PEEL REGION URBAN FOREST BEST PRACTICE GUIDE 5

Working With Trees: Best Practices for a Resilient Future

October 2021

Peel Region Urban Forest Best Practice Guide 5

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Working together as part of the Peel Climate Change Partnership

Acknowledgments

This guide is the last in a series of five deliverables developed for Peel Region and its partners as part of the Peel Region Urban Forest Best Practices project. This guide draws from the other four documents and, like all the deliverables for this project, has been developed collaboratively with input and guidance from members of the Project Team, Peel Urban Forest Working Group, Peel Climate Change Partnership and other urban forestry and arboriculture professionals. Specific thanks are extended to:

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In addition to technical support, TRCA has also provided graphic design support.

Disclaimer

The guidance provided in this document is primarily intended for street and park trees in the Region of Peel and its local municipalities (i.e., the Town of Caledon, City of Brampton and City of Mississauga) as their urban forest planning evolves both in anticipation of and in response to shifts associated with climate change. Aspects of this guidance may be applicable to trees in natural areas and to other urbanizing areas in southern Ontario and beyond. The guidance in this document is intended to serve as a resource for application at the user's discretion; it does not reflect the position or direction of any of the partner agencies listed above.

Cover graphic credit: The MBTW Group

Executive Summary

The Region of Peel and its municipal and agency partners (the City of Brampton, City of Mississauga, Town of Caledon, Credit Valley Conservation Authority [CVC] and Toronto and Region Conservation Authority [TRCA]) have worked collaboratively for over a decade to identify and implement strategies to protect and enhance Peel's urban forest, and to help local communities mitigate and adapt to climate change. These partners are working together to address issues related to climate change adaptation through the Peel Climate Change Partnership (PCCP).

The PCCP has identified increasing the number of healthy trees in priority areas as one of its three strategies. In addition, one of the objectives of the Peel 2020 - 2030 Climate Change Master Plan is to "*protect and increase green infrastructure throughout Peel*" with tree planting and a management program for new and existing trees identified as key actions to achieve this objective. The Peel Region Urban Forest Best Practices project provides technical tools and guidance to implement these actions. The purpose of the project was to help sustain and expand tree cover in Peel's urban areas where it can provide benefits to the greatest number of people in the Region while also contributing to climate change mitigation and adaptation.

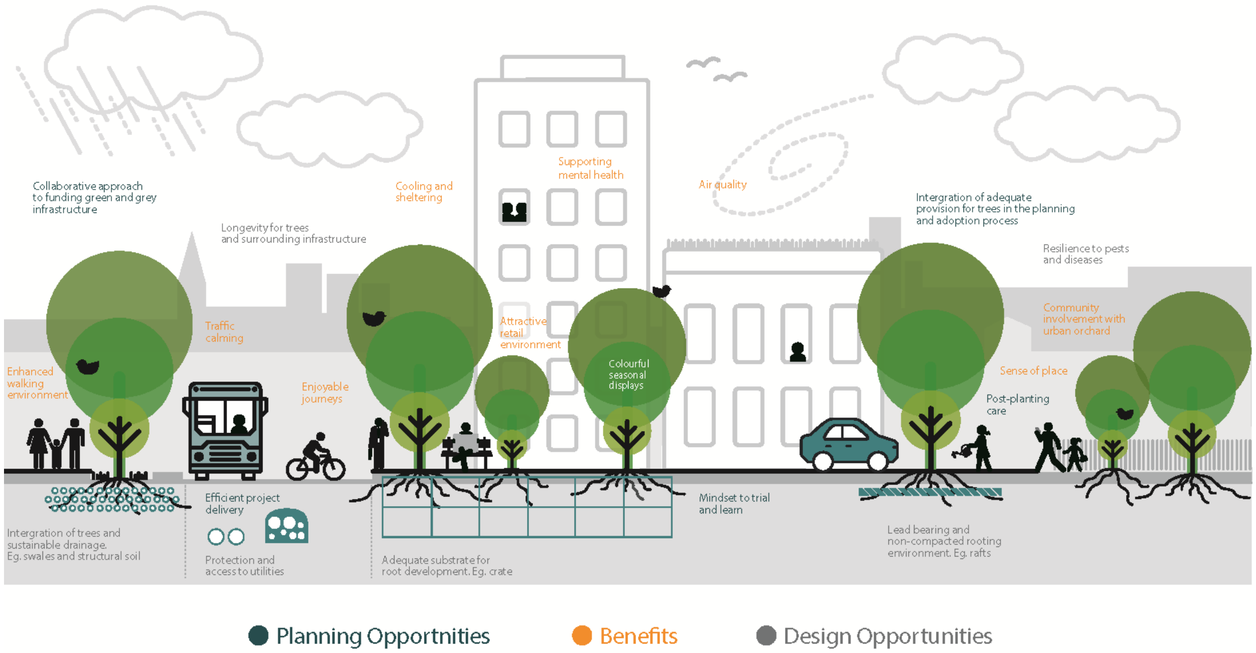
This guide is the fifth in a series of five documents developed as part of the *Peel Region Urban Forest Best Practice Resources* project. All five documents focus on guidance for street and park trees in Peel's urban areas. They provide strategic and technical guidance for different aspects of urban forest planning and management. This fifth guide highlights principles and lessons learned from the four other guides through a climate change lens.

- Guide 1: Best Practices Guide for Urban Forest Planning in Peel
- Guide 2: Urban Forest Management Best Practices Guide for Peel
- Guide 3: Guide for Tree and Shrub Standards and Specifications for Regional Roads in Peel
- Guide 4: Potential Tree Species for Peel in a Climate Change Context, and
- **Guide 5: Working with Trees: Best Practices for a Resilient Future**.

While this guide is meant to engage people with varying levels of knowledge about trees and urban forestry, the guidance is intended to be implemented with input from professionals with expertise in urban forestry, arboriculture and related fields.

While climate change has increased the need for more healthy and mature trees in busy urban spaces, it has also made it more difficult to provide trees with suitable habitats. The more frequent and intense flooding, heat, drought and storm events associated with climate change add additional stresses to the lives of urban trees, which already tend to be exposed to stressors (such as salt spray and vandalism). Consequently, sustaining and enhancing street and park trees, and the urban forest as a whole, requires a sustained commitment to providing the best possible growing conditions for trees and embracing a tree-friendly culture, not just among those directly involved in caring for these trees, but throughout the community.

The principles and strategies outlined in this guide are intended to help inform that commitment and are intended to be implemented within the adaptive framework provided.



Adapted from "https://www.tdag.org.uk/trees-planning-and-development.html", Trees and Design Action Group

Tree-related challenges and opportunities in a built urban setting

FIVE PRINCIPLES FOR BUILDING URBAN FOREST RESILIENCE IN A CHANGING CLIMATE

1. **Take Action Now:** The planet is on a "worst case" scenario trajectory for climate change, therefore the need to take actions to protect and enhance the urban forest has never been more urgent.

2. **Seek "Best Bets, No Regrets" Actions:** In general, if the perceived risks outweigh the potential benefits, consider other options, but if the value of the anticipated benefits outweighs the anticipated costs of failure, then push forward with the action.

3. **Right Tree, Right Place:** It is important to understand the range of conditions a given tree species is naturally adapted to, and work to match or provide as many of these conditions as possible when selecting establishment sites in cities.

4. **Plan to Adapt:** There continues to be uncertainty as to how climate change will impact the urban forest and how the urban forest will respond, therefore being able to collect and to respond to new information will be key.

5. **Be Proactive, Be Prepared:** Municipalities must actively plan and prepare for more frequent extreme events and other impacts of climate change that may negatively impact the urban forest. Time and effort invested pro-actively will save both money and resources when there is a need to respond.

UNDERSTANDING THE URBAN FOREST ASSET IN A CHANGING CLIMATE

Trees are a diverse group of organisms with variable tolerances and sensitivities to environmental conditions and stressors. Therefore, having a good understanding of the trees themselves (e.g., species, size, condition) and the locations in which they are being planted or are already growing is key to supporting their successful establishment and maintaining their health.

The different species of native and naturalized trees that occur in Ontario have adapted over centuries and millennia to a diverse range of climate and site conditions and to living naturally in co-dependent communities with other plants, wildlife and other organisms (such as fungi and bacteria in the soils). For trees to thrive outside of these communities in built-up urban areas, human intervention and management is usually needed to try and provide at least some of their basic needs for nutrition, water and space. This can be more effectively achieved in a built-up area by planning for and installing what are called "tiny" or "Miyawaki" forests, with at least a few other species in soils with some organics, moving away from individual trees in planters or boxes in the ground. In a rapidly changing climate there also should be consideration for incorporating species with historical and current ranges just south of the target planting area.

For urban trees to meet the expectations placed on them for environmental services, urban forest management needs to provide and maintain "habitats" for the trees, even on a micro-scale, that allow them to do more than just survive.

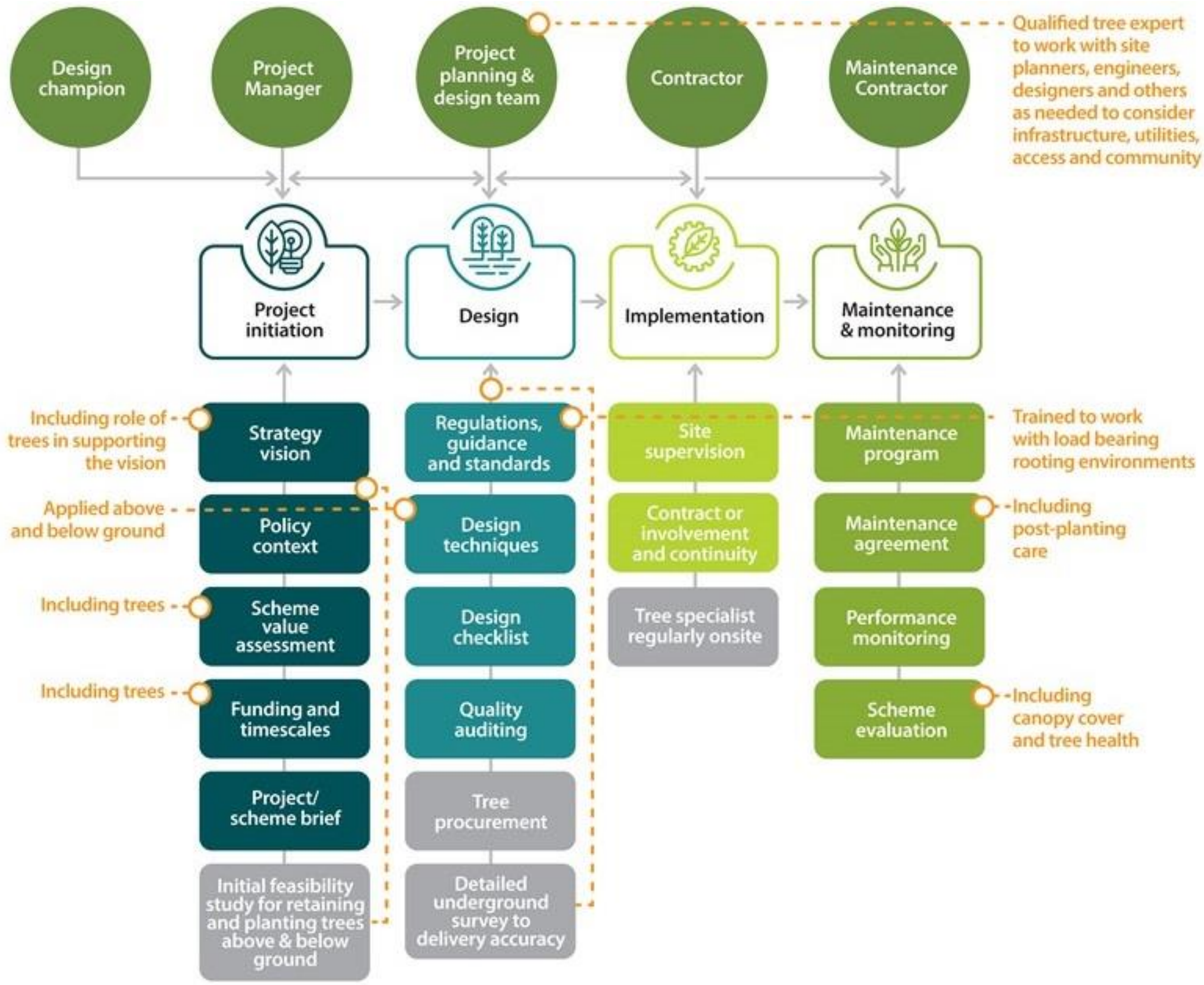
A good understanding of the urban forest is rooted in a comprehensive inventory of municipal trees that is maintained and can be shared, complemented by a jurisdiction-wide urban forest monitoring program that leverages the power of remote sensing. This understanding can inform strategic decision-making about where and how best to invest in establishing additional trees and maintaining the existing urban forest. It should also be supplemented by a willingness and ability to assess the site-specific context and conditions prior to investing in new plantings.

ENHANCING URBAN FOREST RESILIENCE AT ALL SCALES IN A CHANGING CLIMATE

The following 10 strategic best practices are key to building urban forest resilience in a changing climate.

1. Value the urban forest as an asset	Incorporate the urban forest into municipal asset management frameworks to ensure trees under municipal ownership are recognized for the services they provide and as assets requiring targeted maintenance and monitoring to sustain those services.
2. Invest strategically	Prioritize investments in actions that increase the resilience of the urban forest to current and anticipated stressors. This will maximize returns in a climate change context. For example, up-front investment in proper street and park tree species selection, establishment and good growing conditions can minimize large expenditures as trees mature.

3. Have a strategic plan	Develop a strategic Urban Forest Management Plan and integrate it with other jurisdiction-wide plans to protect, maintain, and establish trees in effective and locally appropriate ways. These plans can also help direct tree-related risk management and provide a framework for adaptive responses to new information and changing conditions.
4. Enhance tree and urban forest diversity	Incorporate structural, functional, and genetic diversity of all types and at all scales into the urban forest system to build resilience in the face of climate change. This should include the careful and gradual introduction of suitable species with ranges slightly south of the target planting area.
5. Plan with equity in mind	Improve the equitable distribution, availability, and quality of public greenspaces and tree cover across the jurisdiction. This may include targeting areas not immediately suitable for trees that require an initial investment and collaborative planning and design to create suitable space above and below-ground.
6. Take an integrated approach to planning	Align other municipal strategic plans with urban forest goals and embed urban forest objectives in all levels of planning to instill a common vision that includes trees as part of the solution to climate change challenges.
7. Take an integrated approach to design	Develop an integrated approach at the site-level to ensure implementation of street and park tree-friendly design through the cooperation, coordination, and expertise of multiple disciplines (e.g., urban foresters/arborists, planners, engineers, landscape architects, architects).
8. Seek climate-positive outcomes	Actively seek opportunities to moderate the urban heat island effect where it is felt by the most vulnerable people. Investing in planting trees able to reach maturity in built areas can provide significant cooling along with other services and benefits such as air quality improvements and wind breaks.
9. Foster a tree-friendly culture	Develop partnerships with other public and private sector landowners to create opportunities for protecting and expanding tree cover on lands not under municipal ownership or management.
10. Be proactive and be prepared	Invest in proactive urban forest management to reduce the negative impacts of an urgent situation like an ice storm or a destructive pest. Have preparations in place, such as emergency plans and funds. Climate change adaptation research in Canada has shown that every dollar invested in being prepared can save between four and six dollars required in reactive emergency responses.



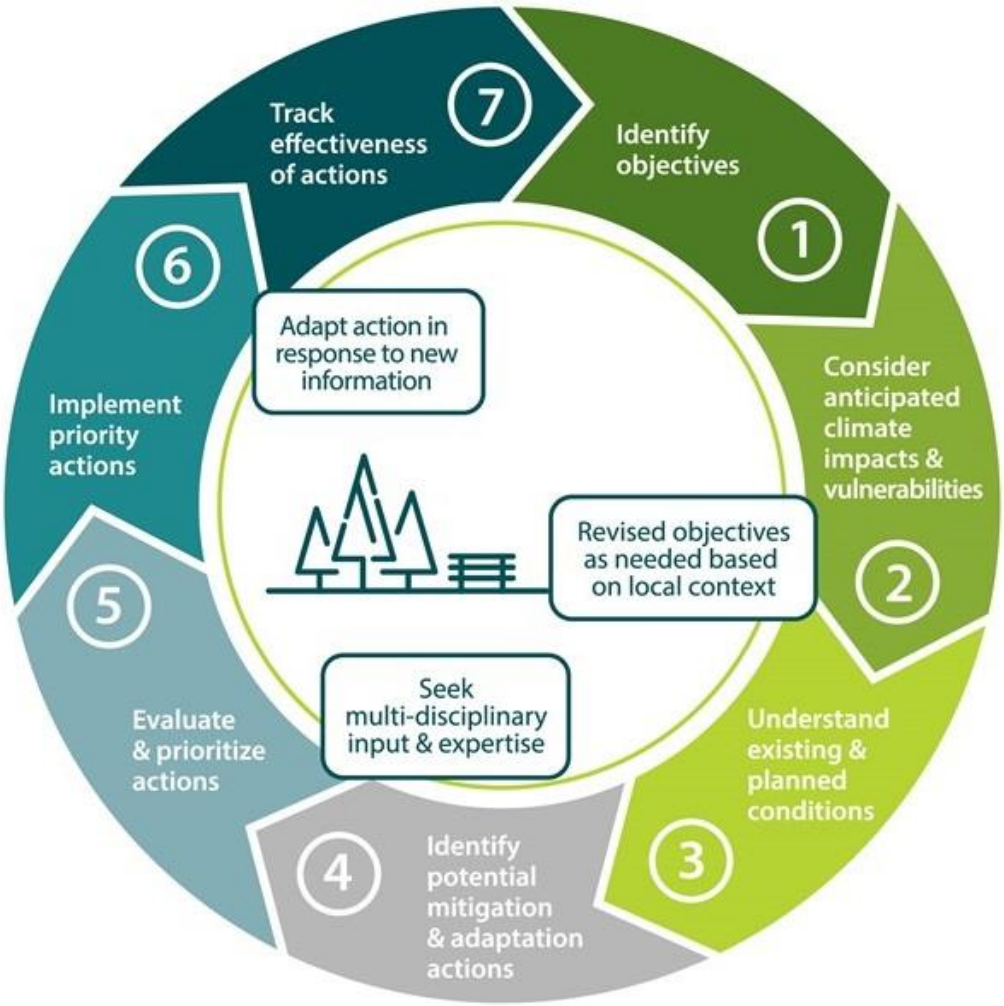
Credit: Adapted from Trees and Design Action Group (tdag.org.uk)

An example of an integrated design process for trees in built-up settings

ADOPTING AN ADAPTIVE PLANNING AND MONITORING FRAMEWORK

A climate change planning and adaptation framework was developed as part of this guide to help with the implementation of best management practices. The framework is intended to be flexible and responsive to new information and changing conditions and can be applied at the jurisdiction-wide scale and at the site-specific scale.

The essence of adaptive management is to learn while doing, monitor progress and be prepared to adjust as required. To learn from successes and mistakes, managers must strategically and repeatedly document actions taken, track the results of these actions, assess the results in achieving the intended outcomes and depending on the outcome of the assessment, continue or revise the approach.



Planning and adaptation framework for trees and the urban forest

CONCLUDING REMARKS AND NEXT STEPS

Climate change has introduced a much greater degree of uncertainty into environmental and community planning, making protecting and sustaining trees in the urban forest challenging, particularly in built-up areas. However, many of these challenges can be overcome with careful and collaborative planning and management undertaken at various scales with input from knowledgeable urban forestry and arboriculture professionals.

Urban forests provide a wide range of services and co-benefits that contribute directly to community health and well-being, with the full value of these services being increasingly recognized. Therefore, investing proactively in the urban forest to help make it more resilient to climate change is a relatively straightforward and cost-effective strategy for helping communities adapt to climate change.

Taking a climate-sensitive approach to urban forest planning and management largely means working to implement many of the same urban forest best practices identified before climate change became such an urgent matter, but with more emphasis on proactive management and more careful consideration for the strategic directions outlined in this guide.

Contents

Tables

Figures

1. Introduction

The Region of Peel and its municipal and agency partners (the City of Brampton, City of Mississauga, Town of Caledon, Credit Valley Conservation Authority [CVC] and Toronto and Region Conservation Authority [TRCA]) have worked collaboratively for over a decade to identify and implement strategies to protect and enhance Peel's urban forest, and to help local communities mitigate and adapt to climate change. These partners work together to address issues related to climate change adaptation through the Peel Climate Change Partnership (PCCP).

The PCCP identifies increasing the number of healthy trees in priority areas as one of its three strategies (as shown in **Figure 1-1**). In addition, one of the objectives of the Peel 2020 - 2030 Climate Change Master Plan is to "*protect and increase green infrastructure throughout Peel*", with tree planting and a management program for new and existing trees key actions to achieve this objective.

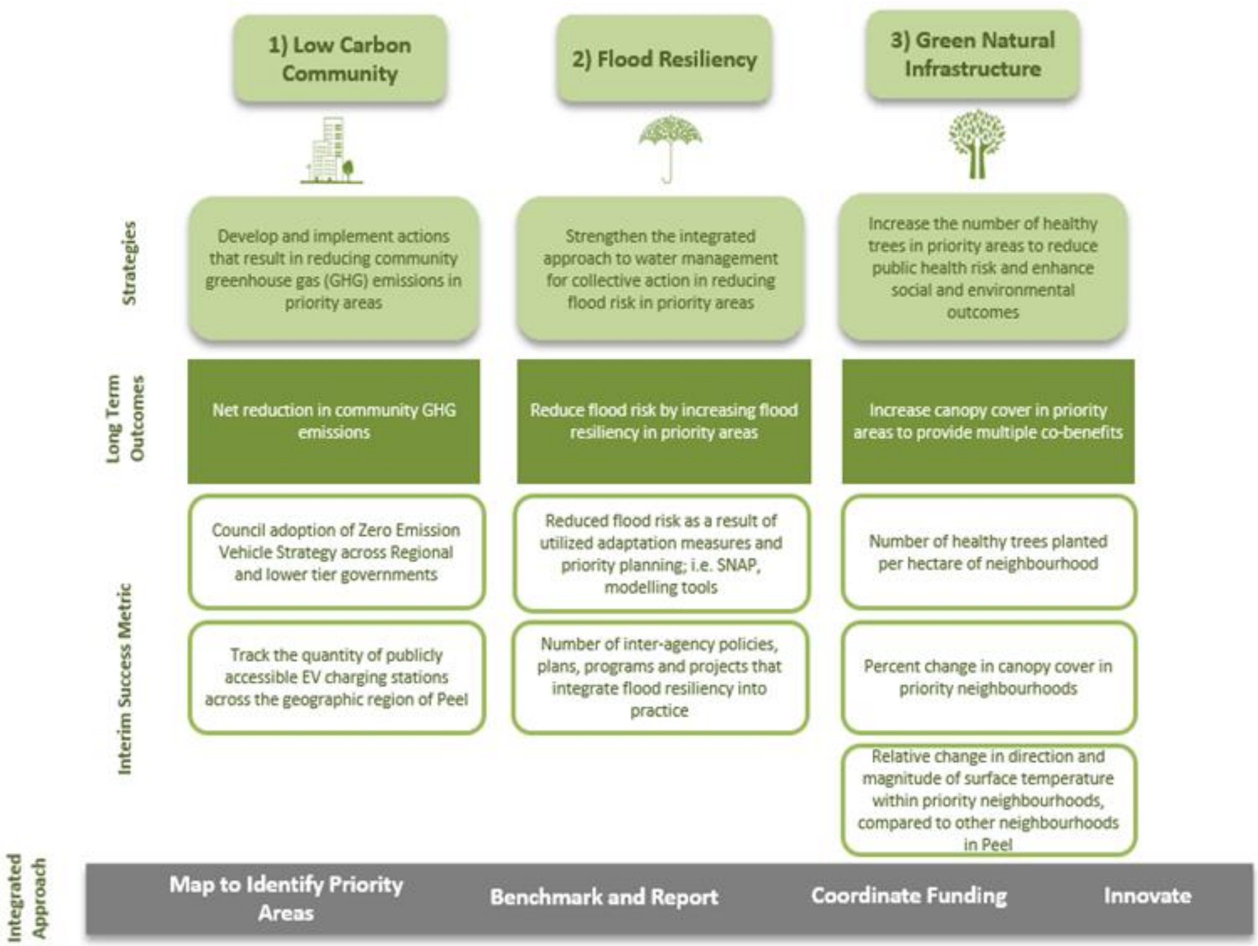


Figure 1-1. Overview of the Peel Climate Change Partnership Strategy 2018 – 2022 components

This guide is the fifth in a series of five documents developed as part of the Peel Region Urban Forest Best Practices project. The aim of the project is to help sustain and expand tree cover in Peel's urban areas, to provide benefits to the greatest number of people while also contributing to climate change mitigation and adaptation[1] (see **Figure 1-2**). All five documents focus on guidance related to street and park trees in Peel's urban areas[2].

The following resources developed for Peel provide strategic and technical guidance for different aspects of urban forest[3] planning and management:

- Guide 1: Best Practices Guide for Urban Forest Planning in Peel
- Guide 2: Urban Forest Management Best Practices Guide for Peel
- Guide 3: Guide for Tree and Shrub Standards and Specifications for Regional Roads in Peel
- Guide 4: Potential Tree Species for Peel in a Climate Change Context, and
- **Guide 5: Working with Trees: Best Practices for a Resilient Future**.

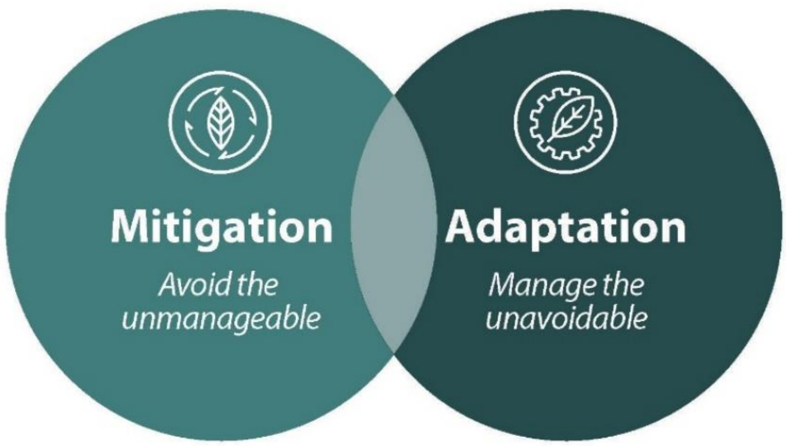


Figure 1-2. Illustration of the distinction between mitigation and adaptation

The best practices and opportunities identified in these guides can also support the implementation of other strategies and plans related to climate change and urban forestry developed by the partners, including: the Region of Peel's *Urban Forest Strategy* (2011); the City of Mississauga's *Urban Forest Management Plan* (2014) and *Climate Action Plan* (2019); the City of Brampton's *One Million Trees Strategy* (2019), *Community Energy and Emissions Reduction Plan* (2020) and *Urban Forest Management Plan* (in progress); and the Town of Caledon's *Tree Seedling Program* (2019) and *Community Climate Change Action Plan 2020 - 2050*.

[1] In the context of climate change, "mitigation" specifically refers to efforts to reduce the causes of and environmental shifts associated with climate change (such as reducing GHGs), while "adaptation" means adjusting responses to changes in the environment to try and manage or limit the negative consequences of these changes.

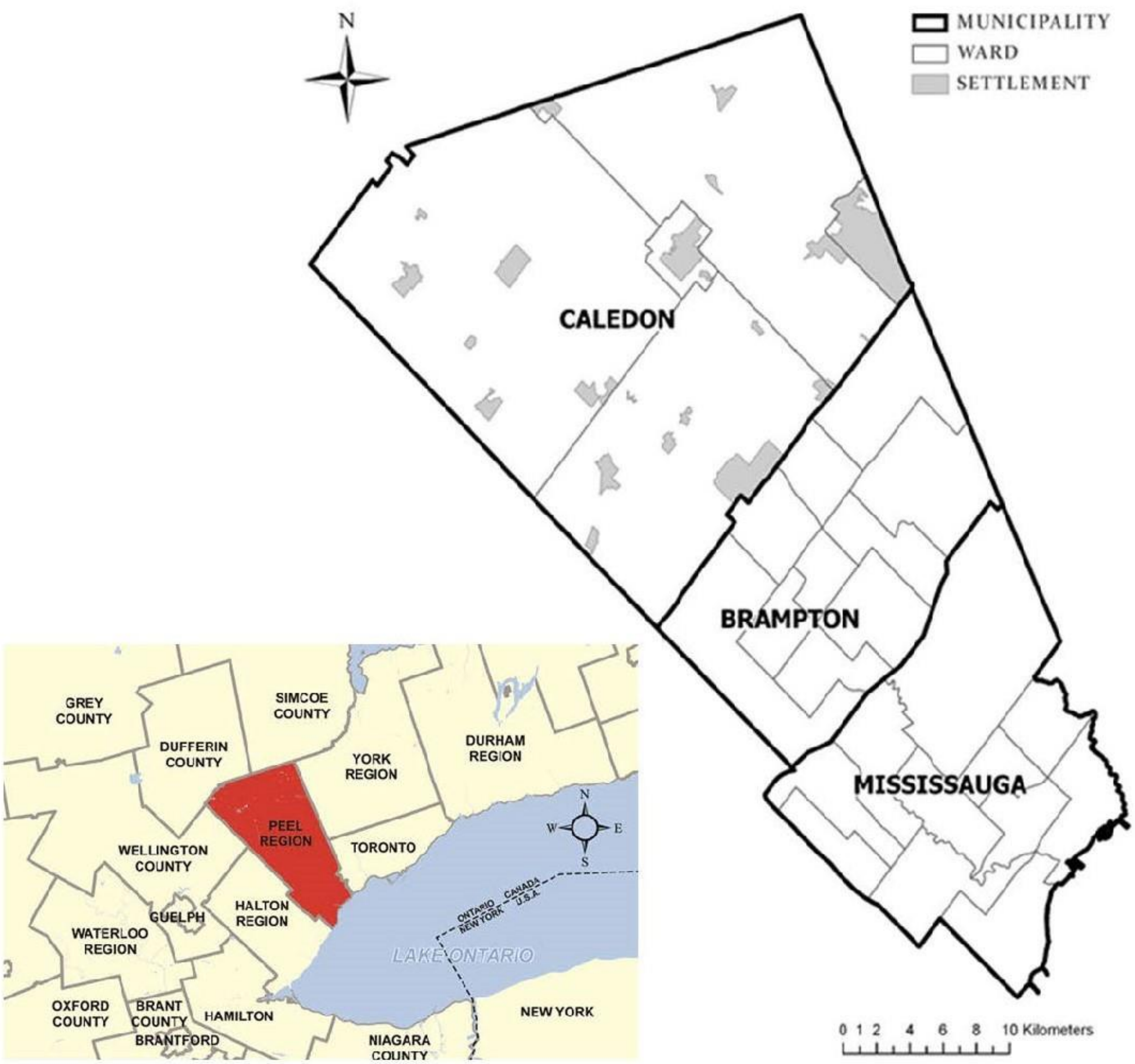
[2] Notably, some of the more strategic-level guidance, particularly in Guides 1, 2 and 5, may also be applicable to trees in other settings (e.g., natural areas, rural areas), and trees in other urbanizing jurisdictions.

[3] Peel defines its urban forest 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" (Region of Peel 2011).

The five documents developed for this project contain best practices for trees in urban areas, with a focus on individual street and park trees on municipal lands. While this guide is meant to engage people with varying levels of knowledge about trees and urban forestry, the guidance is intended to be implemented with input from professionals with expertise in urban forestry, arboriculture and or related fields.

GEOGRAPHIC AREA OF FOCUS

Peel Region is a 1,247 km^2 wedge of land extending from Lake Ontario in the south to beyond the Niagara Escarpment in the north. It consists of three local municipalities: the cities of Brampton and Mississauga, which are entirely urban and almost entirely built out, and the Town of Caledon, which is largely rural with scattered settlement areas (see **Figure 1-3**).



Credit: Adapted from B.A. Blackwell & Associates Ltd. (2017)

Figure 1-3. Location of Peel Region and its three local municipalities

Peel's population was 1.5 million in 2020 and is projected to grow to close to 2 million by 2041, with most of that growth expected in urban areas. At the same time, unprecedented shifts in temperature and precipitation associated with climate change have already begun having impacts in Peel (e.g., Tu *et al.,* 2017; Region of Peel 2018). This emerging reality has created an urgent need for actions to slow the pace of climate change and reduce greenhouse gas (GHG) emissions (i.e., mitigation) and to help communities prepare for and respond to these changes (i.e., adaptation).

Proactively identifying and implementing nature-based solutions to climate change is an approach with increasing appeal because these approaches can be introduced cost-effectively with existing tools and offer results in the near-term, while providing a broad range of local services and co-benefits that directly contribute to improved human health, such as cooling and reducing air pollution (e.g., Domke *et al.,* 2020; Nowak 2013; Nowak *et al.,* 2018).

CONTENTS AND INTENT OF THIS GUIDE

This document is intended to help sustain and increase the number of healthy trees in priority areas by outlining an urban forest planning and adaptation framework appropriate for Peel, including five guiding principles (**Section 2**), and providing high-level best practices to support the implementation of that framework, including:

- Considering anticipated climate impacts and vulnerabilities (**Section 3**)
- Providing strategies for assessing and monitoring the urban forest at regional, municipal and sites-specific scales (**Section 4**), and
- Providing an overview of best practices and opportunities to maximize the resilience of the urban forest, with a special focus on municipal street and park trees (**Section 5**).

More specific information to supplement the high-level best practice directions identified in this guide is provided in the four other guidance documents developed for Peel Region and its partners as part of the Peel Region Urban Forest Best Practices project.

This guide highlights a range of best practice strategies but does not identify priorities for implementation and monitoring in Peel Region, or elsewhere. Selecting priorities for implementation and monitoring should be done by each municipality or jurisdiction with its partners based on local conditions and resources as part of sustained efforts to develop, update and implement urban forest strategies, plans and policies for building resilience.

Trees have tremendous capacity to help communities deal with climate change but are also living organisms that can be impacted by environmental stressors (e.g., heat, drought, extreme storms), many of which are exacerbated by the urban environment and climate change, making protecting and sustaining trees in the urban forest challenging. This guide outlines principles and high-level strategies for addressing these challenges while building urban forest resilience.

2. Guiding Principles and Framework

Trees are increasingly recognized and valued for the wide range of services they provide to communities. These include:

- Storing carbon[4]
- Improving air quality
- Moderating extreme heat (e.g., through shading and cooling) in the summer
- Providing wind breaks
- Helping to manage both water quantity (e.g., flooding) and quality (e.g., erosion)
- Supplementing local food sources (e.g., edible nuts, fruits and syrup), and
- Providing habitat for other plants and wildlife that may provide additional services (e.g., insects that provide pollination for other food crops).

Many services provided by urban trees[5] also support community-level mitigation of and/or adaptation to climate change. These services are particularly valuable in urban areas that are increasingly exposed to more intense periods of heat, flooding and storms under climate change (described further in **Section 3.1**). Trees have the capacity to help communities adapt to climate change by providing the services noted above and also have the unique ability to increase the provision of services exponentially as they mature. However, as biological organisms they are also vulnerable to environmental stressors, including many that are exacerbated by climate change (described further in **Section 3.2**). Therefore, a framework for leveraging the urban forest to support community mitigation and adaptation to climate change should incorporate approaches that support and sustain healthy mature trees, while also reducing urban forest vulnerabilities to climate change. Frameworks should also be flexible and responsive to new information and changing conditions.

This section outlines five key principles that have emerged out of the research and engagement completed for this project (**Section 2.1**). They provide a framework for urban forest planning and adaptation (**Section 2.2**) that embeds an adaptive management approach, which will be key to management of trees in a climate change context.

This framework can be applied at the jurisdiction-wide scale and the site-specific scale and can be used to help implement the urban forest best practices identified for urban trees in a climate change context in **Section 4** and **Section 5**.

[4] Recent assessments estimated that Peel's urban forest stores more than 12 million metric tonnes of CO_2 and provides air quality control to the tune of about $39.5 million CAD annually (B. A. Blackwell & Associates Ltd. 2017).

[5] A literature review of the benefits and services provided by trees and the urban green spaces conducted for Peel Region and its partners can be found in Priority Tree Planting Areas to Grow Peel's Urban Forest (Beacon *et al.*, 2015).

2.1 Guiding Principles for Building Urban Forest Resilience

The following five guiding principles for building urban forest resilience in Peel have been identified based on insights gathered from input from the Project Team, research on urban forestry best practices and opportunities, and engagement with professionals in a variety of sectors involved in tree establishment and maintenance in urban settings[6].

PRINCIPLES FOR ENHANCING THE URBAN FOREST IN A CLIMATE CHANGE CONTEXT

1. TAKE ACTION NOW
2. SEEK "BEST BETS, NO REGRETS" ACTIONS
3. RIGHT TREE, RIGHT PLACE
4. PLAN TO ADAPT
5. BE PROACTIVE, BE PREPARED

PRINCIPLE 1: TAKE ACTION NOW

In 1992, an international accord on climate change was signed under the auspices of the United Nations. There have been numerous subsequent international and sub-national agreements since then to address the threats from climate change. This includes, in October 2019, the Region of Peel joining many other jurisdictions in declaring a climate change emergency. Today's science indicates, more than ever, that without significant and widespread reductions in greenhouse gas emissions, the planet is on a "worst case" scenario trajectory for climate change (IPCC 2018). This scenario anticipates large and likely irreversible changes to planetary systems and processes that make the planet livable for people and trees. The need for action has never been more urgent.

PRINCIPLE 2: SEEK "BEST BETS, NO REGRETS" ACTIONS

Forest managers can be challenged to make decisions in the face of incomplete information and uncertainty. Adopting a strategy of searching for "best bets-no regrets" options involves making decisions using the best available information, preferably using multiple lines of evidence, from trusted sources that will contribute to adaptation and diversity while doing no harm (FGCA 2017). In general, if the perceived risks outweigh the potential benefits, consider other options; if the value of the anticipated benefits outweighs the anticipated costs of failure, then push forward.

PRINCIPLE 3: RIGHT TREE, RIGHT PLACE

Many of the best practices identified for trees in urban areas simply come down to understanding the range of conditions a tree is naturally adapted to and trying to provide growing conditions that approximate what favours a species in its natural environment. Integrating more healthy trees into urban areas requires a better understanding of the range of conditions (e.g., soils, drainage, exposure) a given species is naturally adapted to, and working to mimic these conditions (even on a small scale) in cities.

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[6] Several of these principles have been adapted from and / or are aligned with the principles for climate change adaptation outlined by the Forest Gene Conservation Association (FGCA) in Ontario https://fgca.net/programs/climate-change/

PRINCIPLE 4: PLAN TO ADAPT

There remains, and will continue to be, substantial uncertainty about how quickly the climate will change, the regional nature of the changes and the ways that different tree species and the urban forest will respond. While this makes decision-making challenging and riskier because decisions made with uncertainty can have unintended negative consequences, the potential risks from taking no action in the face of climate change are most likely greater. There is still a great amount of uncertainty related to how climate change will impact the urban forest and how the urban forest will respond, therefore being able to collect
and to respond to new information will be key.

PRINCIPLE 5: BE PROACTIVE, BE PREPARED

Investing in good planning and enforcement along with proactive and strategic urban forest maintenance and monitoring can go a long way toward reducing the negative impacts of a wind or ice storm, or a destructive pest or disease. However, since the frequency and intensity of such events is expected to increase, having preparations in place (such as emergency tree response plans) to guide responses when needed, and having an emergency reserve fund (to address post-emergency remediation when required) can pre-empt the need for unplanned emergency responses. In addition, urban forest planners and managers need to find ways to stay abreast of current developments related to trees and climate change adaptation as part of their work (e.g., through partnerships, conferences, multi-disciplinary teamwork). This will be critical to inform ongoing decision-making related to street and park trees and the broader urban forest, including how to prioritize investments and actions.

2.2 Planning and Adaptation Framework

A climate change planning and adaptation framework has been developed for Peel's urban forest as part of this project. This framework is comprised of a seven-step adaptive management cycle, as illustrated in **Figure 2-1** and outlined below. The circular structure of this framework embeds the principle of adaptive management, while the steps in the framework embody many of the guiding principles outlined in **Section 2.2**.

The framework is intended to help implement the best practices outlined in this Guide (along with supplemental information provided in the other four Guides developed for this project), and is aligned with the strategic best practices appropriate for Peel's urban forest, as follows:

- Identification of Peel-wide climate change objectives related to the urban forest, as per Step 1, is provided in **Section 1**
- Consideration of climate impacts and vulnerabilities related to Peel's urban forest, as per Step 2, is provided in **Section 3**
- High-level guidance for understanding and monitoring existing conditions, as per Step 3, is provided in **Section 4** and
- High-level guidance to inform potential mitigation and / or adaptation actions, as per Step 4, is provided in **Section 5**.

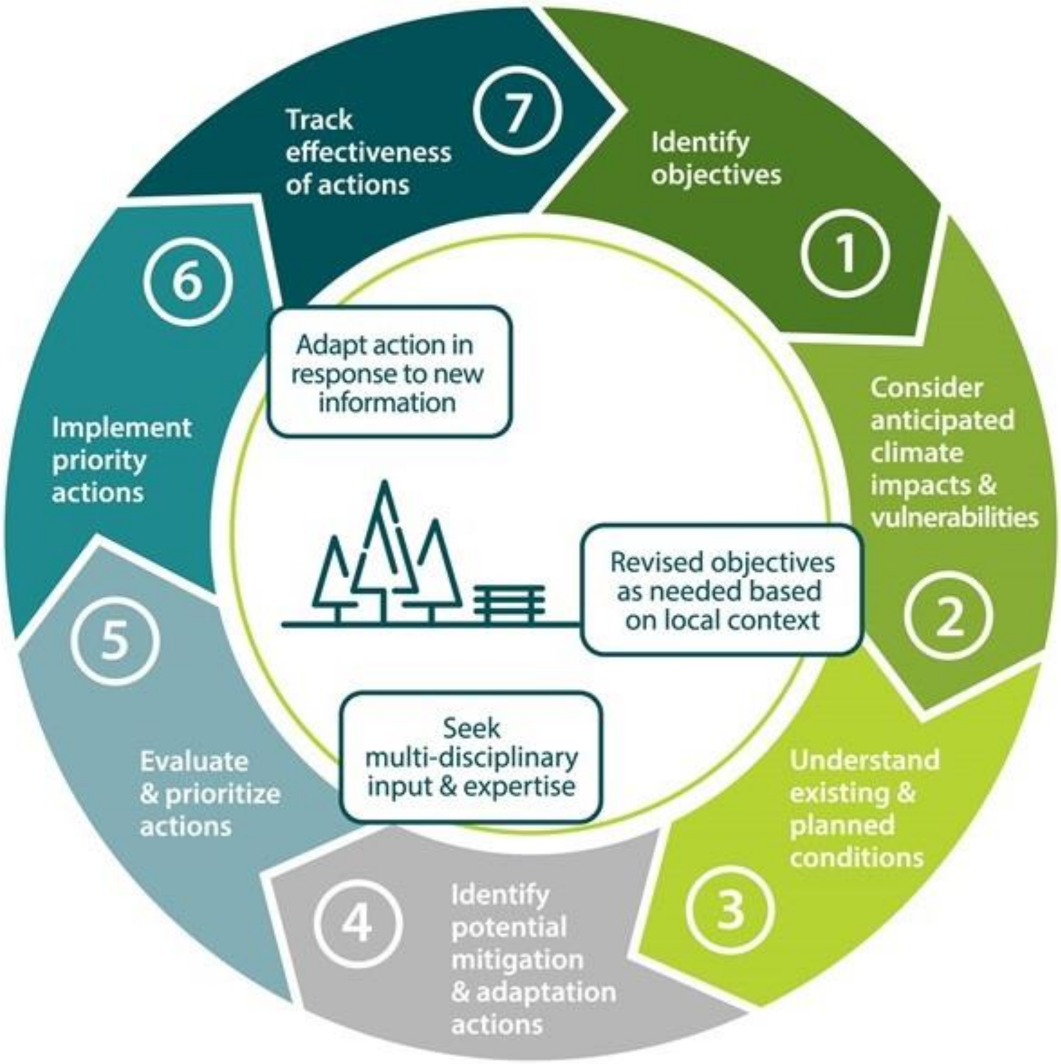


Figure 2-1. Planning and adaptation framework for Peel's urban forest

This framework can be applied at the strategic jurisdiction-wide scale and at the site-specific scale. In addition, although it was developed for municipal street and park trees in Peel, it could also be applied to other treed assets and in other jurisdictions.

Action prioritization, implementation and monitoring (as per Steps 5 through 7 in the framework) can be undertaken by the Region of Peel and its partners as part of their ongoing efforts to develop, update and implement urban forest strategies, plans and policies at various scales in a climate change context.

Additional guidance appropriate for Peel to supplement the high-level best practices in this guide is provided in the four other guidance documents developed as part of the Peel Region Urban Forest Best Practices project. The information and best practice guidance provided in these guides can be used to select and prioritize mitigation and / or adaptation actions at the strategic jurisdiction-wide scale as well as at the area or site-specific scale.

3. Climate Change Impacts and Vulnerabilities

Global climate change is the term used to describe the average long-term changes in climate over the entire Earth. It is well established that significant shifts in Earth's climate are occurring at an unprecedented rate and that these shifts have been triggered by human activities. Scientists have observed significant warming of the Earth's surface, with many of the warmest years on record occurring in the past 20 years. To be able to manage for this ongoing change, it is necessary to understand what future climate is anticipated for Peel Region and how this may affect the local urban forests.

Trees are long-living resilient biological organisms that present unique opportunities and challenges in relation to climate change. Trees have significant capacity to help communities both mitigate and adapt to climate change (see **Section 5.1**), but can also be negatively impacted by environmental stressors, including those exacerbated by climate change (see **Section 3.2**).

The Intergovernmental Panel on Climate Change (IPCC) is the United Nations body tasked with assessing the science related to climate change. Since the 1990s, researchers from around the world have been collaborating to develop scenarios of projected changes in climate for use in impact and adaptation assessments and to inform mitigation opportunities (IPCC 2014). In Peel, climate projections have been interpolated to the regional scale (Auld *et al.,* 2016). These assessments have informed strategic directions for the Peel Climate Change Partnership (PCCP) and climate change action planning across the Region.

Based on the current science and assuming continued greenhouse gas emissions increases, the planet is on track to follow what is referred to as the "business as usual" or the "worst case" scenario, also known as RCP8.5 (IPCC 2018; NRCan 2021). This project looked at the projected climate in the 2041 to 2070 window under the RCP8.5 scenario to consider how anticipated climate conditions in Peel may affect the vulnerability of Peel's urban forest (as outlined in **Section 3.1** and **Section 3.2**).

Details of the methods and results for vulnerability assessments for 88 tree species that are currently, or could become, established in Peel under projected conditions in the 2041 to 2070 window under the RCP8.5 scenario are provided in Guide 4. Guide 4 also includes additional details about anticipated climate conditions and impacts to the urban forest, as well as guidance as to how the vulnerability assessments can be used to inform selection and diversification of street and park tree plantings in Peel under a changing climate.

The following sub-sections outline (i) anticipated climate conditions in Peel based on local projections (**Section 3.1**) and (ii) the key vulnerabilities of trees and risks to the urban forest under these anticipated conditions (**Section 3.2**).

3.1 Anticipated Climate Conditions in Peel

> *Climate change is one of the greatest challenges humans face in the 21st century… The warming trend is no longer reversible … even if we drastically curb greenhouse gas emissions today, we will still continue to experience devastating climate change effects for decades to come. Adaptation is needed at all levels, from local to global, to adjust to the new reality …*
>
> *Natural Systems Vulnerability to Climate Change in Peel Region* (Tu *et al.,* 2017)

Climate change will reduce liveability and pose threats to human health and to the biophysical systems humans depend upon, especially in urban areas. Anticipated changes for Peel Region include warming temperatures, altered precipitation and increases in extreme climatic events. Regionally specific projections for the period 2041 to 2070 under an RCP8.5 scenario include the following (from Auld *et al.,* 2016).

TEMPERATURES

- Mean annual temperatures in Peel Region are expected to increase by 2°C, with the greatest increases in winter.
- In the summer, days above 30˚C are likely to increase from 12 to 26 days per year, including days with temperatures exceeding 35˚C, which have not historically occurred in Peel.
- The greatest increases in temperature will occur in Mississauga and Brampton, where the urban heat island effect[7] will raise extreme temperatures even higher.

PRECIPITATION AND DROUGHT

- Annual increases in precipitation are expected, but coupled with higher evaporation rates, the anticipated outcome is an overall drier growing season (i.e., from a 9.3 mm historical water surplus to a water deficit of 19.5 mm).
- More frequent and more intense heavy precipitation events:
    - The worst 1% and 5% of extreme rainfall events will increase by 51% and 28%, respectively; and
    - The heaviest 1% of precipitation events will produce 50% more rainfall than has historically been the case.

STORMS

- While the risk of ice storms will decrease in spring and fall, the frequency of freezing rain events over winter is projected to increase by 40%.
- Wind gusts of 70 km/h or higher are expected to be about 17% more frequent than under current conditions (although there is considerable uncertainty in this projection).

[7] Urban heat island effect: When dark coloured surfaces like roads and rooftops absorb heat from the sun, they trap and slowly release heat back into the air, increasing temperatures in the surrounding environment and creating "islands" of heat. Heat islands often get hotter throughout the day, becoming more pronounced after sunset because the heat that was stored is slowly released at night.

3.2 Understanding Climate Change Vulnerability

Climate change vulnerability has three components:

- Exposure to climate-caused stresses
- Sensitivity of the selected element (in this case, the trees) to that stress, and
- The potential of the element to adapt to that stress (also called adaptive capacity).

There are two broad kinds of actions that can be taken to reduce vulnerability: (1) reduce exposure to the stressor(s) and (2) increase adaptive capacity of the element (in this case, the trees). For the urban forest, these types of actions may be undertaken at different scales, ranging from site-specific to jurisdiction-wide, as per the examples provided in **Table 1**.

Table 1. Examples of urban forest actions to reduce vulnerability to climate change

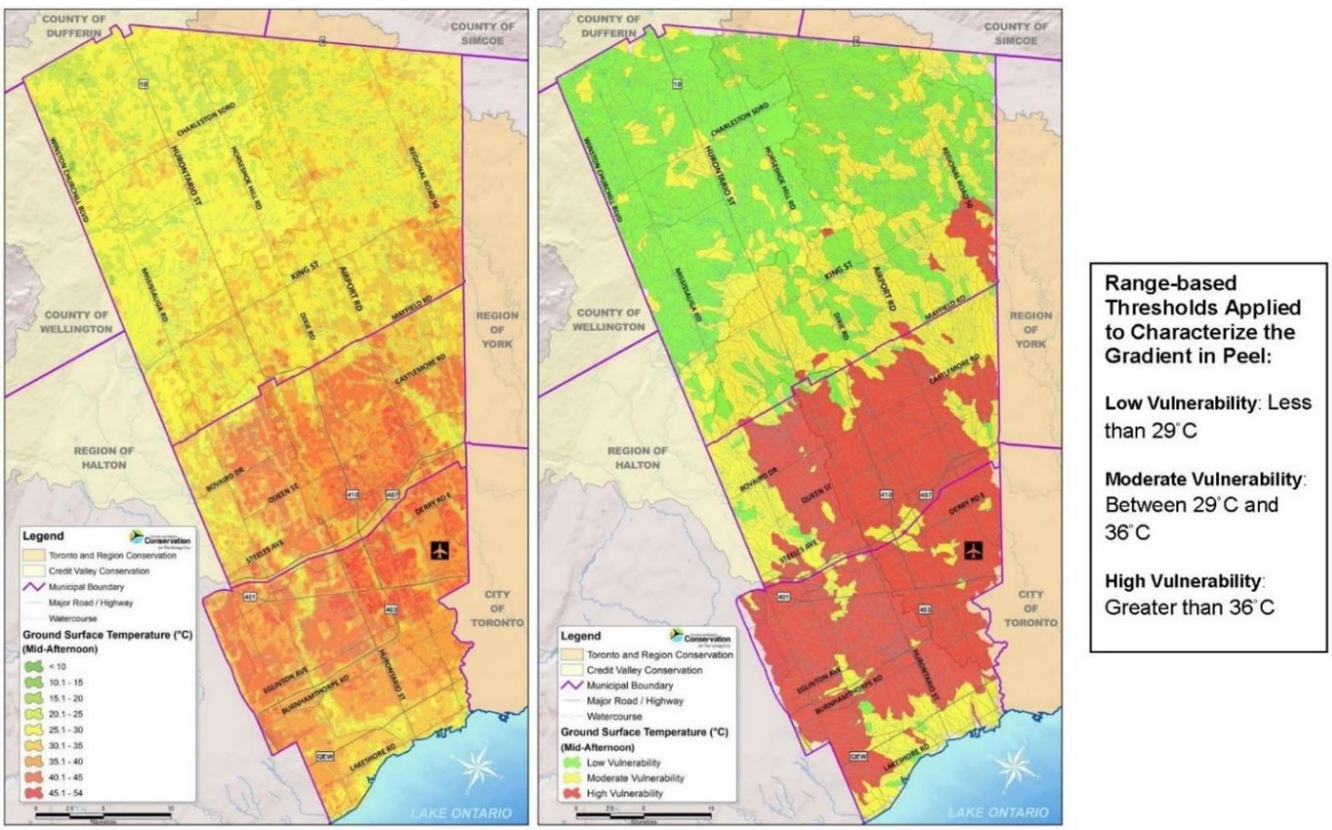
Scale of Action	Action Type	Example of Action
Site-specific	Reduce exposure	Flush the rooting area for a boulevard tree with fresh water after snow melt in the spring to dilute and rinse out the salts accumulated from winter sidewalk and road safety applications.
Jurisdiction-wide	Reduce exposure	Perform regular and proactive tree pruning on municipally owned and managed lands.
Site-specific	Increase adaptive capacity	Plant a tree in a parking lot island, providing it with ample rooting space, good quality soil, passive and active water sources, and adequate drainage.
Jurisdiction-wide	Increase adaptive capacity	Increase the diversity of trees planted to include a range of species and genera from local sources and some sources from more southerly zones.

The guiding principles and the planning and adaptation framework identified for Peel's urban forest (provided in **Section 2.2** and **Section 2.3**) are intended to promote actions that both reduce / manage exposure to both urban and climate change stressors and / or increase the adaptive capacity of the trees in the urban forest to respond to those stressors.

3.3 Key Urban Forest Vulnerabilities and Risks

Although forests in Canada are anticipated to be impacted much less severely than those in tropical regions over the next century (Duffy *et al.,* 2021), they are still expected to be challenged by both "primary" and "secondary" environmental stressors (e.g., Tu *et al.,* 2017; CVC 2018; Zhang *et al.,* 2019; Lehman *et al.,* 2020). These stressors have the potential to impact trees in natural areas as well as more isolated individual street and park trees.

"Primary" environmental stressors include: increased average temperatures, more frequent and extended periods of heat (see **Figure 3-1**) and drought, wider temperature fluctuations, and altered intensities of precipitation and high winds, including both flooding and ice storms. These stressors can directly impact the ability of trees in the urban forest to become established, grow and survive. There are also a host of "secondary" environmental stressors that have the potential to be introduced and / or exacerbated by climate change, such as tree diseases and pests currently in Peel becoming more robust, and diseases and / or pests spreading into Peel that were previously absent because of the generally colder winters.



Credit: *Natural Systems Vulnerability to Climate Change in Peel Region* (Tu *et al.,* 2017)

Figure 3-1. Mid-afternoon ground surface temperatures in Peel (left) and terrestrial vegetation vulnerability to ground surface temperatures (right)

These primary and secondary environmental stressors are expected to impact trees throughout Peel, but trees in Peel's urban areas are particularly vulnerable. This is because even without climate change, trees in urban areas are already subject to warmer temperatures, more air pollutants, longer periods of drought and more unpredictable access to water due to the predominance of buildings, paved surfaces and infrastructure. These stressors will be exacerbated by climate change. How these projected climatic changes will impact trees in Peel's urban areas, and how these changes can contribute to making Peel's urban forest more vulnerable, are summarized in **Table 2** and illustrated in **Figure 3-2**. Further discussion on this topic is provided in Guide 4.

Table 2. Overview of potential climate change effects on and risks to trees in Peel

Anticipated Climate Changes 2041 - 2070[1]	Potential Effects on Trees[2]	Risks to the Urban Forest[2]
Increased average temperatures all year-round, with the greatest increases in urban areas (i.e., mainly Mississauga and Brampton)	• May increase the growth of hardwood trees, if soil moisture is not limiting, but not conifers (Way and Oren 2010), particularly for species at the northern end of their natural range • When temperatures exceed a tree's threshold, physiological functions are impaired and tissues can be permanently damaged • Uneven and even failed flowering and budburst, impacting seed production and natural regeneration due to asynchrony between flowering and the timing of insect pollinator emergence or early budburst followed by frost	• Reduced growth of some species, but increased growth of others (if moisture is not limiting) • Uneven and even failed flowering, threatening seed production • Increased damage related to more robust populations of pests/diseases that already occur in Peel and increases in incidences of non-native pests/diseases able to move into Peel (e.g., Lehmann *et al.*, 2020; Bale and Hayward 2010)
Increased frequency and intensity of extreme heat events	• Reduced growth, stress responses (such as early defoliation) and even mortality	• Limited growth and increased mortality • Increased susceptibility to pests, diseases and other stressors
More variable temperatures	• Mild winters and warm, early springs followed by late spring frost can damage or kill plant tissues that have begun to grow, including newly formed leaves, shoots and flowers • Long winter thaws followed by freezing without snow cover can damage or kill roots, limiting water and nutrient uptake in spring and summer	• Reduced growth and increased mortality • Increased susceptibility to pests, diseases and other stressors

Anticipated Climate Changes 2041 - 2070[1]	Potential Effects on Trees[2]	Risks to the Urban Forest[2]
More frequent and extended periods of drought	• Diminished photosynthesis, reduced leaf size • In increasingly severe instances - leaf curl, browning, leaf drop, branch dieback, and crown thinning	• Limited growth and increased mortality • Increased susceptibility to pests, diseases and other stressors
More frequent and more intense precipitation and wind events (flooding and ice storms)	• In the case of flooding, leaf chlorosis, reduced leaf size, early leaf drop, formation of water sprouts and crown dieback • Increased mechanical damage from ice storms • Secondary impacts of increased salt use in response to more frequent ice storms	• Dieback or death of trees and shrubs intolerant to waterlogged soils and/or salt exposure • Increased erosion in and loss of riparian areas • Decline in tree growth and condition due to widespread mechanical damage • Increased susceptibility to pests, diseases and other stressors
More tree pests and diseases	• Variable effects depending on the pest or disease and the species and condition of the affected trees • Can range from limited tissue damage to widespread damage leading to tree mortality	• Dieback or death of trees and shrubs • Loss of certain species or genera in the urban forest

[1] These changes have been identified based on analyses completed for Peel Region (Auld *et al.*, 2016; Region of Peel 2018).

[2] Potential effects on trees and risks to the urban forest have been identified based on research done in Peel (e.g., Tu *et al.*, 2017), across Canada (e.g., Zhang *et al.*, 2019) and consideration for additional scientific sources cited in Table 2 and in Guide 4. Impacts and risks described in this table reflect responses under the "business as usual" RCP8.5 projected for the 2041 – 2070 period.

Credit: *Peel Climate Change Plan* (2019)

Figure 3-2. Extreme weather events in the Peel and Toronto areas impacting trees

4. Understanding the Urban Forest

A fundamental best practice that emerged from the Peel Region Urban Forest Best Practices research is the importance of having a good understanding of the condition of the urban forest. Although all trees share the same basic requirements for survival (e.g., water, nutrients, light), they are a diverse group of organisms with variable preferences, tolerances and sensitivities to environmental conditions and stressors. Therefore, having a good understanding of the trees themselves (e.g., species, size, condition) and the locations in which they are being planted or are already growing is key to supporting their successful establishment and maintaining their health.

Fundamental principles of effective urban forest management include getting "the right tree in the right place" and "you cannot manage what you do not understand". Implementing these principles becomes even more critical with climate change. Increasing mature tree cover in urban areas is a priority strategy in Peel for helping communities adapt to the more extreme environmental conditions already being experienced.

Getting and sustaining mature canopy cover requires a good understanding of the trees already in the region, on both municipal and non-municipally owned lands. This understanding can then inform strategic decision-making for where and how best to invest in establishing additional trees and maintaining the existing ones.

This section provides a high-level overview of best practices appropriate for Peel for assessing the urban forest on a jurisdiction-wide scale (**Section 4.1**), understanding existing and proposed site conditions (**Section 4.2**), and monitoring the urban forest (**Section 4.3**). This guidance is presented separately from the remaining best practice guidance because it provides the foundation for other approaches, practices and opportunities outlined in **Section 5**.

More specific guidance and additional technical resources are provided in *Guide 2: Urban Forest Management Best Practices Guide for Peel*. This guidance should be implemented by or with input from professionals with expertise in trees and urban forestry.

4.1 Inventory and Assess

Sound urban forest planning and management is rooted in a good understanding of the extent and condition of the urban forest. A good understanding of the urban forest is more critical than ever with the added challenges brought by climate change.

There are a variety of tools that are used at various scales to collect jurisdiction-wide data related to the urban forest, but the two most widely used tools in municipalities are (a) inventories, and (b) urban tree canopy (UTC) assessments.

Best practices related to inventories include developing and maintaining comprehensive inventories of all individual trees on municipally owned and managed lands (typically streets and parks) that can be used to proactively manage tree maintenance and replacement, as needed. For municipalities that own and / or manage treed natural areas, having current assessments of those features and plans to guide the management of both the vegetation and the people in these areas is another best practice.

Best practices related to UTC assessments include undertaking analyses every 5 to 10 years and supplementing the remote assessments with targeted field-collected data (e.g., collected in accordance with the requirements of the i-Tree Eco™ model[8] or something comparable). Data from UTC assessments can be used to:

- Inform jurisdiction-wide planning and management
- Generate valuations of ecosystem services provided by the urban forest
- Provide updates and outreach to decision-makers and the community, and
- Feed into ongoing urban forest tracking and monitoring.

> ***Having quantitative information to describe the value of the urban forest is extremely useful information for land managers. Historic undervaluation of forests and trees in economic decision-making has made them more vulnerable to development and conversion to other uses.***
>
> ***Every Tree Counts* (City of Toronto 2011)**

Assessments of UTC are an excellent tool for both tracking urban canopy cover across a jurisdiction on public and private lands and for identifying opportunities to enhance it. Ongoing developments in remote sensing are providing increasingly accurate and cost-effective tools to assess both the composition and condition of the urban forest from the sky.

Peel and its partners undertook their first jurisdiction-wide urban forest studies (on all lands across the Region – public and private) in 2009, with updates to urban tree cover assessments carried out between 2015 and 2017. Recent assessments found that Peel has 34% tree canopy cover overall, with 20% of that canopy found in its urban areas and the remaining 14% largely concentrated on and north of the Niagara Escarpment (B. A. Blackwell & Associates Ltd. 2017). As shown in **Figure 4-1**, the highest levels of canopy cover by ward and most of the forest cover are in the northern rural portion of the Region, whereas in urban areas, where the population densities are higher and which are expected to be harder hit by climate change (see **Section 3.1**), have much less consistent and sparser tree and forest cover.

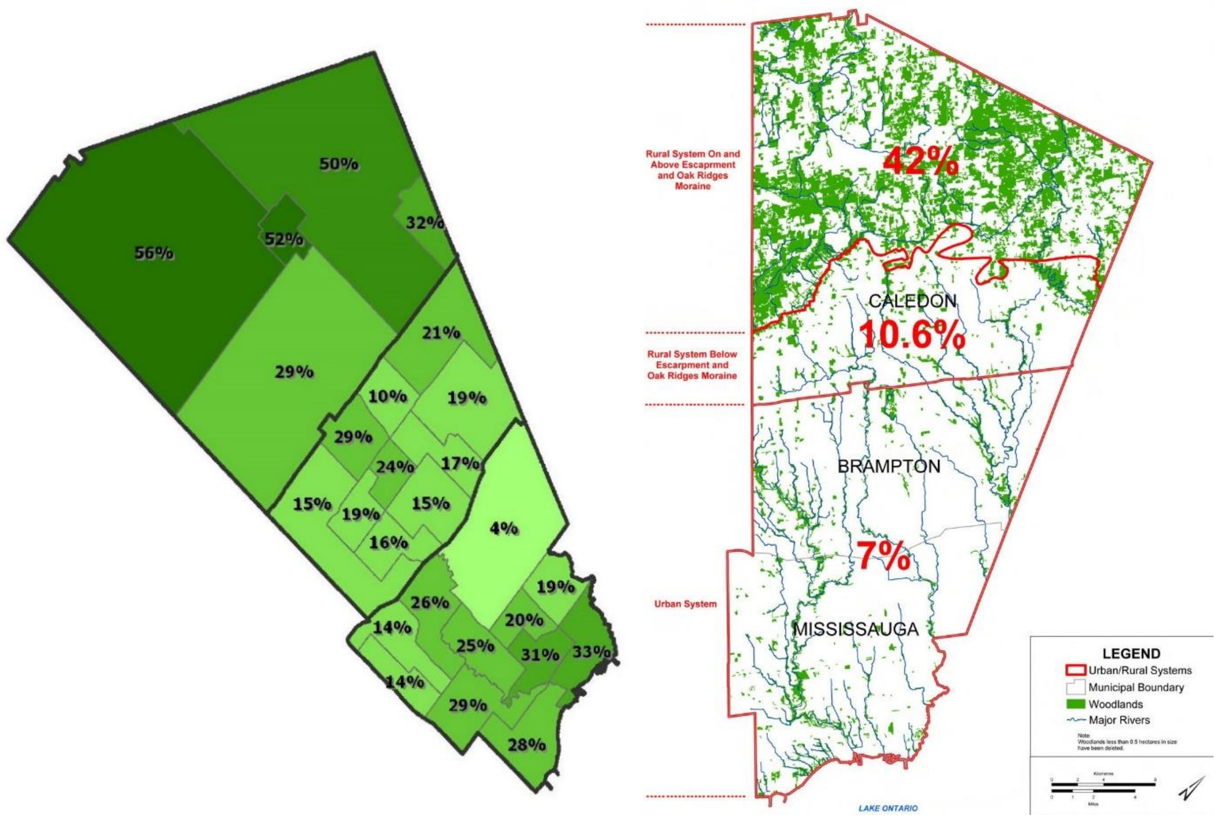
This data can be used to focus tree protection and establishment efforts in Peel's urban areas, and to update Peel's Tree Planting Prioritization Tool (Beacon *et al.,* 2015; Richardson 2015) to help identify priority areas.

[8] Since 2006, i-Tree has been a cooperative effort between the USDA Forest Service, Davey Tree Expert Company, The Arbor Day Foundation, Society of Municipal Arborists, International Society of Arboriculture, Casey Trees and SUNY College of Environmental Science and Forestry. More information can be found at https://www.itreetools.org/tools/i-tree-eco

The current tools available through i-Tree Eco™ include:

- Functional analyses to estimate the amount and value of a wide range of ecosystem services related to climate change adaptation, including: pollution removal and human health impacts, carbon sequestration and storage, hydrology effects (avoided run-off, interception, transpiration) and building energy use
- Forecasting modeling options related to tree planting inputs, extreme event impacts for weather and pests, and annual mortality adjustment, and
- The ability to undertake pest risk analyses and cost benefit analyses.

These tools are continually being updated by the USDA Forest Service and their partners. As part of Peel's next UTC assessment, it would be worthwhile exploring how these tools could be used to help inform urban forest planning and management in relation to climate change.



Credits: B.A. Blackwell & Associates Ltd. (2017) (left), Peel Region 2008

Figure 4-1. Relative percent tree canopy cover by ward (left) and relative percent forest cover in rural and urban areas (right) in Peel Region

4.2 Know Your Site

The urban environment often provides site conditions that are sub-optimal for trees. But whatever the site conditions and challenges may be, it is impossible to mitigate or improve them if they are not recognized. It is not unusual for plans to be developed for a site without knowing whether trees are present or anything about trees that do occur (e.g., the number, size, species and condition of trees). It is also not unheard of to develop planting plans for a site with limited information about the existing biophysical conditions, and / or with an incomplete understanding of planned changes to the site and how they may affect trees identified for protection.

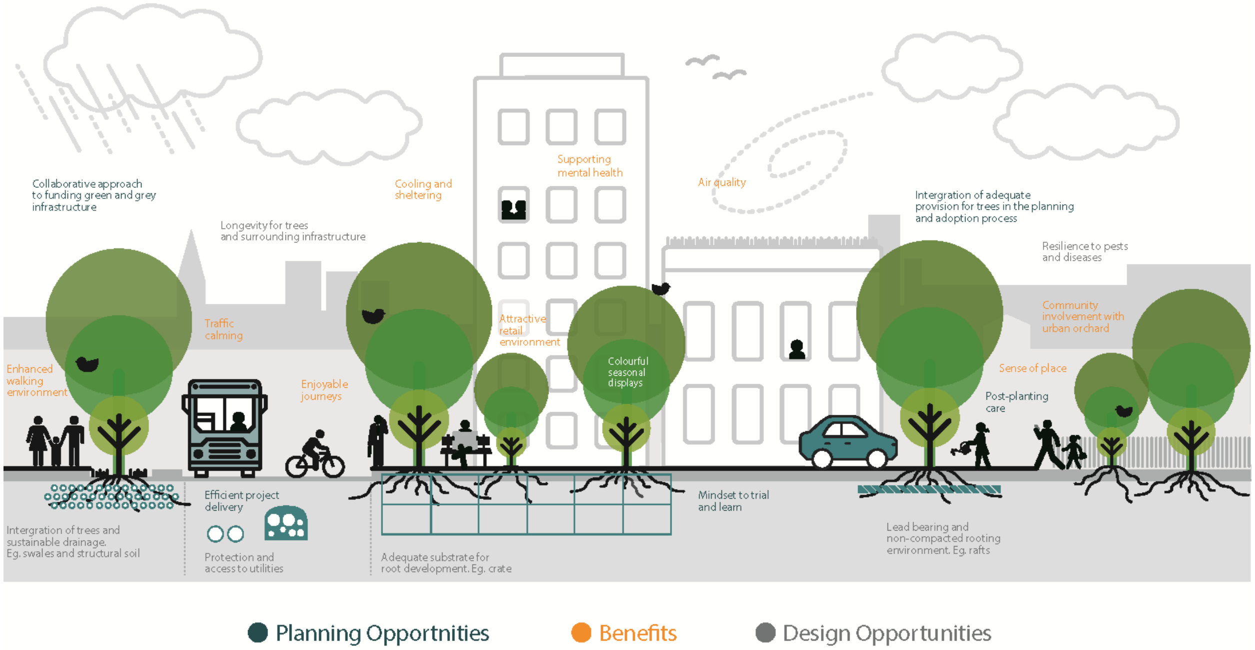
The existing biophysical conditions and context of a site should be assessed to inform planning, especially as it relates to below-ground conditions, because these can significantly affect tree establishment and growth. Site factors that should be considered include physiography, topography, soil quality, water availability and drainage, light and microclimate.

Site assessment should inform an understanding of the planting areas and the immediately surrounding lands that can influence drainage, water availability, exposure to light and microclimate. Additional factors to consider, particularly in urban areas, include above and below-ground infrastructure, extent of on-site and nearby impervious surfaces, access points and ongoing maintenance practices that may impact trees (e.g., winter salting, snow clearing).

In cases where a site is being developed or re-developed, a good understanding of the anticipated site conditions is just as, or perhaps more, important than understanding current site conditions. Changes in land use and different site layouts and infrastructure alternatives can also significantly influence the above and below-ground conditions in which trees and shrubs are being protected and / or into which they are being established. For example, there will be different considerations for a tree being maintained or planted adjacent to a busy arterial road as opposed to a quieter residential street. Another example is having consideration for the amount of direct light trees will be exposed to once new buildings are constructed.

Key elements of new developments or re-developments to consider for urban trees include the extent of hardscaping, stormwater management approaches, location of utilities and other infrastructure, accommodations for pedestrian access, snow and salt management, extent of shade and direct light (both over the course of the day and seasonally) and anticipated wind tunnels that may be created. Some of these challenges and opportunities for addressing them in a tree-friendly way are illustrated in **Figure 4-2**.

Understanding the existing and anticipated conditions and potential tree stressors is a critical starting point for urban tree management and provides the basis for: (a) having discussions with the Project Team about potential refinements to plans to improve conditions for trees, and (b) informing planting locations and species selections to ensure trees have the best chance to become well-established and thrive. Without this information, the risk of wasting resources is great (e.g., by accommodating tree plantings that may not perform well or, worse, by creating spaces that can only sustain trees for a few years or not at all).



Adapted from "https://www.tdag.org.uk/trees-planning-and-development.html", Trees and Design Action Group

Figure 4-2. Tree-related challenges and opportunities in a built urban setting

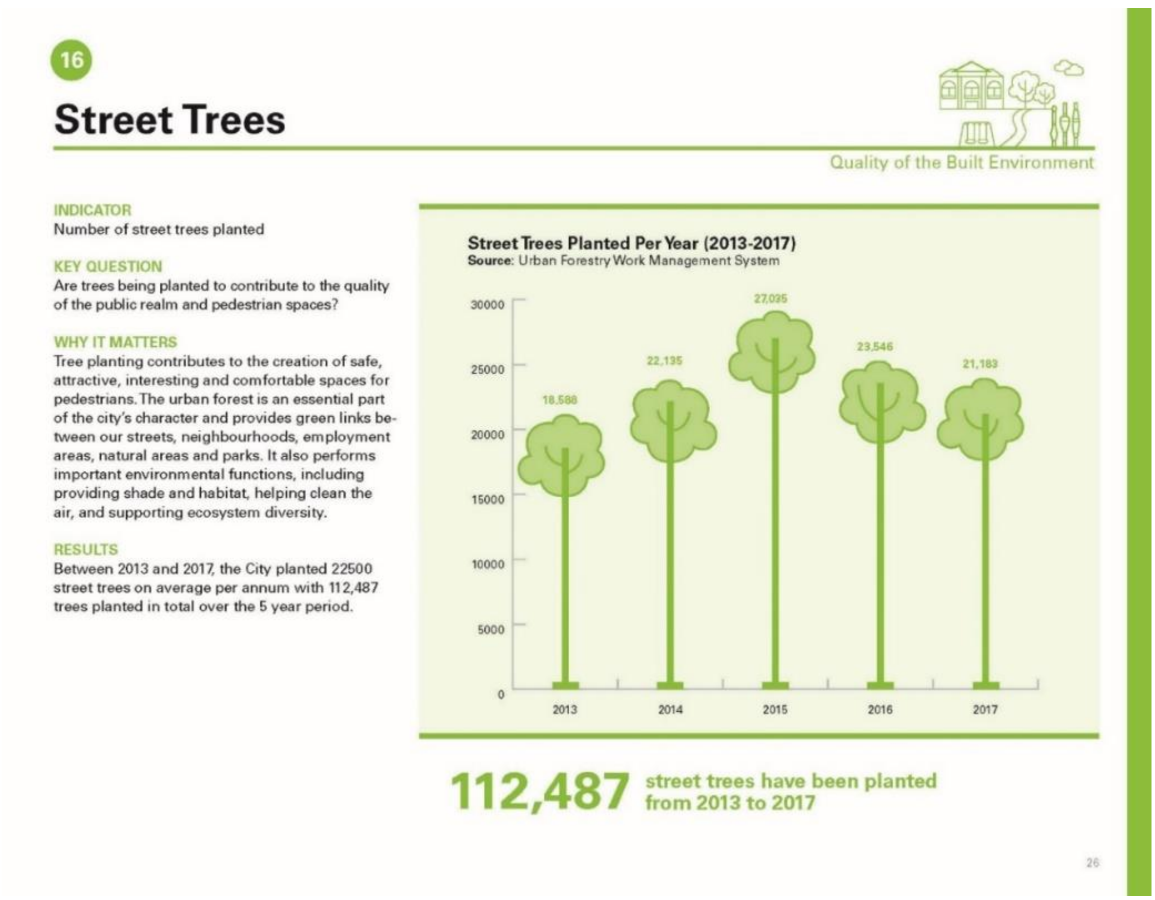
4.3 Track and Monitor

Many species of trees can live for hundreds of years in natural environments, but in harsh urban environments, trees may survive only for decades. Because of the long life spans of trees, evaluating a new treatment or approach to urban tree management can take decades to evaluate. Therefore, to learn from successes and mistakes, managers must document actions taken, track the results of these actions, assess the results in achieving the intended outcomes and depending on the results, continue or revise the approach. This is the essence of adaptive management (as illustrated in **Figure 2-1**) – to learn while doing, monitor progress and be prepared to make adjustments as required – which should be the framework guiding all urban forest activities. Climate change adds additional uncertainties into environmental and urban forest planning (as outlined in **Section 3.2**) and underscores the importance of incorporating adaptive management and long-term monitoring at all scales, from regional to site-specific.

Key focal areas of municipal urban forest assessment and monitoring are collecting, maintaining and assessing indicators of the condition of: (1) street and park trees, (2) municipally owned and/or managed forests, and (3) jurisdiction-wide urban tree canopy cover. In addition, municipalities should establish measures to allow for monitoring the effectiveness of: (4) internal and external multi-disciplinary collaborations, (5) partnerships with public and private sector organizations, and (6) outreach to and engagement with the community on tree-related matters.
Specific areas for urban forest research and monitoring in a climate change context include:

- Tracking the number of trees being planted along with the number approved for removal (to assess annual net gain or net loss of trees)
- Monitoring the effectiveness of measures that integrate trees with other types of low impact development (such as swales, infiltration trenches, permeable pavement) in achieving various design and stormwater management objectives (see examples illustrated in **Section 5.7**)
- Ongoing monitoring of forest pests and invasive trees / shrubs to support management prioritization and enable early detection of and response to outbreaks of existing or new pests and invasive species
- Monitoring changes in overall UTC (as per **Section 4.1**) and the condition of the urban forest in terms of overall species and structural diversity, as well as changes in cover with objectives for improving equity and access for vulnerable populations in mind (as per **Section 5.2**), and
- Monitoring of assisted migration trials in partnership with others to introduce and test a diversity of non-local tree seed and nursery stock to evaluate the performance of different species and provenances in a range of settings across Peel's urban areas.

These monitoring efforts should be considered in the context of the adaptation planning and implementation framework provided in **Figure 2-1**.



Credit: *City of Toronto Official Plan Indicators Report* (2018)

Figure 4-3. Example of an Official Plan-level monitoring metric for street tree planting

5. Key Best Practices and Opportunities

Urban forests are generally managed for the short and long-term benefits and services that living trees provide to communities (unlike private woodlots or commercial forests that may be managed for tree removals). As such, well-managed urban forests have significant potential to serve as long-term carbon sinks. Planting trees that store carbon as they grow and are retained on the landscape for as long as possible is part of the solution for mitigating climate change (e.g., Bastin *et al.,* 2019, Bastin *et al.,* 2020).

Urban forests provide a wide range of services and co-benefits that contribute directly to community health and well-being (see **Section 5.1**). Therefore, planning for and managing the urban forest to maximize the canopy cover provided by a diversity of healthy trees is also one of the best ways to help communities adapt to climate change.

While sustaining and enhancing the urban forest can contribute to climate change mitigation and adaptation, it is important to keep in mind that trees are living organisms that can be impacted by environmental stressors (e.g., severe weather, pests, diseases, etc.). Some of these stressors tend to be more pronounced in urban environments and exacerbated by climate change (e.g., exposure to heat and drought) (see **Section 3.2**). Sustaining and enhancing the urban forest in an urban context of climate change requires careful, collaborative planning and management, input from knowledgeable urban forestry and arboriculture professionals, and an ability to refine approaches in response to change.

Best practices for having healthy individual trees in urban environments can be distilled to selecting trees that are suitable for the local climate and biophysical conditions, providing them with a good growing environment (above and below-ground), and protecting them from impacts that will limit their ability to survive to maturity. These practices are even more important in a climate change context.

The following sub-sections outline 10 strategic areas of best practice for urban forest planning and management identified for Peel that are key to building resilience and leveraging the forest's ability to enhance both social and environmental outcomes:

- Value the urban forest as an asset (**Section 5.1**)
- Invest strategically (**Section 5.2**)
- Have a strategic plan (**Section 5.3**)
- Maximize diversity (**Section 5.4**)
- Take an integrated approach to planning (**Section 5.5**)
- Take an integrated approach to design (**Section 5.6**)
- Plan with equity in mind (**Section 5.7**)
- Seek climate-positive outcomes (**Section 5.8**)
- Foster a tree-friendly culture (**Section 5.9**)
- Be prepared (**Section 5.10**)

This section builds on the research and findings documented in the four other *Peel Region Urban Forest Best Practice* project guides and is also intended to help municipal staff and their partners identify, evaluate and prioritize potential mitigation and adaptation actions, as per the planning and adaptation framework for Peel's urban forest, provided in **Section 2.3**.

5.1 Value the Urban Forest as an Asset

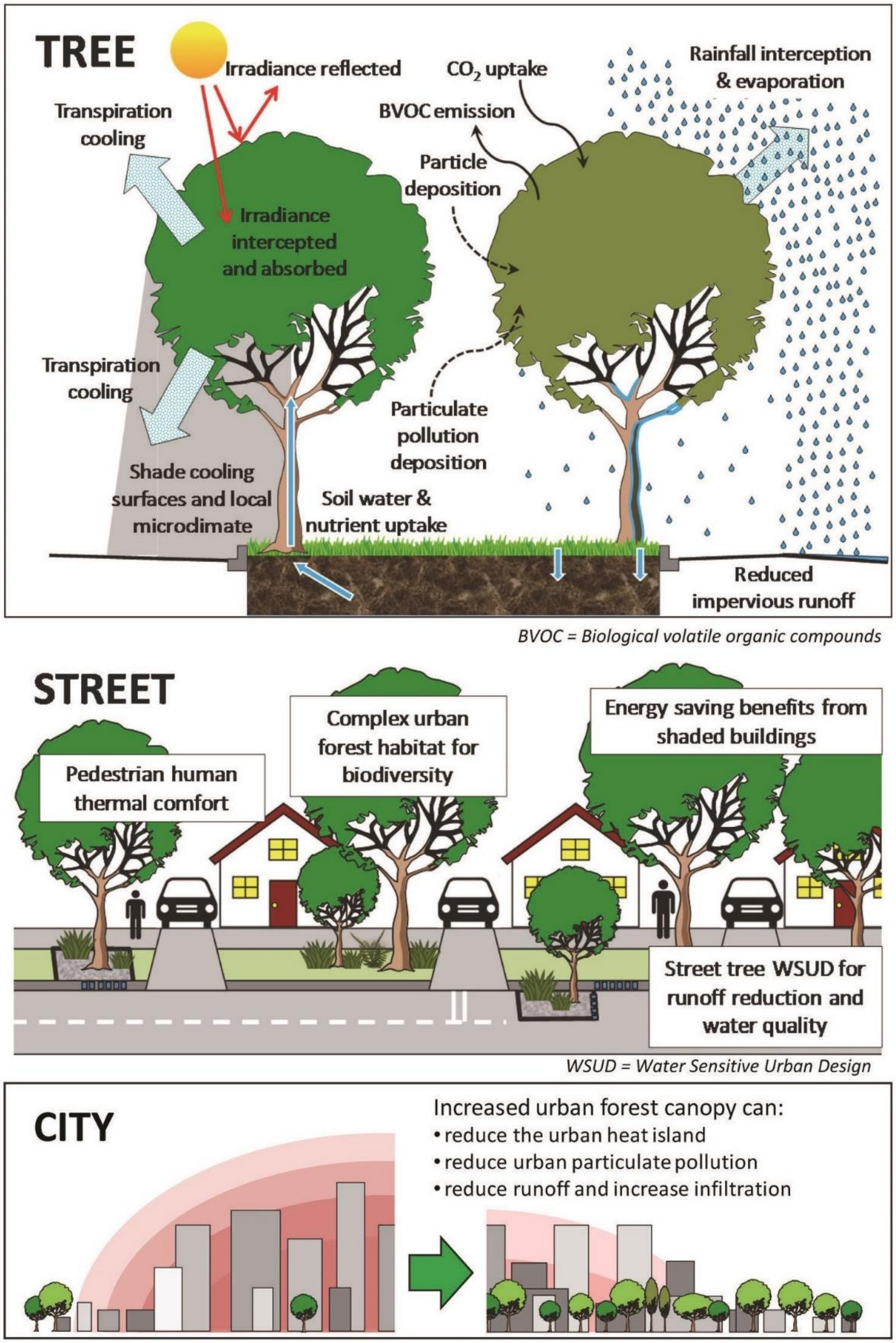
> *The solution starts with understanding and accepting a simple truth: our economies are embedded within Nature, not external to it.*
>
> *The Economics of Biodiversity: The Dasgupta Review* (2021)

Communities around the planet are already experiencing the harmful effects of climate change and their associated costs (IPCC 2018). In southern Ontario, two examples of extreme weather events over the past decade that both impacted the urban forest and incurred significant costs include: an extreme rainfall (125 mm in a two-hour window) on July 8, 2013, that flooded more than 2,000 basements in Peel Region and resulted in over $1 billion in insured damages across the Greater Toronto Area (GTA) (CVC 2018), and the April 2014 ice storm that affected southern Ontario and resulted in more than $190 million in insured damage (Niagara Region 2019).

Using conventional economic accounting (e.g., labour, materials), it is easy to undervalue the benefits of urban forests and simply conclude that forestry-related expenses exceed forestry-related income year-over-year, particularly in urban settings where the forests are not being managed for wood products (e.g., Escobedo and Seitz 2019, Whiteman *et al.,* 2015). It is also highly likely that climate change will increase urban forestry expenses, as additional care is almost certainly going to be required to, for example, sustain trees through longer droughts and maintain or replace them following more frequent storm events. However, two critical considerations are lacking from conventional cost-benefit analyses of urban trees:

a) it does not provide a full accounting that includes the value of the broad spectrum of social and ecological benefits and services provided by trees in cities (see **Figure 5-1**), and
b) conventional accounting does not use a life cycle approach that considers costs and benefits in a timeframe that reflects the typical life span of a tree in an urban area, in which the upfront costs to establish trees are not equated against the full benefits provided by urban trees, which are only obtained decades later, when trees are mature.

Unfortunately, the costs involved in building urban resilience compared to the value of the services provided by trees in a climate change remain difficult to evaluate. This is partly because it is only relatively recently that many of the social and environmental services provided by the urban forest have been well-documented, and although tools are being developed to estimate the economic value of some of these services (see **Table 3**), there are still significant data gaps and no widely accepted approaches for cost-benefit analyses of the urban forest in a climate change context (CFS and UBC 2016, Escobedo and Seitz 2019, Song *et al.,* 2018).



Credit: Livesley *et al.*, (2016)

Figure 5-1. Some of the services and benefits provided by the urban forest at different scales

Table 3. Overview of services provided by trees that contribute to climate change adaptation

CLIMATE CHANGE IMPACT [1]	CLIMATE ADAPTATION SERVICE PROVIDED BY TREES [2]
Summer heat events that are more frequent and of greater duration	• Moderated air temperatures, which can reduce energy consumption (and costs) for cooling • Improving human health, reducing health care costs
Greater incidence of poor air quality days, particularly on hot summer days	• Increase air mixing to disperse pollutants • Cooling to reduce formation of some pollutants • Limited uptake and reduction of some air pollutants [3]
Wind events of greater intensity and frequency	• Blocking wind, which can reduce energy consumption for heating
Storm events of greater frequency and intensity	• Tree leaves, branches and trunks intercept rain, reducing the amount and rate at which water reaches the surfaces below • Tree roots and associated soils intercept, store and absorb water, reducing runoff • Trees and their soils also interact with the urban hydrologic cycle by enhancing infiltration
Water quality deterioration and erosion hazards associated with more intense and frequent storm events	• Tree roots and associated soils intercept, store and uptake water, nutrients and some heavy metals • Tree roots and associated biota improve slope stability and reduce erosion
Increased risks to human physical health and well-being	• Improved air quality linked to reduced incidence of asthma and other environmentally induced respiratory illnesses • Providing cooling, reducing incidence of heat-related illnesses • Providing shading limiting exposure to harmful ultraviolet rays • Health benefits linked with activities in treed / forested environments
Increased risks to human mental health and well-being	• Improved cognition and attention restoration • Reduced anxiety, stress • Improved clinical outcomes linked with views of and access to treed / forested environments
Increased food insecurity	• Contributing to local food security by increasing access to and use of trees with edible fruit, nuts and sap

[1] Adapted from climate change assessments for Peel Region (i.e., Auld *et al.,* 2016, CVC 2018, Cheng *et al.*, 2012, Region of Peel 2018, Savanta and GM Blue Plan 2020, Tu *et al.,* 2017).
[2] Adapted from selected urban forestry literature reviews (e.g., Bardekjian 2018, Wolf *et al.,* 2020, CFS and UBC 2019, Livesley *et al.,* 2016) and supplemental sources (e.g., Armson *et al.,* 2013, Berland *et al.,* 2017, Brown *et al.,* 2015, Bunge *et al.,* 2019, Chuang *et al.,* 2017, Greene *et al.,* 2018, Mitchell and Popham 2007, Rugel *et al.,* 2019, Vaz Monteiro *et al.,* 2019, Wang and Akbarib 2016).
[3] In addition to filtering air pollutants, some tree species emit biogenic volatile organic compounds (BVOCs) that under certain conditions are a precursor to smog formation (Livesley *et al.,* 2016).

> *In light of ambitious goals in many cities to increase tree cover, ongoing advances in valuation methods need to provide a more comprehensive accounting of benefits and costs, and to better integrate economic assessment into the decision-making process.*
>
> *The economic benefits and costs of trees in urban forest stewardship: A systematic review* (Song *et al.,* 2018)

The municipal asset management framework is a well-established tool used by many municipalities that has begun to be applied to so-called "natural" and "enhanced" assets, including the urban forest in Peel and elsewhere in Canada (MNAI 2017). Although practitioners are still working on how to refine this framework for green infrastructure[9] (see **Figure 5-2**), the municipal asset management system is currently one of the best frameworks for undertaking comprehensive and locally informed cost-benefit analyses of urban forests. An asset management framework can also account for risks to the urban forest from climate change.

An overview of the services provided by trees that contribute to climate change adaptation and some of the estimated values of those services in Peel are presented in **Section 5.1.1.** Some best practice examples of using the municipal asset management framework to assess, value and plan for urban forest resilience are provided in **Section 5.1.2**.

5.1.1 Value the Urban Forest

Urban forests and other green infrastructure components are increasingly recognized as cost-effective investments to help reduce greenhouse gases, while providing valuable services that help urban communities adapt to climate change (e.g., GIF and OPA 2019, McPherson *et al.,* 2015, MNAI 2019, Perdeaux 2017, WBG and WRI 2019). For example:

- the City of Mississauga estimated that its urban forest provided more than $123 million in air quality benefits in 2014 (Plan-it Geo 2014), and
- a study by TD Bank estimated that the City of Toronto's urban forest provides residents with over $80 million in environmental benefits annually (i.e., stormwater interception, air pollution removal, and energy use and carbon emissions reductions), with every $1 spent on urban forest maintenance returning between $1.35 to $3.20 of benefits and cost savings each year (Alexander and McDonald 2014).

Unfortunately, i-Tree Eco™[10] (the most widely used tool) only provides rough estimates of the value of urban forest services and some of its assumptions are not entirely appropriate for southern Ontario. Furthermore, many of the most critical services provided by the urban forest cannot yet be fully valued with available tools. There is an urgent need for a framework and mechanism that provides more comprehensive and more locally defensible valuations of urban forest services.

[9] Green infrastructure is defined as including natural heritage features and systems, parklands, stormwater management systems, street trees, urban forests, natural channels, permeable surfaces and green roofs. It is often presented as an alternative or add-on to municipal grey infrastructure which includes things like roads, bridges and sewers.

[10] www.itreetools.org/about

5.1.2 Leverage the Asset Management Framework

Municipalities in Ontario are now required to incorporate natural assets into their broader asset planning and management. Specifically, the *Municipal Asset Management Planning Regulation* (O. Reg. 588/17) requires municipalities in Ontario to have a comprehensive asset management plan in place by July 1, 2023, which takes "natural assets" and "enhanced assets" (see **Figure 5-2**) into account. It also requires municipalities to consider options to reduce full life cycle costs of assets in the context of infrastructure and climate change challenges, including the potential use of green infrastructure solutions. As depicted in **Figure 5-2**, forests, (natural) soils and (individual) urban trees are all recognized components of municipal green infrastructure to be considered in municipal asset management planning.

Credit: Adapted from Municipal Natural Asset Initiative (MNAI 2017)

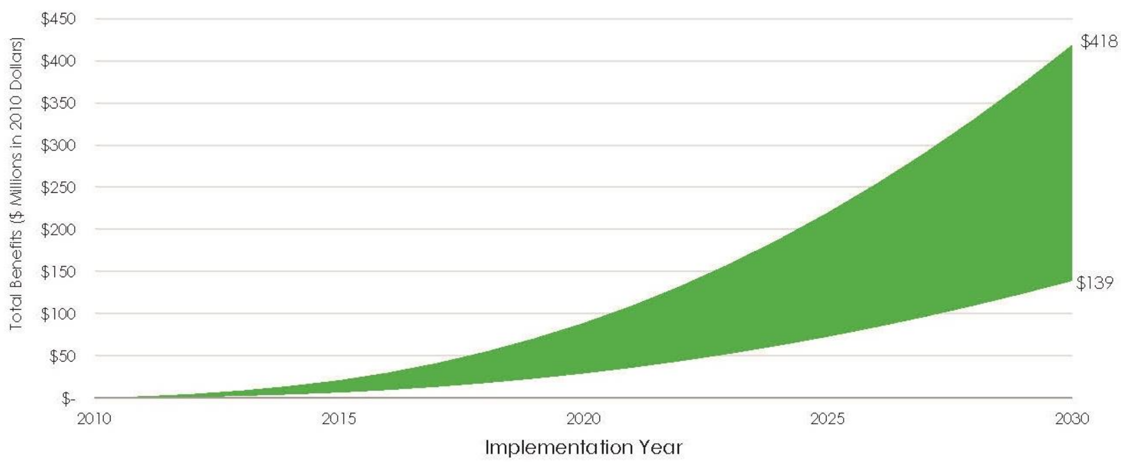
Figure 5-2. Types of green infrastructure to be considered in municipal asset management

Key steps involved in incorporating the urban forest into an asset management framework include: having an inventory of the asset, assessing the condition of and risks to that asset (including those related to climate change), identifying the primary services to be provided by the asset and valuing that service provision, estimating the costs of maintaining the established levels in a life cycle context, and then undertaking cost-benefit analyses.

The *Green Infrastructure Ontario Primer* on natural asset management (GIO 2018) identifies key opportunities and challenges as they relate to the integration of green infrastructure into the asset management process, including the following specifically related to the urban forest.

- OPPORTUNITIES: Use maintenance and replacement costs of street and park trees (including growing media) to value these assets; use management and restoration costs to value wooded natural areas; and use ecosystem service valuations to help define and measure levels of service.
- CHALLENGES: Trees (unlike grey infrastructure) tend to appreciate, not depreciate, over time, until they either die or need to be removed for other reasons. Forests can be sustained indefinitely, making life cycles difficult to define. Levels of service are hard to accurately value as they include community services, technical services and performance measures, as well as co-benefits.

Several studies completed over the past decade have started to address these challenges and build the case for investment in the urban forest (and other types of green infrastructure), as illustrated in **Figure 5-3**.



Credit: *NYC Green Infrastructure Plan* (Bloomberg and Holloway 2018)

Figure 5-3. Example of exponential increase in green infrastructure value over 20 years

In Peel, the cities of Brampton and Mississauga have begun integrating the urban forest into their asset management planning, and CVC has led several projects and tools to inform and facilitate this process, including:

- The *Business Case for Natural Assets in the Region of Peel: Benefits to Municipalities and Local Communities* (CVC 2020), based on two case study areas in the Region
- *Life Cycle Costing of Restoration and Environmental Management Actions* (Beacon 2020), which included cost estimates for individual trees and forests
- Natural asset sensitivity analyses and the Risk and Return on Investment Tool (RROIT), focussed on flood management (ongoing), and
- The Sustainable Technologies Evaluation Program (STEP) Life Cycle Costing Tool[11] for Low Impact Development features, developed by CVC, TRCA and Lake Simcoe Region Conservation Authority.

[11] sustainabletechnologies.ca/lid-lcct/

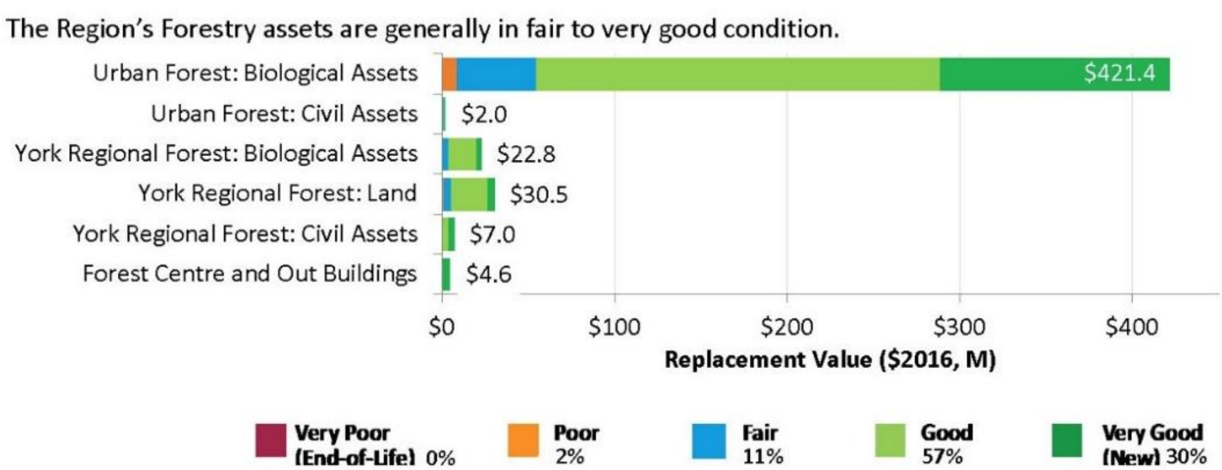
Examples of jurisdictions that have taken strides to integrate the urban forest into their asset management systems include the Town of Richmond Hill, City of London and Region of York.

- The Town of Richmond Hill included its 43,000 street trees and 700 ha of natural forest in its 2016 Asset Management Plan as "Environmental Assets".
- The City of London's Asset Management Plan (2019) used available data to forecast gaps in lifecycle infrastructure funding for management of municipal street trees, park trees and woodland trees.
- York Region's 2018 Asset Management divided urban forest assets into "biological assets" (e.g., trees, soil), "civil assets" (e.g., soil cells, irrigation, drainage, trails, municipal parking lots, fences, signs) and buildings (see **Figure 5-4**).

In a presentation to the Canadian Network of Asset Managers (Sawka and Lane 2018[12]), staff of the Green Infrastructure Ontario Coalition (GIO) and York Region noted that:

- The total cost for an urban forestry program varies significantly depending on the level of investment in increasing the tree population and the rate of tree growth, and
- Having a forestry replacement reserve can minimize the impacts of funding peaks.

The Region of Peel and its local municipalities should continue to collaborate with each other and with the local conservation authorities to align their approaches and tools for incorporating the urban forest into their asset management planning.



Credit: *York Region Asset Management Report* (2018)

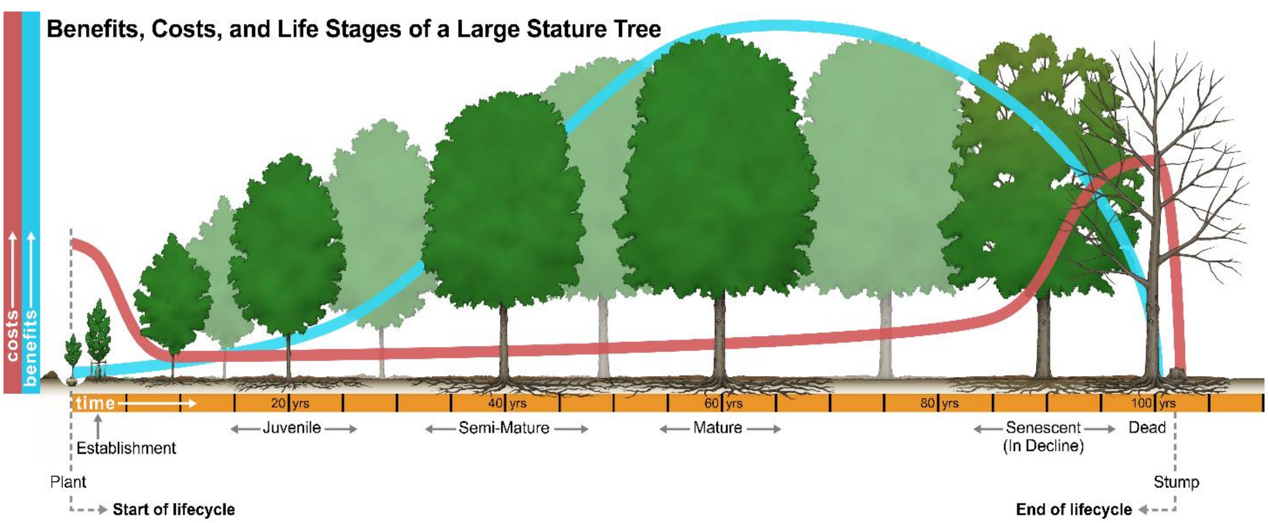
Figure 5-4. Urban forest asset types, life cycles and estimated replacement values in York Region

[12] cnam.ca/wp-content/uploads/2018/07/22A.pdf

5.2 Invest Strategically

Although trees have tremendous potential to both mitigate and help communities adapt to climate change, as biological entities they are also vulnerable to stresses caused by climate change. This is particularly true for individual street and park trees already subject to harsh urban conditions. Therefore, leveraging the services provided by trees requires a sustained commitment of strategic investment.

There are many ways for municipalities to invest strategically in the urban forest. Priorities for resource allocation vary depending on a variety of factors, including the municipality's land use and biophysical context, the extent and condition of the urban forest, the local policy and legislative framework and the local social and political context. In general, the best way to leverage the capacity of trees to help communities adapt to climate change, while minimizing the risks of the urban forest being negatively impacted by climate change (or other stressors), is to prioritize investments in actions that maximize the resilience of the urban forest to current and anticipated stressors.
Costs associated with urban forest establishment, maintenance and management can be substantial. However, it is increasingly recognized that up-front investment in proper establishment and good growing conditions can minimize large expenditures as trees mature. In addition, when trees are provided with conditions that allow them to reach maturity, the cost of the initial investment is far outweighed by the value of the services and co-benefits provided (as illustrated in **Figure 5-5**).



Credit: E. Damstra, with permission 2020

Figure 5-5. Municipal costs versus benefits over a hypothetical 100-year tree lifespan

In the absence of full-cost accounting and / or the urban forest being integrated into a municipal asset management system (as per **Section 5.1**), a business case can still be made for investing in the urban forest based on targeted economic analyses and economic case studies undertaken in urban jurisdictions in southern Ontario, as presented in **Section 5.2.1**.

Assuming investments in the urban forest are part of a strategy for building community resilience to climate change and providing a host of other services and co-benefits (as it is in the Region of Peel and among its partners), **Section 5.2.2** provides high-level best practices for how to invest strategically to maximize urban forest services

5.2.1 The Investment Imperative

At the municipal level, urban forestry staff and departments (where they exist as self-contained units), compete with other municipal priorities for resourcing and funding. This is both normal and expected, as municipal governments are accountable for how taxpayer dollars are spent. However, those making the case for maintaining or increasing resources allocated to urban forestry should have accurate information to build that case.

From an economic and a municipal perspective, key reasons for investing in municipal forestry include the following.

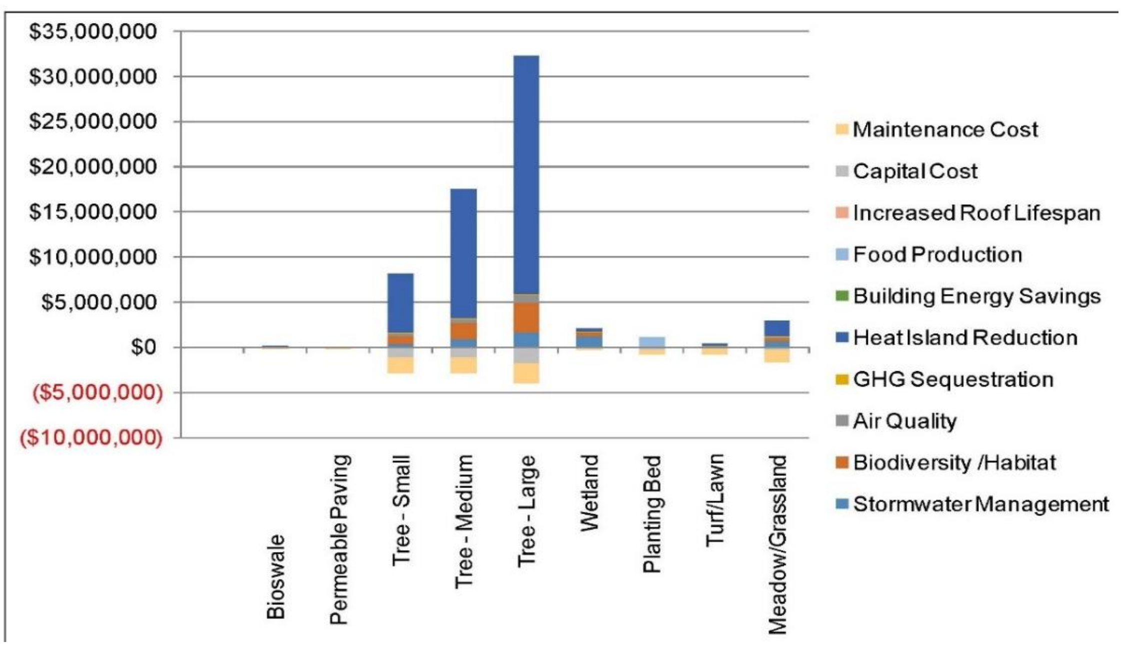
- Healthy and long-lived trees provide a wide range of services and co-benefits to a community, many of which have not to date been accounted for (as per **Section 5.1**).
- Although trees in a natural setting can sustain themselves, to sustain healthy trees and forests in an urban setting, some planning, maintenance and monitoring is required.
- Trees are long-lived organisms that are resilient and have evolved to be part of a forest community. Therefore, investment to sustain them should be in a framework that is long-term, strategically targets ways to support their innate resilience, and considers trees as individuals within a broader, diverse community (a.k.a. the urban forest).
- The services and co-benefits provided by trees acquire additional value in a climate change context. Climate change also introduces additional challenges for managing the urban forest. Therefore, where there is a municipal commitment to include trees as part of the climate change response, there is a need to invest adequately to maintain them.
- There are many opportunities in urban areas to integrate trees into the community cost-effectively and creatively, while also meeting other municipal objectives (e.g., related to planning, community safety and climate change adaptation).

The recently released *Green Infrastructure for Climate Adaptation: Visualization, Economic Analysis, and Recommendations for Six Ontario Communities* (GIO and OPA 2019) is one of the first studies in Ontario to undertake a longer-term cost-benefit analysis of green infrastructure. Excerpts from a case study in the City of Brampton (Peel Region) are provided below to highlight the projected returns over 50 years from investment in the urban forest as part of an approach to build community resilience to climate change.

CASE STUDY IN PEEL:
RIVERSTONE GOLF COURSE REDEVELOPMENT, BRAMPTON, ONTARIO
The purchase and conversion of the Riverstone golf course and clubhouse in the City of Brampton to a community facility and public conservation area provided opportunities to integrate urban forest enhancement with other green infrastructure and educational elements. Enhancements to be undertaken by the City and their partners included: planting 10,000 trees, floodplain naturalization, creation of stormwater management wetlands, and a trail system (see **Figure 5-6** and **Figure 5-7**).

Credit: GIF and OPA 2019

Figure 5-6. Green redevelopment concept for Riverstone Park in Brampton



Credit: GIF and OPA 2019

Figure 5-7. Cost-benefit analysis of green infrastructure for Riverstone Park in Brampton over 50 years

Cost benefit analyses of the green infrastructure elements proposed over a 50-year period estimated initial construction costs of $5.5 million and annual maintenance costs of $241,600, with these expenditures being recuperated in less than six years and the area providing a net present value (NPV) of $27.56 million in 50 years. The benefits considered in the valuation included: the increased roof lifespan provided by the green roof retrofit on the clubhouse, food production from the planned community gardens, building energy savings, heat island reduction, greenhouse gas sequestration (by the woody plants established), air quality improvements, habitat creation and stormwater management.

As shown in **Figure 5-7**, by far the most significant contributors to NPV are the heat island reduction benefits provided by the trees planted, that greatly exceed the maintenance and capital costs combined.

5.2.2 Best Practices for Maximizing Returns on Investments

> ***The most expensive tree is the one you replant every 10 to 20 years.***
>
> **Unknown**

As resources for municipal urban forest planning and management are almost always limited, understanding when and how to prioritize investments to maximize urban forest services is critical to building a sustainable urban forest program.

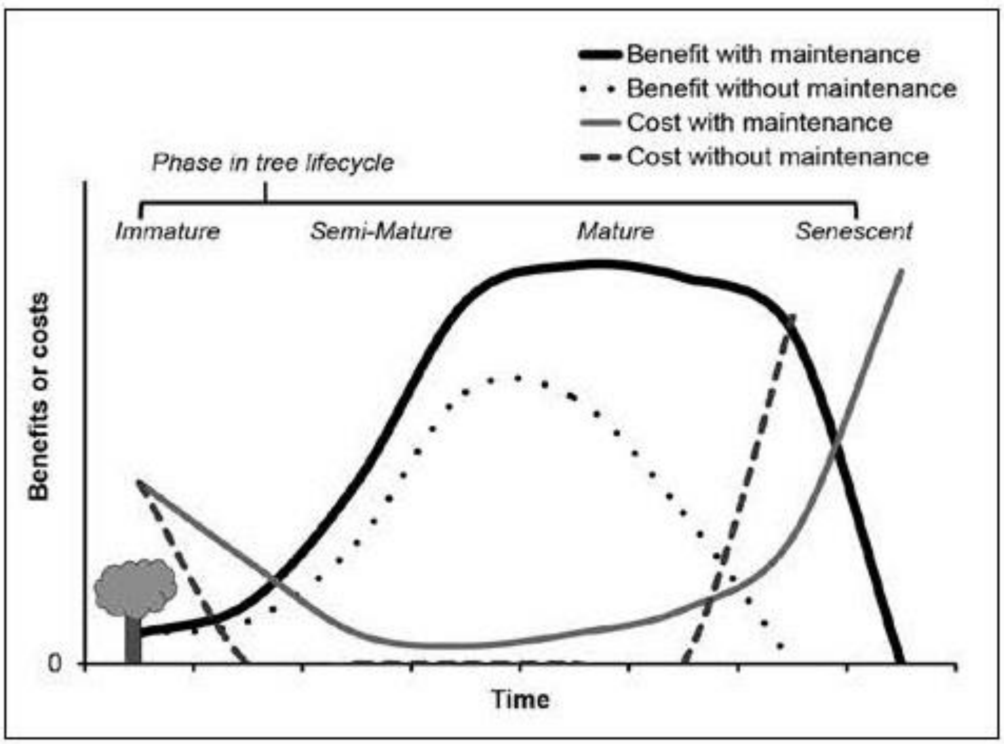
The costs associated with urban forest establishment, maintenance and management can be substantial and can be increased by climate change (e.g., need for responses to more persistent pest infestations or more frequent-than-typical ice storms) (e.g., Vogt *et al.,* 2015, Escobedo and Seitz 2019). However, strategic planning and investment undertaken with a good understanding of urban forests (as per **Section 4**) can help ensure that allocated dollars help maximize the services and benefits provided by this asset.

One broad misconception is that simply prioritizing investments in planting more trees will result in a healthier and more expansive urban forest. However, planting more trees without investing in proper species selection and tree establishment (i.e., from the site conditions to post-planting maintenance) can increase long-term costs and risks while failing to maximize the potential tree-related services. Therefore, taking a more comprehensive and strategic approach to urban forest management is recognized as a best practice in many municipalities across Canada (discussed further in **Section 5.3**) (e.g., City of Cambridge 2015, City of Toronto 2013, City of Mississauga 2014, Ordóñez and Duinker 2013, York Region 2016).

Another best practice is proactive management and up-front investment in proper establishment and good growing conditions, which can minimize large expenditures as trees mature (e.g., City of Kitchener 2017, City of Mississauga 2014, City of Toronto 2011, Nowak *et al.,* 2010). This is particularly true for individual trees in urban settings (e.g., street and park trees) where focussed investment during the planning and tree establishment phases (including watering, mulching and young tree pruning), followed by some basic maintenance as the tree matures (e.g., pest / disease management and hazard reduction) can maximize services provided by individual trees (as illustrated in **Figure 5-8**).

Trees are naturally long-lived and resilient organisms whose services tend to increase in value exponentially as they mature. Therefore, the initial investment in planting the right tree in the right place and providing basic maintenance to ensure it is well-established can provide returns for the next 50 to 100 years, or longer.

Increasingly, municipal urban forest managers recognize that investing in proper planning, site preparation, tree selection, planting and establishment at the outset is much more cost-effective than failing to make these initial investments and then having to expend more on maintenance later and / or having the tree decline and need to be replaced prematurely. "Front-loading" street and park tree investments to make sure the right tree is well established in the right place reduces tree-related risks and improves the odds that the tree will reach maturity, thereby maximizing the benefits and services provided.



Credit: Vogt *et al.* (2015)

Figure 5-8. Conceptual benefits versus costs over the lifespan of a tree

Protected wooded natural areas and woodland restoration areas can also contribute significantly to local climate change mitigation and adaptation. Although public natural areas in urban centres can be subject to degradation, having these areas in public ownership facilitates their protection and management (e.g., Whiteman *et al.,* 2015). However, outright purchase of wooded natural features in urban areas can be prohibitively expensive. Greenlands / natural areas securement programs provide a mechanism to help protect such areas and are considered a best practice in urban areas where land values tend to be high. In Peel, the Peel Greenlands Securement Program provides a framework for land acquisition with conservation partners (e.g., CVC, TRCA, Oak Ridges Moraine Land Trust, Bruce Trail Conservancy and local municipalities).

Additional high-level best practices for maximizing returns on municipal urban forest investment in a climate change context include investing in:

- Diversifying species for tree planting (see **Section 5.4**)
- Focussing tree establishment where human population densities are high and tree cover is low (**Section 5.5**)
- Tree-positive planning and design processes (see **Section 5.6** and **Section 5.7**)
- Plans that integrate urban forestry and climate change objectives (see **Section 5.8**)
- Tree-positive outreach, education and stewardship (see **Section 5.9**), and
- Proactive maintenance and preparedness related to trees, including response plans and emergency funds (see **Section 5.10**).

5.3 Have a Strategic Plan

A sustainable urban forest program is one that:

- *the community can afford now, and in the future*
- *maximizes the benefits of the urban forest*
- *minimizes the associated risks and costs, and*
- *has a supportive and active community.*

City of Kitchener's Sustainable Urban Forest Strategy 2019 – 2028

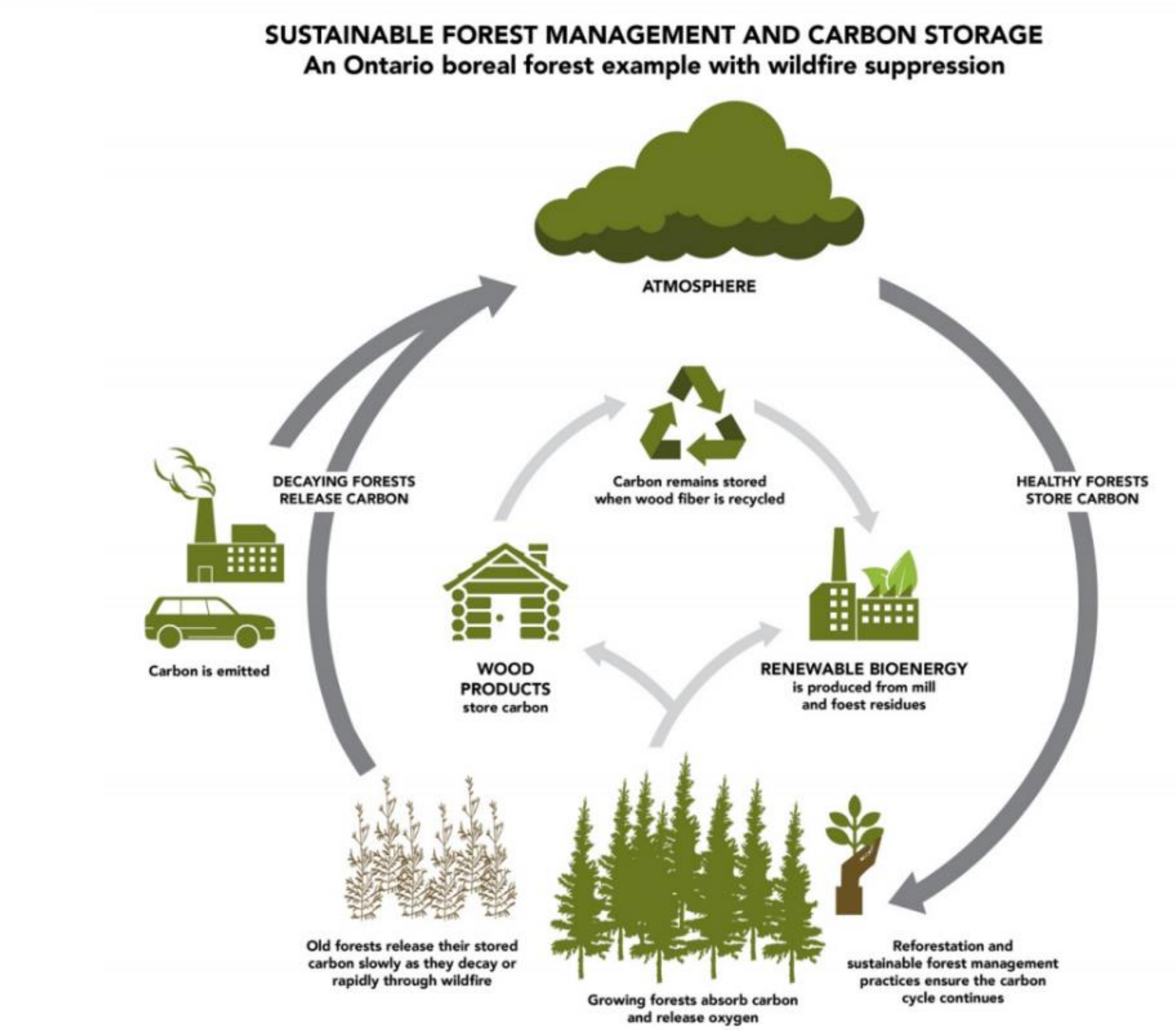
Over the past two decades, and particularly in larger urban and urbanizing jurisdictions, there has been an increasing recognition that (a) trees provide a multitude of benefits and services to the community, (b) proper planning for and management of trees in urban areas must be multi-disciplinary, and (c) effective planning and management of trees requires strategic direction, as well as the buy-in of local leaders.

In this context, an increasing number of urban and urbanizing municipalities in southern Ontario have developed (or are developing) strategic Urban Forest Management Plans (UFMPs) or Strategies that identify and prioritize actions intended to maintain and enhance the sustainability of their tree assets (e.g., City of Cambridge 2015, City of Mississauga 2014, Region of Peel 2011, City of Toronto 2013, York Region 2016).

An UFMP can provide strategic guidance and proactive direction for management efforts, a basis for securing funding from the municipal tax base and other sources, and a framework for adaptive management in response to regular monitoring. UFMPs can also: direct the effective allocation of available resources, help manage risks to trees on municipal lands and help standardize policies and practices surrounding activities related to trees (Bardekjian 2020, APWA 2019). In addition, UFMPs should consider landscape-scale and ecological factors (such as the use of native species and landscape connectivity of tree cover), as well as climate change, community partnerships and economic incentives for supporting urban forest objectives (Ordóñez and Duinker 2013).

Another related best practice is to ensure strategic planning related to the urban forest is integrated into other jurisdiction-wide strategic plans, including plans to reduce risks to human health from climate change (e.g., Region of Peel 2019, Region of Peel 2020). This helps ensure that the urban forest remains a high priority for municipal decision-makers.

An UFMP can also contribute to mitigation by recommending expansion of canopy cover while using wood from trees that must be removed for: long-lived wood products (highest mitigation benefit), burning to produce energy in place of fossil fuel (next best mitigation option), and / or converting it to mulch that is spread around younger trees to promote their growth (McPherson *et al.,* 2015) (see **Figure 5-9**).



Credit: Government of Ontario (www.ontario.ca/page/managed-forests-and-climate-change)

Figure 5-9. Illustration of how sustainable forest management can help mitigate climate change

Peel Region released its first *Urban Forest Strategy* in 2011, Mississauga released its *Urban Forest Management* Plan in 2014, and Brampton has an *Environmental Master Plan* (2014) and recently initiated the development of an *Urban Forest Management Plan*.

> ***We can store more carbon in our forests by:***
> - ***sustainably managing Ontario's forests***
> - ***growing more trees***
> - ***growing healthy trees faster and longer***
> - ***restoring damaged and degraded forests***
> - ***directing harvested wood into longer-lasting wood products***
>
> **Ontario Government (2020)**

5.4 Enhance Tree and Urban Forest Diverity

The changing climate (see **Section 3**) is expected to make conditions less suitable for some tree and shrub species that currently occur in Peel, and more suitable for others that currently occur within the southern portions of or just south / southwest of Peel's boundaries. These changes will be felt most acutely in built-up urban areas, and the responses of different species to these changing conditions is not well understood. Therefore, increasing the diversity of the urban forest is a key best practice for building resilience in the face of this uncertainty.

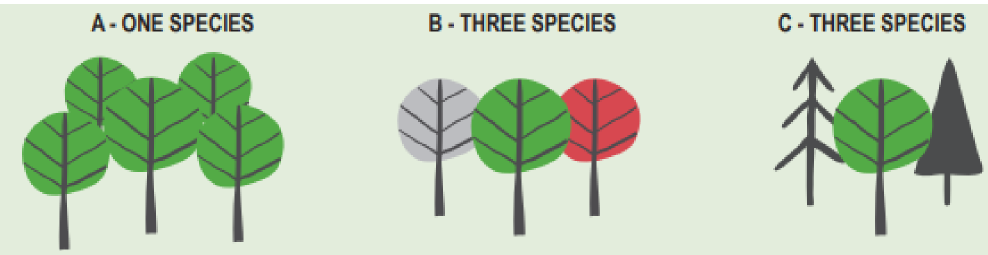
Urban forest "diversity" can refer to different things, including structural, species, genetic and functional diversity (as illustrated in **Figure 5-10** and **Figure 5-11**). All are extremely important for building urban forest resilience in the face of climate change, and all types of diversity should be optimized in a jurisdiction at different scales. As in natural and forested systems, diversity in the urban forest should be considered, introduced and maintained at the jurisdiction-wide (e.g., regional or local municipal), ward, neighbourhood and street scales.

STRUCTURAL DIVERSITY: The services and benefits provided by trees tend to increase exponentially as trees mature, being greatest for large stature trees. Therefore, the foundation of a sustainable urban forest able to help a community adapt today and into the future is laid by planning for and managing to optimize urban forest canopy cover. An optimal tree cover is provided by healthy trees of different ages and sizes spread evenly within a community, which have been provided with growing conditions and proactive maintenance that can maximize their life spans.

SPECIES DIVERSITY: One of the most difficult lessons learned by urban foresters and planners over the past century is that a limited range of species (e.g., red maple, sugar maple, silver maple) and / or genera (e.g., maple, elm, pine) being planted greatly increases the risk of large losses from tree pests or diseases that target specific species or genera. Climate change magnifies the risks to a non-diverse urban forest, whereas the broader the range of species the more likely it will be that some will do well under projected climate conditions.

GENETIC DIVERSITY: In addition to species diversity, there is growing recognition of the importance of genetic diversity within a species (as per **Figure 5-11**), with some provenances[13] being more tolerant of different stresses. Introducing and tracking the performance of individuals from the same species but from different provenances is another recognized strategy for helping to build resilience in the face of climate change.

FUNCTIONAL DIVERSITY: This aspect of diversity is based on traits that determine where trees can thrive and how they interact with other species. A functional trait is any feature that can affect a tree's performance, and can be a physical trait (e.g., branching or rooting patterns), a physiological trait (e.g., tolerance to shade or drought) or a phenological trait (e.g., time of flowering or budbreak) (see **Figure 5-10**). Some functional traits influence tolerance to environmental stressors and can determine a species' resilience to urban conditions and climate change.



Here are three tree communities: Community A is composed of a single species; communities B and C consist of three species each.

By increasing the number of species (community A to B or C), we increase species diversity (biodiversity in the common sense). However, the choice of species is important.

Community B is composed of three species that are similar in their biological characteristics (functional traits). For example, imagine a mix of silver maple, Norway maple and red ash.

Community C is also composed of three species. However, the characteristics of these species are very diverse. For example, imagine a mix of chicot from Canada, serviceberry and thuja.

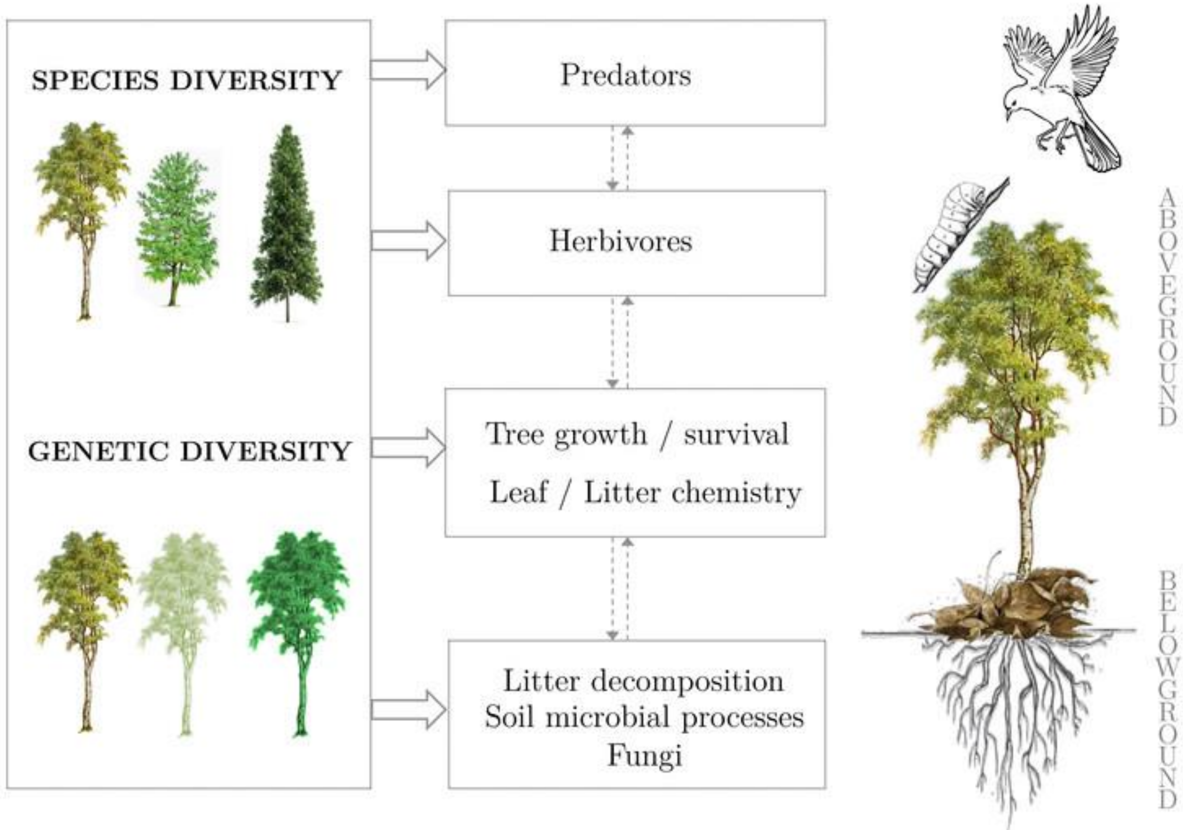
As a result, despite the diversity of species in communities B and C, community C has greater functional diversity, providing more ecological services and greater resilience.

Credit: Paquette (2016) as cited in City of Pointe Claire *Urban Forest Policy* (2017)

Figure 5-10. Illustration and explanation of functional diversity

Given the climatic changes being projected over the next 30 years and beyond (see **Section 3**), choosing the "right" tree for the right place has never been more challenging. Enhancing all aspects of urban forest diversity in this context remains a widely accepted best practice. However, enhancing urban forest diversity to address climate change does not mean abandoning all species whose ranges currently overlap with and currently grow well in Peel and replacing them exclusively with species whose current ranges are further south. Diversification should be undertaken with input from professionals with knowledge of species' ranges, tolerances, and sensitivities, as well as an understanding of how climate may change over time.

[13] "Provenance" refers to the original geographic area in which genetic material originally evolved over time (Hirons and Sjöman 2019). For trees, provenance is site-specific, typically represented by a local stand of trees.



Credit: Satakunta Forest Diversity Experiments (sataforestdiversity.org)

Figure 5-11. How species and genetic diversity contribute to overall forest diversity

Although there continues to be some debate about using assisted migration to introduce species that may be better adapted to changing climate (discussed further in **Section 5.4.1**), urban forest diversification best practices considered appropriate for Peel through this project are as follows:

- Work to enhance structural, species and genetic diversity across the urban forest.
- Implement diversification at multiple geographic scales (e.g., street level, site level, neighbourhood, ward level).
- Diversify at the genus and species levels, and within species with different provenances.
- Include assisted migration as part of overall species diversification efforts, but:
  - Prioritize species whose current ranges overlap with the proposed site (i.e., "assisted population migration")
  - Followed by some species whose current ranges are just south of the proposed site (i.e., "assisted range expansion"), such as introductions of species historically found in Niagara Region or Ohio but not in Peel, and
  - With limited introductions of species whose ranges are currently far from Peel (i.e., "assisted long-distance migration") such as from Tennessee or Arkansas.

- Exclude species:
    - that currently occur in Peel and are known to be invasive
    - not currently known to occur in Peel from further south that are invasive and therefore potently invasive in Peel
    - associated with serious pests/pathogens, and
    - known to hybridize with other species native to Peel Region (especially if they are provincially threatened or endangered, or locally rare or uncommon).
- Request, advocate for and track source information for planting stock.
- Where source information is obtained, track the success of different species and provenances in a standardized and targeted manner, with support from partners.

At the site and street scale, diversification tools and approaches in a context of climate change for street and park trees[14] include the following.

- Enhance diversity and growing conditions by creating planting "nodes", "Miyawaki" or "mini" forest communities (i.e., groupings of several trees with understory plantings and mulch instead of a single tree with mown grass or permeable hardscaping underneath).
- Select species suited to the existing site conditions while also considering anticipated climate suitability (see **Section 5.4.2**).
- Plant multiple genera, species and – if possible – provenances on a single street (they may be selected for similar form / appearance if visual consistency is being sought).
- Plant a higher diversity of species where growing conditions are less stressful (e.g., parks)
- Incorporate long-lived species as much as possible.
- Diversify locations of new plantings strategically on streets in different quadrants of the jurisdiction over successive years to sustain and build age / size diversity.

5.4.1 Assisted Migration

One of the greatest climate change factors affecting trees is that the natural ability of trees to migrate in response to changes in the climate (generalized by the FGCA at about 100 m per year) will be greatly outpaced by the changes in climate anticipated under the "worst case" scenario (i.e., RCP8.5) (which are estimated by the FGCA to require tree migration at about 3000 m per year). Because many tree species will be increasingly maladapted as climate change progresses and different species have different tolerances to environmental conditions and stressors, integrating greater urban forest diversity is a way to enhance resilience in the urban forest.

Trees have adapted to conditions across North America since the glaciers last retreated about 10,000 years ago. There are hundreds of species of trees (and shrubs) occurring in eastern North America that have developed ingenious strategies to survive and spread over time, and there are over 130 species whose current ranges extend into Peel Region. In addition, many tree species with broad ranges may have provenances that are adapted to different geographic regions within their range.

[14] Note that an assisted migration planting plan for a natural community would need to include different considerations, such as the current community type.

THREE TYPES OF ASSISTED MIGRATION

1. **ASSISTED POPULATION MIGRATION: The human-assisted movement of populations (with different genetic makeup) of a given species within that species' current range (i.e., where it would naturally spread).**
2. **ASSISTED RANGE EXPANSION: The human-assisted movement of a given species to areas just outside its current range, assisting or mimicking how it would naturally spread.**
3. **ASSISTED LONG-DISTANCE MIGRATION: The human-assisted movement of a given species to areas far outside its current range (beyond where it would naturally spread).**

Adapting Sustainable Forest Management to Climate Change (Ste-Marie 2014)

Relatively few of the tree and shrubs species native to Peel Region are commonly used as street or park trees, in part because of the challenging growing conditions, but more importantly because they are not widely grown by the nursery trade and therefore many are not available. As a result, the narrow palette of options for street and park trees has come to include non-native and even invasive species able to withstand harsh urban environments. Climate change presents a unique opportunity to expand the variety of native, and potentially non-native and non-invasive, tree and shrub species being established.

Municipal street and park trees in southern Ontario, even when they are species considered native to the region, are often from seed and/or stock from south of Ontario, often from Ohio or Illinois and sometimes from as far south as Texas[15]. So assisted migration has been occurring for decades, even if it has not been recognized as such. However, there are significant risks associated with assistant migration, particularly from assisted long-distance migration. These risks include introducing species that:

- Become invasive in Peel and negatively impact the biodiversity and ecological functions of natural communities
- Bring pests or diseases that negatively impact native and/or non-native species already established in Peel, and
- Hybridize with native species and cause genetic dilution of the native gene pool.

Given these risks, assisted migration should be undertaken gradually, with care and with precautions in place. For example, some practitioners suggest for a given assisted migration planting trial that about 34% of the species are native or local to the planting area, 33% are from a nearby seed zone or Ecoregion to the south but not necessarily local to the planting site, and 33% are species whose ranges are from slightly further south.

[15] Municipal urban foresters have shared that in their experience most nurseries do not source larger stock locally – like that typically used for street and park trees – because it is much quicker and more cost effective to have these trees started further south in the United States where the growing season is longer and then shipped to Ontario for a season of hardening off before planting.

Despite the risks, well-documented assisted migration is supported as a best practice for Peel, not only because of concerns related to climate change, but also because natural migration is too slow to keep pace with the rate of climate change, in addition to which both the Great Lakes and urbanization itself present significant barriers to the natural movement of potentially suitable species from southern zones.

Tracking and assessing ongoing assisted migration should be considered another best practice. Historically, there has been little to no tracking of tree seed or nursery stock genetic source, and very limited monitoring of how trees and shrubs from different sources respond to urban conditions in Ontario. The Forest Gene Conservation Association (FGCA) and Forests Ontario are among the organizations working with landowners, government and other organizations to undertake assisted migration trials for trees and shrub species considered native to southern Ontario[16]. Additional work in urban areas with street and park trees is required in Peel and elsewhere.

Knowledge gaps in this area can be filled by urban forestry practitioners and others by:

- Preferentially working with Ontario nurseries that grow nursery stock from source-identified seed from certified collectors
- Supporting and participating in trials with different potentially suitable woody genera, species, cultivars and provenances to expand the list of stock considered "proven" in Peel's urban areas, in partnership with other agencies and organizations, and
- Considering woody species from the list of potentially suitable species for Peel developed for this project (see **Section 5.4.2**).

Research trials can have tremendous outreach value to help communicate and demonstrate the impacts of climate change to the general public and decision-makers. Opportunities to undertake such trials should be pursued and marketed as part of broader outreach related to the urban forest and climate change (see **Section 5.9**).

Some of the northern tree species may not be able to adapt to the increasing temperature and may be replaced by more southern species that are expanding their range … However, it is important to consider barriers to these southern, more adaptable species, which include lower habitat connectivity in south and middle Peel Region, urbanization along the shoreline extending from the Greater Toronto Area to Niagara, and the Niagara Escarpment acting as a pinchpoint.

Natural Systems Vulnerability to Climate Change in Peel Region **(Tu *et al.*, 2017)**

[16] The MNRF has divided the Province of Ontario into "ecodistricts"[16] which are used by the Province as geographic units for defining seed source areas, as well as developing guidance on suitable planting areas for different seed sources in a context of assisted migration. Peel Region falls within Ecodistricts 6E-7 to the north and 7E-4 to the south, and most of the climatically suitable areas for seeds tentatively identified for Peel are in southwestern Ontario (e.g., from Fort Erie to Windsor) and the nearby northern U.S. states (e.g., Illinois, Michigan, Ohio, New York) bordering the Great Lakes (MNRF 2020).

5.4.2 Trees Suitable for Peel's Urban Areas

One of the key deliverables for the Peel Region Urban Forest Best Practices project was *Guide 4: Potential Tree Species for Peel in a Climate Change Context*. This guide includes vulnerability assessments for 88 tree species, most of whose ranges are currently within or just south of Peel, based on projected conditions in the 2041 to 2070 timeframe under the "worst case" scenario (i.e., RCP8.5). As described in Guide 4, more than half of the species assessed were ranked as being "highly" or "extremely" vulnerable under projected conditions. While this does not imply that these species will no longer be able to survive in Peel under projected conditions, it does indicate that Peel will generally no longer provide an optimal climate for their growth and therefore these species will be less likely to thrive and may be more susceptible to stress and mortality when climate change exacerbates existing stressors.

One of the central challenges for urban forest management in Peel going forward will be enhancing biodiversity while limiting the introduction of invasive tree species. The tree species vulnerability assessments provided in Guide 4 are intended to inform selection of tree species for planting in Peel Region, in particular for its urban areas. However, total exclusion of species assessed as "highly" or "extremely" vulnerable in this assessment or in others (e.g., Sansom 2020) is not recommended. This is because there is some uncertainty associated with these assessments (as discussed in Guide 4) and also because projected species vulnerability should be considered in conjunction with other factors, such as site conditions (see **Section 4.2**) and other aspects of species' tolerance and sensitivity (e.g., tolerance to ice damage or flooding).

5.5 Plan with Equity in Mind

The impacts of climate change will not be felt equitably in Peel (or around the world). Some of the anticipated changes that will pose the greatest risks to human health – such as more days with dangerously high temperatures and poor air quality – will disproportionately affect vulnerable populations (e.g., children and the elderly), low-income communities[17], people with respiratory illnesses and those who work or spend long hours outdoors (e.g., the homeless).

While some of the greatest opportunities for carbon capture are through the creation and restoration of forested natural areas, well-managed individual trees along streets and in other open spaces (such as parks, residential yards, institutional and commercial landscaped areas) also provide adaptive benefits to the people who live and work in those areas.

In Peel, tree cover tends not to be spread equitably across its urban areas, and as a result neither are many of the services and co-benefits associated with urban trees. Although the results of research to date have been mixed (e.g., Chuang *et al.,* 2017), the greater availability and quality of greenspaces in urban areas tends to be linked to more affluent neighbourhoods (CFS and UBC 2016). The positive effects of urban greenery on health are also more pronounced among lower income groups (Mitchell and Popham 2007).

[17] Low-income households are more likely not to have air conditioning or to not be able afford to fully operate their air conditioning systems and are also more likely to live further from large green spaces (American Forests 2020).

Equitable distribution of public green spaces helps ensure that all residents have access to the services these areas provide. Peel and its partners are committed to providing these services equally to support broad societal well-being. Therefore, planning with equity in mind is a best practice for urban forest climate change adaptation in Peel.

Strategies are to be developed by working "*collaboratively with key stakeholders to drive local climate action and secure investment that enables the rapid and equitable transformation of municipalities and broader community … to become low carbon and resilient*".

Peel Climate Change Partnership Terms of Reference 2018 – 2022

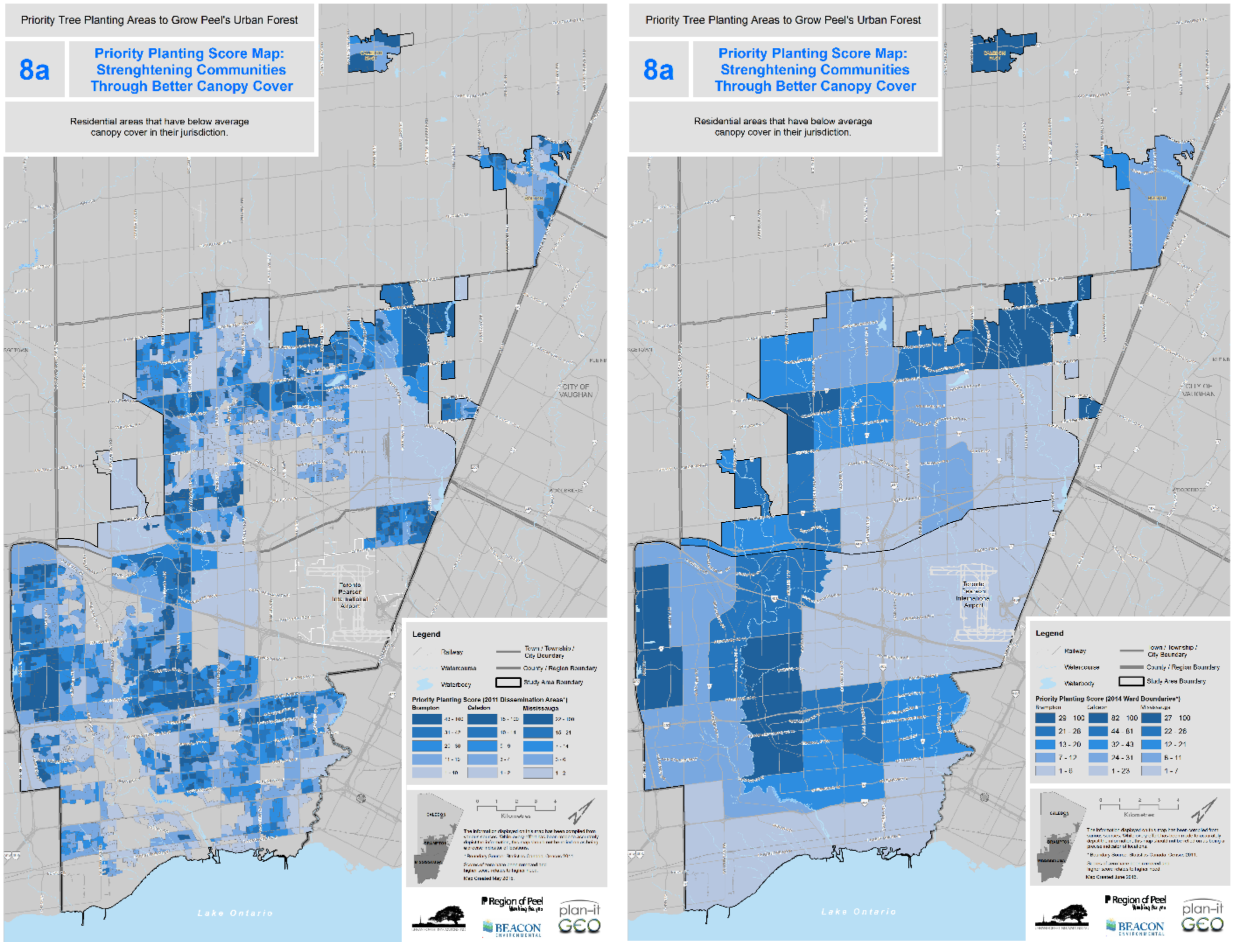
Planting and conserving trees is one equitable way to reduce urban heat islands and save lives.

American Forests website (2020)

Peel Health's strategic priorities include reducing health-related impacts of climate change and advancing health equity (Region of Peel 2020). Prioritizing investment in green infrastructure, including the urban forest, is increasingly recognized as a "win-win" approach that can help address social inequities, while also reducing health risks to those already vulnerable and providing benefits to the entire community (e.g., WBG and WRI 2019). Therefore, best practices in Peel should continue to prioritize tree protection and establishment in areas with concentrations of vulnerable persons and / or low-income households that also have limited tree canopy cover.

An available tool that can be used to address the inequitable distribution of trees and green spaces and to prioritize them for action is the Region's GIS-based Tree Planting Prioritization Tool (TPPT), which, among other things, can map priority areas for tree establishment based on a single or a combination of variables, including canopy cover (see **Figure 5-12**), household income and urban heat island effects (Beacon *et al.*, 2015, Richardson 2015). This tool is currently underutilized but remains relevant, particularly in the context of climate change, and could be used to help direct tree planting to, for example, areas in Peel most vulnerable to urban heat island effects or most lacking in canopy cover.

Focusing tree protection and establishment efforts where vulnerable and / or low-income persons and communities in Peel will benefit the most can also be done by targeting efforts in and adjacent to parks, public schools, long-term care facilities, hospitals and community centers.



Credits: *Priority Tree Planting Areas to Grow Peel's Urban Forest* (Beacon *et al.*, 2015)

Figure 5-12. Priority tree planting areas based on canopy cover at two different scales

5.6 Take an Integrated Approach to Planning

Peel's population was just under 1.5 million in 2018 and is projected to grow to close to 2 million by 2041. This growth provides many opportunities for building smart and sustainable communities. However, if this growth is not planned or managed with the urban forest at the forefront, it may result in communities that fall short of trees, natural areas and other green open spaces that are needed to help the community adapt to and mitigate climate change. Effective management and planning of the urban forest requires a multi-disciplinary and multi-departmental approach. Therefore, in addition to having a stand-alone urban forest management plan or strategy (see **Section 5.3**), it is also a best practice to align other strategic documents with the vision, goals, objectives and targets identified for the local urban forest.

Examples include incorporating urban forest policies in official plans and secondary plans and aligning other municipal strategic plans with urban forest goals (e.g., Vancouver's 2018 *Climate Change Adaptation Strategy* includes supporting the City's *Urban Forest Strategy* as a priority focus area and integration with other strategies, including a Living Systems Strategy). Peel's

Climate Change Master Plan 2020-2030[18] and Mississauga's *Climate Change Action Plan* (2019)[19] are local examples of documents that incorporate urban forest objectives. Peel and its local municipalities have also begun to link urban forest planning and climate change, through initiatives such as the Peel Climate Change Partnership's *Green Natural Infrastructure Strategy*.

The municipalities that seem to have the most success in moving urban forest objectives forward are those that have: (a) urban forest goals embedded in all levels of planning, (b) a range of complementary planning tools related to the urban forest, and (c) broad support for and buy-in to goals for the urban forest. Having urban forest planning tools at all levels that work together is key to accomplishing community goals for urban forests. For example, complementary planning is promoted by strong policies at the Official and Secondary Plan levels supported by zoning and/or Site Plan Controls; woodland and tree bylaws that are consistent with and linked to site-specific guidelines; and manuals providing specific directions related to tree protection and establishment techniques in accordance with best practices.

In addition, having municipal tree protection and establishment standards, integrating those standards into other municipal specifications can also facilitate implementation. For example, the City of Guelph has a *Tree Technical Manual* (2018) that consolidates its tree-related guidance and also incorporates some of this guidance into the City's *Development Engineering Manual* (used by engineering staff), the *Linear Infrastructure Standards* (used by transportation staff) and the *Downtown Streetscape Manual and Built Form Standards* (used by the city's Urban Planners).

> ***We've had some success with these issues by incorporating the soil volume requirements into the city's engineering manual, and also in downtown streetscaping guidelines. The standard is less likely to get missed when it's incorporated into existing development policy.***
>
> **Brian Geerts, Manager of Operations, City of Cambridge, ON**
> **(from CANUFNET Sept. 9, 2019)**

A variety of municipal guidelines, standards and tools aiming to ensure effective tree establishment practices are implemented through the subdivision and site planning processes. Beyond municipal tree protection and establishment standards, these include green standards and sustainability tools currently being implemented in southern Ontario through municipal planning processes. For example, the City of Brampton, City of Vaughan, Town of Richmond Hill and City of Burlington have developed Sustainability Guidelines (e.g., **Figure 5-13**) that include specific measures which require and encourage: protection of existing trees, planting a diversity of trees in adequate soil volumes, meeting canopy cover targets and enhancing the natural heritage system.

[18] Peel's Climate Change Master Plan 2020-2030[18] identifies "*implement tree planting and management program for new and existing trees*" as Task 14.3 as part of a broader action to protect and increase green infrastructure and highlights the importance of monitoring and reporting (e.g., Activities 15.1 and 15.4).

[19] The City of Mississauga's Climate Change Action Plan (2019) includes Action 10 to "*maintain and enhance the urban forest to improve air quality, reduce greenhouse gas emissions, and improve resilience*" with five supporting actions that speak to expanding tree canopy, increasing species diversity, implementing management programs and undertaking monitoring.

Credit: City of Brampton (2018)

Figure 5-13. The City of Brampton's Sustainable Community Program

More specific guidance and planning resources are provided in the Peel Region Urban Forest Best Practices project *Guide 1: Best Practices Guide for Urban Forest Planning in Peel* (2021).

5.7 Take an Integrated Approach to Design

Establishing and maintaining large statured trees in built-up urban areas can be very challenging due to the intense competition for space and environmental conditions that are often sub-optimal. Having to consider threats to trees caused by climate change (see **Section 3**, **Table 2**) adds another layer of complexity to this process. However, these challenges can be overcome with careful and collaborative planning and design with input from knowledgeable professionals.

The health and resilience of the urban forest ultimately depends on the health of the individual trees within it. Therefore, a key best practice to help manage the challenges associated with both urbanization and climate change is ensuring the right tree goes in the right place at the site level and maintaining it to maturity. To this end, the following sub-sections focus on:

- Taking an integrative approach to site design so that healthy trees can be established and maintained while also meeting other site-specific objectives (**Section 5.7.1**), and
- Key best practices for optimizing growing conditions for trees in challenging urban settings (**Section 5.7.2**).

More specific best practice guidance and resources are provided the Peel Region Urban Forest Best Practices project *Guide 2: Urban Forest Management Best Practices Guide for Peel* (2021).

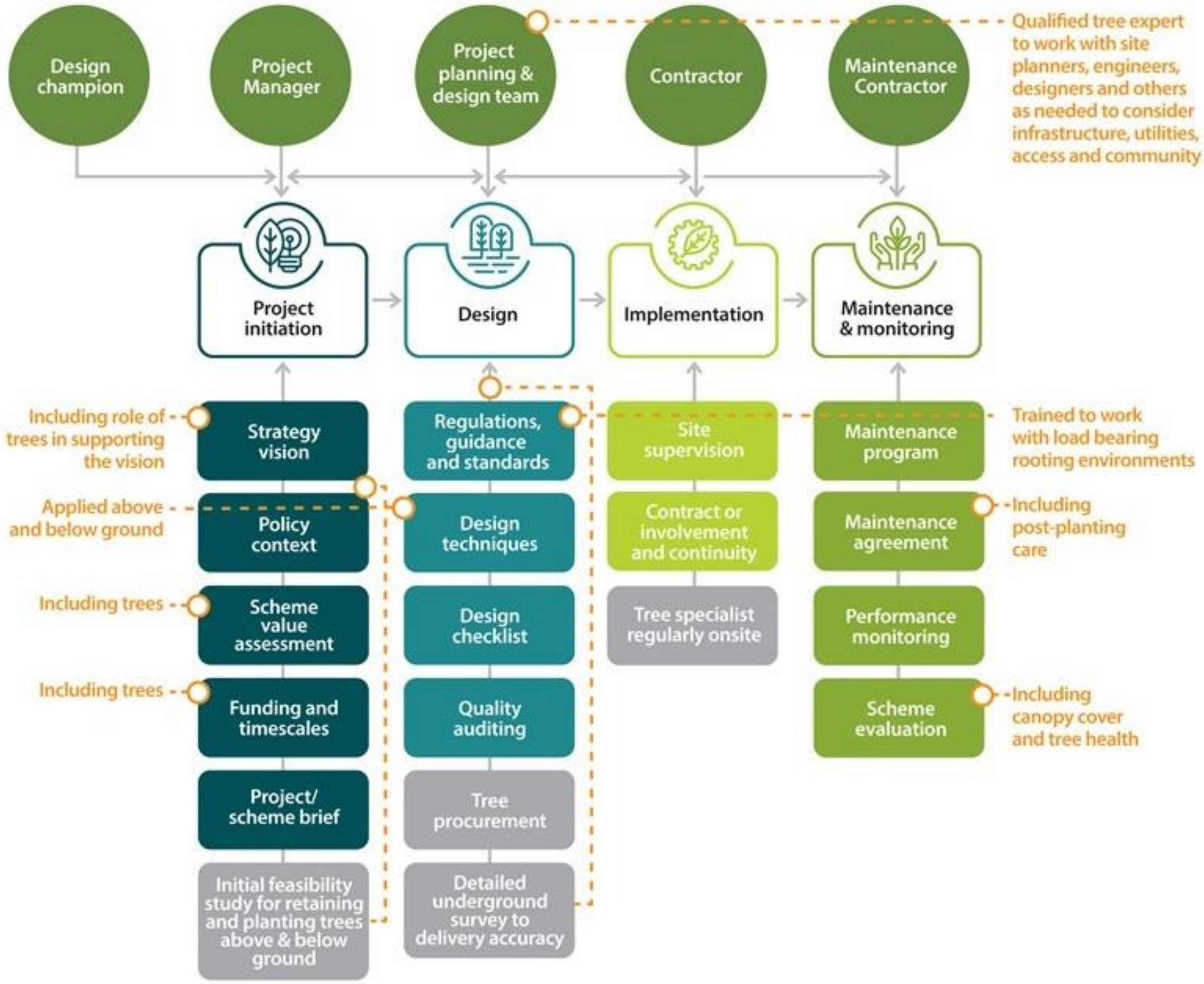
5.7.1 Meet Multiple Objectives

Construction, maintenance and redevelopment of functional urban communities requires planners, architects, engineers and others, such as infrastructure operations staff, to collaborate. Similarly, getting trees into urban areas, and particularly into built-up up areas, requires a cross-disciplinary and collaborative approach. To be effective, this approach must be adopted from the first stages of project planning and initiation through to design, installation, maintenance and monitoring, *as per* the example in **Figure 5-14**.

Examples of best practices that can help ensure “tree-positive” outcomes include:

- Involvement of representatives from all relevant departments and / or organizations (including above and below-ground utilities, transportation, municipal maintenance, etc.) along with at least one professional with sufficient arboriculture knowledge to ensure tree technical and biological needs, both above and below-ground, can be met
- Review of conceptual plans and designs, project requirements and potential conflicts with trees, as well opportunities for establishment early in the process
- Consultation with the local community and stakeholders
- Confirming at the detailed design stage or prior to implementation that adequate above and below-ground space can be provided, along with access for tree maintenance, and
- Involvement of a tree specialist to inform species selection, stock inspection, tree installation, post-installation care and monitoring for long-term maintenance.

As growth of urban areas intensifies, so too does competition for space. The above and below-ground space required for medium to large-statured trees to reach maturity is not highly flexible. So, finding ways to meet other planning and/or design objectives while also providing suitable space for trees is key to establishing more trees.



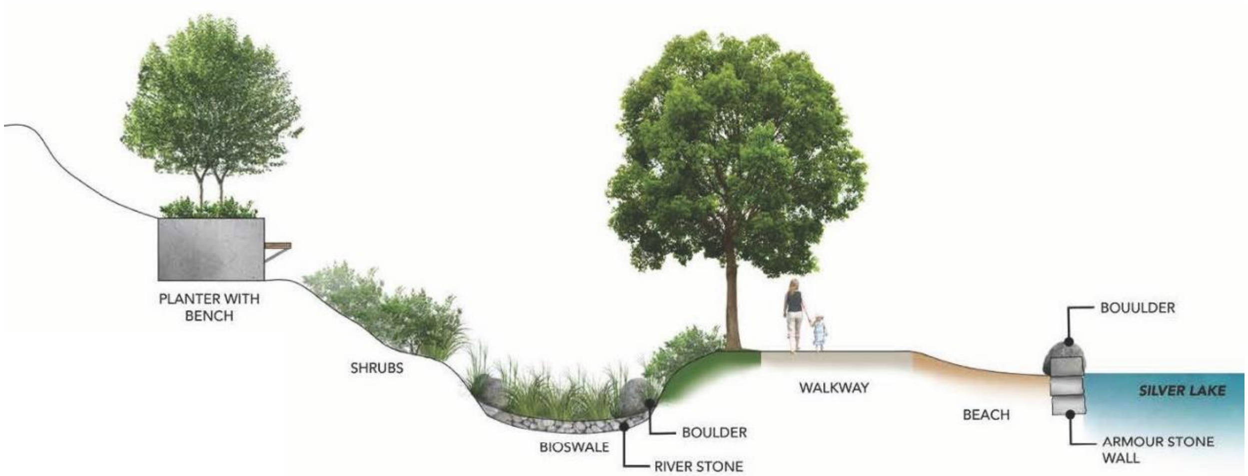
Credit: Adapted from Trees and Design Action Group (tdag.org.uk)

Figure 5-14. An example of an integrated design process for trees in built-up settings

Examples of site-specific designs that dovetail objectives related to the provision of canopy cover, stormwater management and human uses are provided below:

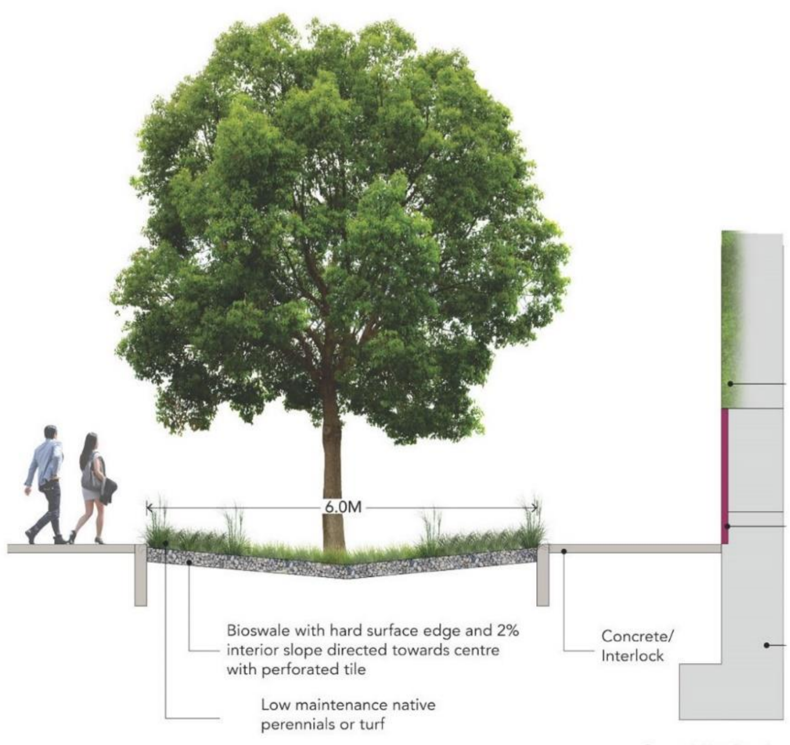
- **Figure 5-15** shows a lakefront area which provides shade and cooling for pedestrians, accommodates a large statured tree, and incorporates a bioswale for infiltration, water storage and water quality functions. The planter not only contributes to slope stability while the trees in it also contribute to canopy cover (e.g., cooling, improving air quality), but it also serves as a local amenity by providing a bench.
- **Figure 5-16** shows a pedestrian walkway design that incorporates a large-statured tree planted adjacent to a swale; the swale provides enhanced rooting area and infiltration and treatment of surface runoff, which is also a passive water source for the tree.
- **Figure 5-17** similarly shows a parking lot design that incorporates medium and large-statured trees with enhanced rooting areas, while also providing swales that allow infiltration and treatment of surface runoff and passive water sources for the trees.

Each of these examples demonstrate how municipal staff in charge of urban forest planning and management can collaborate with others to provide climate change adaptations related to the urban forest (e.g., cooling, water quantity management, water quality management), while using the same or overlapping areas to also provide stormwater management (e.g., Berland *et al.,* 2017) and help support human health.



Credit: GIF and OPA 2019

Figure 5-15. Combining canopy cover, infiltration, water quality and human-use objectives



Credit: GIF and OPA 2019

Figure 5-16. Combining canopy cover and infiltration objectives in a streetscape

Credit: Diamond Head 2017b

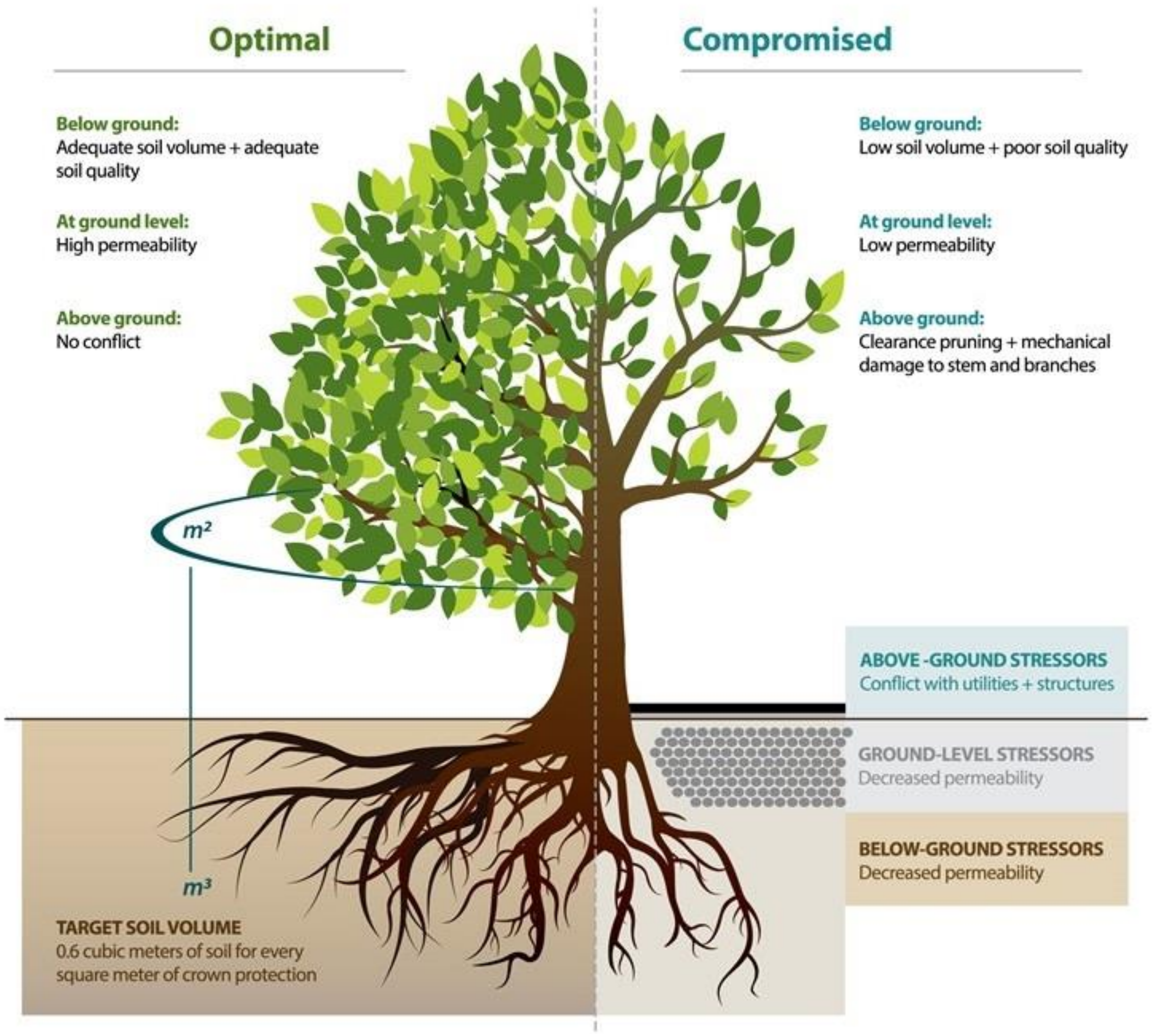
Figure 5-17. Combining canopy cover and infiltration objectives in a parking lot

5.7.2 Optimize Growing Conditions

The urban environment rarely presents optimal establishment or growing conditions for trees. Furthermore, many of the environmental stressors that trees are exposed to in urban environments (e.g., intense heat and winds, drought) can be exacerbated by climate change (see **Section 3.2**). Therefore, where a decision is made to plant, it is imperative to (a) undertake a thorough site assessment (see **Section 4.2**), (b) invest in site-appropriate and diverse tree selection (see **Section 5.4**) and (c) ensure site-specific conditions can support healthy tree establishment and future growth, as discussed further below.

As long-lived biological entities, trees have tremendous capacity to be resilient to environmental stressors and provide a wide range of co-benefits that increase exponentially as they grow. However, living organisms have their limits. As illustrated in **Figure 5-18**, the three key components of an optimal site are:

1. Soil with adequate volume (i.e., space) and quality for rooting
2. Allowing for moisture and oxygen to reach the roots at ground level (i.e., high permeability, limited compaction), and
3. Little or no above-ground conflicts, allowing the tree to grow without interference or awkward pruning and with adequate access to sunlight.



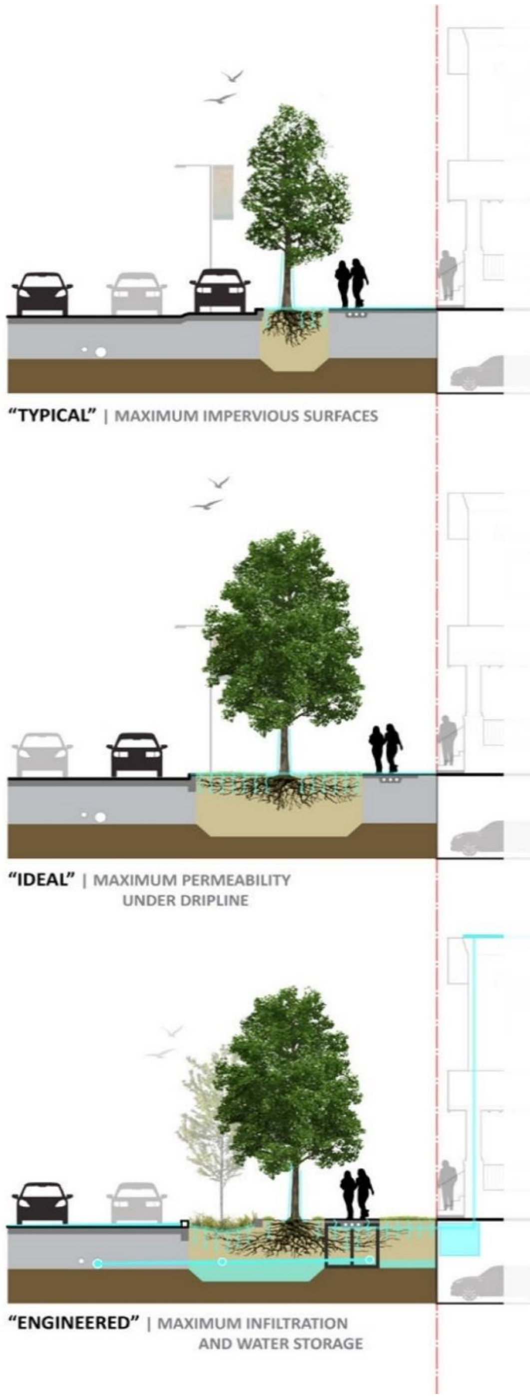
Credit: Adapted from Diamond Head 2017b

Figure 5-18. Key differences between optimal and sub-optimal tree growing conditions in urban areas

Key site-specific design features and approaches related to soils, water and tree maintenance to help ensure optimal conditions for trees (adapted from Diamond Head 2017a) are summarized below.

SOIL MANAGEMENT

- Maximize soil volumes by designing for shared soil volumes (e.g., open-topped tree pits shared by multiple trees and / or with companion plantings), incorporating break out areas under impermeable surfaces that connect to permeable areas (e.g., use of suspended pavement, soil cells, etc., in hardscapes).
- Protect soils from excessive compaction, salt accumulation or other contaminants (including those that affect pH) before, during and following installation.
- Preserve or improve soil quality (e.g., support re-use and re-conditioning of locally available soils where possible; limit and/or manage sources of contamination such as salts; include organic matter in introduced soils).



Credit: Diamond Head 2017b

Figure 5-19. Illustration of design options to meet infiltration objectives

WATER MANAGEMENT

- Provide mechanisms for passive surface water infiltration (e.g., directing surface runoff to rooting areas, maximizing permeable area) (as per **Figure 5-19**).
- Recognize that different species use water differently (Canon 2019), so provide for supplemental active watering when needed (e.g., water bags, drip irrigation).
- Ensure adequate drainage and that site design does not create conditions for localized flooding / waterlogging.
    - Minimize interfaces between the soil in the planting pit and the adjacent substrate (e.g., try to match the soil being introduced with the tree to the surrounding soil type, or at least ensure there are opportunities for drainage from the rooting area to the surrounding interface).
- Increase water storage capacity and reduce water loss (mulching, avoid turf grass within drip line and add amendments where appropriate to increase soil porosity).
- Irrigate efficiently (e.g., establish local rainwater harvesting or greywater reuse).

PROACTIVE TREE CARE

- Implement and supervise proper tree protection / installation during construction.
- Invest in proper young tree care and maintenance, particularly watering, pruning and protection from damage (e.g., mulch over rooting area, main stem protection).

Notably, more emphasis is on below-ground than above-ground measures because the size and nature of the tree's root system and rooting environment are critical to helping it survive periods of heat and drought. If trees are to survive and even thrive in urban settings with climate change, then site-specific design and maintenance that prioritizes the area for roots to develop and the quality of below-ground conditions is essential.

5.8 Seek Climate Positive Outcomes

Protecting and enhancing the urban forest so that it moderates climate extremes in areas where it can have the greatest human health benefits was one of the primary reasons to develop the five Peel Region Urban Forest Best Practices guides. Therefore, this section focusses specifically on best practices related to the urban forest's ability to moderate local urban heat island effects.

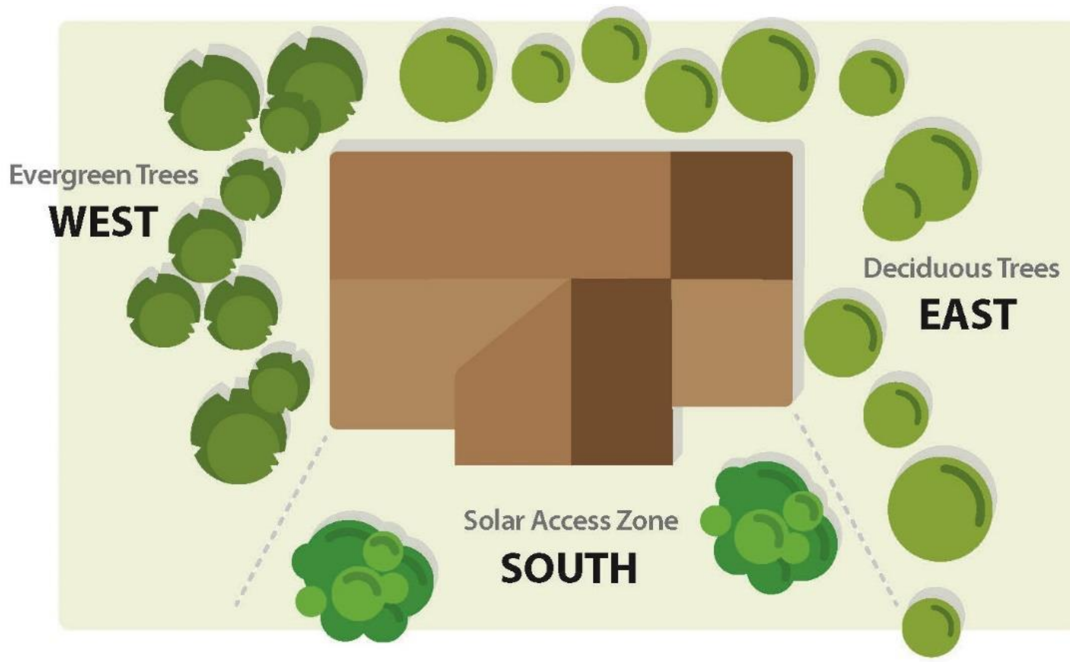
Anatomical features of trees that promote cooling of the environment include the following (as per Rahman *et al.,* 2020):

- Leaf area index (the leaf area per square metre of ground surface)
- Leaf colour (dark green leaves provide better shading and higher transpirational cooling than lighter green leaves)
- Leaf thickness (thinner leaves provide more transpirational cooling)
- Leaf shape (simple leaves provided greater transpirational cooling than compound leaves), and
- Diffuse porous wood anatomy (which provides greater transpirational cooling than ring porous species).

As a result, deciduous trees generally provide better cooling than coniferous trees, and trees with diffuse porous wood anatomy, simple leaf shape and lower leaf thickness, such as red maple (*Acer rubrum*), can provide far greater air-cooling than similar size trees without these attributes, such as honey locust (*Gleditsia triacanthos*) (Rahman *et al.,* 2020).

While species functional differences in this regard should be one of the considerations that informs site-specific or neighbourhood-specific species selection, this should not override broader diversity targets or objectives (as per **Section 5.4**). The potential for reducing temperature extremes should also not be considered more important than appropriate site placement, since good growth conditions for trees will maximize their contribution to climate moderation. In eastern North America, placement of deciduous trees north and east of a building is known to provide effective cooling in summer, while conifers to the west and south provide effective wind breaks in winter months (see **Figure 5-20**). In addition, a mature tree of almost any species will provide much greater cooling than a recently established one, so the most important design approach is to provide conditions that will support the survival and health of trees to maturity.

Recent modelling of two urban study areas in Peel Region found that areas with 50% "green" cover experienced average daily ambient temperature decreases of 0.8 to 1.3 °C, while sites with 80% "green" cover experienced average daily ambient temperature decreases of 1.5 to 2 °C, compared to locations in Peel without these amenities (BeTop Labs 2020). It was also noted that, depending on wind conditions, cooling effects could extend up to 250 m downwind, the shade under a single tree could make it feel 3°C cooler, and within ravines with extensive canopy cover it could feel as much as 11°C cooler in the early evening on a hot summer day. In a similar study in Montreal, Quebec, Wang and Akbarib (2016) likewise found that during daytime, tree cover could reduce tree level air temperatures by 2 to 4 °C.



Credit: Adapted from the Town of Caledon and The MBTW Group 2017

Figure 5-20. Site-specific planting to provide wind breaks and reduce home heating costs

Vaz Monteiro *et al.* (2019) discussed how management of urban trees with climate change in mind can directly and indirectly reduce the urban heat island effect. For example:

- Drought tolerant species are better able to cool their environment than species that are sensitive to drought, because they are less likely to shed their leaves if moisture stressed and will continue to transpire and provide shade and cooling
- Targeted watering during heat waves and providing planting spaces with adequate soil volume promotes cooling by trees by supporting transpiration, and
- Avoiding soil compaction can increase water penetration into the soil and provide better soil aeration, which promotes tree root spread and water absorption, while also supporting transpiration by the tree and evaporation from the surrounding soil.

Additional site design tools and approaches that support urban heat island reduction and human health by cooling, while also providing shade and air quality benefits (adapted from Barron *et al.,* 2019), include:

- Selection and placement of trees to shade well-used open spaces and areas
- Investing in protecting and maintaining mature trees in urban areas
- Placing trees to maximize shade provision and trying to create areas of continuous canopy cover along active transportation routes and other places of congregation, and
- Planting trees and shrubs in river valleys adjacent to watercourses to cool water temperatures.

5.9 Foster a Tree-Friendly Culture

Protecting and increasing green infrastructure, including trees, throughout Peel will be increased through partnerships. Municipalities in Ontario are responsible for planting and maintaining trees along their roads and in their public open spaces, but many of the opportunities for protecting and expanding tree cover are on lands that are not under municipal ownership or management. Therefore, partnerships with other public sector and private sector landowners are required.

Urban forest management, especially in a climate change context, can also benefit from the support and insights of various Indigenous, academic, private sector, governmental and non-governmental partners. For example, even municipalities with well-funded forestry programs typically do not have the scientific expertise or resources to undertake local tree seed collection or planting trials with different species of street trees. The collaborative and multi-disciplinary Peel Urban Forest Best Practices project that generated five guides, including this one, is a good example of the types of partnerships needed to move urban forestry forward.

Urban forestry professionals recognize the importance of having support for trees in all departments and levels of a municipality, and among key stakeholders and community members. This section highlights some best practices for fostering a tree-friendly culture within the municipal organization (**Section 5.9.1**) and across the community, including opportunities for enhancing partnerships (**Section 5.9.2**) to effectively advance urban forestry objectives.

5.9.1 Municipal Networking

For municipal urban forest objectives to be implemented, all levels of staff in all departments must have a common understanding of the vision for the urban forest and of how the available tools work together from planning to design, to achieve the desired goals. One fundamental best practice is internal coordination and buy-in among municipal staff in different departments and between regional and local municipalities, where applicable (as in Peel).

> **Even with policies in place, opportunities can be missed due to gaps in the process, including:**
>
> - ***the lack of involvement by staff focused on tree preservation and/or replacement at the outset of the process …***
> - ***the absence of City-wide standard engineering specifications or detailed drawings …***
> - ***the lack of consistent requirements for site supervision and follow[-up] inspection by a Certified Arborist at key points during and following construction.***
>
> ***City of Mississauga Urban Forest Management Plan* (2014)**

Recognition of the need for and the benefits of interdepartmental coordination and cooperation when planning for the urban forest on both private and municipal lands is included in most municipal urban forest strategies / plans. Some specific examples are provided below.

- In the Town of Oakville, all local and regional capital projects must be supported by a complete arborist report, including a tree inventory, tree preservation / removal plan, tree compensation calculation and, where required, tree injury or removal permits. Securities can also be held by the department of the municipality responsible for signing off on the tree-related / landscaping works.
- York Region's Forest Management Plan (2016) includes the following action items:
  - *Identify and share best practices through communication and collaboration with local municipalities and other partners* (Goal 1), and
  - *Increase communication, collaboration and alignment with other regional departments, local municipalities, academia, institutions, private industry, business improvement area groups, and nongovernment organizations* (Goal 5).

The Peel Urban Forest Working Group (UFWG), established in 2009, continues to meet regularly, and includes representatives from the Region, its local area municipalities, CVC and TRCA. This group also works with the Peel Climate Change Partnership (PCCP) to coordinate urban forest issues as they relate to climate change actions and priorities. The Peel UFWG is a good example of a vehicle for internal information sharing and coordination.

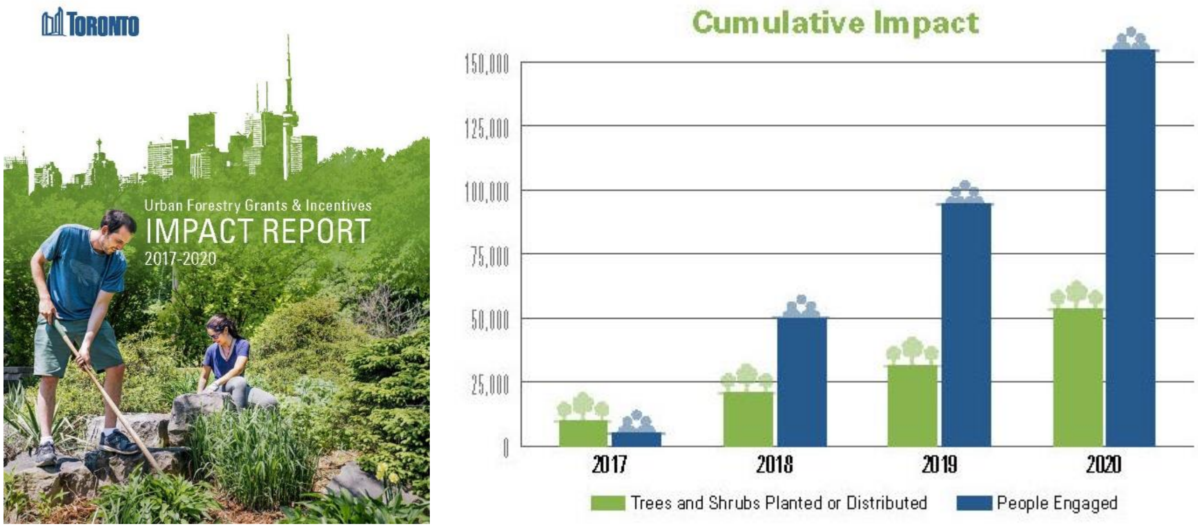
5.9.2 Community Networking and Partnerships

It is widely recognized by those involved in urban forestry that broad community engagement is central to the effective development and implementation of urban forest policies and practices (e.g., FAO 2016, Bardekjian 2018). Although many of the best practices in this guide have focussed on municipal practices and what can be done on public lands, many of the opportunities for expanding the urban forest in Peel and across southern Ontario are lands owned and / or managed by other public and private entities (e.g., academic institutions, health units, utility and transportation agencies, private golf courses, residential yards, condo blocks). Therefore, it is critical to engage external partners, stakeholders and a broad spectrum of the community on urban forest and greenspace planning and stewardship on a regular basis.

> ***Our vision is for a healthy and resilient urban forest that provides diverse and sustained benefits to all and is grown from a shared commitment by all members of the community to the stewardship and care of this vital infrastructure.***
>
> ***Peel Region Urban Forest Strategy* (2011)**

People who are engaged in urban forest issues are much more likely to understand and support them. There are many approaches and tools for effective community engagement related to the urban forest. Key examples of community engagement include: strategic use of municipal websites and social media, developing and implementing marketing campaigns, providing applied information and education (e.g., see the Toronto-based Local Enhancement & Appreciation of Forests programs, a.k.a. LEAF) and incentivizing and engaging a broad range of stakeholders and partners in the delivery of urban forest initiatives (e.g., see **Figure 5-21** and **Figure 5-22**).

Some of the important messages to include in community outreach in support of the urban forest and climate change adaptation include highlighting human health benefits, climate change mitigation and adaptation opportunities, and social equity objectives that can be achieved with the help of trees and good urban forest planning and stewardship.



Credit: City of Toronto, Urban Forestry Grants & Incentives (2021)

Figure 5-21. Report for Toronto's Urban Forest Grants and Incentives Program (left) and overview of the results of this program (right)

Credit: City of Ottawa 2019

Figure 5-22. City of Ottawa urban forest outreach campaign digital postcard

Peel's *Urban Forest Strategy* (2011) and Mississauga's *Urban Forest Management Plan* (2014) recognize the value and importance of community engagement in advancing municipal urban forest objectives, and both Mississauga and Brampton have active *One Million Tree* campaigns that are being pursued with a broad range of private and public sector partners, including: Peel Public Health, local conservation authorities, local school boards, local boards of trade, environmental organizations, building and land development associations, youth groups, post-secondary education institutions, climate change organizations and local utilities.

Indigenous communities and organizations are another source of potential partnership for urban forest initiatives (see **Figure 5-23**) and could also serve as potential resources for information about native trees (e.g., from an ecological, medicinal and / or edible perspective). In Peel, efforts to engage with the Mississaugas of the Credit First Nation (MCFN), Six Nations of the Grand River, Haudenosaunee Confederacy Chiefs Council and Métis Nation of Ontario in a meaningful way should be part of any urban forest project.

Credit: Tree Canada 2020

Figure 5-23. Group photo from an Indigenous-led urban forest project in Ontario

5.10 Be Proactive and Be Prepared

Climate change has introduced a much greater degree of uncertainty into weather patterns and extreme weather events, a trend that will be ongoing (IPCC 2018; NRCan 2021). Consequently, just like municipalities and conservation authorities must now plan and prepare for more intense and more frequent flooding, municipalities must also plan and prepare for more frequent events that will negatively impact local trees and forests.

Fortunately, taking a climate-sensitive approach to urban forest planning and management largely means working proactively to implement the same urban forest best practices identified before climate change was such an urgent matter, but with more consideration for the principles, strategic directions and best practices outlined in this guide.

Although municipalities only have direct control over the trees and wooded natural areas under their ownership and / or management (i.e., their natural assets), by implementing and demonstrating best practices of the trees under their care, they can lead others in the community by example.

Leading by example includes demonstrating good arboricultural practices for trees on municipal lands throughout the tree's lifespan, from selection and establishment to mature tree risk management. It also means applying and enforcing, at a minimum, equivalent standards for tree / woodland protection, maintenance and establishment (including compensation) on municipal capital projects as are required through the planning process for trees on private property. Efforts to implement progressive urban forest planning measures on private lands through the planning process can be seriously undermined if proponents and / or community members see that the municipality is not applying comparable practices on its own lands.

Nothing speaks hypocrisy like a local government requiring a private proponent to invest in better soils and more space for a diverse palette of carefully selected trees for a streetscape, and then planting a row of invasive Norway maples in the adjacent compacted right-of-way without any amendments.

Examples of area and site-specific processes that help ensure that a municipality is leading by example in its urban forest planning and management include:

- A multi-disciplinary review of conceptual plans, project requirements and potential conflicts with trees as well as opportunities for tree planting undertaken early in the planning process
- Requiring compensation for municipal trees removed in accordance with standards applied to private lands
- Ensuring consideration of tree biological needs (e.g., appropriate space, soils, drainage, species selection) to optimize tree establishment success and longevity, and
- Involvement of municipal arborists (or contract arborists who report to the appropriate municipal staff) during site review and inspections to ensure tree protection and establishment in accordance with approved standards.

Examples of jurisdiction-wide urban forest best practices that become even more important in a climate change context include four strategic management components:

- KNOWING WHAT YOU HAVE: Having and maintaining a comprehensive inventory of trees under municipal ownership and / or management to inform short and long-term asset planning and investment (as per **Section 4.1**).
- PROACTIVE PRUNING: Performing regular tree maintenance (typically through block pruning) to pre-empt structural weaknesses and remove dead or weakened limbs to reduce the risk of damage from severe wind and / or ice storms (Hauer *et al.,* 2006).
- PROACTIVE PEST MANAGEMENT: Developing and implementing an Integrated Pest Management (IPM) program to inform diversity objectives and help plan for pests and diseases that may expand into Peel with climate change (as illustrated in **Figure 5-24**).
- PROACTIVE MONITORING: Keeping a pulse on the condition of individual trees and treed natural areas under municipal ownership and / or management so that issues can be identified and addressed and used to inform changes in approach if needed (**Section 4.3**).

Credit: E-Journal of Entomology and Biologicals (2020) (ucanr.edu/blogs/strawberries-vegetables/index.cfm)

Figure 5-24. An Integrated Pest Management (IPM) approach

Being able to undertake the tasks above assumes that there is a corporate commitment to and support for investing in sustaining and enhancing the local urban forest. Good planning and enforcement along with proactive and strategic urban forest maintenance and monitoring (as noted in preceding sections) can go a long way to minimizing the negative impacts of an unexpected wind or ice storm, or even a destructive pest or disease.

In addition to having an overarching strategic plan for the urban forest (as per **Section 5.3**) that is implemented within an adaptive management framework (as per **Section 2.3**), it is also advisable to have: (a) emergency tree response plans in place to guide responses to events that can cause significant damage, such as ice storms, when needed, and (b) an emergency reserve fund to address post-emergency remediation required by such events (e.g., City of Kitchener 2017).

Giving due consideration to the condition and risk of the municipality's treed assets and to planning so that the extent of impacts or severity of that risk can be minimized, are already built into the existing municipal asset management process (MNAI 2019). Therefore, integration of municipal treed assets into asset management planning (as per **Section 5.1**), provides an ideal framework for urban forest monitoring and service valuation that also accounts for the short and long-term risks and costs associated with investments in this asset.

From a climate change perspective, it has been broadly estimated that every dollar spent on adaptation preparedness will save between $4 and $6 on costs relative to no preparations being made (City of Vancouver 2020). This perspective is closely aligned with good urban forest planning and management best practices, whereby proactive and early investment in getting trees well-established has been shown to optimize the services and benefits provided by those trees (as per **Section 5.2**).

Urban forests provide a wide range of services and co-benefits that contribute directly to community health and well-being, with the full value of these services being increasingly recognized. Therefore, investing proactively in the urban forest to help make it more resilient to climate change is a relatively easy and cost-effective strategy for helping communities adapt to climate change.

6. Summary and Next Steps

This document is the last in a series of five guidance documents developed for Peel Region and its partners as part of the Peel Region Urban Forest Best Practices project. The main purpose of this guide, and all the guides in this series, is to help sustain and expand tree cover in Peel's urban areas to provide local benefits to the greatest number of people while also contributing to climate change mitigation and adaptation.

This guide is meant to engage interested persons with varying levels of knowledge of trees and / or urban forestry. However, the strategies and approaches outlined in this guide are most likely to be optimized when implemented by professionals with experience and expertise in urban forestry, arboriculture and / or related fields. To that end, it includes:

- A framework for building urban forest resilience, including ten guiding principles and an adaptive management framework (**Section 2**)
- High-level strategic best practice guidance primarily for municipal street and park trees, appropriate for Peel's urban areas aligned with the framework, including:
    - Identification of management objectives (see **Section 1**)
    - Assessment of anticipated climate impacts and vulnerabilities (**Section 3**)
    - Guidance for approaches and best practices to adopt for acquiring and maintaining an understanding of existing urban forest conditions (**Section 4**), and
    - Guidance and best practices to help implement mitigation and adaptation actions related to urban forestry (**Section 5**).

Getting trees successfully established and thriving in places like Peel's urban areas requires the collaboration and expertise of people from multiple disciplines (e.g., Urban Foresters, Arborists, Planners, Engineers, Landscape Architects, Architects). It also means that providing conditions that trees need must be considered at all levels and stages in the planning process – from high-level jurisdiction-wide strategic plans to site-specific detailed designs, and from the outset of a project to post-installation monitoring. Many of the best practices outlined in this guide underscore the importance of taking an integrated approach to effectively protect existing trees and get new trees established.

More specific guidance appropriate for Peel to supplement the high-level mitigation and / or adaptation best practices identified in this guide is provided in the four other guidance documents developed for Peel Region and its partners as part of the Peel Region Urban Forest Best Practices project. The information and best practice guidance provided in these guides can be used to help prioritize mitigation and / or adaptation actions at the strategic jurisdiction-wide scale as well as at the area or site-specific scale.

The development, updating and implementation of urban forest strategies, plans and policies at various scales are primarily the responsibility of the Region and its partners. The identification of municipal urban forestry priorities and the actions required to implement these priorities, including monitoring to track the effectiveness of the actions and inform adjustments to actions as needed, are part of a comprehensive municipal urban forest management program.

The City of Mississauga already has a comprehensive urban forestry program and strategy that it follows and updates. The City of Brampton is in the process of developing such a strategy, and the Town of Caledon and the Region of Peel have indicated a commitment to advancing both their urban forestry programs and strategies in the coming years.

Well-managed urban forests have significant potential to serve as long-term carbon sinks. While it is recognized that investing in planting trees that grow to maturity and are retained on the urban landscape for as long as possible should not be the only strategy for mitigating climate change, it remains part of an effective solution.

Urban forests provide a wide range of services and co-benefits that contribute directly to community health and well-being. Therefore, planning for and managing the urban forest to maximize the canopy cover provided by diverse, locally adapted, healthy trees is one of the best overarching actions to help communities adapt to climate change.

Despite their tremendous capacity to help communities deal with climate change, trees are also living organisms that can be impacted by stressors that affect all tree populations. Many of these stressors are worsened both by the urban environment and by climate change. This makes protecting and sustaining trees in the urban forest challenging, particularly in the most built-up areas. However, many of these challenges can be overcome with careful and collaborative planning and management undertaken at various scales with input from knowledgeable urban forestry and arboriculture professionals.

Climate change has introduced a much greater degree of uncertainty into weather and extreme weather events. Consequently, municipalities should prepare for more frequent events that will negatively impact local trees and forests. Fortunately, taking a climate-sensitive approach to urban forest planning and management largely means working proactively to implement many of the urban forest planning and management best practices recommended before climate change was such an urgent matter. These practices must now be implemented with greater consideration for the principles, framework, strategic directions and best practices outlined in this guide.

7. Glossary of Key Terms

Many of the following terms relate to climate change. Text in italics has been quoted *verbatim* from the source indicated. Text not in italics has been adapted or provided by the toolkit authors.

(climate change) Adaptation	*Adjustment in natural or human systems in response to actual or expected climate stimuli and their effects, which moderates harm or exploits beneficial opportunities. There are various types of adaptation, including anticipatory, autonomous and planned adaptation* (Richardson 2010). Coping is not same as adaptation: coping reflects existing abilities, adaptation is a change in the framework (e.g., change in species in a forest) in which coping takes place.
Adaptive capacity	*The whole of capabilities, resources and institutions of a country, region, community or group to implement effective adaptation measures* (Richardson 2010). The capability to adapt.
Assisted migration	(As defined in research supported by the Canadian Forest Service, see Ste-Marie 2014) *The human-assisted movement of species in response to climate change (also called "assisted colonization" and "managed relocation").* *Assisted migration can take three forms:* *1. Assisted population migration: The human-assisted movement of populations (with different genetic makeup) of a given species within that species' current range (i.e., where it would naturally spread).* *2. Assisted range expansion: The human-assisted movement of a given species to areas just outside its current range, assisting or mimicking how it would naturally spread.* *3. Assisted long-distance migration: The human-assisted movement of a given species to areas far outside its current range (beyond where it would naturally spread)*
(climate change) Exposure	Exposure consists of what can be affected by climate change and the change in climate itself. When exposure is evaluated, each of the elements that can be at risk from climate change is considered (e.g., people, infrastructure, ecosystems, trees) along with the aspect of climate that will affect the elements, (e.g., temperature, precipitation, extreme events). Exposure may be quantified in terms of its frequency, intensity, or duration.

Green infrastructure	*An infrastructure asset consisting of natural or human-made elements that provide ecological and hydrological functions and processes and includes natural heritage features and systems, parklands, stormwater management systems, street trees, urban forests, natural channels, permeable surfaces and green roofs* (Government of Ontario 2020b).
Green natural infrastructure (a.k.a. natural assets)	*The stock of natural resources and ecosystems that yield a flow of benefits to people… including wetlands, forests, parks, lakes / rivers / creeks, fields and soil* (MNAI 2017). Green natural infrastructure, as defined by the Peel Climate Change Partnership, includes all trees in the urban forest (see definition below) in both natural and built environments.
(climate change) Hazard	Climate-related hazards are aspects of the climate system that potentially can cause damage (e.g., drought, high temperature, ice storms, heavy precipitation events, etc.).
(climate change) Impacts	*The adverse and beneficial effects of climate change on natural and human systems* (Richardson 2010). An impact of climate change on a biological system can be, for example, a change in a plant's productivity or quality, a plant population's competitive ability, or a species range.
IPCC (Intergovernmental Panel on Climate Change)	*A panel established by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) in 1988 to assess scientific, technical and socioeconomic information relevant for the understanding of climate change, its potential impacts, and options for adaptation and mitigation* (Richardson 2010).
Mitigation	*In the context of climate change, mitigation is an anthropogenic intervention to reduce the anthropogenic forcing of the climate system; it includes strategies to reduce greenhouse gas sources and emissions and enhance greenhouse gas sinks* (Richardson 2010).
Plasticity	Plasticity is a plant's ability to adapt behaviour or characteristics to cope with changes in environment. Plasticity responses are physiological, but can be manifested by changes in biochemistry, physiology, morphology, behavior or life history. The timing, specificity, and speed of plastic responses are critical to their adaptive value. Phenotypic plasticity, through its ecological effects, can facilitate genetic change through mating, seed production and seedling survival.
Provenance	"Provenance" as it relates to tree seeds refers specifically to the original geographic area in which the seeds originally evolved over time (Hirons and Sjöman 2019). A provenance is site-specific, typically represented by a local stand of trees.
RCP (Representative Concentration Pathways)	*A Representative Concentration Pathway (RCP) is a greenhouse gas concentration (not emissions) trajectory adopted by the IPCC. Four pathways were used for climate modeling and research for the IPCC fifth Assessment Report (AR5) in 2014. The pathways describe different climate futures, all of*

	which are considered possible depending on the volume of greenhouse gases (GHG) emitted in the years to come. The RCPs – originally RCP2.6, RCP4.5, RCP6, and RCP8.5 – are labelled after a possible range of radiative forcing values in the year 2100 (2.6, 4.5, 6, and 8.5 W/m^2, respectively). Since AR5 the original pathways are being considered together with Shared Socioeconomic Pathways: as are new RCPs such as RCP1.9, RCP3.4 and RCP7 (Wikipedia, accessed 2020-12-31). Each RCP scenario considers different the concentrations of greenhouse gases, atmospheric aerosols and other chemically active gases, as well as projected changes in land use and land cover over time (Moss *et al.*, 2008). The greatest increase in radiative forcing is given by RCP8.5, which is the scenario considered for the tree and shrub species analyses conducted for this toolkit.
Resilience	*The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the same capacity for self-organization and the same capacity to adapt to stress and change* (Richardson 2010). The strengthening of coping capacities usually builds resilience to withstand the effects of hazards.
(climate change) Risk	*A combination of the likelihood (probability of occurrence) and the consequences of an adverse event* (Richardson 2010). Risk is the potential for climate change to have an adverse consequence, determined by integrating exposure and vulnerability. For example, there is a risk that climate change will produce droughts causing mortality of some tree species. Risk of an impact is proportional to exposure to a climate change hazard and vulnerability of the system. To determine whether climate change will be damaging for any ecosystem or species requires assessing its exposure and vulnerability to specific hazards.
(climate change) Sensitivity	*Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate variability or climate change. The effect may be direct … or indirect* (Richardson 2010). For plants, it relates to the biophysical effect of climate change, such as a change in tree growth, plant mortality, etc., caused by exposure to a change in climate. Each element, such as different tree species, has its own sensitivity to a specific aspect of climate change, and sensitivity can be changed by changes in environment.
(biological) Stress	A biological stress is any environmental factor capable of inducing a potentially injurious response (or strain) on an organism. Stress may be manifested physically (e.g., reduced cell division) or chemically (e.g., a shift in metabolism). Some changes in physiological processes caused by stress can cause injury or death. The presence of both stress avoidance and stress tolerance mechanisms increases the likelihood of survival during stress.
(biological) Stress avoidance	Stress avoidance is the extent to which a plant can reduce the level of or to postpone exposure to a stress. Stress avoidance mechanisms may allow a stress to be avoided entirely or in part or may postpone the time for which the stress is experienced.

(biological) Stress tolerance	The level of stress at which physiological impairment occurs.
Urban heat island (UHI) effect	*When dark colored surfaces like roads and rooftops absorb and hold heat from the sun, they trap and slowly release heat back into the air, increasing temperatures in the surrounding environment and creating little islands of heat. Heat islands often get hotter throughout the day, becoming more pronounced after sunset because the heat that was stored is slowly released at night. Urban areas tend to have more roads and rooftops, so they experience warmer temperatures than nearby rural areas* (American Forests 2020).
Urban forest	*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* (Region of Peel 2011).
(climate change) Vulnerability	*Vulnerability is the susceptibility to be harmed. Vulnerability to climate change is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability to climate change is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity* (Richardson 2010). For plants, vulnerability to climate change is the risk of undesirable things happening (i.e., how prone a species or ecosystem is to be adversely affected by an event or change). Vulnerability is a function of three factors: exposure, sensitivity and adaptive capacity to a hazard. More exposure and sensitivity increase vulnerability, while more adaptive capacity decreases it. An assessment of vulnerability should consider all three factors. Reducing vulnerability involves altering the context in which elements are exposed to climate change hazards (e.g., high temperature, extreme precipitation events). Vulnerability is determined by the ability to cope with or adapt to climate change hazards.

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