Implementing Climate Change Adaptation

in Prince George, BC

Volume 3: Forests

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Executive Summary:

Implementing Climate Change Adaptation in Prince George, BC
Volume 3: Forests

The City of Prince George is the largest city in northern British Columbia and has a long history tied to forestry. Although the local economy is becoming increasingly diversified, 28% of the city's income is dependent on the forest industry, which also represents 22.1% of the total revenue for the region. Natural forests, greenbelts, and landscaped areas (such as parks) represent over 65% of the land within the Prince George city limits and are central to the identity and well-being of Prince George residents.

The vulnerabilities of Prince George's natural forests, greenbelts and landscaped areas, as well as the forests in the surrounding region, have been realized in recent years with the outbreak of the mountain pine beetle (MPB; *Dendroctonus ponderosae*). From 2001 to 2007, the City salvage harvested the equivalent of 733 logging truck loads of MPB-affected lodgepole pine from within the city limits. Forest management practices that have increased the amount of mature lodgepole pine in forest stands (notably fire suppression and planting pine monocultures) and warmer than average winter temperatures are considered the main contributing factors to the MPB epidemic. Between 1918 and 2006, Prince George's mean annual temperature has increased by 1.3°C, and the annual minimum temperature has warmed even more, rising by 2.3°C. Prince George temperatures are projected to increase an additional 2.2–3.7°C by the 2080s and precipitation is predicted to increase 6–15% annually.

Extreme events, such as wildfires, windstorms, and extreme precipitation events, are also predicted to increase in the region. Wildfires have already increased in part due to the additional fuel load caused the MPB-killed trees. Fires have caused significant air quality problems in Prince George in recent years, representing a major potential risk for the city. Projected changes in temperature and precipitation may lead to increased evaporation rates in the summer months, which can reduce soil moisture and stress trees. These impacts may lead to changes in species suitability for the environment and the introduction of new species, pests and diseases, impacting the health of individual tree species and the health and productivity of the forest ecosystem.

Over the last decade, the City of Prince George has been adapting its forest management and operations to the changing climate. Many strategies for Prince George's forested areas have been primarily focused on reducing the risks of wildfires. These include the following initiatives:

- Developing a Community Wildfire Protection Plan for natural forested areas, focusing on public education on how to reduce wildfire hazards, implementing guidelines for new developments, and identifying fire hazard areas for abatement operations
- Developing and implementing a Fuel Management Program to manage local fire hazards primarily related to the MPB within the municipal boundary
- Managing Crown natural forest land within the municipal boundary through a Community Forest Agreement and exploring opportunities to expand and diversify the community forest to extend to wildfire hazard areas outside of the municipal boundary

The City has also been undertaking many management strategies that will allow landscaped areas to be more resilient to the uncertain future climate. Some examples of these strategies include:

- Selecting and recommending more pest-tolerant species for new plantings in parks, streets, and new developments
- Planting a variety of tree species in landscaped areas rather than a single species to avoid losing all trees to a single pest like the MPB
- Introducing tree species that traditionally grow in warmer and/or wetter climates
- Creating inventories and databases to aid in monitoring species health and reduce impacts of potential pest and disease outbreaks

Although Prince George has led the way in addressing the challenge of climate change impacts on forests, there are many more opportunities for Prince George to continue to plan for climate change. Opportunities to further adaptation efforts related to natural forests, greenbelts, and landscaped areas include:

- Incorporating climate change impacts and adaptation into public documents and resources to create more community awareness of the importance of adaptation
- Discussing information needs and further modelling requirements that will inform adaptation strategies for future forest management
- Identifying key linkages and partnerships with other levels of government as well as industry to help develop policies and management objectives regarding climate change adaptation and forest management
- Developing more opportunities for planting pest-tolerant and diverse species to better prepare for the uncertain future climate
- Conducting seminars and workshops with local tree nursery professionals, tree experts, and arborists to create awareness and to gather data on potential stresses to trees and the arrival of pests and diseases that may impact tree health
- Increasing public education of current forest management by partnering with local post-secondary educational institutions to educate students (e.g. natural resource management students) on the impacts of climate change to Prince George's forests and how management has been adapted to these impacts

Together, these adaptation strategies may enable the City to minimize negative impacts from climate change while providing opportunities to take advantage of some possible benefits associated with the changing climate. These strategies may be used as guidelines for resource managers and decision makers in communities similar to Prince George, where forests and forestry are important to the livelihoods of the community residents.

Background

Natural Resources Canada established the Regional Adaptation Collaborative (RAC) program in 2008 to assist communities and regions across the country as they adapt to climate change. Adaptation refers to actions that respond to or prepare for changes in the climate that are either expected or already occurring. Actions can be taken to become more prepared for unexpected events, to minimize the negative impacts of events already occurring or expected, or to maximize any positive benefits that may arise. Adaptation is different than climate change mitigation, which refers to actions that reduce the amount of greenhouse gases (GHGs) in the atmosphere.

Prince George has become a leader in community adaptation, and has been pursuing this topic for over five years in partnership with many organizations. The City was selected to be one of four community case studies to participate as part of the British Columbia (BC) RAC program (NRCan, 2011). The RAC funding allows for Prince George to build upon its climate change adaptation efforts to incorporate adaptation into local plans and begin implementing actions to address priorities within city administration. The City of Prince George has worked closely with the University of Northern BC (UNBC) and the Fraser Basin Council on this project, along with many other collaborators.

Although the focus of the Prince George RAC project is on adaptation, actions that address both adaptation and mitigation are encouraged whenever possible. Both adaptation and mitigation will be necessary for communities to prepare for and respond to climate change. Adaptation is needed to respond to the changes that are occurring in the climate, and mitigation is required to prevent further changes that may severely impact natural and human systems in the future.

The adaptation work conducted in Prince George under the RAC program is documented in this written case study, consisting of eight volumes. Each volume discusses an impact priority or a specific project from the many and varied community initiatives that RAC team members have contributed to in Prince George. Where applicable, the case study draws direct links to Prince George's adaptation priorities, as identified in the strategy document, '*Adapting to Climate Change in Prince George: an overview of adaptation priorities*' (Picketts et al., 2009a)), which was received by City Council in November 2009.

The Volumes *Implementing Climate Change Adaptation in Prince George* are as follows:

Volume 1: The *myPG* Integrated Community Sustainability Plan

Volume 2: The Official Community Plan

Volume 3: Forests

Volume 4: Flooding

Volume 5: Transportation Infrastructure

Volume 6: Natural Areas and Ecosystems

Volume 7: Precipitation and Freeze-Thaw

Volume 8: Ongoing and Future Initiatives

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Glossary of Terms

CFS: Canadian Forest Service

CPG: City of Prince George

MFLNRO: Ministry of Forests, Lands and Natural Resource Operations

MOFR: Ministry of Forests and Range

MOFML: Ministry of Forests, Mines and Lands

MPB: Mountain Pine Beetle

PCIC: Pacific Climate Impacts Consortium

PGCF: Prince George Community Forest

PGTSA: Prince George Timber Supply Area

Introduction

Situated within the Rocky Mountain trench at the confluence of the Fraser and Nechako rivers in the central interior of British Columbia, Prince George is the largest city in northern British Columbia and is known as "BC's Northern Capital." Due to its central location in the province and its specific location at the crossroads of the east-west Highway 16 and the north-south Highway 97, Prince George is an important hub in BC and has an important economic and cultural role in BC's history. Prince George has become a centre for forestry and has a long history of forestry operations that continue to drive the local economy today. The city hosts 12 sawmills, three pulp mills and a growing bio-energy sector in a City of 77,000 residents (CPG, 2011).

Because of Prince George's unique setting, it is often referred to as a city within a forest (Figure 1). There are 20,000 ha of naturally forested land and over 1,500 ha of landscaped parks within the city limits, which is itself approximately 33,000 ha in size; these areas represent over 65% of the city's land(CPG, 2005). Forests and natural areas remain central to the social identity and well-being of Prince George residents. In Prince George's Integrated Community Sustainability Planning process, residents identified the city's "spectacular natural setting" as one of its greatest strengths (CPG, 2009).

Figure 1. Aerial view of a Prince George neighbourhood. (Source: PGCF, 2011)

Recently, the City of Prince George, in collaboration with other organizations, undertook a series of events and workshops with local stakeholders and community members to discuss the potential impacts of climate change that were of most concern for the area (Picketts et al., 2009a). Not surprisingly, the results of each event showed forests or forest fires to be the number one climate change adaptation priority of concern for participants. This document builds on this research by exploring forests and climate change in Prince George in more detail.

The vulnerabilities of forests and forestry to climate change have already been experienced in Prince George and throughout BC. Over the past century, Prince George and the region have experienced a rise in mean annual temperature of 1.3˚C (Picketts et al., 2009b). These warmer than average temperatures, especially warmer winter temperatures, in addition to a history of fire suppression that has increased the amount of mature lodgepole pine in forest stands, are often cited as the main contributing factors to the mountain pine beetle (MPB; *Dendroctonus ponderosae*) epidemic. The increased potential for wildfires in the region caused by the additional fuel load from the MPB-killed trees is a significant impact that is partially attributable to climate change (Figure 2). The wildfires in the summer of 2010 burned nearly 340,000 ha in BC and had several impacts on the central interior region where the vast amount of MPB-killed lodgepole pine exists.

Figure 2. Lodgepole pine trees killed by MPB in a Prince George resident's backyard. (Source: CPG, 2006)

Climate change models predict that temperatures in the region may increase by 1.6°C to 2.5°C by the 2050s (as compared to average temperatures from 1961 to 1990) (Picketts et al., 2009b). This increase will likely lead to an increased severity of forest impacts in Prince George and create more insecurity and instability of the future forest ecosystem. The MPB outbreak and recent major wildfires in the province have illustrated the need for Prince George to adapt to these impacts and other impacts that will occur regardless of any type of mitigation strategy. It is important for Prince George and other communities that rely heavily on the forestry sector to adapt to climate change impacts for the sake of community safety and to help maintain the social, economic, and ecological benefits that remain of their forests.

Adaptive actions can be either in response to a climate change impact (reactive) or they can be advanced measures to prepare for future impacts (proactive) (MOFR, 2006). This report will discuss some of the impacts of climate change for Prince George and will describe the City of Prince George's strategies for adaptation. These strategies include programs and management strategies as well as private, local and provincial initiatives. Explicit adaptation strategies (i.e. those that state climate change as a motivator) for Prince George's forested areas have been primarily focused on reducing the risk of wildfire from the increased fuel load caused by MPB (a reactive strategy) and the predictions of hotter,

drier summers and more extreme events for the region (a proactive strategy). The City has also been undertaking many management strategies, both reactive and proactive, that while not specifically identified as adaptation strategies nonetheless allow forests, parks, greenbelts and boulevard areas to be better prepared for the future climate. Selecting species that are more pest tolerant and planting species that traditionally grow in warmer and/or wetter climates are some examples of these strategies. These adaptive strategies may enable the City to minimize negative impacts of climate change, while allowing them to take advantage of some possible benefits of climate change.

The adaptation strategies outlined in this report can be used as guidelines for resource managers and decision-makers in communities similar to Prince George where forests are important to the livelihoods of residents. Although Prince George is ahead of many communities in the province and the country with respect to addressing the challenge of climate change impacts on forests, the city has a long and challenging road ahead. Future adaptation strategies must tackle the many social, economic, and environmental impacts that climate change will present to the community. This report therefore also makes recommendations for further climate change adaptation strategies for the City of Prince George to consider in its future policy and management. Lastly, it is important to note that the natural forest area comprises over 60% of the land base within Prince George's city limits. This feature makes management of the City's forests at times similar to management of a larger area, such as a Regional District. Therefore, when reading this document, managers and decision-makers should identify which management strategies and recommendations are appropriate to consider for their own community's natural forests and/or landscaped areas.

Climate Trends and Projections

Global climate has been shifting and changing throughout history and species and ecosystems have adapted to these changes. An overwhelming body of scientific evidence suggests that the current global warming trend is largely influenced by human activity that is likely to continue to accelerate at an unprecedented rate over a relatively short period of time. Over the past century (1918-2006) Prince George's mean annual temperature has warmed by 1.3°C and the mean annual minimum temperature has warmed even more, rising by 2.3°C, resulting in more precipitation falling as rain rather than snow in the winter months (Picketts et al., 2009b).

By the 2080s it is projected that without any mitigative measures to reduce carbon emissions, the province as a whole may warm by 3–5°C (MOFML 2010). Although this may not seem like a large change in temperature, the difference in average annual temperature between Kelowna in the hot, dry southern interior and Prince George in the cooler, continental climate of the central interior is only 3.7°C (Rodenhuis et al., 2009). In Prince George, temperatures are projected to increase by 2.2°C to 3.7°C by the 2080s and precipitation is projected to increase by 6–15%, primarily in winter with possible decreases in summer. These climate-modelling projections suggest that Prince George will continue to become less cold and that a greater percentage of precipitation will fall as rain rather than snow

(Picketts et al., 2009a). Along with regional changes in temperature and precipitation, there is a general understanding that we may experience a greater statistical variability in the future climate than we have in the past. This would mean an increase in extreme events such as thunderstorms, windstorms, hailstorms, intense precipitation events, drought, heat waves and abnormally warm winters, possibly by as early as 2030 (Williamson et al., 2009).

Climate Change Impacts on Forest Ecosystems

Climate change will impact forest ecosystems as changes in temperature, precipitation and extreme events will alter the structure, composition, functional/ecological processes and health of forests. Changes in the forest ecosystem will have varied social and economic impacts, especially for forestry-reliant communities. Climate change generally impacts forest ecosystems, and consequently forest-reliant communities, in three main ways (Williamson et al., 2007):

1. Climate change has biophysical impacts on the forest ecosystem
   (e.g. increased wildfires due to warmer and drier climate, increased pests, changes to hydrology, changes to species ranges).

2. Climate change impacts on the forest ecosystem can subsequently have direct social impacts on the community
   (e.g. visual quality, property values, and health and safety impacts of urban-interface wildfires and dead falling trees).

3. Climate change has impacts on the timber supply and thus impacts the local economy and global forest product markets
   (e.g. insecurity and loss of employment within the community).

These impacts are often interrelated and complex; one impact can often exacerbate another. For example, the additional fuel load resulting from the MPB-killed pine will increase the risk of wildfires in those areas, especially as these trees fall down and pile up at ground level where ignition commences. The following sections identify and explain some of the main impacts that are of concern for Prince George as a forest-reliant community. It should be noted, however, that this document does not fully cover the complexity of these impacts, only introducing them in the Prince George context under the following areas:

- pests
- wildfires
- forest hydrology

- species range
- economic and community impacts

Pests

Not many communities in BC have experienced the impacts of climate change quite like those in the central interior. The current MPB outbreak is like no other in recent history and has killed more than double the number of lodgepole pine trees compared to past outbreaks (Hrinkevich and Lewis, *in press*). The presence of large areas of mature lodgepole pine and the warming trend over the last century have allowed the MPB to survive during winter, greatly increasing its populations (Taylor et al. 2006). As of 2010 it is estimated that 17.5 million hectares of land have been impacted by MPB in British Columbia; MPB has killed 50% of BC's commercially important pine, reaching areas that have not been previously exposed to attack (Figure 3). To put this in perspective, this is an area twice the size of New Brunswick (Caroll, 2006; CFS, 2011). By the year 2014 the MPB is projected to kill approximately 77% of the mature lodgepole pine in BC (Walton et al. 2007). As lodgepole pine is the main tree species in the Prince George Timber Supply Area (PGTSA), the Prince George community, which lies within the PGTSA, has been severely impacted by the MPB epidemic (Williamson et al., 2008).

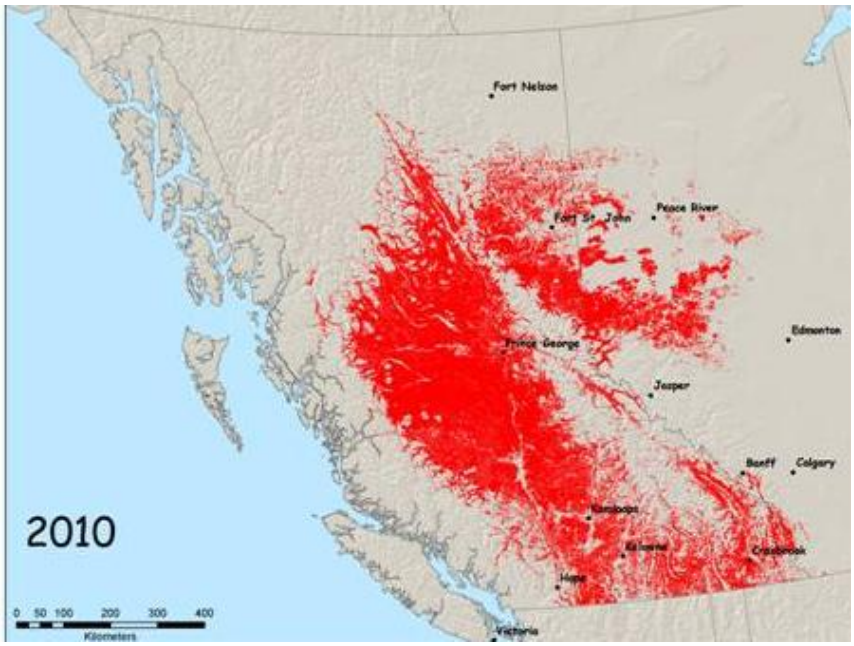


Figure 3. Cumulative range of the MPB epidemic in western Canada as of 2010. (Source: CFS, 2011)

Although the MPB is the most notable pest in Prince George and throughout the region, it is not the only forest pest that the city has dealt with in recent years. In 2006, Prince George lost a total of 39 black ash

(*Fraxinus nigra*) trees in a matter of six months to the cottony psyllid (*Psyllopsis discrepans*), an invasive insect that feeds on ash species causing curled or wilted ("cauliflowered") leaves and premature leaf drop in the summer (CPG, 2011). Prince George horticulturists and arborists cannot say whether climate change has influenced the outbreak of this pest in the city, but in Edmonton this pest has killed over 90% of the city's black ash trees and the outbreak there has been attributed to warming temperatures and drought stress that has made the trees more susceptible to infestations (City of Edmonton, 2010). Over the past decade, the Douglas-fir beetle (commonly referred to as the IBD; *Dendroctonus pseudotsugae*) has increased in numbers and spread northward into the Prince George region (MOFR, 2011a). IBD spreads by attacking trees that have been weakened by stress, such as drought, fire or other pest stresses and breed in trees that have been felled, by wind or fire for example (Bailey 2011). IBD is currently of concern for Prince George urban foresters, who feel that Douglas-fir trees in this region are drought stressed and are thus more at risk to IBD attack (L Phillips pers. comm., 2011). Although IBD infestations have historically been small in scale, the potential for increased felled trees due to extreme events (e.g. wildfires, storms) may allow for IBD to increase its range and populations and become more of a concern for Prince George foresters and for the region. Furthermore, climate change may influence the population and severity of other forest pests (discussed in detail in the *Species Range* section). If certain environments change and become inhospitable to some tree and plant species and these species cannot adapt quickly enough to the changed environment, their defenses will be weakened, leaving them more prone to attack by pests and diseases.

Wildfires

Climate change will influence the number and severity of wildfires within BC in a number of complex and interrelated ways. The climate projections for BC are in the direction of warmer, drier summers, thus increasing the risk of wildfires for many parts of the province. For example, between 2000 and 2003, southern BC experienced its driest three-year period on record. As a result, the 2003 fire season in BC proved to be one of the most destructive fire seasons ever with 2500 fire starts destroying 260,000 ha of forestland (Filmon, 2004). These fires had unprecedented social impacts, displacing over 30,000 people and destroying hundreds of homes and businesses (CPG, 2005). The increased incidence and severity of wildfires is a direct or primary impact of climate change on BC's forests.

Although the trends for warmer, drier summers are of greatest concern for the southern region of the province that already suffers from dry summers, the MPB epidemic has left an enormous amount of dead lodgepole pine within the central-interior forests. The dried needles of dead standing trees are known to dramatically increase the fuel load; as well, dead lodgepole pine trees that fell 3–15 years after the initial MPB attack also pose a wildfire threat. Bark and twigs from these dead trees can be carried to other areas of the forest, starting spot fires and further exacerbating the risk of wildfires (Stirling, 2007; Gabbert, 2011). The increase in the risk of wildfires in this region caused by MPB-killed trees is an example of an indirect or secondary impact of climate change on BC's forests. In the summer of 2010, nearly 340,000 ha of land in BC burned due to wildfires and greatly impacted the central-

interior region, in part due to the extra fuel load caused by the MPB-killed trees. These fires resulted in 11 evacuation orders and 16 evacuation alerts throughout the province and caused significant air quality problems in Prince George. The amount of forest burned more than quadrupled the provincial 10-year forest fire average, raising the awareness of the implications of climate change in BC (MOFR, 2011b). Discussed below, wildfires also create and exacerbate other climate change impacts on the forest ecosystem, further demonstrating how climate change impacts are complex and interrelated.

Forest Hydrology

As a city at the confluence of two major rivers, Prince George is subject to both spring and winter seasonal flooding and the health of the surrounding forests play a major role in the quality, quantity, and timing of hydrological flows. The increased incidence of wildfires due to climate change and other disturbances can have great impacts on forest hydrology. Severe burns or areas that have been salvage logged result in areas with dead and highly damaged trees that lose their ability to capture precipitation as quickly or effectively as they could prior to the disturbance. Even without wildfires or salvage logging, the standing lodgepole pine trees that have died due to MPB can no longer intercept precipitation with their needles and branches and can no longer absorb precipitation through their roots in the soil like a living tree does. Thus, a forest composed of primarily dead lodgepole pine is very similar to a disturbed forest in its ability to capture precipitation. The reduced precipitation interception by a burnt or MPB-killed forest decreases soil moisture, increases erosion, and increases surface runoff and the amount and rate of water entering local streams, rivers and lakes (Neary, 2004; Curran et al., 2006). For example, after the 2003 wildfires in the southern interior of BC, large-scale erosion and flooding events were more common in the region, with at least five major soil erosion and/or flooding events occurring related to these events (Curran et al., 2006).

The Forest Practices Board investigated the impacts of MPB salvage harvesting on stream flows within the Baker Creek watershed near Quesnel, BC (FPB, 2007). Baker Creek watershed is representative of the Prince George watershed, having plateau topography, low relief and mostly pine forests that have been impacted by MPB. Modelling techniques predict that peak flow changes following MPB attack could be dramatic depending on the management practices implemented. For example, the combination of normal tree harvesting practices with MPB-killed tree harvesting would result in a 60% increase in the peak stream flows and increase normal 1:20-year peak flow events to 1:3-year peak flow events. An increase in peak flow events could cause damage to river channels, destabilize slopes, and alter the soil conditions needed for reforestation (MOFR, 2009).

If forest managers within a community were to leave MPB-killed pine (called grey-attack) standing, although less than an alive tree, these trees would continue to hold some snow and provide shade, reducing the rate of snow melt in the spring. As a result, the annual peak flows in the stream would be delayed and the changes less significant than if these trees were salvage harvested (FPB, 2007). Not harvesting, however, leaves these grey-attack stands vulnerable to fire, which would have a similar

hydrological impact as harvesting. Furthermore, there may be an additional water quality impact if silt and nutrients are washed from the burned soil into the watershed.

The choice for forest managers to remove or leave MPB-killed trees within the forest stand is complex. It is up to forest managers to weigh the costs and benefits to salvage harvest these trees while meeting all economic, social, and environmental considerations. The Province has been salvage harvesting MPB-killed trees since the onset of the MPB epidemic in the mid 1990s (BC Parks, 2011) and has made several recommendations to address the additional hydrological concerns of these operations (see *Recommendations* for examples). However, the extent and rate of the salvaging is also an important factor to consider, and may not necessitate additional measures already in place under normal harvesting operations. Prince George harvesting operations are relatively low impact and small scale in comparison to MPB timber harvesting occurring throughout the PGTSA and the rest of the central-interior region (see *Wildfire Management Strategies*) and operations in Prince George have adhered to all government regulations relating to water, fish, and riparian areas (CPG, 2006a).

Species Range

The suitability of tree species in Prince George and across BC will be influenced by a changing climate. The changes will lead to landscape composition shifts, making the future forest environment suitable for new species of trees and other understory plants, altering species' natural ranges (Hamann and Wang, 2006). With milder, warmer temperatures, tree species will start to migrate northward and Prince George may start to see species that have historically not been suitable for this northern latitude (Iverson and Prasad, 2002). This may provide new opportunities for the forestry industry if the ranges of commercial species, such as interior Douglas-fir, migrate northward as predicted (Figure 4; Murdock and Flower, 2009). In addition, warmer temperatures may result in more frost-free days, warmer soils, and many plants breaking bud earlier in the spring thus allowing for a longer growing season and increased productivity for the region (Rehfeldt et al. 1999, 2001).

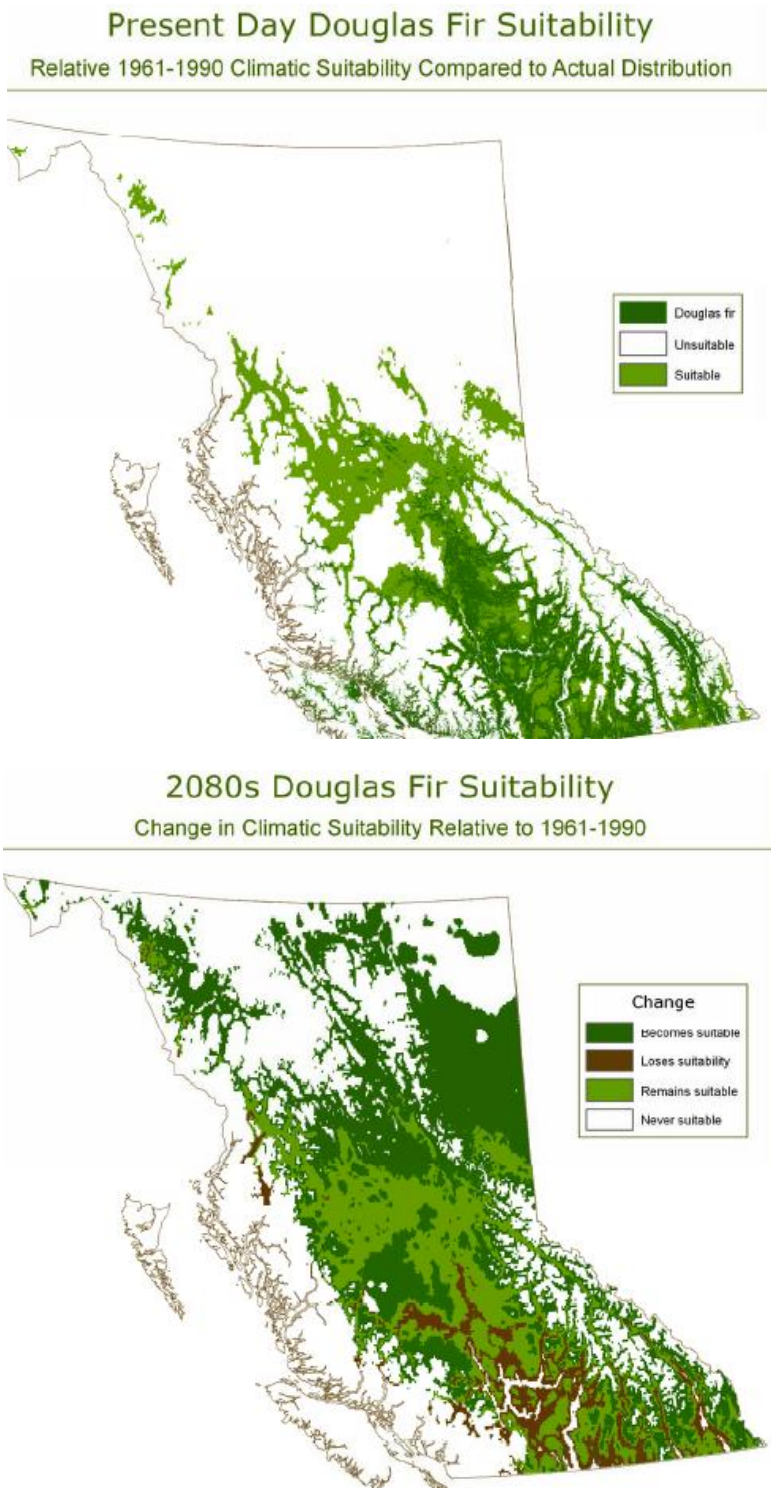


Figure 4. Current suitability of Douglas-fir in BC (upper image) and the projected suitability in the 2080s. (lower image) (Source: Flower and Murdock, 2009) Douglas-fir may become more suitable in the Prince George region due to climate change.

Although some of these changes may seem positive, forests and their associated organisms that constitute a functioning ecosystem may not adapt and migrate as quickly as the climate changes. Tree species can naturally migrate at about 100 m per year, but the current climate change predictions would require species to migrate several thousand metres per year to keep up with surrounding environmental conditions (Cullington et al., 2008). New environments will lead to new competition with other species. Predictions of warmer summer temperatures and possible decreases in summer precipitation for the region (Rodenhuis et al., 2009), may increase evaporation rates and decrease soil moisture, stressing trees and providing opportunities for more drought-tolerant species. Increases in extreme events may lead to increases in disturbed sites, which are ideal for invasive plant species. The pace of climate change may therefore result in species becoming ill suited for their environment, reducing the health and productivity of the forest ecosystem (Spittlehouse, 2008). The reduced health of forest ecosystems will allow pests and diseases to more easily attack these ill-suited species, further exacerbating climate change impacts.

Economic and Community Impacts

The forest industry accounts for 28% of the local income for Prince George (Horne, 2009), representing 22.1% of the total revenue for the region 6.1% of the province's total revenue (Patriquin et al., 2005). Although Prince George's economy has become more dependent on the service sector over the last decade (Statcan, 2006), forestry in the region is still an important economic sector for the residents of Prince George. Consequently, impacts such as the MPB epidemic and large wildfires throughout the region have dramatically affected the economic security of Prince George.

The PGTSA covers 7.5 million ha of land and encompasses three main communities (Prince George, Vanderhoof, and Fort St. James) and several other smaller communities within Northern BC (MOFR, 2008). From the mid-1990s to 2004, the Annual Allowable Cut (AAC) in the PGTSA increased from 9.4 million cubic metres/year to 14.9 million cubic metres/year to encourage salvage harvesting of MPB-affected timber. The AAC is determined by the Province based on multiple factors such as the long-term timber supply and socioeconomic considerations to ensure that the forests are managed sustainably (Williamson et al. 2008). Although an increased AAC may boost the forest economy temporarily, climate change has increased the instability in the local resource supply and will lead to large fluctuations in the AAC over the coming decades (Williamson et al., 2008). Currently, the AAC is still higher than pre-MPB epidemic levels at 12.5 million cubic metres/year (MOFML, 2011). However, by 2015 the Province predicts that the AAC will be reduced again to 7.9 cubic metres/year due to a decrease in the mid-term timber supply and the fact that much of the MPB-killed timber will become non-salvageable and too decayed to be made into profitable products (Figure 5). In the longer term, climate change may influence an increase in the timber supply if growing seasons become longer and MPB-affected trees have regenerated. However, future forest pests and other disturbances (e.g. wildfires and extreme

events) exacerbated by the changing climate increase the insecurity in the timber supply, putting communities like Prince George at risk (Williamson et al., 2008). As one of the least economically diversified regions of the province, the central-interior of BC is highly vulnerable to climate changes in the forest sector (Horne, 2009).

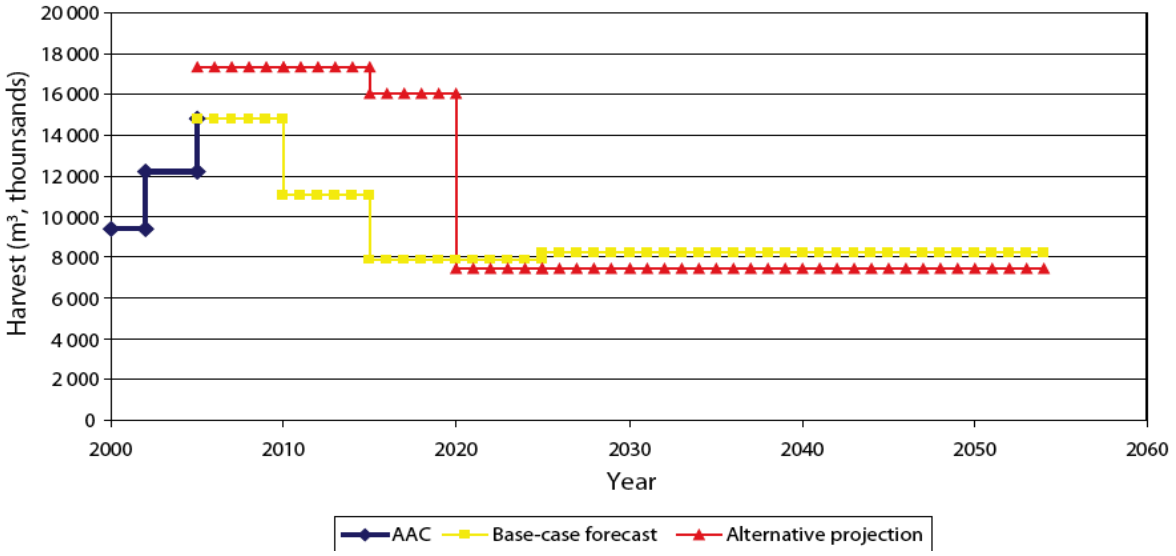


Figure 5. The increase in the annual allowable cut (AAC) from 2000 to 2004 (blue) and simulations of future harvesting amounts for the Prince George Timber Supply Area from 2004 to 2055 (red and yellow). (Source: Williamson et al., 2008) As of 2011, the AAC is similar to the base-case forecast (yellow), showing how future harvesting rates will drop again between 2010 and 2020.

The standing MPB-killed trees also pose a huge safety concern for local residents in terms of the danger of falling trees and increased fuel load for wildfires. Douglas-fir plays an important role in maintaining slope stability in many steep and sensitive slope areas within the city (L. Phillips, pers. comm., 2011). If an outbreak of the Douglas-fir beetle were to occur in the region, this would have huge implications for the stability of certain slopes and thus the safety of infrastructure and residences in close proximity to these areas. An increase in wildfires, as projected, will impose heavy costs on the region and Prince George, including reduction of timber supply, property damage, mobilization of wildfire crews and equipment, evacuation of residents and work stoppages for industries operating in forest lands in addition to potential impacts to the local health care system due to health impacts of wildfire smoke. For instance, the total cost of BC's 2003 wildfire season has been estimated at $700 million (Filmon, 2004). Furthermore, both wildfires and the MPB infestation have impacts on the tourism industry due to wildfire smoke, unsightly fire damage, and vast areas of dead, MPB-affected stands or clearcut areas due to MPB salvage harvesting (Ni and Lavoie, 2003).

Prince George's forests are of high importance socially, playing an integral part in the identity and unity of the community. Forests are important for recreational activities and have aesthetic value. As a result

of the MPB epidemic, the landscape within Prince George has been noticeably altered from one of healthy pine stands into almost prairie-like landscape in some areas (CPG, 2008). Thousands of MPB-affected pine trees have been removed from city parks and two golf courses that lie within the city limits have been devastated by the MPB, resulting in huge economic and social impacts for community members (Figure 6).

Figure 6. Images Prince George golf courses dominated by lodgepole pine trees before the MPB epidemic (left) and during the epidemic in 2005 (right). The majority of the dead pine trees have now been removed from the golf courses. (source: CPG, 2011)

Adaptation Strategies in Prince George

Over the last decade, the City of Prince George has been adapting (both reactively and proactively) to the impacts of climate change on its forests, incorporating adaptation into forest management and operations. Prince George is particularly vulnerable to climate change impacts on forest ecosystems due to the abundance of forested areas (both natural forests and landscaped areas) within and surrounding its municipal boundary. Natural forest areas are areas that have been preserved as natural habitat and functioning ecosystems. This unique feature makes Prince George literally a city within a forest. Although managed by separate City divisions, the natural and landscaped forest areas are together known as the "Urban Forest" (Table 1). Both management divisions have begun to respond to climate change, and in some cases have developed explicit strategies to prepare for future changes in natural and landscaped forest areas.

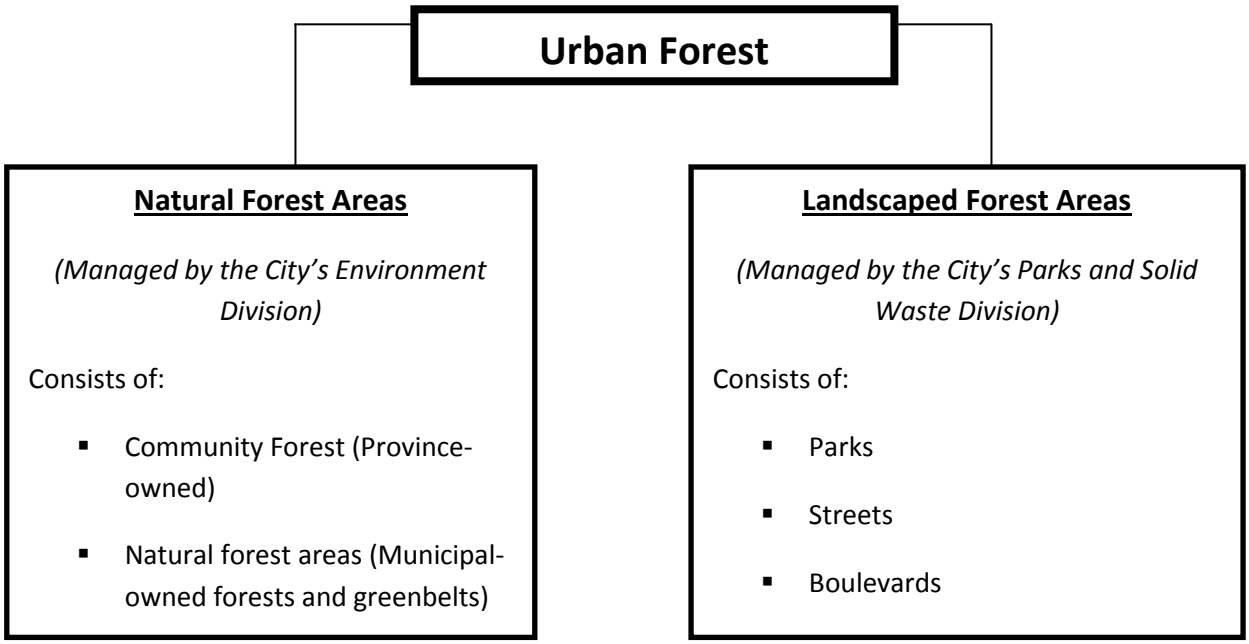
The presence of the MPB has been the most noticeable impact of climate change for Prince George, and over the last decade the City has been actively responding to the infestation. With the additional fuel load caused by the MPB-killed lodgepole pine trees, wildfire management is noted as a main adaptation strategy. Climate change adaptation strategies include:

- Development of Community Wildfire Protection Plan
- Fuel Management Program in Natural Forest Areas (Community and Municipal Forest)

- Community Forest Future Opportunities

Climate change adaptation is not an explicit part of the management of City-owned parks, streets, and boulevard areas, but it has been implicitly incorporated in their management. Planting program incentives and species selection guidelines are some of the strategies that the City has adopted that allow them to adapt to potential climate change impacts on their landscaped areas. Investment in bio-energy for the community as a whole is another step that is being taken by the City to diversity the local economy and adapt to potential impacts of climate change on the local forests. Within the following subsections, each of the above-mentioned strategies and management is described from an adaptation perspective.

Table 1. City of Prince George urban forest structure.



Wildfire Management Strategies

The MPB epidemic has left an enormous amount of dead lodgepole pine standing within the forests of the central-interior region, including over 1.3 million cubic metres of vulnerable forest within the municipal boundary of the City of Prince George. The MPB-affected pine and other forest types that possess characteristics that lead to high or very high fire hazards are of particular importance to Prince George as the risk of urban-interface fires (e.g. fires that occur at the boundary between residential areas and wildfires) threaten the safety and security of the community. In attempts to both slow down the spread of the MPB and to proactively manage forests for the increased risk of wildfire, the City has

been actively harvesting MPB-affected pine and other high-fire-hazard fuels within the city limits. This section outlines the specific forest management and strategies that the City has undertaken to ensure the safety and security of the community while also providing for the future health of the natural forest areas within the municipal boundary.

Development of a Community Wildfire Protection Plan (CWPP)

In 1994, the City of Prince George started removing MPB-killed and infected trees within the municipal boundary in an attempt to slow down the spread of the MPB and to reduce the risk of wildfire caused by the increased fuel load; however, over the following decade the fuel load continued to increase. In 2005, Prince George prepared a community wildfire protection plan (CWPP) that laid out comprehensive strategies and specific tools to reduce the long-term wildfire hazard for the city and was one of the first communities in BC to draft such a plan. Some broad strategies that were highlighted in the plan include:

- public education on how to reduce wildfire hazards on private residents' properties
- implement FireSmart guidelines for new developments in interface areas
- identification of "very high," "high," and "moderate" fire hazard areas, prioritized for treatment

More than 70% of the land within Prince George is privately owned and the City has been very active with educating residents and private developers about the risks of wildfires (Table 2). As part of this initiative, the City has embraced the provincial FireSmart program, which was created to increase public awareness of wildfire prevention measures to reduce the risk of wildfires spreading to private property. Prince George's urban foresters have been proactive in their educational outreach by broadcasting FireSmart safety tips for residents over the radio and hosting workshops and giving public presentations essential to engage and educate private landowners of the wildfire risks on their properties.

In 2007 and 2008, the City of Prince George and Service Canada conducted a mountain pine beetle tree-debris-removal assistance program for residents with MPB-killed or infected trees on their property. This program hauled cut trees off of residents' properties free of charge, thereby reducing the costs of tree removal on private land and reducing the fire hazard associated with the dead trees and tree debris on private land within the city. It should be noted that the City's ability to reduce the risk of wildfires on private land is limited by the willingness and understanding of property owners to implement these initiatives. on how reduce the risk and intensity of future fires on private property (Figure 7). These initiatives are essential to engage and educate private landowners of the wildfire risks on their properties.

Table 2. Land ownership classification by area of land in the City of Prince George. (source: CPG, 2006b).

Classification	Area (hectares)
Other	3,145
Private	22,605
Municipal	1,077
Crown	5,443
Total	**32,270**

For the safety of the community, the City has identified several wildfire-interface development permit areas (WIDPA) within the municipal boundary using GIS mapping. These are areas that would require a permit for development with specific guidelines related to reducing wildfire risks. However, these areas need to be refined using more on-the-ground assessments to ensure they are in fact deserving of wildfire-interface development area permits. The City is in the process of developing specific permitting guidelines related to reducing the risk of interface fires for developers wanting to develop on these WIDPAs. However, the general understanding of the fuel loading potential and wildfire behaviour is not a common skill for professional foresters, resulting in some challenges when delineating these development permit areas and defining permit guidelines.

From 2001 to 2007, the City salvage harvested the equivalent of 733 logging truck loads of MPB-affected lodgepole pine within the city limits (D. Adamson, pers.comm. 2011). Although the City was working hard to remove these trees, the extra fuel load was not being removed at a fast enough rate and needed a more strategic plan for addressing the growing wildfire concern for the community. Outlined within the Prince George CWPP are several areas within the municipal boundary that are considered high fire hazard areas recommended for prioritized treatment. By focusing efforts on these high fire hazard areas, the City intended to better address the risks of forest fires within the city limits. The areas that were considered of highest concern for wildfire risk were natural forest areas owned by the provincial government (i.e. Crown land), by the City (i.e. municipal land), and privately owned land. Although the City has the capability to manage its own natural forest areas for wildfire protection, a significant proportion of these natural forest areas are on Crown land within the municipal boundary (CPG 2008), which the City traditionally has no authority to manage (MFLNRO 2011).

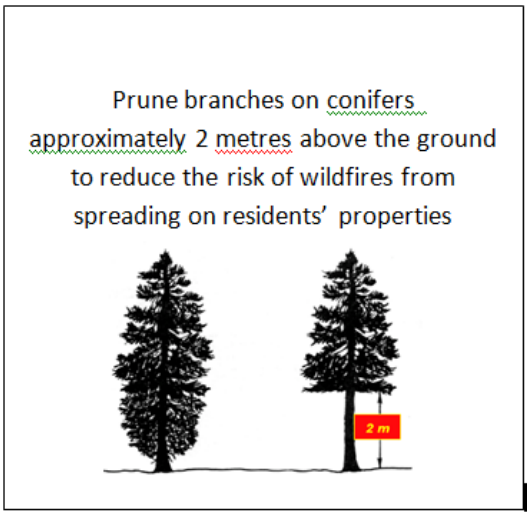


Figure 7. Example of a City of Prince George FireSmart Recommendation for Residents. (source: Gilday, 2011).

Fuel Management Program in Natural Forest Areas

At the same time the Prince George CWPP was being created, the Province invited the City to apply for a probationary Community Forest Agreement (CFA) license. In British Columbia, the community forest program was developed with the intention of local governments, community groups, or First Nations being able to manage their own forests to meet their own defined objectives. The provincial government's objectives for community forests were to "provide long-term opportunities for achieving a range of community objectives, including employment, forest-related education and skills training and other social, environmental and economic benefits" (MNP and Enfor Consultants, 2006). For the City of Prince George, a CFA would allow the City to integrate the management of the 3,800 ha of natural forest areas on Crown land within the city boundary (CPG, 2010) with the 873 ha of municipally owned natural forest areas already managed by the City (CPG, 2006b).

In 2005, it was estimated that there were at least 60,000 cubic metres of dead pine on Crown land to remove in Prince George (PGCF, 2011). After consultations with the Regional District, the Province, the Lheidli T'enneh Nation and other stakeholders, the City applied for a 5-year probationary CFA, which was successfully received in 2006. The Prince George CFA was developed and has three main objectives:

1. Managing fire hazards in and around the city
2. Managing the impacts of MPB on the natural forest
3. Supporting the City's Official Community Plan, which emphasizes "improving safety and security in the city" as part of its mission to improve quality of life for residents

The Prince George CFA is unique because the forested area is dispersed throughout the municipality, as opposed to being outside of the municipal boundary as most CFAs are (Figure 9a; PGCF 2011). The Prince George CFA management plan is also unique in that it has been designed with the specific short-term management goal of fire suppression instead of financially sustainability (which is the goal for nearly all other community forests). As it is structured today, the management plan is not economically sustainable and is in need of restructuring for community forest operations to continue. Due to the low commercial value of the salvaged trees, the less-destructive equipment used, and the added cost to clean up the debris and restore the salvaged areas, any revenue received from the sale of the harvested trees to local sawmills is used to reduce the cost of the program and no profit is made by the City.

The community forest operation began in 2007 with the City hiring local contractors to perform fuel treatments and remove dead trees, mainly pine, that pose a fire hazard within the community forest and in other municipally owned, naturally forested land (PGCF 2011). Thinning, selective patch cutting, pruning and understory removal operations have been occurring in the priority treatment areas outlined in the CWPP document. These priority treatment areas are prioritized based on the risk of wildfires occurring in these areas and the risk of wildfires damaging community infrastructure (such as residences, buildings, and other infrastructure).

Figure 8. The City creatively used wood chips from removed trees to surface forest recreational trails. (source: CPG 2011).

To minimize the impacts to recreational areas, the City has been proactively working with community organizations, such as the Prince George Bike Club, the Caledonia Nordic Ski Club, and the Cranbrook Hill Greenway Society, that each regularly use the community forest areas for recreation. In one recreational forest area, several walking trails were severely damaged during removal operations. However, crews began almost immediately to repair the damage to the trails, allowing the community forest to continue to be used as a recreational area by the community (Figure 8).

Within the last five years, the City has harvested over 21,030 cubic metres of MPB-affected lodgepole pine and other high-fire-hazard fuel types within the Prince George Community Forest. These treatment operations have reduced the fire hazard from high-very high to low-moderate in several areas of the community forest (L. Phillips, pers. comm., 2011). The consultants Needoba and Blackwell (2009; p. 3) assessed the effectiveness of the tree removal operations, and indicated the following:

> *The current fuel treatment program is effectively reducing the fuel hazards identified in the CWPP and is mitigating the risk of fire traveling out of, or into, the treated areas as well as reducing the risk of hazardous fire behaviour within these areas.*

Although this license has been effective at reducing the risk of wildfires within the municipal boundary, it does not address areas outside the municipal boundary that are deemed high-wildfire-hazard areas. Without managing these areas outside the city limits, Prince George is still vulnerable to wildfires, in spite of their current efforts to reduce this risk (Needoba and Blackwell, 2009).

Community Forest Future Opportunities

The current smaller scale, municipal-bound community forest agreement, focusing on dead pine and removal of forest fuels, was never intended to be economically sustainable and is primarily dependent on City and other government funding for operations to continue. More importantly, this community forest agreement "does not address the arguably greater risk to the City and surrounding rural residents posed by a landscape-level fire event causing an ember shower from a distant fire to rain down on the City" (Needoba and Blackwell, 2009). With this in mind, the City, with its partners the Lheidli T'enneh First Nation and the Regional District of Fraser-Fort George, have been looking at a concept for expanding the CFA to incorporate parcels of land around Prince George that are set aside for agriculture development. By working with the agriculture sector, a community forest could play a role in supporting the conversion of fire-prone forests to agricultural land and assisting with the costs of agriculture conversion (stumping, burning, discing, root raking, etc.). This concept has the potential to add an additional 38,000 ha to the current community forest area of 3,800 hectares (Figure. 9a, b) (CPG, 2010).

This is a complex integrated land use concept and would require a number of management factors to be put into place. Management that protects and supports the original intent for the agriculture development areas, factors in the wildfire hazard reduction objectives, ensures the community forest operations are to high standards, and provides broad community benefits.

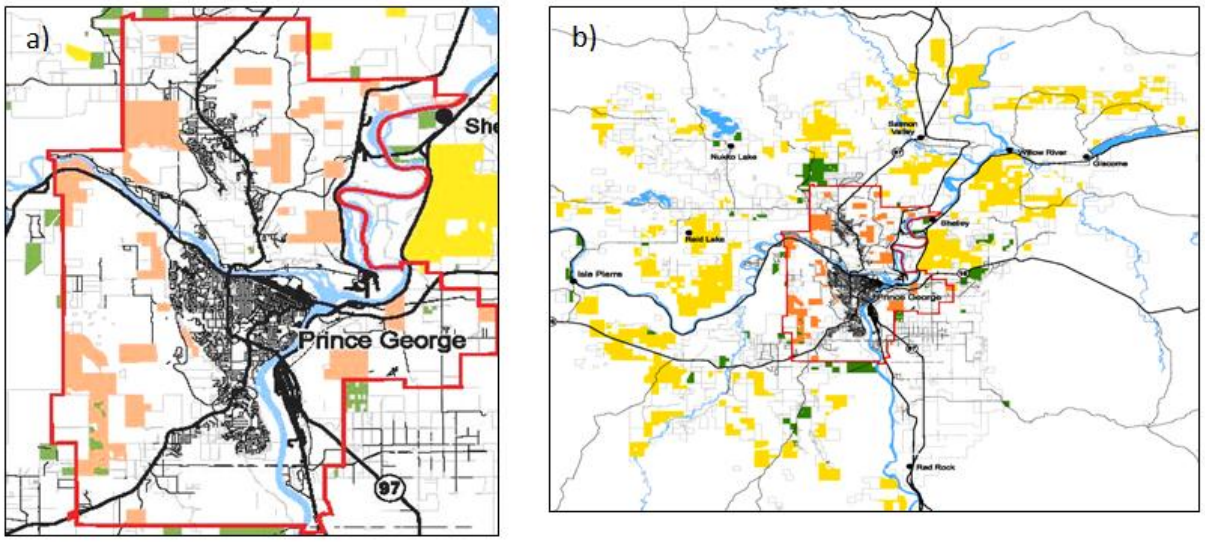


Figure 9. Maps of the (a) current Prince George community forest (highlighted in pink) within the Prince George municipal boundary, and (b) the potential expanded community forest concept (currently under discussion and review), which includes the which includes the current community forest in addition to Agriculture Development Areas (highlighted in yellow) and Settlement Reserve Areas (highlighted in green) outside the municipal boundary. (source: PGCF, 2011)

One concept that has been discussed is the potential for an agroforestry operation such as a Christmas tree farm interspersed with rangeland and berry production crops (Figure 10) (CPG, 2010). Other options for fuel treatment operations within the proposed expanded community forest could be:

- Removing and replacing MPB-killed lodgepole pine with hybrid poplar or willow species, to be utilized as fibre material for bio-energy markets
- Harvesting trees and “stumping” to create opportunities for crops
- Allowing the natural conversion to deciduous species and encouraging conversion of coniferous stands to deciduous or mixed stands
- Patch cutting to reduce the fire hazard and to retain shelter belts, range barriers, and calving grounds

Figure 10. Depictions of agroforestry operation concepts for the proposed expanded Prince George community forest featuring: a rangeland and native Christmas tree operation (left); and a timber and non-timber (i.e. berry) harvesting operation (right). (Source: AIDI, 2011)

The partners are continuing their discussions with the agriculture sector, farmers, stakeholders, and provincial staff to develop aspects of the potential management model and determine the level of support and the pros and cons of this concept. Currently, the City is organizing public consultations and workshops with key stakeholders (local farmers, agricultural institutes, First Nations) to discuss the feasibility and benefits of developing these lands for agricultural purposes.

Although forestry is a dominant sector of the local economy, the impacts of the MPB emphasize the need for the community to become less reliant on the potentially unstable forestry sector and/or diversify this sector to reduce the community's risk of further climate change impacts. At the peak of the MPB outbreak, the Omineca Beetle Action Coalition (OBAC) was formed by local governments (including the City of Prince George) with Federal Mountain Pine Beetle Recovery funding. This coalition spans the Omineca region of BC from Valemount in the east, west to Smithers. OBAC's primary mandate is to build a diversification plan for the region's communities that are highly dependent on the forest industry. One of OBAC's main strategies is to take advantage of a high potential for more agroforestry development within the region, combining forested land with other crop/livestock production (OBAC, 2009). Within the Prince George area, there are opportunities in the range industry due to the availability of relatively low-cost rangeland.

Furthermore, although there are many negative impacts associated with climate change within the region, one possible benefit is a potential increase in agricultural development due to increased growing

seasons. A region's growing degree-days are used as an agricultural indicator of when or if crops will reach maturity in a season. For Prince George and the surrounding region, the annual total growing degree-days have historically ranged from 1000 to 1500 for 1961-1990, whereas projections expect the growing degree-days to increase to 1500 to 2000 in the valley areas surrounding Prince George by the 2050s. This climate change impact may increase opportunities for heartier and more diverse crops, such as canola, which has historically not been able to grow to maturity in the region, as well as increased yields in existing crops (NDAWN, 2007).

Opportunities in Bio-Energy

In the wake of the MPB epidemic, communities like Prince George are extremely vulnerable to threats to forest ecosystems, shifts in timber supplies, and changing forestry markets. Climate change will continue to cause uncertainty in timber supplies and the forest industry, and Prince George must diversify the forest sector and its economy in general. The use of wood biomass to produce energy and bio-products represents a significant opportunity in BC and is a means of adding value to the abundance of underutilized wood waste from the forestry industry (sawmill residues, logging debris, MPB-killed wood, etc.). In addition to the wood waste left after logging operations (FPB, 2010), the MPB epidemic has added to the amount of wood for bio-energy purposes, as many of these trees are dying at a faster rate than they can be salvaged for use in traditional forest products (Stennes and McBeath, 2006). Investing in bio-energy will allow Prince George to benefit from the surplus of timber and increased AAC within the province, while investing in cleaner, carbon-neutral energy to mitigate further climate change impacts.

At the University of Northern British Columbia (UNBC) in Prince George, the campus currently has two bio-energy operations. One bio-energy project uses wood pellets from a local pellet producer to heat the enhanced forestry lab and another larger plant extracts clean-burning gas from wood waste to supply 85% of campus heating needs (Figure 11; UNBC, 2011). Recently, UNBC was recognized for leadership in bio-energy, winning a 2010 AASHE (Association for the Advancement of Sustainability in Higher Education) Award for Best Campus Sustainability Project in North America (UNBC, 2011). Although the increased amount of timber from the MPB epidemic is a key underpinning of the increase in bio-energy projects in BC and the central interior, the wood waste received for energy generation at UNBC accounts for only 5% of the total wood waste produced by the local sawmill, not including MPB-affected timber (D. Claus, pers. comm., 2011).

Figure 11. Wood waste used as fuel (left) for the bio-energy plant at UNBC (right), which extracts clean-burning gas from a local sawmill's wood waste to supply 85% of campus heating. (source: UNBC 2011)

With 12 sawmills in the city, Prince George has access to an abundance of cheap potential energy sources in the form of sawdust and other wood waste. One locally owned sawmill in Prince George currently burns its wood waste to heat its own facility. The City of Prince George has taken advantage of this system and has recently begun construction for a Downtown District Energy System that will utilize the excess heat not captured in this system to provide heat and hot water to several downtown buildings. The City is also modifying the existing facility by installing an electrostatic precipitator, which will capture much of the particulate matter and minimize impacts to the City's air quality (CPG 2011). Furthermore, the concept of an expanded community forest could include planting some areas with hybrid poplar or willow species as one option for fibre material to be used for bio-energy (Figure 12). These areas would only be developed for this use where it was deemed acceptable and compatible with future potential agricultural uses for specific sites. This potential opportunity would allow the city to contribute to the area's bio-energy supply, increasing the future security of this market and benefiting the local economy.

By investing in bio-energy, the community is investing in the diversification of their local economy while ensuring the security of the forest sector, and thus future bio-energy supplies. Even after the MPB-affected timber is reduced and no longer salvageable, Prince George is positioned to benefit from investment in bio-energy because of the diversity of the timber supply used for bio-energy products and due to the already existing facilities, technologies, and partnerships that have developed within the community.

Figure 12. A plantation growing willows for biomass. (source Maine Organic Farmers and Gardeners Association, 2011)

Management of Landscaped Areas

Prince George is unique in that there is an abundance of natural intact forest ecosystems within the municipal boundary (Fig. 9a). Like most communities, Prince George also has standard landscaped areas that are not managed as part of the natural forest areas. These areas include landscaped parks, as well as trees and plants along streets and boulevards, all of which provide ecological, recreational, and economic value to the community. Climate change may also impact these areas and could affect the health and viability of the trees and plants of these landscaped areas. Potential impacts include increases in pest infestations, disease, invasive species, and extreme events. City horticulturists and arborists within the Parks and Solid Waste Management Division manage these landscaped areas and have already implemented programs and strategies that align with climate change adaptation. Although climate change adaptation is not an explicit strategy in Prince George's management of these landscaped areas, it has been implicitly incorporated through several planting programs, policies, and management practices, described within this section.

As a result of the MPB infestation, Prince George has had to deal with large numbers of dead standing pine trees throughout its parks, streets and boulevards. Not only do these trees pose a considerable fire and safety hazard for residents, the aesthetic and recreational purposes of these areas, which were once dominated by pine trees, have been significantly impacted (Figure 6). Over the last decade, the City has removed several thousand MPB-killed pine trees throughout such landscaped areas. Replanting initiatives have been focused on neighborhood parks and areas that are most visible to residents (Figure13). However, City staff have been actively applying for grants and other funding opportunities to diversify the species and areas planted. For example, in 2009, the City received $50,000 in funds from the Trees for Tomorrow grant, allowing it to replant areas with a wider variety of species (L. Ward, pers. comm. 2011).

Figure 13. City residents volunteer to plant trees within parks areas where MPB-killed pine has been removed. (source: CPG, 2006)

Key species outbreaks, such as the MPB and the cottony psyllid (see *Pests*), gave the City more incentive to be proactive in its planting decisions. As a result, the City has implemented the following planting programs

- **Memorial Tree Program**: A program offered to residents where they can purchase trees to be planted in memory of loved ones at Memorial Cemetery in Prince George. The City provides a list of recommended trees that will survive best and what the City is in most need of (e.g. deciduous and pest-tolerant species).
- **Adopt a Tree Program**: Citizens can pay to "adopt" a tree to be planted on City property (mostly along boulevards and parks). According to City horticulturists and arborists, this program has not been overly successful and could be restructured to increase community incentive.

Prince George has also created guides for residents and developers to use when deciding on which species to plant on private properties within Prince George. These guides recommend a variety of species, most of which are highly pest-tolerant and deciduous, as the City felt the need for more deciduous trees in the community after the devastation of the lodgepole pine trees. Deciduous trees improve air quality, sequester carbon, and have higher fire resistance compared to coniferous species.

This demonstrating how the City is implicitly incorporating both mitigation and adaptation into landscaped forest areas management and planning.[1]

According to Rehfeldt et al. (2004), given that species will be unable to keep pace with climate change through migration, selection, and gene flows, human intervention in the form of redistributing genotypes to ensure that there is a match between genotypes and the climate for which they are best suited is a possible adaptation strategy. Due to the uncertainty surrounding climate change, planting and monitoring the health of a diverse array of species that could be suitable for a multitude of future climate scenarios may give managers insight into what works best for a given environment (Cullington and Gye, 2010). The more recent trends of less cold winters in Prince George have enabled the City to successfully plant different species such as *Gingko biloba* that would normally grow in warmer climates (Figure 14). Table 3 lists some of the tree species that have been experimentally planted in Prince George or that the City recommends to plant.

Figure 14. A Gingko biloba tree planted outside of Prince George City Hall.

In order to monitor the health of the species, over the last five years the City has been creating inventories of the species planted, documenting their location, name, health, age, size (DBH) and general condition at the time of inventory. Each species planted is input into a GPS unit and is then added into a tree inventory database, accessed through Prince George's electronic mapping system[2] . Continuous monitoring occurs for those species that are in need of pruning and information on the

[1] The City of Prince George recommended species lists can be found at: http://princegeorge.ca/environment/urbanforestry/trees/treeplanting/Pages/Default.aspx.

[2] PG Map is available at: http://princegeorge.ca/cityservices/online/pgmap/Pages/Default.aspx

health of the tree at the time of pruning is updated in the tree inventory database. These measures will ensure that health or pest problems do not go unnoticed, reducing the chance of severe pest outbreaks. The City of Prince George's current management practices of increasing species diversity, planting more pest-tolerant and deciduous trees, and continuous monitoring of the species planted are all adaptation strategies which will help to reduce risks from an uncertain future climate for on its landscaped areas (Cullington and Gye 2010).

Table 4. Tree species that have been planted or are recommended for planting by City of Prince George.

Tree Species	Rationale for Planting and Recommendation (CPG 2008)	Additional Adaptation and Mitigation Co-Benefits			
		Carbon storage (s: summer, w: winter)	Higher fire resistance	Shade for snow pack	Increase species diversity
Brandon elm (*Ulmus americana*)	Adaptable and very tolerant of multiple environments and urban areas	√ (s)	√		
Amur maackia *(Maackia amurensis)*	Low maintenance and adaptable; virtually pest-free	√ (s)	√		
Bur oak *(Quercus macrocarpa)*	Extremely tolerant in urban areas; very hardy; native species	√ (s)	√		
Balsam fir (*Abies balsamea*)	Generally insect/pest-free	√ (w)		√	
Ironwood *(Ostrya virginiana)*	Experimental: testing for hardiness; low maintenance and adaptable	√ (s)	√		√
Japanese tree lilac *(Syringa reticulata)*	Tolerant tree for urban areas	√ (s)	√		√
Gingko biloba *(Gingko biloba)*	Experimental: Traditionally lower latitude and wetter environment; pest/disease tolerant	√ (s)	√		√
Sugar maple (*Acer saccharum*)	Experimental: Traditionally lower latitude and wetter environment; pest-tolerant	√ (s)	√		√

Recommendations

There is a huge number of potential initiatives to create new plans or explicitly incorporate climate change into existing plans. Climate change will have widespread impacts on natural and landscaped forest areas within the City, as well as unique impacts in certain areas. Therefore, some of the following recommendations are applicable to both natural and landscaped areas, whereas other recommendations are directed specifically towards managers of only natural or landscaped areas. Table 5 outlines the recommendations for adaptation of natural and forested areas in Prince George:

Table 5. Recommendations for further climate change adaptation strategies for the City of Prince George's Natural and Landscaped Forest Areas.

Forest Type		Type of Adaptation Strategy	Description of Strategy	Example(s) of Strategy
Natural	Landscaped			
√	√	Outreach	Communicate the principles of climate change, impacts and adaptation to the public and specifically to the City staff involved in the Prince George wildfire management and education activities.	▪ Consider partnering with local post-secondary educational institutions to educate students (eg. natural resource management students) on the impacts of climate change to Prince George's forests and how management has been adapted to these impacts. ▪ Have future climate projections incorporated into the emergency response and environmental division operations planning process and the FireSmart educational workshops/sessions for residents.
√	√	Manage-ment	Allow for more interaction and communication between the City's Environmental Services Division that manages the natural forest and the City's Parks and Solid Waste Management Division that manages the landscaped parks, boulevards and streets.	▪ Consider the creation of an Urban Forest Committee to discuss issues and management to create plans that align with both the natural and landscaped forest areas. Members from the Parks and Solid Waste Management Department, for example, may be able to inform the Environmental Services Department on the success of specific trees planted in the City. This information may be useful for future planting operations if the proposed expanded community forest license is approved.

Forest Type		Type of Adaptation Strategy	Description of Strategy	Example(s) of Strategy
Natural	Landscaped			
√	√	Manage-ment and Outreach	Continue to incorporate climate projections and climate change adaptation strategies into management plans and policy.	▪ Continue with the development of an Urban Forest Management Plan that has subsections related to both the Natural Forest and Landscaped areas. Within this plan, incorporate climate change adaptation strategies into decision-making and policies for the current and proposed expanded community forest. ▪ As part of these management plans, consider developing an Integrated Pest and Disease Management Strategy (Cullington et al. 2008), as pests and diseases are likely to become more problematic with future climate predictions in both natural and landscaped forest areas.
√		Outreach	Communicate climate change impacts and adaptation into public documents and resources	▪ Consider explicitly referencing climate change adaptation as a strategy for the expanded community forest area on the Community Forest website (http://communityforest.princegeorge.ca/).
√	√	Manage-ment	Continue to seek long term external funding so that the City can support continued work on wildfire hazard reduction and new programs and management that incorporate climate change adaptation	▪ Continue to search on Civic Info BC which has a searchable grants website (http://www.civicinfo.bc.ca/18.asp) that includes several grants specific to wildfire mitigation and management programs, such as the Union of BC Municipalities 2011 Fuel Management Prescription Program. ▪ Environmental Services and Parks and Solid Waste Management Departments should

Forest Type		Type of Adaptation Strategy	Description of Strategy	Example(s) of Strategy
Natural	Landscaped			
			strategies.	consider hiring an intern or part-time employee dedicated to grant writing.
√		Manage-ment	Interact with City workers representing diverse sectors to ensure forest operations related to wildfire risk management are effectively communicated to the community.	▪ Interact with City workers representing police fire and rescue services, real estate and municipal emergency and response city sectors to ensure all aspects of community safety are identified related to wildfire risk management operations.
√		Manage-ment	Identify strategies to effectively work and communicate with by-law enforcement to implement policy related to Wildfire Interface Development Permit Areas (WIDPA).	▪ Consider communicating with other municipalities where Wildfire Interface Development Policies are in place to inform the City of Prince George's WIDPA process. For example, the City of Kamloops has developed policy where a proposed development situated in the pre-determined moderate, high or extreme wildfire hazard classes cannot be built unless the landowner abides by the minimum FireSmart guidelines and provides a site-specific wildfire hazard assessment to the City.
√		Manage-ment and Outreach	Management of the community forest should also include input from local First Nations	▪ Ensure the continued involvement by the Community Forest Advisory Committee made up of representatives from all levels of government, First Nations, academia,

Forest Type		Type of Adaptation Strategy	Description of Strategy	Example(s) of Strategy
Natural	Landscaped			
			academic experts, community members, and members of other levels of government to help steer forest management actions.	outdoor recreational groups, forestry experts and the general public. Ensure all stakeholders are represented in the committee and seek other stakeholders to join the committee where appropriate
√		Manage-ment and Outreach	Identify key linkages and partnerships with other levels of government as well as industry to help develop policies and management objectives regarding climate change adaptation and forest management, especially related to the expanded community forest agreement (if approved).	▪ Consider conducting discussion sessions and/or workshops with private land owners, industry members, such as Canadian Forest Products and other stakeholders such as BC Timber Sales to understand current forest management strategies to inform management of the proposed expanded community forest.
√	√	Manage-ment and Research	Discuss information needs and further modeling requirements that will inform adaptation strategies and vulnerability assessments as outlined by Williamson et al (2007) for the future expanded community	▪ Consider funding options to expanding the City's current Terrestrial Ecosystem Mapping (TEM) and Sensitive Ecosystem Inventory (SEI) Project to the proposed expanded community forest area beyond the municipal boundary. The TEM and SEI project would help inform a vulnerability assessment for the expanded community forest and/or the Prince George TSA. A

Forest Type		Type of Adaptation Strategy	Description of Strategy	Example(s) of Strategy
Natural	Landscaped			
			forest. A vulnerability assessment allows a community to systematically determine the sources of vulnerability to climate change, considering social, environmental and economic impacts while assessing a community's capacity to adapt to these impacts.	vulnerability assessment was created for the Kamloops TSA (Kamloops Future Forest Strategy; http://k2kamloopstsa.com/), which utilizes forestry models to predict potential vulnerabilities and sensitivities of the future forest.
√		Manage-ment and Research	Assess and consider hydrological impacts of MPB-salvage harvesting and wildfire reduction strategies for management of the expanded community forest (if approved), incorporating general recommendations made by the Ministry of Forests and Range (http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/stewardship/hydrology/) and associated reports (eg. MOFR 2004, 2009).	▪ Ensure implementation of different harvesting and retention strategies to protect slope stability and reduce runoff and erosion. This will be of particular interest in larger plots of land if the expanded community forest license is approved. Strategies such as maintaining and protecting young trees and other understory vegetation under dead pine stands to speed up reforestation or setting aside reserve areas to protect sensitive watershed areas (MOFR 2009).

Forest Type		Type of Adaptation Strategy	Description of Strategy	Example(s) of Strategy
Natural	Landscaped			
	√	Manage-ment and Outreach	Continue to examine opportunities for diversifying the species planted with climate change adaptation as part of the decision-making process. Seek new grant opportunities and create more programs where community members are aware of the links between trees and climate change adaptation and mitigation.	▪ Consider restructuring the Adopt a Tree Program from a climate change adaptation or air quality perspective to give more incentive to local residents (i.e. planting more deciduous trees will absorb more CO_2 and produce more O_2 to improve air quality and help to mitigate climate change impacts). ▪ Provide recommendations of where to plant species on private property to help with energy efficiency and thus climate change mitigation. For example, deciduous species planted on the south and west sides of homes and buildings can provide shade in summer, but allow light through in winter, and therefore reduce need for air conditioning in summer and heating in the winter.
	√	Outreach and Research	Partner with nursery professionals, tree experts and arborists to gather data/information on potential tree stresses related to the future climate and arrival of new pests and diseases.	▪ Consider conducting seminars and workshops with local tree nursery professionals, tree experts and arborists to create awareness and to gather data/information on potential stresses to trees and the arrival of pests and diseases that may impact tree health.

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