
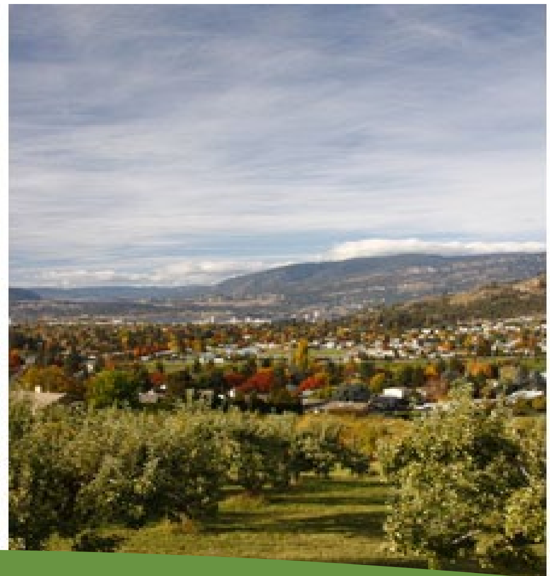


Urban Forests:
A Climate Adaptation Guide

Fraser Basin Council

Natural Resources Canada | Ressources naturelles Canada

Canada

British Columbia

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This guide is a part of the program *Preparing for Climate Change: Securing BC's Water Future*, also known as the *BC Regional Adaptation Collaborative (RAC)*. The program consists of 21 collaborative projects across the province to support decision-making on water allocation and use, forest and watershed management, flood protection and floodplain management and community planning.

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INTRODUCTION

"We are becoming more vulnerable to the impacts of climate variability and change because of increasing urbanisation, a growing and aging population and deteriorating public infrastructure. These changes put more people, property and ecosystems at risk."

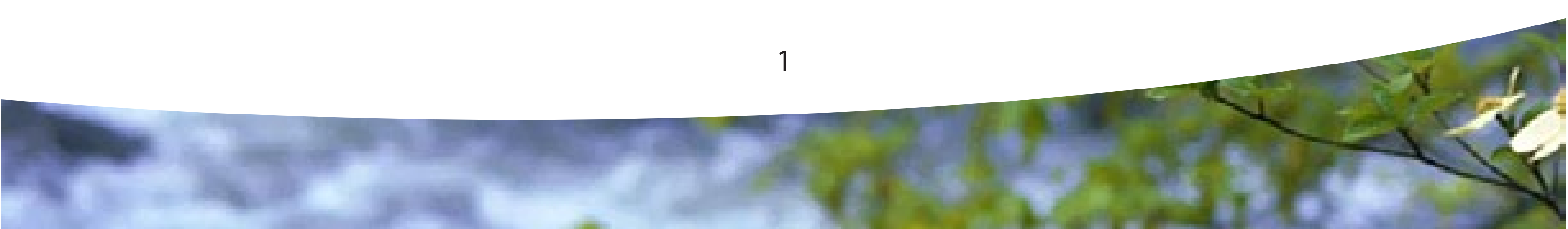
- Black et al.[2]

This guide has been prepared to help communities in British Columbia (B.C.) identify and prepare for some of the impacts of climate change. It provides information on how you can use urban forests to manage some of the impacts of changing climates, and how to adapt these urban forests so that they survive and thrive in future climates.

This is a high-level overview that can be used by staff and elected officials in B.C.'s communities—small and large, rural and urban—including those who do not have professional arborists or urban foresters on staff. If you have comments or suggestions to improve this resource, please contact **treesfortomorrow@gov.bc.ca**.

Global Climate Change

The Earth is heating up. While natural causes have played a role, most of the atmospheric warming observed over the last 50 years is attributed to burning of fossil fuels, land clearing, and other human activities that have increased the concentrations of greenhouse gases in the atmosphere. This has already changed climates in British Columbia and around the world, and scientists warn that further climate change is unavoidable.[1]



Climate change is not just about changes in temperature. The warming of the atmosphere leads to long-term changes in rain and snowfall patterns, wind and ocean currents, ice and snow accumulation, and other aspects of climate. It can increase the frequency of droughts, heat waves, heavy rainfall and snowfall, and other extreme weather events. These changes affect fisheries, forests and rangelands, and the jobs that depend on those resources. They increase the risk of damage to infrastructure from increased flooding, landslides, melting permafrost, and coastal storm surges, but also the risk of water shortages. Such impacts will increasingly challenge the capacity of government, business, and community leaders to protect public safety, manage natural resources, and promote social and economic sustainability.

Climate Change Adaption

Much emphasis has been placed on ways to **mitigate** climate change by reducing use of fossil fuels and cutting greenhouse gas emissions. This remains of great importance. However, even if all greenhouse gas emissions were to stop tomorrow, the excess greenhouse gases already in the atmosphere would continue to affect climate for the next 30–40 years. In addition to reducing emissions, communities need to **adapt** to climate change impacts—to prepare for a different future. 'Business as usual' is no longer an option.

Adaptation to climate change means making adjustments to minimize adverse effects and maximize opportunities. It is sometimes also described as an ongoing process that involves:

- Assessment to identify relevant climate changes and impacts, vulnerabilities, and priorities for action;
- Implementation of these plans; and
- Monitoring results and updating plan(s) as new information becomes available.

Urban forests are an invaluable part of communities across British Columbia, yet they are often under-recognized and under-valued. For this reason, the Union of British Columbia Municipalities and Ministry of Community, Sport and Cultural Development prepared Planting our Future: A Tree Toolkit for Communities. The toolkit helps communities—small and large, rural and urban—to maximize the values from their urban forests and to address challenges that they are facing. This urban forest adaptation guide is a companion piece to Planting our Future.

Planting our Future includes information on the values of urban forests, issues and challenges, and tools and strategies to achieve a healthy and sustainable urban forest. It is available from http://www.treesfortomorrow.gov.bc.ca/.

The communities that take proactive steps to adapt to climate change will be better prepared for its impacts. The attention, time and money invested will produce valuable returns in terms of cost savings (e.g., related to energy, fire suppression or storm-clean up) and improved economic performance (e.g., through enhanced livability, business and staff recruitment, tourism, and property values). Done well, steps to adapt to climate change could protect human life and property, avoid or reduce future costs, and exploit new opportunities related to changes in local climate—making lemonade from climate change lemons!

"Integrating climate change adaptation into decision-making is an opportunity to enhance resilience and reduce the long-term costs and impacts of climate change." ***- Natural Resources Canada***[3]

Mitigation refers to actions that reduce human-caused greenhouse gas (GHG) emissions into the atmosphere.

Adaptation refers to actions that better prepare communities and businesses for climate change and its impacts. Adaptation actions typically reduce risks and increase opportunities related to climate change.

Sequestration refers to the removal of carbon from the atmosphere. Trees and other vegetation sequester carbon as they grow, storing it in their trunks, roots, branches, and leaves.

Urban Forests and Climate Change Adaptation

While there are many benefits to be derived from urban forests (see **Planting our Future**), this document focuses only on those related to climate change adaptation. Equally, there are many ways to adapt communities to climate change, but this document focuses only the 'tree-centric' approaches (Figure 1). However, this guide is linked to much wider thinking about climate change adaptation, including broader impacts on land use, infrastructure, and utilities planning.

Section 2 of this guide provides an overview of some of the impacts of climate change on communities and urban forests, such as more frequent heat waves and intense precipitation events. Section 3 outlines ways that urban forests can help to manage these impacts, for example by providing shade and detaining stormwater. Section 4 recognizes that urban forests themselves will be under stress from new climatic conditions and new pests and diseases, and looks at ways to manage urban forests so that they survive and thrive in future climates.

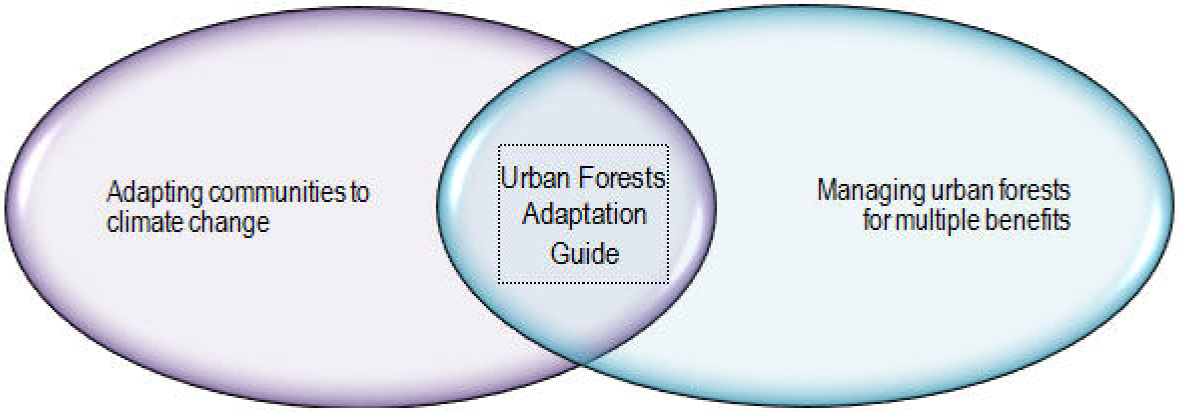
Provincial Climate Action Initiatives

The Province is undertaking a variety of initiatives to mitigate and adapt to climate change. These include the following.

- The **Greenhouse Gas Reduction Targets Act** (2007) set legislated targets of provincial emissions reductions of 33% below 2007 levels by 2020 and 80% below 2007 levels by 2050.
- The **B.C. Climate Action Plan** (2008) outlines strategies and initiatives to reduce greenhouse gas emissions.
- More than 179 local governments have signed the **Climate Action Charter**, committing to carbon neutrality by 2012.
- The **Climate Action Toolkit** is a website providing information and cases studies of local government initiatives towards climate action.
- **Preparing for Climate Change: British Columbia's Adaptation Strategy** (2009) outlines government's approach to adaptation, builds on the Province's past accomplishments, and provides a framework for future climate change adaptation initiatives.
- The B.C. **Regional Adaptation Collaborative** aims to advance adaptation decision-making in British Columbia. One of its programs is developing tools and adaptation plans for communities.
- The Ministry of Forests, Mines and Lands established a Climate Change Task Team to review potential impacts of climate change on provincial forest and range resources and identify knowledge gaps, with recommendations provided in **Preparing for Climate Change: Adapting to Impacts on British Columbia's Forest and Range Resources**
- The **Future Forest Ecosystems Initiative** focuses on adapting B.C.'s forest and range management framework so that it continues to maintain and enhance the resilience and productivity of B.C.'s ecosystems as the climate changes.
- The **Zero Net Deforestation Act** encourages an equal area of trees be planted for carbon storage to offset any forest land that is permanently cleared for another use.
- The Community Energy and Emission Inventory is tracking land use change at the Regional District level, including an estimate of deforestation and the resulting CO_2 emissions.

More information and links to these provincial initiatives can be found at **http://www.env.gov.bc.ca/cas/resources/reports.html** and **http://www.toolkit.bc.ca**.

Figure 1: Climate adaptation and urban forests



"**Urban forests**" are the total collection of trees and their growing environments found within our communities and their surrounding areas, from villages to city centres. They include the treed environments on both public and privately owned lands—in parks and backyards, along paths and boulevards, and other 'green' areas. They include cultivated landscapes, natural areas and, in some communities, local 'working' or managed forests. Although they are referred to as 'urban' forests, this term applies equally to small and rural communities.

"**Urban forestry**" is the deliberate management of these treed environments to provide a wide array of economic, environmental and social services to communities. Urban forests can be a key asset in supporting more liveable, healthy, sustainable and economically vibrant communities.

2

Climate Change and Your Comunuity

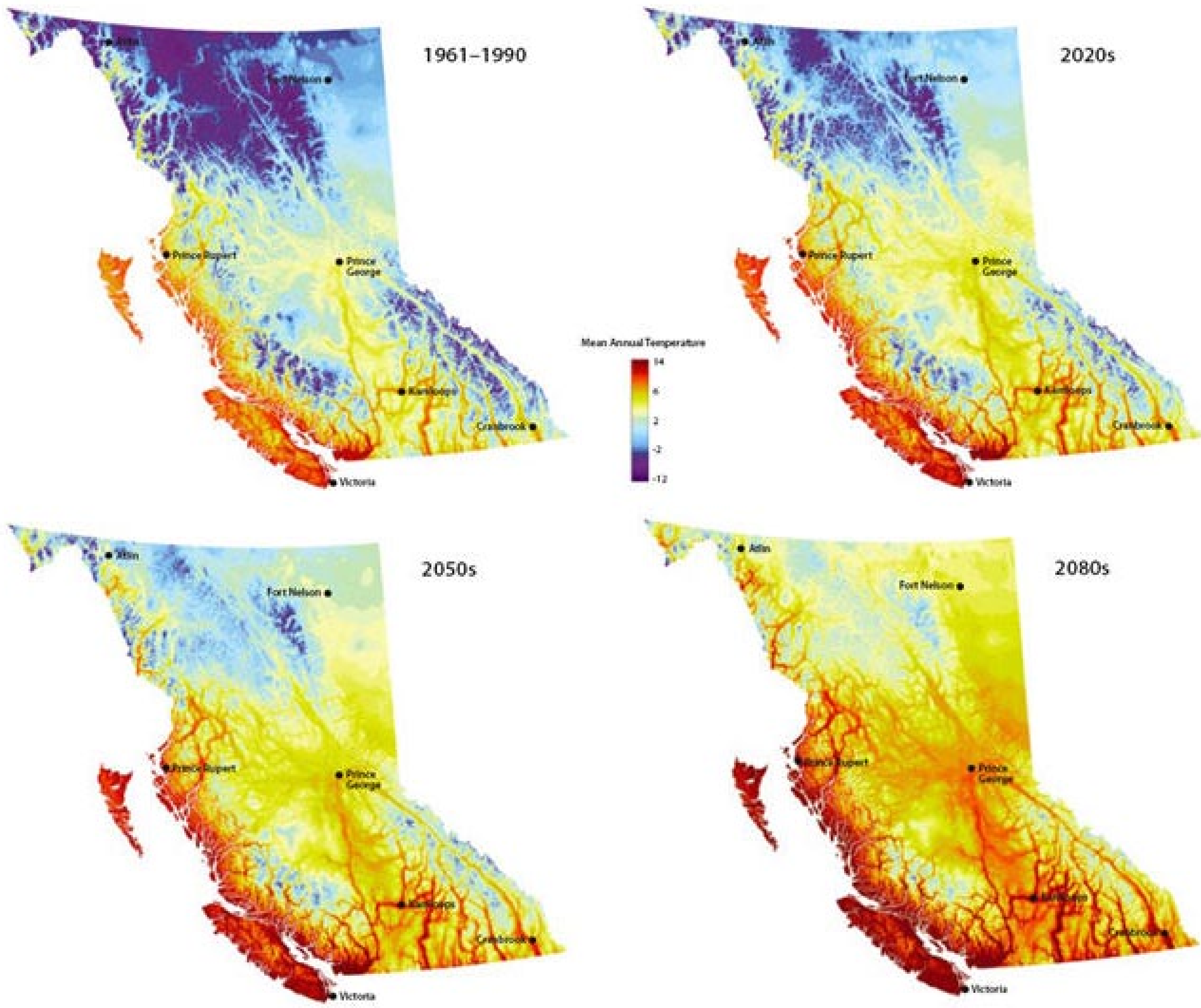
From Impacts to Adaptation: Canada in a Changing Climate 2007 (Natural Resources Canada, 2007) includes a discussion of expected climate change impacts and case studies of responses.

Future climates and related impacts will vary from place to place, but all communities in B.C. will be affected in some way. This guide does not provide detailed information about future climate predictions for specific regions in B.C., but that information is available from the **Pacific Climate Impacts Consortium**[4] (PCIC). A good place to start is the PCIC **Plan2Adapt** website, which includes information on predicted impacts by regional district. PCIC can also provide information tailored to your community. Projected climate changes for British Columbia as a whole, and some of the ongoing and expected impacts, are described below.

Climate Change in B.C.

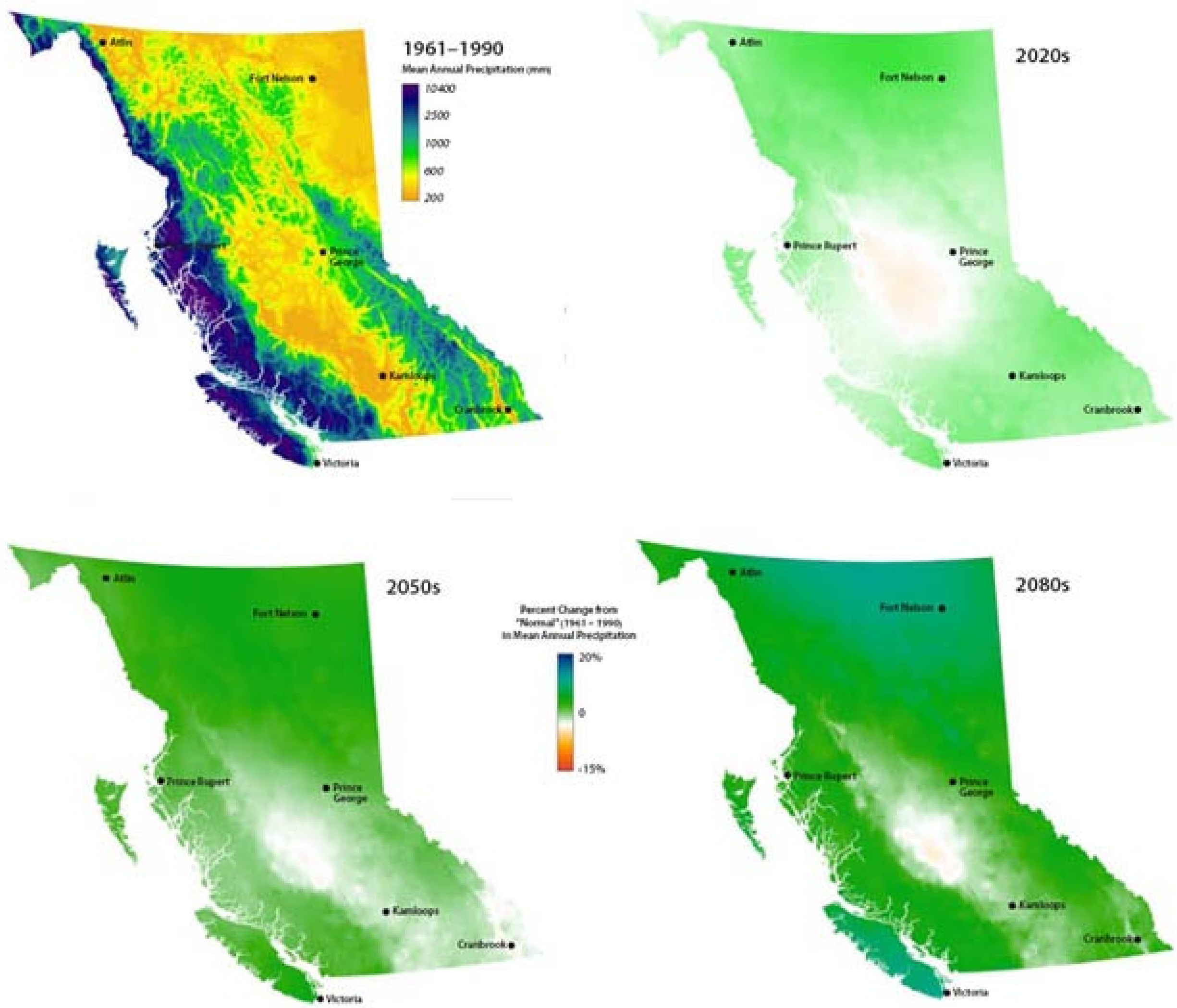
Places in the northern latitudes—such as British Columbia—are expected to experience greater warming than the global average. Climate scientists expect that all parts of the province will be warmer, especially in the winter, with the greatest increase in northern B.C. (Figure 2). Winters will likely be wetter throughout the province, with smaller snow packs and earlier snowmelts. Southern and central B.C. are expected to get drier summers, while the northern B.C. summers are likely to be wetter (Figure 3).[6] Changes will vary by region and by altitude.

Figure 2: Actual and projected temperature change, B.C. 1961-2080



Source: Spittlehouse, 2008. Actual mean annual temperature 1961-1990, projected using the A2 emissions scenario for 2020, 2050 and 2080

Figure 3: Actual and projected precipitation change, B.C. 1961-2080



Source: Spittlehouse, 2008. Mean annual precipitation 1961-1990, projected using the A2 emissions scenario for 2020, 2050 and 2080

The climate projections shown in both figures are based on the assumption that global greenhouse gas emissions will continue to increase during the decades to come, and that climate will therefore change more rapidly than in the past. These maps represent only one of a range of possible futures for British Columbia; while scientists can tell us a lot about what is likely to happen, there is still uncertainty in these projections.

One of the challenges of adaptation is to identify strategies that are robust across the full range of possible futures.

Changes to Forested Ecosystems

Future forests will be different from those of today. The climate 'envelopes' suitable for many tree species currently found in B.C. are moving north and to higher elevations. With even a 1°C increase in mean annual temperature, ecosystems are expected to shift up to 150 km northwards and 300 m higher. These changes will have profound impacts not only on the trees, but on the associated plants, animals and ecosystem processes (e.g., pollination systems) that rely on B.C.'s forests. Many species of plants and animals will likely become endangered or perhaps even extinct.

B.C.'s conifer species in particular are expected to lose much of their climatically suitable habitat.[8] A study of future forest ecosystems in B.C. predicts that in the 21st century, climatic suitability for spruce and Douglas-fir forests will

Climate and Weather

The weather varies from place to place, from year to year and even from decade to decade, subject to natural cycles such as the El Niño Southern Oscillation (ENSO). For example, in 100 Mile House, an El Niño winter can mean winter temperatures 4–6°C warmer with 10–15% less precipitation, while a La Niña winter makes it 1–2°C cooler than average with 10–15% more precipitation.[7] This is further complicated by a longer term natural cycle, the Pacific Decadal Oscillation, which can further affect annual and seasonal temperature and rainfall.

Climate is measured based on long-term averages of weather in many different places and environments. Climate is always changing, even without human influence, as evidenced by past ice ages. However, emissions of greenhouse gases into the atmosphere are creating significant global climate warming that is superimposed on the 'natural' rate of change. Moreover this anthropogenic (or humanly-modified) warming, and the changes associated with it, is occurring very quickly. The long-term trend of global climate warming can be clearly seen, even though the weather will continue to vary from one place and time to another.

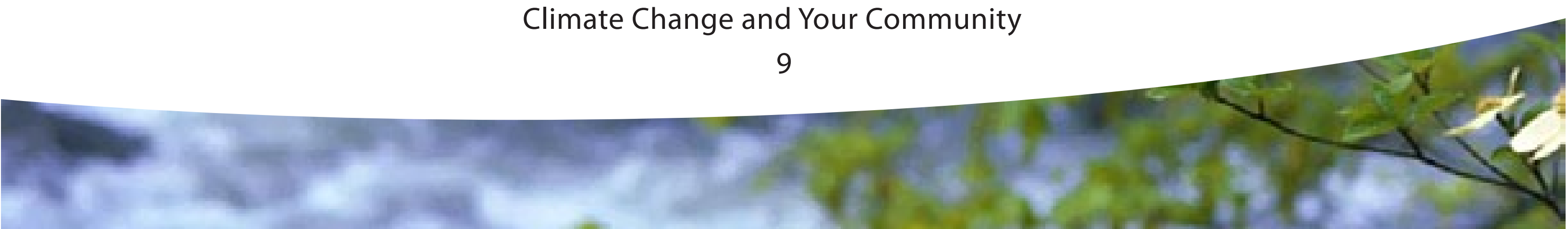


Table 1 identifies some of the climate changes that have already occurred, and shows projections for the next 40 years together with some of the related impacts.

Table 1: Historical and projected climate change for British Columbia

Change	1950-2000	By 2050	Related Impacts
Mean annual temperature	+1-2°C	+2-3°C coastal Up to 4°C interior	Increased wildlife risk Threats from insects continue to increase
Mean spring temperature	+1.5-3°C	+2-4°C coastal Up to 5°C interior	
Frost free days	+10 per decade	+10 per deacde	
Growing degree days	+5-6% per century	+10%	Desynchronization of flower emergence and pollinator prescence
Annaul Precipitation	+10-25%	+10% north +5% south	Increased probability of flooding Summer water shortages
Spring precipitation	10% north +30-40% south	+10% north +5% south	
Rain intensities (heavy precipitation days)	+5% / decade south	+5-15% increase	
River flows	Increased winter / spring Decreased summer / fall	Peak 15-40 days earlier Trends to continue	
Snowpack, April 1	20-60% decline	Continued decline	Summer water shortages
Intense winter storms	Increased frequency +10%	+13% frequency	Increased probability of blowdown

Adapted from: Black et al. 2010
Note: these trends and projections are estimated averages for British Columbia. Local trends and projections, especially in mountainous areas may be different

decrease in southern interior valleys and increase at higher elevations and latitudes, with a more substantial decrease for spruce. Figure 4 shows how the climate envelope suitable for spruce is expected to change over the next 70 years, and Figure 5 shows the same for Douglas-fir trees.

Natural tree migration may no longer occur fast enough to keep the landscape forested. Tree species can naturally migrate at about 100 m per year—but would need to migrate several thousand metres per year in order to keep pace with expected climate change.

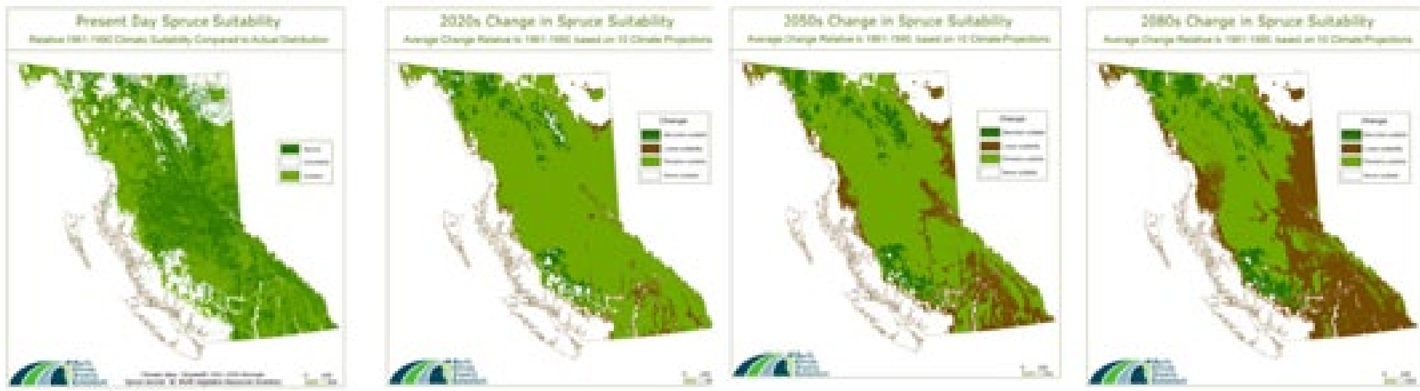
On a more positive note, trees currently growing at the northern edge of their distribution, such as Garry oaks, arbutus or coast redwood, may thrive as more regions and new sites may become suitable for these species. Another potentially positive effect of climate change (for trees) is that with more carbon in the atmosphere, tree growth rates may increase in some areas as long as other supporting factors, such as soil moisture, remain available. Also, a lengthened growing season in higher latitudes and elevations is leading to increased tree growth rates and accelerated maturation processes—both positive for the rate of carbon sequestration.

Mountain pine beetles are indigenous to pine forests in B.C., but population numbers were kept in check by periods of low temperatures. Another contributing factor to the mountain pine beetle epidemic is the abundance of hosts, like old pine, that are stressed by changes such as longer periods of drought. With warming winters and longer periods of drought, beetle populations have exploded and killed trees on more than 16.3 million hectares in the province. Similar warming and variable winter conditions may also allow the Douglas-fir beetle and spruce beetle to flourish. Other insects such as spruce bud worm and tussock moth are also expected to become more prolific. The risk of outbreaks of western spruce budworm (which attacks Douglas-fir) and spruce bark beetle is projected to decrease in southern and central interior valleys as these trees become less prevalent, and increase in north-western B.C. In addition, tree diseases caused by fungi and bacteria are becoming more prevalent, and expected to get worse as trees already stressed by changes in local climate are more susceptible to pathogens.[9]

The 2006 windstorms in southern B.C. were the most destructive storm event for hydro and phone infrastructure in the Province's history, with huge costs to industry and communities.

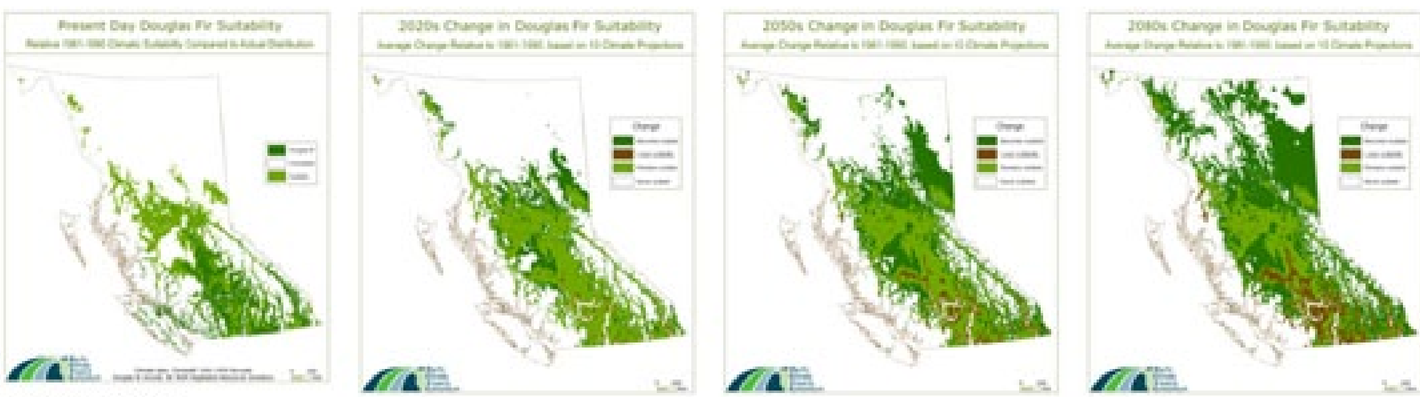
Extreme events recorded by B.C.'s Provincial Emergency Program (PEP) from 2003–2005 cost an average of $86 million per year, compared to $10 million per year from 1999–2002.[10]

Figure 4: Change in climate suitable for spruce from present day–2080



Source: PCIC, 2009.

Figure 5: Change in climate suitable for Douglas-fir from present day–2080



Source: PCIC, 2009.

Impacts to Communities

Extreme Weather Events

Climate change is bringing more frequent extreme weather events that can occur earlier or later than 'normal', and last longer. This includes wind-, rain- and snow-storms, prolonged droughts, and heat waves. Extreme weather and related impacts such as landslides create major challenges for communities, including the cost of replacing damaged property and infrastructure.

Floods and Drought

The impacts of climate change on water will vary by region. In watersheds with winter snow, warmer temperatures will speed up spring melt, increase spring flooding, and reduce the flow and availability of water in summer. In watersheds where precipitation falls mainly as rain, more intense winter rains will increase the risk of downstream flooding. For many interior watersheds, tree cover loss associated with climate change and the mountain pine beetle epidemic will increase runoff and flooding. More prolonged summer droughts will change community water supplies. Climate change and its impacts on water flow will also affect drinking water quality, municipal infrastructure, public safety, aquatic and riparian habitats, hydro generation and other water-related values, and exacerbate conflicts between water users.

Wildfire

In many regions of B.C., warmer temperatures in late spring and early fall, less summer precipitation, and more frequent periods of drought mean a longer fire season and increased risk of a catastrophic forest fire. In parts of the Interior that support large areas of beetle-killed trees, and in areas where past fire suppression has increased fuel loads, the risk is even higher.

Figure 6: Wildfire

> The Insurance Bureau of Canada identified the 2003 Kelowna firestorm as the single largest Canadian insurance loss for a wildfire at $250 million. [11]

Sea Level Rise

Sea levels are expected to rise along many parts of the B.C. coast. Depending on location, sea level on some parts of the coast is expected to rise by up to one metre by the end of the century (others will experience a much lower increase).[12] The effects of sea level rise will be compounded by greater storm surges and may cause significant erosion to coastal shorelines.

For more information on regional implications for sea level see **Projected Sea Level Changes for British Columbia in the 21st Century.**[13]

Health Impacts

Climate change has health implications.

Heat waves cause a variety of mild to severe symptoms linked with heat-related illnesses, including thirst, dizziness, confusion, weakness and fainting/collapsing.[15] Smog (ground-level ozone) also worsens during heat waves, causing problems for people with heart or respiratory problems. Wildfires, which are more frequent with drought conditions, also create air quality problems and related health advisories.

Network Rail in the UK is spending £750,000 to identify safety threats related to sea level rise and increased storm surges. However, they estimate that it will save the industry over £1 billion over the next 30 years by improving safety and preventing emergencies.[14]

More intense rain and flooding can cause turbidity and water quality issues for drinking water supplies.

New forest pests and diseases are able to migrate and survive with the warming climate. Cryptococcus gatti, a tropical fungus, first appeared in 1999 on the south east coast of Vancouver Island, likely due to changing climatic conditions. This fungus has caused more than 100 cases of human illness and appears to be spreading from Vancouver Island to the Lower Mainland.[16]

Social and Economic Impacts

There will be numerous social and economic impacts associated with climate change; however these are not discussed in this document. Forestry and forest product industries will be greatly affected by these changes, including dramatic fluctuations in timber supply, with high harvest levels following major insect epidemics to reduced supplies as those forests grow back under more drought-stressed conditions.

On the positive side, some communities are finding creative ways to use beetle-killed wood.

Impacts to Urban Forests

Climate change is already being noticed within urban forests. Tree species that were well suited to the climates in which they were planted—say 20 or 50 years ago—can become 'maladapted' (no longer well suited)[12] to changed temperature

A study of street trees in the City of Victoria found that more than half of the Prunus (cherry and plum) species were in "fair to dead" condition, likely due to summer moisture deficit, and that projected drought conditions for 2050 and 2080 would have a devastating effect on street trees.[22]

Graduate students at the **University of Northern B.C.** have created a product called "Beetlecrete". It combines flakes of blue beetle-killed wood with Portland cement to form a marbled material with the strength of concrete, but the look and feel of wood.

The massive ceiling (200 ha) of the **Richmond Oval**, built for the 2010 Winter Olympics, is made of salvaged beetle-killed wood from interior B.C. forests.[18]

The **B.C. Forestry Climate Change Working Group** is working with the forest industry to explore options to use beetle-killed wood to generate bio-fuels.

"We have seen a lot of symptoms of drought in recent years, e.g., native Douglas-fir mortality as well as drought symptoms on urban trees." (City of Kelowna)[19]

"Loss of western red-cedar and grand fir in areas where they were on the edge of their ecological niche… We have also seen a significant increase in the number of new invasive species." (District of Saanich)[20]

"…the boreal forest, predominant in the Burns Lake region, is expected to undergo an extensive reduction in size, as grasslands and temperate deciduous species may invade from the south, and northern expansion is limited by poor soils and insufficient sunshine amounts. Forest fires and pest infestations are expected to increase in frequency, area, and intensity due to warmer and drier conditions." (Village of Burns Lake)[21] and precipitation conditions on a site. This creates stress on individual trees, and reduces the geographic range or extent of the species as trees growing in vulnerable locations succumb to drought, pests or disease. Some species will be better at adjusting than others.

Extreme weather events affect urban forests. Climate change could result in more frequent extreme windstorm events, with more trees blown over and large branches broken. Homeowners often remove tall trees from their property for fear of wind damage. Major snowstorms are also causing trees to lose limbs to heavy snow.

Flooding can cause erosion of soils along streambanks, undermining trees and their roots. Flooding is projected to become both more intense and more frequent as a result of climate change, inhibiting the early-successional riparian regrowth that occurs on islands and low areas susceptible to inundation. Lowland riparian woodlands, stream health and fisheries will suffer as a result.

A Role for Urban Forests

All of these climate change effects impact people, ecosystems, economic well-being, and quality of life. Sections 3 and 4 of this guide provide some suggestions on ways that communities can use urban forests to adjust to the new climate reality, and manage their urban forests so they survive and thrive in new climate conditions.

On December 15, 2006, the biggest windstorm in more than forty years roared through Vancouver, causing significant damage to Stanley Park. This was followed by two major windstorms in January 2007. As a result of the storms, approximately 10,000 trees fell (5–10% of all trees in the park) and there was severe damage to about 40 hectares of the forest. A bibliography of tree–wind literature is available from **www.treelink.org**.[24]

Figure 7: Flooding can cause erosion along streambanks

3

Adapting Communities to Future Climates

"Adapting for climate change often brings with it surprising extra economic, social and other environmental benefits."

UK Commission for Architecture and the Built Environment, 2008

"Integrating climate change and sea-level rise into infrastructure planning improves risk and life-cycle cost management, and will reduce the vulnerability of B.C.'s critical infrastructure."

Natural Resources Canada, 2007

Many communities—from electoral areas to villages and cities—are thinking about how climate change will affect them and are taking steps to prepare and adapt. This section provides information on how communities can use urban forests as a tool for climate change adaption.

Urban forests can help communities to adapt to climate change in ways that enhance their residents' quality of life and mitigate or solve anticipated problems. For example, planting large-canopy trees in parking lots provides welcome shade that makes summer parking more pleasant. It also reduces air pollution, as the leaves absorb airborne particulates and the shade reduces toxic off-gassing from hot car engines. As well, asphalt lasts longer in shaded areas. These same trees can be part of the site's rainwater management system, while enhancing the visual appeal of the built environment. And all of these benefits enhance the experience of visitors using this facility to access nearby services and businesses, and supports business activity.[25] Planning for multiple benefits such as this is part of good urban forest management.

Below are some suggestions on ways to use urban forests to adapt to various impacts from climate change. However, there

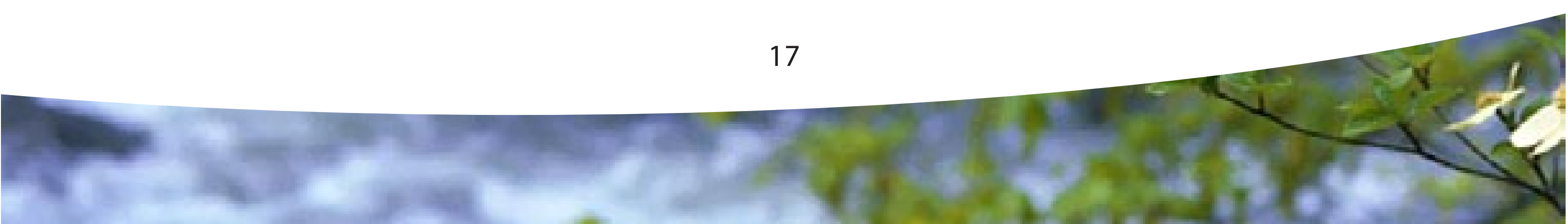


Figure 8: Trees in a parking lot

is no 'one-size-fits-all' solution, and decisions must be based on local circumstance, impacts, vulnerabilities, political and socio-economic priorities, and good baseline information.[26]

Warmer Summers

Climate change will mean longer, warmer summers for many B.C. communities, and some will experience more heat waves. Strategically-placed shade trees can dramatically reduce summer heat and UV radiation.

Selecting the 'Right' Species
This document makes reference to tree species that could be considered for specific purposes. However, the choice of the best species for the site (sometimes referred to as "right tree right place") will vary depending on local climatic conditions (current and future), site conditions (e.g., slope, aspect, soils, available rooting space) and local preferences (e.g., low-maintenance variety, flowering). For more information on species selection, see page 37).

Evapo-transpiration is a term used to describe the evaporation and plant transpiration from the Earth's land surface to the atmosphere. Evaporation accounts for the movement of water to the air from sources such as the soil and canopy interception. Transpiration accounts for the movement of water within a plant and the subsequent loss of water as vapour through stomata (pores) in its leaves.[27]

Reduce the Heat Island Effect

Larger communities will feel a more pronounced 'heat island' effect with built-up areas that are hotter than nearby rural areas. (A large city can be 1–3°C warmer than its surroundings, or as much as 12°C hotter in the evening.) Heat islands can increase summertime peak energy demand, air conditioning costs, air pollution and greenhouse gas emissions, and heat-related illness and mortality.

- Place groves of large-leaved trees and shrubs upwind of heat island areas. The evapo-transpiration from the vegetation will create cooler, moister air that blows into the 'hot spots'.

- Plant and maintain green roofs and green walls, which help to cool the air through evapo-transpiration of plants.

The **City of Kelowna** planted trees to provide shade in the Mission Recreation Park, especially in parking areas. Trees were selected to be heat and drought tolerant, and pest resistant. The trees have interpretive signs to educate the public about the species chosen.

The **District of Saanich** has a Significant Trees bylaw that protects heritage trees. If a large shade tree is designated as a 'significant tree', the homeowner can apply for a grant to be reimbursed for up to 50% of the cost of tree work that is considered beneficial to the tree.

Increase Shade over Pavement

Large shade trees can reduce local ambient temperatures by 2–4°C.

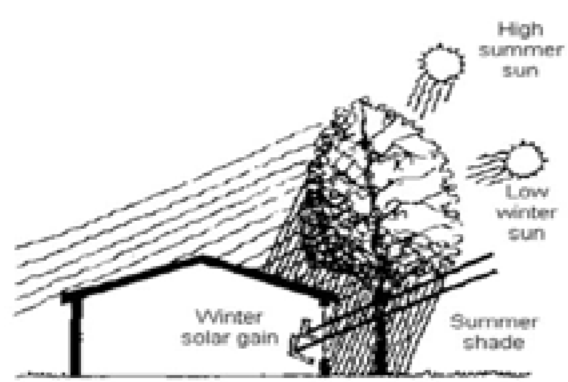
- Shade large areas of asphalt, such as parking lots. As noted above, this also reduces air pollution and provides a more pleasant environment for parking. Studies found that cars parked in parking lots with 50% canopy cover emit 8% less pollution (from the evaporation of volatile organic compounds) than cars in parking lots with only 8% canopy cover.[28]
- Shade streets and sidewalks. Trees help to reduce street repaving costs as shading helps to increase the life span of asphalt. When asphalt paving becomes too hot, its oil binder volatizes and leaves the stone aggregate unprotected, so that vehicle use loosens the aggregate and grinds down the pavement. One study found repaving could be deferred by 10 years on a well-shaded street and perhaps 25 years on a very heavily-shaded street, reducing repaving costs by 58% over a 30-year period. Larger trees provided greater benefits—shade from small trees reduced costs by only 17%.[29]

Create Comfortable Outdoor Spaces

Green spaces with a generous planting of trees can contribute to cooler, cleaner air.

- Plant large shade trees in public spaces. With hotter summers and concern about skin cancer, more people are seeking out shaded areas to sit or walk in. Clusters or groves of trees, preferably with multiple canopy layers, amplify these benefits.
- Plan for successive plantings that produce a diversity of hardy species, age classes and growth rates, to ensure continuous canopy cover over time.

Figure 9: Solar friendly trees for southern exposure



Source: Climate Action Reserve, 2010

Fort Collins, USA's Forestry Division justifies its large annual budget of almost one million dollars by calculating the economic benefit produced by their trees (net annual benefits total $1.17 million). Their "Save our Shade" program helps residents to protect existing trees and plant drought-resistant trees to address water shortages in their arid climate.[30]

Provide Shade for Buildings

Large deciduous trees have particular value in cooling air and shading buildings in summer. Shade trees planted on the west and south sides of a home can reduce cooling needs (and costs) by 25–40% and reduce peak energy demand by up to 30%. Reducing energy use is also important for climate mitigation.

- Plant trees on the west side of buildings for maximum shade benefit, as this reduces solar gain from the warm afternoon sun.
- Plant solar-friendly trees to the south-east or south-west of buildings, i.e., trees that allow heat from the low winter sun to enter the building, while blocking high-angle summer rays (Figure 9). Solar-friendly trees have more diffuse canopies that allow light to penetrate while still providing shade. Good candidates may include some oaks, most ash species, black or honey locust, ginko, Lombardy poplar, Douglas-fir, or large pine species.
- Locate south-side shade trees about 3–7 m from the building. As the tree grows taller, prune the lower branches to allow more winter sun to reach the windows (if this will not weaken the tree structure). Avoid placing trees too close to the building foundation to avoid damage from roots or problems with branches against the roof or walls.
- Plant deciduous trees on the east side of buildings to provide morning sun for heat in the winter, but shade in the summer.
- Shade air conditioning units, as this allows the unit to run more efficiently.
- Ensure that trees are selected or placed so that they do not block solar installations (e.g., solar panels for hot water heating).

Increased Precipitation

Many B.C. communities will experience greater winter precipitation, including more intense rainstorms. Flooding is expected to become more frequent in some areas, with higher flood levels.

Trees and shrubs can be part of a community's rainwater management system, helping to manage or avoid stormwater flows in three ways. First, the tree canopy intercepts rainfall, directing some of it down the trunk and into the ground, and returning some to the air through evapo-transpiration. (The amount of interception will depend on the tree species, shape, size, and leaf area density.) Second, the tree roots detain some of the rainwater in the ground (reducing peak

Chiswick Business Park in **London, England** includes a large area of open spaces that is designed to help regulate outdoor temperatures. It is designed to be comfortable for users now and as the climate changes over the next 40–60 years. This sets it apart from competing business parks that will be "unpleasant places to work in without significant air conditioning". [31]

flows). The exposed soil directly surrounding a tree (or root zone) has a higher infiltration rate than compacted soil, because roots loosen the soil and increase water penetration. Third, the root systems deeply penetrate the soils, allowing for more groundwater infiltration. This means that there will be more groundwater available to supply streams during summer drought periods. Figure 10 shows how under natural forested conditions, about 90% of the rainfall is either returned to the atmosphere via evapo-transpiration or enters and moves through the ground as interflow. The rest recharges groundwater aquifers, and less than 1% becomes overland runoff. As urbanization occurs and there are more impervious surfaces and fewer trees, much more goes to overland runoff. Planting significant numbers of trees and shrubs, particularly in clusters or groves, can help to reverse these effects.

Increase the Canopy Cover

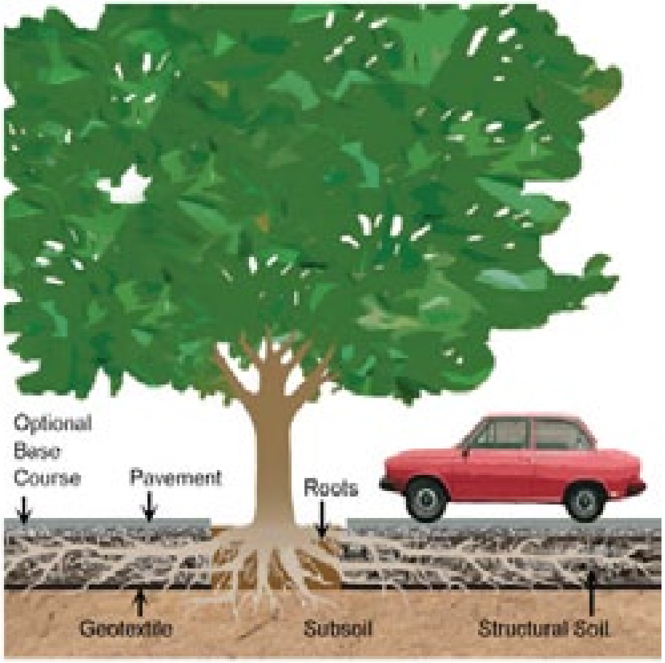
Increasing canopy cover (leaf area) allows for greatest interception of rainfall. Large mature trees provide the greatest benefit, since they have the most surface area to retain water.

- Plant and retain large-canopy trees. The amount of rainwater a tree detains depends largely on its size. Large, broad-leafed or coniferous trees intercept far more water than smaller ornamental species.
- Consider using more coniferous tree species, where appropriate. Unlike

Figure 10: Water balance before and after suburban development

Source: Stormwater Planning: A Guidebook for British Columbia

Figure 11: Structural soils



This system both serves as a parking lot and as a stormwater management facility. In addition to this double use of space, the structural soils also provide vastly greater soil volumes for tree root growth than traditional parking lot construction. Note: Gravel base course is optional, since the structural soil is designed to be as strong as the base. Figure by Sarah Dickinson

A study of the heat island effect in the City of Toronto found that residents could save about $11 million per year in energy costs. Savings from cool roofs (green roofs) are about 20%, shade trees 30%, wind shielding of trees 37%, and ambient cooling by trees and reflective surfaces 12%.[32]

Studies in the U.S. found that three mature trees around energy-efficient homes can reduce a typical home's heating demand by 25–43% and peak cooling demand by 12–23%.[33]

deciduous trees, which are leafless during the rainy season, evergreen conifers continue to detain large amounts of rainwater throughout the year. Native or zonally-adapted conifers (like Douglas fir, most pines and many spruce species) are also well-adapted to cope with dry summers, as they do most of their photosynthesis in the moister shoulder seasons.

- On sites that are moist throughout the growing season, consider planting anaerobically tolerant trees,[34] [such as many poplar and willow species and some deciduous conifers, such as Swamp cypress or Dawn redwood, as they will take up and transpire large amounts of water.
- Replace trees with sparse canopies. Trees need large, full canopies with healthy leaves to provide optimum shade and cooling through evapo-transpiration.

> The City of Kelowna has a "Neighbourwoods" program to fund tree planting on private property. In April 2010, residents bought 450 trees at a discount ($30 per tree) to celebrate Earth Day.[35]

Make it Easy for Water to Seep into the Ground

As communities grow, trees are removed to make way for impervious surfaces such as parking lots, roads and buildings (see Figure 10). Constructed stormwater facilities (which are expensive to build and maintain) are built to compensate for the loss of natural infiltration. The cost has been calculated to be in excess of $100 billion nationally.[36]

As well, even open ground in urbanized areas is commonly disturbed or compacted, limiting normal soil hydrologic functions. Tree roots that penetrate typically impermeable urban soil layers can increase rainwater infiltration rates.

- Plant more trees and shrubs! Root growth improves the both the hydrological and biological function of urban soils and increases rainwater infiltration rates.
- Use mulches and native groundcovers, or permeable paving stones layered on a sand base, to keep the ground absorbent.
- Have deep soils (at least 15 cm) for planting. Better yet, keep lawn size to a minimum and use native groundcovers where practical.
- Provide loose, uncompacted soils as these are important for healthy tree growth. Use of 'structural soils' or 'soil cells' are options to avoid soil compaction (Figure 11 and Figure 12). Structural soils are made up of a compacted matrix of angular stone, with uncompacted mineral soils in the spaces within. This meets the structural requirements for parking lots, roads and other paved surfaces while supporting tree root growth under the pavement. The deep rooting of trees in these soils helps to prevent heaving of sidewalks, curbs and gutters by tree roots. However, the amount of soil with a structural soil is only about

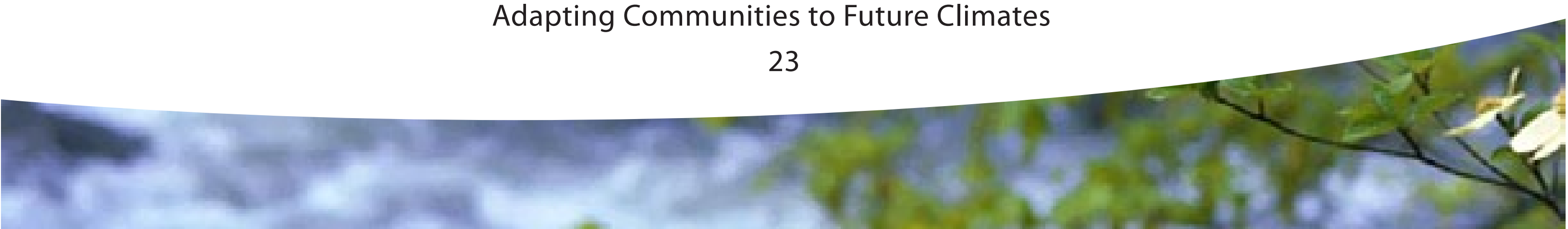


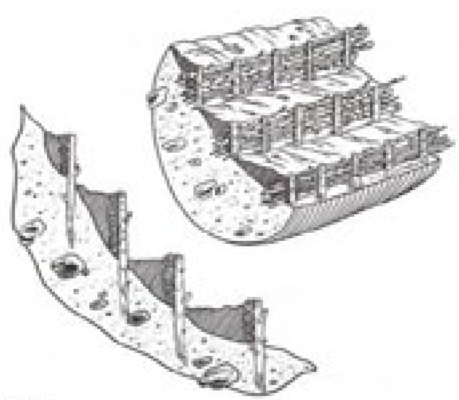
Figure 12: Raingarden

one-third that of native soil so a large space is required to support each tree (inadequate soil volume leads to premature decline of trees).

Soil cells are modular, pre-engineered plastic cells—much like milk baskets—which are locked together and filled with soil. The cell structure and pavement takes the load of the traffic, while tree roots make use of the soil as a growing medium. Soil cells provide significantly more soil per volume than structural soils and are designed to meet a support up to 3,630 kg per wheel to a maximum of 14,515 kg per axle. Greater rooting space allows trees to grow larger, and thus provide more shade, interception and other benefits. Although soil cells appear to be more expensive, they provide significantly more soil per unit volume than structural soils so less product is required, reducing the relative cost.

- Retain large natural treed areas, which typically absorb and store more water than disturbed areas. The runoff from an undisturbed remnant forest is negligible compared to open ground and even turf areas. Native understory will support treed areas much better than lawns, which have a poor infiltration rate (at times only slightly better than pavement).
- Maintain or restore the historical surficial hydrology of a site when retaining existing trees and vegetation in new developments. Very often, natural water movement on a site is changed by development and the vegetation that depended on that water

Figure 13: Bioengineering approach to streambank



Source: Polster, 2002

supply dies, as rainwater running off new impervious surfaces (roof, driveway, sidewalks and roads) is channelled away into 'stormwater management systems'. Often, with a little bit of thought, rainwater can be re-directed and dispersed back into the natural environments, while still managing the risk of extreme stormwater events. Be careful in engineering these rainwater interflows, as too much water can kill a tree just as readily as too little.

Create Raingardens to Manage Overland Flow
Raingardens are vegetated depressions designed to absorb precipitation, allowing the water to soak slowly into the ground.

Direct rainwater into raingardens, allowing the water to soak into the ground. An additional benefit of this approach is that these natural systems filter out many pollutants, especially from small storm events which are the greatest source of pollutant loading. Trees in raingardens help to increase their natural function.

Extreme Weather Events

Use Root Systems to Create Slope Stability
Intense rainstorms, runoff and flooding can erode soils, especially on steep slopes. Root systems of trees and large shrubs can be useful for stabilizing the soil and minimizing erosion.

- Retain or restore vegetation on steep slopes. Species of trees and shrubs with extensive rooting systems, such as willow species, maple or Sitka alder, are good candidates. Native willow is particularly effective if a bioengineering approach is

The City of Seattle's Street Edge Alternatives Project (SEA Streets) was designed to provide drainage that mimics the natural landscape prior to development. Impervious surfaces were reduced to 11% less than a traditional street, surface detention was directed to swales, and over 100 evergreen trees and 1,100 shrubs were added to the street. This approach has reduced the total volume of stormwater leaving the street by 99%. [38]

A school in Qualicum Beach created a raingarden to capture stormwater runoff. Despite one of the heaviest recorded rainfalls immediately after its completion, the raingarden absorbed all the water inflow, allowing it to gradually soak into the soil.[39]

Stormwater from a parking lot at the University of California Davis drains toward a wide, deep swale planted with London planetrees and filled with a mixture of 75% lava rock and 25% clay-loam soil. The swale provides a growing medium for trees and shrubs and a storage area for runoff, while the soil itself helps trap pollutants as the rainwater filters through it. The system is designed to capture 97% of all rainfall events, as well as removing nutrients and heavy metals from the runoff.[40]

anticipated (see below).

- Bioengineer vegetation to stabilize slopes and streambanks. Biodegradable mesh, crib walls (logs with holes for willow and dogwood cuttings) and herbaceous understory plants (such as wild ginger or wild strawberry) can be used to control erosion. Several methods for riparian restoration are provided in **Soil Bioengineering Techniques for Riparian Restoration.**[42]

Provide Protection from Strong Winds

- In open areas, create windbreaks by placing rows of trees perpendicular to the prevailing wind, about 8–15 m from the building. Design the windbreak to be longer than the building (see Figure 15) because wind speed increases at the edge of the windbreak. Dense evergreens that grow to about twice the building height are ideal. Place them far enough from the building so that they will not cause property damage if they blow down or block low-angle winter sun.

For more information on rainwater management at the watershed level, see **Beyond the Guidebook 2010: Implementing a New Culture for Urban Watershed Protection and Restoration in British Columbia**.[41]

Allow shrubs to form thick hedges, especially on north, west and east walls, to act as windbreaks.

Wildfire

Interface wildfires are a growing concern in many interior communities, especially those surrounded by forests affected by mountain pine beetle.

Design Communities to Minimize Wildfire Risk

- Choose 'fire smart' trees and landscaping.[45] In fire-prone areas, deciduous trees may be a better choice near buildings (as coniferous trees are more volatile and have the greatest potential to produce high-

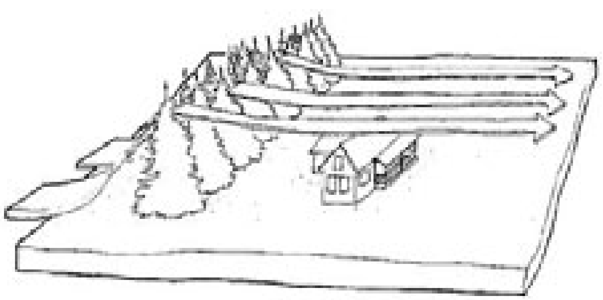
The **City of White Rock** has revised its tree management bylaw to protect trees in Ecosystem Enhancement Areas (steep slope and ravine areas) "where the City has targeted areas of natural drainage and or sloped areas with a need to preserve or enhance the tree canopy to protect soils, minimize erosion and reduce greenhouse gases in conjunction with the Integrated Storm Water Protection and the Climate Action Plans."[43]

The **District of Saanich** has designated steep slope areas. If more than two trees or any stumps are to be removed from these slopes, a geotechnical engineer is required to provide a letter that confirms the removals will not destabilize the steep slope.

intensity crown fires).[46]

- Maintain safe distances between trees and houses.
- Avoid new 'satellite' subdivisions that project into forested areas, where possible. A more compact growth form for communities helps to maintain surrounding forested areas, and minimizes the amount of wildfire interface area. If necessary, follow FireSmart guidelines to treat the surrounding forested area in order to minimize the risk of a wildfire causing damage. The Ministry of Forests, Mines and Lands has information to guide the design of new subdivisions, and the planning and treatment of forests around homes in existing rural subdivisions or remote areas.[47]
- Engage a knowledgeable forester to assist your community with its wildfire interface risk management planning. (See also Section 4.)

Figure 14: Evergreen plantings as a windbreak



Source: Climate Action Reserve, 2010

Health and Air Quality

Air quality (smog) will likely worsen with climate change in some regions, especially in summer. Trees remove air pollutants by trapping particulate matter in their leaves, needles and bark. Better air quality reduces health care costs, and improves the quality of life for everyone, especially those with compromised health, such as asthmatics. Beware that trees can also give off aromatic compounds that can irritate some people at certain times of the year and contribute to ground-level ozone formation. There is considerable species variation in the emission of volatile organic compounds (VOCs), so consider this when selecting what tree species to plant.

> The **City of Prince George** is examining ways in which trees can help to mitigate air quality problems.

Plant Trees to Improve Air Quality

- Retain healthy large-stature trees. Large coniferous and broad-leafed trees with dense foliage collect the most particulate matter.
- Plant additional trees in areas where air quality is a concern, for example along busy urban roads.
- Consider long-lived and low-maintenance trees for these plantings.
- Plant leafy shrubs in areas not suited to trees; these too will remove air particulates.
- Provide ample water for urban trees and shrubs. This enhances their ability to remove pollutants in the atmosphere,

Windbreaks can reduce typical home heating demand by 5–15% (1–3% for a single tree).[44]

and their ability to reduce the ambient air temperature through evapo-transpiration.

Food Production

As global temperatures rise, the tropics and sub-tropics will be significantly affected, reducing food production in these areas and likely increasing food costs worldwide.

Provide Opportunities to Grow Local Food
One of the benefits of changing climates is that many regions of B.C. will be able to grow fruits and other food crops currently associated with more southerly locations. Local food production also helps to reduce greenhouse gas emissions.

- Consider planting fruit and nut trees currently suited to more southerly climates,

Figure 15: Fruit tree planting, Ucwalmicw Centre Society

Figure 16: Apple trees

in anticipation of being able to get them to produce fruit as they mature. Ensure they are hardy enough for the current climate, or provide appropriate winter protection such as mulching, wrapping stems, or windbreaks.
- Consider what opportunities there may be in parks or other municipal lands for local food production (e.g., community gardens, park trees).
- Ensure that trees are placed and pruned to avoid shading community gardens.

The City of Victoria has grown ornamental banana trees for many years. In 2010, for the first time, a banana tree growing in the greenhouse blossomed and produced fruit, likely due to the previous summer's heat wave. [48]

The City of Victoria also allows the growing of food in city boulevards (with permission).

Carbon Credits from Forests

Retaining and planting treed areas are important for climate mitigation (by sequestering carbon). However, afforestation (land that has been without forest for much longer than land what would be considered reforested) is also becoming a source of income to fund climate action (including adaptation programs).

Consider afforestation projects to capture carbon. In May 2010, the **Pacific Carbon Trust** issued its first call for proposals to buy carbon offsets created as a result of afforestation (planting) projects, providing that the carbon sequestration benefits could be verified. Afforestation initiatives need to be over and above that needed for 'normal' or historic levels of urban forest restocking in order to qualify as a valid offset.[49] Carbon credits can also be awarded for avoiding deforestation through the retention of trees.

Consider community energy projects which convert waste wood from parks and forests into energy, generating revenue and carbon credits. This is part of an **Integrated Resource Recovery**[50] approach to waste management.

4

Adapting Urban Forest Management to Future Climates

As well as adapting communities to climate change, it is also important to adapt urban forests so that they survive and thrive in changing climates. Urban forests are part of a community's 'green' infrastructure that can be purposefully designed and managed to provide a myriad benefits to community. However, these urban forests need maintenance and re-investment just as much as 'grey' infrastructure (roads, sidewalks and pipelines). In return, they provide a variety of economic and other benefits (see **Planting our Future**).

'Climate-proofing' urban forests helps communities to protect their green infrastructure, manage tree-related risks and reduce associated insurance costs. Failure to invest in re-structuring the urban forest to meet future climates could result in increased costs for clean-up after wind- or snow-storms, or unnecessary loss to wildfire or pests. Proactive management—an ounce of prevention—is almost certainly cheaper than an ounce of clean-up after a disaster.

Urban forests in your community are already subject to variable weather conditions, including extreme events such as heat waves, dry spells, heavy precipitation, and strong winds. As the climate changes such events are likely to become more frequent

Figure: 17: Maffeo-Sutton Park, City of Nanaimo

and more extreme. Average precipitation, temperature and growing degree days—all factors that affect tree establishment, growth and survival—will also change. Trees will likely be exposed to new pests and diseases as well as competition from new invasive species. As a result of the climate change already experienced during the last century, mature trees that were planted many years ago may already be showing signs of distress. For example, many cedars planted as hedges in Victoria and Vancouver are unable to survive drier summers without supplemental irrigation. Seedlings planted today not only need to grow well under present conditions but in climates 40–50 years from now. Adapting urban forests to climate change aims to reduce their vulnerability to adverse effects and to create treed environments that will thrive into the future. This involves:

- Reducing urban forests' exposure to risk; and
- Increasing urban forests' resiliency to disturbances.

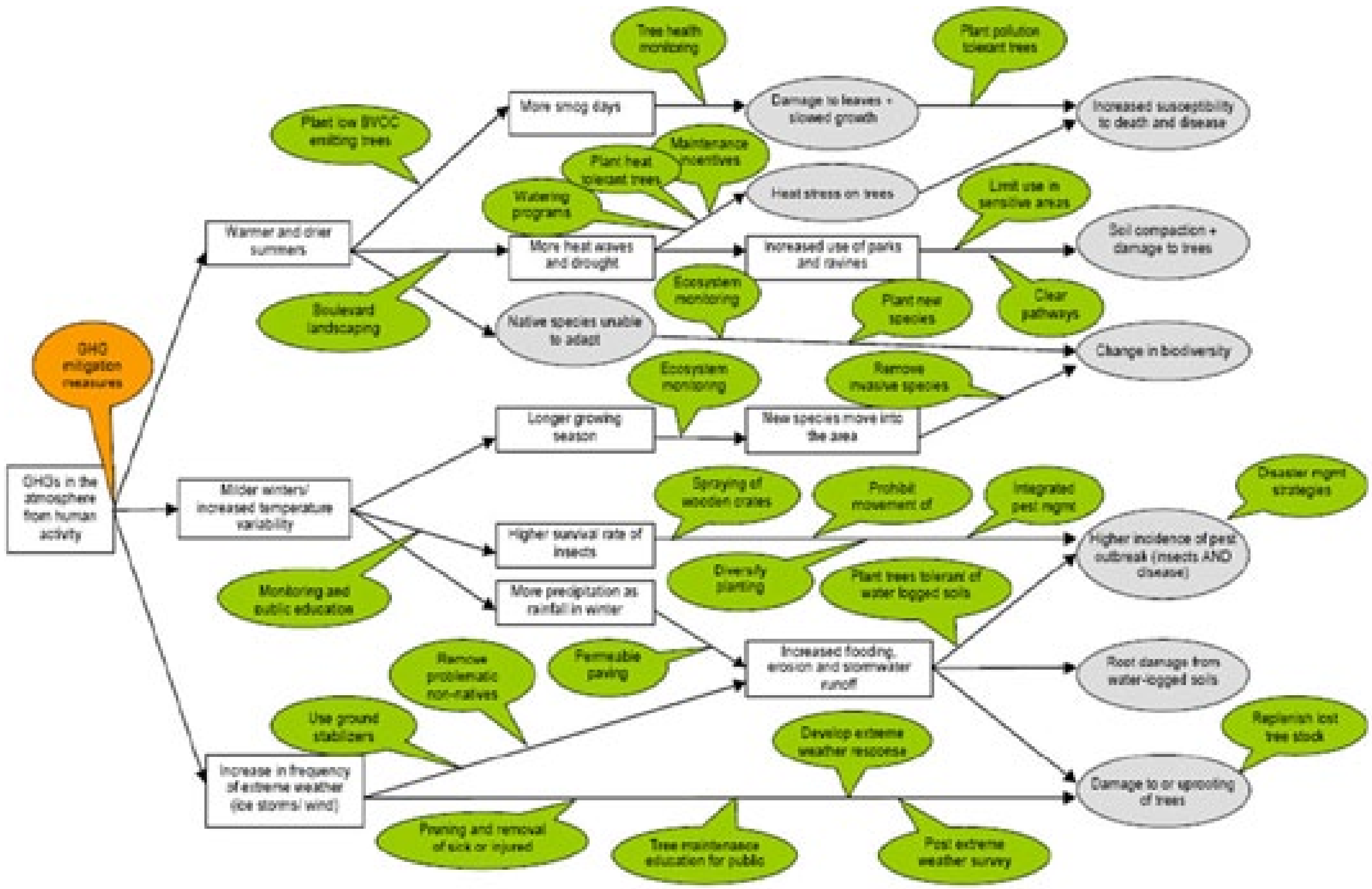
Figure 19 shows a diagram prepared as part of the City of Toronto's urban forest adaptation study, and illustrates expected climate change impacts on the city's urban forest and potential adaptation strategies. While it is unlikely that a small community would be able to implement all of these adaptation strategies, this diagram may help communities to generate ideas.

Risk Management

Climate change is exposing urban forests to new vulnerabilities and risks. Many communities are all too aware of the increased risk of wildfire and insect damage associated with climate change. Other impacts—including drought, extreme

i-Tree is a software suite from the USDA Forest Service that provides urban forestry analysis and benefits assessment tools. i-Tree tools include i-Tree Eco (formerly known as UFORE), which creates spatial mapping of the urban forest, and can generate a report on the value of its ecosystem services (e.g., air pollution removal). Other programs allow urban forest managers to determine where and what species to plant for maximum benefits, and to model the effects of planting programs in various parts of a community. Some of these applications are currently only available in the U.S., but should be available in Canada in the near future.

Figure 18: Adaptation strategies for the urban forest in the City of Toronto



This diagram was produced by the Clean Air Partnership in Toronto show the inter-relationships between greenhouse gas emissions, climate change and related impacts, together with options for addressing these issues.

Source: Clean Air Partnership 2007

winds and heavy precipitation events—will likely result in higher levels of tree death and structural failure (loss of branches or the entire tree).

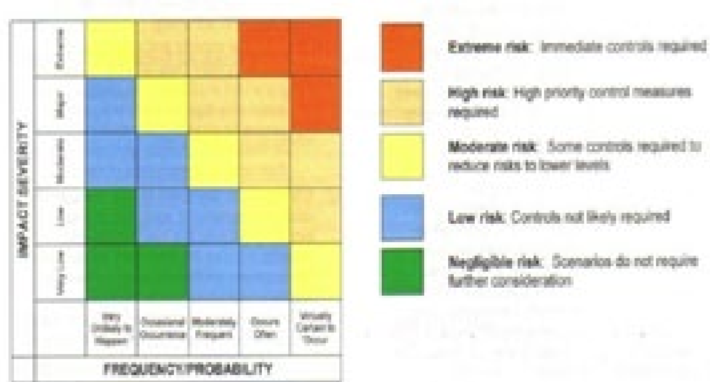
Get to Know your Urban Forests

- You can't manage what you can't measure. Inventory and map your urban forests so that you can better manage the resource and any risks that may threaten it. Think carefully about how this information will be used when developing your data collection fields. Several web-based tools can provide assistance, such as the i-Tree tools described in **Planting our Future**. A full mapping and assessment of the ecological health of a community brings many benefits including a good understanding of the condition of the urban forests. However, the investment of time and money may be beyond the means of smaller communities. In this case, a simple inventory of street and park trees and their associated environments may be a good place to start. Note that for many communities, much of the urban forest is on private land and this too should be considered.

> The City of Duncan and Cowichan Tribes developed an urban tree inventory, funded by a Green Streets Canada grant. The survey was conducted by one person on a bicycle. As well as being a low-cost method and environmentally-friendly, this approach provided an opportunity for the surveyor to meet and talk to residents about what he was doing.[51]

- Use the information gathered in the survey and mapping of your urban forest to assess its age, species and condition. Are the age classes and genera of your forest diverse enough? How much of your urban forest is over-mature or, in other words, those trees that harbour diseases and insects, whose environmental/social value is diminishing (e.g. are rotten or are losing branches during storms), and whose maintenance costs are much higher than achievable? Also note the site conditions within which your trees are growing. Are they dry? Steeply sloped? Disturbed? Associated with watercourses or wetlands?

Figure 19: Risk evaluation matrix



Identify Risk Factors

- Identify the climatic changes anticipated for your region (see Section 2). Brainstorm with others to identify what this could mean for your urban forest.
- Assess where vulnerabilities may exist, and identify the probability of these occurring and the likely severity of impact (see Figure 19).

The **City of Victoria** has an Integrated Pest Management Policy[55] that is part the City's environmental stewardship of all public lands and facilities.

This will allow you to identify and prioritize risks.

Plan for the Worst

- Develop emergency response plans for responding to extreme weather events that may impact your urban forests. Potential threats include prolonged drought, windstorms, rain-or snowstorms, and for increased flooding, pests, or competition from invasive species.

The process for developing an extreme weather plan could include the following:

- Determine who should be involved (agencies, groups, government) and their financial and human resources;
- Hire a program coordinator to work with the many different groups and agencies involved;
- Have trained staff assess and inventory tree damage;
- Provide a list of arborists for each municipality to assist in damage assessment and clean-up efforts;
- Establish a toll-free number and staff to deal with public inquiries;
- Prepare press releases and extension notes;
- Prepare and deliver workshops for home and land owners on tree care before and after a major storm;
- Assign work crews to assist in the clean-up of parks, trails, roads, and waterways; and,
- Provide on-site advisory service for home and land owners.[52]
- Prepare for higher incidences of pests and disease. More frost-free days, combined with earlier spring weather, will increase the over-wintering survivability of pests. Warm, moist conditions in spring and fall will enhance conditions for fungi, mildew and bacterial diseases of trees. Also prepare for threats from new invasive pests (such as Asian long-horned beetle, pine shoot beetle or emerald ash borer) and ornamental plant species such as Japanese knotweed, giant hogweed, and Himalayan balsam.[53]
- Establish a process for early detection and treatment of pests and disease, as this can minimize or delay the most severe impacts. Managing infestations could involve massive removal of infected trees to contain the spread of disease.

The **Community Wildfire Protection Plan** (CWPP) program assists communities in the development of plans that will assist them in improving fire prevention and protection measures in the interface areas. The CWPP will define risk areas for interface fires, identify measures necessary to mitigate those risks, and outline a plan of action to implement the measures.

Communities such as **Revelstoke**, **Kamloops**, **Maple Ridge** and the **regional districts of Nanaimo** and **Okanagan-Similkameen** have already completed Wildfire Protection Plans.

The **Neskonlith Indian Band** has created a fire break around the community, and is planting the fire break with pest-resistant firs to accelerate forest regeneration.

- Develop an integrated pest management plan. For more information, see **Planting our Future and the Integrated Pest** and the **Management Manual for Landscape Pests in British Columbia**.[54]
- Develop a community wildfire protection plan. For information on developing a plan see the **Fuel Management** website.[56] Local governments can access funding available from the **Union of B.C. Municipalities** to help develop these plans; First Nations communities can receive assistance from **Indian and Northern Affairs Canada** and should contact the **First Nations Emergency Services Society (FNESS)** for information.

Address Priority Risks

- With an arborist's advice, selectively remove branches to make vulnerable trees more wind firm. If the only option is to remove the hazard tree, consider topping it at 3–5m instead, or leave some large downed logs on the ground, as these will provide important wildlife habitat. At the same time, be strategic about leaving biomass which could act as forest fuels, increasing the risk of forest fires.
- Remove sick or damaged trees to reduce risks from tree failure or spread of insects and disease. Ensure that staff are adequately trained and certified in Tree Risk Assessment and Integrated Pest Management.
- Where there is a high risk of interface fires, follow the **FireSmart** guidelines to reduce risk to property. (See also page 27)

During the windstorms of 2006–07, more than 10,000 trees in **Vancouver's** Stanley Park blew down. Trees that were deemed a risk to visitors and park workers were removed. About 75% of trees and snags were retained, and about 80–120 tonnes per ha of fallen trees and stumps were left to provide wildlife habitat. Exposed trees at the edge of the blowdown area were made wind firm through careful thinning.

The **City of Edmonton** has prepared an urban forest management plan, which includes a direction to address the risks from emerald ash borer and Dutch elm disease. Green ash and American elms make up approximately 46% and 32% of the City's street trees, respectively.[57]

The **Ministry of Forests, Mines and Lands** provides an online **Tree Species Compendium**[59] that includes information on natural distribution, soil preferences, rooting systems, tolerances, and much more for a variety of native B.C. tree species.

Evergreen Canada has a **Native Plant database**[60] (including tree species) that includes information on preferred growing conditions.

Species Selection

Species selection is all about finding the right tree for the right place and time. Consider the specific needs and challenges of the planting site, as well as regional conditions and future climate impacts. Note that this document cannot provide species-specific guidance as the variety of 'suitable' species varies tremendously with climate, elevation, hydrology and soils across the province. Instead, it provides some principles that may help you to determine appropriate choices.

Determine the Most Appropriate Species for your Location and Future Climate

- Consider what tree species do well on drier, less nutrient-rich sites within your area. Some species that prefer moist and nutrient-rich sites may have their geographic extent reduced as temperatures warm, particularly in the interior of the province.
- Look at regions that currently have the climate that your community is expecting by 2050. What species grow well there? This can provide guidance to the trees that might do well in your region in future. For many parts of B.C., this means looking south or to lower elevations.
- Consider the use of non-native species, but do so with considerable care. The distinction between 'native' and 'non-native' will become more blurred in the next decades as species distributions shift. Whether native or introduced, one important consideration is whether the species planted is climatically adapted. This may make species that are not native to the area the most resilient choice. However,

Prince George has a program to reduce the forest fuel in the interface area to reduce risk of wildfire damage to the city.

Figure 20: Wildlife tree

The **City of Grand Forks** has a policy to replace every tree that is removed to maintain the tree canopy. Trees are selected from a list of native and climate-appropriate species.

be cautious of exotic tree and ornamental species (or their pests) that can become invasive in neighbouring forests. The black locust tree, for example, is an invasive species[61] in parts of North America. A safer choice may be to use species that occur nearby (not from a different continent) and are currently at their northern or upper elevational limit.

Consider Current and Future Tree Stressors

For areas subject to greater heat:

- Plant heat tolerant trees in locations impacted by urban heat islands (e.g., in parking lots or town centres).
- Create clustered plantings of trees and shrubs that will create their own micro-climate, and cool the surface and soils beneath the canopy, allowing a variety of species to survive under harsher future climate conditions.
- Where appropriate, use porous pavers instead of asphalt, as this will absorb less heat than black pavement.

Plant pollution-resistant species. Hotter summers can create greater concentrations of ground-level ozone, which leaves trees vulnerable to death and disease.

For areas subject to greater drought:

- Select species habituated to drier sites in the area or from further south. In general, native conifers will do better than deciduous species, because conifers limit photosynthesis during the dry season.
- Consider water needs. Trees will be stressed (and survival rates reduced) in areas with long drought periods. Combine smart species selection (drought tolerant) with best planting practice, generous soil volumes, mulching (to retain soil moisture),

In **Toronto** and **Chicago**, neighbourhood watering programs use volunteers to water trees in parks and neighbourhoods during drought periods.[62]

Village Tree Way in the **Village of Pemberton** has been planted with trees that need little watering, reducing maintenance costs. They also selected non-fruit bearing species that would not attract bears.

San Francisco allows residents to convert a portion of the sidewalk into a landscaped area. Trees and plants with low water needs are encouraged.

good site design (to allow harvesting of local rainwater interflows) and water-smart irrigation systems. Irrigation is most critical in first three years of establishment. At the same time, take care not to water native trees beyond this stage as it could reduce root depth penetration and make them more susceptible to blow down.
- In areas with a cheap and plentiful water supply (e.g., groundwater), consider increasing summer watering programs. Community volunteers could be recruited to help. Be careful not to overwater species that grow deep taproots. Under conditions of over-watering, these species do not become wind firm and may be susceptible to blowing down.

For areas subject to more intense rain or flooding events:
- Choose trees that can tolerate waterlogged soils for short periods of time. Select species that tend to dominate in seasonally wet sites. Examples of water-tolerant species include cottonwood, swamp cypress, many willows, red maple, and alder.

For areas subject to high winds:

- Choose wind-firm, drought-tolerant species (as wind desiccates plants). Select species with attributes such as sound branch attachments, high wood strength and a well-distributed root system. Allow for deep growing soils.
- Retain open-grown trees that are adapted to winter storm winds in areas of risk. Close-growing trees, once thinned, may be susceptible to blowing down as they will not have formed broad, secure rooting systems.
- Consider planting in larger groups where possible—trees are more wind firm as a group than isolated as individuals.
- Avoid planting on ridge tops or leaving narrow remnant strips of natural forests on exposed ground.

Planting and Maintenance

Proper planting and maintenance will give young trees the best chance of surviving and thriving. Guidelines for planting and maintenance are included in **Planting our Future**. From a climate adaptation perspective, the aim is to minimize stress on trees, so that they can respond better to the challenges associated with climate change. Key practices include the following.

Choose the Right Tree for the Right Place and Right Time

- Select species for the given site conditions and future climates, as described above.
- Choose healthy stock with well developed root systems. Avoid root-bound container grown stock.
- Ensure the planting site provides adequate space for tree root growth. In urban settings, use structural soils (see page 22).

Use Best Planting Practices

- Plant in loam soils that are loose (not compacted) and deep enough to support healthy root development (at least 60–75 cm).
- Stake the tree low enough on its stem to ensure that the roots don't move, while the upper portion of the tree can sway.
- Avoid adding organic amendments to the soil (<5% by weight or 20% by volume); instead top dress with about 10 cm of organic mulch. Do not mulch above root ball; mulch beyond this point instead, so as not to encourage fine root development up into the mulch layer. Irrigate deeply two–three times per week during dry season (more if in a windy area).

Helpful resources in good planting and early tree care practice are found at the ISA website

- Avoid soil compaction, as this can considerably shorten the life of the tree.
- Hire or train staff to become ISA Certified Arborists who are competent in all aspects of tree care.

Use Best Maintenance Practices

- Prune young trees to develop a sound 'architecture' that can withstand snowfall, windstorms, etc. For tree pruning information see the **International Society for Arboriculture** website.[63]
- Avoid unintended consequences—such as damage to bark from mowing machines or weed-whackers, or damage to roots from building activities or utility maintenance. Create turf-free areas around the base of trees; invest in education and training of turf-maintenance staff; and place plastic tree guards around the base of young boulevard trees.
- For a variety of best management practices see the **Compendium of Best Management Practices for Canadian Urban Forests**.[64]

Monitor Urban Forest Conditions

- Routinely monitor trees for new pests and diseases. This can help to avoid or minimize problem insects. It can also avert a potentially catastrophic infestation from a foreign pest taking hold, such as the Asian long-horned beetle or European ash borer.

Figure 21: Site preparation, Ucwalmicw Centre Society

> An **International Tree Failure Database** (ITFD) is a searchable database with information on tree failure from countries throughout the world. This information is gathered to help tree managers and researchers worldwide in uncovering tree failure patterns, allowing for better prediction of tree failures, the creation of appropriate standards for species selection and maintenance, and reduced impacts from tree failures.[65]

Community volunteers can be trained to help monitor trees in their neighbourhood.

- Monitor and report on tree conditions. This is important as it provides feedback on how trees are responding to climatic changes, and which species are proving the best-adapted. With the right training, volunteers can be asked to help with tree monitoring.

Diversity and Resilience

Conservation of biodiversity in the landscape is a key strategy for coping with climate change. The term 'ecosystem resilience' refers to an ecosystem's ability to adjust to and recover from changing circumstances such as climate change. The more complex and sizeable the natural areas that remain, the more likely species within a landscape will be able to adapt to change successfully. The more fragmented and simplified a landscape is, the less likely that successful adaptation will occur.

Many urban landscapes are quite simplified—such as a row of cherry trees along a downtown street. This makes them vulnerable to a single pest disease (e.g., bacterial canker) that could wipe out all of the trees. A more complex ecosystem with a variety of tree species and age classes will likely survive that pest infestation—even if the cherry trees are affected. Resilience can be improved by conserving natural areas, increasing species diversity, providing ecosystem connectivity, careful species selection, and good planting/maintenance practices.

> **Ecosystem Resilience at a Landscape Scale**
>
> Urban forests are not isolated entities, but exist within a much larger regional landscape (ecosystem), sometimes intimately connected to the surrounding forests, woodlands and grasslands. It is helpful to think on a range of scales when developing strategies for adaptation.
>
> Agencies such as the Ministry of Forests, Mines and Lands are actively working to develop climate change adaptation strategies at larger (bioregional) scales. Recognizing the role of urban forests within the larger regional context, and working with other players in this field of research, can amplify efforts being made at a more local scale and provide greater access to resources and expertise

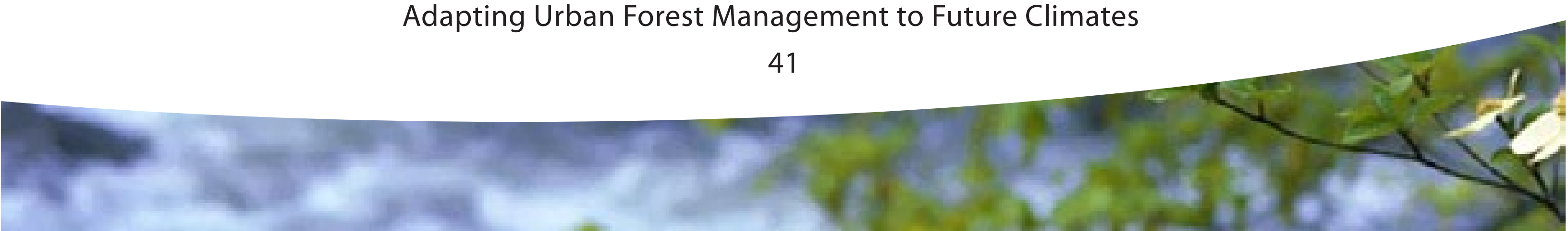
Increase the Biodiversity of Urban Forests

- Plant a diversity of tree and shrub species. This avoids monocultures that make it easy for pests and disease to spread, and raises the odds that at least some of the tree species will thrive in future climates and be resistant to new pests and diseases. The Municipal Specialist Certification Guide recommends the "10/20/30 rule": no more than 10% of one species or cultivar, 20% of one genus, or 30% of one family.[66]
- Ensure that there is a healthy distribution of age classes and growth rates within your tree population. Many communities with street trees have even-aged trees that are reaching the end of their safe and useful life.
- Protect critical habitat and ecosystem components, particularly around streams and wetlands. Ensure that riparian setbacks are adequate to ensure that large trees and their associated vegetation can be retained well into the future.
- Create greenspace connections between treed and other natural ecosystems. This will help to support local biodiversity.

The **City of Prince George** has been experimenting with different species of trees in city parks, including cultivars, in case native trees do not survive changing climates.
The **District of Invermere** is planting a diversity of deciduous and coniferous trees to create a "resistant urban forest".

The **District of Sparwood** has removed beetle-killed trees to reduce fire risk in residential interface areas. The District is replacing is replanting with a diversity of species and age-classes of trees, in order to reduce the risk of tree loss from pests and disease.

The **Mayne Island Conservancy** is working on a restoration project for Henderson Park that will enhance the resiliency of the park's forest ecosystem.



5

Five Quick Ideas to Get Started on Climate Change Adaptation

Climate change is already here, and its effects on communities will become even more noticeable over time. Managing urban forests well is just one part of climate change adaptation, but it can be an effective and simple place to start—and can generate numerous co-benefits.

Below are a few ideas to get started.

Get to Know your Urban Forests

- Conduct an inventory of your urban forest—simple or in-depth—and determine how well suited it is to the changing climate in your area. Where are areas of greatest risk? What are the priorities for action?

Decide What Type of Adaptation is Most Important to Your Community

- Find out what the expected effects of climate change are for your community. What is the most important function that trees and shrubs can do—slope stabilization? shading? rainwater infiltration?—and look at how you can enhance these benefits.

Figure 22: Tseshaht First Nation and Province of British Columbia Trees for Tomorrow

Look After Existing Trees

- Mature trees provide much greater benefits than young saplings. Consider how best to maintain this valuable asset.

Plant Shade Trees Suitable for Current/Future Climates

- Determine a variety of good tree species for new community plantings. Then host a tree planting event—a fun way to engage the community and provide education about urban forest values, as well as getting more trees in the ground. Communicate why you have chosen these species for this given location, and what benefits you are aiming to get from the trees as they mature.

Share Your Wisdom

- Climate change adaptation is a relatively new concept, and use of urban forests as a tool to reduce negative impacts on communities is not well understood. Share your findings, successes and failures with your colleagues and people in your community, so that we can all learn together. If you have stories to be shared, comments or suggestions, please contact **treesfortomorrow@gov.bc.ca**.

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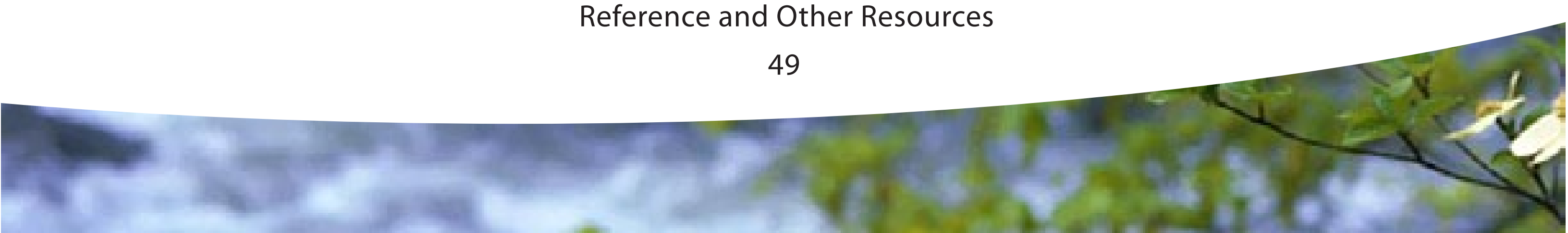

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