Canadians have a long and proud heritage tied to their country’s natural forests, but for the more than 80% of Canadians who live in cities, their knowledge of trees and wooded areas comes from interactions with urban forests. Urban forests have important direct effects on Canadians – they keep our homes cooler in summer, they make breathing healthier by removing pollutants from the air, provide flood and erosion control, foster community engagement and identity, and they bring the natural world into the urban environment.

Today, across Canada, the sustainability of urban forests is constantly being challenged by: air pollution; compaction of soils; restriction of root systems, invasive species; and increasingly from climate change. Climate change not only affects the health of urban forests, it also impacts their ability to blunt some of the worst effects of climate change on people. For example, trees reduce the urban heat island effect by providing shade to cool homes and the cityscape; they reduce flooding from heavy downpours by intercepting rain; and their root systems reduce soil erosion.

Just as the city’s “grey” infrastructure, like sewers, roads or bridges, needs to be maintained, so too does the “green infrastructure” – our urban forests. Adapting Canada’s urban forests to address climate change over the long term is one of the great challenges facing our urban environments.
Urban trees are at risk of damage, dieback and even death due to the effects of climate change, including extreme weather events; long-term increases in temperature; more frequent and severe droughts; and increased risks from diseases and damaging insects.

The risks from climate change are especially serious for trees in cities as they are often already under stress as part of their normal existence. For example, roots of street and boulevard trees have limited space to grow, reducing their access to water and nutrients. Soils in residential and commercial properties may be compacted or have had nutrient-rich soil removed. Asphalt or concrete covering tree roots can reduce soil aeration and result in tree decline. Furthermore, air pollutants, such as ground level ozone and nitrous oxide, can be toxic to trees. Taken altogether, such stresses make urban trees more susceptible to damage from attack by insects and diseases.

In addition, non-native insects and diseases can have devastating effects on urban trees. In the twentieth century, for example, Dutch elm disease largely eradicated white elm from cities in eastern North America, eradicating this predominant urban tree species from most eastern Canadian cities. At present, two other exotic insect species that are a threat to trees are present or spreading in Canada, the emerald ash borer and the Asian long horned beetle. Two other exotic insect species that are a threat to trees are present or spreading in Canada, the emerald ash borer and the Asian long horned beetle. At present, two other exotic insect species that are a threat to trees are present or spreading in Canada, the emerald ash borer and the Asian long horned beetle. At present, two other exotic insect species that are a threat to trees are present or spreading in Canada, the emerald ash borer and the Asian long horned beetle. At present, two other exotic insect species that are a threat to trees are present or spreading in Canada, the emerald ash borer and the Asian long horned beetle. At present, two other exotic insect species that are a threat to trees are present or spreading in Canada, the emerald ash borer and the Asian long horned beetle. At present, two other exotic insect species that are a threat to trees are present or spreading in Canada, the emerald ash borer and the Asian long horned beetle.

The Many Benefits of Urban Forests:

Urban forests contribute in numerous ways to cities as revealed in several national studies.

Social – trees are beautiful – they improve psychological well-being; increase property values; are used for outdoor recreation;
Health – trees provide evaporative cooling and shade; block harmful UV radiation; reduce asthma by cleaning the air of pollutants; patients can recover more smoothly from surgery if they view trees from their hospital; neighbourhoods with trees have fewer low weight babies; children are less likely to be overweight; and elderly live longer.
Infrastructure – trees reduce energy-use by cooling cities; reduce street repair because shading slows asphalt breakdown, giving streets fewer cracks and potholes; trees intercept rain, reducing peak loads on storm sewers and water treatment systems.
Ecological – trees absorb CO\textsubscript{2} and store carbon, which slows climate change; provide habitat for birds and other animals and plants.

The effects of a warming climate will alter the timing of spring budbreak. Warmer winters in mild cities, such as Victoria, B.C., may mean some trees do not receive enough chilling to fully break dormancy, so they flower and resume shoot growth later in spring. This may cause them to be out-of-synch with animals and insects, potentially harming urban forest ecosystems. Where winters are cold enough to meet chilling requirements, warmer springs could result in earlier bud flushing. This can expose sensitive shoots and flowers to damage if temperatures later drop to freezing, reducing seed production important for wildlife, causing dieback of branches, and disrupting production from fruit trees. Warmer winters caused by climate change may also be harmful if they allow survival of damaging insect pests.

Warming could raise average summer temperatures in Canada by 3 to 4°C by mid-century. However, the warming will be worse in cities due to the urban heat island effect, which occurs because built surfaces absorb radiant energy from the sun and re-radiate it into the air. The urban heat island is 1-3°C warmer than the surrounding countryside, but in extreme local cases it raises temperatures by 12°C. These increases are on top of those projected to occur due to climate change. In some cases, temperatures may increase enough to damage young tree shoots. Higher temperatures increase evaporation – and if rainfall decreases because of climate change, or does not increase enough to offset evaporation, drought can cause shoot dieback, increase susceptibility to insects and diseases, and in severe cases cause tree mortality, as we saw in Vancouver in 2015 when otherwise healthy mature trees died.

Extreme weather is projected to increase with climate change. In particular, increases in the number of high wind and freezing rain events will escalate the risk of large branches falling and trees being uprooted. Such events not only damage trees, but endanger human lives and city infrastructure. An example was the crippling ice storm of 2013 in Toronto, which felled trees across the city and cut power to more than 300,000 residents, causing damage costing the City of Toronto more than $106 million (see photos).

The Dedicated volunteers of GOERT and GOMPS are models for how people across the country could come together to protect and promote urban forest values in other.
MANAGING URBAN FORESTS FOR CLIMATE CHANGE RESILIENCE

Urban tree management to increase resilience is an important tool to respond to climate change. Good standard practices can include:

• Employing arborists and skilled labour to carry out proper pruning and urban tree management
• Preventative tree maintenance (e.g., pruning, pest and invasive species control)
• Avoiding mechanical damage and soil compaction during building construction
• Increasing the diversity of species planted to reduce risks from insect pests, diseases and environmental stress
• Selecting species for replanting that tolerate stressful environmental conditions
• Implementing a plan for tree replacement and increasing urban forest canopy cover

Conserving large natural areas and protecting forest patch connectivity within cities and into forests in suburban and rural areas can provide corridors for natural movement of plants and animals. Some animal and plant species can then move and gene flow can happen across a larger landscape, which may aid natural adaptation to changing climate.

Developing policies and supporting budgets to carry out sustainable urban forestry are important elements for adapting urban forests to climate change. At the community level, city planning and bylaws can protect healthy urban trees and provide trained personnel to carry out sustainable urban forest management.

Provincial and federal governments, while not usually directly responsible for managing urban forests, have expertise in forestry that can improve decision-making to help urban forests adapt to climate change. The federal government (and some provinces) also have research capacity that could tackle knowledge gaps. For example, research is being conducted by federal, provincial and university scientists to develop guidelines for species and genetic sources of trees better adapted to warmer temperatures and drought. Such knowledge can be used to address climate change through selection of trees more appropriate for planting in urban settings.

The benefits of urban forests can be spread more evenly within cities by increasing tree cover in areas with lower forest canopy coverage. In urban areas without much green space, this will have to be done creatively, such as by greening roofs, street tree planting, and perhaps even converting some streets into green areas. Expanding or conserving urban forests also can be taken into account when municipal governments are considering increasing the densification of neighbourhoods.

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The Emerald Ash Borer: Crisis for Canadian Urban Forests:

Discovered in Windsor, Ontario in 2002, this extremely damaging insect native to Asia has spread across southern Ontario into southern Quebec, and north to Manitoulin Island and Sault Ste. Marie. It attacks all ash species, killing trees within four years of infestation when larvae girdle the stem. The emerald ash borer has few natural enemies in North America.

The effects of the emerald ash borer on urban forests in central and western Canadian cities have been extensive. In Toronto, there are more than 750,000 ash trees, almost all likely to be killed by the insect (see photos, left). Treatment by tree injection with an extract of Neem tree seeds, an insecticide developed by scientists with Natural Resources Canada (NRCan), can be effective if treatments occur before significant infestation has occurred. While treatment needs to be repeated annually when the infestation is ongoing, its cost needs to be weighed against the loss of benefits from a tree that is removed and the costs of tree removal and replacement.

Infestations like the emerald ash borer, Asian longhorned beetle and, before them, Dutch elm disease, increase the threat to Canada’s urban forests. They increase the challenge of retaining a healthy urban forest that can withstand the added stresses of climate change.
COMMUNITY ENGAGEMENT IN URBAN FORESTS

Many municipal governments are taking action to maintain and enhance urban tree canopies. At the same time, in towns and cities across Canada, thousands of people are engaged in activities to protect and grow their urban forests. Some examples of community action groups involved in urban forest issues include:

- **Clean** – a non-profit, non-governmental environment organization coordinating tree planting events in Atlantic Canada for school groups, families and workplaces
- **La Société de verdissement du Montréal métropolitain (SOVERDI)** – its goal is greening Montreal by increasing the size and health of the urban forest
- **Lower Mainland Green Team** – involved in a range of activities, including planting native plants and trees in the Lower Mainland of B.C.
- **Planting for Change** – a schoolyard tree planting program run by ACER (Association for Canadian Educational Resources)
- **REAP and Enactus Calgary** – plant fruit bearing trees in lower income communities with support from Calgary businesses, addressing food insecurity and sequestering carbon
- **Trees Winnipeg** – with a mission to “protect, preserve & promote the urban forest & urban environment.” Its Broadway Restoration Project is designed to preserve the 75-year-old elms lining Winnipeg's signature business area
- **The UVR Working Group of the Toronto Cancer Prevention Coalition** – an advocate for trees as a natural shade for the purpose of public health implemented a Shade Policy for the City of Toronto
- **Tree Canada** – a non-profit organization that shares knowledge and greens communities across Canada by “providing education, technical expertise, and resources to plant and care for urban and rural trees.”

Such volunteer organizations have important roles in maintaining healthy urban forests under worsening climate change.

Managing Urban Forests Sustainably:

“Trends in Canada’s Urban Forests,” a recent report commissioned by Tree Canada, found that only 20% of surveyed Canadian communities have a comprehensive management plan for urban forests, and 25% have no tree inventory.

Clearly, there are benefits to investments by municipalities for sustainable management to make urban forests more resilient to stresses. Reducing vulnerability to climate change is an important management objective to make urban forests sustainable. Sustainable management of urban forests requires four resources:

- A tree inventory (species, age, condition, and distribution);
- Skilled professionals with resources to manage the forest;
- A plan with criteria for economic, social and environmental values, each with performance indicators; and
- Involvement and support from citizens and volunteers caring for trees on private and public land.

CONCLUSION

Urban forests help make cities more liveable today and have the ability to blunt some of the harmful effects of climate change. Without urban forests, many of the risks from climate change will be magnified for people living in cities, due to urban environments that experience hotter temperatures and poorer air quality. However, urban forests will be under greater stress by climate change. For these reasons, best practices in sustainable urban forest management and design of new tree cover need to be applied, to increase their resilience in a future with climate change.

To increase the likelihood that urban forests will be sustainable, even with climate change, investments in human resources and financial capital are required. Managing this green infrastructure will also depend on establishing wide-ranging partnerships between all levels of government, environmental organizations, academic and research institutions, and citizens. Together, their contributions will help make urban forests and city landscapes more enjoyable, beautiful and healthier places for Canadians to live.
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