community. The 2015 i-Tree Eco study found that the structural value of Oakville's urban forest is currently \$1.04 billion and its population has grown to about 2 million trees. Additionally, Oakville's urban forest delivers annual environmental services valued at approximately \$2.9 million. Oakville's urban forest stores more carbon than it did in 2005, while annual carbon sequestration rates are approximately the same as in 2005. Pollution removal rates appear to have decreased slightly, but monitoring of pollutants may be affected by several factors, including wind and weather, and changes in emission levels, which can in turn affect the estimates produced by i-Tree Eco. The rapid expansion of European buckthorn, particularly in Oakville's woodlots, was identified as a major management challenge for the Town.

Oakville's street tree population, while only about 5% of the total tree population, represents a significant asset, with a total replacement value of approximately \$201.6 million and an annual delivery of services worth about \$11.9 million. A pre-storm survey using i-Tree Storm protocols estimates that a severe storm could inflict damages to Oakville's urban forest with an estimated recovery cost of about \$7 million. An i-Tree Hydro analysis modeled the increase in stream flow during storm events that would be caused by an increase in impervious ground cover and a loss of urban forest cover in the East Sixteen Mile Creek watershed. An urban forest canopy analysis revealed that Oakville's urban forest canopy has expanded, despite the impacts of emerald ash borer, ice storms, and various other causes of tree mortality. Urban forest currently covers about

27.8% of the Town, an increase of approximately 1.3% since 2005, and up to 50% of land in the Town of Oakville is potentially available for the establishment of additional urban forest canopy.

The public is particularly influential in determining the course of Oakville's future urban forest. An examination of tree removal notifications submitted to the Town of Oakville suggests that Oakville's residents are responsible for higher rates of tree loss than from urban development. In order to expand Oakville's canopy cover, the participation of the public must be harnessed to an even greater degree than it is at present. The long-term viability of Oakville's urban forest will depend on the combined efforts of a diverse set of stakeholders who must be aligned with the singular goal of improving Oakville's livability by enhancing its urban forest resource. In order to achieve a canopy cover goal of 40% and conserve a healthy urban forest for Oakville's future, the Town must address numerous challenges and barriers.

Significant expansion of Oakville's urban forest may be achieved through extensive cooperation between the Town, the public, and private enterprise. Urban forest management strategies aimed at enhancing structural diversity and ecological resilience will build upon the important work done so far. Ongoing assessments of the Town's urban forest will assist in reaching these goals by providing vital data to track success. The urban forest will play an invaluable role in growing a more livable Oakville, providing investment in this resource is sufficient to ensure its vitality into the future.

7 | Recommendations



Summary

- Recommendations are based on the implications of the findings generated from the i-Tree Suite, the Urban Forest Canopy Analysis, and an analysis of planning in the Town of Oakville.
- Recommendations focus on several key areas:
 - **Communication:** Building & strengthening partnerships across departments and sectors
 - **Management:** Enhancing and adapting management practices to address pertinent issues, like invasive species and enhancing urban forest health
 - **Planning:** Developing tools for improved procedures and supporting urban forest management with current, high-quality data
 - **Planting:** Re-evaluate and refine planting strategies to maximize the ecological services of Town-owned trees

Communication

Recommendation: The Town of Oakville should consider developing an outreach program to local businesses, promoting the benefits of tree planting and maintenance, with a view to increasing urban forest canopy cover on properties in the Commercial and Employment land use classifications.

Recommendation: The Town of Oakville should consider investigating the feasibility of establishing incentive programs to encourage tree planting on private property.

Recommendation: The Town of Oakville should consider investigating the feasibility of establishing an incentive program to encourage green roof installation on private property, with a focus on employment and commercial properties with restricted plantable space.

Recommendation: The Town of Oakville should relate tree planting efforts to greater Town-wide initiatives and priorities, such as achieving sustainable community design and minimizing the Town's ecological footprint.

Management

Recommendation: Continue to maintain high percentages of trees in good condition and low percentages of trees in poor condition or dead/dying, through routine maintenance pruning, hazard pruning as required, and removing dying or dead trees in a timely manner. It is recommended that the Town implement a routine preventive pruning cycle to achieve this objective.

Recommendation: The Town of Oakville should continue to invest in the protection of its street ash trees in order to prevent significant reductions to environmental benefits.

Recommendation: The Town of Oakville should establish internal street tree size diversity targets and plant large-stature trees that have the potential to become large-diameter trees and reach the size of 62 cm DBH and up.



Recommendation: In order to prevent the continued expansion of European buckthorn at the expense of native large-stature trees and native forest ecosystems, the Town of Oakville should devise and implement a targeted European buckthorn management strategy that includes a variety of treatments, including, but not limited to, prescribed burns, plant removal, and herbicide applications.

Planning

Recommendation: The Town of Oakville should devise and implement a scheduled process for updating its street tree inventory and strengthen the QA/QC policies related to street tree data collection.

Recommendation: The Town of Oakville should continue to conduct annual monitoring activities of active and potential pests in order to prevent large-scale damage to Oakville's urban forest.

Recommendation: Given the impacts of tree mortality on canopy growth in Oakville, the Town should consider implementing a study to ensure a better understanding of the causes contributing to tree mortality.

Recommendation: The Town of Oakville should consider adopting a canopy growth tool to address priority planting areas and assist in its efforts to expand urban forest cover.

Recommendation: The Town of Oakville should consider developing an action plan for post-storm surveys. This plan should include a process chart that clearly outlines individual responsibilities for initiating a post-storm survey, coordinating with utility officials, establishing communication methods, data collection and transfer, and safety measures.

Recommendation: The Town of Oakville should conduct periodic re-assessments of its urban forest, employing a full suite of assessment tools, such as i-Tree, and an urban forest canopy analysis, using LiDAR, if available, aiming for 95% overall accuracy. Re-assessments should take place in cycles of up to 10 years.

Recommendation: The Town of Oakville should integrate the findings and recommendations of this study and future assessments into the periodic reviews included in the Urban Forest Strategic Management Plan.

Planting

Recommendation: The Town of Oakville should review its approach to street tree species selection and devise a planting strategy to reduce the dominance of specific genera and species in the street tree population. Special attention should be given to reducing the dominance of maples overall, particularly the relative population of Norway maple.

Recommendation: The Town of Oakville should maintain high stocking levels by continuing to replace every tree removal where site conditions permit, as outlined in the Town's Official Plan.

Recommendation: Discontinue planting hawthorn as a street tree species. It is not a good performer in Oakville, and the sharp thorns on its branches make it ill-suited to public spaces.

Recommendation: Gradually replace American elms, which are susceptible to Dutch Elm Disease (DED), with other species and varieties of elm that are resilient to DED such as Accolade, Liberty, and Triumph elm.

Recommendation: Due to high-performance and currently low numbers, the Town of Oakville should consider increasing the number of the following species in the street tree planting program: London planetree, European beech, and eastern hophornbeam in sites that will accommodate large- and medium-stature trees. For sites that require smaller stature trees, common lilac and dogwood species should receive increased attention.

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9 | Additional Resources

i-Tree Official Website: www.itreetools.org

i-Tree Eco: <https://www.itreetools.org/eco/index.php>

- **i-Tree Eco Manual (contains Methodology):**
https://www.itreetools.org/resources/manuals/Eco_Manual_v5.pdf

i-Tree Hydro: <https://www.itreetools.org/hydro/index.php>

- **i-Tree Hydro Manual (contains Methodology):**
https://www.itreetools.org/resources/manuals/Hydro_Manual_v5.pdf

i-Tree Storm: <https://www.itreetools.org/storm/index.php>

- **i-Tree Storm Manual (contains Methodology):**
<https://www.itreetools.org/resources/manuals/i-Tree%20Storm%20Users%20Manual.pdf>

i-Tree Streets: <https://www.itreetools.org/streets/index.php>

- **i-Tree Streets Manual (contains Methodology):**
https://www.itreetools.org/resources/manuals/Streets_Manual_v5.pdf

Oakville's Urban Forest: Our Solution to Our Pollution (2005 urban forest report):

<https://www.itreetools.org/resources/reports/Oakville's%20Urban%20Forest.pdf>

Town of Oakville, Trees & Woodlands:

<http://www.oakville.ca/residents/trees-woodlands.html>

10 | Glossary



Base flow – The water in a river that comes from groundwater.

Carbon sequestration – The removal and capture of atmospheric carbon from the air by trees.

Carbon storage – Carbon currently held in the woody tissue of trees, as a result of the carbon sequestration process.

DBH – Diameter at breast height, or 1.37 metres from the ground.

High-performing – A term used in i-Tree Streets to identify a species of street tree in the inventory data input into the Streets model that is characterized by a high proportion of trees in good condition, relative to that species' population.

Invasive – A characteristic of flora or fauna that describes their tendency to quickly proliferate and dominate a habitat or natural system by outcompeting resident species, leading to undesirable changes in an ecosystem. Not to be confused with “non-native,” which merely indicates that a species is living in a location that is outside of its natural range.

Leaf area – The sum of the surface area represented by living leaf tissue.

Leaf area density – The amount of leaf area per unit of land area (ex. Square meters of leaf area per hectare of land).

Plantable space – The area of ground space that is available for planting trees, where ground cover is suitable and where tree planting is not precluded by land use (ex. Baseball diamond).

Prescribed burn – A controlled surface fire in a natural area intended to stimulate the growth of fire-dependent native species and suppress the growth of competing and invasive species.

QA/QC – The combination of quality assurance and quality control.

Shrub – In accordance with i-Tree protocol, any woody plant species that measures less than 2.5 cm DBH is classified as a shrub.

Single-family house – A detached residential building, as opposed to a multi-unit residential building.

Standard error (SE) – A statistical term that indicates how accurately a sample represents the larger population from which it was taken. A high standard error indicates that the sample is less precise because it deviates more widely from the actual mean of the population compared to a low standard error, which approaches more accurately the actual mean of a population. In general, a larger sample size translates to a lower standard error.

Structural value of trees – The value represented by the estimated costs required to theoretically remove and replace trees. Excludes the value of ecological services provided by trees.

Tree – In accordance with i-Tree protocol, any woody plant species that measures at least 2.5 cm DBH is classified as a tree.

UFORE – Stands for Urban Forest Effects Model. This urban forest inventory protocol was developed by the United States Department of Agriculture Forest Service and is the precursor to i-Tree Eco, a component of the i-Tree suite of urban forest analysis and benefit assessment tools.

Urban forest – All the trees, shrubs, vegetation, and soil that exist in areas of settled human populations and their zones of influence. Provides habitat for associated insects, microbial life, and wildlife.

Urban forest canopy (UFC) – The amount of surface area when viewed from above that is covered by trees and/or shrubs; usually expressed as a percentage of total land area.

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Appendix 1: Land Use Classifications³⁵

Land Use	Definition	2005 Size (ha)	2015 Size (ha)	Change of Size
Agricultural	Open areas used for agricultural purposes	434.7	197	-57.3%
Commercial	Lands designated and developed for concentrations of retail and service commercial uses. Lands where residential, commercial, and office uses are integrated in a compact urban form at higher development densities.	439	533.6	+21.5%
Employment	Lands for industrial, business, and office activities, including limited areas of service commercial uses.	1669.7	1652.4	-0.01%
Open Space and Parkway	Community lands used for parks, trails, and recreational activity. Private lands used for recreational activity. Lands protected under or regulated by Provincial legislation.	1698.6	1462.2	-0.002%
Public Use	Infrastructure and lands serving health, educational, religious, recreational, or cultural facility needs.	214.5	193.3	-9.9%
Residential Class A (2005 classification: Residential Low Density)	Lands for housing with minimum front yard requirements of greater than 7.5 metres (primarily detached dwellings and apartment buildings on large lots).	1126	966.1	-14.2%
Residential Class B (2005 classification: Residential Medium Density)	Lands for housing with minimum front yard requirements equal to or greater than 3.0 metres and less than or equal to 7.5 metres (all housing forms).	3388.6	3491	+3%
Residential Class C (2005 classification: Residential High Density)	Lands for housing with minimum front yard requirements of less than 3.0 metres (primarily townhouse dwellings and detached dwellings on small lots).	2.8	1.1	-60.7%
Woodlots	Rivers, streams, forests, and natural areas	908.8	1408.1	+55%

The 2015 land use classifications and sizes are similar to the 2005 classifications. The most significant change within the study area is the disappearance of agricultural land. Over half of the agricultural lands remaining south of Dundas Street in 2005 have been or are in the process of being developed. The lands are now used primarily for residential purposes—primarily, Residential Class B—but with significant commercial, community use, and open space elements. Those lands have been reclassified in the 2015 data to reflect their current uses of land and front yard requirements.

Further, the extent of lands zoned for environmental protection purposes has increased significantly between the 1984 and 2014 zoning by-laws. The amount of land zoned as Natural Area (N) recognizes hazard lands, flood regulated lands, and other environmental features not otherwise recognized in previous zoning. A large proportion of these lands reclassified as Woodlot in 2015 were previously Residential Low Density (now Class A), where environmental protection zoning did not apply. The actual use of the majority of these lands has not changed since 2005, given the hazards associated with the lands.

³⁵Courtesy of Planning Services and Strategic Business Support, Town of Oakville.

i - Tree Plot Atlas

Plot: 332



X COORDINATES: 601427.197

Y COORDINATES: 4809323.641

Address:

Land Use: Commercial

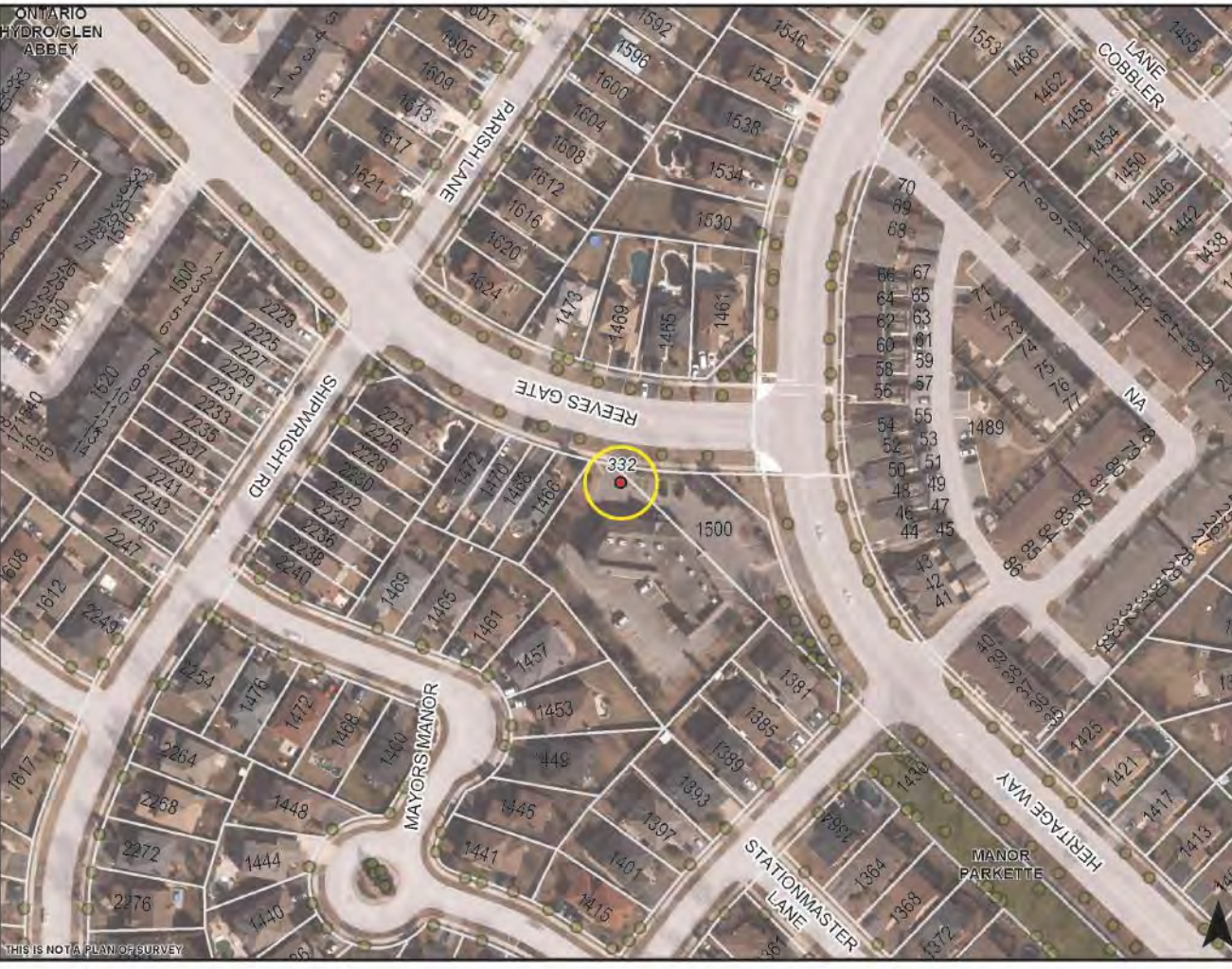
Ward: 4

Scale: 1:2,000

Date: 3/6/2015

Parks and Open Space, Forestry Section
 1225 Trafalgar Road
 Oakville, Ontario L6H 0H3
 905-845-6601

- i - Tree Plots
- i - Tree Plot Buffers
- Existing Town Trees
- Parks
- Park Trails



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