AN ASSESSMENT OF URBAN FOREST CANOPY MISSISSAUGA, ONTARIO

DECEMBER 2014

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“Together we will protect, enhance, restore, expand and connect Mississauga’s Natural Heritage System and Urban Forest to sustain a healthy community for present and future generations.”

- Mississauga Urban Forest Management Plan Vision, approved January 2014

AN ASSESSMENT OF URBAN FOREST CANOPY MISSISSAUGA, ONTARIO

COMPLETED DECEMBER 2014

Prepared By

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Acknowledgements

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Prepared For

City of Mississauga
One Million Trees Mississauga

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EXECUTIVE SUMMARY

The City of Mississauga's Urban Forest is comprised of trees, shrubs and understory plants, as well as the soils that sustain them, located on public and private property. This urban forest provides numerous benefits by making environments cleaner, safer, and more livable, therefore contributing directly to public health and reducing the costs associated with many required services. To manage, monitor and enhance the quality and stream of benefits received from its urban forests, the City of Mississauga initiated this study assessing the extent of Urban Forest Canopy (UFC) across the entire municipality. This report presents results for current land cover and UFC distribution as well as canopy cover changes over time. It includes data analysis, custom maps and tools, and broad recommendations for setting and achieving canopy objectives.

URBAN FOREST ASSESSMENT APPROACH

Natural resource managers use top-down (aerial imagery) and bottom-up (field based) approaches to measure land cover, trees other types of green infrastructure, and associated ecosystem functions. Terms and methods for this UFC assessment are presented within Project Fundamentals on page 6.

URBAN FOREST CANOPY IN MISSISSAUGA

This study encompasses 29,201 hectares defined by the city limits of Mississauga, Ontario. Based on the total area, the City has 5,614 hectares (19%) of UFC in 2014. There are 6,788 hectares (23%) of Potential Planting Areas (PPA), defined for this project as vegetated grass and open spaces where tree planting is feasible. Additionally, 16,800 hectares (58%) of Mississauga is unsuitable for tree planting. The land cover data was used to assess similar metrics for the City's wards, land use types, small geographic units (SGU), and service delivery areas (SDA). See Results section on pages 12-18.

5,614
Hectares of Urban Forest Canopy in 2014 Citywide

19%
Average UFC% across Mississauga City Limits

28%
Average Residential UFC % in 2014

2-4%
Estimated increase in canopy cover from 2007-2014

Ecosystem Services Analysis

Urban trees and forests in communities provide many "ecosystem services", or direct and indirect economic and environmental benefits such as removing air pollutants, storing and sequestering carbon, mitigating stormwater runoff, conserving energy through shade and wind block, improving public health, and providing wildlife habitat. Mississauga's tree canopy currently provides an estimated $3.5M in air quality services and $123M in annual carbon sequestration benefit annually. See Ecosystem Services section on page 18.

Trends in Canopy Cover

UFC cover is impacted by natural events (i.e. tree mortality), manmade influences (i.e. development and construction projects), and land cover mapping accuracy. A previous study using 2007 satellite imagery estimated 15% average UFC in Mississauga. This study compared UFC for 2007 and 2014 across multiple scales and analyzed changes over this period. This identified a 4% gain and illustrated that all wards increased in UFC with Wards 2 and 11 increasing the greatest (7% each).

For a more historical analysis, UFC cover was estimated using i-Tree Canopy software for 1992 and 2013 aerial imagery. By tallying canopy vs. non-canopy land cover for 1,250 random sample points, results estimate 15% UFC in 1992 and 18.6% in 2013 (1.1% SE), or a 3.5% UFC gain citywide.

Recommendations and Conclusions

To balance future development and growth with effective urban forestry planning, City officials must value Mississauga's canopy cover in environmental, social, and economic terms during planning processes. Maintaining and enhancing this green infrastructure will involve ongoing care and protection, strategic canopy increases, and education to expand awareness of UFC benefits. To complement the City's existing Urban Forest Management Plan, Natural Heritage & Urban Forest Strategy, and Mississauga's One Million Trees Campaign, this report provides hard data required for natural resources planning, policy-making, and outreach.

30%
Proportion of the Mississauga's Urban Forest canopy from natural areas and woodlands

6,788
Hectares available for potential tree planting citywide in 2014

1,226
New hectares of forest canopy from 2007-2014

31%
Proportion of potential planting area citywide in Mississauga that is found on Residential land use

PROJECT BACKGROUND

In recent years, the City of Mississauga has made great strides to improve the natural and built environment to ensure a sustainable urban forest for future generations. Related efforts include Mississauga's 2014 Urban Forest Management Plan, the Natural Heritage & Urban Forest Strategy, a 2011 Urban Forest Technical Report (UFORE study), the Region of Peel's Planting Spaces Analysis, and Mississauga's One Million Trees Campaign.

Mississauga covers approximately 292 square kilometres and has a population of approximately 756,000 (2014). As a follow-up to a 2007 study, the City contracted with Plan-It Geo in 2014 to re-assess Mississauga's Urban Forest Canopy (UFC). Using Geographic Information Systems (GIS), the process measures existing UFC and provides baseline information for increasing human health and environmental services from the urban forest. This project will strengthen partnerships, build awareness of urban forest benefits, enable the City of Mississauga to establish, monitor, and implement canopy goals and strategies, and to fulfill Urban Forest Management Plan objectives.

Figure 1: City boundary of Mississauga, the study area for the UFC Assessment, including 11 ward boundaries.

In 2008, Emerald Ash Borer (EAB), an invasive species, was first detected in Mississauga. The destruction of ash trees in Mississauga by EAB coupled with a severe ice storm in December 2013 presented a need to assess changes in UFC over. This assessment uses two approaches to compare and evaluate trends in UFC from 1992 to 2013 and from 2007 to 2014.

Data from this assessment will be used to:

- Evaluate canopy cover goals and reasons for changes in UFC
- Monitor & assess the effectiveness of tree-related policies
- Prioritize tree plantings and strategies
- Inform plans and budgets, and engage citizens

Mississauga's UFC Assessment is a top-down approach which provides data and tools to enhance planning, management, and value received from the City's urban forest. Additional bottom-up inventory and assessment can ground-truth viable planting areas as well as provide data on species composition, condition/quality, safety, and forest structure to augment this assessment. The products and outcomes will support developing and monitoring of canopy objectives, data-driven resource management plans, refinement of policies and by-laws, and help to foster a greater understanding of urban forest benefits.

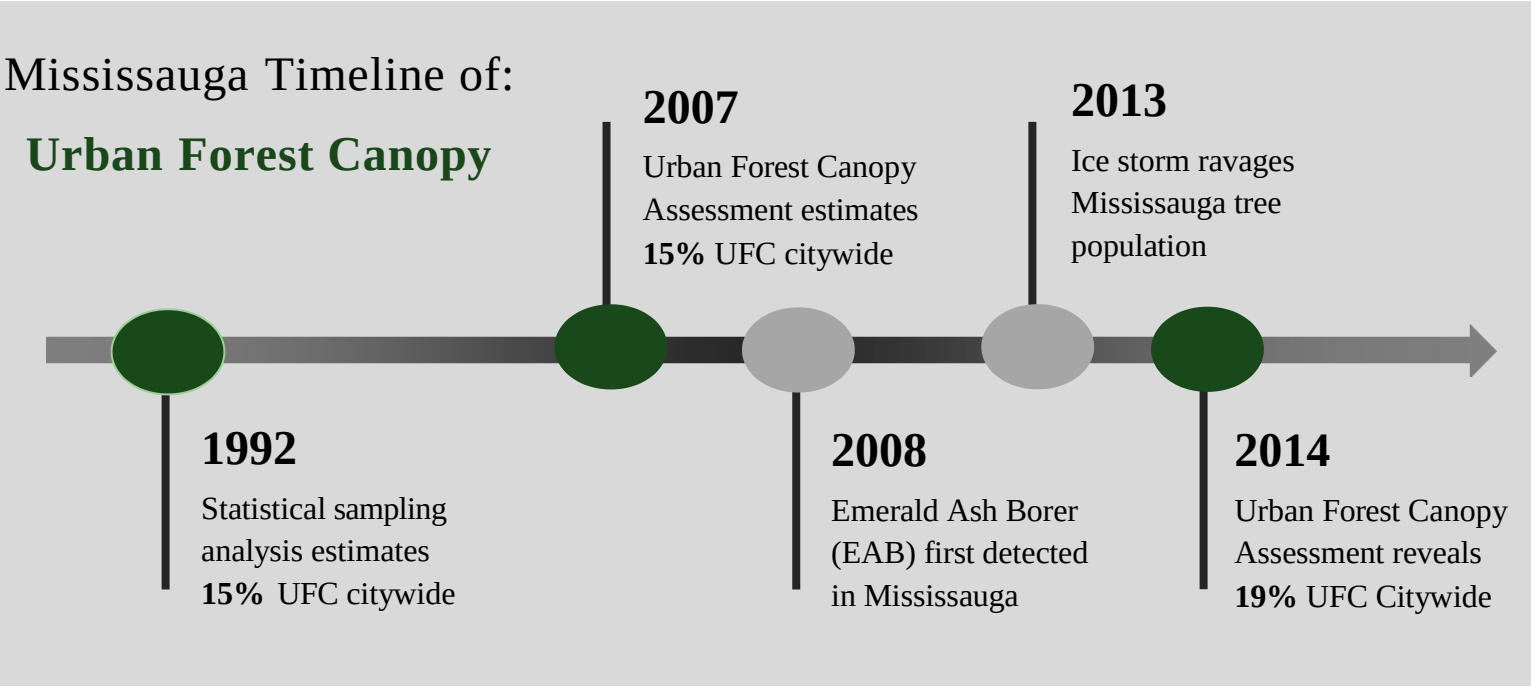


Figure 2: Urban Forest Canopy (UFC) assessment benchmarks and recent events impacting Mississauga's UFC.

MAJOR FINDINGS

LAND COVER & URBAN FOREST CANOPY:

- Mississauga has approximately 19% urban forest canopy (UFC) cover in 2014, or 5,614 hectares.
- 23% of the City (6,788 hectares) is available expanding UFC in lawns and open space. 5% of the City is considered unsuitable for tree planting (sports fields, Pearson Airport, etc.). Combined, 28% of the City is non-tree canopy vegetation.
- 53% of the City was mapped as "Other" land cover (impervious surfaces, water, soil, etc.).

CANOPY COVER ACROSS PLANNING & MANAGEMENT SCALES:

- Residential zoning comprises of 29% (8,597 hectares) of the total land area. With 2,396 hectares of tree canopy on residential land, this makes up 43% of all UFC citywide.
- Street Rights-of-Way exhibit 15% UFC in relation to total ward area as an average and have 27% (1,821 hectares) of planting space.
- Ward 2 has the highest UFC at 35% (988 hectares) while Ward 5 has the lowest UFC at 7% (572 hectares)

URBAN FOREST ECOSYSTEM SERVICES:

- The current Urban Forest removes nearly 454 tonnes of air pollutants from the air annually, valued at $3.6 million per year.
- Mississauga's canopy provides $123 million in carbon storage and sequestration benefits annually.

CANOPY COVER CHANGE (2007 TO 2014):

- Based on spatial analysis, canopy cover in Mississauga increased from 15% in 2007 to 19% in 2014. The reported 4% increase (1,226 hectares) is discussed further below in greater detail.
- Canopy cover in Ward 2 exhibited the greatest overall increase in UFC at 203 hectares, or 7%.
- 43% (1,868 hectares) of all canopy gain occurred in residential areas.

HISTORICAL CANOPY COVER TRENDS:

- Using a statistical sampling approach, canopy cover in 1992 was estimated at 15% and at 18.6% in 2013; a 3-4% increase citywide.

PROJECT FUNDAMENTALS

A "top-down" urban forest canopy cover assessment provides an accurate baseline analysis of canopy cover within the City of Mississauga's corporate boundary. It requires inputs of aerial or satellite imagery, remote sensing classification, modelling and trends analysis using Geographic Information Systems (GIS), assessment protocols, and more.

Background information and methods used in this assessment are presented for the following analysis tasks:

- ✓ Land cover mapping
- ✓ Assessment terminology
- ✓ Urban forest canopy assessment boundaries
- ✓ Ecosystem services: ways urban forests give back
- ✓ Analyzing urban forest ecosystem services
- ✓ Spatial analysis of canopy cover change (2007 to 2014)
- ✓ Statistical analysis of historical canopy cover trends (1992 to 2013)

MAPPING LAND COVER AND URBAN FOREST CANOPY

To delineate canopy cover, 2014 half-metre resolution satellite imagery was used as the basis for this UFC assessment. Object-based image classification results were combined with GIS data provided by the City to produce a three (3) class land cover layer described below. Detailed classification techniques are described in the Appendix on page 27.

Urban Forest Canopy:
Trees and large shrubs, when viewed and mapped from above

Vegetation:
Herbaceous, low-lying non-tree/shrub vegetation

Other:
All other features (water, roads, buildings, etc.)

A variety of GIS data layers from the city were used to map the following three land cover classes in Mississauga: (1) tree canopy, (2) other vegetation (grass / open space) and (3) other (non-vegetation). An existing woodlands map layer was overlaid and pieced together with the automated canopy classification. To eliminate areas unsuitable for planting: the airport grounds, golf courses, agricultural lots, baseball diamonds, and other recreational spaces were manually digitized and removed from plantable areas in the vegetation land cover class. After rigorous Quality Assurance / Quality Control, the land cover data was finalized and the input to assessing UFC metrics at multiple scale boundaries (see page 8).

TERMINOLOGY

The land cover classes described above were grouped into "UFC Assessment Types" for the study. UFC types categorize the landscape so that metrics can be summarized consistently but across different spatial scales for various planning, policy, management and outreach applications. These terms below are the UFC assessment metrics analyzed and used throughout the report. The following page illustrates the geographic boundaries assessed for these UFC types.

UFC Types assessed in this report:

Existing UFC

Comprises forests and individual trees when viewed and mapped from above.

Potential Planting Area (PPA)

Area of grass and open space where tree canopy does not exist and it is biophysically possible to plant trees.

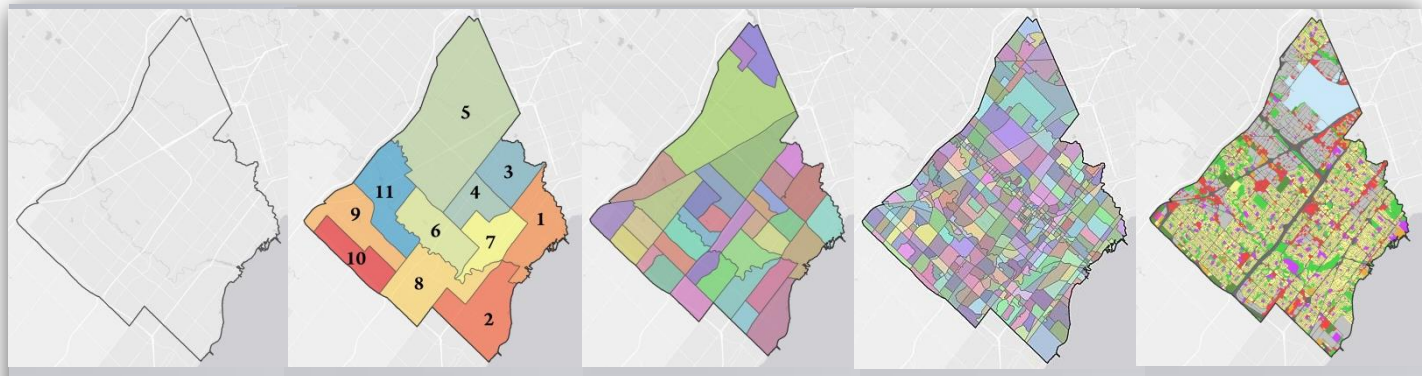
Unsuitable UFC

Areas in Mississauga where it is not feasible to plant trees. Areas such as ball fields and the Pearson Airport grounds were manually mapped or incorporated from existing data sources and defined as unsuitable planting areas.

From the citywide scale to each individual parcel-level lot, the area and percent of these UFC types was calculated. This is used in map-making and tabular summaries.

UFC Assessment Boundaries

Assessing canopy cover across different scale geographic boundaries provides a link to where we live, work, play and set policies impacting overall tree canopy and the benefits. Metrics for UFC Types on the previous page were assessed for the GIS boundaries below. These summaries provide benchmark data for resource managers, planners, and others in Mississauga at different spatial scales.



Boundary:	City Boundary	Wards	SDA (Service Delivery Areas)	SGU (Small Geographic Units)	Land Use by Parcel
No. of Features:	1	11	30	496	9
Description:	Mississauga City Limits	Areas representative for electoral, or administrative purposes	Geographies intended to support service planning and delivery	Developed to analyse community census data	Classes: Agricultural, Airport, Commercial, Green Space, Industrial, Institutional, Residential, ROW, Vacant

Ecosystem Services – Ways The Urban Forests Give Back

The Urban Forest is an integral part of the character for all those that live, work, or visit the City of Mississauga. Benefits of trees are referred to as "ecosystem services" and describe the ways that urban forests impact our lives and the environment. The information below and the figure on the following page outline and justify the many reasons to promote, establish, manage, and maintain a robust, "working" urban forest in Mississauga.

Environmental

Air Quality: 
Trees absorb, trap and offset air pollutants such as particulate matter, ozone, sulfur dioxide, carbon monoxide, and CO2.

Water Quality and Stormwater Runoff Mitigation: 
Soil aeration, evapotranspiration, and rainfall interception by trees increases water quality and reduces stormwater flow.

Erosion control: 
Tree roots hold soil together along stream banks and steep slopes.

Increased wildlife habitat:
Trees increases biodiversity and our connection to nature in urban areas.

Economic

Property value:
Residential homes with healthy trees add property value (up to 15%) (Releaf n.d.).

Energy conservation:
Trees lower energy demand through summer shade and winter wind block, additionally offsetting carbon emissions at the power plant.

Stormwater facilities:
Trees and forests reduce the need for or size of costly grey infrastructure.

Social

Public health:
Trees help reduce asthma rates and reduce UV-B exposure by about 50% (Releaf n.d.).

Crime and domestic violence: The urban forest helps build stronger communities. Trees provide settings in which relationships grow stronger and violence is reduced.

Noise pollution:
Trees reduce noise pollution by acting as a buffer and absorbing up to 50% of urban noise (U.S. Department of Energy study).

Ecosystem Services – Analysis

Trees are often appreciated for their aesthetic appeal; however, they greatly contribute to the health and vitality of resident's daily life. This project quantifies some of the ecosystem services provided by urban trees. While the net benefits of urban trees are usually positive, costs are also part of this study's ecosystem service evaluation and scenario tools for managers. Ecosystem benefits were calculated using i-Tree Canopy software. The figure below describes how trees can be valued in terms of public health, energy demand, and public infrastructure savings.

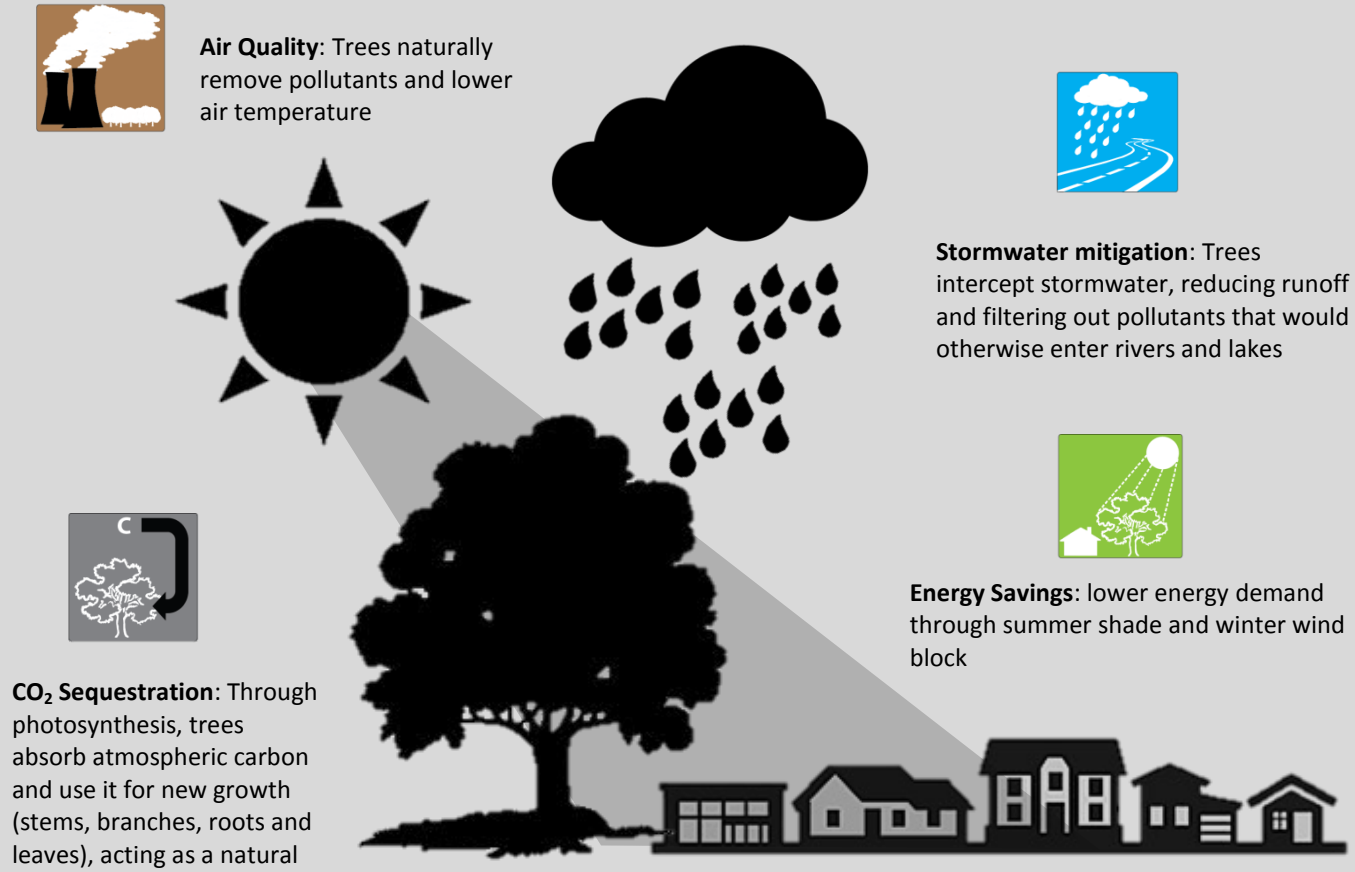


Figure 3: Ecosystem Services that Trees Provide

Canopy Cover Change 2007 to 2014- Spatial Analysis

The UFC study from 2007 indicated 15% forest cover within Mississauga City Limits. This data was overlaid and compared to the 2014 land cover and UFC metrics analysis to map and quantify gains and losses in canopy cover. This was performed citywide and across other finer-scale geographies. This method provides a comprehensive spatial analysis of canopy trends and change. See results on pages 12, 15, and in the Appendix.

Historic Canopy Cover Trends in Mississauga

In order to provide an additional comparison of canopy cover trends and also look farther back in time, a statistical point-based sampling approach was performed using 1992 aerial imagery provided by the City and 2013 aerial imagery available in Google Maps. This was conducted using i-Tree Canopy software where 1,250 randomly generated sample points were evaluated for "canopy vs. non-canopy" land cover using 1992 imagery as well as 2013 imagery. Additionally, Urban Forest services were valued using the *Ecosystem Benefits Report* from the 2013 i-Tree Canopy analysis.

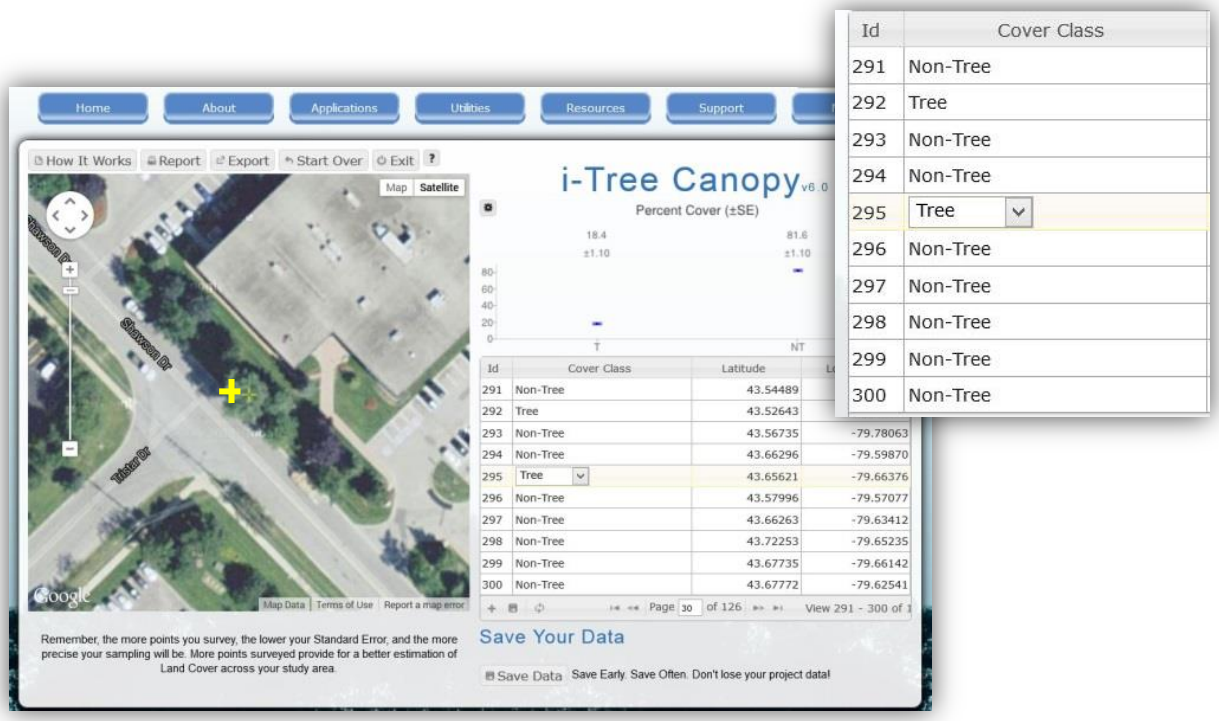


Figure 4: i-Tree Canopy software

Assessment Results and Products

The UFC boundaries assessed in Mississauga are governed, owned, managed, and used in different ways by residents in the community. Therefore, the UFC data and analysis results are presented for multiple scales and purposes to inform planners, managers and citizens alike.

The following sections present canopy cover and planting potential across geographic assessment boundaries and describes how the City can use the data to develop ways to manage this important resource.

19% Existing Urban Forest Canopy

53% Other Land Cover

23% vs. 5%

Open Space Vegetation Potential vs. Unsuitable to Expand Canopy

(See page 7 for definitions)

Tree Canopy in Mississauga

This study encompasses 29,201 hectares defined by the City limits of Mississauga and provides a snapshot of land cover based on 2014 satellite imagery. Tree canopy covers 5,614 hectares (19%) of Mississauga.

Potential Planting Area in Mississauga

Non-tree canopy vegetation (grass and open space) where tree planting is feasible covers an additional 6,788 hectares (23%). This metric excludes sports fields and vegetation near Pearson Airport.

Changes and Trends in Canopy Cover

From 2007 to 2014, land cover mapping indicates a change from 15% to 19% average UFC, or a 4% gain citywide. Using this method, the largest gain at the ward-level was 7% (203 ha) in Ward 2. As discussed further below, slight inaccuracies and differentiations in data quality between the 2007 and the 2014 canopy mapping mean that the net increase is likely between 2% and 4% in this nearly 10-year period. See page 30 in the Appendix for more information.

The historical canopy trends analysis using a random point sampling method reveals an estimated 3% gain in UFC from 1992 to 2013. Both techniques indicate Mississauga's UFC is increasing due to tree planting, protection and maintenance even with canopy loss from EAB and the recent ice storm. Additionally, a forest canopy projection was made to 2024 using Plan-It Geo's "Canopy Calculator Tool" (described on page 27 in the appendix) which models growth of 144,000 trees planted by the City's Million Trees Initiative, (as of December ,2014) resulting in an estimated 22% UFC by 2024.

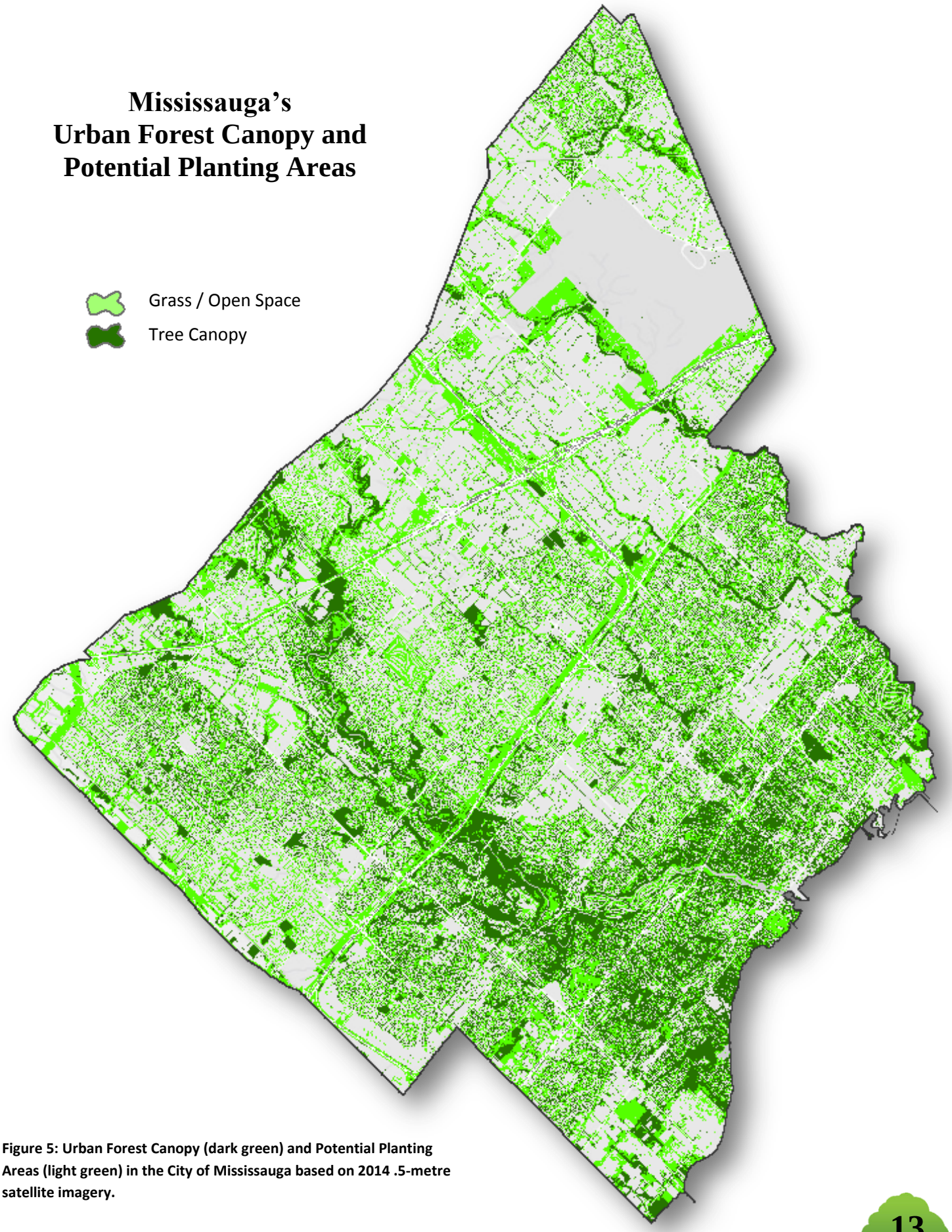


Figure 5: Urban Forest Canopy (dark green) and Potential Planting Areas (light green) in the City of Mississauga based on 2014 .5-metre satellite imagery.

TREE CANOPY BY LAND USE

Many of the policies, regulations, by-laws, and actions influencing tree canopy in Mississauga are dependent on land use. To provide data that advances urban forest policy and management, nine land use categories were assessed for tree canopy and potential planting area (see Figure 5). Results include both parcel-level data and summary-level data. At the detailed parcel scale, data can be queried and symbolized using GIS to identify specific planting opportunities in wards or properties in specific land use types. Table 1 provides results for 2007-2014 UFC and trends by land use.

There is significant variation in canopy cover by land use, with 46% on "green space" land use, 28% on residential, 15% over street rights of way, and just 5% UFC in Industrial areas. Note that 67% of all UFC change (all gains) occurred on Residential (43%) and Green Space (24%) land uses, and 27% of all PPA is in the Street ROW. For complete land use results, see Appendix page 25.

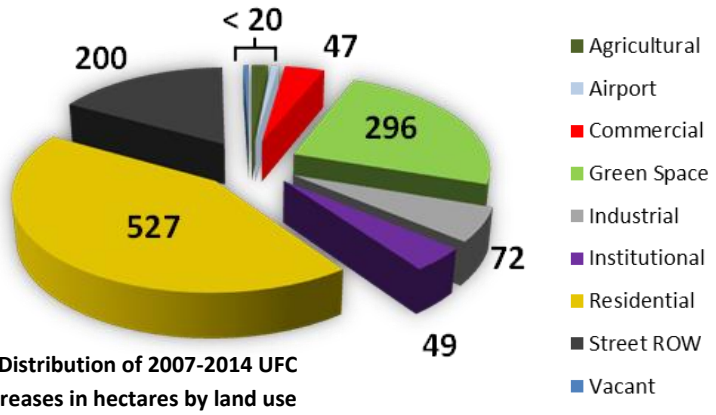


Figure 6: Distribution of 2007-2014 UFC increases in hectares by land use

Table 1: UFC Results by Land Use

Land Use Category	Total Hectares (ha)	% of City	2014 UFC (ha)	2014 UFC %	UFC Change (ha)	UFC Change %
Agricultural	549	2%	103	19%	+19	+3%
Airport	1,819	6%	39	2%	+9	+1%
Commercial	1,917	7%	151	8%	+47	+2%
Green Space	3,027	10%	1,394	46%	+296	+10%
Industrial	4,591	16%	242	5%	+72	+2%
Institutional	1,370	5%	218	16%	+49	+4%
Residential	8,597	29%	2,396	28%	+527	+6%
Street ROW	6,522	22%	983	15%	+200	+3%
Vacant	808	3%	88	11%	+6	+1%
TOTALS	29,199	100%	5,613	19%	+1,226	+4%

Old neighbourhoods in Mississauga exhibit the healthiest urban forest characteristics and provide the most ecosystem services to the City, while newer developments have many young trees which should one day contribute towards much of Mississauga's Urban Forest canopy.

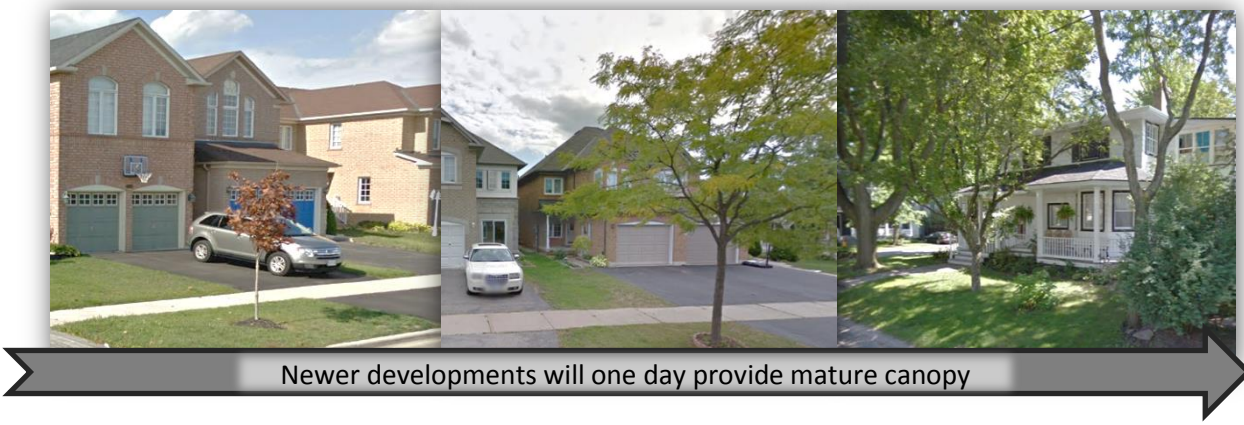


Figure 7: New to old neighbourhood developments and the urban forest canopy within each.

Tree Canopy Trends by Wards

In Mississauga's 11 wards, existing UFC ranges from 7% in Ward 5 (572 hectares) to 35% in Ward 2 (988 hectares). From 2007-2014, Ward 2 had the highest overall gain at 7% (203 ha) while Ward 5 increased modestly by 2% (162 hectares). No wards indicate a net loss when aggregated at that scale. For a citywide map of canopy change by parcel, see page 30 in the Appendix.

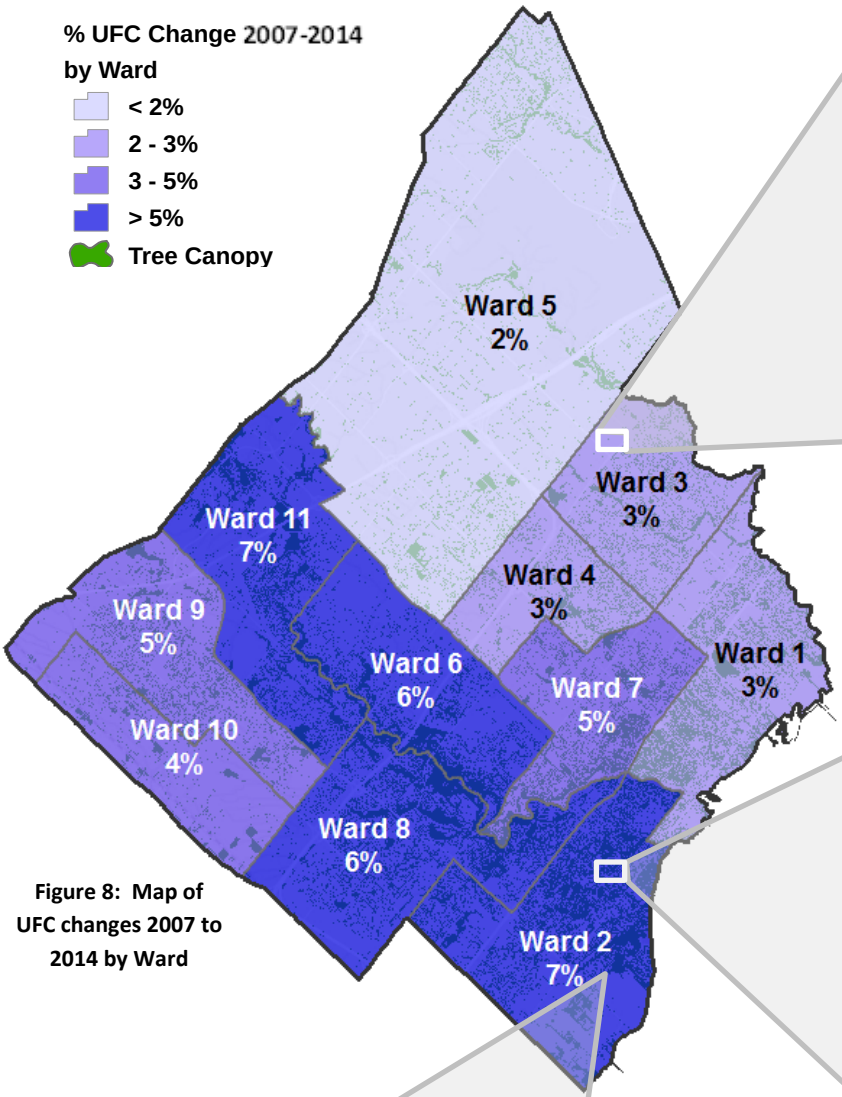


Figure 8: Map of UFC changes 2007 to 2014 by Ward

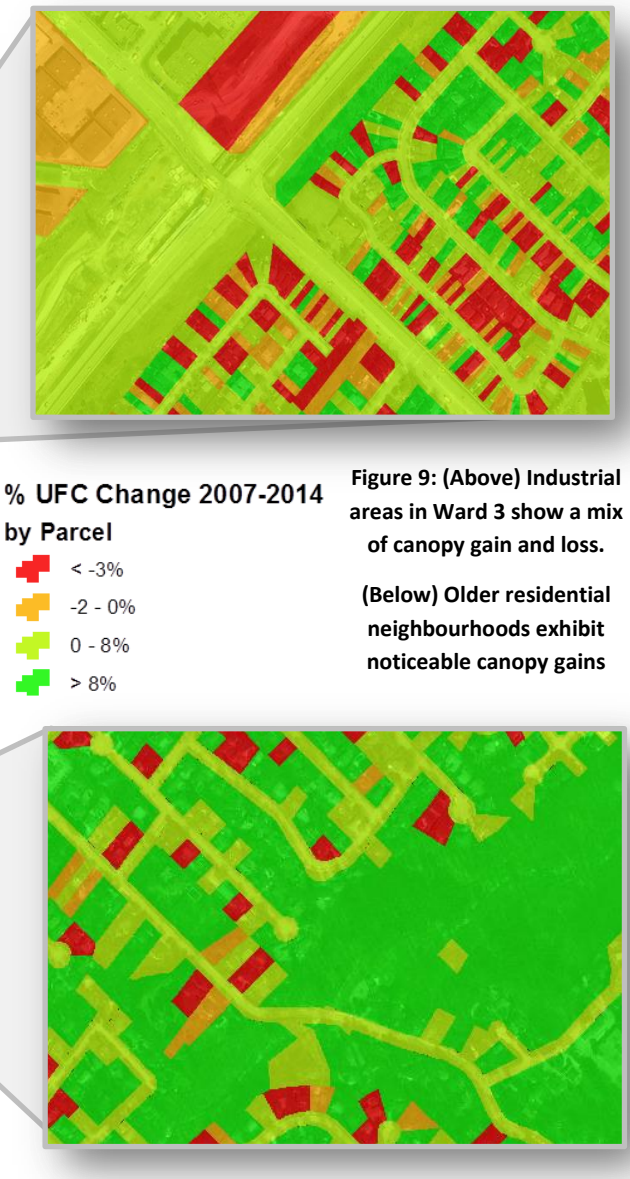
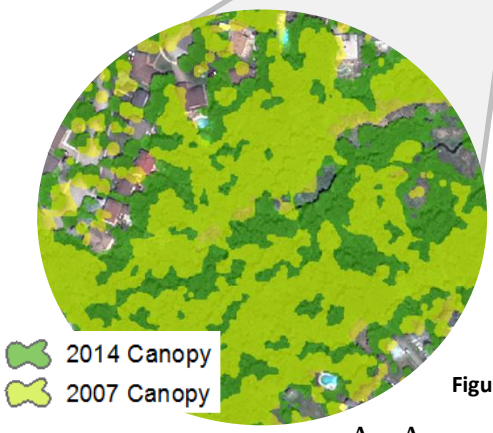


Figure 9: (Above) Industrial areas in Ward 3 show a mix of canopy gain and loss.

(Below) Older residential neighbourhoods exhibit noticeable canopy gains



Canopy increase in highly industrialized areas such as Wards 3 and 5 was less substantial than in the rest of the city.

Woodlands exhibit noticeable canopy gains and little loss, even after the destructive ice storm in 2013. Canopy mapping accuracy from 2007 vs. 2014 analyses may play a role in some gains (see pages 27-28 in Appendix). Losses are apparent in many areas from individual tree removal; however the net result indicates a positive gain overall.

Figure 10: Canopy Growth in Forest Stands 2007-2014

Tree Canopy By Smaller Geographic Units (SGU)

Small geographic units, or SGUs, are used for mid-scale census data dissemination and analysis, and are created to correspond with the unique geographical features found in the Region of Peel. SGUs are units created by the Region of Peel in partner with its municipalities to analyze community census data. Forest canopy in SGU's ranged from 1% to 74%. Canopy change from 2007-2014 ranged from -45% UFC loss to an 18% gain in Mississauga's SGU's.

While the data from this assessment can be used for targeting tree planting opportunities, provide an existing baseline of canopy, and forecast future canopy trends, an ancillary use is to identify where new trees need the most maintenance. Areas of Mississauga that exhibit low UTC and high PPA often contain many new tree plantings. Just as important as tree planting efforts, tree maintenance of these young trees is vital to the health of the Mississauga's future Urban Forest.

Results for Service Delivery Areas (SDA's) in Mississauga can be found in the Appendix.

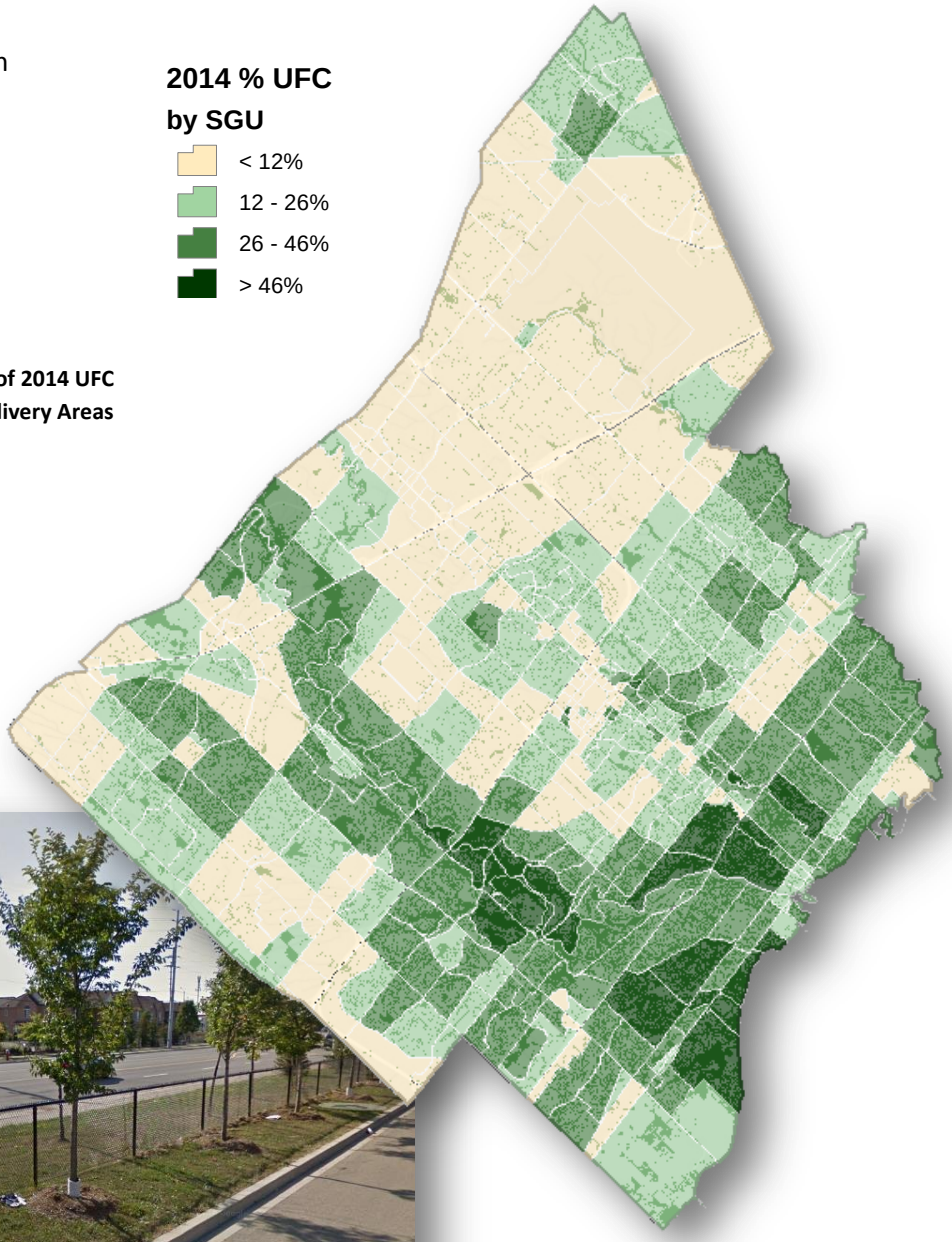
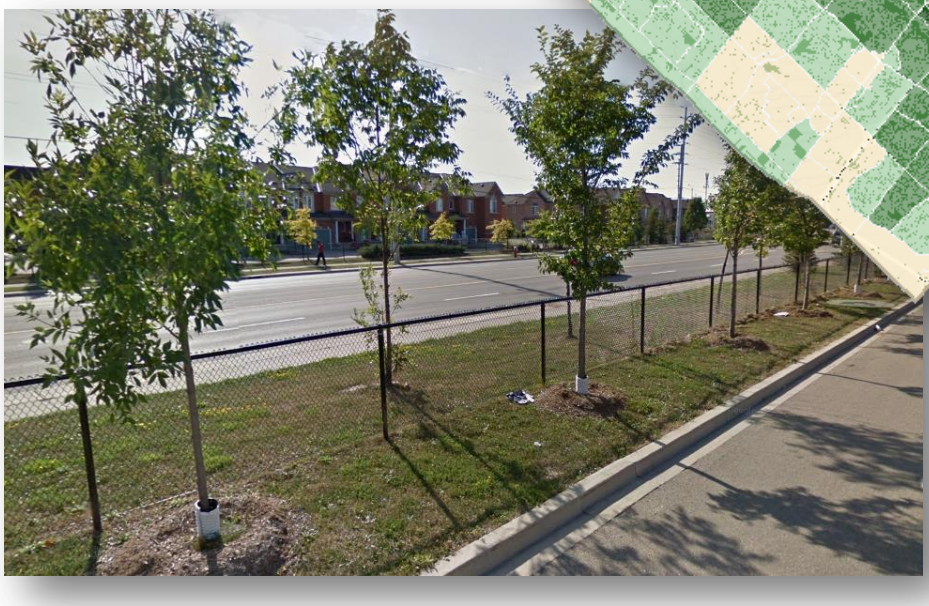


Figure 11: Map of 2014 UFC by Service Delivery Areas

Figure 12: Thousands of newly planted trees will continue to increase Mississauga's canopy with proper maintenance and care.



Future Canopy Cover and Urban Forest Planning

Canopy cover in Mississauga is influenced both positively and negatively through natural processes such as tree age and health, ice and wind storms, pests and diseases, and regeneration, as well as through manmade processes such as tree planting, tree maintenance, and removals during development. Future UFC can be estimated under certain assumptions.

With support from government, business, and citizens, the One Million Trees Mississauga program has already planted over 144,000 trees, more than 10% of their goal to date. Using Plan-It Geo's Canopy Calculator spreadsheet tool developed for this assessment, it is possible to "grow out" these recently planted trees, add new canopy to the existing canopy, account for certain mortality, and see the net impact citywide.

(Accessed online in December 2014)

By growing out 144,000 recently planted trees for the next 10 years, assuming 3% mortality for new trees and 7% annual mortality for the existing UFC (to account for EAB loss and other natural and manmade influences), the Urban Forest Canopy will increase by 3% (670 hectares), yielding 22% average UFC citywide. For more information on the Canopy Calculator tool, see page 26 in the Appendix.

2014 Existing UFC:		2024 Canopy Projection:
19% UFC	→	**22% UFC**

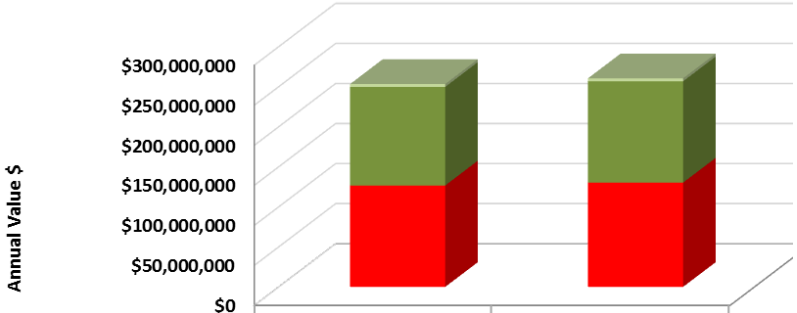
*This estimation is provided as an example only. It projects future UFC by starting with the existing UFC and growing out 144,000 recently planted trees. This analysis does not include potential canopy growth from the average of 45,000 tree plantings that may occur annually over the next 10 years per the City's website. Other tree growth and mortality assumptions can be used for realistic projections by the City using local tree monitoring and research and the Canopy Calculator tool provided through this study.

URBAN FOREST ECOSYSTEM SERVICES

Assigning a dollar value to the benefits provided by Mississauga's trees and forests can further motivate people to preserve and enhance the Urban Forest. This is critical to understanding how trees impact our homes, communities, and overall environment.

Carbon and Air Quality Findings:

Based on the data provided by i-Tree software, existing canopy in Mississauga stores approximately 14 million tons of carbon; a service valued at $310 million, and each year sequesters approximately 570,000 thousand tons of carbon dioxide, valued at $123 million. Findings also reveal that tree canopy in Mississauga removes 454 tons of air pollution annually, valued at $3.6 million.



	19% Existing Conditions	22% 2024 Projection
Carbon Sequestration	$3,583,123	$3,683,450
Air Pollution	$123,050,310	$126,495,718
TOTALS	$126,633,433	$130,179,168

Figure 13: Annual Ecosystem Services Savings

Canopy Projections and Ecosystem Savings:

The projected 2024 UFC, with an average 22% cover citywide, would provide an increase in annual savings of $3.5 million from existing canopy savings. The newly planted trees will store an additional 16,000 tons of carbon annually, valued at $3.4 million, as well as remove an additional 13 tons of air pollutants annually, valued at $100,000/year.

RECOMMENDATIONS

This project mapped land cover across the City of Mississauga, assessed benefit values of current and future canopy cover, and developed data and tools allowing managers to identify where urban trees can be planted for specific purposes and measure progress. Based on the results of this work, the following broad recommendations are provided on how to best use these data, tools, and information to implement urban forestry objectives in Mississauga.

TECHNICAL → LAND COVER DATA & ANALYSIS

- ✓ Disseminate the land cover data to partners for urban forestry and other applications while the data is current and most useful for decision-making and implementation planning.
- ✓ Re-assess canopy cover in 5-10 year intervals using best available imagery, aiming for 95% overall accuracy.
- ✓ Apply the data and tools from this assessment in conjunction with the Peel Planting Space Analysis project to target high priority tree planting areas, engaging diverse citizens and businesses in the process.
- ✓ Promote web & mobile technologies to monitor urban forest dynamics and engage and educate the public.

FUNCTIONAL → ECOSYSTEMS SERVICES

Overall Tree Canopy

- ✓ Use the results to develop targeted presentations for City leaders, planners, engineers, resource managers, and the public on the functional benefits of trees in addressing environmental issues.

Tree Canopy for Air Quality

- ✓ This study identified 1,821 hectares of potential space for growing and expanding canopy in street rights-of-way. City/Forestry staff can partner to target canopy increases in corridors as an air pollution mitigation strategy.
- ✓ Prioritize tree planting events and programs near impervious areas to mitigate urban heat island effects.

Tree Canopy for Energy Conservation

- ✓ Develop strategies to plant and maintain trees for energy efficiency. There are 36,735 residential parcels with less than 5% canopy which can be targeted for energy conservation benefits from trees.

Tree Canopy for Stormwater & Water Quality

- ✓ Work with the Stormwater Management Program to prioritize areas for forest restoration in flood-prone areas.

PLANNING → POLICY& DEVELOPMENT, MANAGEMENT, AND OUTREACH

- ✓ Continue to systematically accomplish objectives set forth in the 2014 Urban Forest Management Plan.
- ✓ Establish procedures and sustained funding sources for maintenance of newly planted trees and mature canopied trees to reach and maintain UFC goals.
- ✓ Update existing street tree inventory and include street and park trees.
- ✓ Develop an invasive species management plan to monitor and manage the health and quality of existing UFC.
- ✓ 31% of all potential space for expanding canopy is found on residential land uses. Develop a homeowner communications and education program to plant, grow, and care for private property tree canopy.
- ✓ Further assess areas of canopy gain and loss to more fully understand the drivers of change.

CONCLUSIONS

Mississauga's Urban Forest is a living and dynamic resource. The canopy is constantly changing based on the growth of newly planted trees and existing canopy as well as loss of trees or entire stands based on storms, natural mortality, or removals for public safety. Through these natural and human processes, including the 2013 ice storm and exotic and invasive pests, Mississauga's urban forest canopy can increase with great effort, as evidenced through this study.

Several factors impact percent UFC cover in Mississauga. Related specifically to this study, these drivers are as follows:

- From a mapping perspective, no method and measure of canopy will be 100% accurate. This study applied a statistical point-based sampling approach and a remote sensing analysis, yielding 18.6% 19% UFC, respectively. With a 1% standard error (SE), these estimates validate one another and the trend of increasing UFC. Review of the 2007 canopy mapping which resulted in 15% UFC indicates a slight underestimation of canopy. Therefore, the absolute measure of canopy change is estimated at 2-4%, knowing that the 2007 data may be slightly high and the 2014 data may be slightly high (based on the SE rates of each method's result).
- From a management perspective, canopy has increased based on impressive tree planting efforts by the City and community. An emphasis on not only tree planting but also tree maintenance (watering, structural pruning, etc.) will help to ensure new and existing trees survive storms and changes in climate, thus reaching their potential size at maturity and contribution to canopy cover and services (monetary, environmental, social, etc.).
- From an ecological perspective, Mississauga's canopy will continue to be impacted by climate change and pests/diseases such as the Emerald Ash Borer (EAB) and Asian Long-Horn beetles, and others. It should be noted that the full effects of EAB on the City's canopy has not yet been realized in this study.

The City's 2014 UFMP listed a UFC goal of 15-20%. Based on this study and unknown effects of the drivers above, a 20% goal is currently recommended. To achieve and maintain this goal, data from this study can be used in the Peel Planting Spaces Analysis Project and to inform private property education and awareness programs, among other efforts.

Managing urban trees and woodlands requires an understanding of where trees are, where they can be planted equitably to maximize benefits, and how to work within regulatory and physical restrictions to achieve goals. A detailed and accurate baseline of land cover has been thoroughly analyzed and presented in this report to assist in the City's near and long-term vision of urban natural resource management. The environmental and economic benefits provided by the city's canopy provide a compelling argument for continuing the funding and collaboration needed to expand and maintain this worthy resource.

APPENDIX

Additional details on the City of Mississauga's 2014 Urban Forest canopy assessment are provided including supporting information on:

A1: Glossary of Terms

A2: Comprehensive Results for Assessment Boundaries

A3: Canopy Calculator for Goal Setting

A4: Land Cover Classification Accuracy Assessment

A5: Canopy Change Examples

Air Quality – The quantity of particulates and other pollutants present in a volume of air relative to necessary compounds such as oxygen. Trees improve air quality by absorbing and trapping air pollutants such as particulate matter, ozone, sulfur dioxide, carbon monoxide, and CO^2 and by decreasing volatility by lowering air temperatures.

Carbon Sequestration – The rate that carbon is removed from the atmosphere by trees. Carbon is considered a very important element because of its recognized influence on climate regulation as a greenhouse gas.

Carbon Storage – Cumulative amount of carbon stored in the stems, branches and roots of trees over time.

Ecosystem Services – The processes of nature needed to support the health and survival of humans. They are required and used by all living organisms but the term typically refers to their direct value (quantified or not) to humans. Direct and indirect benefits provided by natural systems. The most common ecosystem services associated with urban trees and forests are air quality improvement, carbon sequestration and storage, energy conservation, and storm water mitigation.

Energy conservation – The amount of energy saved due to the presence of trees. Summer cooling through shade, and by wind blocking in the winter reduces total energy used.

Geographic Information Systems – Computer mapping systems used to understand how resources are distributed across a given land extension.

i-Tree Canopy– As part of the i-Tree suite developed by the USDA Forest Service, this tool estimates tree cover and tree benefits for a given area with a random sampling process that allows easy classification of ground cover types.

i-Tree Eco- As part of the i-Tree suite developed by the USDA Forest Service, this tool is a software application designed to use field data from complete inventories or randomly located plots throughout a community along with local hourly air pollution and meteorological data to quantify urban forest structure, environmental effects, and value to communities

PPA Total – (Potential Planting Area) associated with vegetation and open space. These are areas where tree planting is potential.

Stormwater Runoff Mitigation and Water Quality – Important ecosystem services related to precipitation events, hydrologic cycles, and urban forests. Trees reduce stormwater runoff and improve water quality by intercepting rainfall, increasing soil permeability, and evapotranspiration.

Urban Forest: City of Mississauga's Urban Forest Management Plan (2014) defines as a dynamic system that includes all trees, shrubs and understory plants, as well as the soils that sustain them, located on public and private property.

UFC – (Urban Forest Canopy) is defined as the layer of leaves and stems of trees that cover the ground when viewed from above.

Urban Heat Island Effect – refers to developed areas that are hotter than surrounding rural areas due to the abundance of man-made materials which absorb the sun's energy much more than trees or other plants, and in turn warm the air around them (Center for Environmental Studies, Brown University, "Trees and the Urban Heat Island Effect", 2010).

The following maps and tables on pages 23-24 provide more comprehensive results for boundaries assessed in this study.

UFC Metrics by Ward

Figure 14: Percent UFC by Ward

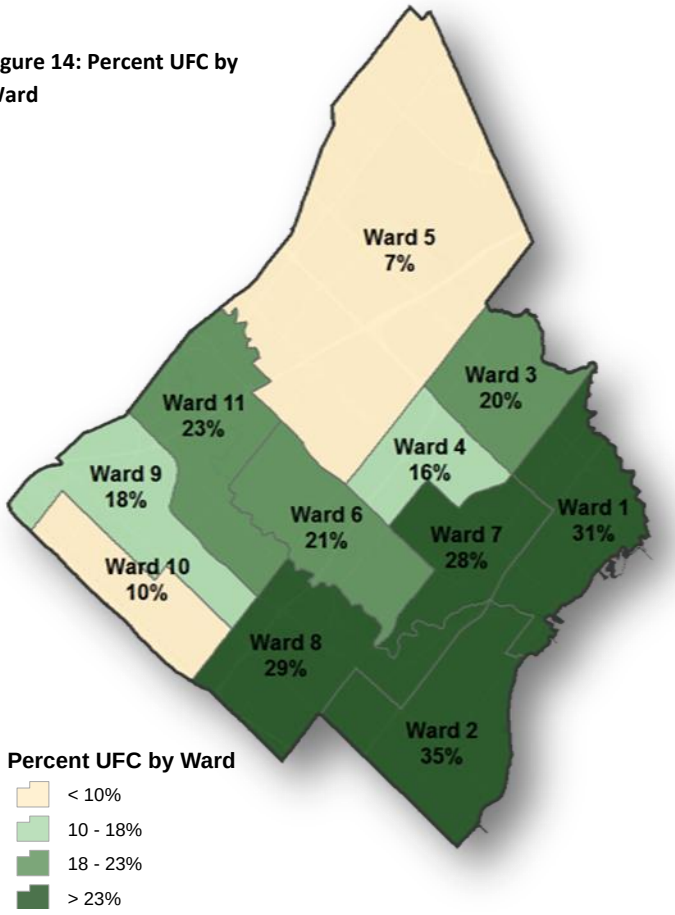


Figure 15: Percent PPA by Ward

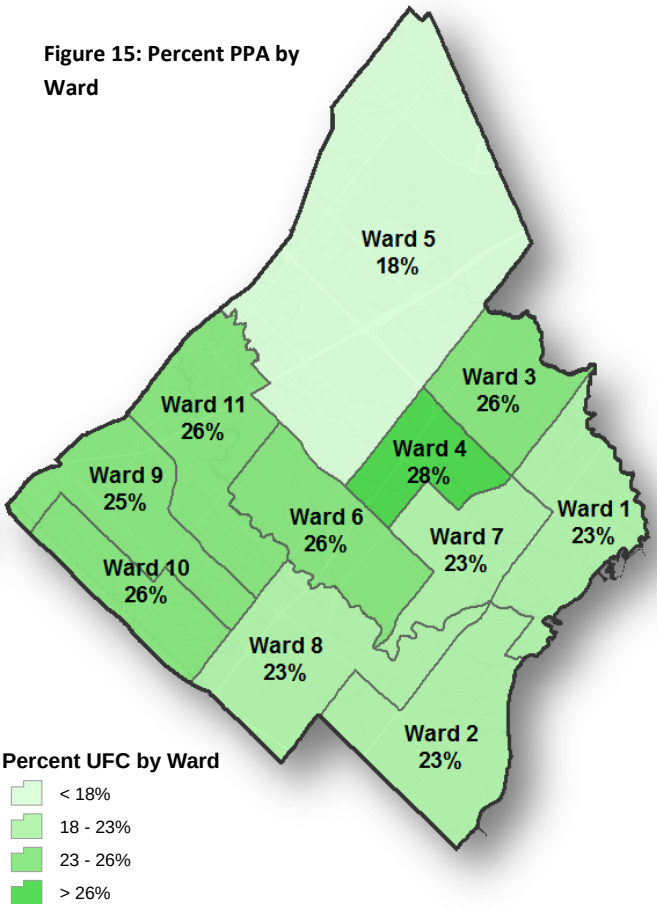


Table 2: Complete UFC Results by Ward

Ward #	Total Hectares	UFC Hectares	UFC %	PPA Hectares	PPA %	Other Hectares	Other %	2007 UFC (hectares)	2007 UFC %	Canopy Change 2007-2014 (hectares)	Canopy Change 2007-2014 %
1	2,322	716	31%	553	24%	974	42%	646	28%	70	3%
2	2,848	988	35%	683	24%	1,119	39%	785	28%	203	7%
3	1,654	338	20%	437	26%	844	51%	289	17%	49	3%
4	1,211	197	16%	341	28%	649	54%	163	13%	35	3%
5	8,563	572	7%	1,596	19%	5,757	67%	411	5%	162	2%
6	2,080	442	21%	542	26%	1,033	50%	320	15%	122	6%
7	1,618	455	28%	377	23%	743	46%	379	23%	75	5%
8	2,755	803	29%	647	23%	1,217	44%	633	23%	170	6%
9	2,108	382	18%	533	25%	1,119	53%	276	13%	106	5%
10	1,492	146	10%	393	26%	810	54%	82	5%	65	4%
11	2,538	572	23%	684	27%	1,166	46%	404	16%	168	7%
TOTAL	29,190	5,612	19%	6,785	23%	15,431	53%	4,387	15%	1,224	4%

UFC Metrics by Service Delivery Area (SDA)

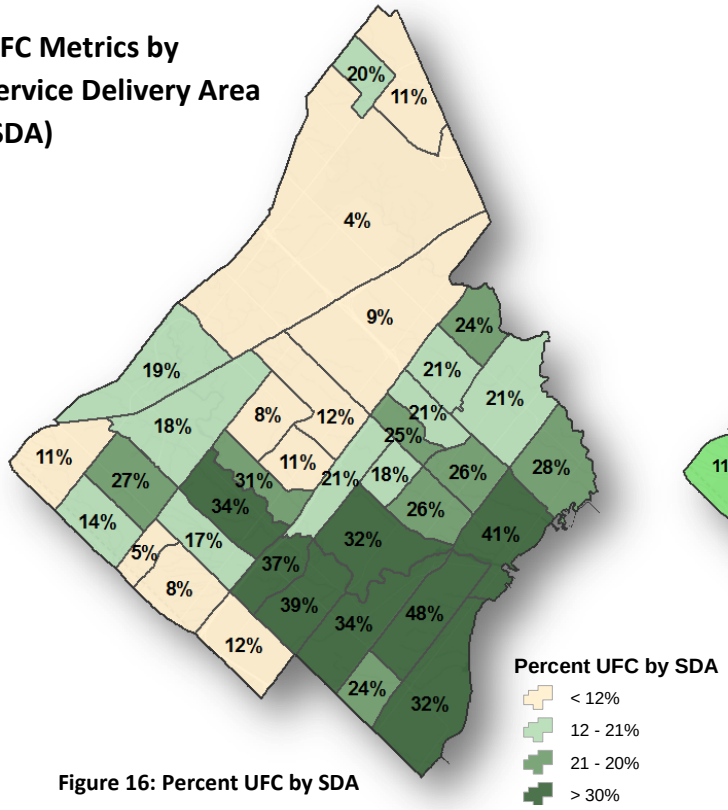


Figure 16: Percent UFC by SDA

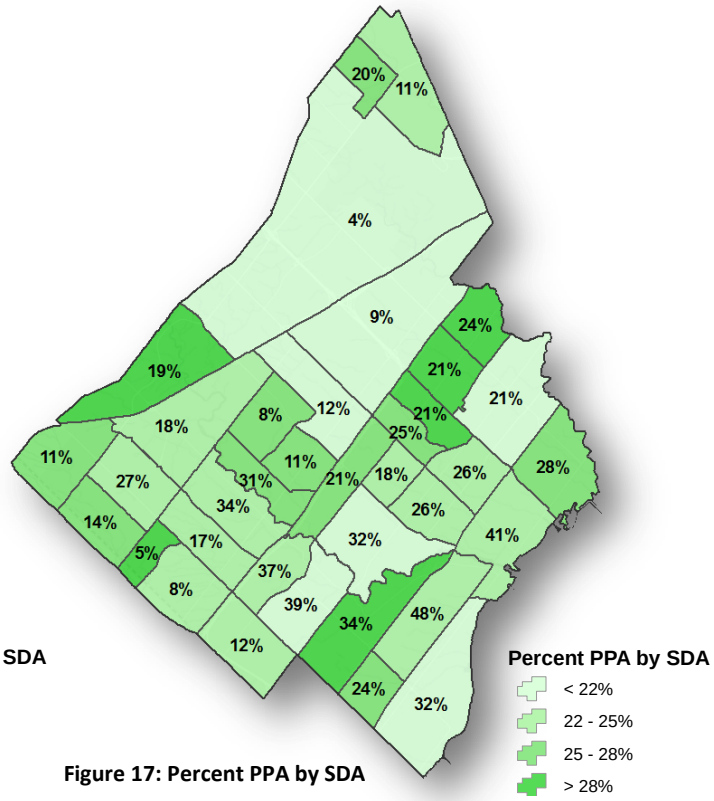


Figure 17: Percent PPA by SDA

Table 3: Complete UFC Results by SDA

SDA Name	Total Hectares	UFC Hectares	UFC %	PPA Hectares	PPA %	Other Hectares	Other %	2007 UFC (hectares)	2007 UFC %	Canopy Change 2007-2014 (hectares)	Canopy Change 2007-2014 %
M001	735	79	11%	201	27%	380	52%	45	6%	33	5%
M002	542	78	14%	148	27%	261	48%	48	9%	31	6%
M003	622	170	27%	155	25%	283	46%	147	24%	23	4%
M004	1,221	223	18%	274	22%	680	56%	153	13%	70	6%
M005	1,086	211	19%	315	29%	479	44%	142	13%	70	6%
M006	5,157	207	4%	930	18%	3,427	66%	147	3%	59	1%
M007	328	65	20%	91	28%	163	50%	47	14%	18	6%
M008	860	90	11%	191	22%	561	65%	74	9%	16	2%
M009	2,121	201	9%	407	19%	1,475	70%	143	7%	58	3%
M010	773	90	12%	161	21%	499	65%	59	8%	31	4%
M011	520	40	8%	147	28%	293	56%	19	4%	21	4%
M012	401	43	11%	112	28%	233	58%	23	6%	20	5%
M013	428	131	31%	110	26%	176	41%	92	21%	39	9%
M014	694	233	34%	161	23%	285	41%	172	25%	61	9%
M016	533	89	17%	122	23%	300	56%	44	8%	45	8%
M017	892	60	7%	73	8%	145	16%	31	3%	29	3%
M018	686	84	12%	155	23%	389	57%	64	9%	20	3%
M019	1,111	424	38%	160	14%	419	38%	347	31%	76	7%
M020	1,499	419	28%	109	7%	157	11%	345	23%	74	5%
M021	296	52	18%	120	41%	281	95%	33	11%	19	6%
M022	279	71	25%	156	56%	281	101%	60	22%	11	4%
M023	349	72	21%	184	53%	415	119%	65	19%	7	2%
M024	931	208	22%	68	7%	166	18%	172	18%	37	4%
M025	1,095	225	21%	70	6%	131	12%	208	19%	17	2%
M026	465	120	26%	111	24%	160	34%	107	23%	13	3%
M027	497	131	26%	131	26%	196	40%	109	22%	22	4%
M028	951	324	34%	148	16%	223	23%	260	27%	64	7%
M029	1,156	469	41%	230	20%	625	54%	385	33%	84	7%
M030	1,679	588	35%	105	6%	232	14%	527	31%	61	4%
M032	1,284	414	32%	116	9%	240	19%	319	25%	95	7%
TOTAL	29,190	5,612	19%	5,461	19%	13,558	46%	4,387	15%	1,224	4%

UFC Metrics by Land Use

Table 4: Complete UFC Results by Land Use

Land Use Category	Total Hectares	% of City	2014 UFC (ha)	2014 UFC %	Distribution of 2014 UFC	2007 UFC (ha)	2007 UFC %	UFC Change (ha)	UFC Change %	Distribution of UFC Change	PPA Veg. (ha)	PPA Veg. %	Distribution of PPA Vegetation
Agricultural	549	2%	103	19%	2%	84	15%	19	3%	2%	48	9%	1%
Airport	1,819	6%	39	2%	1%	30	2%	9	1%	1%	254	14%	4%
Commercial	1,917	7%	151	8%	3%	104	5%	47	2%	4%	267	14%	4%
Green Space	3,027	10%	1,394	46%	25%	1,098	36%	296	10%	24%	1,050	35%	15%
Industrial	4,591	16%	242	5%	4%	170	4%	72	2%	6%	516	11%	8%
Institutional	1,370	5%	218	16%	4%	169	12%	49	4%	4%	382	28%	6%
Residential	8,597	29%	2,396	28%	43%	1,868	22%	527	6%	43%	2,133	25%	31%
Street ROW	6,522	22%	983	15%	18%	783	12%	200	3%	16%	1,821	28%	27%
Vacant	808	3%	88	11%	2%	82	10%	6	1%	1%	317	39%	5%
TOTALS	29,199	100%	5,613	19%	100%	4,387	15%	1,226	4%	100%	6,787	23%	100%

To assist in advanced UFC goal setting, Plan-It Geo's Canopy Calculator (MS Excel) tool is provided as a sophisticated yet easy-to-use tool to the City of Mississauga. The City may quickly and easily enter various goals and determine future tree canopy cover and tree planting scenarios.

Mississauga, ON

Land Use Classes		Total Area (ha)	Existing UTC (ha)	Existing UTC (%)	Total Possible Planting Area (ha)	Total Possible Planting Area (%)		Urban Tree Canopy (%)	Urban Tree Canopy (No. Trees)
Agriculture	Current	549	103	*18.8%*	48	*9%*	Goals	*19%*	-
Airport		1,819	39	*2.1%*	254	*14%*		*3%*	-
Commercial		1,917	151	*7.9%*	267	*14%*		*10%*	-
Green Space		3,027	1,394	*46.1%*	1,050	*35%*		*48%*	-
Industrial		4,591	242	*5.3%*	516	*11%*		*7%*	-
Institutional		1,370	218	*15.9%*	382	*28%*		*18%*	-
Residential		8,597	2,396	*27.9%*	2,133	*25%*		*32%*	-
Street ROW		6,522	983	*15.1%*	1,821	*28%*		*20%*	-
Vacant		808	88	*10.9%*	317	*39%*		*12%*	-
Citywide Total		**29,200**	**5,614**	***19%***	**6,788**	***23%***		***22%***	**3,995**

Predictions	(+) Natural Regeneration (ha)	(+) Natural Regeneration (%)	(+/-) Canopy Growth & Mortality (ha)	(+/-) Canopy Growth & Mortality (%)	(-) Loss to Development (ha)	(-) Loss to Development (%)	(+) Tree Planting Required (ha)	(+) Tree Planting Required (No. Trees)	(=) Net UTC Increase (ha)	(=) Net UTC Increase (%)	(=) UTC in 2044 (ha)	(=) UTC in 2044 (%)
	1	*1%*	(27)	*-26%*	(33)	*-32%*	62	97	1	*1%*	104	*19%*
	8	*20%*	(10)	*-26%*	(33)	*-85%*	53	83	16	*40%*	55	*3%*
	8	*5%*	(39)	*-26%*	(33)	*-22%*	108	171	41	*27%*	192	*10%*
	32	*2%*	(363)	*-26%*	(33)	*-2%*	436	686	59	*4%*	1,453	*48%*
	15	*6%*	(63)	*-26%*	(33)	*-14%*	165	259	79	*33%*	321	*7%*
	11	*5%*	(57)	*-26%*	(33)	*-15%*	110	174	29	*13%*	247	*18%*
	64	*3%*	(624)	*-26%*	(33)	*-1%*	977	1,535	355	*15%*	2,751	*32%*
	55	*6%*	(256)	*-26%*	(33)	*-3%*	573	900	321	*33%*	1,304	*20%*
	10	*11%*	(23)	*-26%*	(33)	*-38%*	57	90	9	*10%*	97	*12%*
	204	***4%***	**(1,461)**	***-26%***	**(300)**	***-5%***	**2,542**	**3,995**	**910**	***16%***	**6,524**	***22%***

*Change Calculated after 30 Years

*Regeneration, Growth, Mortality, and Loss may result in negative Planting numbers

Figure 18: Screenshots of Mississauga's UFC Calculator illustrating an increase from 19% to 22% UFC.

Mississauga Land Cover Classifications

This report describes the methods used and generated results in mapping land cover types across the City of Mississauga. 2014 0.5-metre resolution, 4-band multispectral satellite imagery and GIS data were combined to map three land cover classes: (1) Tree Canopy, (2) Green Vegetation, and (3) Other. Object-based image analysis (OBIA) was used to map tree cover and other non-tree vegetation.

Accuracy Assessment

The main purpose of classification accuracy assessment is to measure how well the land cover classification estimates actual land cover on the ground. Even with high resolution imagery, very small differences in classification methodology and image quality can have a large impact on overall map area estimations.

The internal accuracy assessment was completed in five steps:

1. Five hundred (500) sample points were randomly distributed across the study area and assigned a random numeric value.
2. Sorting from lowest random value to highest (to ensure sequential randomized locations of reference), each sample point was referenced using the satellite imagery and assigned one of the three land cover classes ("Ref_ID").
    - In the event that the reference value could not be discerned from the imagery, the point was dropped from the accuracy analysis (no points were dropped for this assessment).
3. An automated script is then used to assign values from the classification raster to each point ("Eval_ID").
4. The classification supervisor provides unbiased feedback to quality control technicians regarding the types of corrections required (for example, "The classification is currently underestimating forest" would instruct the QC technician to focus on adding more tree canopy to the current classification *across the entire study area*[i].[1]
5. Accuracy is re-evaluated (repeat steps 3 &4) until an acceptable classification accuracy is achieved.

[1] This is "unbiased information" because there is no spatial component to the instructions. The QC technician applies edits across the entire study area.

		Reference Data			
		Tree Canopy	Vegetation	Other LC	Total Reference Pixels
Classification Data	Tree Canopy	99	8	0	107
	Vegetation	1	111	6	118
	Other LC	4	12	260	276
	Total	104	131	266	470
				Total Points ->	501
			Overall Accuracy =	94%	

Producer's Accuracy		User's Accuracy	
Tree Canopy	95%	Tree Canopy	93%
Vegetation	85%	Vegetation	94%
Other	98%	Other	94%

Figure 19: Sample Error Matrix

Sample Error Matrix Interpretation

Statistical relationships between the reference pixels (representing the true conditions on the ground; "Reference Data") and the intersecting classified pixels ("Classification Data") are used to understand how closely the entire classified map represents the Mississauga landscape. The sample error matrix represents the intersection of reference pixels manually identified by a human observer (columns) and classification category of pixels in the classified image (rows). The white boxes along the diagonals of the matrix represent agreement between the two pixel maps. Off-diagonal values represent the number of pixels manually referenced to the column class that were classified as another category in the classification image.

Overall accuracy is computed by dividing the total number of correct pixels by the total number of pixels reported in the matrix (99+111+260= 470 / 501 = 94%), and the matrix can be used to calculate per class accuracy percent's. For example, 99 points were manually identified in the reference map as Tree Canopy, while 1 point that should have been tree canopy was classified as vegetation, and 4 pixels were identifies as Other LC in the reference map. This relationship is called the "Producer's Accuracy" and is calculated by dividing the agreement pixel total (diagonal) by the reference pixel total (column total). Therefore, the Producer's Accuracy for Tree Canopy is calculated as: (99/104 = 0.95), meaning that we can expect that ~95% of all urban forest canopy in the Mississauga study area is covered by the "Tree Canopy" classification map. Conversely, the "User's Accuracy" is calculated by dividing the number agreement pixel total by the total number of classified pixels in the row category. For example, 99 classification pixels intersecting reference pixels were classified as Tree Canopy, but 8 pixels were identified as Vegetation, in the reference map. Therefore, the User's Accuracy for Tree Canopy is calculated as: (99/107 = 0.93), meaning that 93% of pixels classified as Tree Canopy in the classification were actual tree canopy in Mississauga. It is important to recognize the Producer's and User's accuracy percent values are based on a sample of the true ground cover, represented by the reference pixels at each sample point (it is cost-prohibitive to sample every pixel, so we use randomly selected points).

From 2007 to 2014, mapping indicates a change from 15% to 19% average urban forest canopy cover, or a 4% gain citywide. While canopy growth can be seen throughout the study area (note arrows in middle graphic below), slight underestimations in the 2007 canopy mapping and slight overestimations in the 2014 mapping mean that the net increase is likely somewhere between 2% and 4%. Unfortunately, the satellite imagery used in the previous analysis was not available in order to perform an independent accuracy assessment and further validate or refine UFC gain.

Figure 20 below illustrates canopy changes by showing 2007 (blue) and 2014 (yellow) UFC mapping, both overlaid on 2014 imagery in the same area. Black arrows show growth in dozens of areas. Figure 21 (next page) depicts canopy change at the parcel-level across the city.

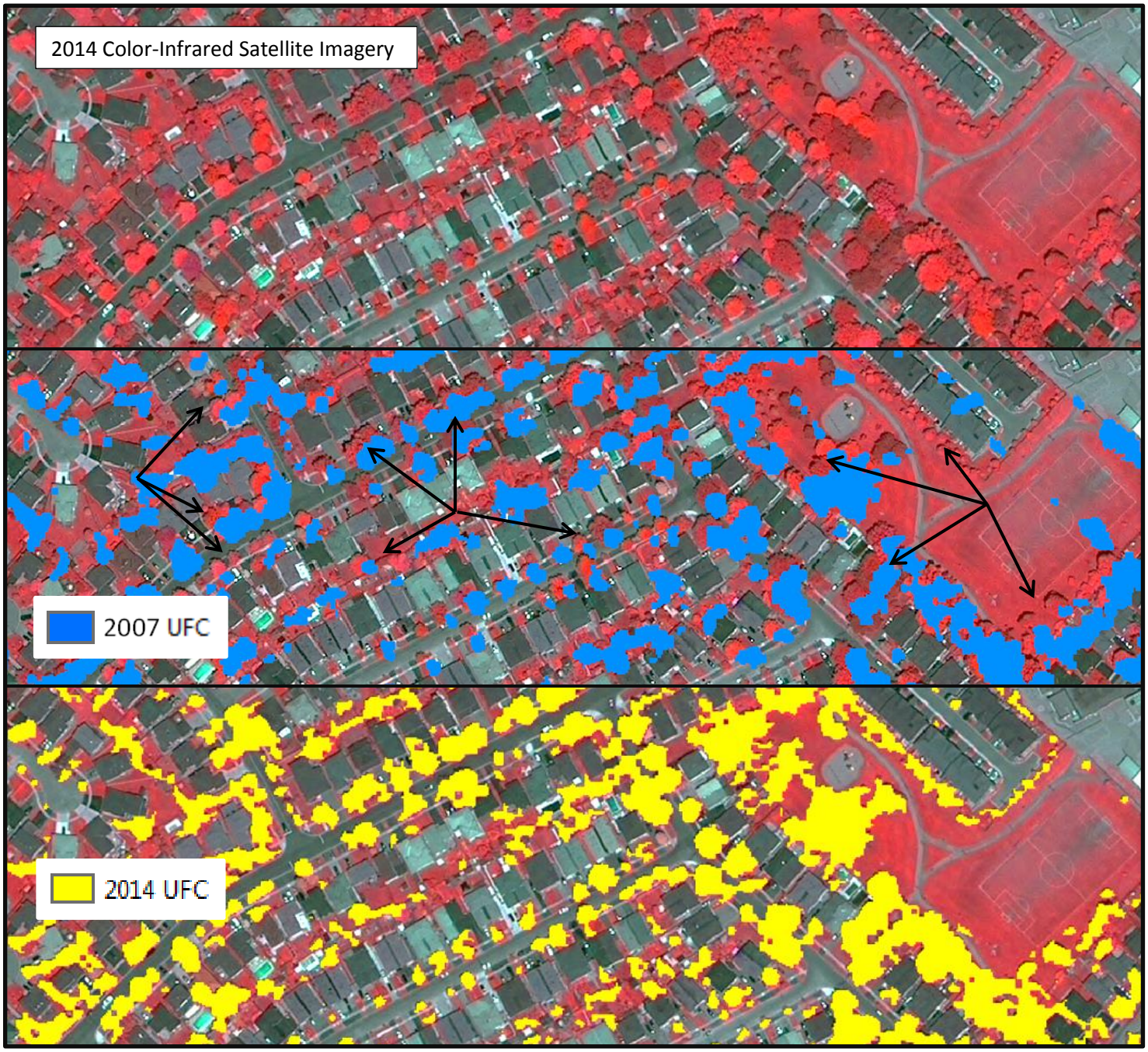


Figure 20: Canopy mapping and examples of gains from 2007-2014

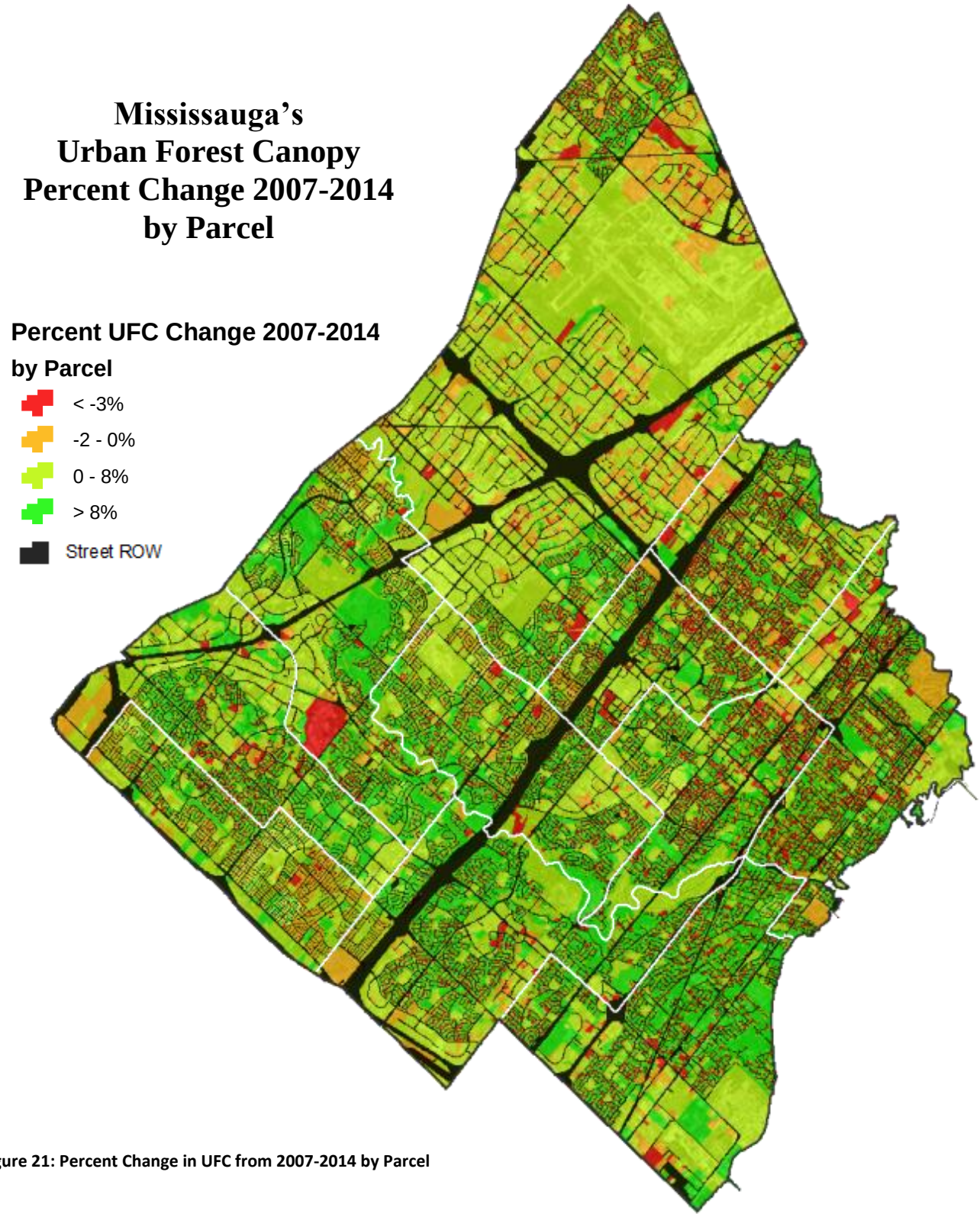


Figure 21: Percent Change in UFC from 2007-2014 by Parcel

	# of Parcels	Area of Parcels
Total Parcels:	143,970	29,200 hectares
Parcels with Canopy Loss:	32,527	253 hectares
Parcels with over 3% canopy Loss:	23,442	232 hectares
Parcels with Canopy Gain	93,715	1,479 hectares
Parcels with over 8% Canopy Gain	50,728	972 hectares

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