Projected Changes in Climate for Alberta and Forest Tree Improvement Program Regions

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Contents

1.0 Background

For over 200 years, genecological studies have revealed a close relationship between plant populations and their environment (Toresson 1923), especially climate (Langlet 1971). Given temperature, heat, moisture and their spatial and seasonal variations exert a direct pressure on plant survival, growth and reproductive processes, plant species exist as a mosaic of genetically differentiated populations each adapted to a local climate (Linhart and Grant 1996). This climatically induced natural selection is well established in forest tree species, especially those in temperate and boreal climates where spatial and seasonal temperature variations are the greatest (see Rweyongeza and Yang 2005; Davis et al. 2005; Loehle 1998).

In forestry, provenance studies involving planting of climatically diverse populations at many sites with different climates have played a great role in formulating seed use guidelines as well as providing initial measures of the potential impact of climate change on forest productivity (Stettler and Bradshaw 1994; Matyas 1994). For example, in British Columbia and Alberta, such studies exist for lodgepole pine (Rehfeldt et al. 1999, 2001; Wang et al. 2006; Rweyongeza et al. 2007), white spruce (Rweyongeza et al. 2007; 2010; Rweyongeza 2011) and aspen (Gray et al. 2011), which are the most important commercial species for Alberta. Preliminary analyses of data from these provenance studies have led to short-term modifications of seed transfer guidelines in British Columbia and Alberta as well as identifying research gaps that must be addressed for better adaptation to climate change.

Climatically induced natural selection and the local adaptation it produces have been a biological reality on which seed transfer to maintain healthy and productive forests is based. For a very long time, climatic similarity between the seed source and reforestation site has been an indicator of the extent to which trees to be planted are considered adapted to the target planting site, including adaptation to biological agents such as insects and diseases whose activities and genetics partly depend on climate. Tree adaptation to local climate is a product of evolution over many generations spanning thousands of years. Therefore, rapid changes in climate occurring in decades will offset the equilibrium between tree biological processes and the environment thereby affecting the health and productivity of forests. To sustain healthy and productive forests in a rapidly changing climate, human intervention will be needed in selecting and/or developing adapted seed and clones as well as identifying and conserving natural populations with unique gene pools.

One of the primary tools in the management of genetic resources in a changing climate is to identify the extent and direction of climate change for climatic variables of biological significance. This would allow policy makers and forest managers to adjust tree planting prescriptions to reduce the impact of climate change in the interim using natural populations and existing seed production facilities (e.g., seed orchards) while pursuing long-term adaptation measures through research. In 2012, the Climate Change and Emission Management (CCEMC) Corporation initiated the Tree Species Adaptation Risk Management project. This project is being implemented jointly by Alberta Environment and Sustainable Resource Development (ESRD) and forest companies involved in tree breeding in Alberta through a consortium known as Tree Improvement Alberta (TIA). The aim of this project is to generate data, scientific-based inferences and recommendations that enable the Alberta government to adopt provincial policies that integrate climate change adaptation into seed and clonal transfer guidelines for reforestation in crown land.

This report is the first in a series of reports and journal articles which will be produced from the Tree Species Adaptation Risk Management project. It covers projections of future climates for selected climatic variables for the entire province and individual tree breeding program regions, also called Controlled Parentage Programs (CPP) regions. These projections will be integrated with the ongoing analysis on biological data and CPP-based climate change risk analysis to address questions on transfer of wild seed among seed zones; transferability of orchard seed and clones among CPP regions; and reconfiguring seed orchards and deciduous species clonal production programs to address future climatic constraints, especially drought tolerance.

2.0 Climate trends and projections

Baseline climate data for Alberta were derived from monthly temperature and precipitation grids that were generated by Daly *et al*. (2008) using the Parameter-elevation Regression of Independent Slopes Model (PRISM) to interpolate climate normal data observed at weather stations throughout the province for the period 1961-1990. This database was enhanced with lapse-rate-based down-sampling to 1km resolution and estimation of biologically relevant variables (Hamann and Wang. 2005; Mbogga et al. 2009; Wang *et al*. 2012). For an overall climatic summary, 12 variables were selected to thoroughly illustrate climate change projected for the province. These variables include: mean annual temperature, mean warmest month temperature, mean coldest month temperature, average winter temperature (December-February), mean summer temperature (June-August), continentality (difference between mean January and mean July temperature), mean annual precipitation, mean growing season precipitation (May-September), frost free period, growing degree days above 5˚C, as well as annual and summer (June-August) climate moisture (dryness) indices according to Hogg (1997). Hogg's dryness indices were selected over alternative methods as they include potential evapotranspiration within their calculation. For the independent species-specific Control Parentage Program (CPP) regions, 6 climate variables were selected for mapping which are considered to be the best indicators of climate changes which may affect tree establishment and growth. These variables include: mean warmest month temperature, mean coldest month temperature, growing degree days above 5˚C , mean growing season precipitation, frost free period, and the summer (June-August) climate moisture (dryness) index according to Hogg (1997).

Climate projections for the province for the 2020s, 2050s, and 2080s were generated by overlaying projections from general circulation models expressed as the difference from the 1961-1990 normal period. The recent Fifth Assessment Report from the Intergovernmental Panel on Climate Change (IPCC) illustrates that the current global emission outputs most closely resembles the projected emission outputs for the pessimistic A1B SRES emission and population growth scenario (Dahe 2014). Therefore for this summary report, future projections were based on an ensemble of outputs from seven modelling groups (CCCMA_CGCM3, Canada; CSIRO_MK3, Australia; IPSL_CM4, France; MIROC3_2_HIRES, Japan; MPI_ECHAM5, Europe; NCAR_CCSM3, United States, and UKMO_HADGEM1, United Kingdom) each implementing the A1B SRES emission and population growth scenario for each future period. All current and future projections were generated using the freely available ClimateWNA software, version 4.71 (Wang *et al*. 2012).

3.0 Projected climate shifts: Alberta

Maps illustrating the shift in each of the climate variables summarized in this report over Alberta are provided in Figures 1-13, with Figures 1-6 representing changes in general temperature variables; Figures 7-8 representing changes in growing degree days and frost variables; Figures 9-10 representing changes in precipitation; and finally Figures 11-12 representing changes in climate moisture.

In general, future projections suggest an overall annual warming throughout the province beginning in the 2020s and accelerating towards the 2080s (Figure 1). However, by comparing the warming trends in both the winter (Figure 2 and Figure 5) and summer (Figure 3 and Figure 6) seasons it is evident that the warming signal is projected to be stronger in the colder months, particularly in the northern mixedwood region of the province (Figure 2 and Figure 5). This is further supported by a continual decrease in continentality in the northern mixedwood region beginning in the 2020s and becoming more prominent in the 2080s (Figure 4).

A steady increase in growing degree days above 5°C (Figure 7) is projected for the future. This trend appears most noticeable in the parkland and northern dry mixedwood and central mixedwood regions. In addition, there is a projected increase in frost free period over the province, which in the high elevation upper boreal highlands and boreal subarctic approximates a 30 day increase by the 2020s and approximately 50-60 days by the 2050s (Figure 8). These projections suggest that the occurrence of frost events may be reduced in the future which could be beneficial for forest productivity.

In addition, future projections suggest a moderate increase in mean annual (Figure 9) and a more prominent increase in growing season precipitation (Figure 10) extending from the foothills ecosystems which follows the eastern slope of the Rocky Mountains, east along the polar jet stream storm track that defines the climatology of the Boreal Plains region. This trend would result in more summer precipitation in the lower foothills, parkland, and southern dry mixedwood ecosystem regions of the province, where the latter two regions are characteristically drier ecosystems. While these precipitation increases appear to be beneficial for tree growth, the annual (Figure 11) and summer (Figure 12) dryness indices indicate a reduction in moisture in these same regions. This dryness trend is likely the product of increase in summer temperatures (Figure 6) exceeding the increase in precipitation (Figure 10), resulting in greater potential evapotranspiration and less moisture availability. This could counter the expected benefits of increased precipitation on tree growth, and potentially result in greater drought events.

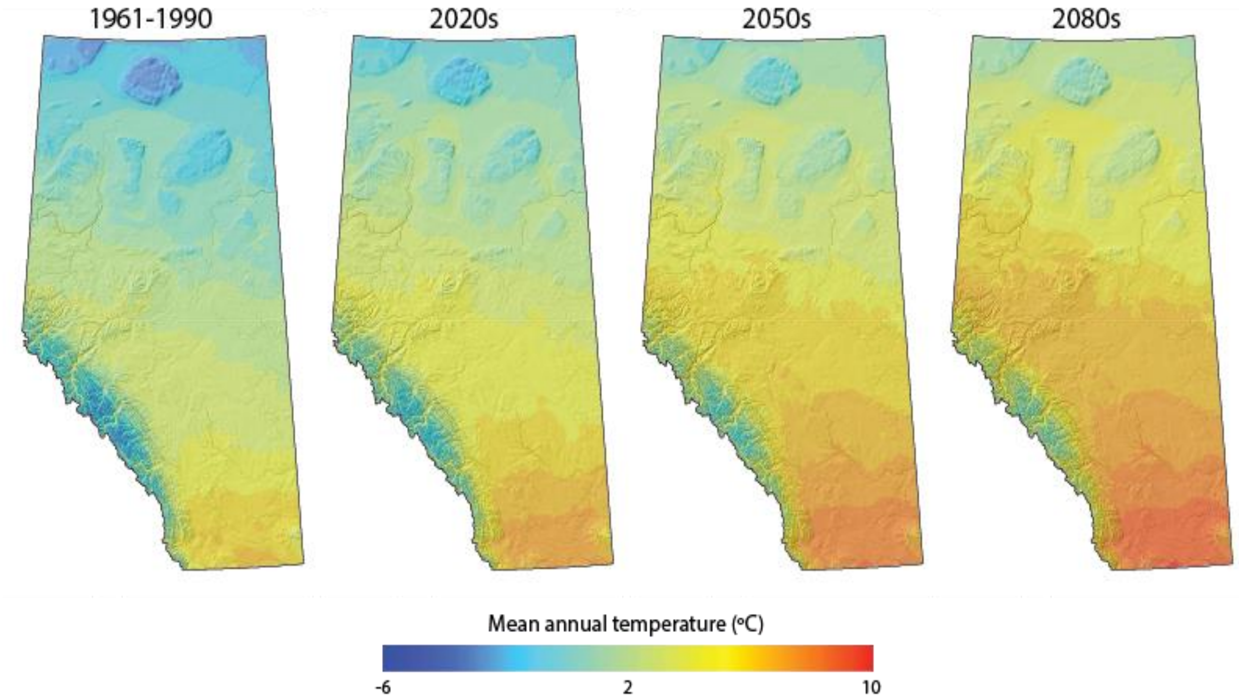

Figure 1: Current and projected future mean annual temperature for Alberta. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

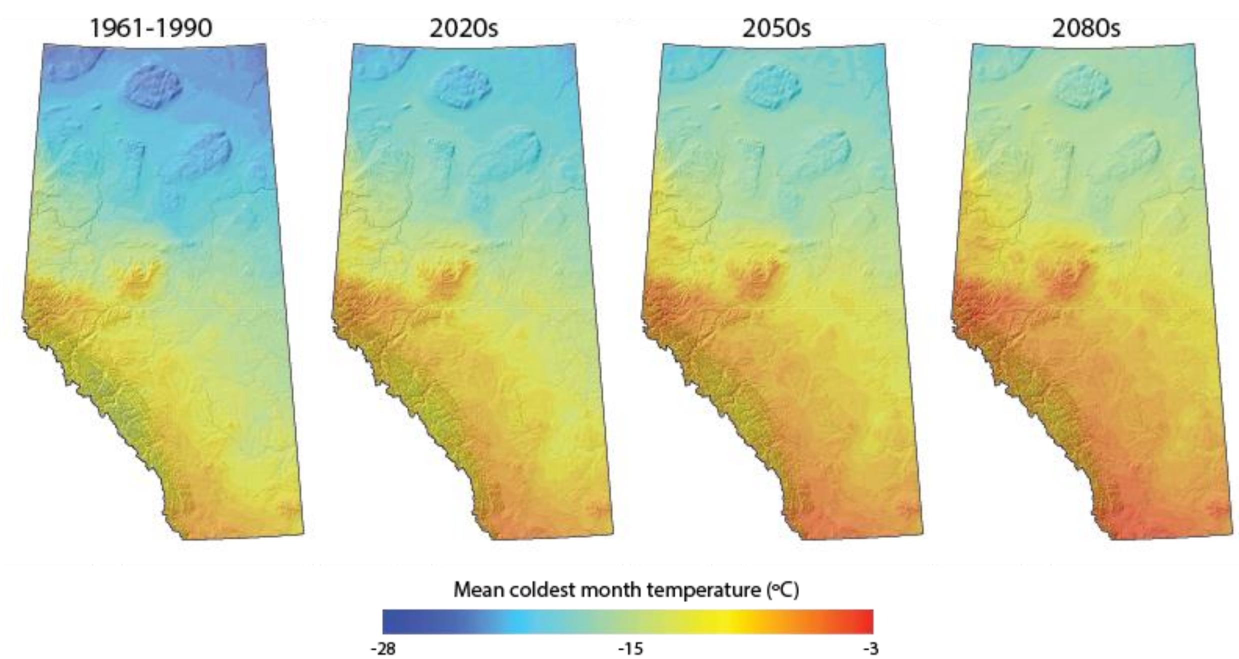

Figure 2: Current and projected future mean coldest month temperature for Alberta. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

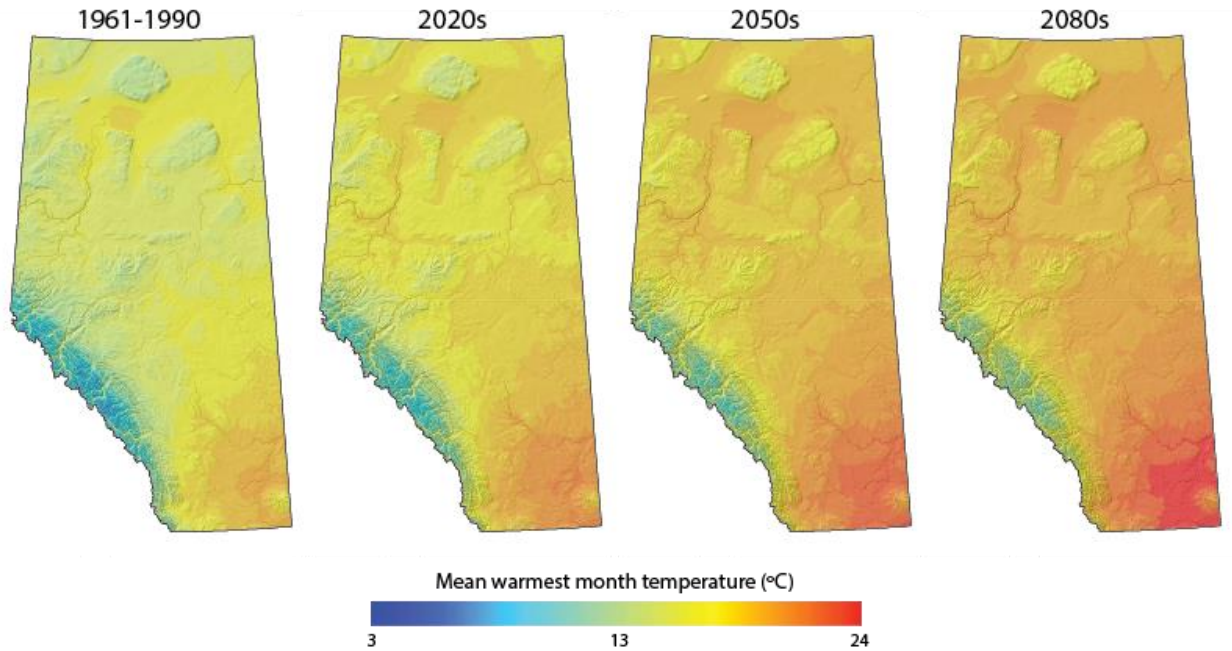

Figure 3: Current and projected future mean warmest month temperature for Alberta. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

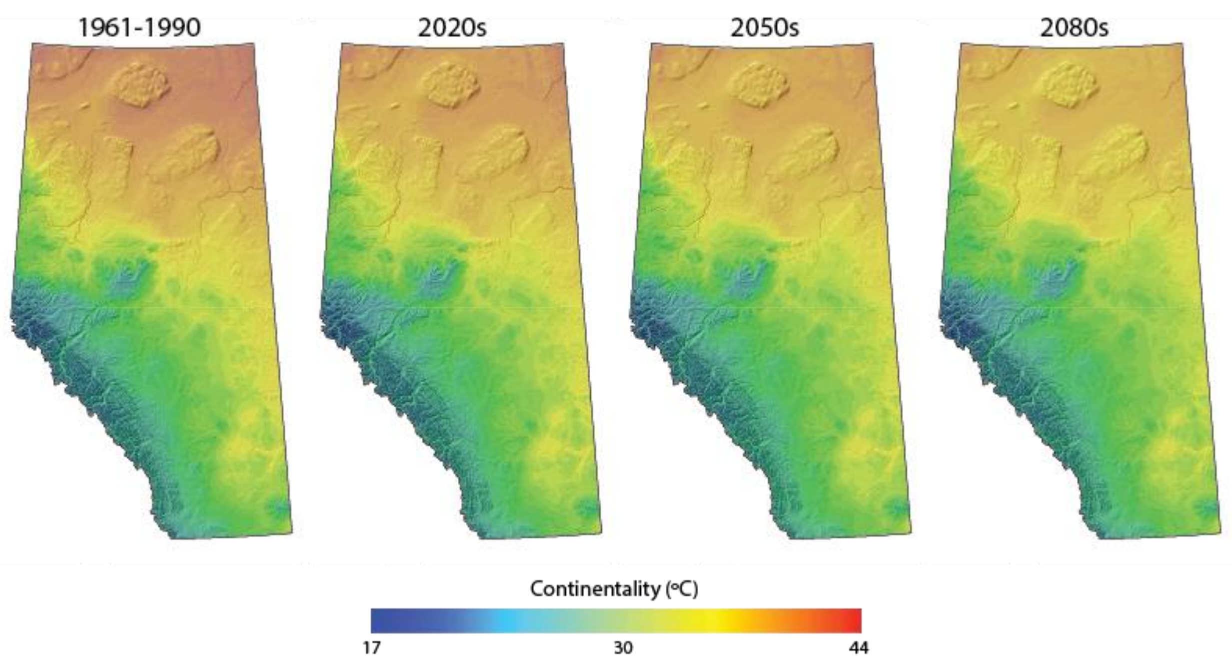

Figure 4: Current and projected future continentality (difference between mean January and mean July temperature) for Alberta. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

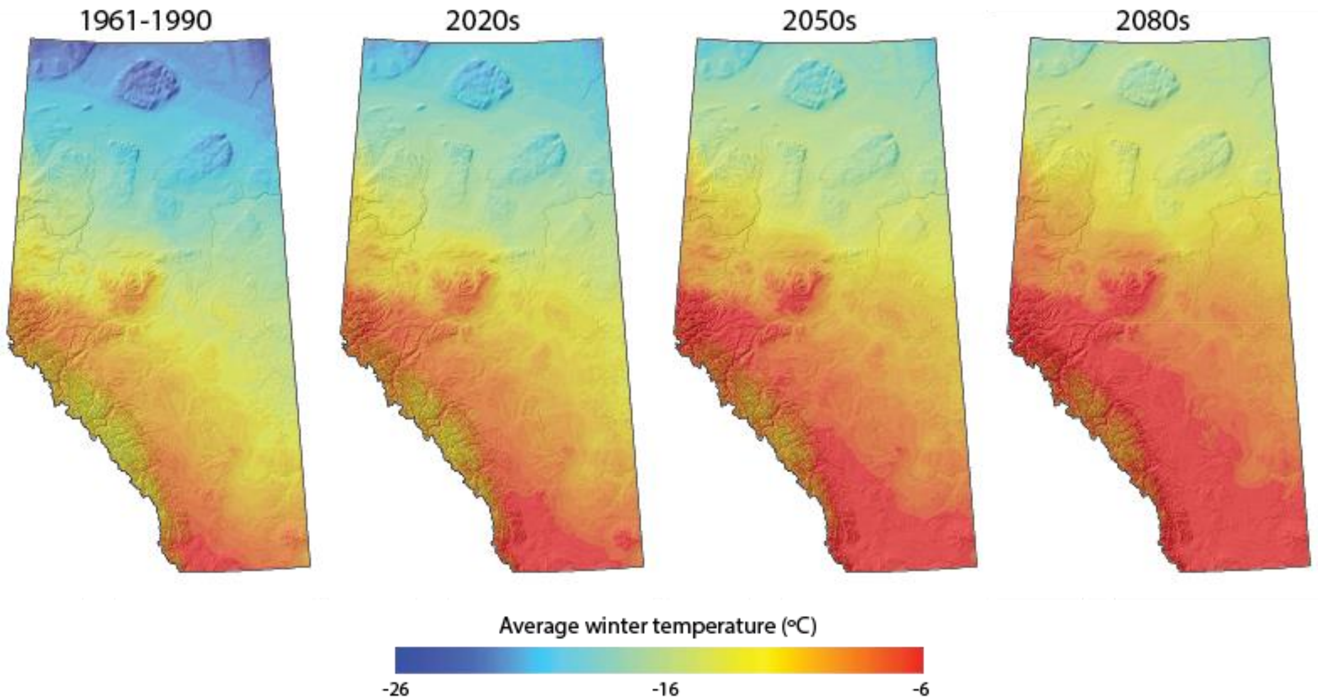

Figure 5: Current and projected future average winter (December-February) temperature for Alberta. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

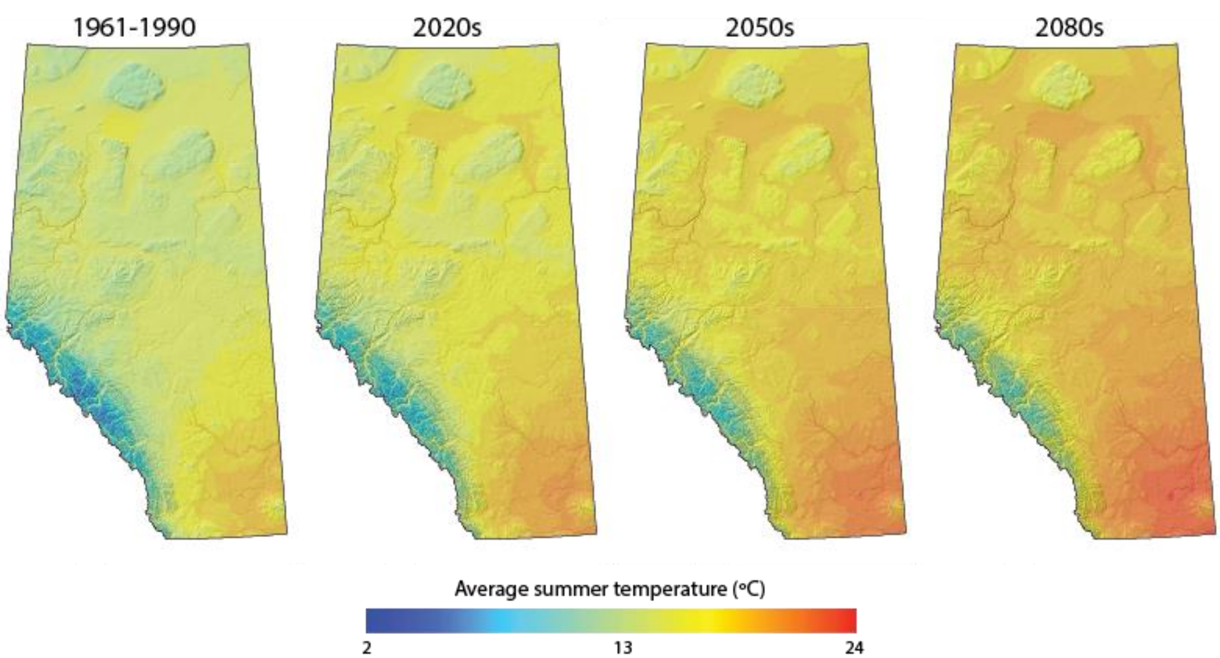

Figure 6: Current and projected future average summer (June-August) temperature for Alberta. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

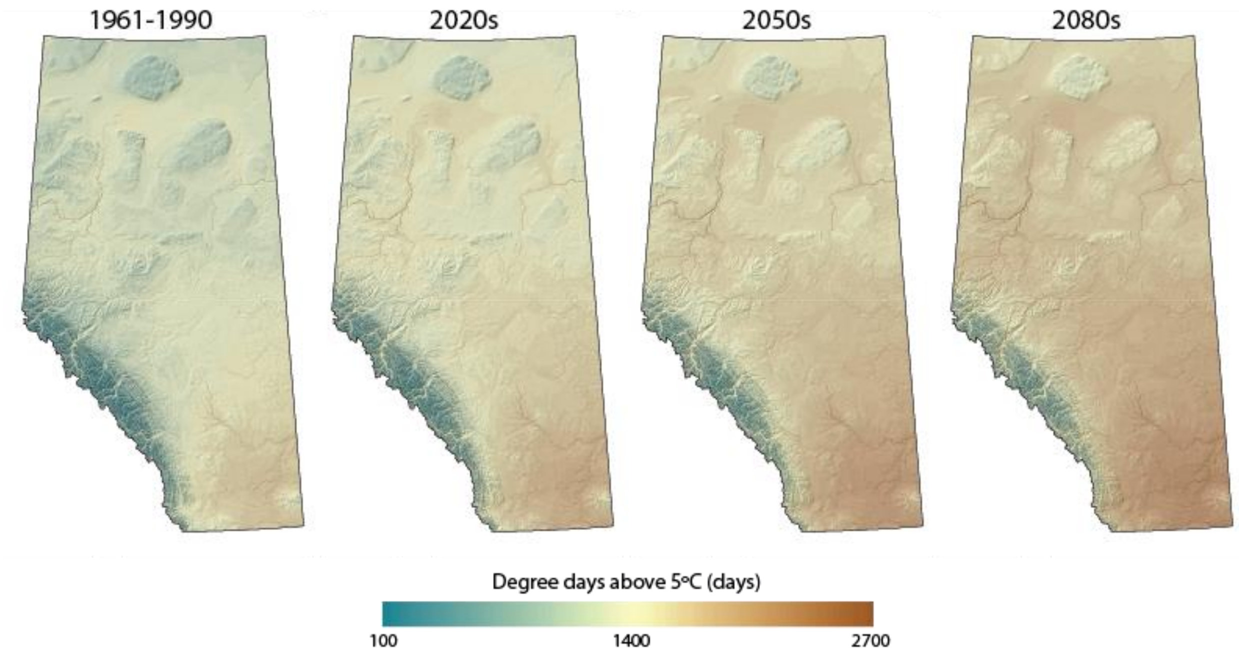

Figure 7: Current and projected future growing degree days above 5˚C for Alberta. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

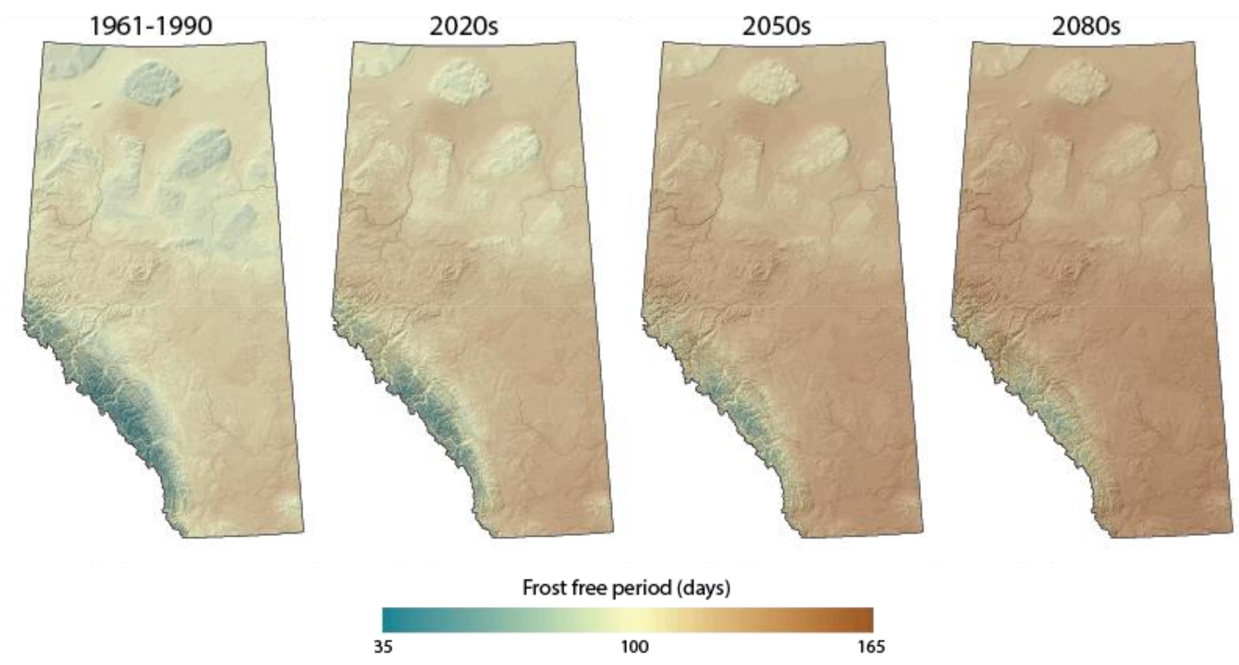

Figure 8: Current and projected future frost free period for Alberta. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

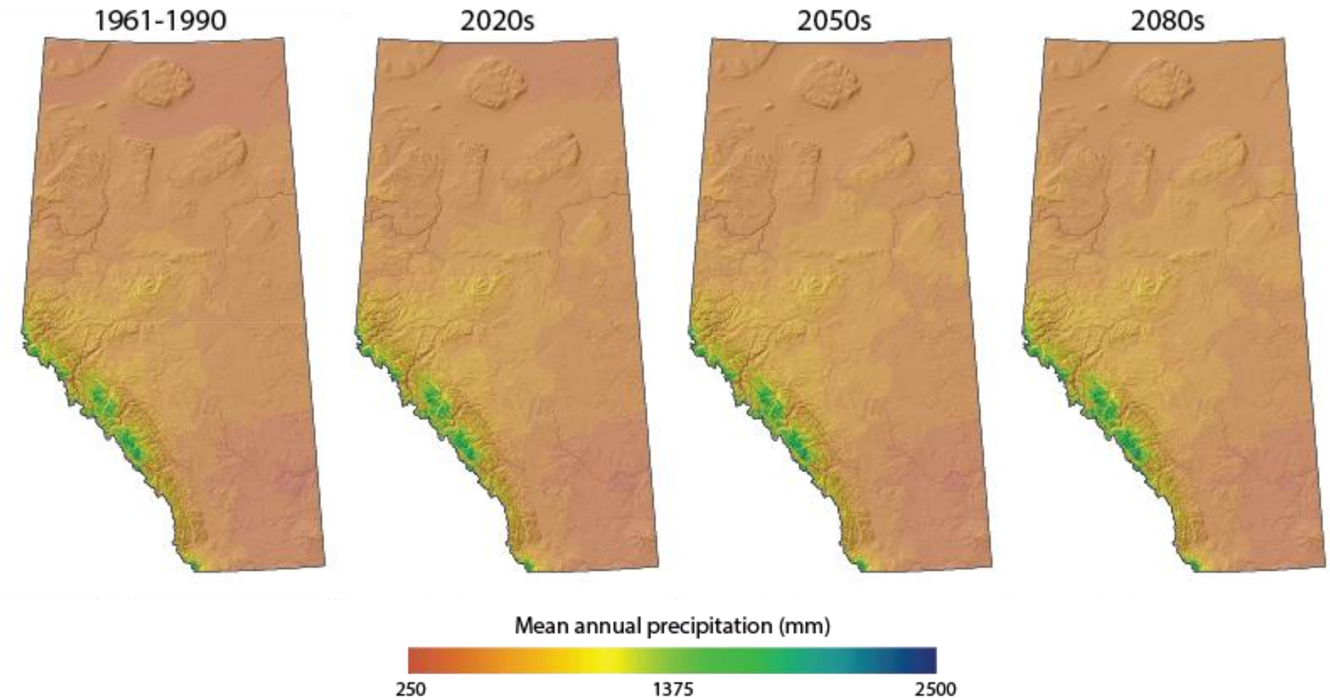

Figure 9: Current and projected mean annual precipitation for Alberta. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

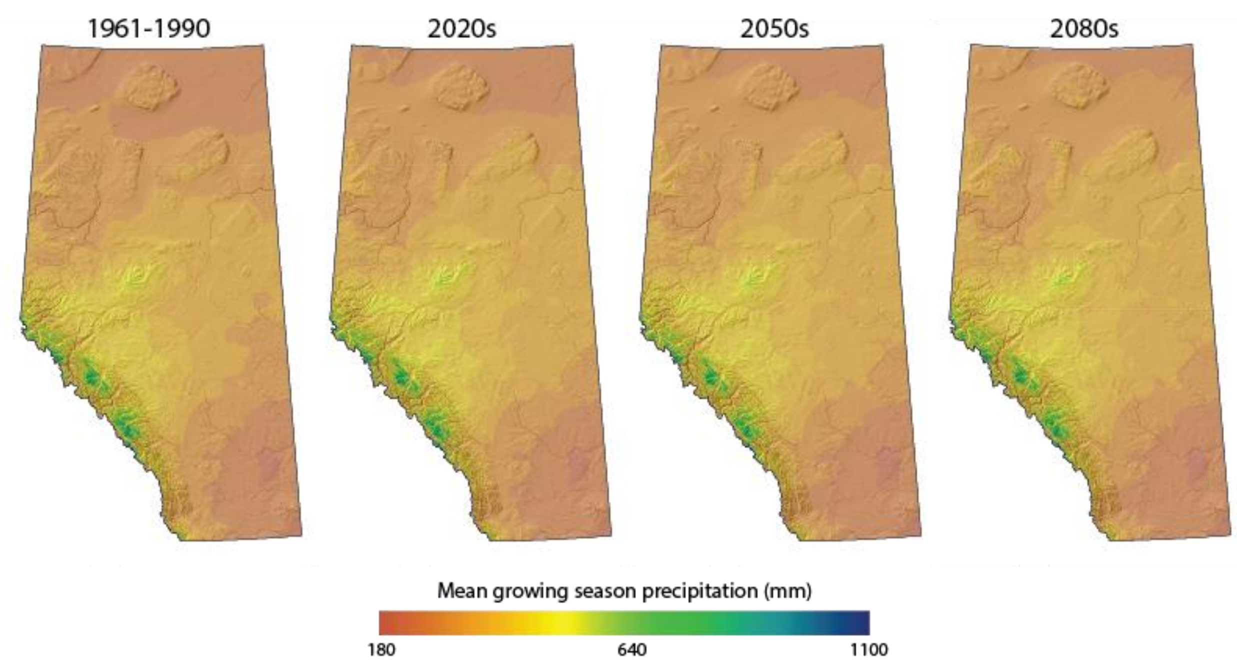

Figure 10: Current and projected mean growing season (May-September) precipitation for Alberta. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

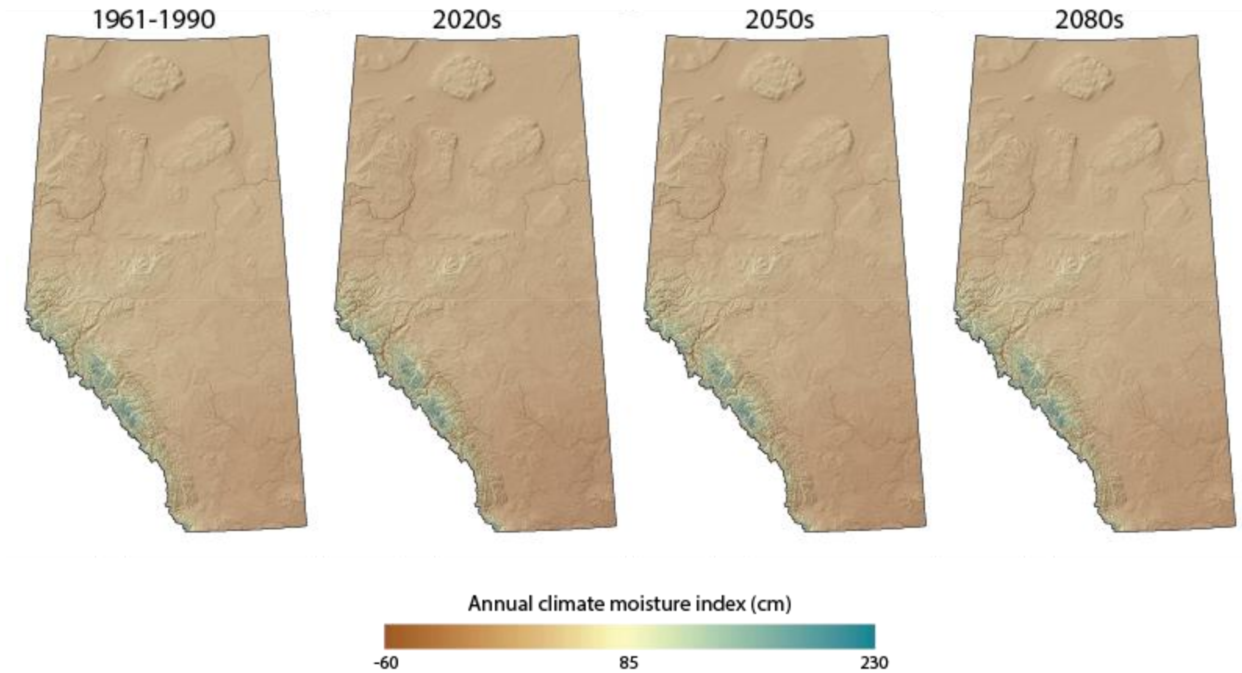

Figure 11: Current and projected annual climate moisture index for Alberta. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

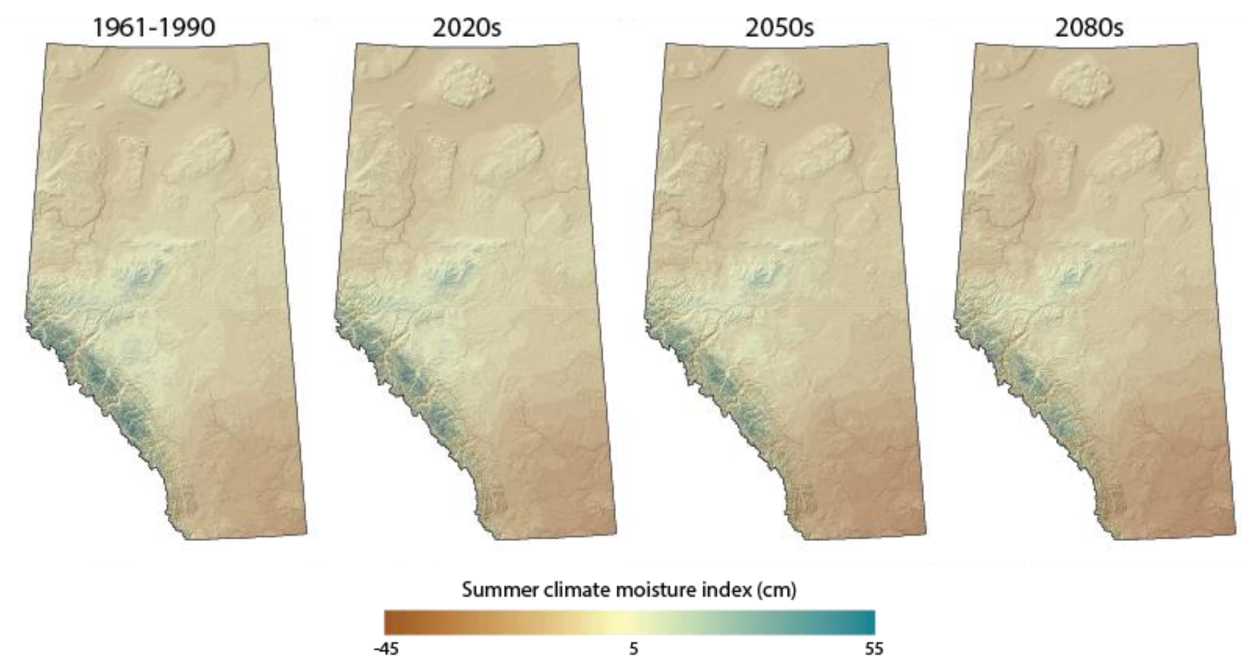

Figure 12: Current and projected summer (June-August) climate moisture index for Alberta. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

4.0 Projected climate shifts: White Spruce Control Parentage Program Regions

Maps illustrating the shift in each of the six climate variables summarized in this report over each of the nine white spruce (*Picea glauca*) Control Parentage Program (CPP) regions (Figure 13) are provided in the following subsections.

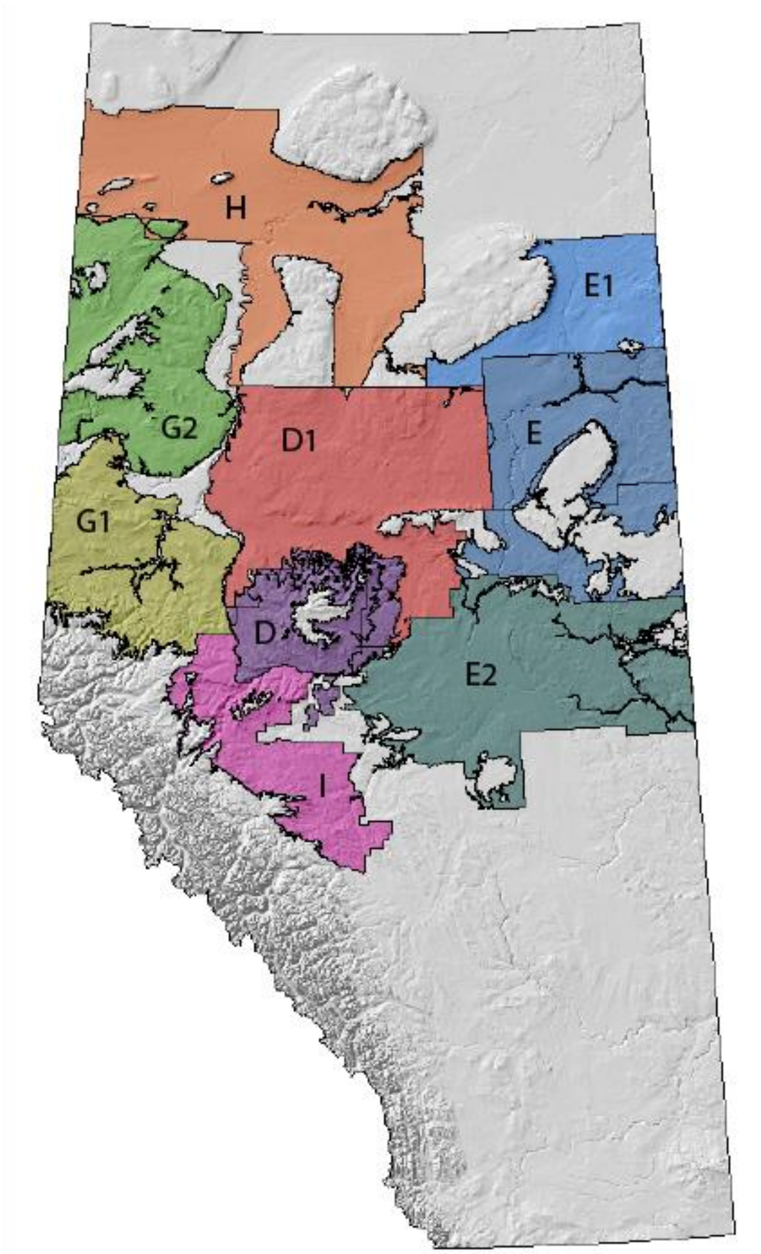

Figure 13: The nine regions of the white spruce (*Picea glauca*) Control Parentage Program (CPP).

4.1 Region D

The white spruce Control Parentage Program (CPP) region D is the smallest of the white spruce CPP regions, approximately 1,656,932 hectares, with parts of it overlapping with the neighbouring CPP regions D1 and I. This region is comprised mainly of lower foothills ecosystems with pockets of central mixedwood ecosystems around its perimeter. The climate of this region is characteristically mild in both the winter and the summer seasons and wetter than the majority of the province.

Maps illustrating the shift in each of the six climate variables summarized in this report over the CPP region D are provided in Figures 14-19, with Figures 14-15 representing changes in winter and summer temperatures; Figures 16-17 representing changes in growing degree days and frost variables; Figure 18 represents changes in precipitation; and finally Figure 19 represents changes in summer climate moisture.

In general, the future projections suggest increased winter warming across the region towards the 2080s, with the most pronounced warming occurring at higher elevations surrounding the upper boreal highlands ecosystems reaching an approximate 6°C increase by the 2050s (Figure 14). Similarly warming is projected for the CPP region in the summer season, however at a lesser magnitude of approximately 4°C and it occurs more prominent at elevations (Figure 15). Further the number of growing degree days above 5°C as well as frost free period are projected to moderately increase by the 2020s, but accelerate towards the 2080s (Figure 16 and Figure 17), suggesting the potential for a longer growing season within the region. Finally precipitation is projected to increase, but by only a small margin and the majority of the increase occurs at higher elevations adjacent to the upper boreal highland ecosystems (Figure 18). This is further supported by only small changes projected in the summer climate moisture index for the region (Figure 19).

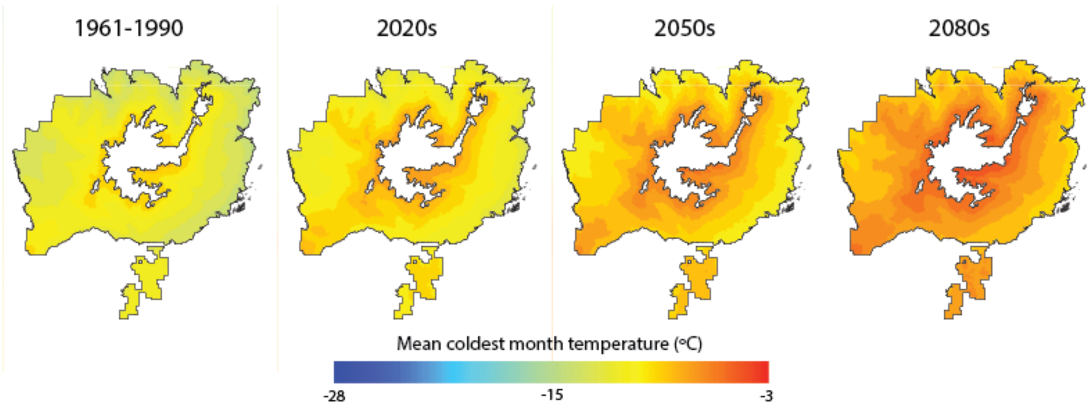

Figure 14: Current and projected future mean coldest month temperature for white spruce Control Parentage Program (CPP) region D. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

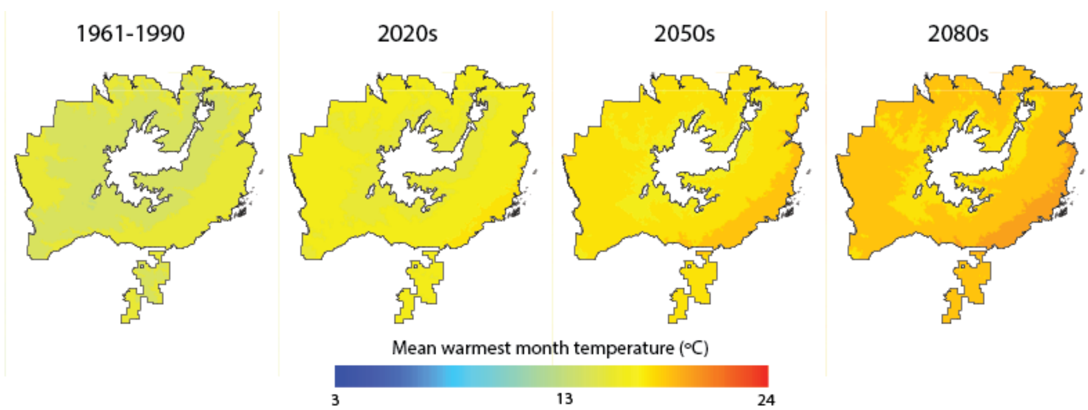

Figure 15: Current and projected future mean warmest month temperature for white spruce Control Parentage Program (CPP) region D. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

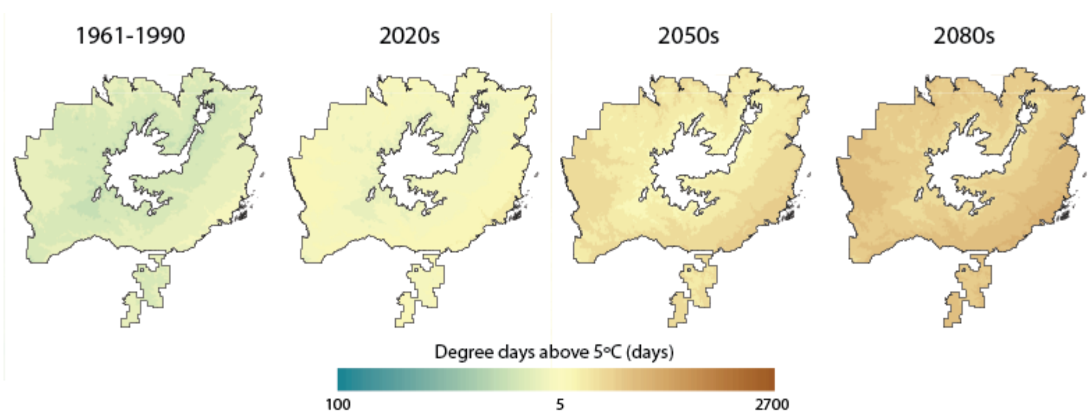

Figure 16: Current and projected future growing degree days above 5°C for white spruce Control Parentage Program (CPP) region D. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

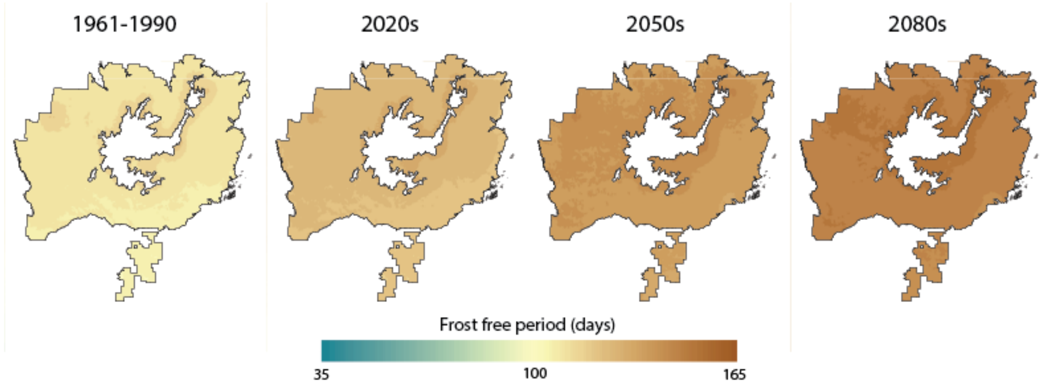

Figure 17: Current and projected future frost free period for white spruce Control Parentage Program (CPP) region D. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

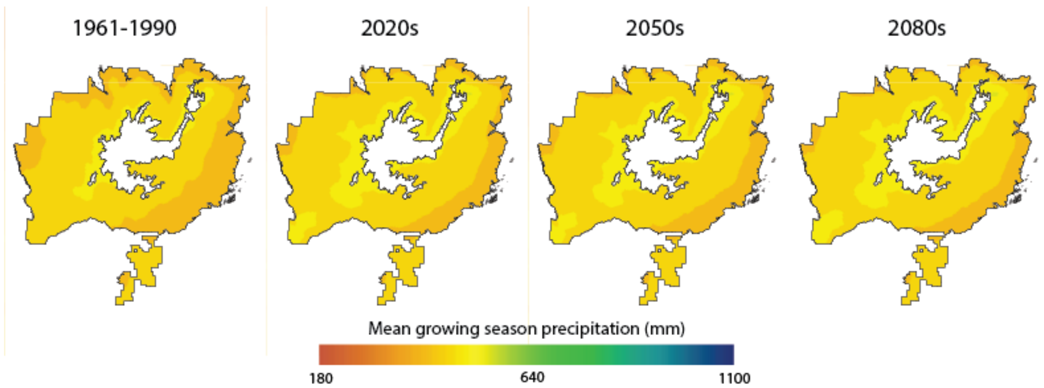

Figure 18: Current and projected mean growing season (May-September) precipitation for white spruce Control Parentage Program (CPP) region D. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

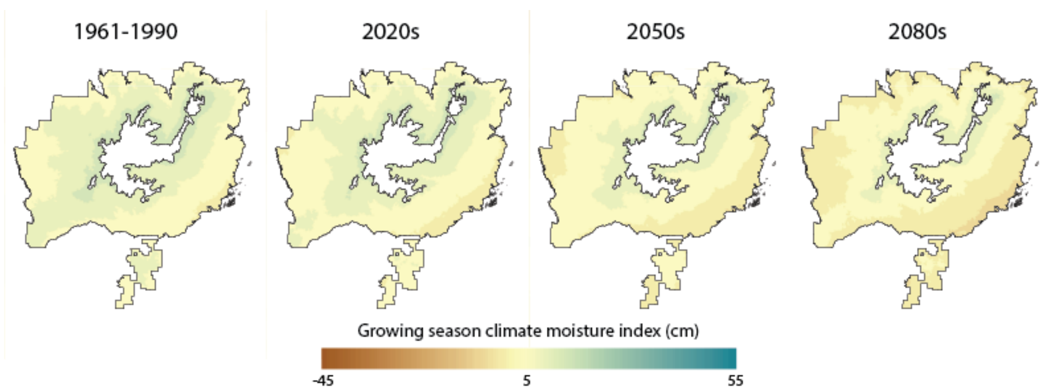

Figure 19: Current and projected future summer (June-August) climate moisture index for white spruce Control Parentage Program (CPP) region D. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

4.2 Region D1

The white spruce Control Parentage Program (CPP) region D1 is the largest of the white spruce region of approximately 5,207,402 hectares, with parts of it overlapping with the neighbouring CPP region D. The southern portion of its boundary follows the division between the lower foothills and central mixedwood ecosystems. The D1 region is thus includes central and dry mixedwood ecosystems with pockets of lower boreal highland ecosystems within its boundary. The climate of this region is characteristically dry and temperatures are cool in both the winter and the summer seasons.

Maps illustrating the shift in each of the six climate variables summarized in this report over the CPP region D1 are provided in Figures 20-25, with Figures 20-21 representing changes in winter and summer temperatures; Figures 22-23 representing changes in growing degree days and frost variables; Figure 24 represents changes in precipitation; and finally Figure 25 represents changes in summer climate moisture.

In general, the future projections suggest increased winter warming across the region towards the 2080s, with the most pronounced warming occurring in the northern portion of the region reaching an approximate 6°C increase by the 2050s in the lower boreal highlands (Figure 20). Projected warming in the summer season is significantly less, with approximately 2-3°C across the region (Figure 21). Further the number of growing degree days above 5°C as well as frost free period are projected to moderately increase by the 2020s, but accelerate towards the 2080s with the largest shifts occurring in the southern portion of the region extending from the border with the lower foothills ecosystems (Figure 22 and Figure 23). This suggests the potential for a longer growing season, particularly in the southern portion of the region. Finally little change in summer precipitation is projected (Figure 24). This coupled with the moderate temperature increases projected in this season (Figure 21) results in significant reduction in available moisture; such that the majority of the region resembles the characteristics of the dry mixedwood ecosystems that currently make up the northwest portion of the region (Figure 25).

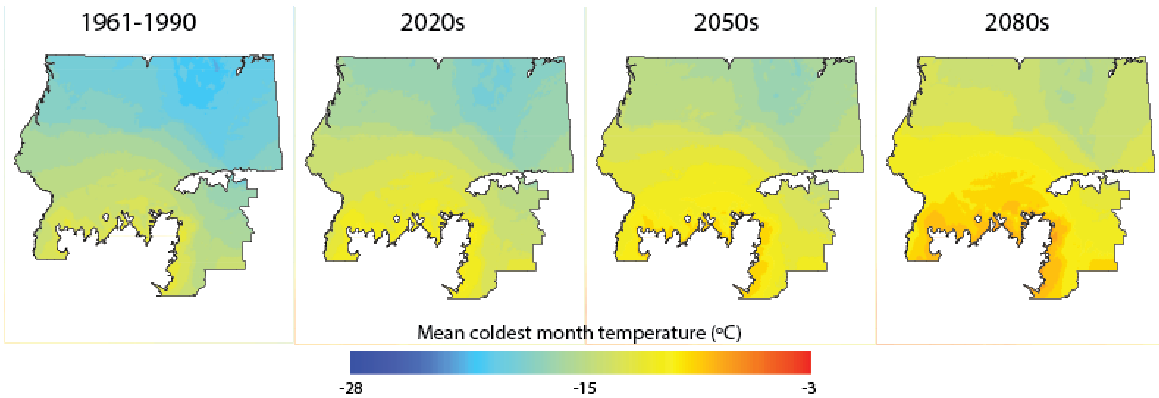

Figure 20: Current and projected future mean coldest month temperature for white spruce Control Parentage Program (CPP) region D1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

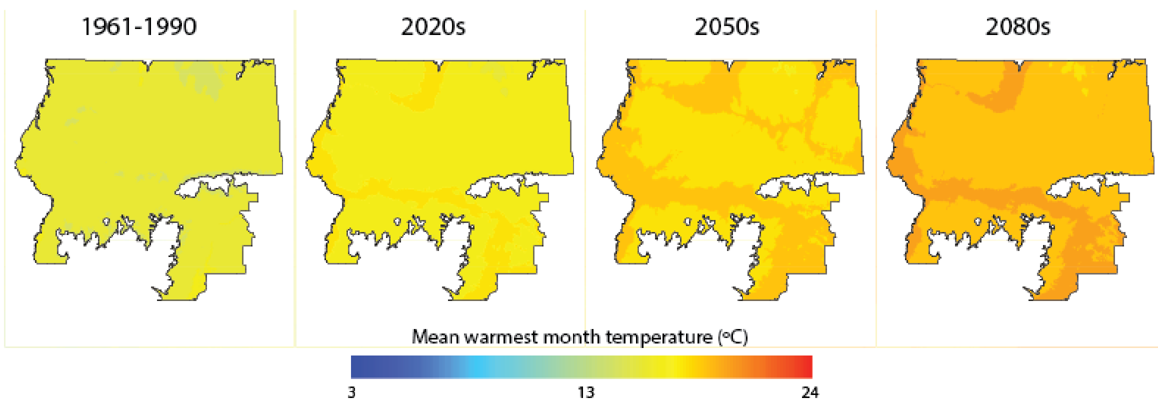

Figure 21: Current and projected future mean warmest month temperature for white spruce Control Parentage Program (CPP) region D1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

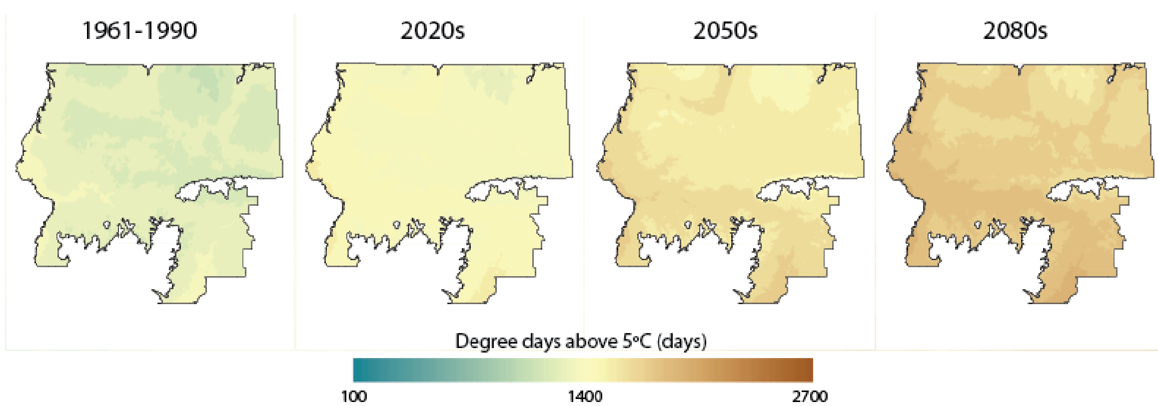

Figure 22: Current and projected future growing degree days above 5°C for white spruce Control Parentage Program (CPP) region D1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

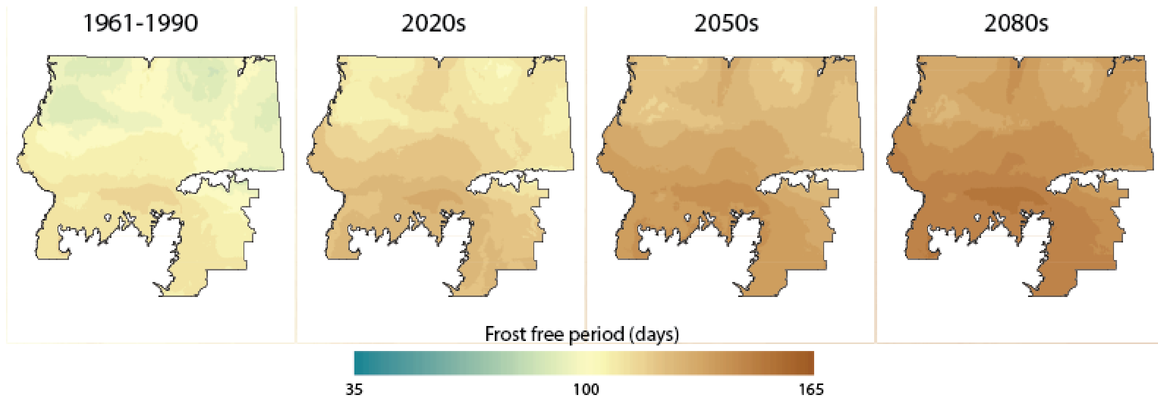

Figure 23: Current and projected future frost free period for white spruce Control Parentage Program (CPP) region D1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

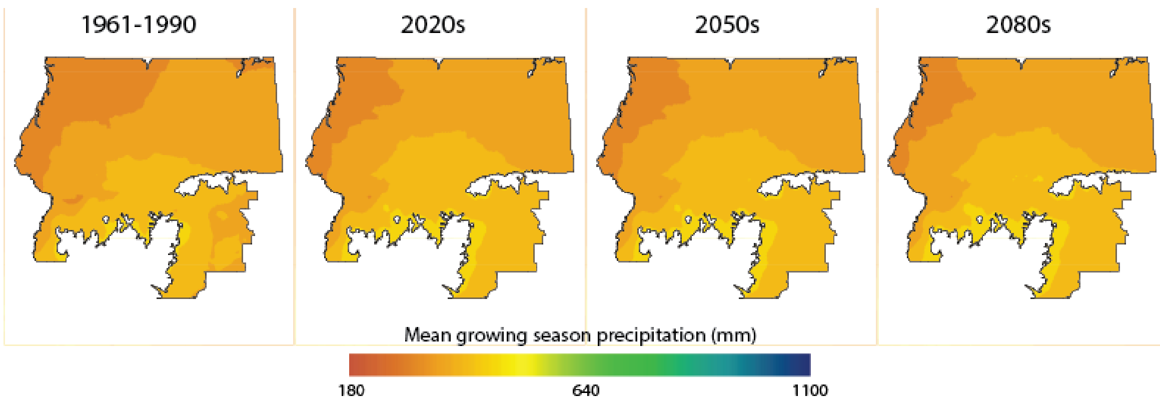

Figure 24: Current and projected mean growing season (May-September) precipitation for white spruce Control Parentage Program (CPP) region D1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

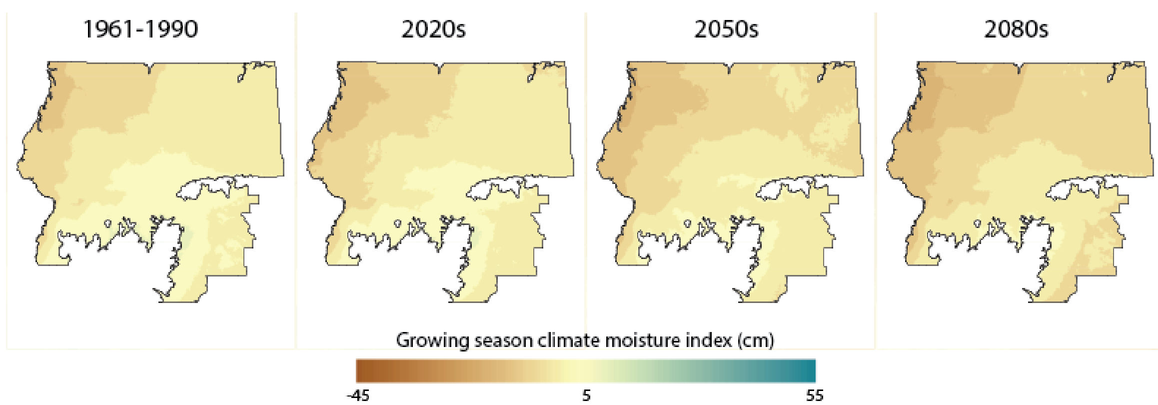

Figure 25: Current and projected future summer (June-August) climate moisture index for white spruce Control Parentage Program (CPP) region D1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

4.3 Region E

The white spruce Control Parentage Program (CPP) region E is geographically located in eastern Alberta, and is made up of approximately 3,288,229 hectares, with a large portion of the region overlapping with the neighbouring CPP region E1. This region is comprised solely of central mixedwood ecosystems with its border following the division between the central mixedwood and lower boreal highlands. The climate of this region is characteristically dry with cool temperatures in the winter and the warmer temperatures in the summer season.

Maps illustrating the shift in each of the six climate variables summarized in this report over the CPP region E are provided in Figures 26-31, with Figures 26-27 representing changes in winter and summer temperatures; Figures 28-29 representing changes in growing degree days and frost variables; Figure 30 represents changes in precipitation; and finally Figure 31 represents changes in summer climate moisture.

In general, the future projections suggest increased winter warming across the region towards the 2080s, with the most pronounced warming occurring in the northern portion of the region reaching an approximate 3-4°C increase by the 2050s (Figure 26). Projected warming in the summer season is approximately the same magnitude as the winter season, but is more pronounced in the eastern portion of the region (Figure 27). Further the number of growing degree days above 5°C as well as frost free period are projected to moderately increase by the 2020s, but accelerate towards the 2080s almost uniformly across the region (Figure 28 and Figure 29). This suggests the potential for a longer growing season throughout the region. Little change in summer precipitation is projected for the southern portion of the region; however precipitation is projected to moderately increase in the northern portion of the region (Figure 30). Finally moderate temperature increases projected in the summer season (Figure 27) coupled with little precipitation change is projected to result in a slight reduction in available moisture for the region (Figure 31).

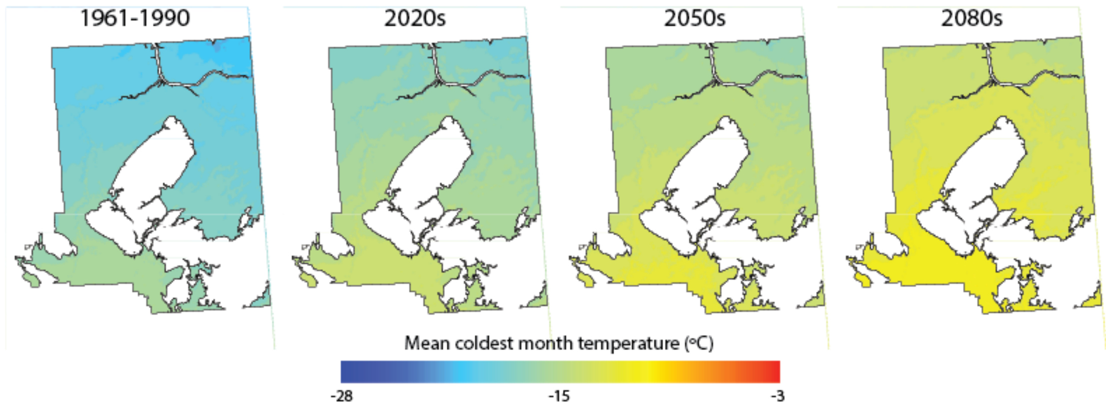

Figure 26: Current and projected future mean coldest month temperature for white spruce Control Parentage Program (CPP) region E. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

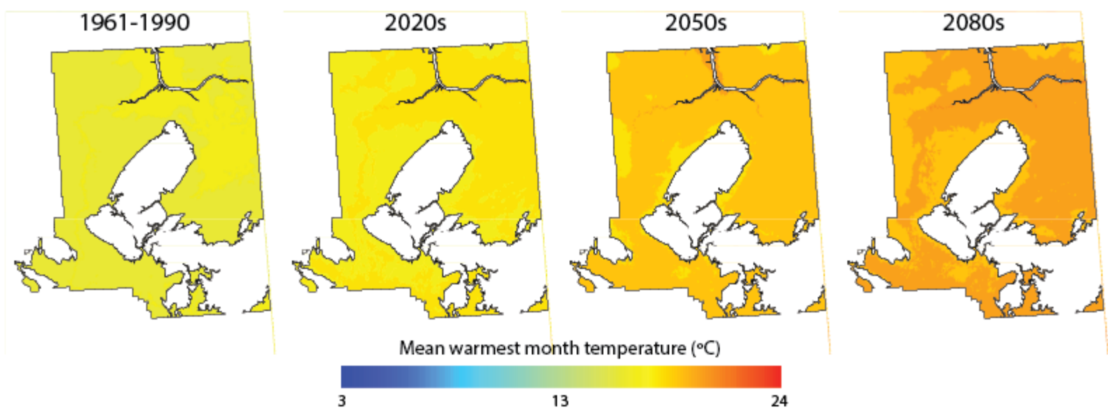

Figure 27: Current and projected future mean warmest month temperature for white spruce Control Parentage Program (CPP) region E. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

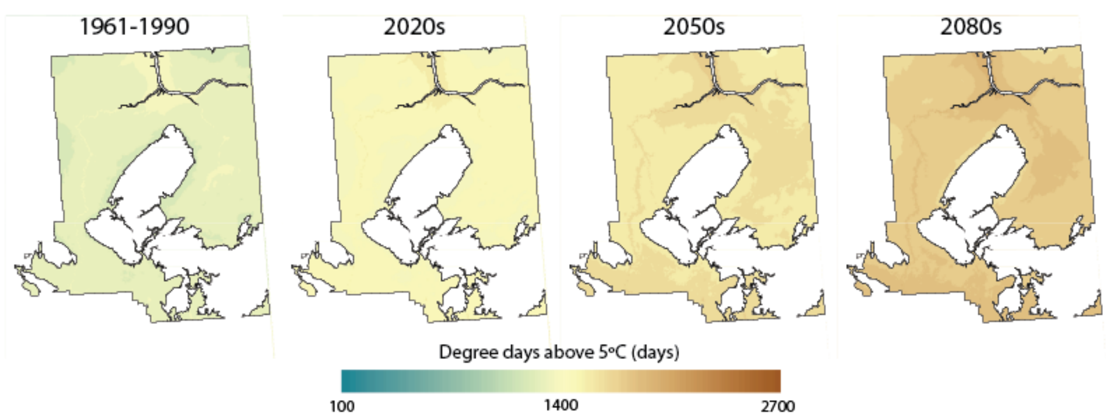

Figure 28: Current and projected future growing degree days above 5°C for white spruce Control Parentage Program (CPP) region E. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

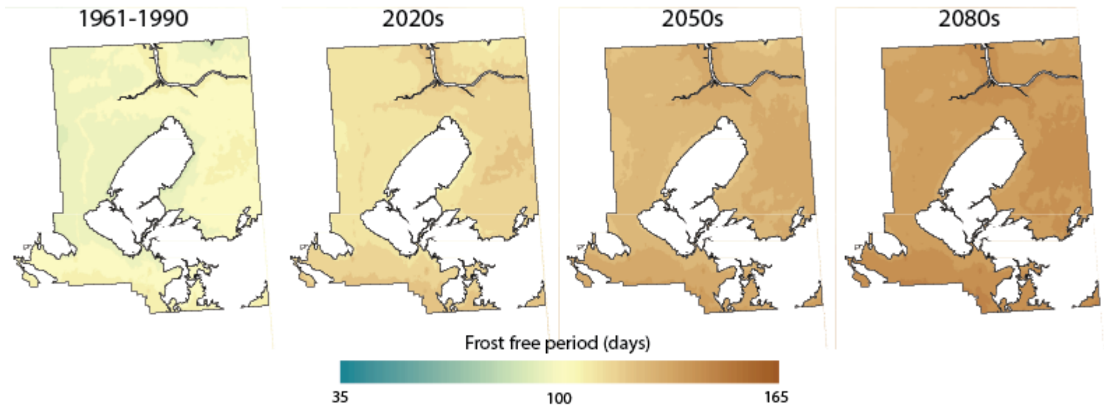

Figure 28: Current and projected future frost free period for white spruce Control Parentage Program (CPP) region E. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

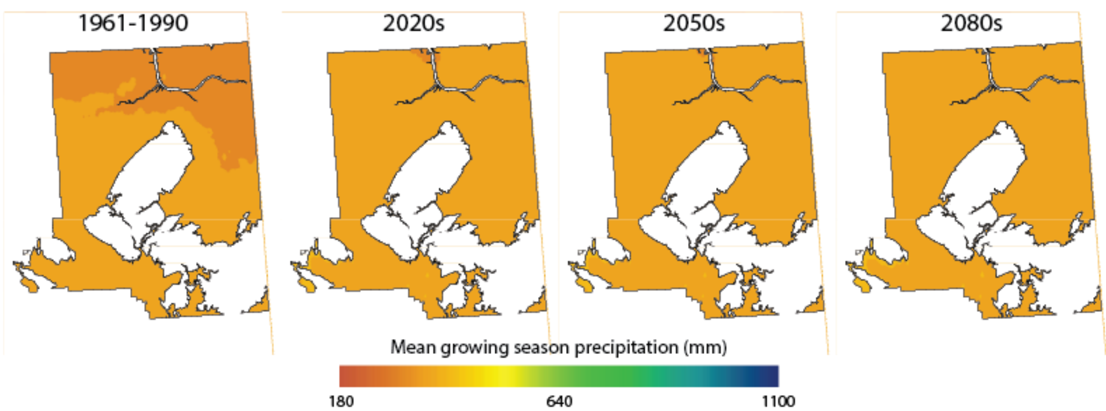

Figure 30: Current and projected mean growing season (May-September) precipitation for white spruce Control Parentage Program (CPP) region E. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

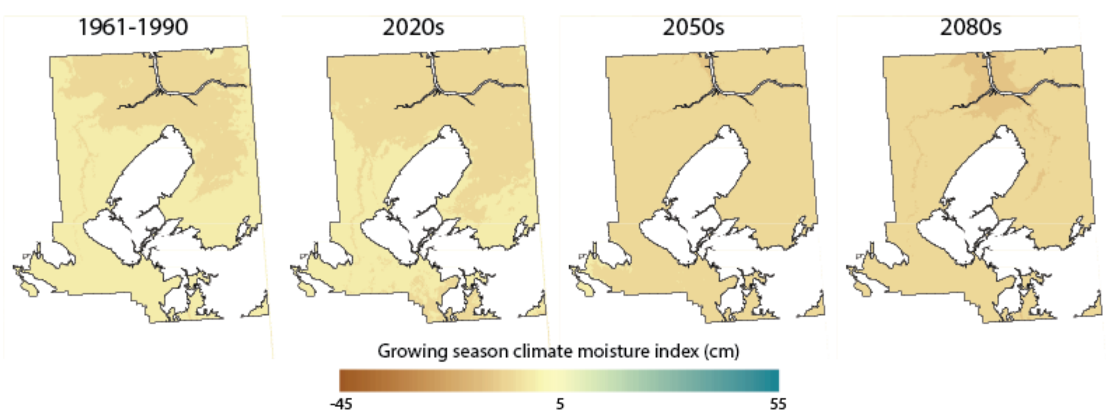

Figure 31: Current and projected future summer (June-August) climate moisture index for white spruce Control Parentage Program (CPP) region E. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

4.4 Region E1

The white spruce Control Parentage Program (CPP) region E1 is geographically located in northeastern Alberta, and is made up of approximately 3,942,060 hectares, with a large portion of the region overlapping with the neighbouring CPP region E. This region is comprised of central mixedwood and Athabasca plains ecosystems with its southern border following the division between the central mixedwood and lower boreal highlands. The climate of this region is characteristically dry with cold temperatures in the winter and the mild temperatures in the summer season.

Maps illustrating the shift in each of the six climate variables summarized in this report over the CPP region E1 are provided in Figures 32-37, with Figures 32-33 representing changes in winter and summer temperatures; Figures 34-35 representing changes in growing degree days and frost variables; Figure 36 represents changes in precipitation; and finally Figure 37 represents changes in summer climate moisture.

In general, the future projections suggest increased winter warming across the region towards the 2080s, with the most pronounced warming occurring in the northern portion of the region reaching an approximate 6˚C increase by the 2050s (Figure 32). Projected warming in the summer season is less than the winter season with approximately 2-3˚C by the 2050s and is most pronounced in the eastern portion of the region (Figure 33). Further the number of growing degree days above 5˚C as well as frost free period are projected to moderately increase by the 2020s, but accelerate towards the 2080s extending from the central portion of the region towards the boarders (Figure 34 and Figure 35). This suggests the potential for a longer growing season throughout the region. Growing season precipitation is projected to moderately increase over the region with the wetter conditions of the southern portion of the region significantly expanding northward by the 2020s (Figure 36). Finally moderate reduction in available moisture for the region is projected for the south western and eastern borders of the region beginning in the 2020s. Further moisture reduction is projected to occur in the north by the 2050s following the warming summer temperatures (Figure 37).

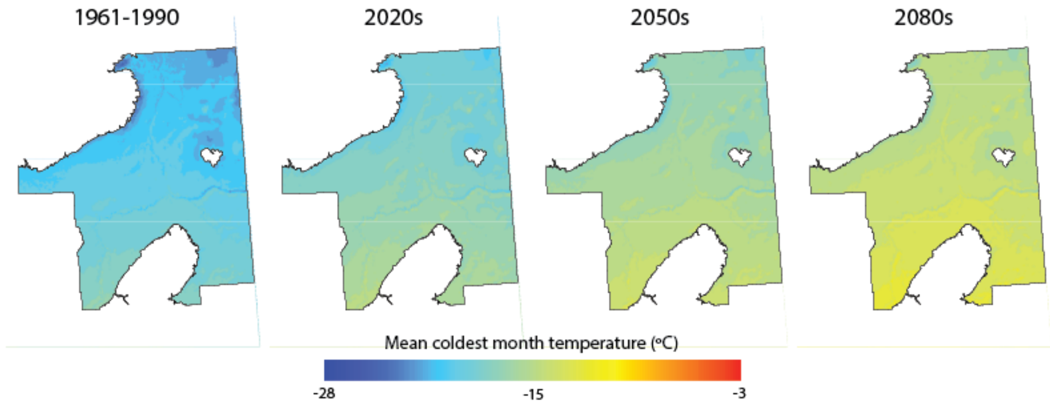

Figure 32: Current and projected future mean coldest month temperature for white spruce Control Parentage Program (CPP) region E1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

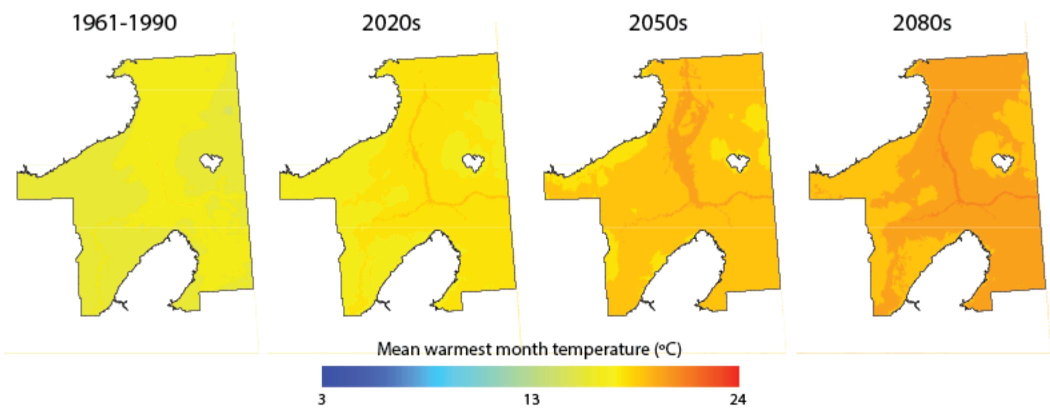

Figure 33: Current and projected future mean warmest month temperature for white spruce Control Parentage Program (CPP) region E1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

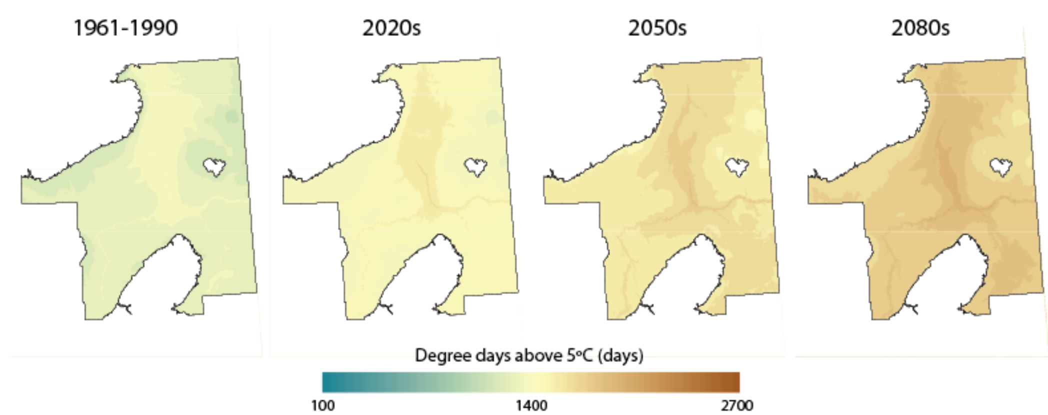

Figure 34: Current and projected future growing degree days above 5˚C for white spruce Control Parentage Program (CPP) region E1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

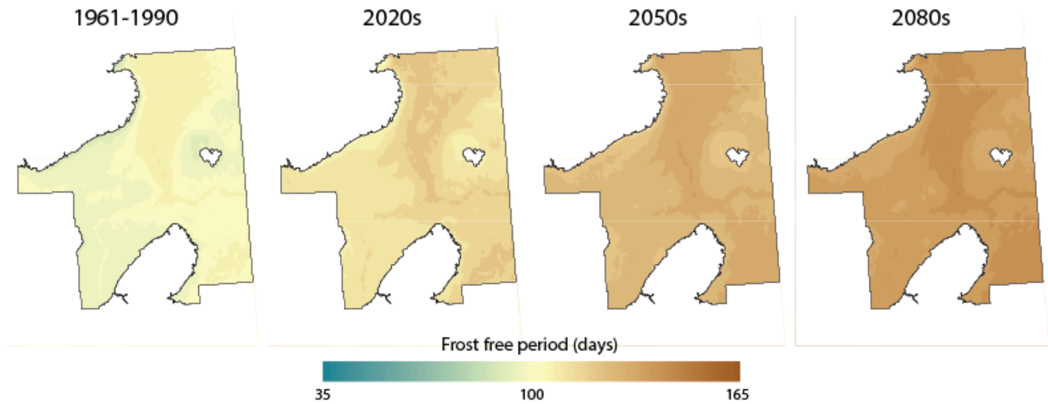

Figure 35: Current and projected future frost free period for white spruce Control Parentage Program (CPP) region E1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

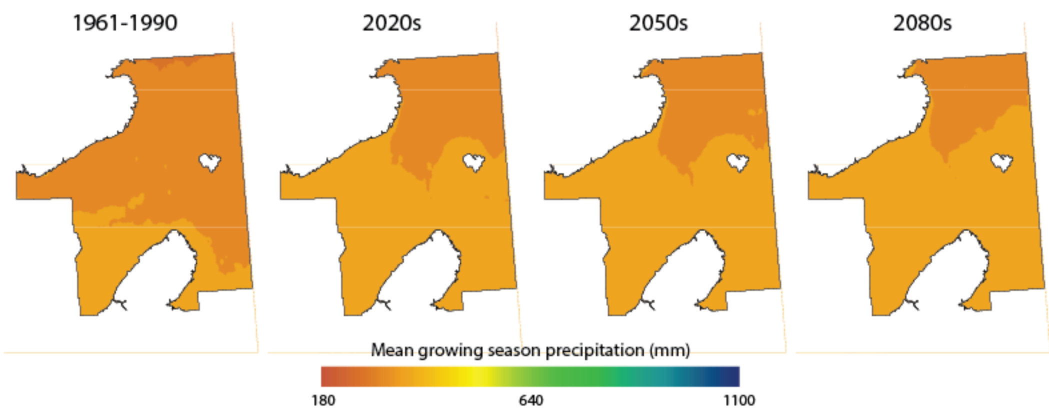

Figure 36: Current and projected mean growing season (May-September) precipitation for white spruce Control Parentage Program (CPP) region E1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

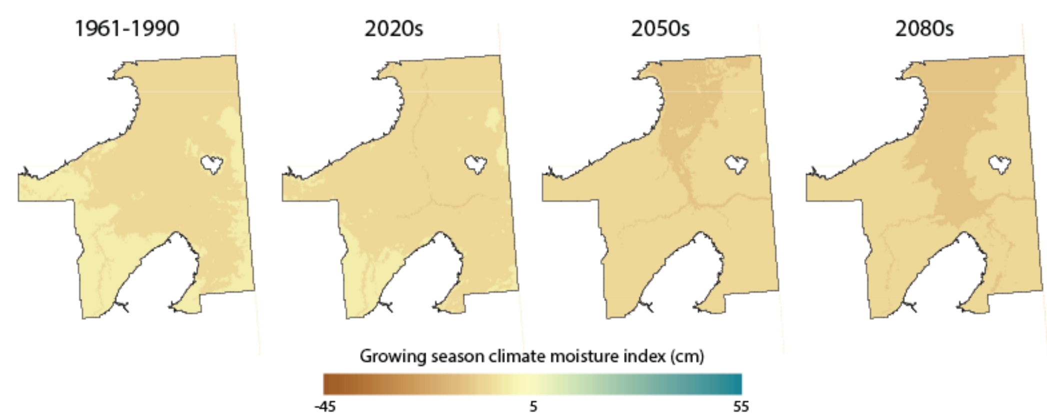

Figure 37: Current and projected future summer (June-August) climate moisture index for white spruce Control Parentage Program (CPP) region E1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

4.5 Region E2

The white spruce Control Parentage Program (CPP) region E2 is geographically located in eastern Alberta, and is made up of approximately 4,528,277 hectares. This region is comprised of dry mixedwood and parkland ecosystems with pockets of central mixedwood ecosystems around it northern perimeter. The climate of this region is characteristically dry with mild temperatures in the winter and the warm temperatures in the summer season.

Maps illustrating the shift in each of the six climate variables summarized in this report over the CPP region E2 are provided in Figures 38-43, with Figures 38-39 representing changes in winter and summer temperatures; Figures 40-41 representing changes in growing degree days and frost variables; Figure 42 represents changes in precipitation; and finally Figure 43 represents changes in summer climate moisture.

In general, the future projections suggest increased winter warming across the region towards the 2080s, with the most pronounced warming occurring in the southern portion of the region which is comprised of parkland ecosystems, reaching an approximate 4°C increase by the 2050s (Figure 38). Projected warming in the summer season is less than the winter season with approximately 2-3°C by the 2050s and is most pronounced in the southwestern portion of the region which again represents the parkland ecosystems (Figure 39). Further the number of growing degree days above 5°C as well as frost free period are projected to significantly increase by the 2050s, with large changes projected for the southern portion of the region (Figure 40 and Figure 41). This suggests a strong potential for a longer growing season in the southern portion of the region. Growing season precipitation is projected to moderately increase in the western portion of the region by the 2020s, but slows thereafter (Figure 42). Finally changes in available climate moisture are projected to follow the changes in degree days above 5°C, with the largest reductions occurring in the southeastern portion of the region by as early as the 2050s (Figure 43).

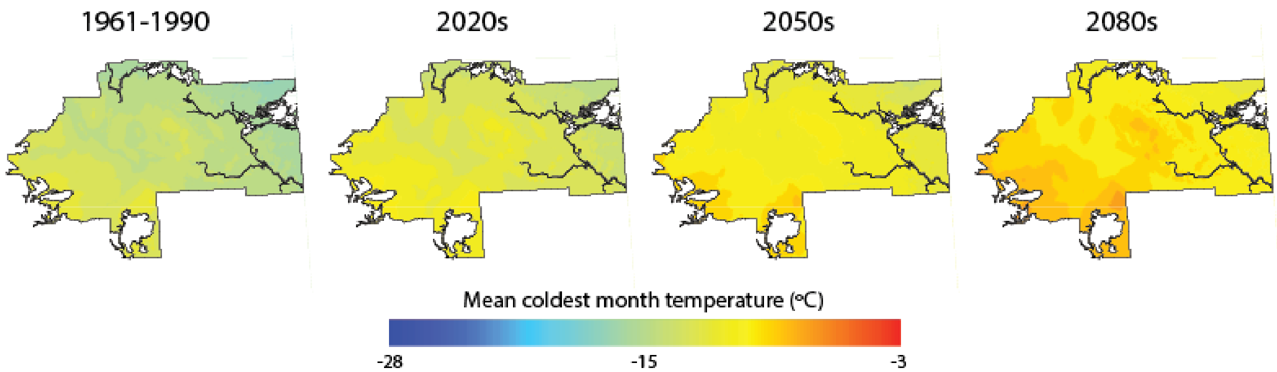

Figure 38: Current and projected future mean coldest month temperature for white spruce Control Parentage Program (CPP) region E2. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

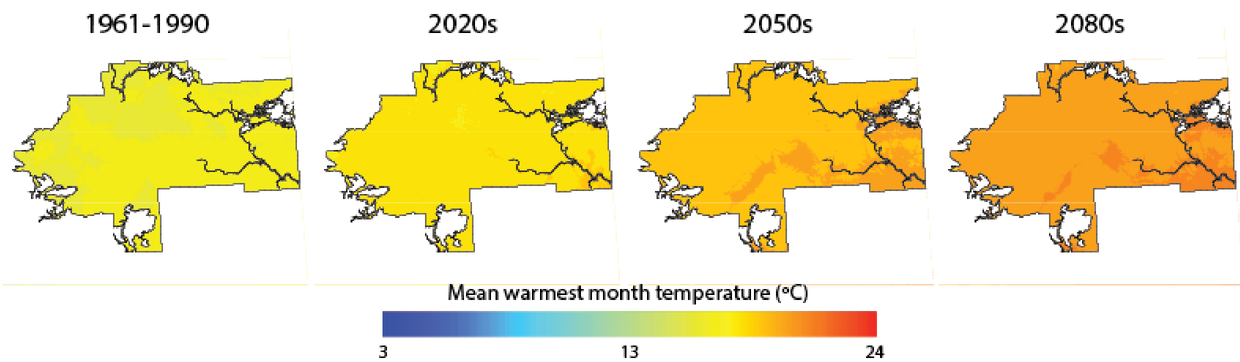

Figure 39: Current and projected future mean warmest month temperature for white spruce Control Parentage Program (CPP) region E2. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

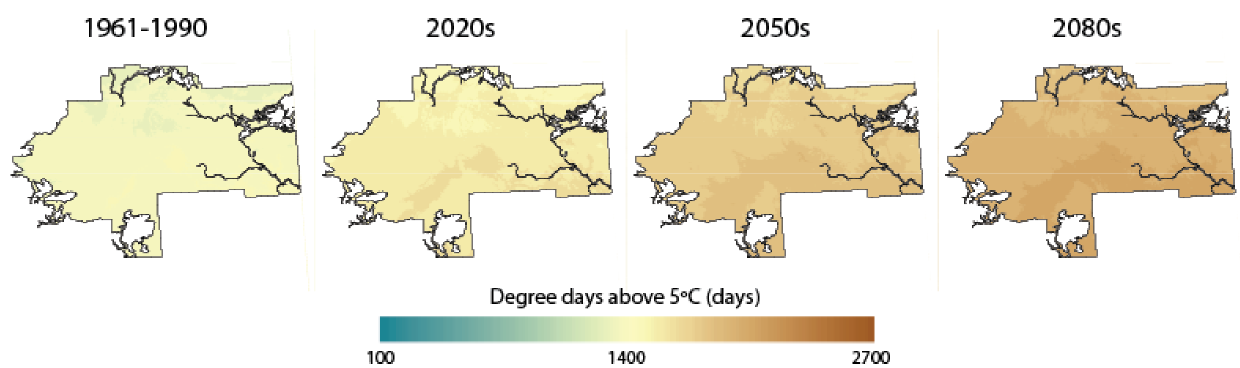

Figure 40: Current and projected future growing degree days above 5°C for white spruce Control Parentage Program (CPP) region E2. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

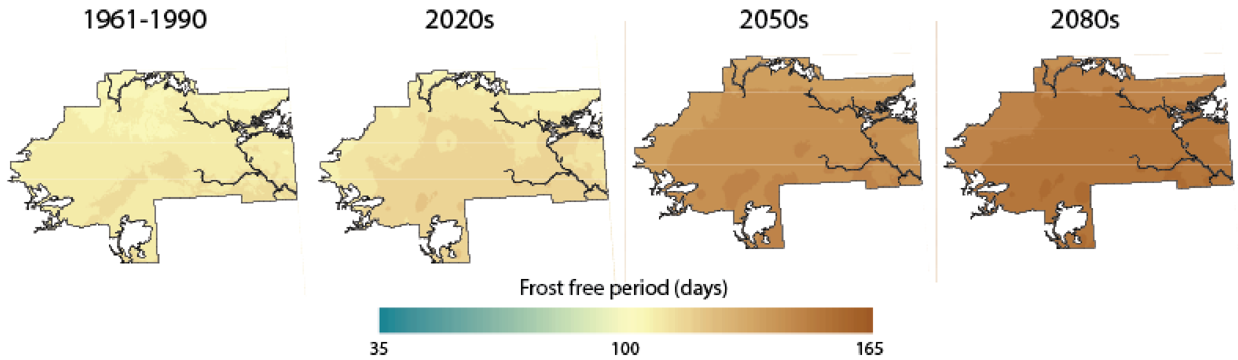

Figure 41: Current and projected future frost free period for white spruce Control Parentage Program (CPP) region E2. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

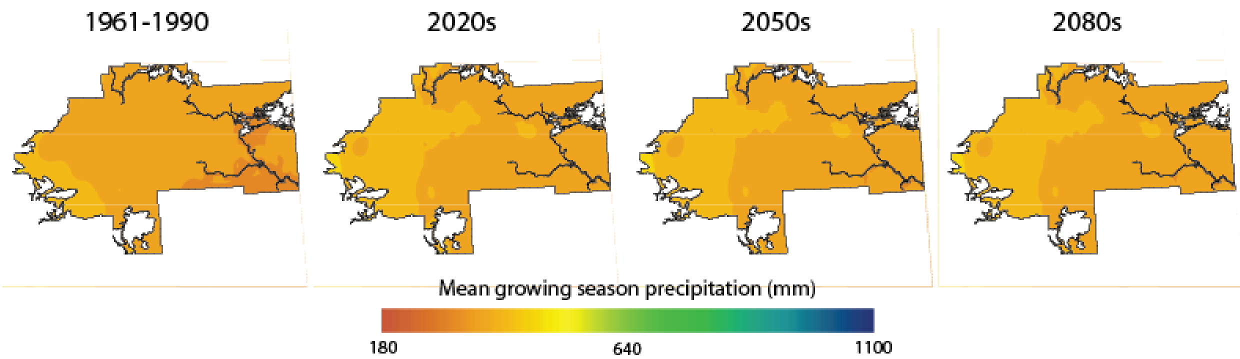

Figure 42: Current and projected mean growing season (May-September) precipitation for white spruce Control Parentage Program (CPP) region E2. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

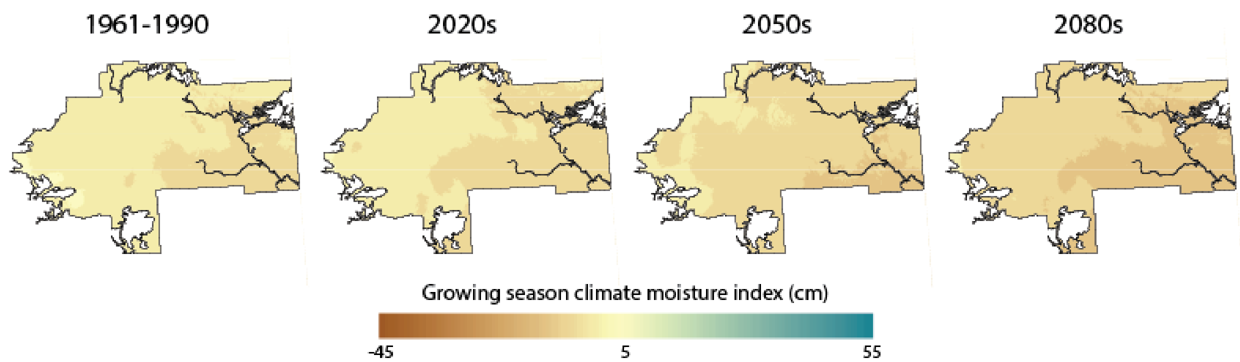

Figure 43: Current and projected future summer (June-August) climate moisture index for white spruce Control Parentage Program (CPP) region E2. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

4.6 Region G1

The white spruce Control Parentage Program (CPP) region G1 is geographically located in western Alberta, and is made up of approximately 2,646,559 hectares. This region is comprised of dry mixedwood, central mixedwood, lower foothills, and Peace River parkland ecosystems. The climate of this region is characteristically dry with mild temperatures in the winter and warm temperatures in the summer season.

Maps illustrating the shift in each of the six climate variables summarized in this report over the CPP region G1 are provided in Figures 44-49, with Figures 44-45 representing changes in winter and summer temperatures; Figures 46-47 representing changes in growing degree days and frost variables; Figure 48 represents changes in precipitation; and finally Figure 49 represents changes in summer climate moisture.

In general, the future projections suggest increasing winter warming across the region towards the 2080s, with the most pronounced warming occurring in the areas comprised of the lower foothills ecosystems. Along the southern border of the region this warming is significant, reaching an approximate 6-7°C increase by the 2080s (Figure 44). Projected warming in the summer season is of a lesser magnitude than the winter season with approximately 3-4°C by the 2050s and is more uniformly distributed over the region (Figure 45). Further the number of growing degree days above 5°C as well as frost free period are projected to significantly increase by the 2050s, with large changes projected for the western border of the region as well as the lower elevation areas in the region’s center (Figure 46 and Figure 47). This suggests a strong potential for a longer growing season in the southern portion of the region. Little change in summer precipitation is projected over the region, however there are small pockets where precipitation is projected to moderately increase (Figure 48). Finally reductions in available climate moisture are projected to be moderate and generally contained to the central mixedwood and dry mixedwood ecosystems within the region (Figure 49).

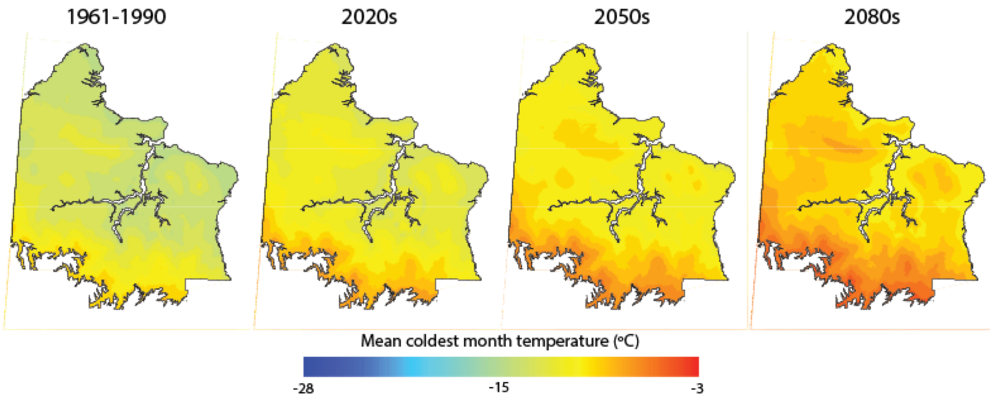

Figure 44: Current and projected future mean coldest month temperature for white spruce Control Parentage Program (CPP) region G1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

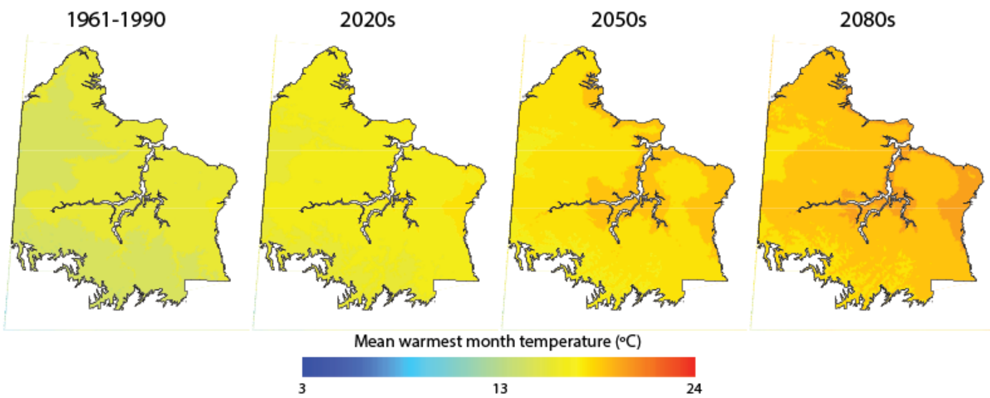

Figure 45: Current and projected future mean warmest month temperature for white spruce Control Parentage Program (CPP) region G1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

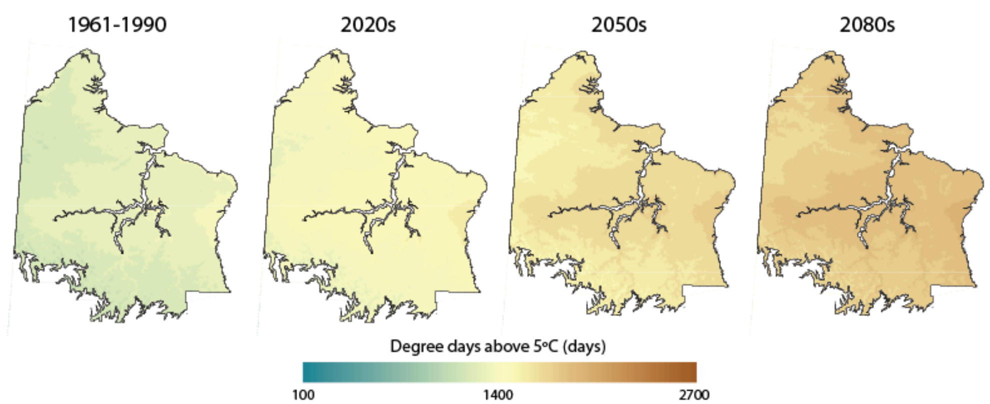

Figure 46: Current and projected future growing degree days above 5°C for white spruce Control Parentage Program (CPP) region G1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

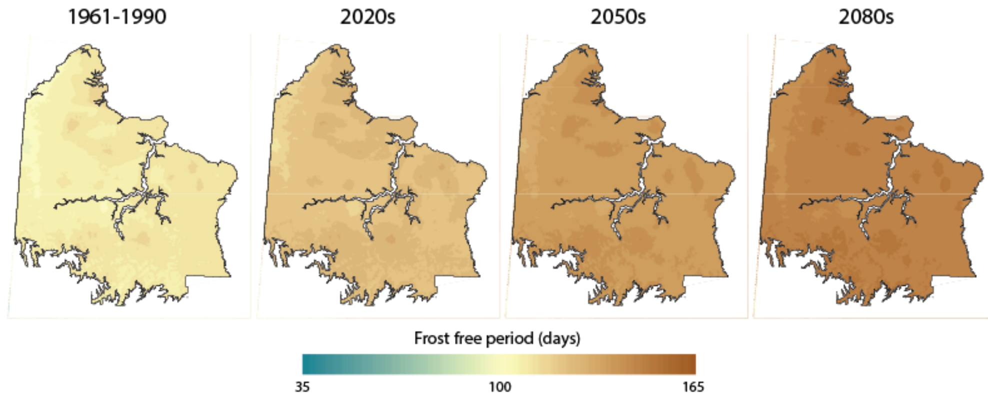

Figure 47: Current and projected future frost free period for white spruce Control Parentage Program (CPP) region G1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

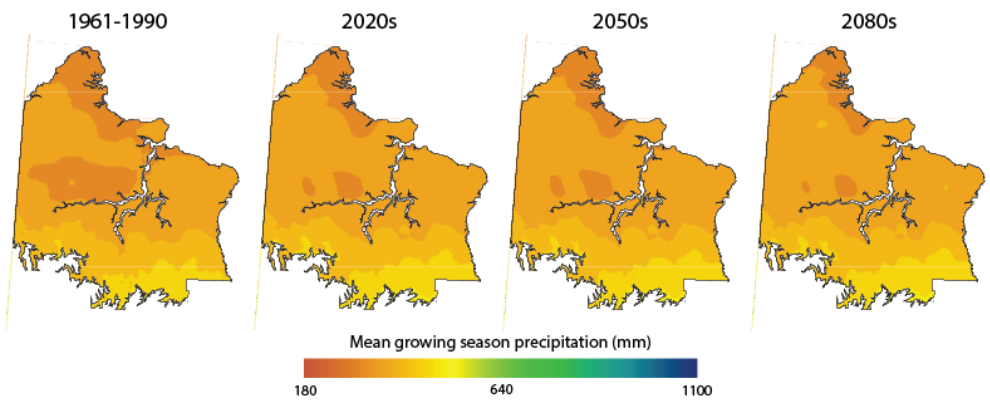

Figure 48: Current and projected mean growing season (May-September) precipitation for white spruce Control Parentage Program (CPP) region G1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

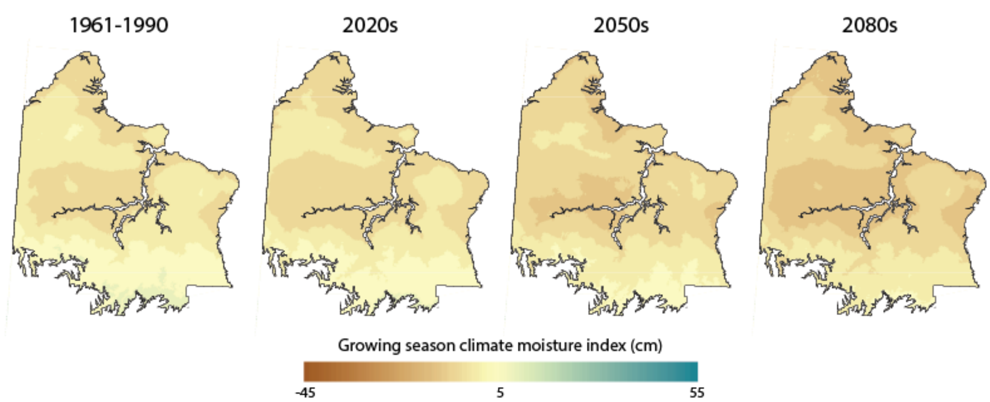

Figure 49: Current and projected future summer (June-August) climate moisture index for white spruce Control Parentage Program (CPP) region G1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

4.7 Region G2

The white spruce Control Parentage Program (CPP) region G2 is geographically located in western Alberta, and is made up of approximately 3,072,903 hectares. This region is comprised of lower boreal highlands, central mixedwood, and Peace River parkland ecosystems. The climate of this region is characteristically dry with cold temperatures in the winter and mild temperatures in the summer season.

Maps illustrating the shift in each of the six climate variables summarized in this report over the CPP region G2 are provided in Figures 50-55, with Figures 50-51 representing changes in winter and summer temperatures; Figures 52-53 representing changes in growing degree days and frost variables; Figure 54 represents changes in precipitation; and finally Figure 55 represents changes in summer climate moisture.

In general, the future projections suggest increasing winter warming across the region towards the 2080s, reaching an approximate 4°C increase by the 2050s (Figure 50). Projected warming in the summer season is of a slightly lesser magnitude than the winter season with approximately 2-3°C by the 2050s and is most pronounced in the central mixedwood ecosystems (Figure 51). Further the number of growing degree days above 5°C as well as frost free period are projected to moderately increase by the 2020s, but accelerate towards the 2080s, with large changes projected again for the central mixedwood ecosystems (Figure 52 and Figure 53). This suggests a potential for a longer growing season in the southern portion of the region. Little change in summer precipitation is projected over the region, however there are small pockets where precipitation is projected to moderately increase in the lower boreal highlands (Figure 54). Finally reductions in available climate moisture are projected to be moderate by the 2020s, but accelerate towards the 2080s, extending from the central mixedwood ecosystems located along the eastern border of the region (Figure 55).

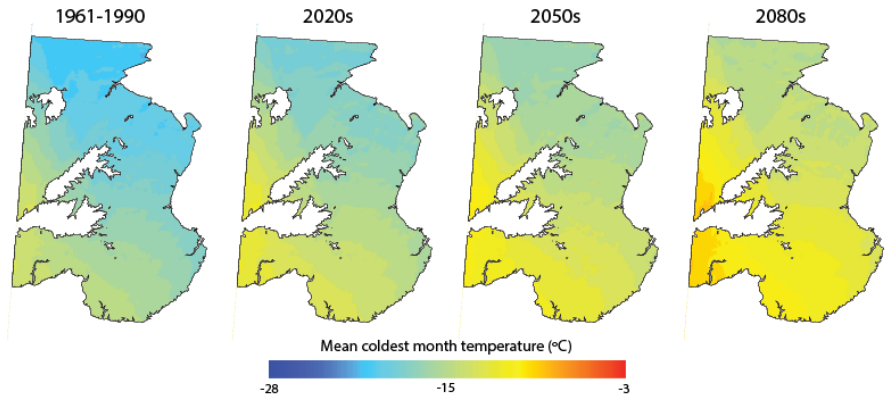

Figure 50: Current and projected future mean coldest month temperature for white spruce Control Parentage Program (CPP) region G2. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

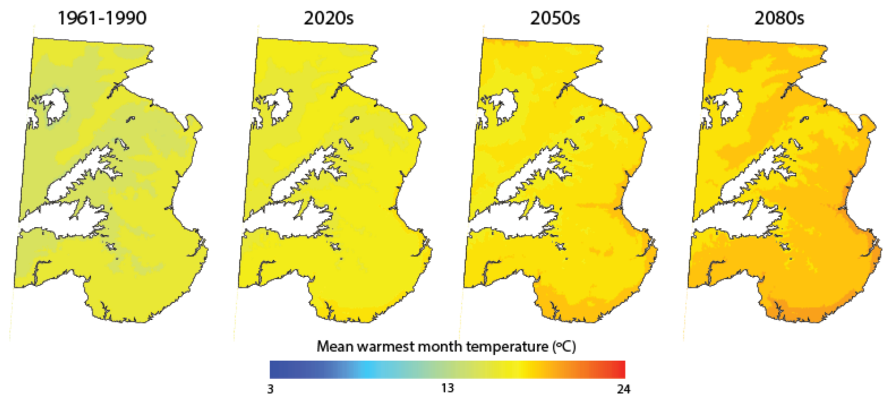

Figure 51: Current and projected future mean warmest month temperature for white spruce Control Parentage Program (CPP) region G2. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

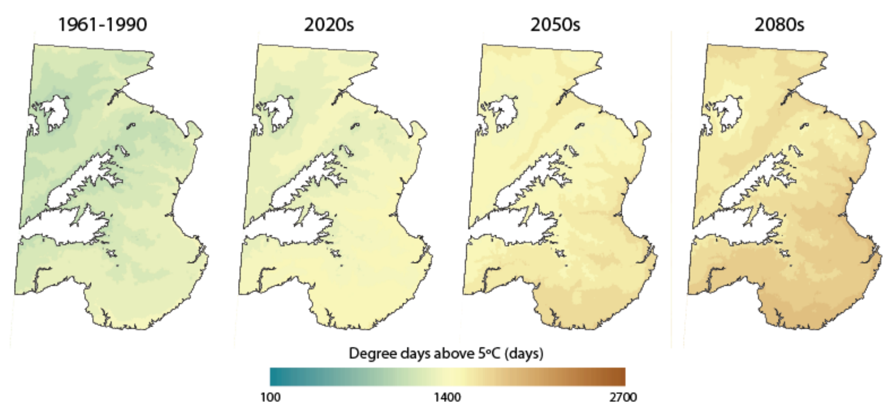

Figure 52: Current and projected future growing degree days above 5˚C for white spruce Control Parentage Program (CPP) region G2. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

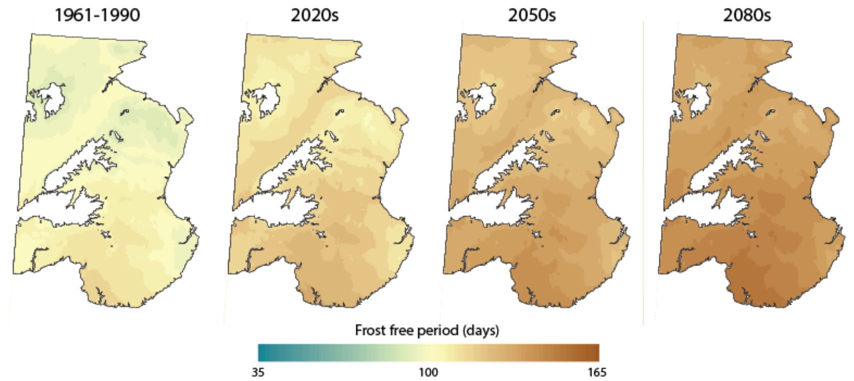

Figure 53: Current and projected future frost free period for white spruce Control Parentage Program (CPP) region G2. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

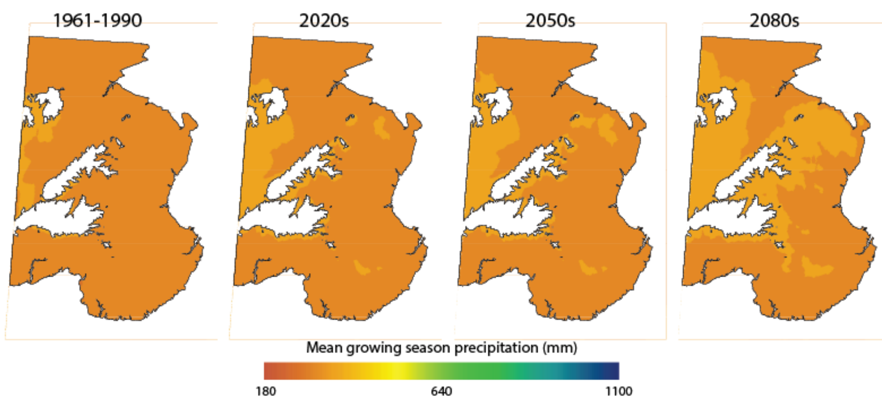

Figure 54: Current and projected mean growing season (May-September) precipitation for white spruce Control Parentage Program (CPP) region G2. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

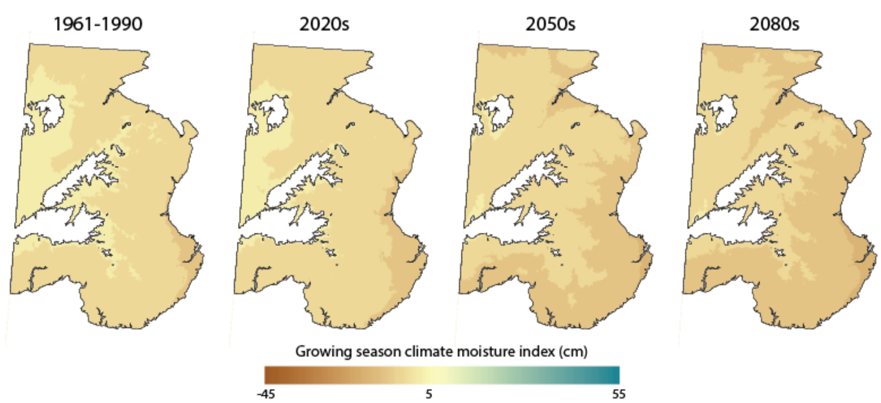

Figure 55: Current and projected future summer (June-August) climate moisture index for white spruce Control Parentage Program (CPP) region G2. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

4.8 Region H

The white spruce Control Parentage Program (CPP) region H is the most northern white spruce region, and is made up of approximately 5,009,373 hectares. This region is comprised of lower boreal highlands, central mixedwood, and dry mixedwood ecosystems, with pockets of northern mixedwood ecosystems along the northern border of the region. The climate of this region is characteristically dry with cold temperatures in the winter and warm temperatures in the summer season.

Maps illustrating the shift in each of the six climate variables summarized in this report over the CPP region H are provided in Figures 56-61, with Figures 56-57 representing changes in winter and summer temperatures; Figures 58-59 representing changes in growing degree days and frost variables; Figure 60 represents changes in precipitation; and finally Figure 61 represents changes in summer climate moisture.

In general, the future projections suggest increasing winter warming across the region towards the 2080s, with the most pronounced warming projected for the northern portion of the region comprised of the central and northern mixedwood ecosystems. Projected winter warming in CPP region H is the most significant of all the white spruce regions, reaching an approximate 10°C increase in the most northern corners of the region by the 2080s (Figure 56). Projected warming in the summer season is of a lesser magnitude than the winter season with approximately 3-4°C by the 2050s and is most pronounced in the dry mixedwood ecosystems (Figure 57). Further the number of growing degree days above 5°C as well as frost free period are projected to moderately increase by the 2020s, but accelerate towards the 2080s, with large changes projected again for the dry mixedwood ecosystems (Figure 58 and Figure 59). This suggests a potential for a longer growing season in the southern portion of the region. Growing season precipitation is projected to moderately increase over the region with the wetter conditions of the southern portion of the region significantly expanding northward by the 2020s, but slows thereafter (Figure 60). Finally reductions in available climate moisture are projected to be moderate by the 2020s, but accelerate towards the 2080s, extending from the dry mixedwood ecosystems to the remainder of the region (Figure 61).

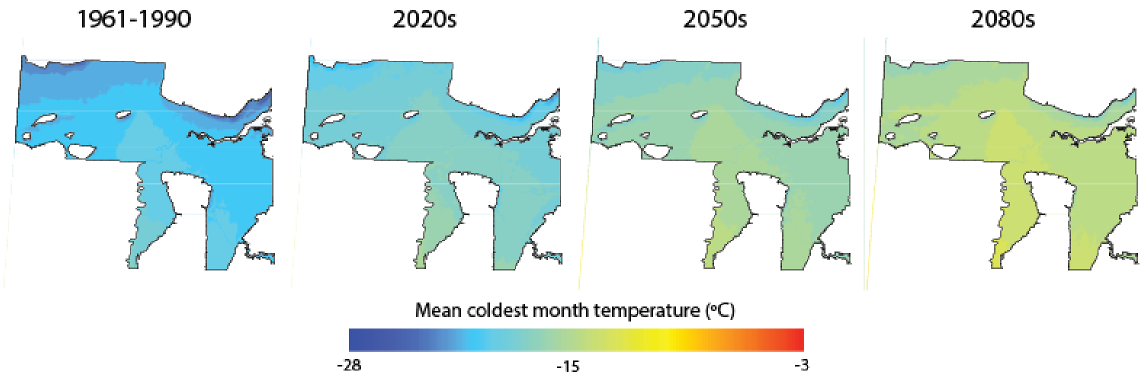

Figure 56: Current and projected future mean coldest month temperature for white spruce Control Parentage Program (CPP) region H. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

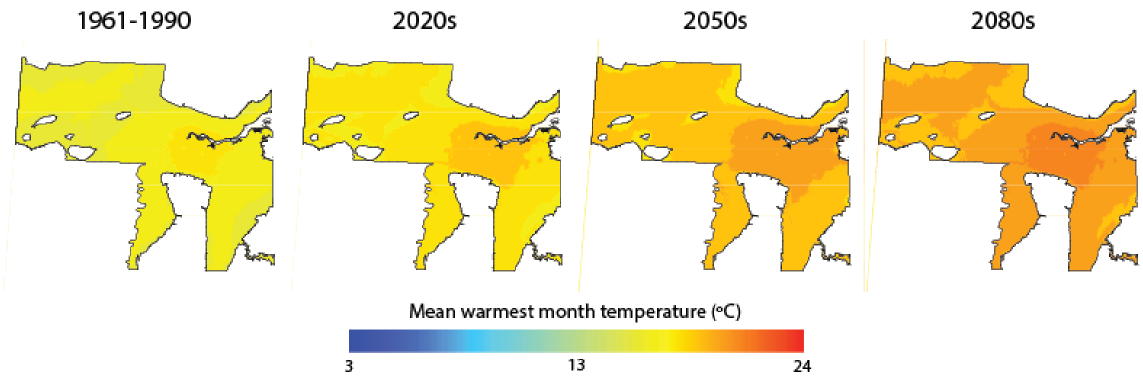

Figure 57: Current and projected future mean warmest month temperature for white spruce Control Parentage Program (CPP) region H. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

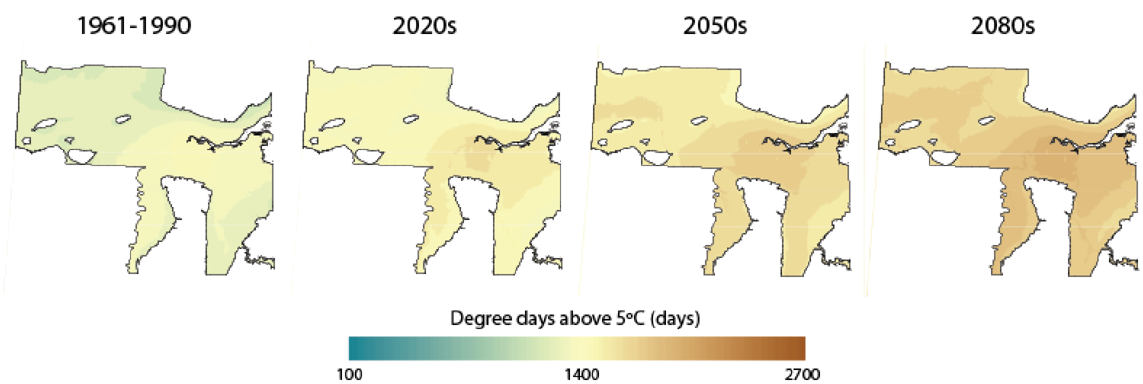

Figure 58: Current and projected future growing degree days above 5°C for white spruce Control Parentage Program (CPP) region H. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

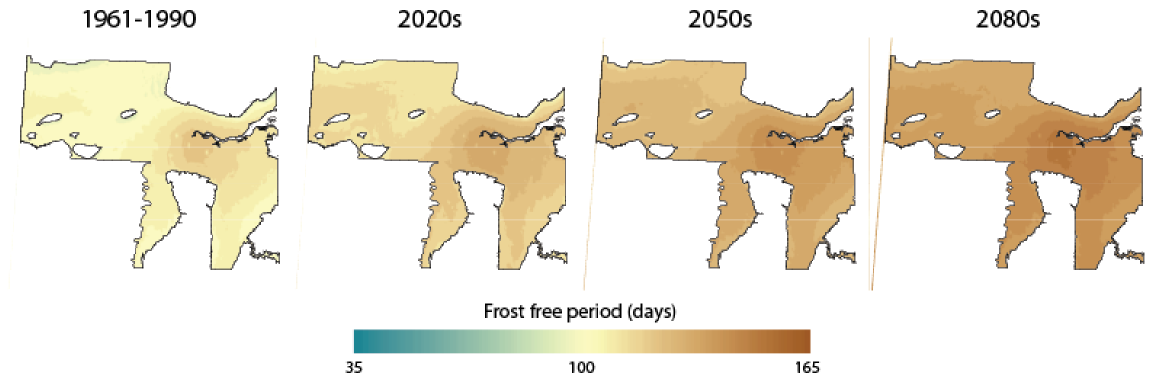

Figure 59: Current and projected future frost free period for white spruce Control Parentage Program (CPP) region H. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

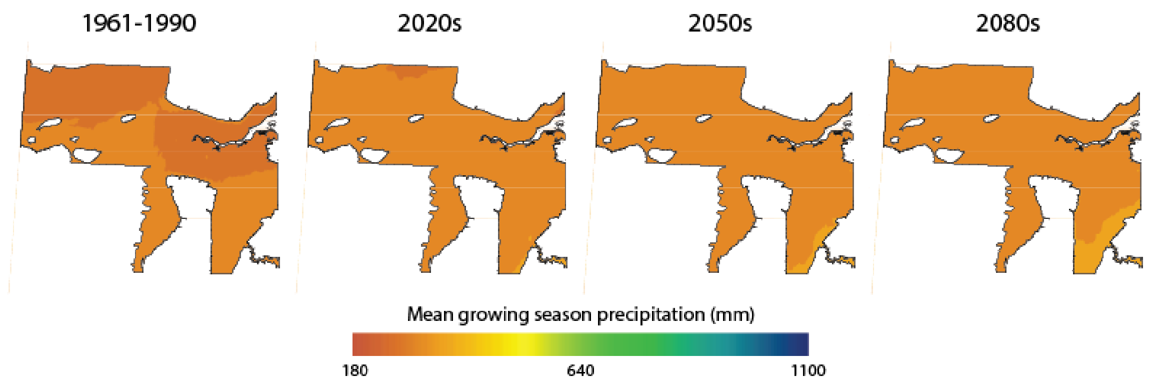

Figure 60: Current and projected mean growing season (May-September) precipitation for white spruce Control Parentage Program (CPP) region H. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

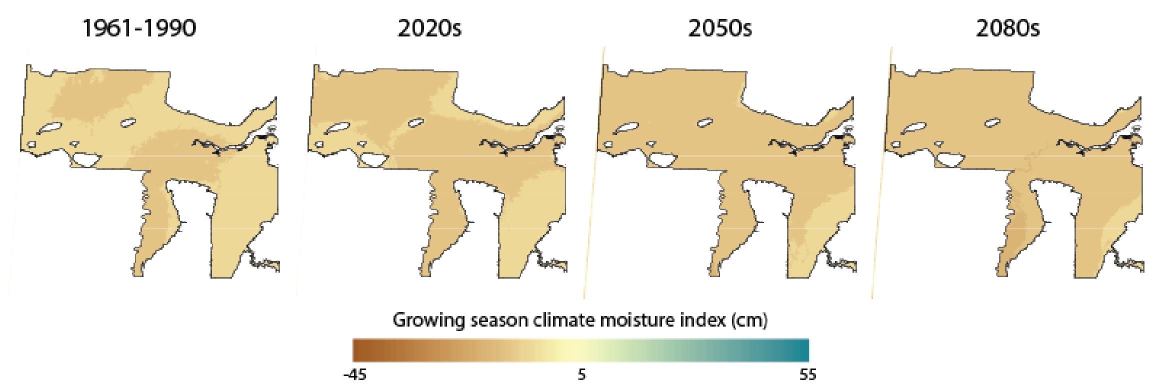

Figure 61: Current and projected future summer (June-August) climate moisture index for white spruce Control Parentage Program (CPP) region H. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

4.9 Region I

The white spruce Control Parentage Program (CPP) region I is the most southern white spruce region, and is made up of approximately 5,009,373 hectares with parts of the region overlapping with the CPP regions D and D1. This region is mainly comprised of lower foothills ecosystems, with pockets of central mixedwood and upper foothills ecosystems along the northwestern and southwestern borders of the region, respectively. The climate of this region is characteristically wet with mild temperatures in both the winter and summer seasons.

Maps illustrating the shift in each of the six climate variables summarized in this report over the CPP region I are provided in Figures 62-67, with Figures 62-63 representing changes in winter and summer temperatures; Figures 64-65 representing changes in growing degree days and frost variables; Figure 66 represents changes in precipitation; and finally Figure 67 represents changes in summer climate moisture.

In general, the future projections suggest increasing winter warming across the region towards the 2080s, with the most pronounced warming projected for the eastern and southern portions of the region comprised of upper foothill ecosystems. Projected winter warming in CPP region I is moderate compared to some of the other white spruce regions, reaching an approximate 2-3°C increase by the 2050s (Figure 62). Projected warming in the summer season is of equal magnitude to projected winter warming in the 2050s and is fairly uniform across the region (Figure 63). By the 2080s, summer warming is projected to be most pronounced in the lower foothills ecosystems within the region. Further the number of growing degree days above 5°C as well as frost free period are projected to moderately increase by the 2020s, but accelerate towards the 2080s, with large changes projected again for the lower foothill ecosystems (Figure 64 and Figure 65). This suggests a potential for a longer growing season over the region. Little change in summer precipitation is projected over the region; however small pockets of moderate precipitation increase are projected by the 2020s stemming from the upper foothill ecosystems (Figure 66). Finally moderate temperature increases projected in the summer season (Figure 63) coupled with little precipitation change is projected to result in a slight reduction in available moisture for the region (Figure 67).

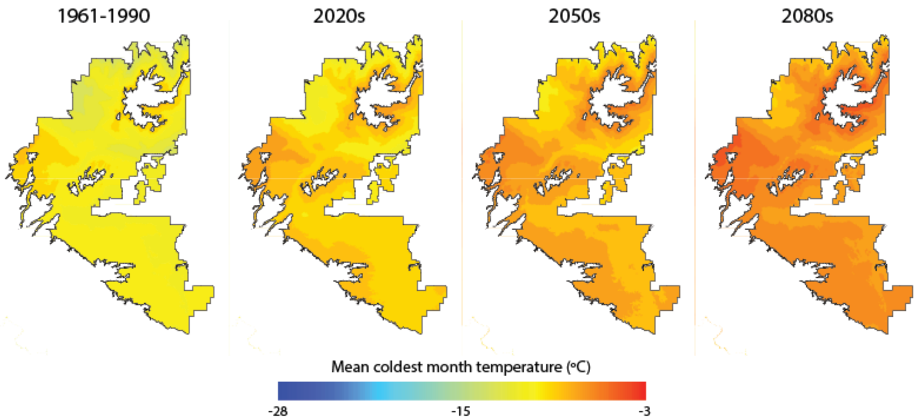

Figure 62: Current and projected future mean coldest month temperature for white spruce Control Parentage Program (CPP) region I. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

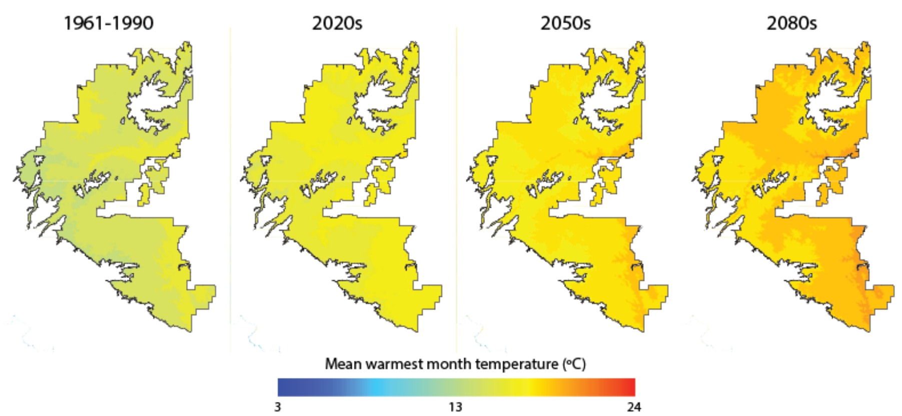

Figure 63: Current and projected future mean warmest month temperature for white spruce Control Parentage Program (CPP) region I. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

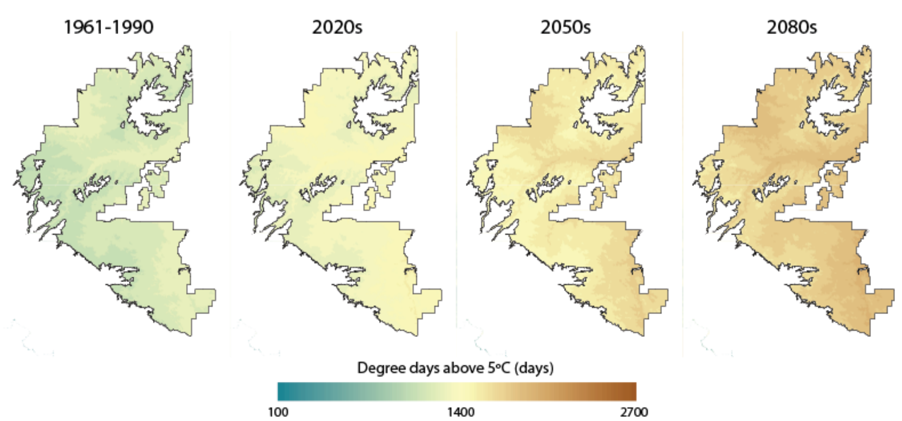

Figure 64: Current and projected future growing degree days above 5˚C for white spruce Control Parentage Program (CPP) region I. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

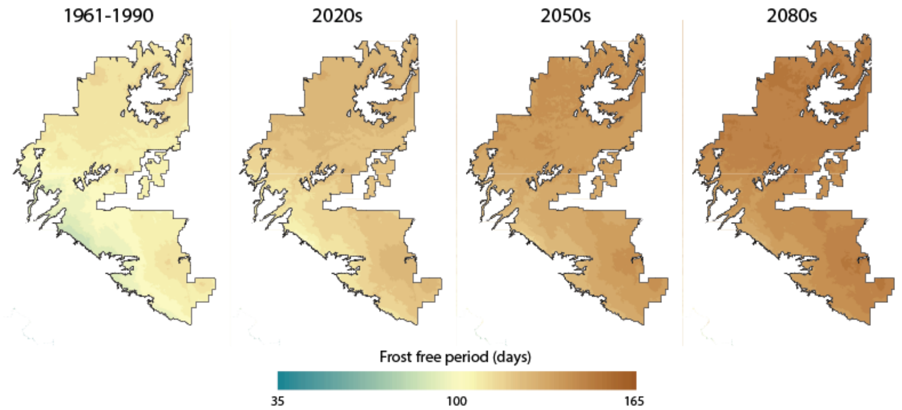

Figure 65: Current and projected future frost free period for white spruce Control Parentage Program (CPP) region I. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

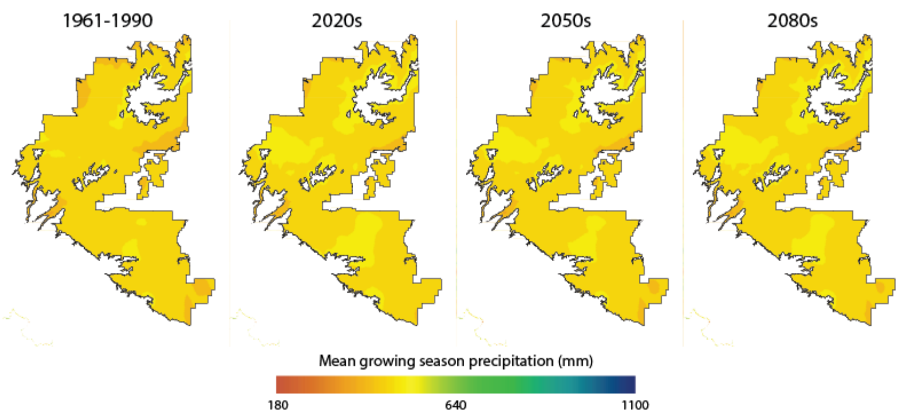

Figure 66: Current and projected mean growing season (May-September) precipitation for white spruce Control Parentage Program (CPP) region I. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

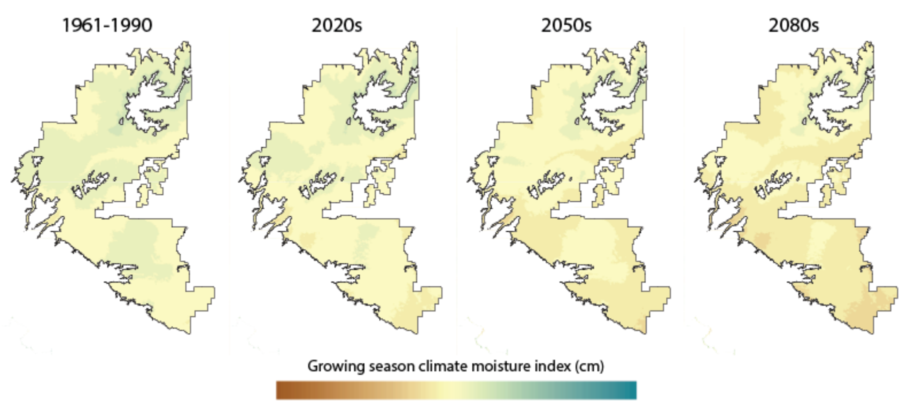

Figure 67: Current and projected future summer (June-August) climate moisture index for white spruce Control Parentage Program (CPP) region I. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

5.0 Projected climate shifts: Lodgepole Pine Control Parentage Program Regions

Maps illustrating the shift in each of the six climate variables summarized in this report over each of the six lodgepole pine (*Pinus contorta*) Control Parentage Program (CPP) regions (Figure 68) are provided in the following subsections.

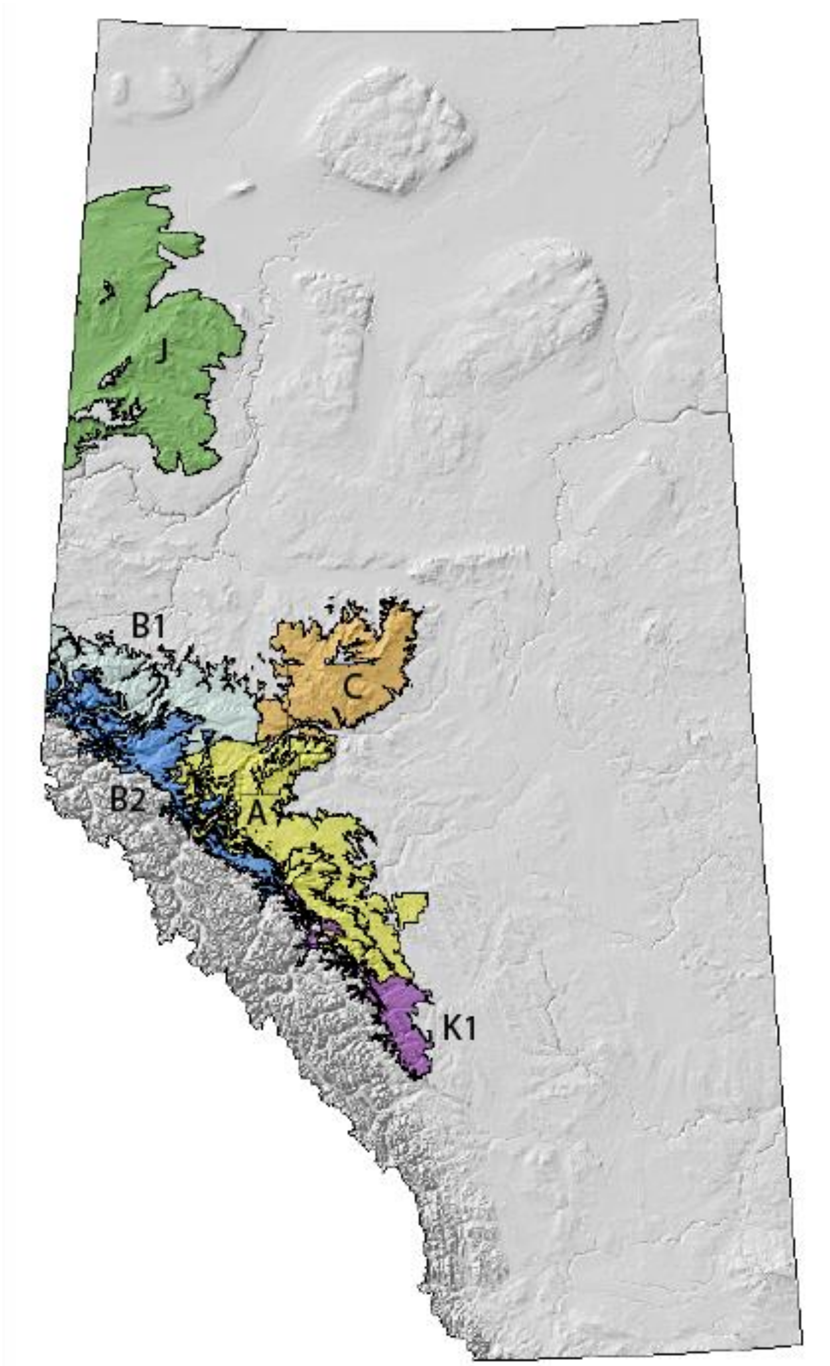

Figure 68: The six regions of the lodgepole pine (*Pinus contorta*) Control Parentage Program (CPP).

5.1 Region A

The lodgepole pine Control Parentage Program (CPP) region A has recently been expanded, and now is made up of approximately 1,965,478 hectares with parts of the region overlapping with the CPP regions B1, B2, C, and K1. This region is mainly comprised of lower foothill ecosystems, with pockets of upper foothills ecosystems along western borders of the region. The climate of this region is characteristically wet with mild temperatures in both the winter and summer seasons.

Maps illustrating the shift in each of the six climate variables summarized in this report over the CPP region A are provided in Figures 69-74, with Figures 69-70 representing changes in winter and summer temperatures; Figures 71-72 representing changes in growing degree days and frost variables; Figure 73 represents changes in precipitation; and finally Figure 74 represents changes in summer climate moisture.

In general, the future projections suggest increasing winter warming across the region beginning in the 2020s and accelerating towards the 2080s, with the most pronounced warming projected for upper foothill ecosystems within the region, reaching an approximate 2-3°C increase by the 2050s (Figure 69). Projected warming in the summer season is of equal magnitude to projected winter warming in the 2050s, however in this season the most pronounced warming is projected for the lower foothills ecosystems (Figure 70). Further the number of growing degree days above 5°C as well as frost free period are projected to moderately increase by the 2020s, but accelerate towards the 2080s, with the projected changes following the change in summer temperatures as seen in the lower foothill ecosystems (Figure 71 and Figure 72). This suggests a potential for a longer growing season over the region, especially at lower elevations. Little change in summer precipitation is projected over the region; however small pockets of moderate precipitation increase are projected by the 2020s in portions of the lower foothill ecosystems (Figure 73). Finally moderate temperature increases projected in the summer season (Figure 70) coupled with little precipitation change is projected to result in a slight reduction in available moisture for the region (Figure 74).

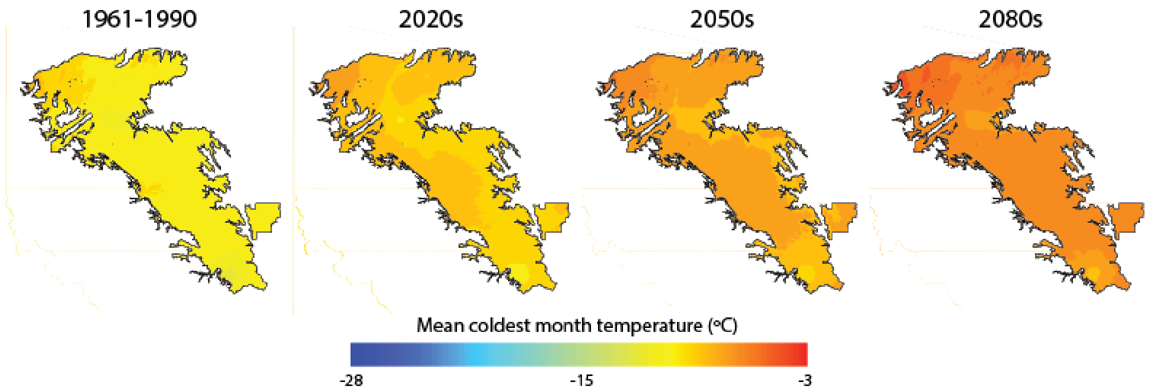

Figure 69: Current and projected future mean coldest month temperature for lodgepole pine Control Parentage Program (CPP) region A. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

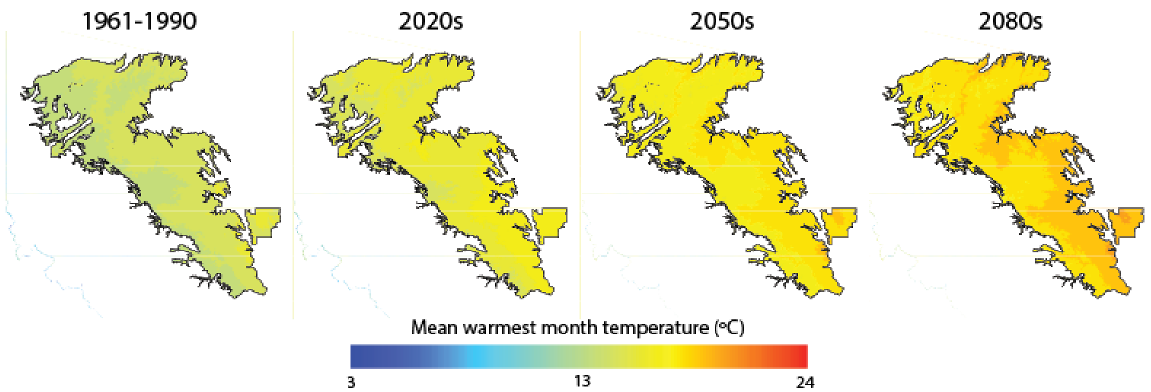

Figure 70: Current and projected future mean warmest month temperature for lodgepole pine Control Parentage Program (CPP) region A. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

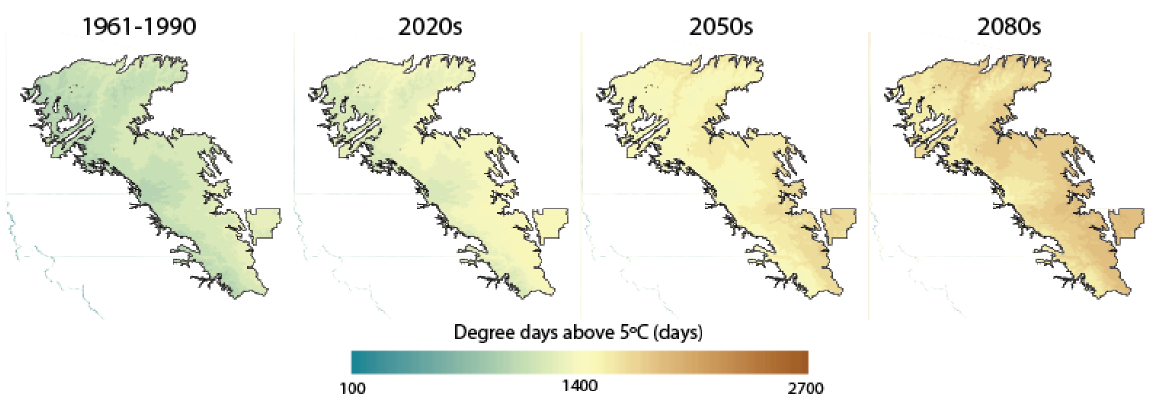

Figure 71: Current and projected future growing degree days above 5°C for lodgepole pine Control Parentage Program (CPP) region A. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

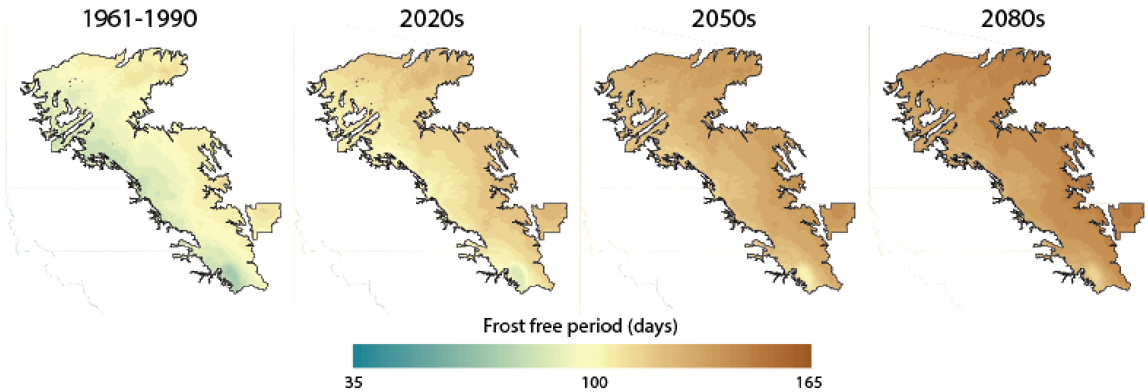

Figure 72: Current and projected future frost free period for lodgepole pine Control Parentage Program (CPP) region A. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

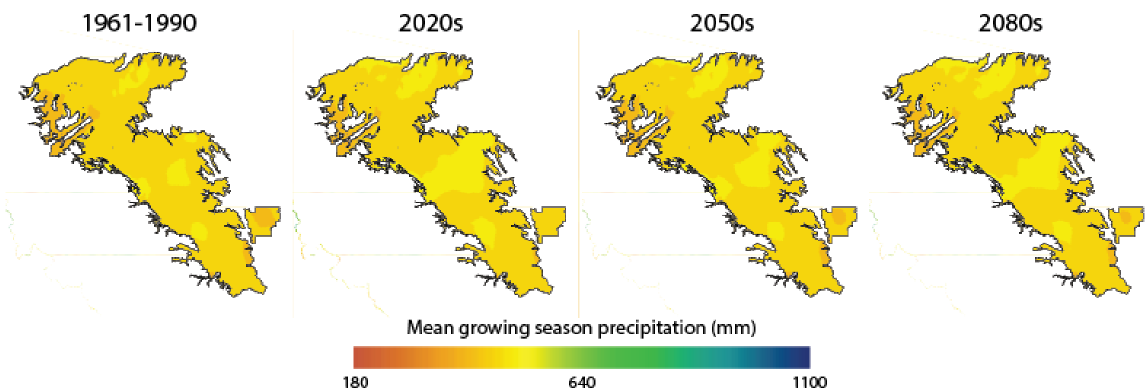

Figure 73: Current and projected mean growing season (May-September) precipitation for lodgepole pine Control Parentage Program (CPP) region A. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

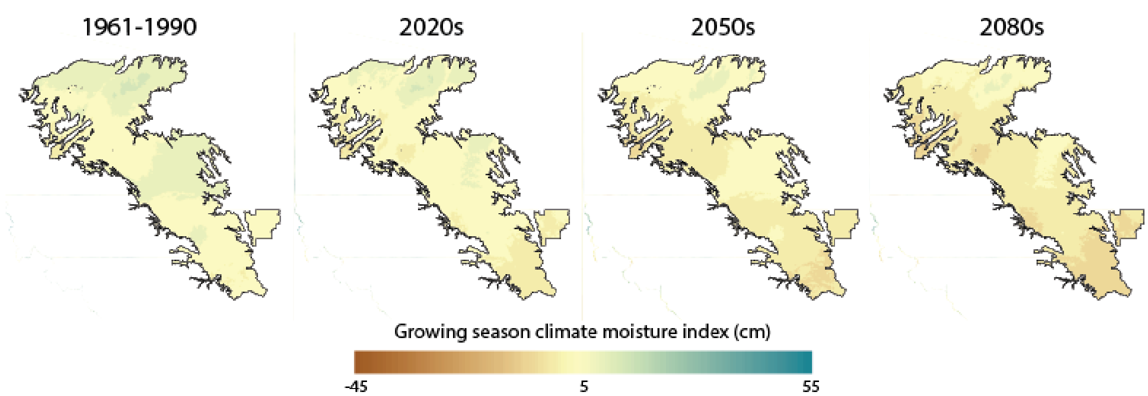

Figure 74: Current and projected future summer (June-August) climate moisture index for lodgepole pine Control Parentage Program (CPP) region A. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

5.2 Region B1

The lodgepole pine Control Parentage Program (CPP) region B1 is geographically located in western Alberta just north of the Rocky Mountain range, and is approximately 1,660,081 hectares with parts of the region overlapping with the CPP regions A, B2, and C. This region is mainly comprised of lower foothill ecosystems, with pockets of upper foothills ecosystems along southern borders of the region. The northern borders of the region follow the division between the lower foothills and central mixedwood ecosystems. The climate of this region is characteristically wet with relatively warm temperatures in the winter season and mild temperatures in the summer.

Maps illustrating the shift in each of the six climate variables summarized in this report over the CPP region B1 are provided in Figures 75-80, with Figures 75-76 representing changes in winter and summer temperatures; Figures 77-78 representing changes in growing degree days and frost variables; Figure 79 represents changes in precipitation; and finally Figure 80 represents changes in summer climate moisture.

In general, the future projections suggest increasing winter warming across the region beginning in the 2020s and accelerating towards the 2080s, with the most pronounced warming projected for upper foothill ecosystems within the region, reaching an approximate 2-3°C increase by the 2050s (Figure 75). Projected warming in the summer season is of equal magnitude to projected winter warming in the 2050s, however in this season the most pronounced warming is projected for the lower foothills ecosystems (Figure 76). Further the number of growing degree days above 5°C as well as frost free period are projected to moderately increase by the 2020s, but accelerate towards the 2080s, with the projected changes following the change in summer temperatures as seen in the lower foothill ecosystems (Figure 77 and Figure 78). This suggests a potential for a longer growing season over the region, especially at lower elevations. Little change in summer precipitation is projected over the region; however small pockets of moderate precipitation increase are projected by the 2020s in the upper foothills ecosystems (Figure 79). Finally little change in available moisture in the summer season is projected within the region (Figure 80).

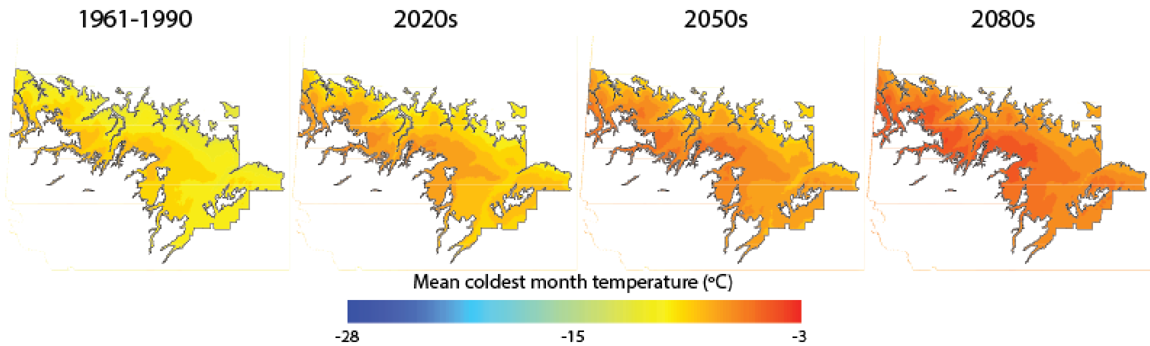

Figure 75: Current and projected future mean coldest month temperature for lodgepole pine Control Parentage Program (CPP) region B1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

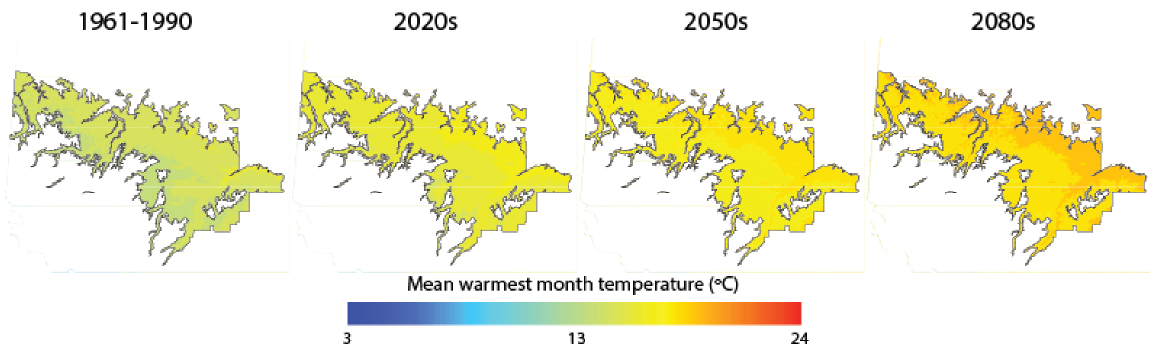

Figure 76: Current and projected future mean warmest month temperature for lodgepole pine Control Parentage Program (CPP) region B1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

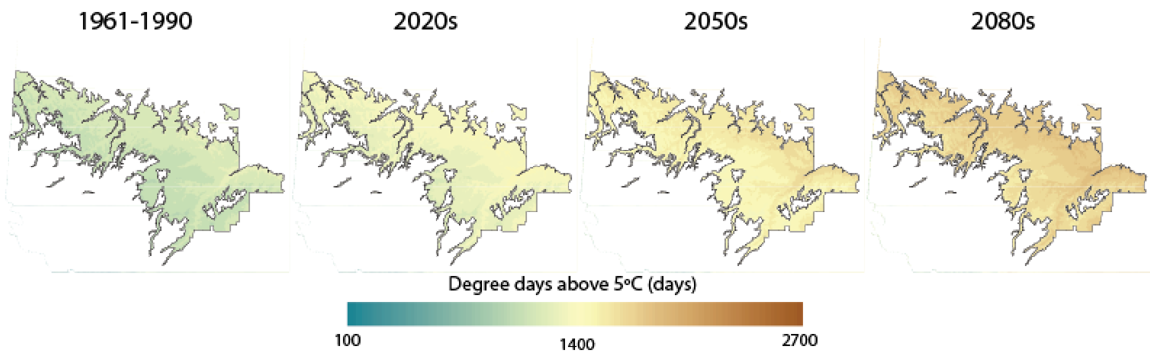

Figure 77: Current and projected future growing degree days above 5°C for lodgepole pine Control Parentage Program (CPP) region B1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

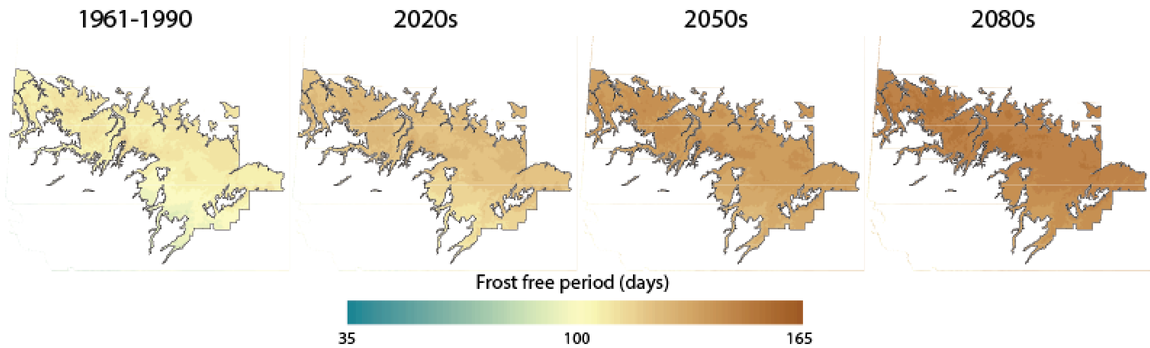

Figure 78: Current and projected future frost free period for lodgepole pine Control Parentage Program (CPP) region B1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

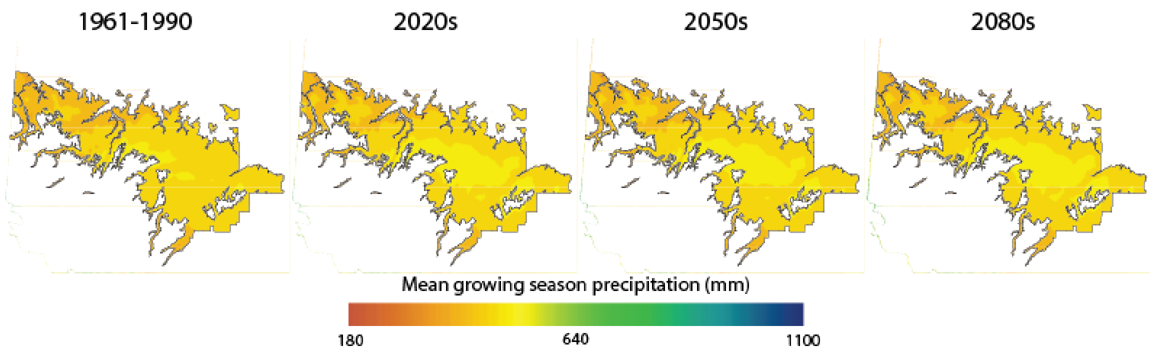

Figure 79: Current and projected mean growing season (May-September) precipitation for lodgepole pine Control Parentage Program (CPP) region B1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

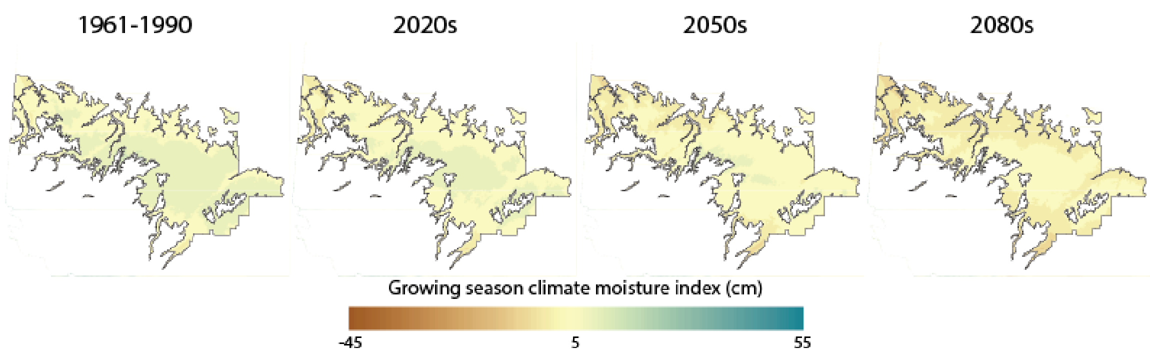

Figure 80: Current and projected future summer (June-August) climate moisture index for lodgepole pine Control Parentage Program (CPP) region B1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

5.3 Region B2

The lodgepole pine Control Parentage Program (CPP) region B2 is geographically located in western Alberta just north of the Rocky Mountain range. It is located at higher elevation than its counterpart CPP region B1, and is approximately 1,106,563 hectares with parts of the region overlapping with the CPP regions A, B1, and C. This region is comprised of upper foothill and subalpine ecosystems. The climate of this region is characteristically wet with relatively warm temperatures in the winter season and mild temperatures in the summer.

Maps illustrating the shift in each of the six climate variables summarized in this report over the CPP region B2 are provided in Figures 81-86, with Figures 81-82 representing changes in winter and summer temperatures; Figures 83-84 representing changes in growing degree days and frost variables; Figure 85 represents changes in precipitation; and finally Figure 86 represents changes in summer climate moisture.

In general, the future projections suggest increasing winter warming across the region beginning in the 2020s and accelerating towards the 2080s, with the most pronounced warming projected for the northern portion of the region, reaching an approximate 2˚C increase by the 2050s (Figure 81). Projected warming in the summer season is of equal magnitude to projected winter warming in the 2050s, however the warming is projected to occur more uniformly over the region (Figure 82). Further the number of growing degree days above 5˚C as well as frost free period are projected to moderately increase by the 2020s, but accelerate towards the 2080s, with the projected changes again occurring fairly uniformly over the region (Figure 83 and Figure 84). This suggests a potential for a longer growing season over the region. Very little change in summer precipitation is projected over the region for all periods (Figure 85). Finally only small changes in available moisture in the summer season are projected within the region, mainly occurring in the upper foothills ecosystems (Figure 86).

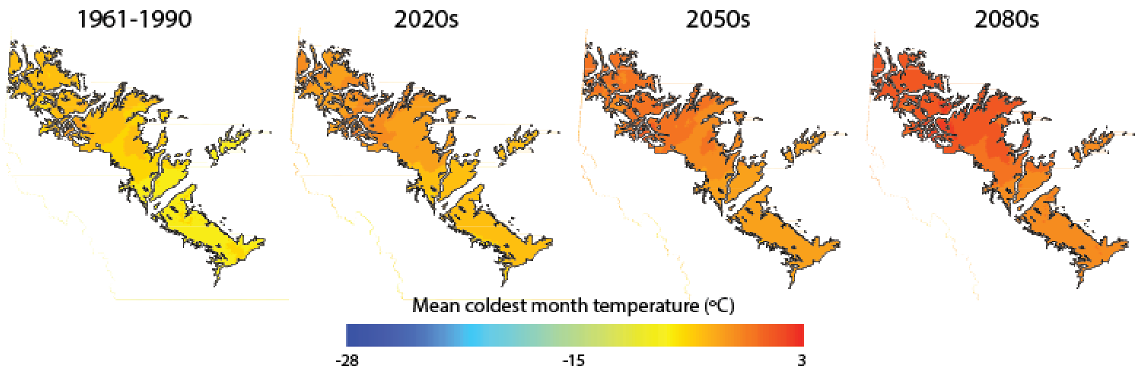

Figure 81: Current and projected future mean coldest month temperature for lodgepole pine Control Parentage Program (CPP) region B2. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

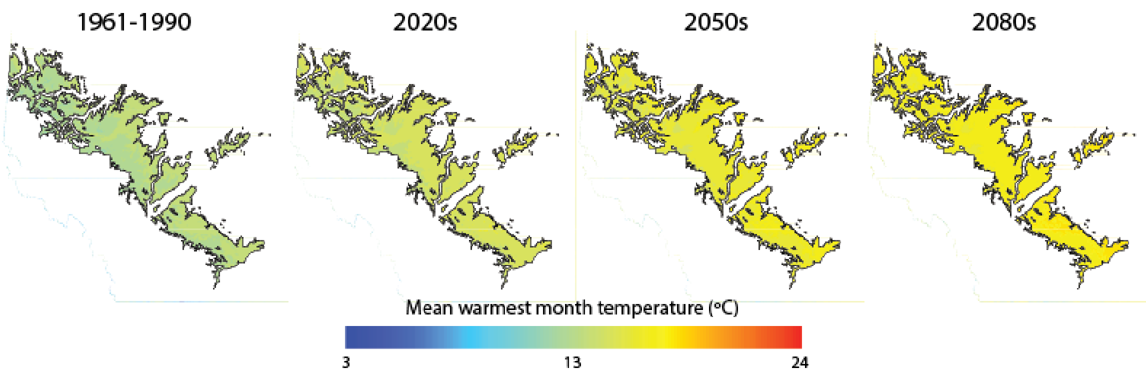

Figure 82: Current and projected future mean warmest month temperature for lodgepole pine Control Parentage Program (CPP) region B2. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

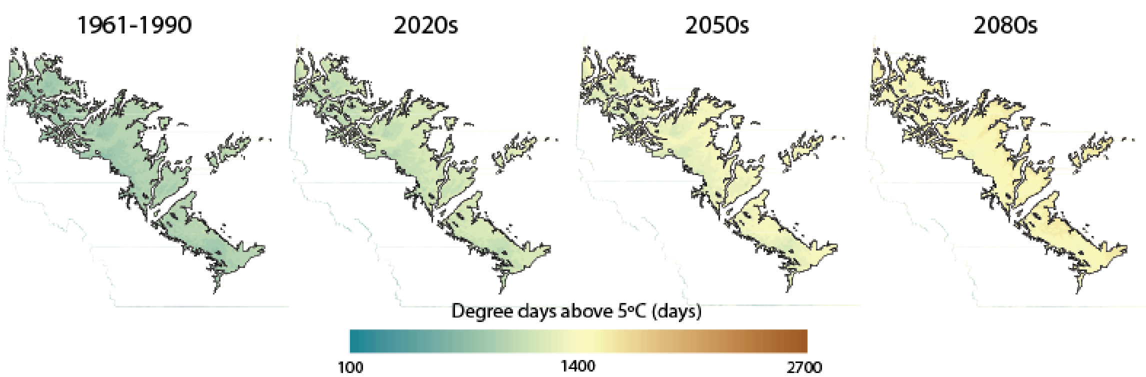

Figure 83: Current and projected future growing degree days above 5°C for lodgepole pine Control Parentage Program (CPP) region B2. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

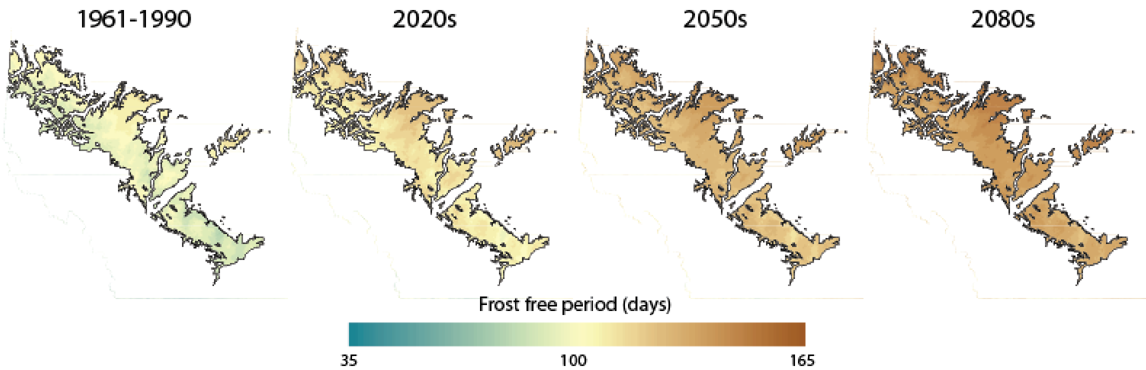

Figure 84: Current and projected future frost free period for lodgepole pine Control Parentage Program (CPP) region B2. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

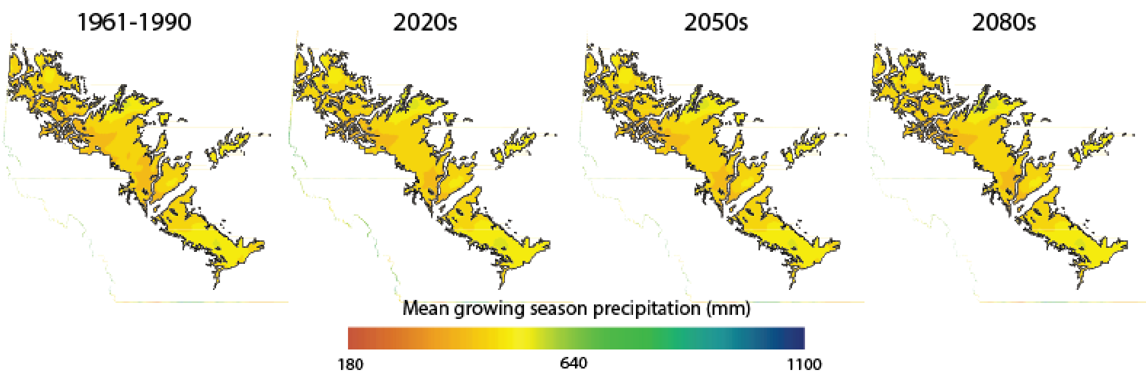

Figure 85: Current and projected mean growing season (May-September) precipitation for lodgepole pine Control Parentage Program (CPP) region B2. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

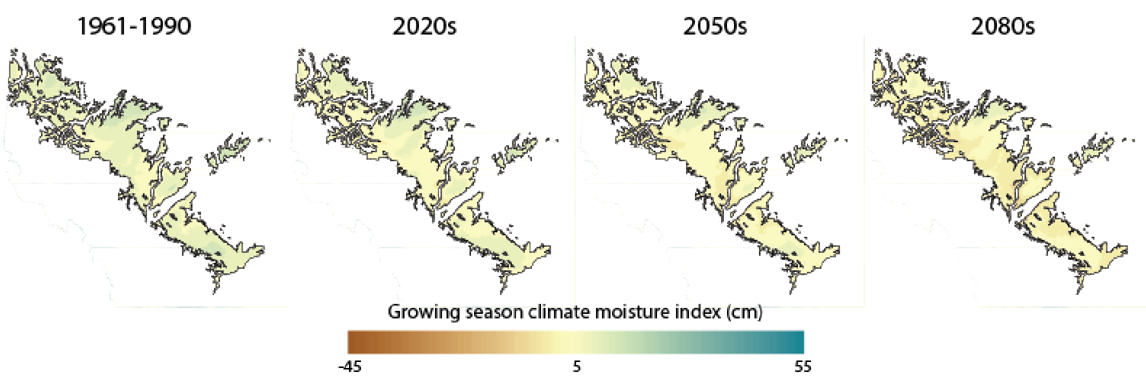

Figure 86: Current and projected future summer (June-August) climate moisture index for lodgepole pine Control Parentage Program (CPP) region B2. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

5.4 Region C

The lodgepole pine Control Parentage Program (CPP) region C is geographically located just east of the other lodgepole pine regions, and is approximately 1,194,757 hectares with parts of the region overlapping with the CPP regions A, B1, and B2. This region is comprised mainly of lower foothill ecosystems with a patch of upper foothills ecosystems in the center. The borders of the region follow the division between the lower foothills and central mixedwood ecosystems. The climate of this region is characteristically wet with relatively warm temperatures in the winter season and mild temperatures in the summer.

Maps illustrating the shift in each of the six climate variables summarized in this report over the CPP region C are provided in Figures 87-92, with Figures 87-88 representing changes in winter and summer temperatures; Figures 89-90 representing changes in growing degree days and frost variables; Figure 91 represents changes in precipitation; and finally Figure 92 represents changes in summer climate moisture.

In general, the future projections suggest a significant increase in winter temperatures across the region beginning in the 2020s and accelerating towards the 2080s, with the most pronounced warming projected for the upper foothills ecosystems in the center of the region, reaching an approximate 2°C increase by the 2050s (Figure 87). Projected warming in the summer season is of a slightly larger magnitude compared to winter warming, reaching a 3-4°C increase by the 2050s, with the most pronounced warming projected to occur in the lower foothills ecosystem along the perimeter of the region (Figure 88). Further the number of growing degree days above 5°C as well as frost free period are projected to moderately increase by the 2020s, but accelerate towards the 2080s, with the projected changes following the change in summer temperatures as seen in the lower foothill ecosystems (Figure 89 and Figure 90). This suggests a potential for a longer growing season, especially along the perimeter of the region. Although a slight increase in summer precipitation is projected for the upper foothills ecosystem within the region, little change in summer precipitation is projected for the majority of the region for all periods (Figure 91). Finally moderate temperature increases projected in the summer season coupled with little precipitation change is projected to result in a slight reduction in available moisture for the region (Figure 92).

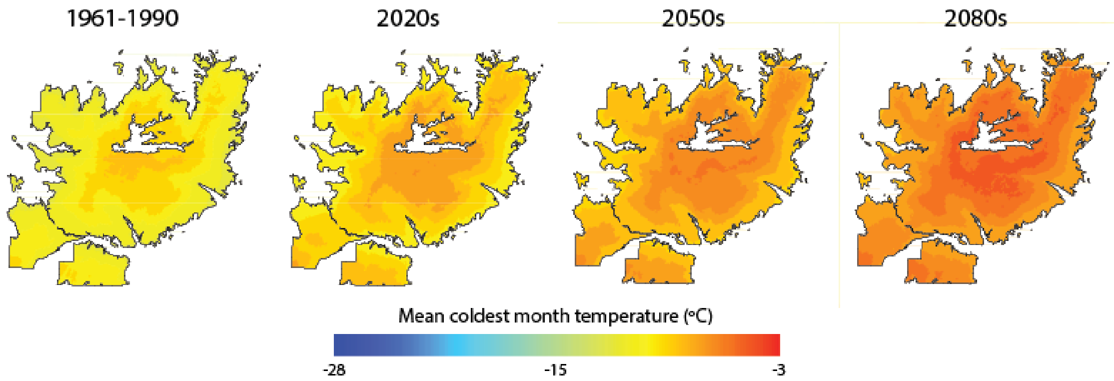

Figure 87: Current and projected future mean coldest month temperature for lodgepole pine Control Parentage Program (CPP) region C. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

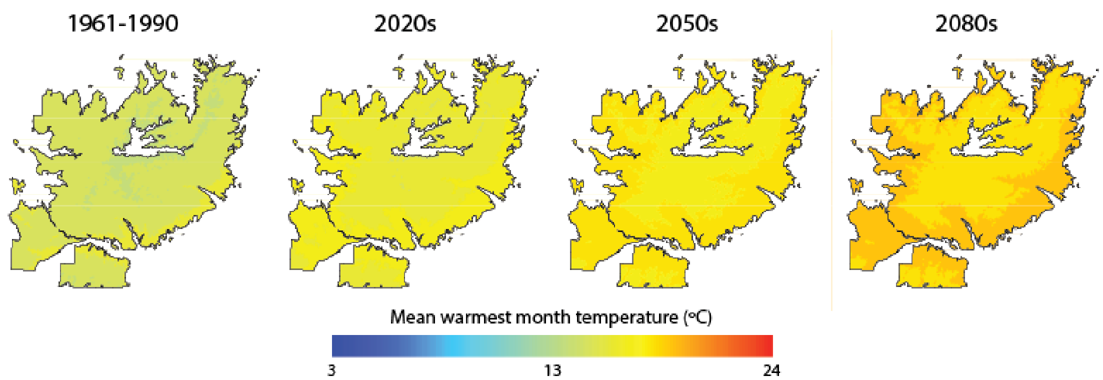

Figure 88: Current and projected future mean warmest month temperature for lodgepole pine Control Parentage Program (CPP) region C. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

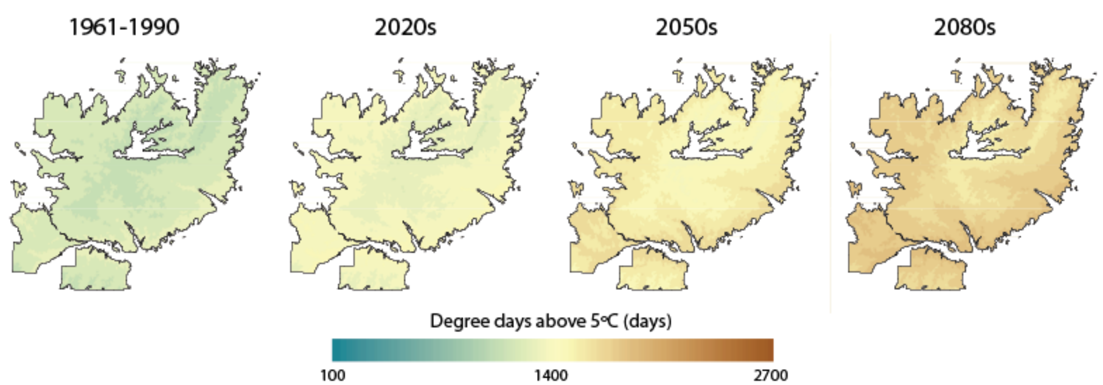

Figure 89: Current and projected future growing degree days above 5°C for lodgepole pine Control Parentage Program (CPP) region C. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

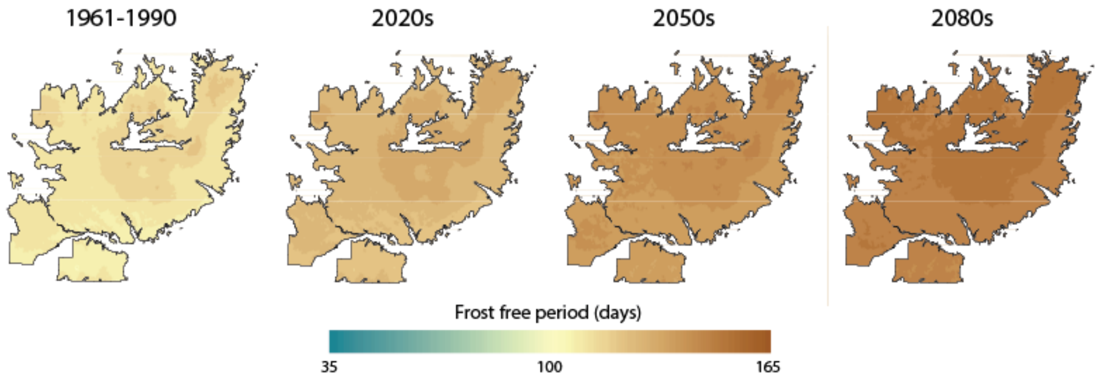

Figure 90: Current and projected future frost free period for lodgepole pine Control Parentage Program (CPP) region C. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

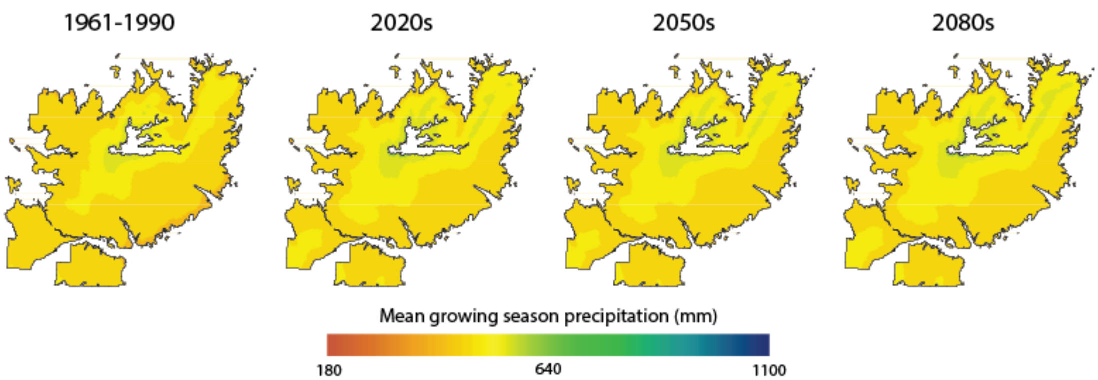

Figure 91: Current and projected mean growing season (May-September) precipitation for lodgepole pine Control Parentage Program (CPP) region C. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

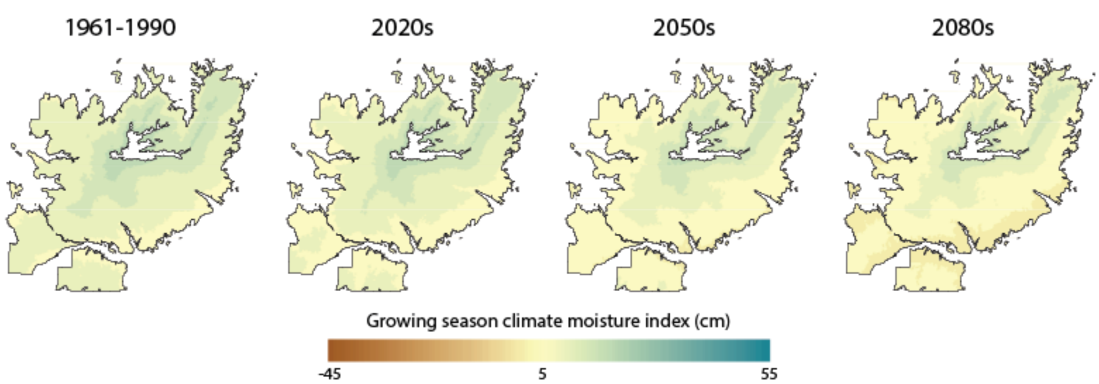

Figure 92: Current and projected future summer (June-August) climate moisture index for lodgepole pine Control Parentage Program (CPP) region C. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

5.5 Region J

The lodgepole pine Control Parentage Program (CPP) region J is the largest and most northern of the lodgepole pine regions, at approximately 2,651,103 hectares. This region is comprised mainly of lower boreal highlands ecosystems, but also includes some lower elevation upper boreal highlands ecosystems within its borders. The borders of the region follow the division between the lower boreal highlands and the central and dry mixedwood ecosystems. The climate of this region is characteristically drier with cold temperatures in the winter season and mild temperatures in the summer.

Maps illustrating the shift in each of the six climate variables summarized in this report over the CPP region J are provided in Figures 93-98, with Figures 93-94 representing changes in winter and summer temperatures; Figures 95-96 representing changes in growing degree days and frost variables; Figure 97 represents changes in precipitation; and finally Figure 98 represents changes in summer climate moisture.

In general, the future projections suggest a significant increase in winter temperatures across the region beginning in the 2020s and accelerating towards the 2080s, with the most pronounced warming projected for the north portion of the region, reaching an approximate 4-5°C increase by the 2050s (Figure 93). Projected warming in the summer season is of equal magnitude compared to winter warming, with the most pronounced warming projected to occur again in the northern portion of the region as well as the higher elevation of the lower boreal highlands (Figure 94). Further the number of growing degree days above 5°C as well as frost free period are projected to moderately increase by the 2020s, but accelerate towards the 2080s, with the projected changes following the change in summer temperatures as seen in the lower foothill ecosystems (Figure 95 and Figure 96). This suggests a potential for a longer growing season over the region. Growing season precipitation is projected to increase beginning in the 2020 in the upper boreal highlands ecosystems and extending west towards the 2080s (Figure 97). Finally reductions in available climate moisture are projected to be moderate by the 2020s, but accelerate towards the 2080s, with the most pronounced decreases projected for the northern and western lower boreal highland ecosystems in the region (Figure 98).

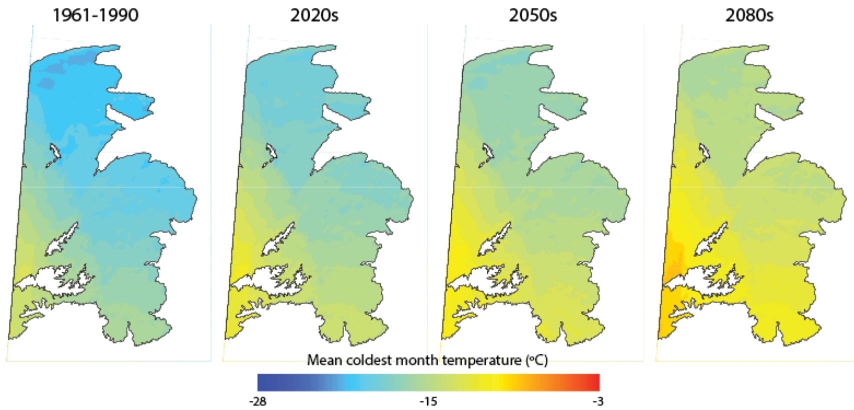

Figure 93: Current and projected future mean coldest month temperature for lodgepole pine Control Parentage Program (CPP) region J. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

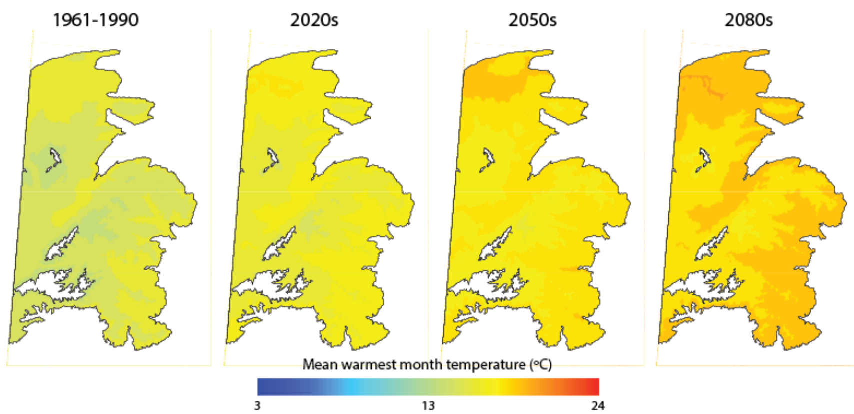

Figure 94: Current and projected future mean warmest month temperature for lodgepole pine Control Parentage Program (CPP) region J. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

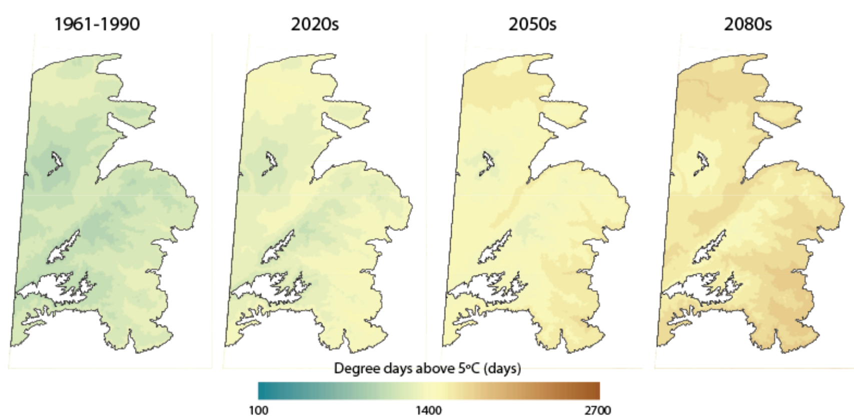

Figure 95: Current and projected future growing degree days above 5˚C for lodgepole pine Control Parentage Program (CPP) region J. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

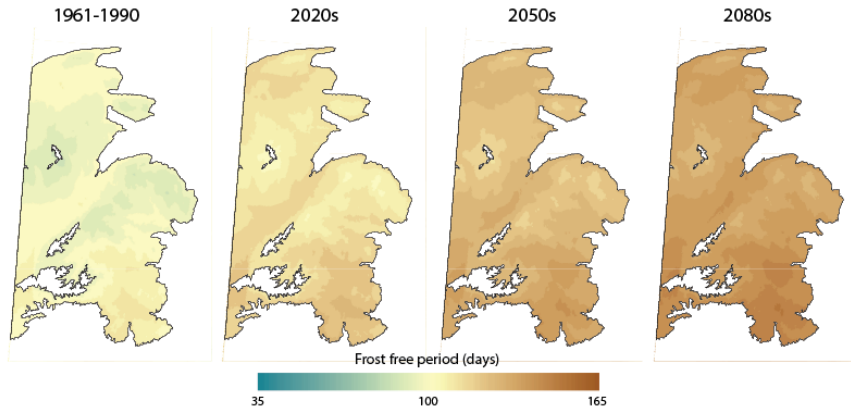

Figure 96: Current and projected future frost free period for lodgepole pine Control Parentage Program (CPP) region J. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

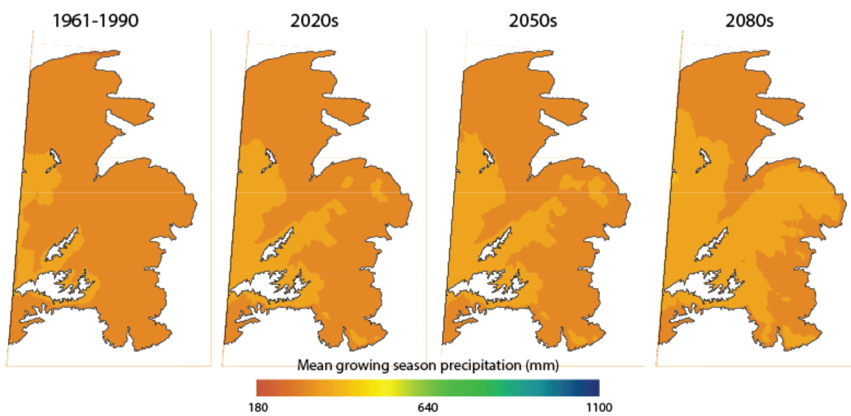

Figure 97: Current and projected mean growing season (May-September) precipitation for lodgepole pine Control Parentage Program (CPP) region J. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

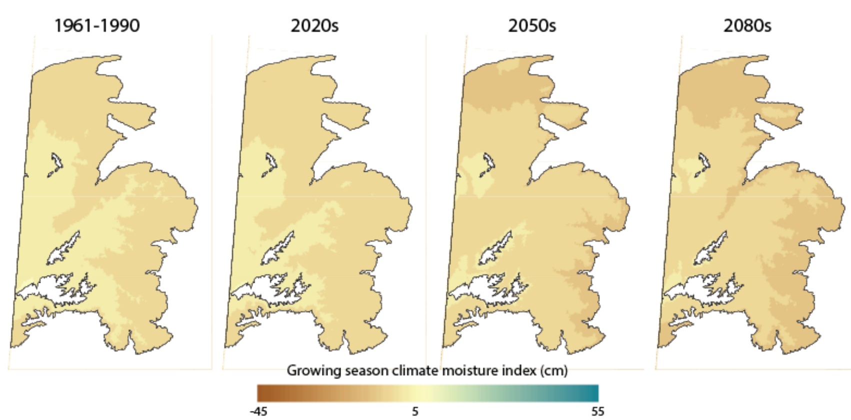

Figure 98: Current and projected future summer (June-August) climate moisture index for lodgepole pine Control Parentage Program (CPP) region J. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

5.6 Region K1

The lodgepole pine Control Parentage Program (CPP) region K1 is the smallest and most southern of the lodgepole pine regions, at approximately 822,893 hectares with parts of the region overlapping with the CPP regions A, B1, and B2. This region is comprised of upper and lower foothills ecosystems. The climate of this region is characteristically wet with mild temperatures in both the winter and summer seasons.

Maps illustrating the shift in each of the six climate variables summarized in this report over the CPP region K1 are provided in Figures 99-104, with Figures 99-100 representing changes in winter and summer temperatures; Figures 101-102 representing changes in growing degree days and frost variables; Figure 103 represents changes in precipitation; and finally Figure 104 represents changes in summer climate moisture.

In general, the future projections suggest a significant increase in winter temperatures across the region beginning in the 2020s and accelerating towards the 2080s, with the most pronounced warming projected for upper foothills ecosystems in the north and lower foothills ecosystems in the south of the region, reaching an approximate 2-3˚C increase by the 2050s (Figure 99). Projected warming in the summer season is of slightly lesser magnitude compared to winter warming, reaching approximately 2˚C increase by the 2050s, and it is projected to occur fairly uniformly across the region (Figure 100). Further the number of growing degree days above 5˚C as well as frost free period are projected to moderately increase by the 2020s, but accelerate towards the 2080s, with the projected changes most prominent in the lower foothill ecosystems (Figure 101 and Figure 102). This suggests a potential for a longer growing season over the region. Very little change in summer precipitation is projected over the region for all periods (Figure 103). Finally moderate temperature increases projected in the summer season coupled with little precipitation change is projected to result in a slight reduction in available moisture for the region stemming north from the lower foothill ecosystems located in the south of the region (Figure 104).

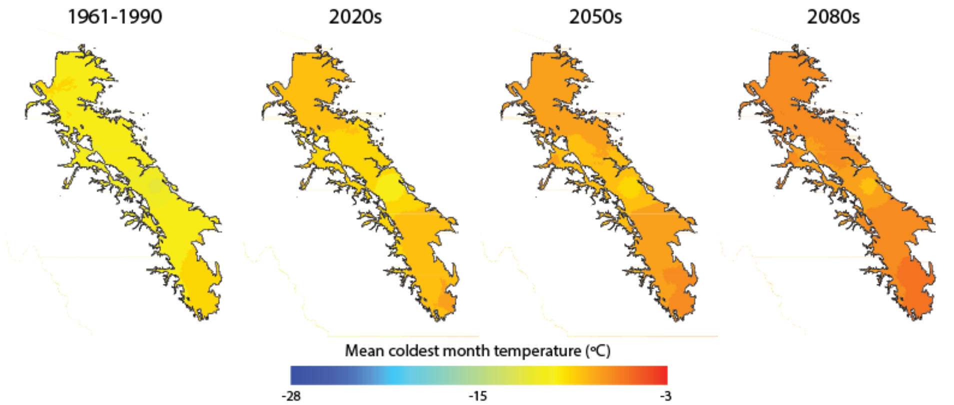

Figure 99: Current and projected future mean coldest month temperature for lodgepole pine Control Parentage Program (CPP) region K1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

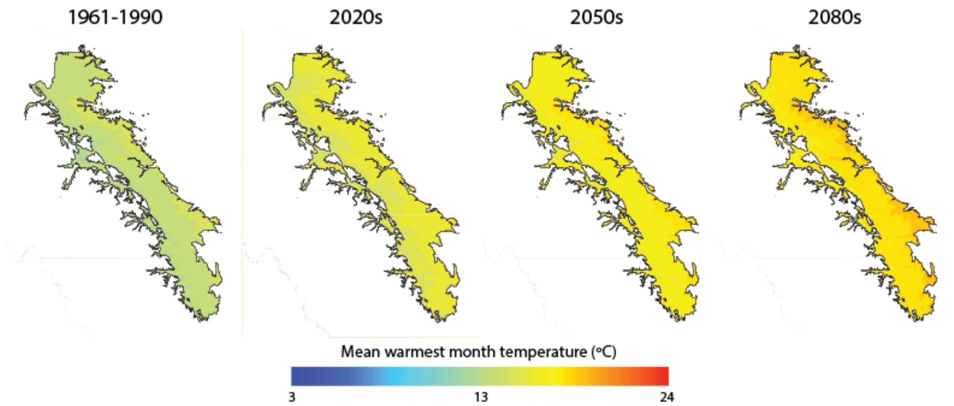

Figure 100: Current and projected future mean warmest month temperature for lodgepole pine Control Parentage Program (CPP) region K1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

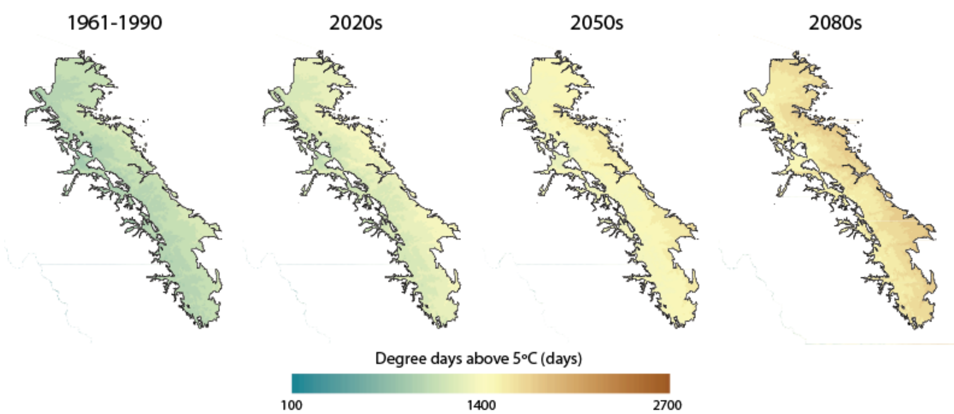

Figure 101: Current and projected future growing degree days above 5˚C for lodgepole pine Control Parentage Program (CPP) region K1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

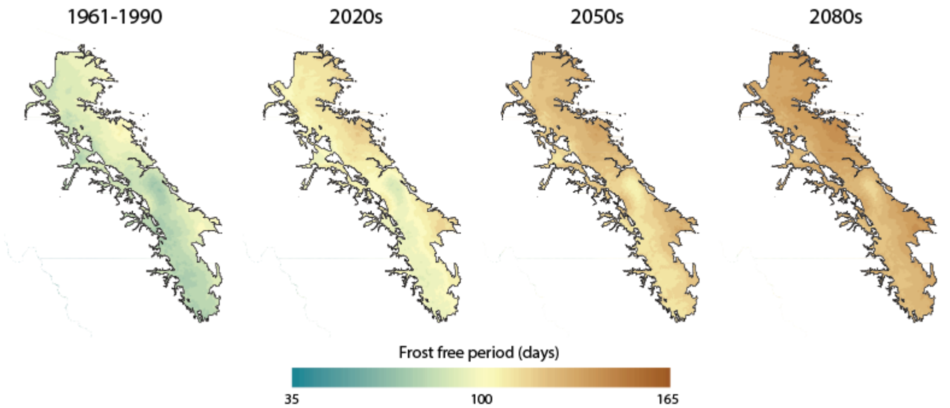

Figure 102: Current and projected future frost free period for lodgepole pine Control Parentage Program (CPP) region K1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

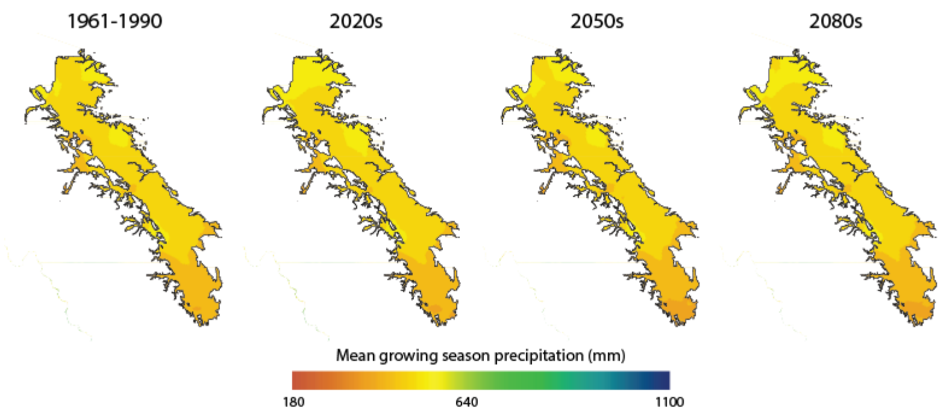

Figure 103: Current and projected mean growing season (May-September) precipitation for lodgepole pine Control Parentage Program (CPP) region K1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

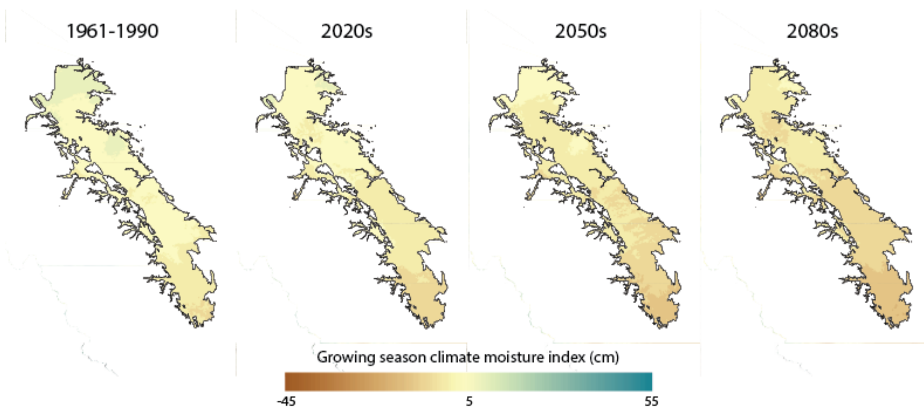

Figure 104: Current and projected future summer (June-August) climate moisture index for lodgepole pine Control Parentage Program (CPP) region K1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

6.0 Projected climate shifts: Jack Pine Control Parentage Program Regions

Maps illustrating the shift in each of the six climate variables summarized in this report over the single jack pine (*Pinus banksiana*) Control Parentage Program (CPP) region (Figure 105) are provided in the following subsection.

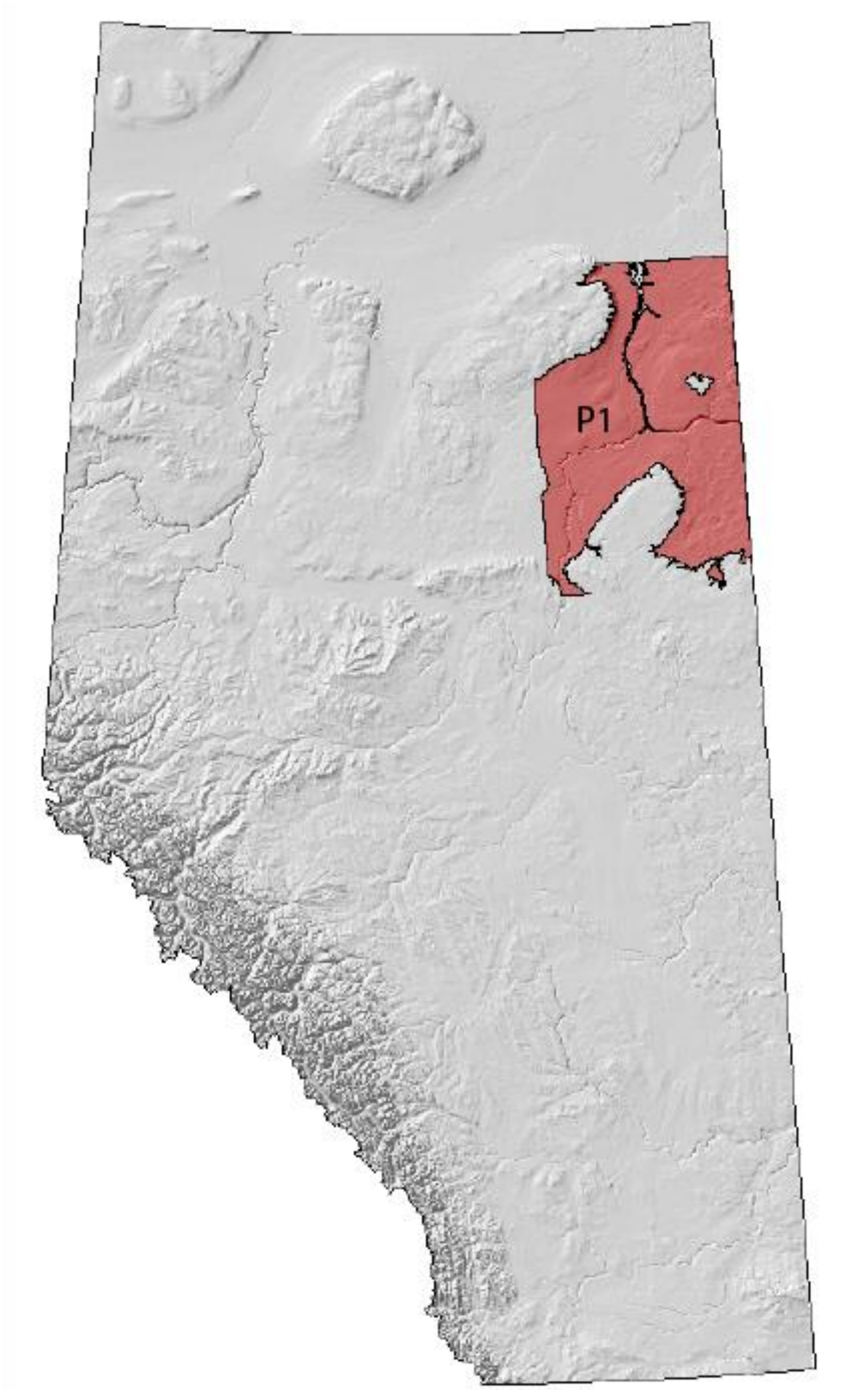

Figure 105: The single region of the jack pine (*Pinus banksiana*) Control Parentage Program (CPP).

6.1 Region P1

The jack pine Control Parentage Program (CPP) region P1 is the single region of the program, and is approximately 822,893 hectares. This region is comprised of central mixedwood and Athabasca plains ecosystems with its southern border following the division between the central mixedwood and lower boreal highlands. The climate of this region is characteristically dry with cold temperatures in the winter and the mild temperatures in the summer season.

Maps illustrating the shift in each of the six climate variables summarized in this report over the CPP region P1 are provided in Figures 106-111, with Figures 106-107 representing changes in winter and summer temperatures; Figures 108-109 representing changes in growing degree days and frost variables; Figure 110 represents changes in precipitation; and finally Figure 114 represents changes in summer climate moisture.

In general, the future projections suggest increased winter warming across the region towards the 2080s, with the most pronounced warming occurring in the northern portion of the region reaching an approximate 6˚C increase by the 2050s (Figure 106). Projected warming in the summer season is less than the winter season with approximately 2-3˚C by the 2050s and is most pronounced in the eastern portion of the region (Figure 107). Further the number of growing degree days above 5˚C as well as frost free period are projected to moderately increase by the 2020s, but accelerate towards the 2080s extending from the central portion of the region towards the boarders (Figure 108 and Figure 109). This suggests the potential for a longer growing season throughout the region. Growing season precipitation is projected to moderately increase over the region with the wetter conditions of the southern portion of the region significantly expanding northward by the 2020s (Figure 110). Finally moderate reduction in available moisture for the region is projected for the south western and eastern borders of the region beginning in the 2020s. Further moisture reduction is projected to occur in the north by the 2050s following the warming summer temperatures (Figure 111).

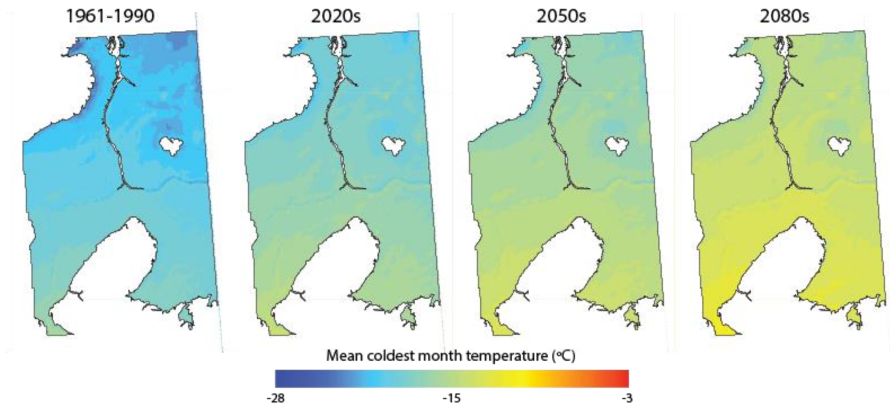

Figure 106: Current and projected future mean coldest month temperature for jack pine Control Parentage Program (CPP) region P1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

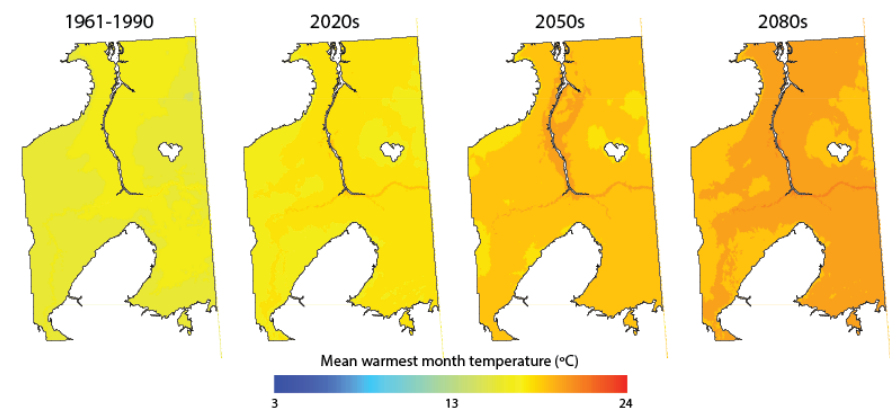

Figure 107: Current and projected future mean warmest month temperature for jack pine Control Parentage Program (CPP) region P1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

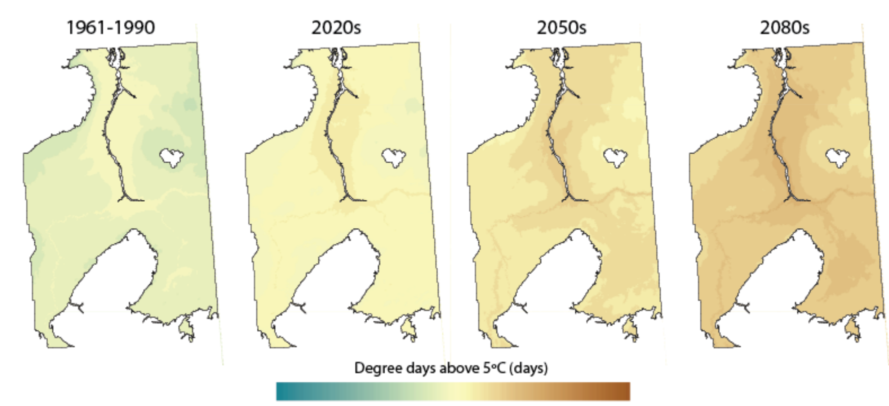

Figure 108: Current and projected future growing degree days above 5°C for jack pine Control Parentage Program (CPP) region P1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

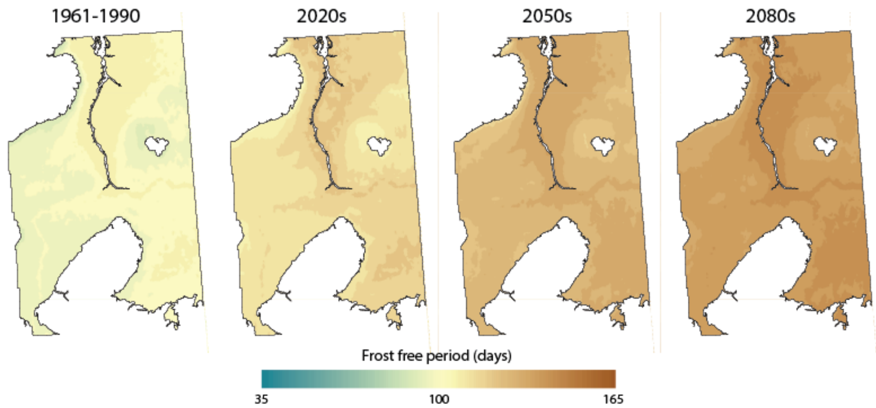

Figure 109: Current and projected future frost free period for jack pine Control Parentage Program (CPP) region P1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

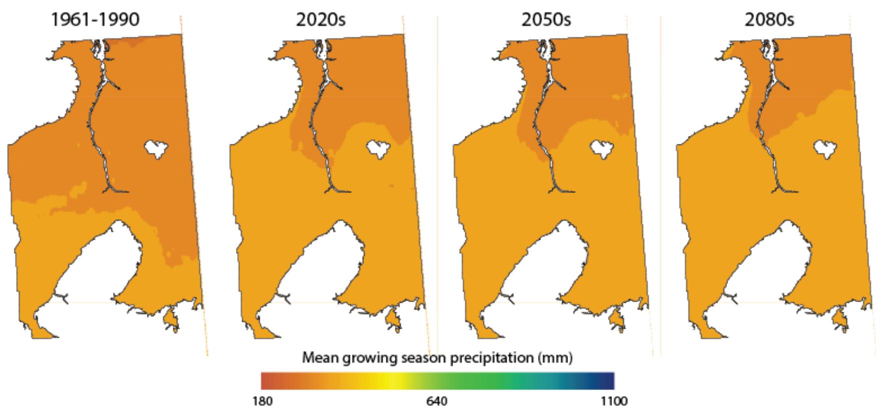

Figure 110: Current and projected mean growing season (May-September) precipitation for jack pine Control Parentage Program (CPP) region P1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

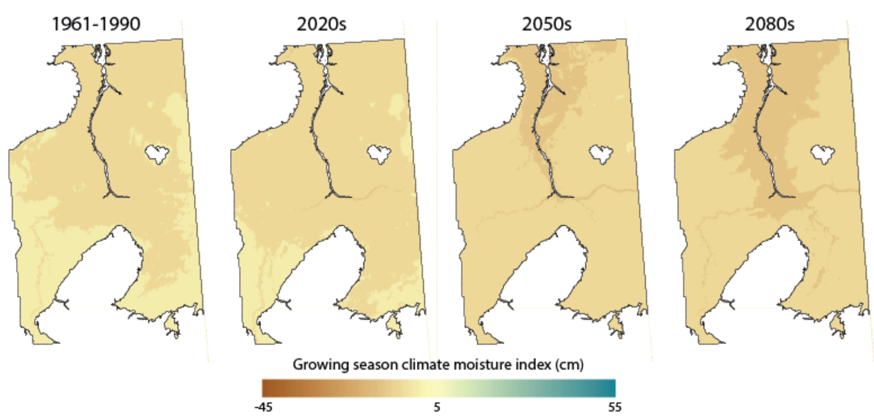

Figure 111: Current and projected future summer (June-August) climate moisture index for jack pine Control Parentage Program (CPP) region P1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

7.0 Projected climate shifts: Black Spruce Control Parentage Program Regions

Maps illustrating the shift in each of the six climate variables summarized in this report over each of the three black spruce (*Picea mariana*) Control Parentage Program (CPP) regions (Figure 112) are provided in the following subsections.

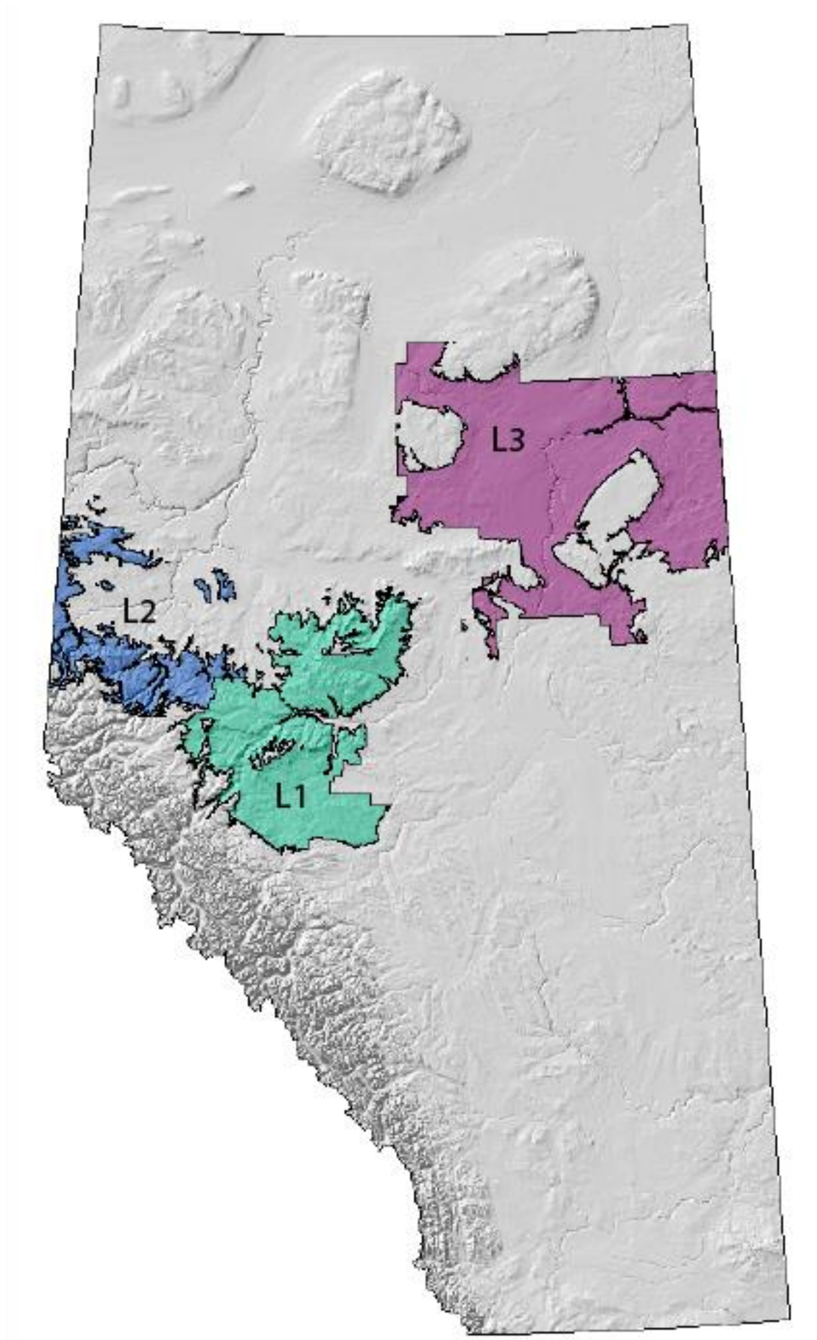

Figure 112: The three regions of the black spruce (*Picea mariana*) Control Parentage Program (CPP).

7.1 Region L1

The black spruce Control Parentage Program (CPP) region L1 is geographically located just east of the Rocky Mountains, and is approximately 2,778,671 hectares. This region is comprised mainly of lower foothill ecosystems with patches of upper foothills ecosystems in the center and along the southern border. The borders of the region follow the division between the lower foothills and central mixedwood ecosystems. The climate of this region is characteristically wet with relatively warm temperatures in the winter season and mild temperatures in the summer.

Maps illustrating the shift in each of the six climate variables summarized in this report over the CPP region L1 are provided in Figures 113-118, with Figures 113-114 representing changes in winter and summer temperatures; Figures 115-116 representing changes in growing degree days and frost variables; Figure 117 represents changes in precipitation; and finally Figure 118 represents changes in summer climate moisture.

In general, the future projections suggest a significant increase in winter temperatures across the region beginning in the 2020s and accelerating towards the 2080s, with the most pronounced warming projected for the upper foothills ecosystems in the west and the center of the region, reaching an approximate 2°C increase by the 2050s (Figure 113). Projected warming in the summer season is of a larger magnitude compared to winter warming, reaching a 4-5°C increase by the 2050s, with the most pronounced warming projected to occur in the lower foothills ecosystem along the western perimeter of the region (Figure 114). Further the number of growing degree days above 5°C as well as frost free period are projected to moderately increase by the 2020s, but accelerate towards the 2080s, with the projected changes following the change in summer temperatures as seen in the lower foothill ecosystems (Figure 115 and Figure 116). This suggests a potential for a longer growing season, especially along the western perimeter of the region. Although a slight increase in summer precipitation is projected for the upper foothills ecosystem within the region, little change in summer precipitation is projected for the majority of the region for all periods (Figure 117). Finally moderate temperature increases projected in the summer season coupled with little precipitation change is projected to result in a slight reduction in available moisture for the region (Figure 118).

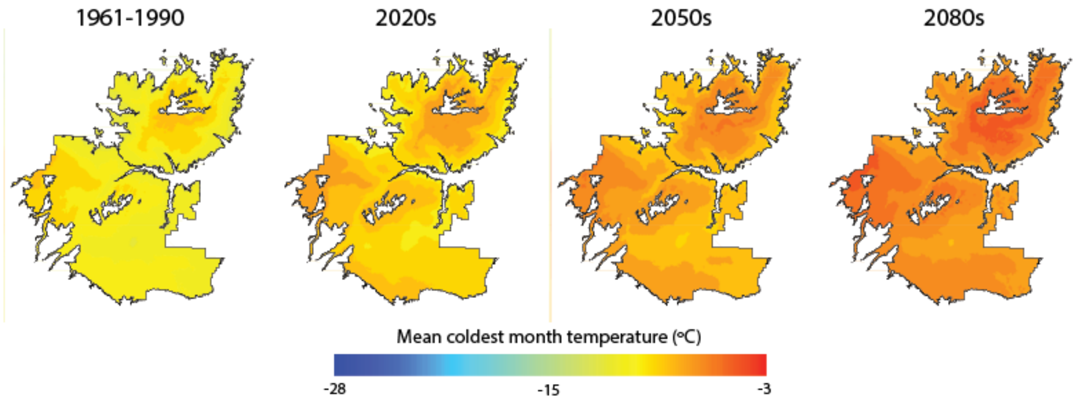

Figure 113: Current and projected future mean coldest month temperature for black spruce Control Parentage Program (CPP) region L1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

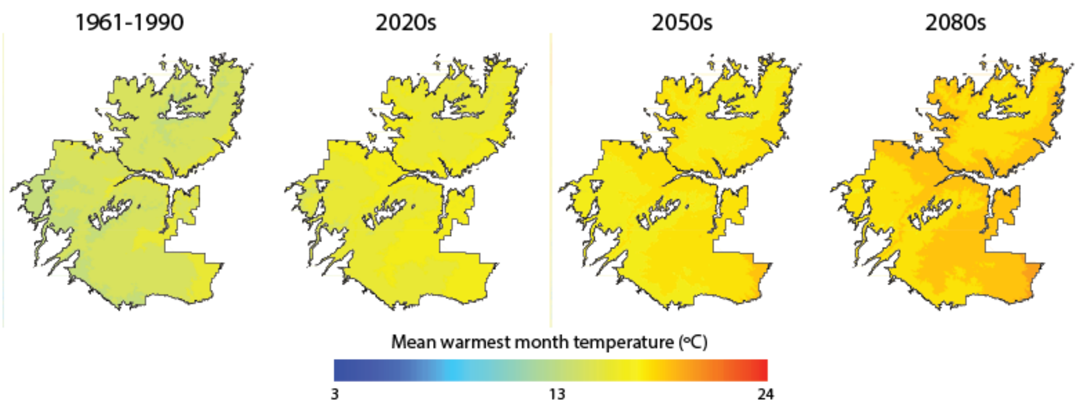

Figure 114: Current and projected future mean warmest month temperature for black spruce Control Parentage Program (CPP) region L1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

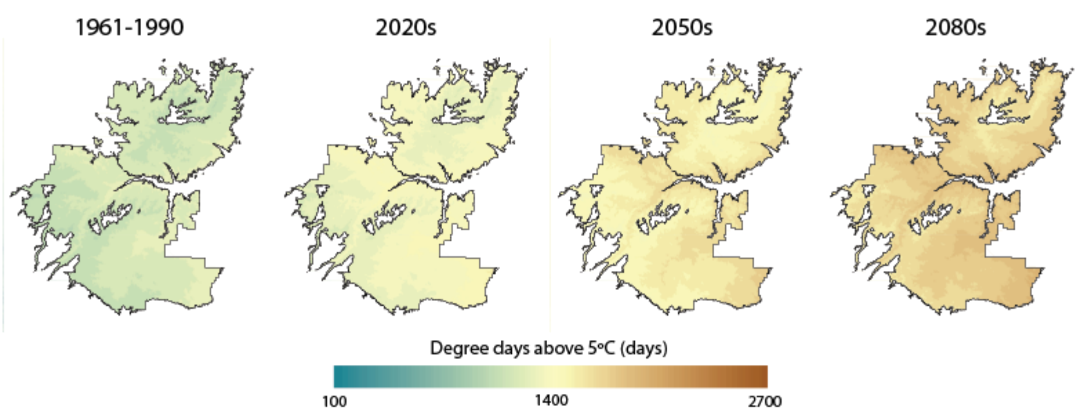

Figure 115: Current and projected future growing degree days above 5°C for black spruce Control Parentage Program (CPP) region L1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

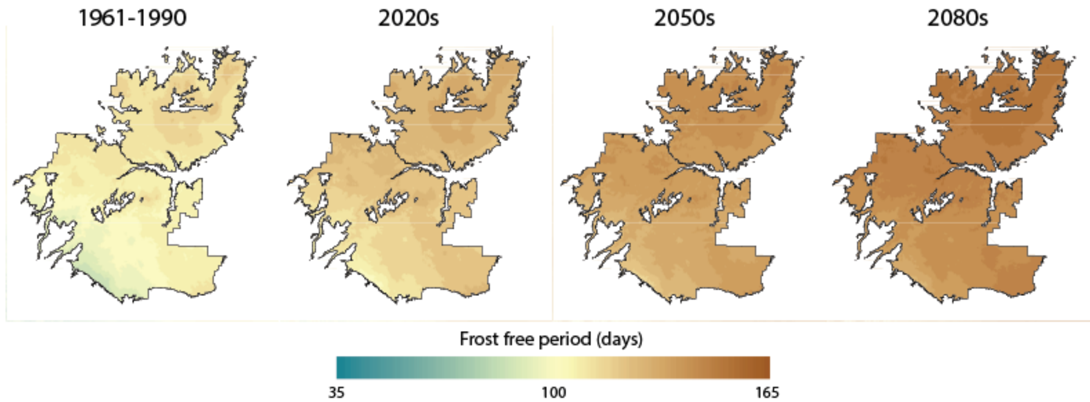

Figure 116: Current and projected future frost free period for black spruce Control Parentage Program (CPP) region L1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

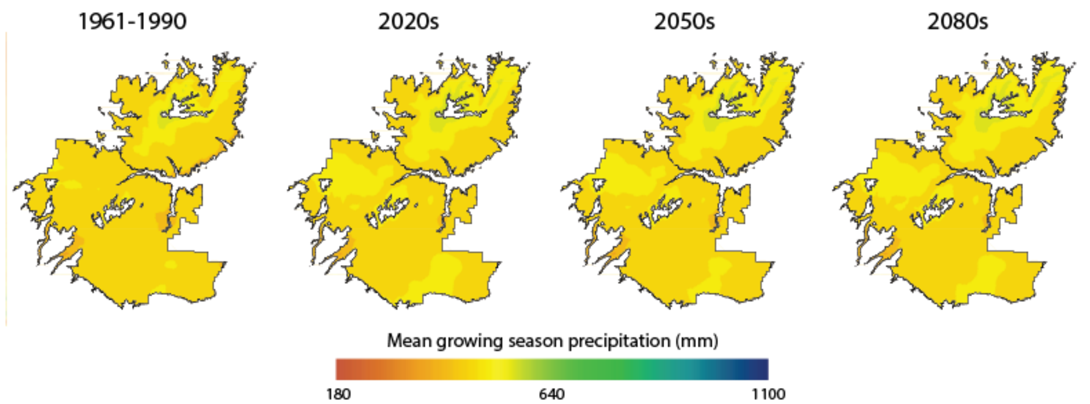

Figure 117: Current and projected mean growing season (May-September) precipitation for black spruce Control Parentage Program (CPP) region L1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

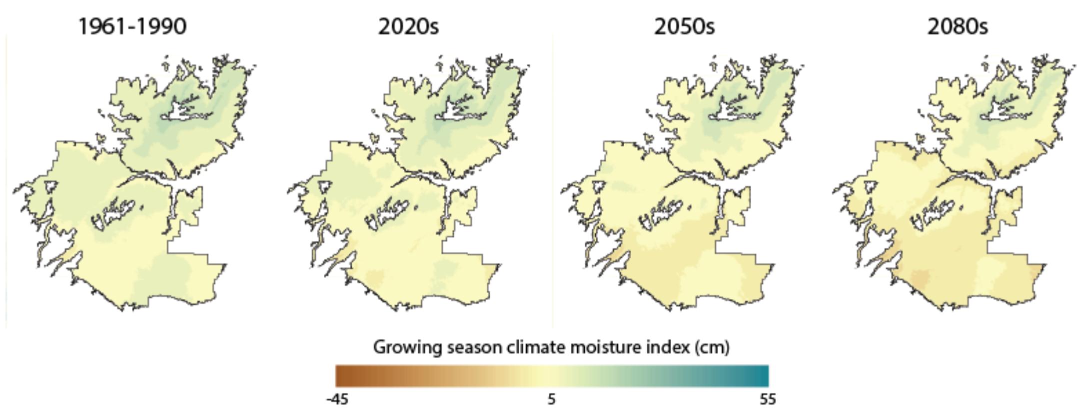

Figure 118: Current and projected future summer (June-August) climate moisture index for black spruce Control Parentage Program (CPP) region L1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

7.2 Region L2

The black spruce Control Parentage Program (CPP) region L2 is geographically located in western Alberta just north of the Rocky Mountain range, and is approximately 1,073,640 hectares. This region is mainly comprised of lower foothill ecosystems, with pockets of central mixedwood and upper foothills and ecosystems along southern borders of the region. The eastern border of the region follows the provincial boundary, and western borders of the region follows the division between the lower foothills and central mixedwood ecosystems. The climate of this region is characteristically wet in the south, drier in the north, with relatively warm temperatures in the winter season and mild temperatures in the summer.

Maps illustrating the shift in each of the six climate variables summarized in this report over the CPP region L2 are provided in Figures 119-124, with Figures 119-120 representing changes in winter and summer temperatures; Figures 121-122 representing changes in growing degree days and frost variables; Figure 123 represents changes in precipitation; and finally Figure 124 represents changes in summer climate moisture.

In general, the future projections suggest increasing winter warming across the region beginning in the 2020s and accelerating towards the 2080s, with the most pronounced warming projected for upper foothill ecosystems within the south of the region, reaching an approximate 2-3˚C increase by the 2050s (Figure 119). Projected warming in the summer season is of equal magnitude to projected winter warming in the 2050s, however in this season the most pronounced warming is projected for the lower foothills ecosystems (Figure 120). Further the number of growing degree days above 5˚C as well as frost free period are projected to moderately increase by the 2020s, but accelerate towards the 2080s, with the projected changes following the change in summer temperatures as seen in the lower foothill ecosystems (Figure 121 and Figure 122). This suggests a potential for a longer growing season over the region, especially at lower elevations. Little change in summer precipitation is projected over the region; however small pockets of moderate precipitation increase are projected by the 2020s in the upper foothills ecosystems in the south of the region (Figure 123). Finally little change in available moisture in the summer season is projected within the region (Figure 124).

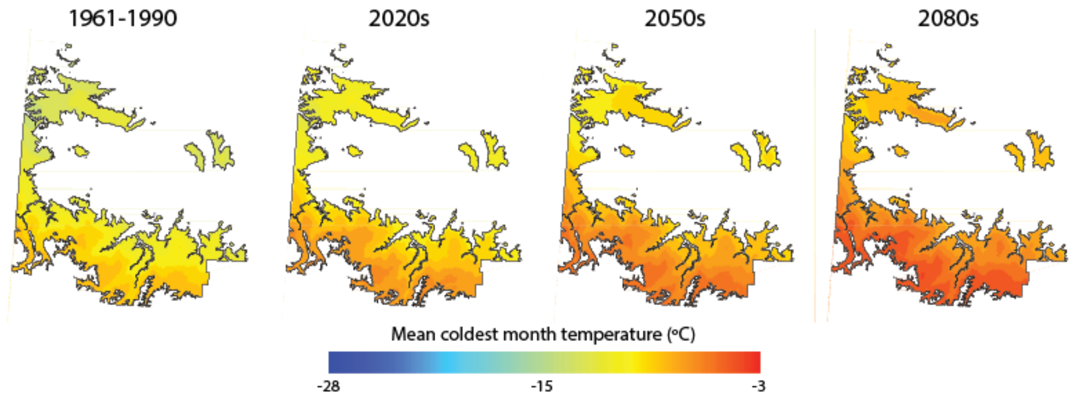

Figure 119: Current and projected future mean coldest month temperature for black spruce Control Parentage Program (CPP) region L2. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

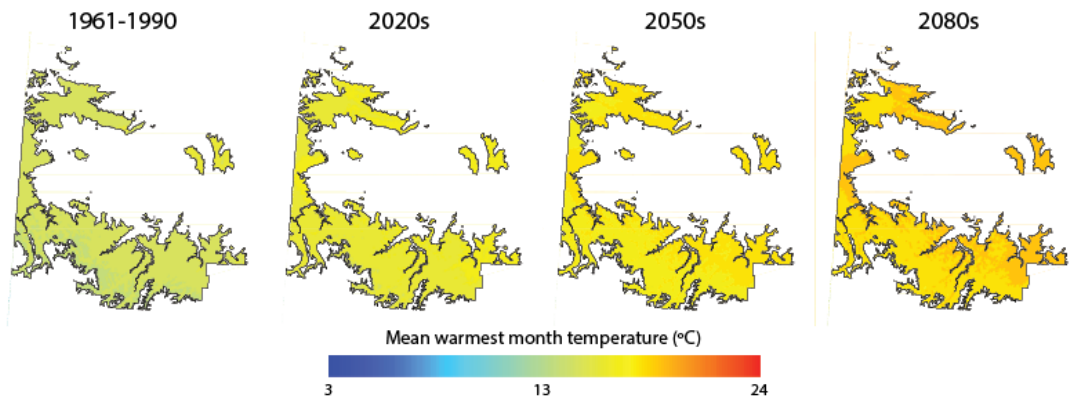

Figure 120: Current and projected future mean warmest month temperature for black spruce Control Parentage Program (CPP) region L2. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

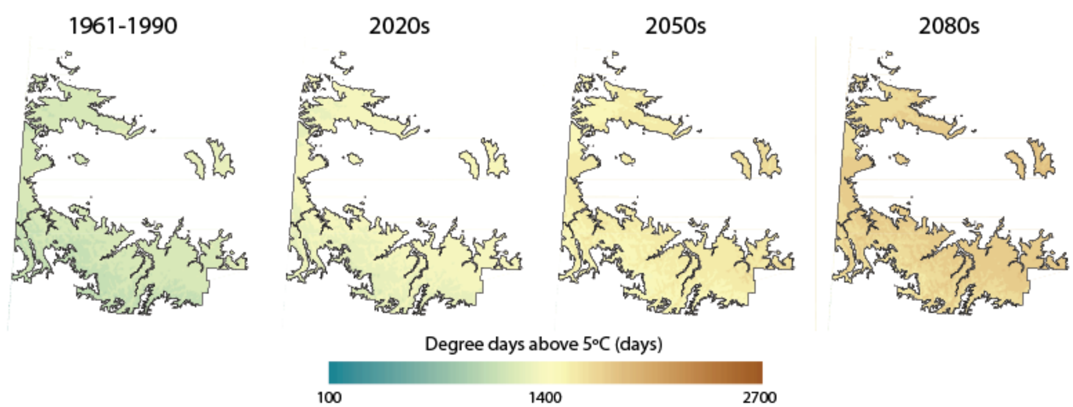

Figure 121: Current and projected future growing degree days above 5°C for black spruce Control Parentage Program (CPP) region L2. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

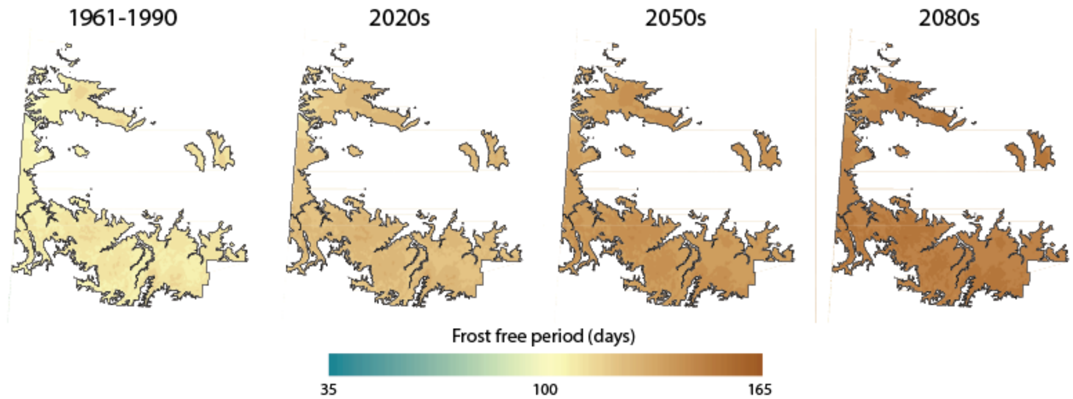

Figure 122: Current and projected future frost free period for black spruce Control Parentage Program (CPP) region L2. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

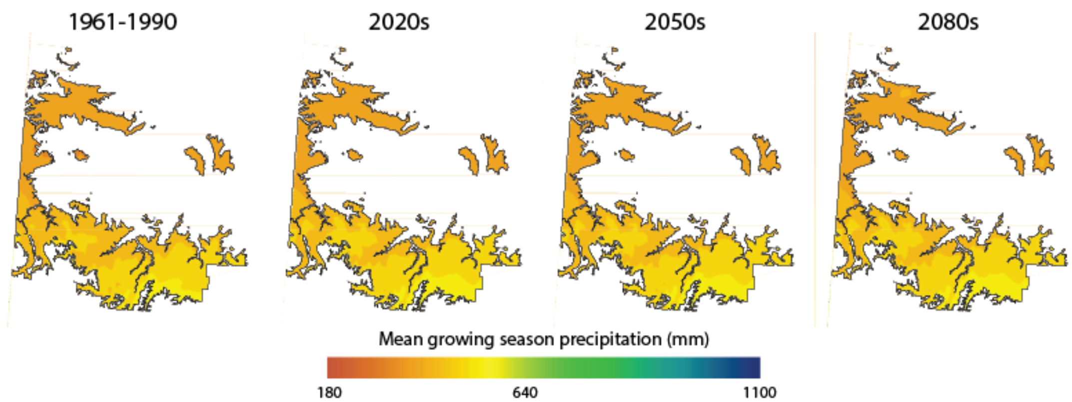

Figure 123: Current and projected mean growing season (May-September) precipitation for black spruce Control Parentage Program (CPP) region L2. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

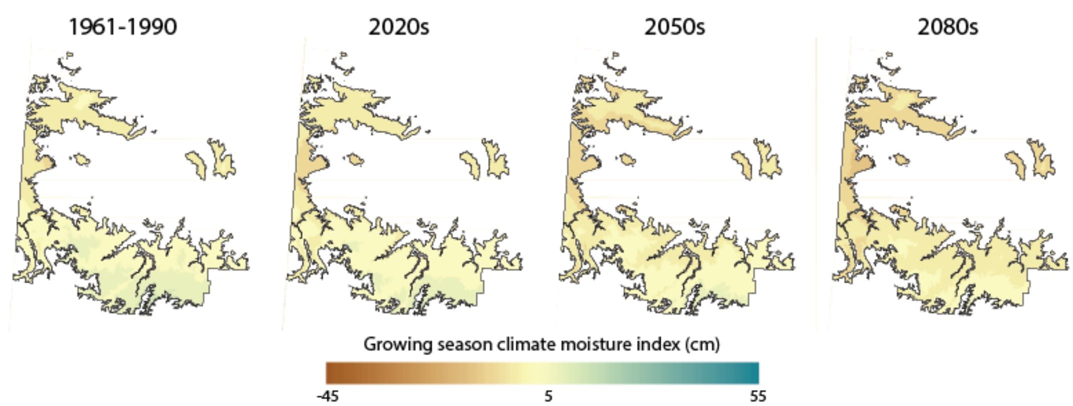

Figure 124: Current and projected future summer (June-August) climate moisture index for black spruce Control Parentage Program (CPP) region L2. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

7.3 Region L3

The black spruce Control Parentage Program (CPP) region L3 is the largest and the most eastern of the black spruce CPP regions, at approximately 4,807,788 hectares. This region is comprised almost entirely of central mixedwood ecosystems with a small patch of Athabasca plains ecosystem in the northeastern corner. The border of this region follows the division between the central mixedwood and lower boreal highland ecosystems. The climate of this region is characteristically dry with cold temperatures in the winter and the mild temperatures in the summer season.

Maps illustrating the shift in each of the six climate variables summarized in this report over the CPP region L3 are provided in Figures 125-130, with Figures 125-126 representing changes in winter and summer temperatures; Figures 127-128 representing changes in growing degree days and frost variables; Figure 129 represents changes in precipitation; and finally Figure 130 represents changes in summer climate moisture.

In general, the future projections suggest increased winter warming across the region towards the 2080s, with the most pronounced warming occurring in the northern portion of the region reaching an approximate 6˚C increase by the 2050s (Figure 125). Projected warming in the summer season is less than the winter season with approximately 2-3˚C by the 2050s and is most pronounced in the eastern portion of the region (Figure 126). Further the number of growing degree days above 5˚C as well as frost free period are projected to moderately increase by the 2020s, but accelerate towards the 2080s extending from the central portion of the region towards the boarders (Figure 127 and Figure 128). This suggests the potential for a longer growing season throughout the region. Growing season precipitation is projected to moderately increase over the region with the wetter conditions of the southern portion of the region significantly expanding northward by the 2020s (Figure 129). Finally moderate reduction in available moisture for the region is projected for the south western and eastern borders of the region beginning in the 2020s. Further moisture reduction is projected to occur in the north by the 2050s following the warming summer temperatures (Figure 130).

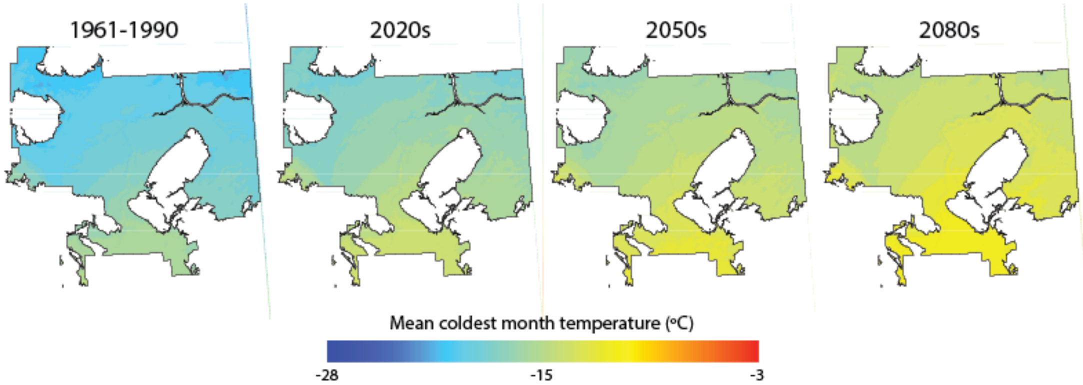

Figure 125: Current and projected future mean coldest month temperature for black spruce Control Parentage Program (CPP) region L3. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

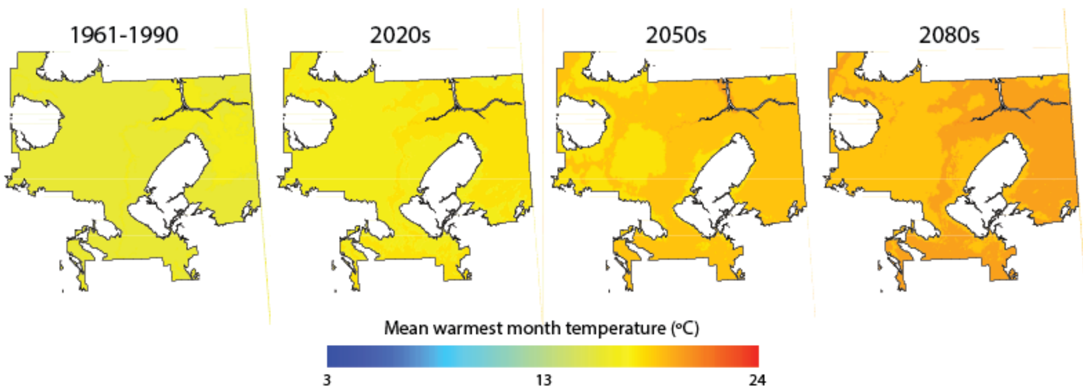

Figure 126: Current and projected future mean warmest month temperature for black spruce Control Parentage Program (CPP) region L3. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

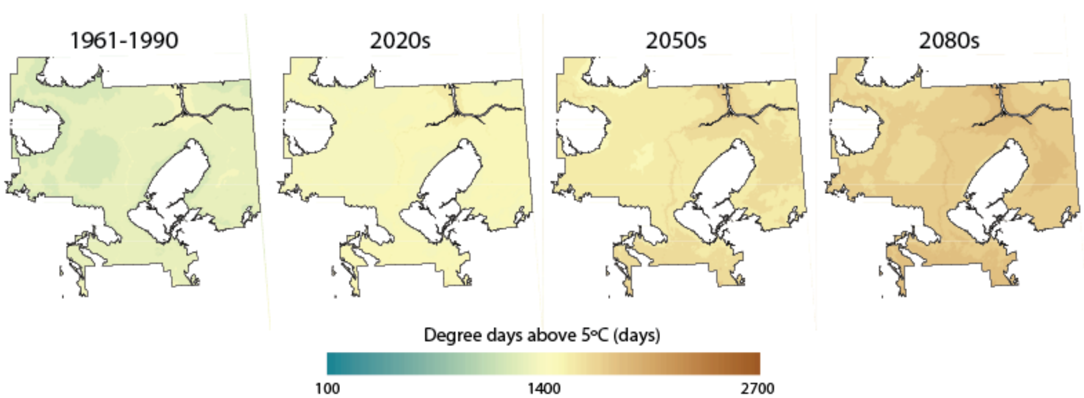

Figure 127: Current and projected future growing degree days above 5˚C for black spruce Control Parentage Program (CPP) region L3. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

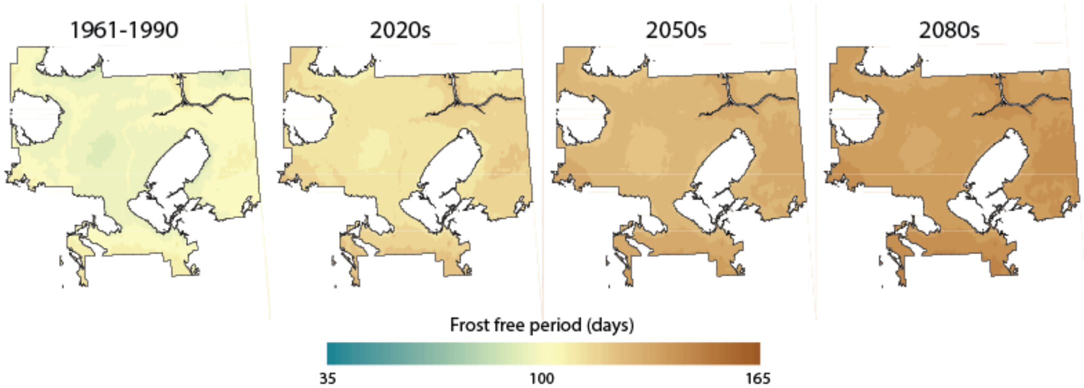

Figure 128: Current and projected future frost free period for black spruce Control Parentage Program (CPP) region L3. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

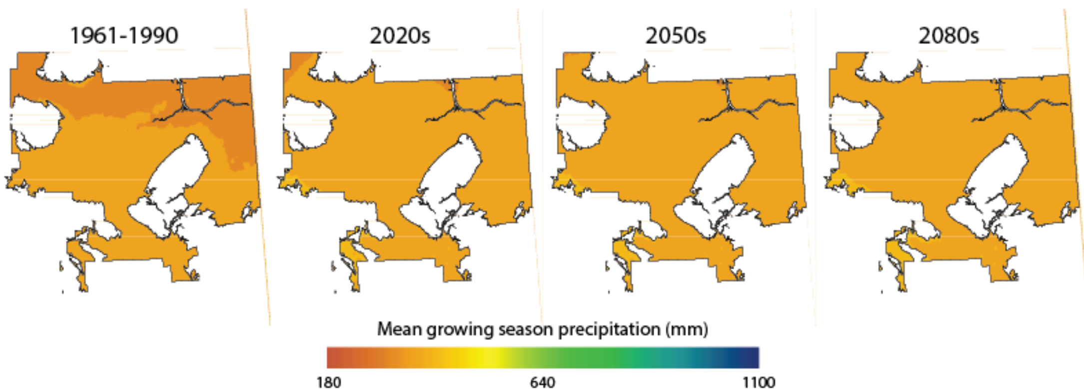

Figure 129: Current and projected mean growing season (May-September) precipitation for black spruce Control Parentage Program (CPP) region L3. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

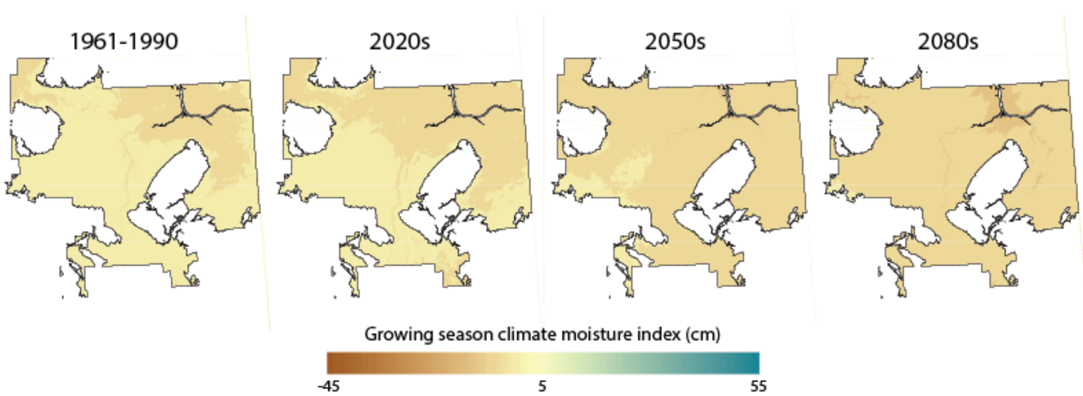

Figure 130: Current and projected future summer (June-August) climate moisture index for black spruce Control Parentage Program (CPP) region L3. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

8.0 Projected climate shifts: Douglas-fir Control Parentage Program Regions

Maps illustrating the shift in each of the six climate variables summarized in this report over the single Douglas-fir (*Pseudotsuga menziesii*) Control Parentage Program (CPP) region (Figure 131) are provided in the following subsection.

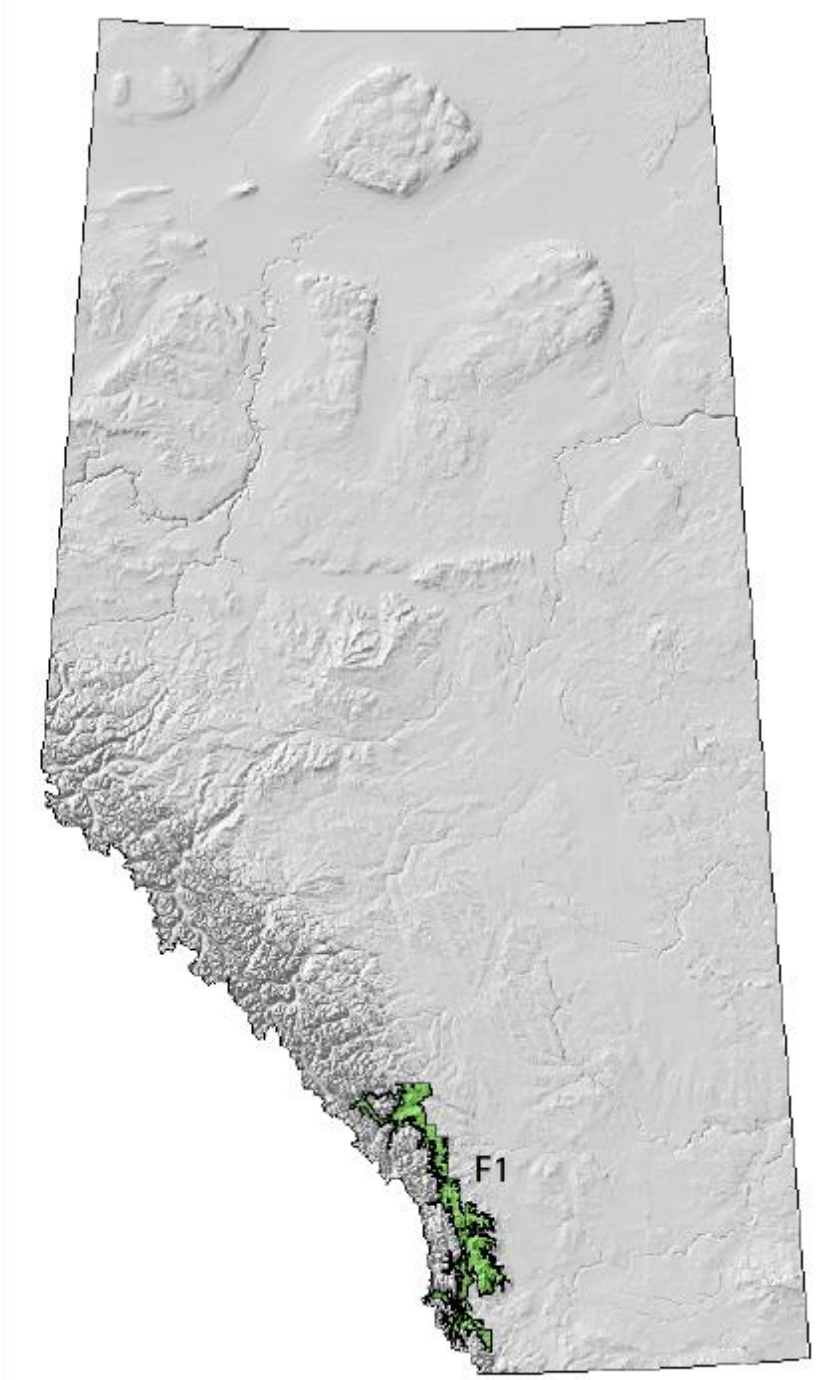

Figure 131: The single region of the Douglas-fir (*Pseudotsuga menziesii*) Control Parentage Program (CPP).

8.1 Region F1

The Douglas-fir Control Parentage Program (CPP) region F1 is the single region of the program, and is approximately 529,714 hectares. This region is comprised almost entirely of montane ecosystems, with a few pockets of foothills parkland ecosystems to the east. The climate of this region is characteristically drier with relatively warm winter temperatures and the mild temperatures in the summer season.

Maps illustrating the shift in each of the six climate variables summarized in this report over the CPP region F1 are provided in Figures 132-137, with Figures 132-133 representing changes in winter and summer temperatures; Figures 134-135 representing changes in growing degree days and frost variables; Figure 136 represents changes in precipitation; and finally Figure 137 represents changes in summer climate moisture.

In general, the future projections suggest increased winter warming fairly uniformly across the region, reaching an approximate 4°C increase by the 2050s (Figure 132). Projected warming in the summer season is less than the winter season with approximately 2-3°C by the 2050s and again is projected to occur fairly uniformly across the region (Figure 133). Further the number of growing degree days above 5°C as well as frost free period are projected to moderately increase by the 2020s, but accelerate towards the 2080s with a slightly larger increase in the foothills parkland ecosystems in the east of the region (Figure 134 and Figure 135). This suggests the potential for a longer growing season throughout the region. A small reduction in growing season precipitation is projected for the region by the 2050s stemming from the exterior of the region towards the center (Figure 136). Finally moderate reduction in available moisture for the region is projected for the south western and eastern borders of the region beginning in the 2020s. Further moisture reduction is projected to occur over the region by the 2050s following the projected reduction in growing season precipitation (Figure 137).

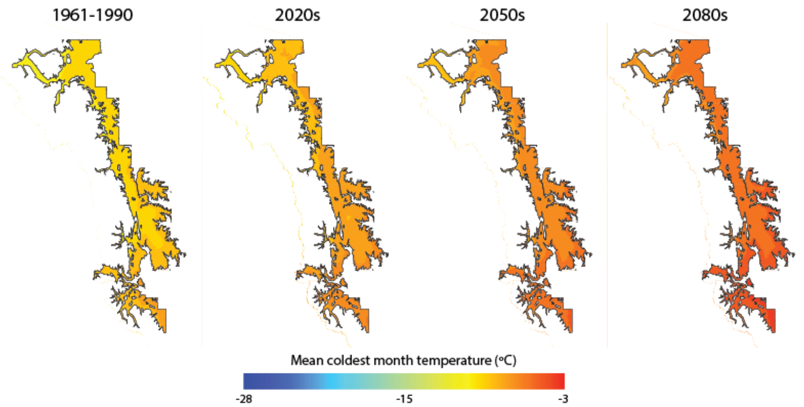

Figure 132: Current and projected future mean coldest month temperature for Douglas-fir Control Parentage Program (CPP) region F1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

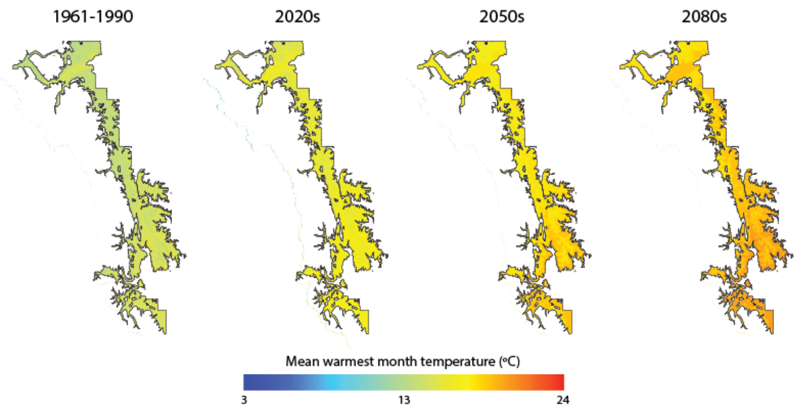

Figure 133: Current and projected future mean warmest month temperature for Douglas-fir Control Parentage Program (CPP) region F1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

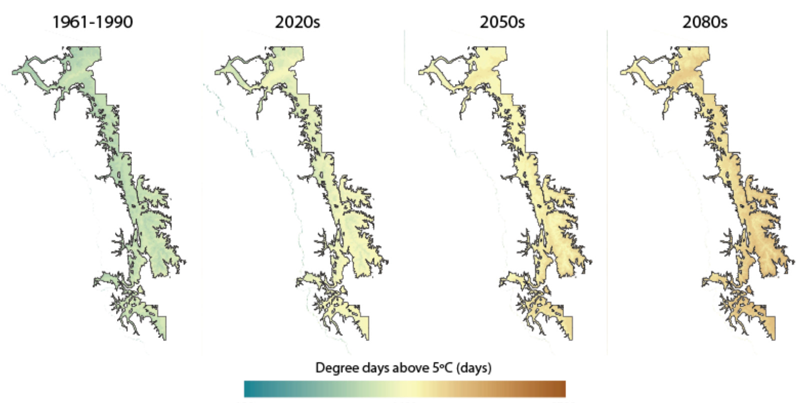

Figure 134: Current and projected future growing degree days above 5˚C for Douglas-fir Control Parentage Program (CPP) region F1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

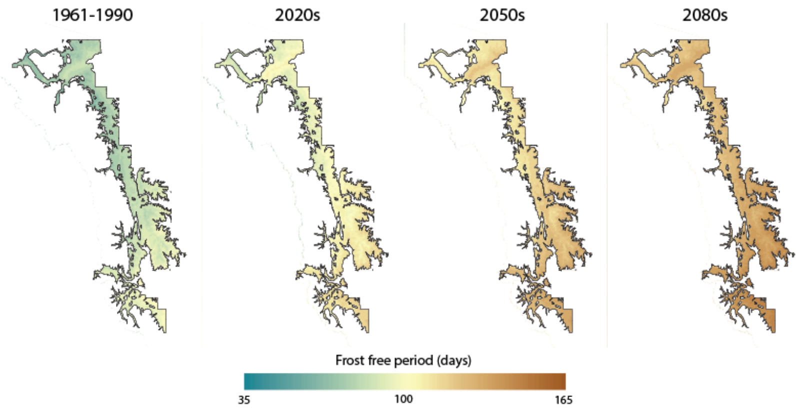

Figure 135: Current and projected future frost free period for Douglas-fir Control Parentage Program (CPP) region F1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

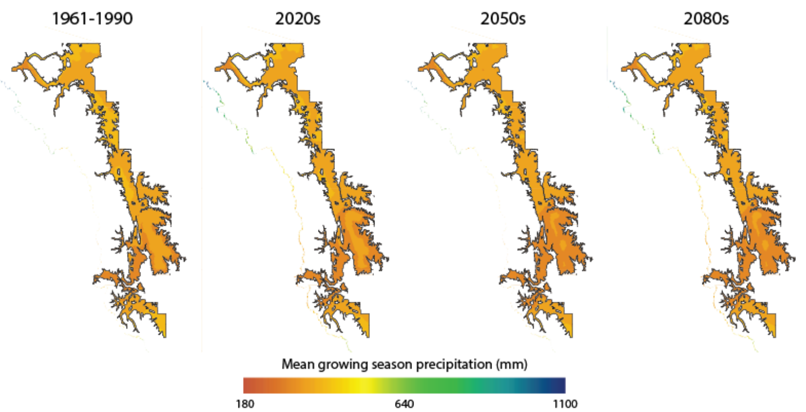

Figure 136: Current and projected mean growing season (May-September) precipitation for Douglas-fir Control Parentage Program (CPP) region F1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

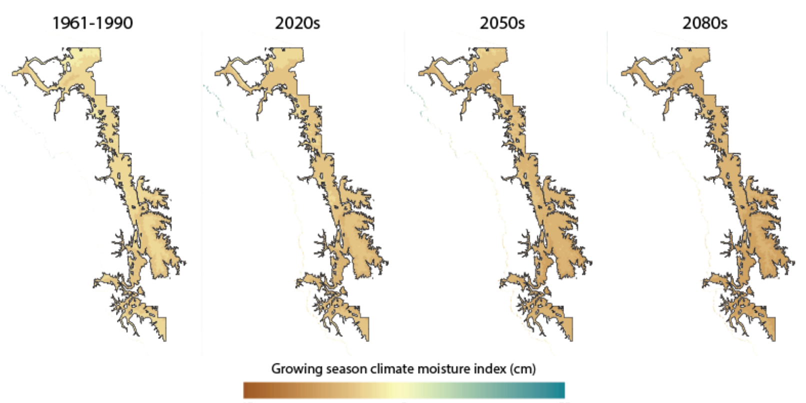

Figure 137: Current and projected future summer (June-August) climate moisture index for Douglas-fir Control Parentage Program (CPP) region F1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

9.0 Projected climate shifts: Western Larch Control Parentage Program Regions

Maps illustrating the shift in each of the six climate variables summarized in this report over the single western larch (*Larix occidentalis*) Control Parentage Program (CPP) region (Figure 138) are provided in the following subsection.

Figure 138: The single region of the western larch (*Larix occidentalis*) Control Parentage Program (CPP).

9.1 Region M

The western larch Control Parentage Program (CPP) region M is the single region of the program, and is approximately 78,924 hectares. This region is comprised of montane and subalpine ecosystems, with a few pockets of foothills parkland ecosystems in the southeast corner of the region. The climate of this region is characteristically drier with relatively warm winter temperatures and the mild temperatures in the summer season.

Maps illustrating the shift in each of the six climate variables summarized in this report over the CPP region M are provided in Figures 139-144, with Figures 139-140 representing changes in winter and summer temperatures; Figures 141-142 representing changes in growing degree days and frost variables; Figure 143 represents changes in precipitation; and finally Figure 144 represents changes in summer climate moisture.

In general, the future projections suggest increased winter warming fairly uniformly across the region, reaching an approximate 3-4°C increase by the 2050s (Figure 139). Projected warming in the summer season is slightly less than the winter season with approximately 2-3°C by the 2050s and again is projected to occur fairly uniformly across the region (Figure 140). Further the number of growing degree days above 5°C as well as frost free period are projected to moderately increase by the 2020s, but accelerate towards the 2080s with a slightly larger increase in the lower elevation montane and foothills parkland ecosystems within the region (Figure 141 and Figure 142). This suggests the potential for a longer growing season throughout the region. A small reduction in growing season precipitation is projected for the region by the 2050s with the most pronounced reductions occurring in the montane ecosystems within the region (Figure 143). Finally moisture reduction is projected to occur over the region by the 2050s following the projected reduction in growing season precipitation (Figure 144).

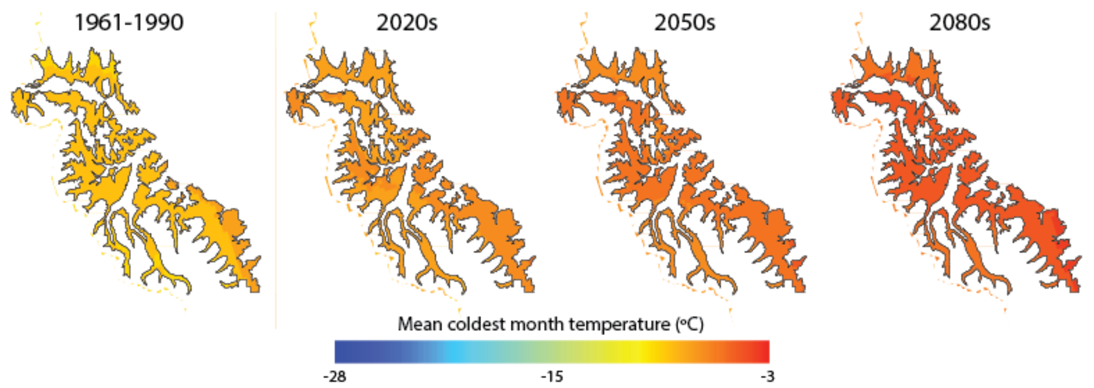

Figure 139: Current and projected future mean coldest month temperature for western larch Control Parentage Program (CPP) region M. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

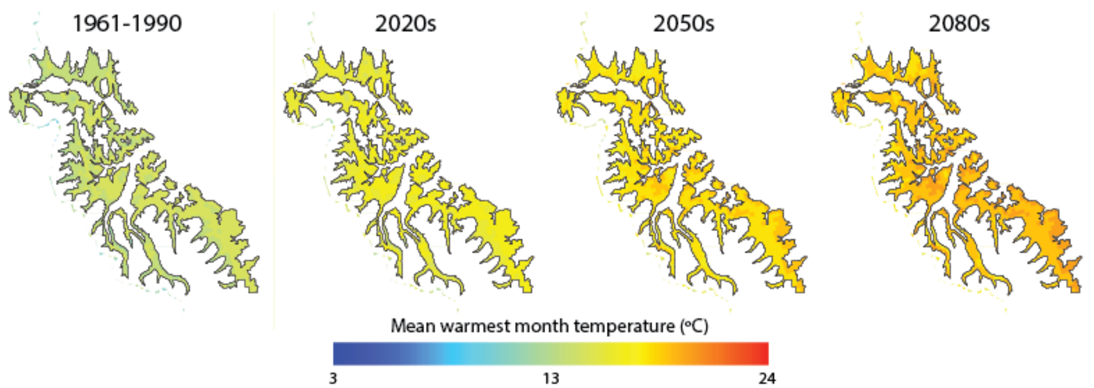

Figure 140: Current and projected future mean warmest month temperature for western larch Control Parentage Program (CPP) region M. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

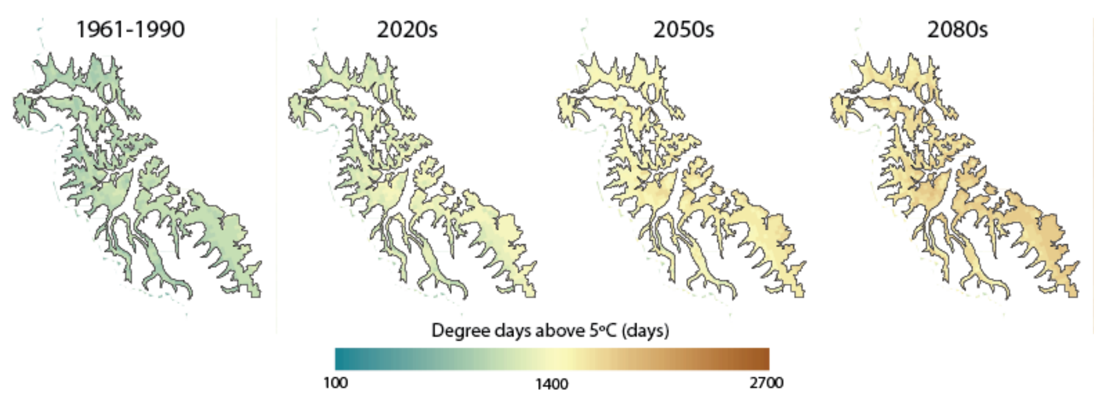

Figure 141: Current and projected future growing degree days above 5˚C for western larch Control Parentage Program (CPP) region M. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

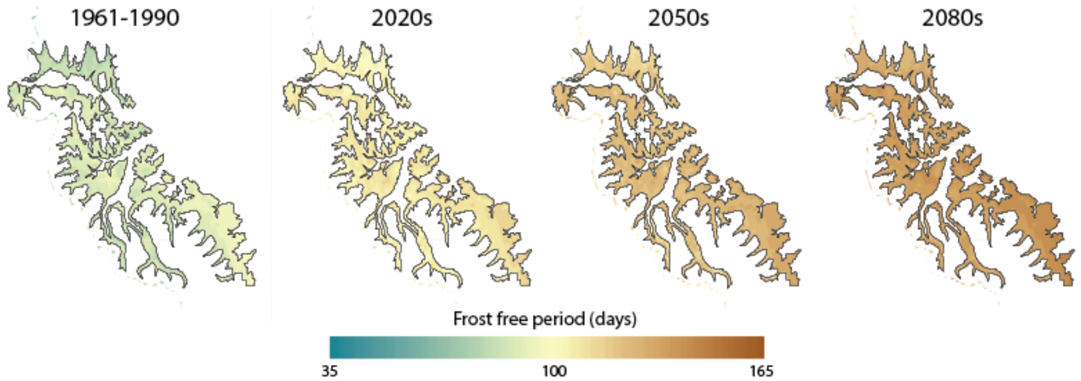

Figure 142: Current and projected future frost free period for western larch Control Parentage Program (CPP) region M. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

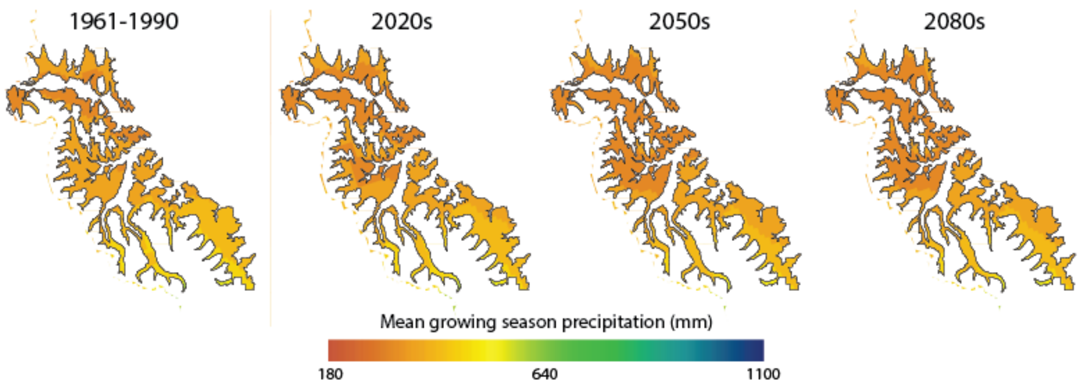

Figure 143: Current and projected mean growing season (May-September) precipitation for western larch Control Parentage Program (CPP) region M. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

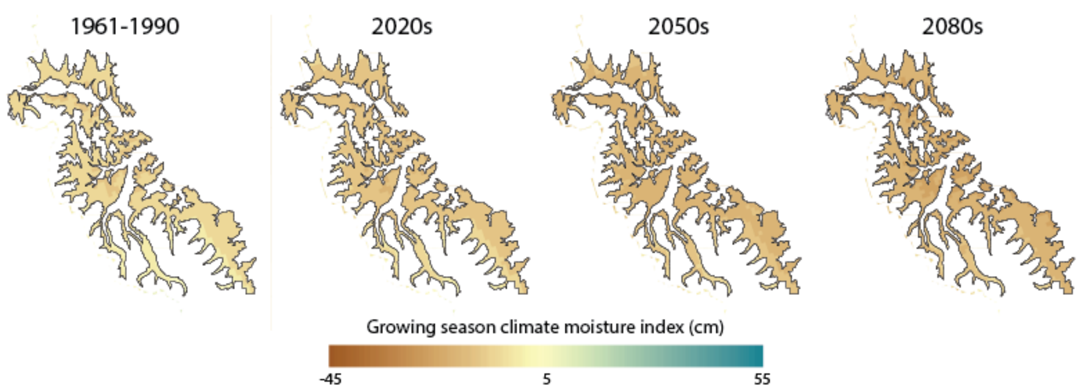

Figure 144: Current and projected future summer (June-August) climate moisture index for western larch Control Parentage Program (CPP) region M. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

10.0 Projected climate shifts: Balsam Poplar Control Parentage Program Regions

Maps illustrating the shift in each of the six climate variables summarized in this report over the single balsam poplar (*Populus balsamifera*) Control Parentage Program (CPP) region (Figure 145) are provided in the following subsection.

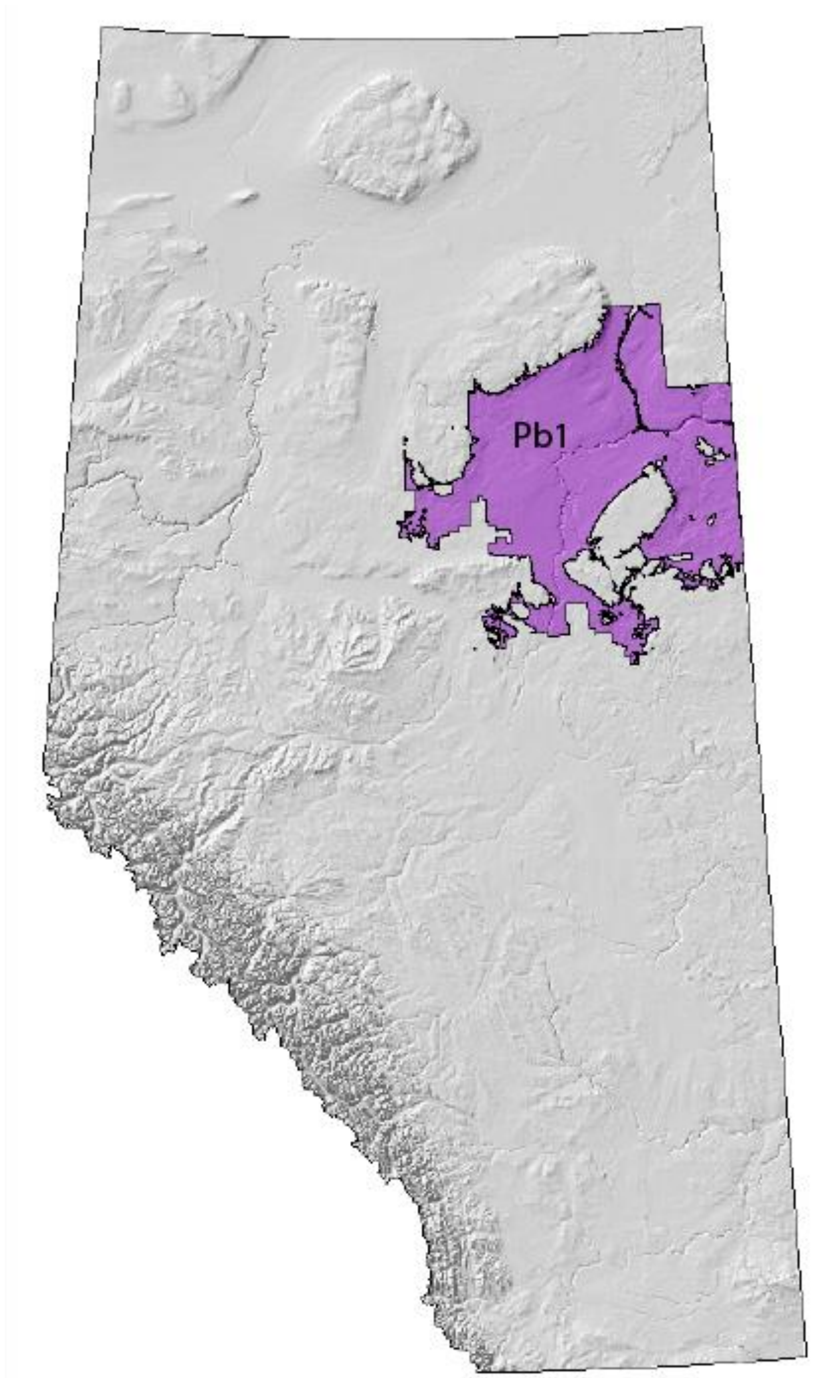

Figure 145: The single region of the balsam poplar (*Poplar balsamifera*) Control Parentage Program (CPP).

10.1 Region Pb1

The balsam poplar Control Parentage Program (CPP) region Pb1 is the single region of the program, and is approximately 145,447,143 hectares. This region is comprised of central mixedwood and Athabasca plains ecosystems with its border following the division between the central mixedwood and lower boreal highlands. The climate of this region is characteristically dry with cold temperatures in the winter and the mild temperatures in the summer season.

Maps illustrating the shift in each of the six climate variables summarized in this report over the CPP region Pb1 are provided in Figures 146-151, with Figures 146-147 representing changes in winter and summer temperatures; Figures 148-149 representing changes in growing degree days and frost variables; Figure 150 represents changes in precipitation; and finally Figure 151 represents changes in summer climate moisture.

In general, the future projections suggest increased winter warming across the region towards the 2080s, with the most pronounced warming occurring in the northern portion of the region reaching an approximate 5°C increase by the 2050s (Figure 146). Projected warming in the summer season is less than the winter season with approximately 2-3°C by the 2050s and is most pronounced in the center of the region (Figure 147). Further the number of growing degree days above 5°C as well as frost free period are projected to moderately increase by the 2020s, but accelerate towards the 2080s extending from the central portion of the region towards the boarders (Figure 148 and Figure 149). This suggests the potential for a longer growing season throughout the region. Growing season precipitation is projected to moderately increase over the region with the wetter conditions of the southern portion of the region significantly expanding northward by the 2020s (Figure 150). Finally moderate reduction in available moisture for the region is projected for the south western and eastern borders of the region beginning in the 2020s. Further moisture reduction is projected to occur in the north by the 2050s following the warming summer temperatures (Figure 151).

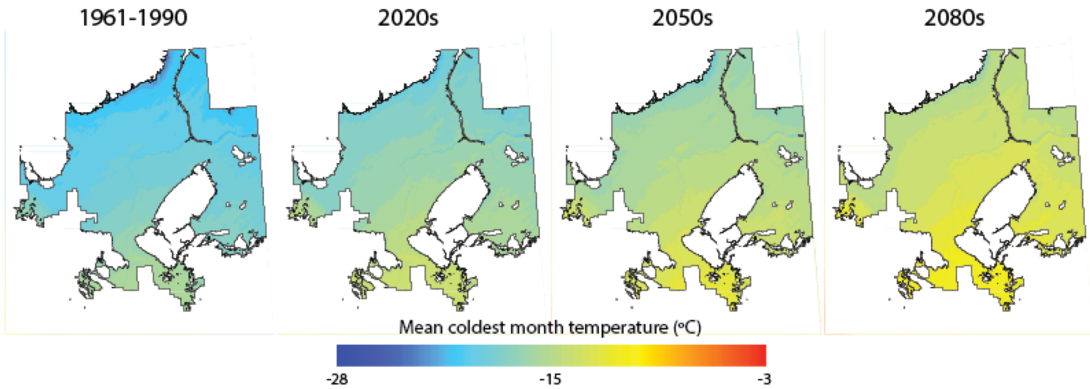

Figure 146: Current and projected future mean coldest month temperature for balsam poplar Control Parentage Program (CPP) region Pb1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

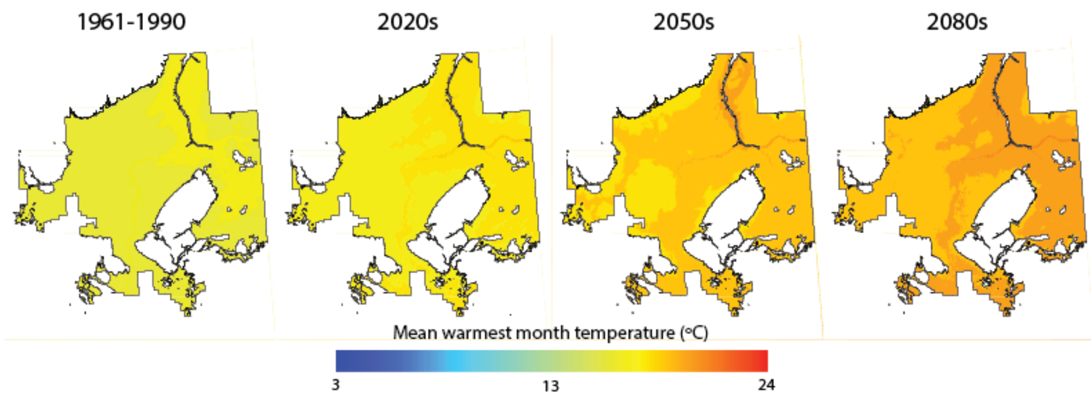

Figure 147: Current and projected future mean warmest month temperature for balsam poplar Control Parentage Program (CPP) region Pb1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

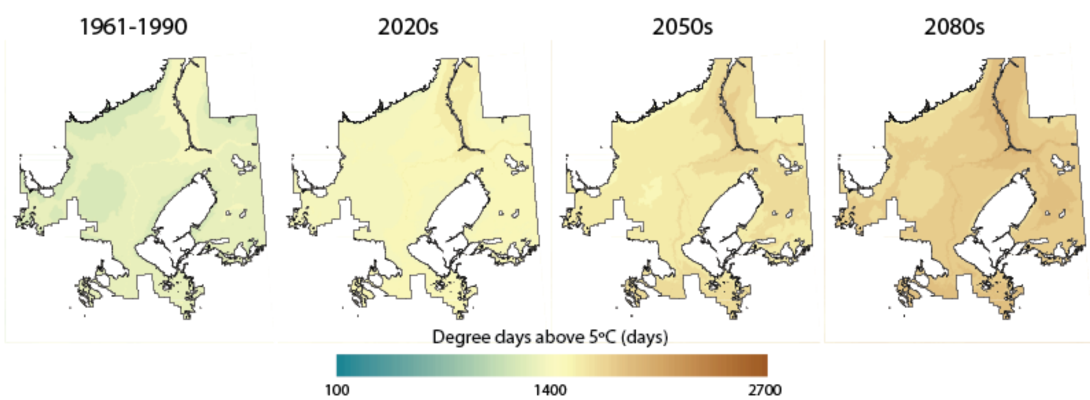

Figure 148: Current and projected future growing degree days above 5˚C for balsam poplar Control Parentage Program (CPP) region Pb1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

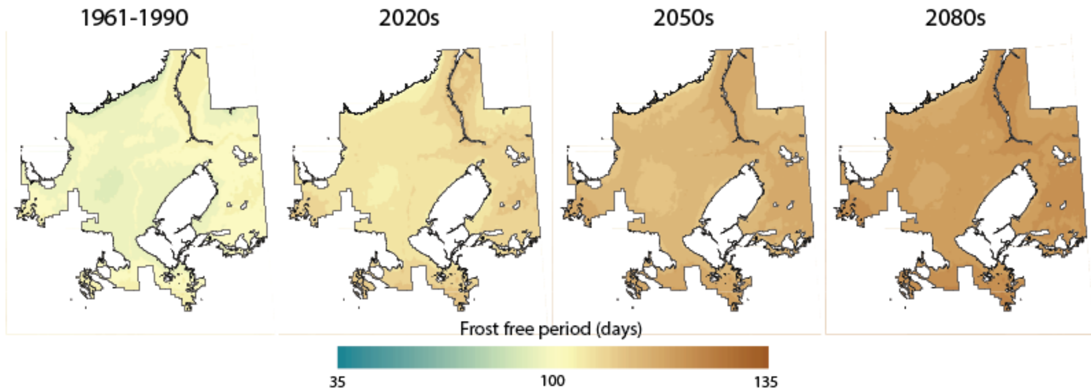

Figure 149: Current and projected future frost free period for balsam poplar Control Parentage Program (CPP) region Pb1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

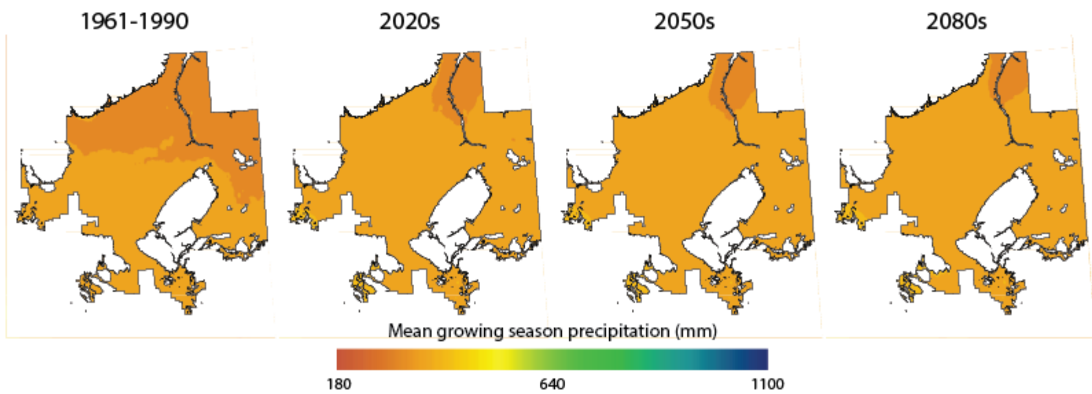

Figure 150: Current and projected mean growing season (May-September) precipitation for balsam poplar Control Parentage Program (CPP) region Pb1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

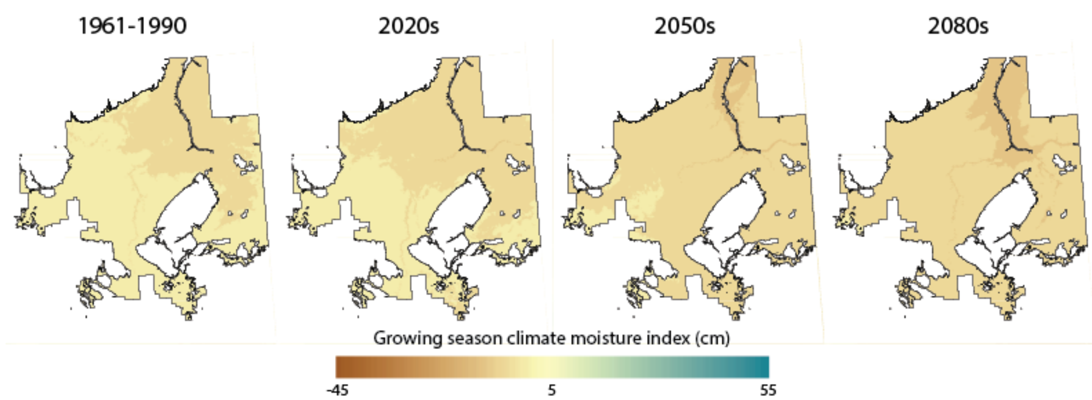

Figure 151: Current and projected future summer (June-August) climate moisture index for balsam poplar Control Parentage Program (CPP) region Pb1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

11.0 Projected climate shifts: Trembling Aspen Control Parentage Program Regions

Maps illustrating the shift in each of the six climate variables summarized in this report over each of the two trembling aspen (*Populus tremuloides*) Control Parentage Program (CPP) regions (Figure 152) are provided in the following subsections. It is important to note that the distribution and boundaries of these CPP regions are still drafts and at this time are not considered finalized versions.

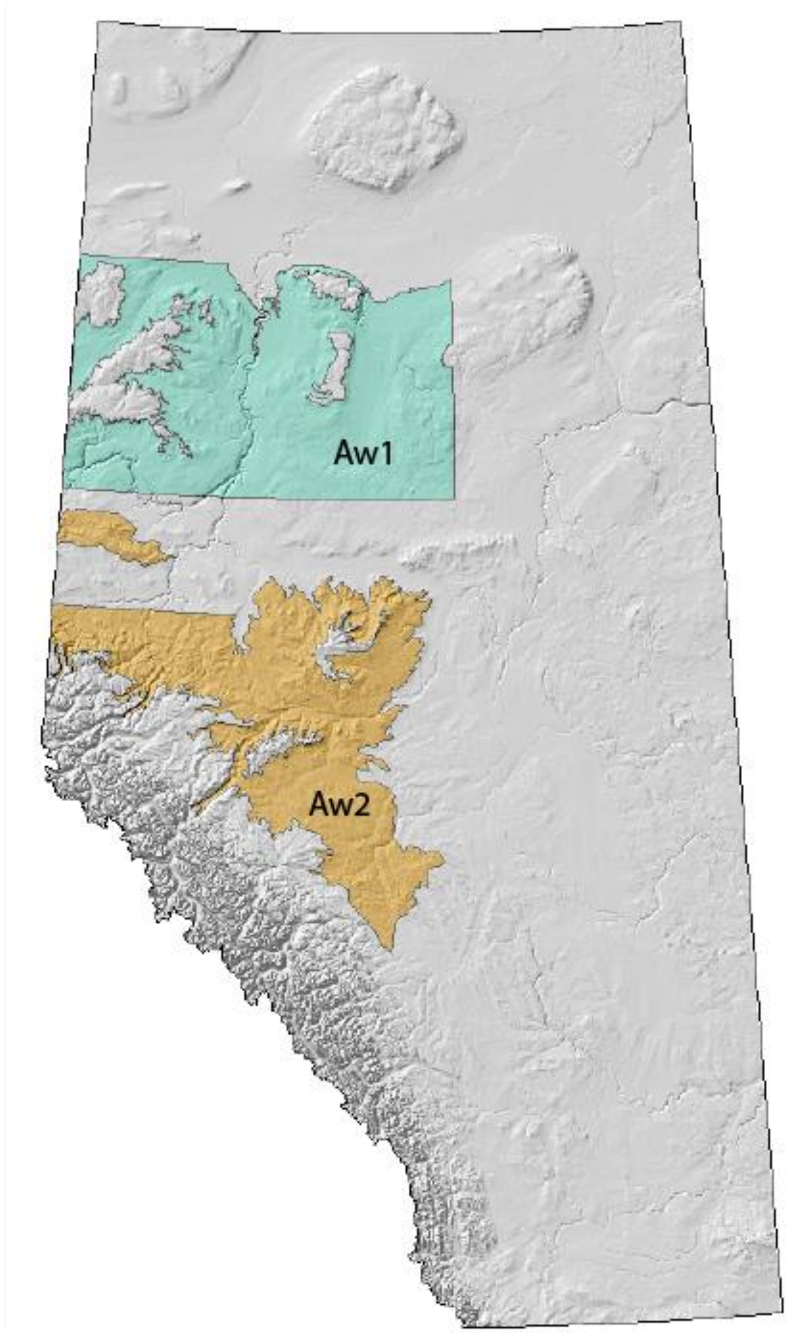

Figure 152: The two regions of the trembling aspen (*Populus tremuloides*) Control Parentage Program (CPP).

11.1 Region Aw1

The trembling aspen Control Parentage Program (CPP) region Aw1 is the smaller and most northern of the trembling aspen CPP regions at approximately 3,646,879 hectares. This region is comprised of central mixedwood, dry mixedwood, and lower boreal highlands ecosystems. The borders of the region follow the division between the lower and upper boreal highland ecosystems. The climate of this region is characteristically dry with cold temperatures in the winter season and mild temperatures in the summer.

Maps illustrating the shift in each of the six climate variables summarized in this report over the CPP region Aw1 are provided in Figures 153-158, with Figures 153-154 representing changes in winter and summer temperatures; Figures 155-156 representing changes in growing degree days and frost variables; Figure 157 represents changes in precipitation; and finally Figure 158 represents changes in summer climate moisture.

In general, the future projections suggest a significant increase in winter temperatures across the region beginning in the 2020s and accelerating towards the 2080s, reaching an approximate 4-5˚C increase by the 2050s (Figure 153). Projected warming in the summer season is of a lesser magnitude compared to winter warming, reaching a 2-3˚C increase by the 2050s, with the most pronounced warming projected to occur in the lower elevation central and dry mixedwood ecosystem within the center of the region (Figure 154). Further the number of growing degree days above 5˚C as well as frost free period are projected to moderately increase by the 2020s, but accelerate towards the 2080s, with the projected changes following the change in summer temperatures as seen in the central and dry mixedwood ecosystems (Figure 155 and Figure 156). This suggests a potential for a longer growing season, especially within the lower elevations of the region. Growing season precipitation is projected to moderately increase over the region with the wetter conditions of the southeastern portion of the region expanding northward by the 2020s (Figure 157). Finally moderate reduction in available moisture for the region is projected for the south western and eastern borders of the region beginning in the 2020s. Further moisture reduction is projected to occur in the north by the 2050s following the warming summer temperatures (Figure 158).

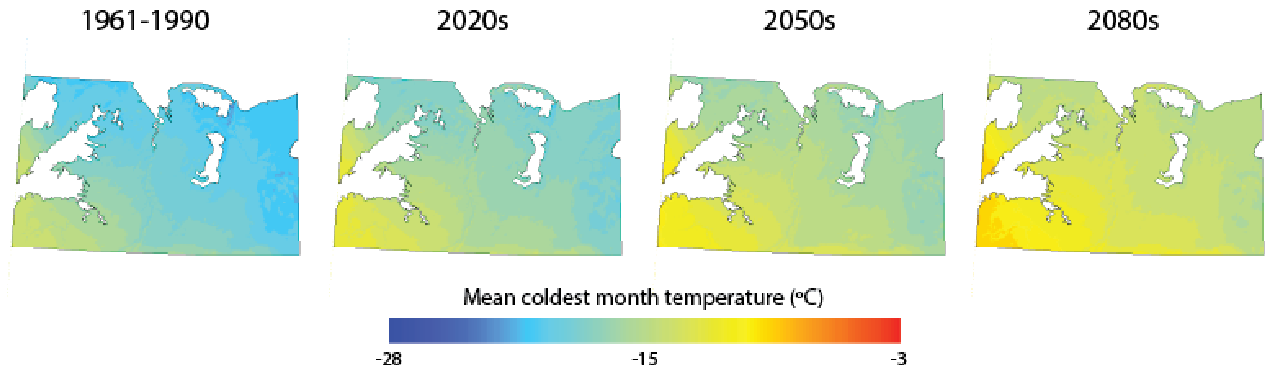

Figure 153: Current and projected future mean coldest month temperature for trembling aspen Control Parentage Program (CPP) region Aw1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

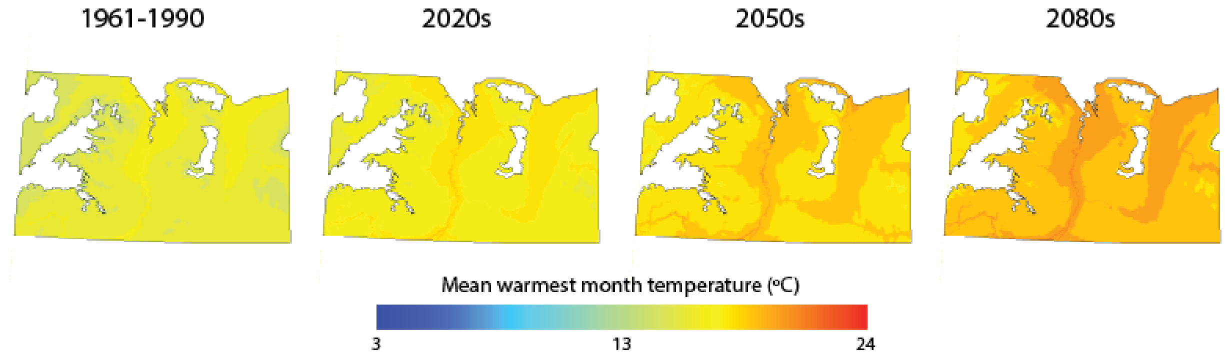

Figure 154: Current and projected future mean warmest month temperature for trembling aspen Control Parentage Program (CPP) region Aw1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

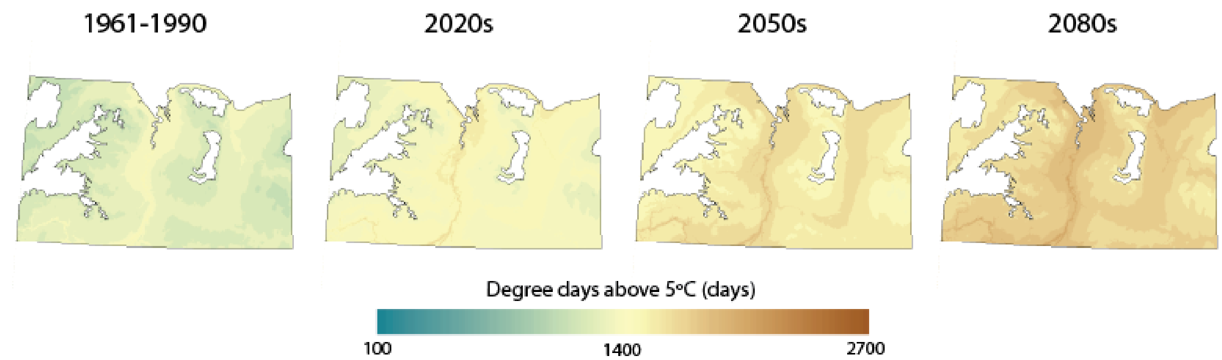

Figure 155: Current and projected future growing degree days above 5°C for trembling aspen Control Parentage Program (CPP) region Aw1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

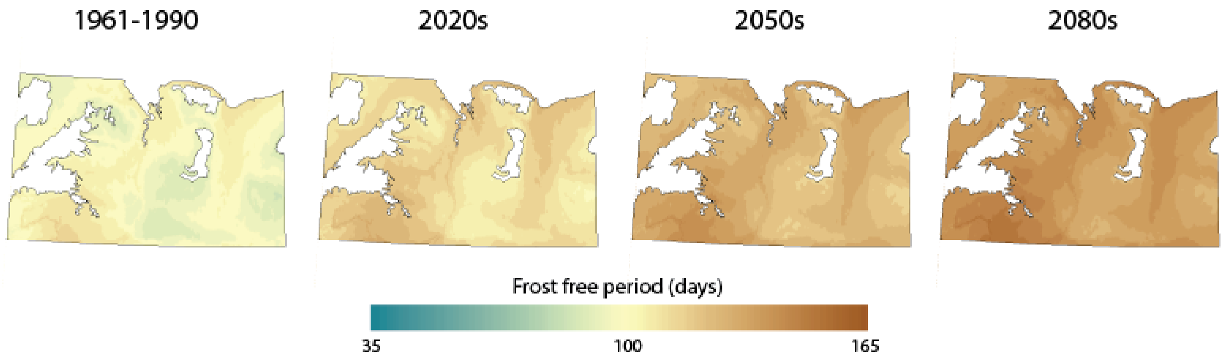

Figure 156: Current and projected future frost free period for trembling aspen Control Parentage Program (CPP) region Aw1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

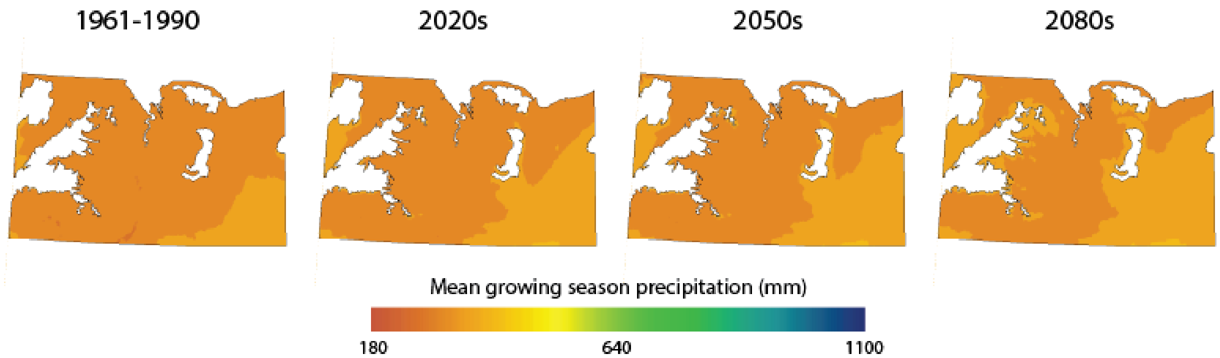

Figure 157: Current and projected mean growing season (May-September) precipitation for trembling aspen Control Parentage Program (CPP) region Aw1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

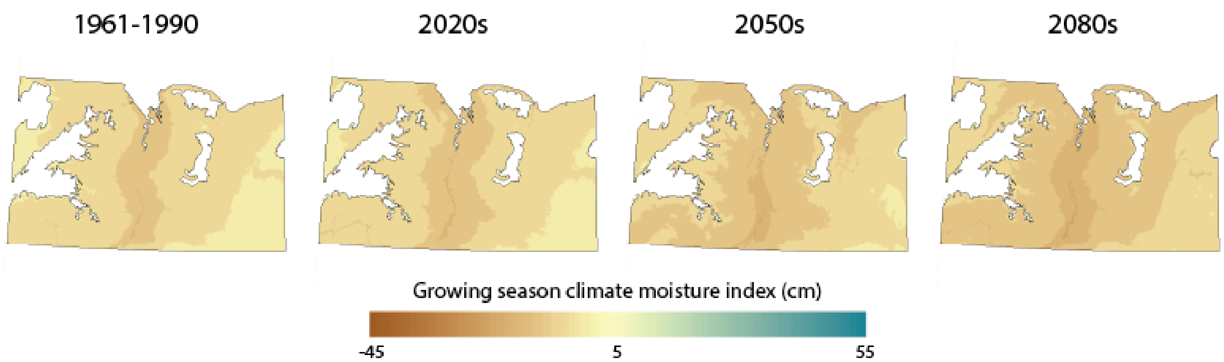

Figure 158: Current and projected future summer (June-August) climate moisture index for trembling aspen Control Parentage Program (CPP) region Aw1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

11.2 Region Aw2

The trembling aspen Control Parentage Program (CPP) region Aw2 is the larger and most southern of the trembling aspen CPP regions at approximately 4,036,271 hectares. This region is comprised of mainly of lower foothills ecosystems with pockets of central mixedwood ecosystems along the northern and eastern borders. The main borders of the region follow the division between the lower and upper foothill ecosystems. The climate of this region is characteristically wet with relatively warm temperatures in the winter season and mild temperatures in the summer.

Maps illustrating the shift in each of the six climate variables summarized in this report over the CPP region Aw2 are provided in Figures 159-164, with Figures 159-160 representing changes in winter and summer temperatures; Figures 161-162 representing changes in growing degree days and frost variables; Figure 163 represents changes in precipitation; and finally Figure 164 represents changes in summer climate moisture.

In general, the future projections suggest a significant increase in winter temperatures across the region beginning in the 2020s and accelerating towards the 2080s, reaching an approximate 3-4°C increase by the 2050s with the most pronounced warming projected for the higher elevation lower foothills ecosystems which border the upper foothills ecosystems along the southern border and in the center of the region (Figure 159). Projected warming in the summer season is of equal magnitude compared to winter warming, with the most pronounced warming projected to occur in the lower foothills ecosystem (Figure 160). Further the number of growing degree days above 5°C as well as frost free period are projected to moderately increase by the 2020s, but accelerate towards the 2080s, with the projected changes following the change in summer temperatures as seen in the lower foothill ecosystems (Figure 161 and Figure 162). This suggests a potential for a longer growing season, especially along the western perimeter of the region. Although a slight increase in summer precipitation is projected for the upper foothills ecosystem within the region, little change in summer precipitation is projected for the majority of the region for all periods (Figure 163). Finally moderate temperature increases projected in the summer season coupled with little precipitation change is projected to result in a slight reduction in available moisture for the region, especially in the higher elevation lower foothills ecosystems which border the upper foothills ecosystems (Figure 164).

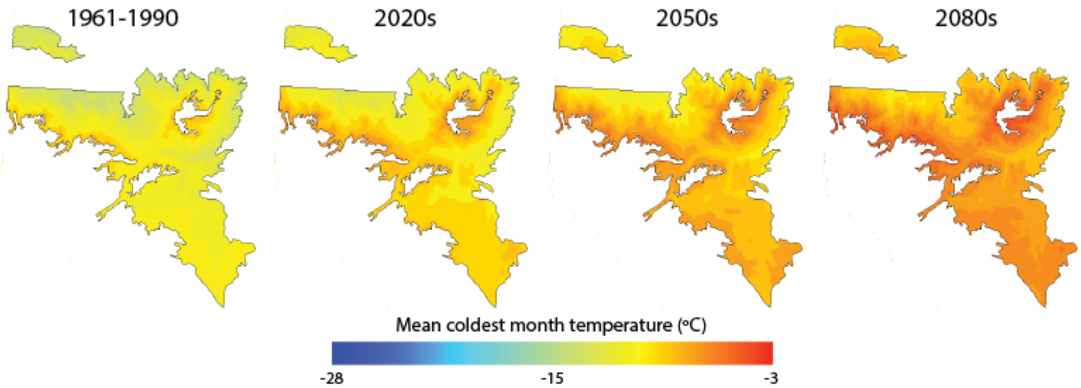

Figure 159: Current and projected future mean coldest month temperature for trembling aspen Control Parentage Program (CPP) region Aw2. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

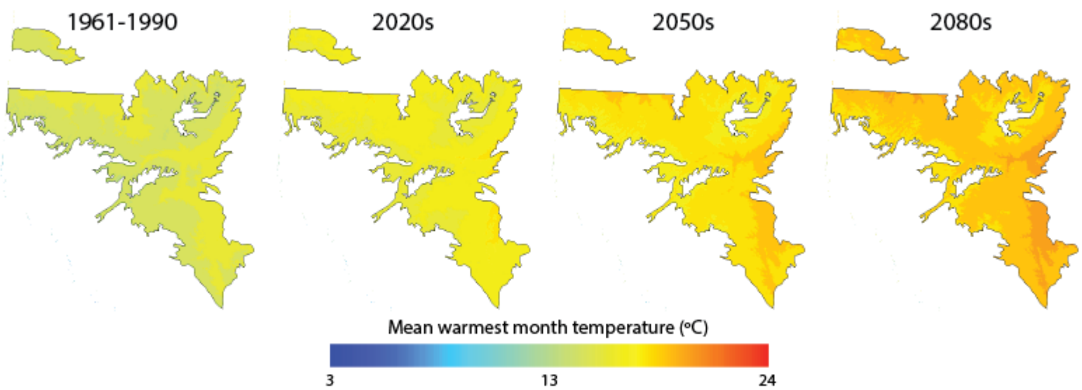

Figure 160: Current and projected future mean warmest month temperature for trembling aspen Control Parentage Program (CPP) region Aw2. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

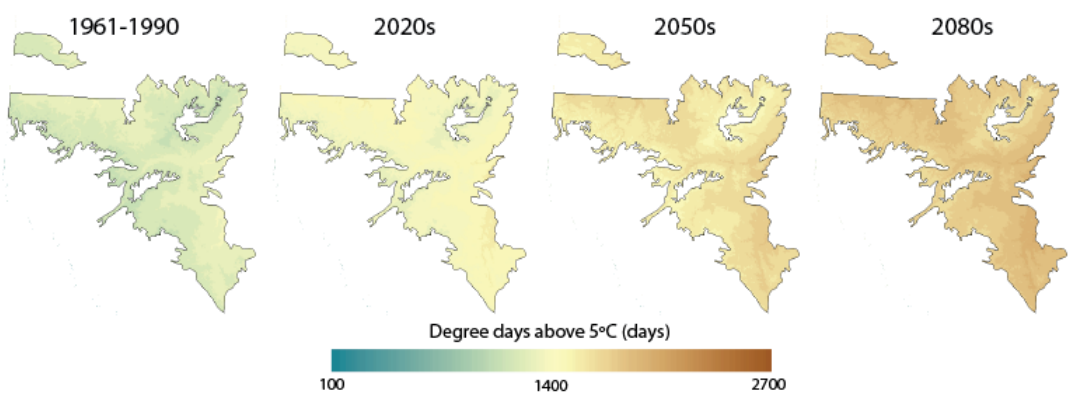

Figure 161: Current and projected future growing degree days above 5˚C for trembling aspen Control Parentage Program (CPP) region Aw2. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

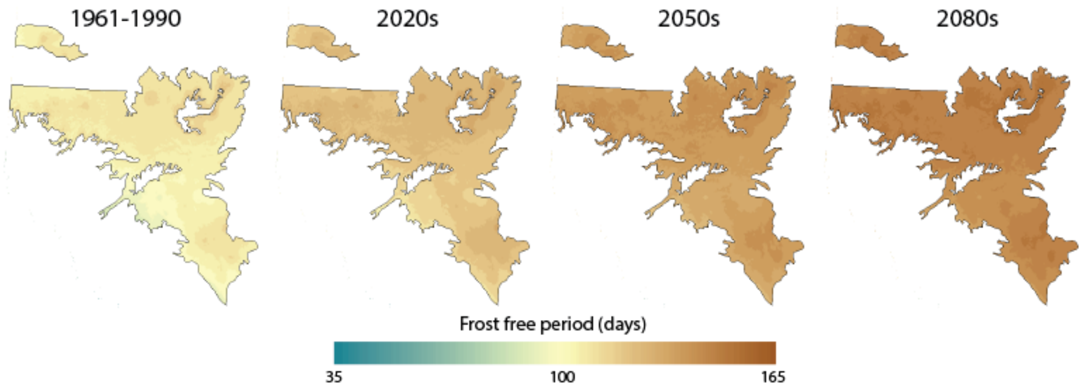

Figure 162: Current and projected future frost free period for trembling aspen Control Parentage Program (CPP) region Aw2. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

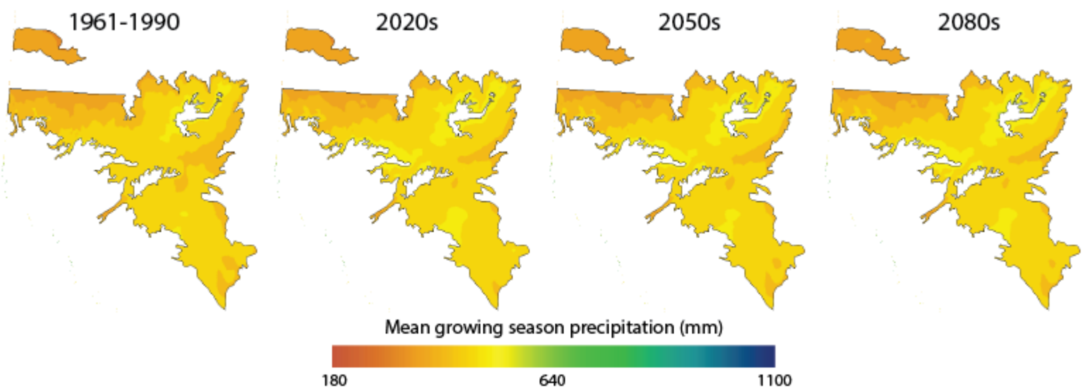

Figure 163: Current and projected mean growing season (May-September) precipitation for trembling aspen Control Parentage Program (CPP) region Aw2. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

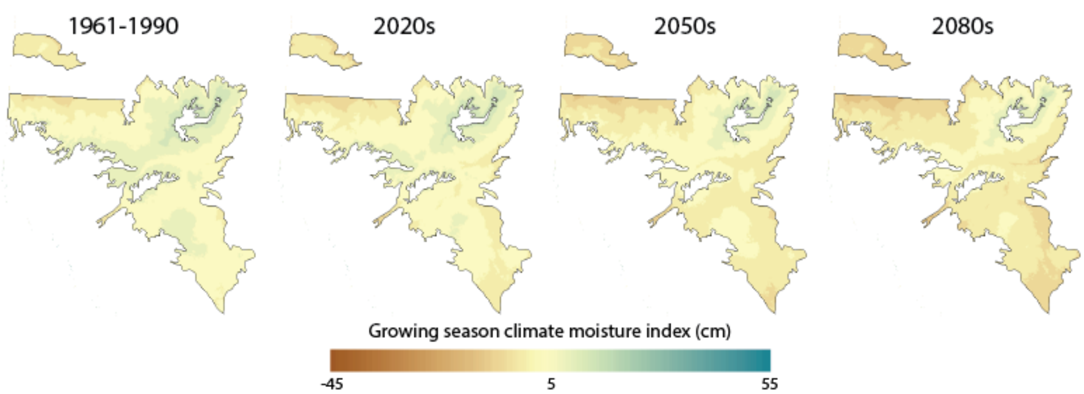

Figure 164: Current and projected future summer (June-August) climate moisture index for trembling aspen Control Parentage Program (CPP) region Aw2. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

12.0 Acknowledgements

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