Tree species Adaptation Risk Management Project

Adapting to Climate Change Through Genetics of Forest Trees

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Outline

- Rationale of the Tree Species Adaptation Risk Management project
- Major components of the project
- Details of the climate change adaptation in breeding regions – white spruce & lodgepole pine
- Learnings from the project
- Applications

Rationale of the Project

- The health, productivity and sustainability of forest ecosystems, trees in these ecosystems, and sustainability of the benefits we get from forests is routed in **seed** from which these trees grew.

- Forests rely on the **genetics** of their trees to cope (**adapt**) with a changing environment.

- Genetics of the trees is mediated through **seed** from which trees grew.

Rationale of the Project

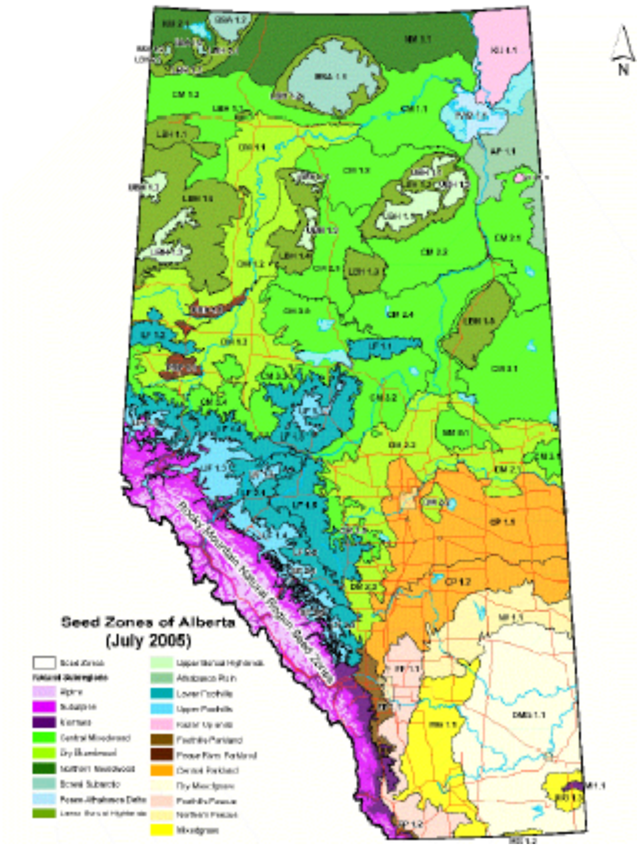
- The importance of **seed** in determining the future of forests is especially important when forests are artificially planted

- When forests are artificially planted, only a small sample of the species' genetic pool is used; seed and genes may be placed in a wrong environment; adaptation of the species may be compromised; and health and productivity of the forests reduced.

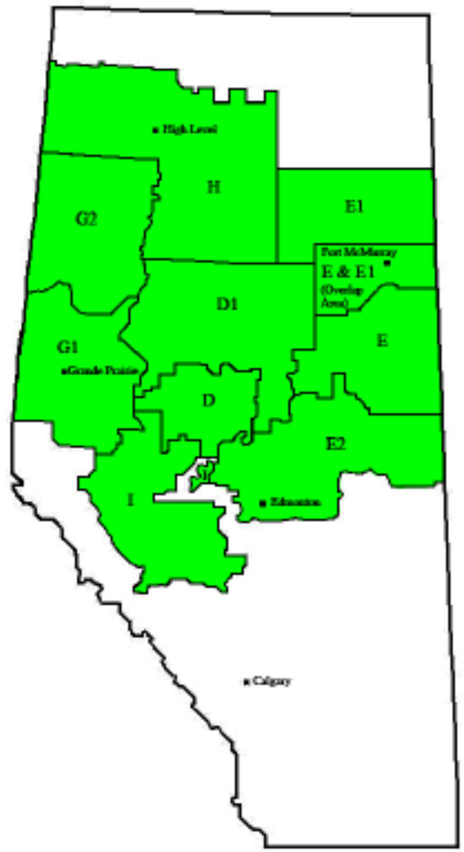
Rationale of the Project

- It is due to this importance of genetics and seed that seed use is regulated by government through **seed transfer standards** (guidelines).
- It is in these standards that climate change adaptation is to be mediated.
- The Tree Species Adaptation Risk Management (TSARM) project was initiated by CCEMC to integrate climate change adaptation in tree breeding and seed transfer standards.

Rationale of the Project



Seed zones for wild seed



White spruce
breeding regions

Lodgepole pine
breeding regions

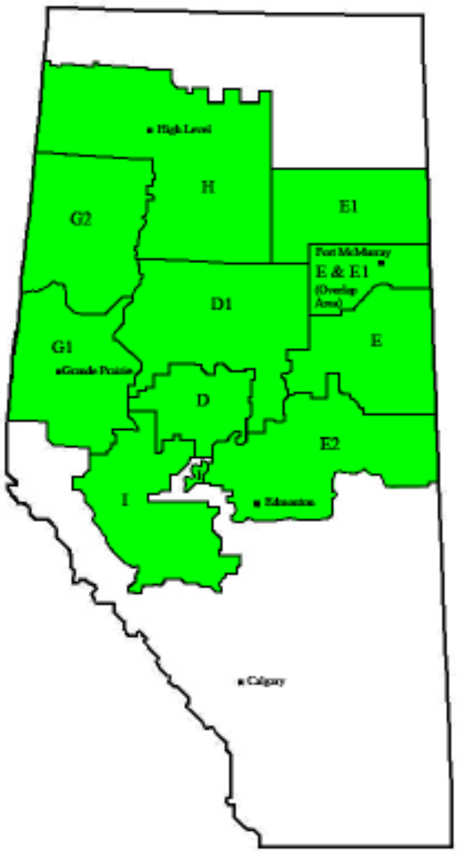
Components of the TSARM Project

- The TSARM project implemented subprojects in government and industry tree breeding programs:
  - Expanding provenance trials to allow testing for drought and cold tolerance
  - Assessing vulnerability and the risk climate change poses to regional breeding programs
  - Climate change modeling for the province and individual tree breeding regions
  - **Conduct climate and genetic analysis in existing field experiments to support climate change adaptation in current seed transfer standards**
  - Develop efficient clonal vegetative propagation methods for aspen

Modeling climate change & biological response to climate change

- The TSARM project was devoted to climate change adaptation in tree breeding programs.
- Alberta has 24 tree breeding programs for conifers (21) and poplars (3) – each provide material for reforestation in a specific part of the province (**see next slide**)
- We wanted to know:
    - How climatically different are these breeding regions now and in the future – climate modeling
    - Are trees (populations & trees within populations) genetically different among these breeding regions? Can these genetic differences be linked to a specific climatic variable?
    - Can we transfer seed among breeding regions as an adaptation to climate change (**assisted migration**)?

Modeling climate change & biological response to climate change



White spruce
breeding regions

Lodgepole pine
breeding regions

Modeling climate change & biological response to climate change

Acknowledgement

This part of the project was implemented by **Dr. Laura Gray** and **Dr. Andreas Hamann** in the Department of Renewable Resources at the **University of Alberta**

Modeling climate change

- Two types of climatic maps were developed through climate modeling describing **temperature** and **precipitation** conditions for
    1. The province as a whole
    2. All 24 breeding regions
- Maps were developed for different **temperature** and **precipitation** variables describing **annual** and **seasonal** climatic profiles for the province and individual breeding regions
- Climate modeling was for 4 time periods:
    1. 1961 – 1990 base period
    2. 2020
    3. 2050
    4. 2080

Modeling climate change - Alberta

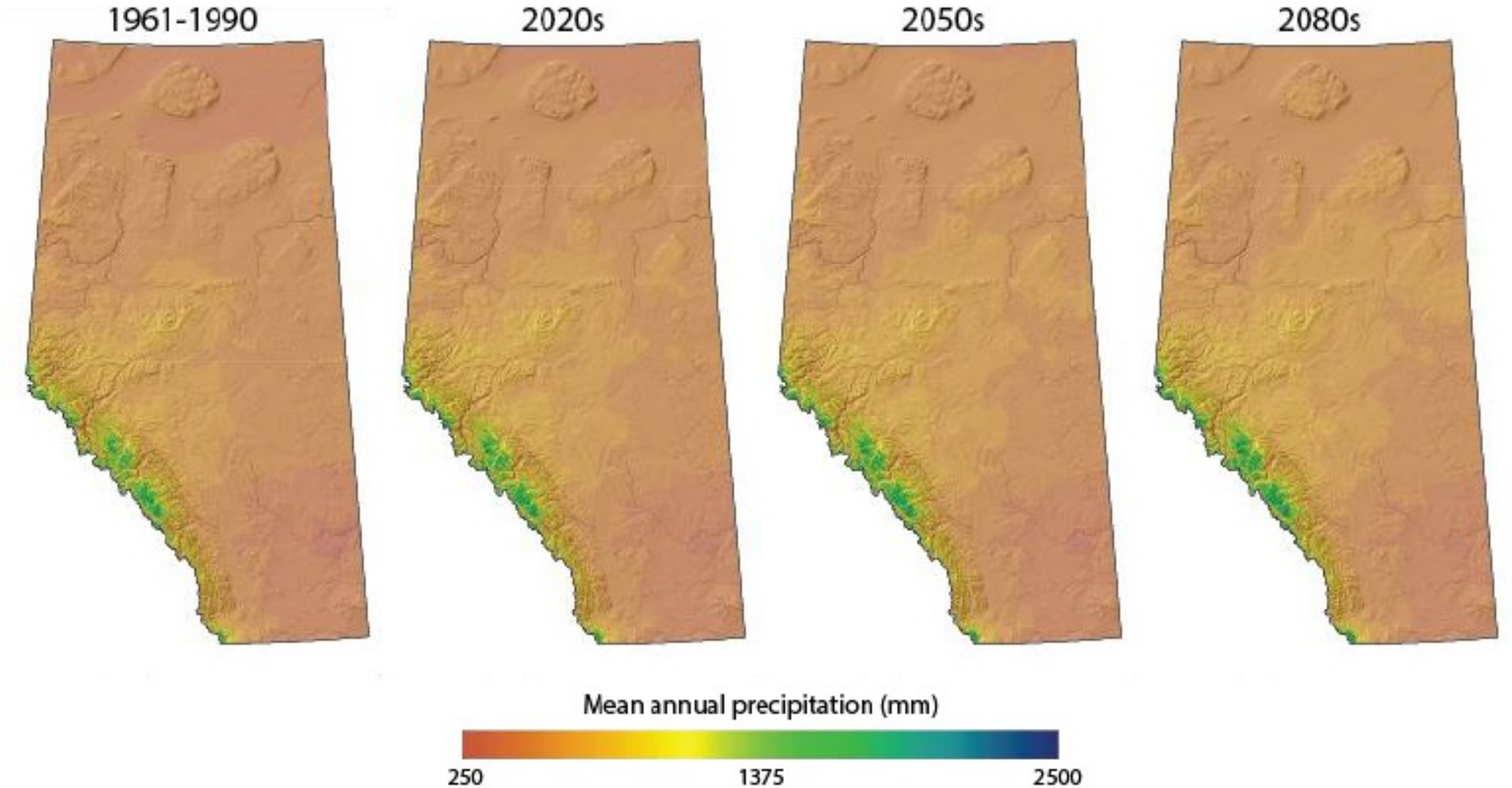


Figure 9: Current and projected mean annual precipitation for Alberta. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

Modeling climate change - Alberta

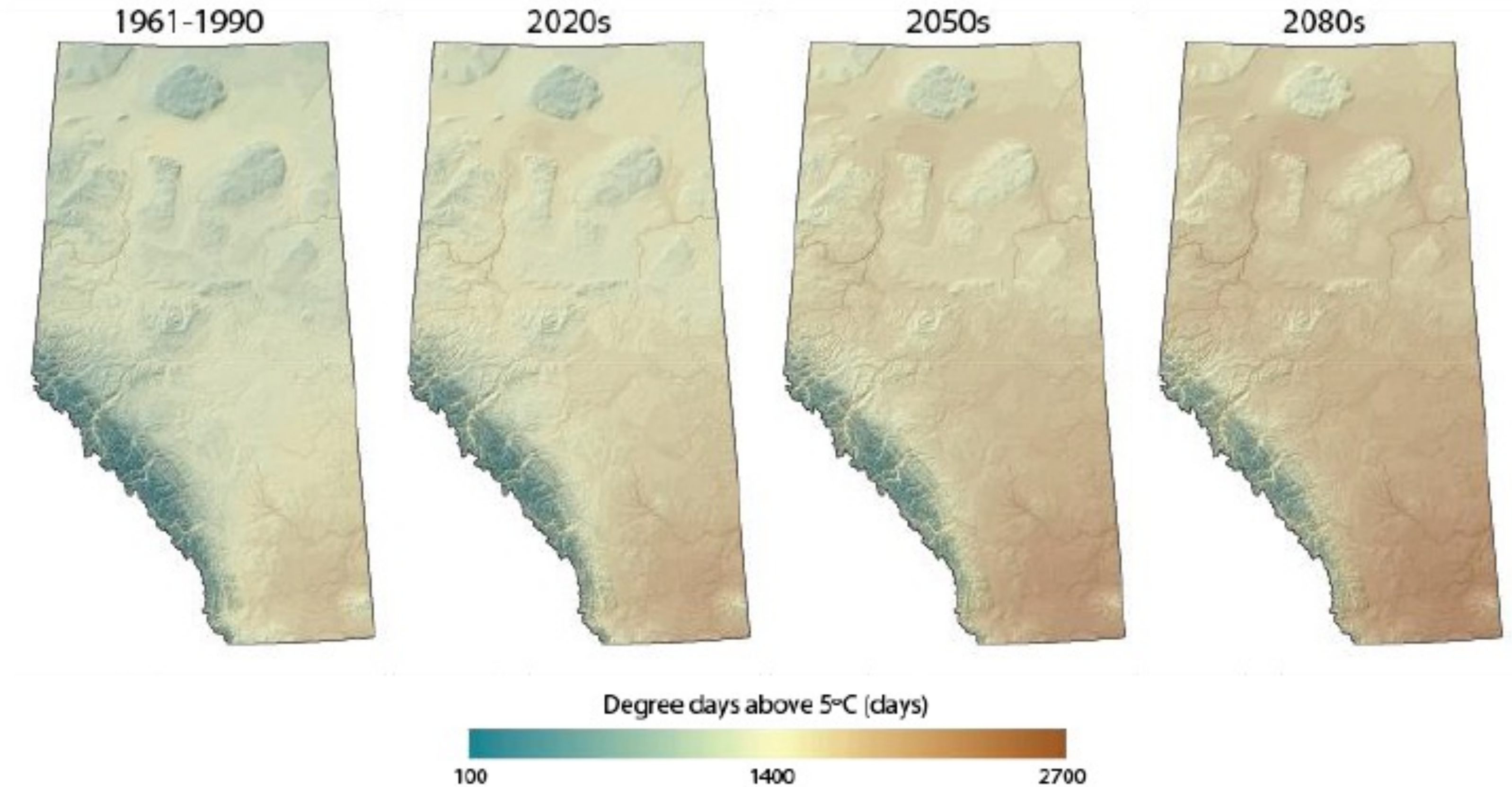


Figure 7: Current and projected future growing degree days above 5˚C for Alberta. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

Modeling climate change - Alberta

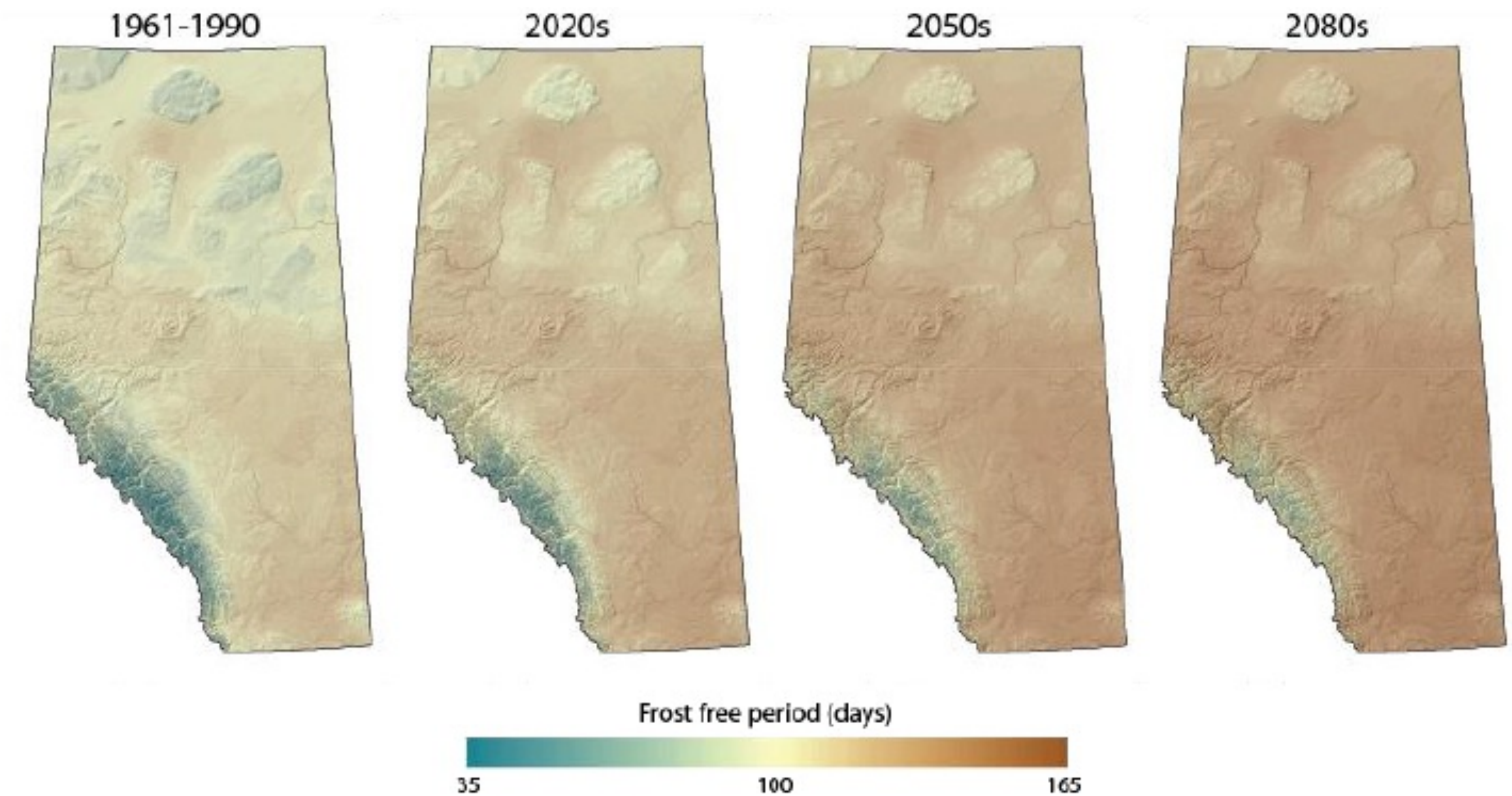
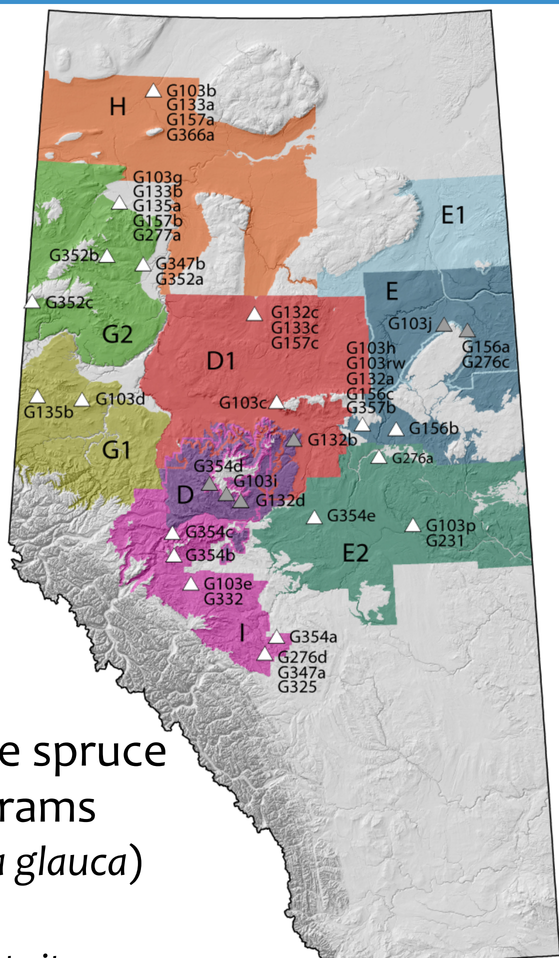
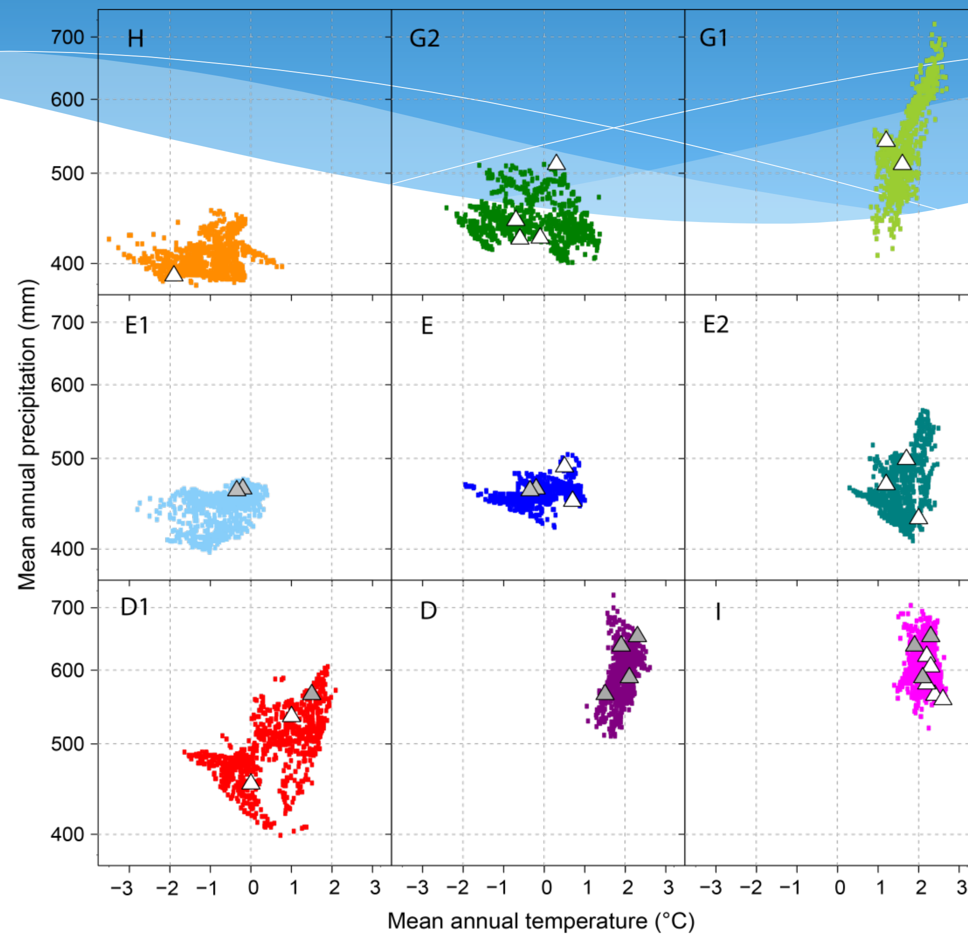


Figure 8: Current and projected future frost free period for Alberta. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

How climatically different are the breeding regions in the current and projected future climate?





White spruce programs
(*Picea glauca*)

△ Test site

Images for all program specific CPP regions are provided in individual risk management reports. Example:
Climate Change Risk Assessment for the Region H White Spruce Controlled Parentage Program (CPP)

Modeling climate change for breeding regions

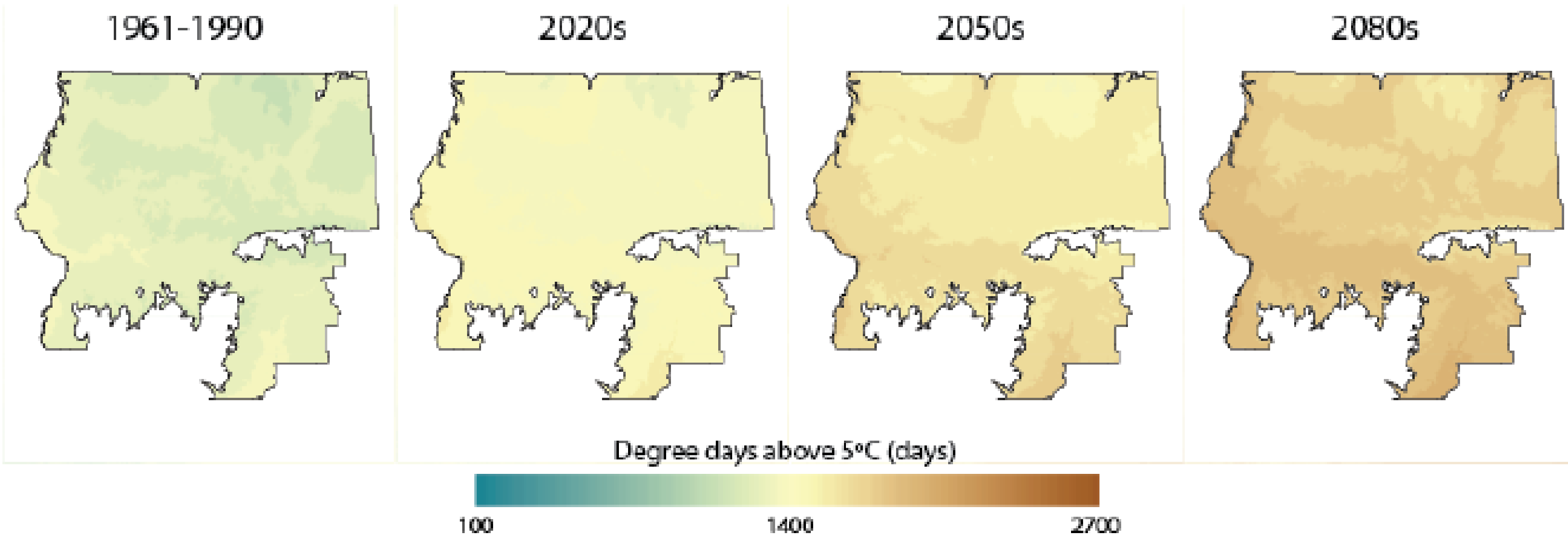


Figure 22: Current and projected future growing degree days above 5˚C for white spruce Control Parentage Program (CPP) region D1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

Modeling climate change for breeding regions

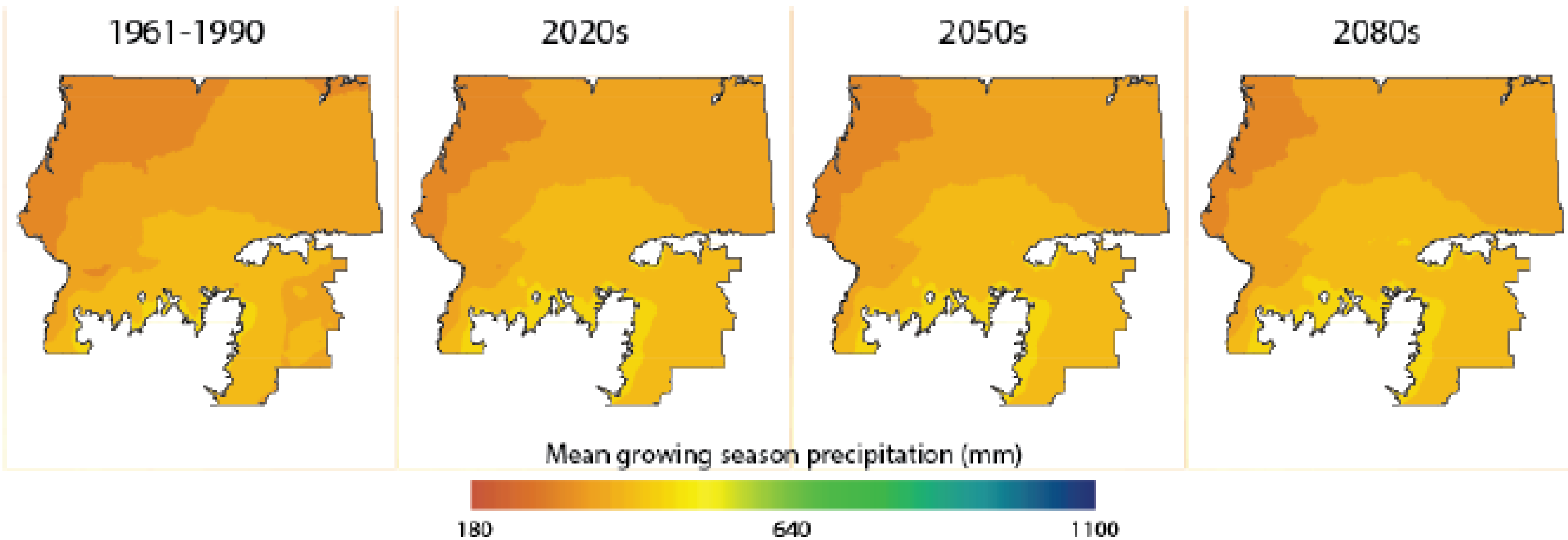


Figure 24: Current and projected mean growing season (May-September) precipitation for white spruce Control Parentage Program (CPP) region D1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

Modeling climate change for breeding regions

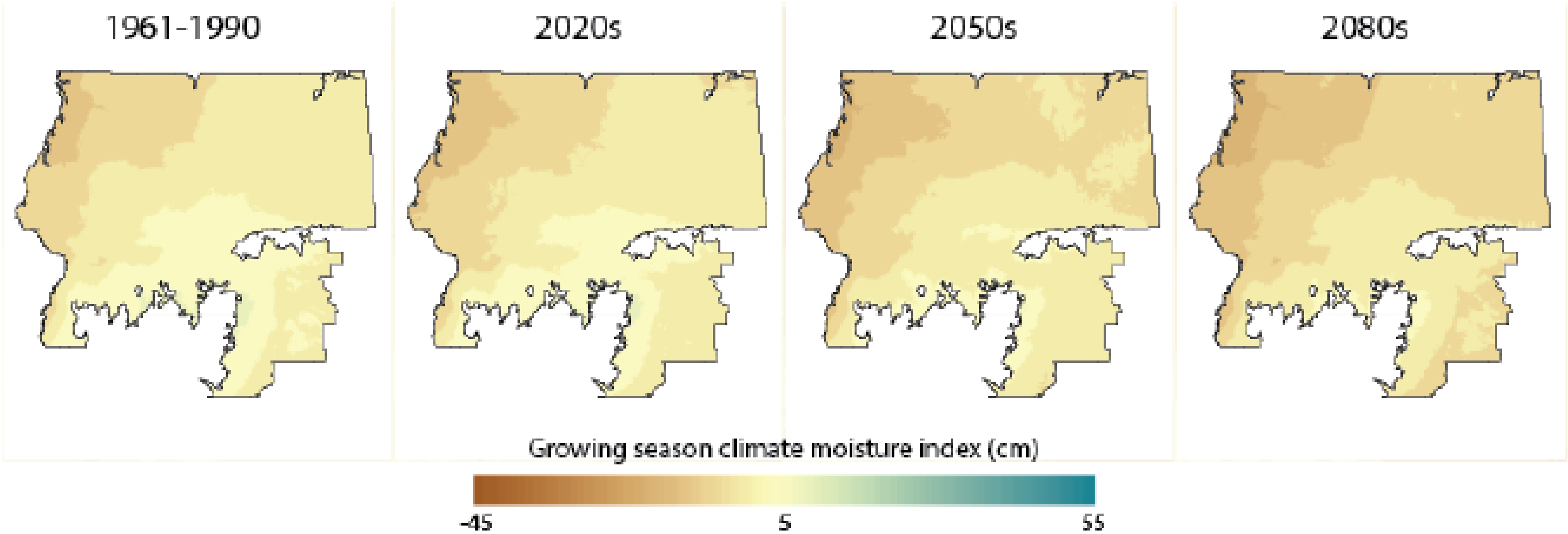


Figure 25: Current and projected future summer (June-August) climate moisture index for white spruce Control Parentage Program (CPP) region D1. Future projections illustrate an ensemble of outputs from seven modelling groups implementing the A1B emission and population growth scenario.

Modeling climate change – main observations

- **Mean Coldest Month Temperature** is projected to significantly increase across Alberta
  - Largest warming winter signals expected in boreal ecosystems in northern Alberta & at higher elevations

- Increases in **Mean Warmest Month Temperature** are less significant than winter months
  - Most pronounced summer warming is projected to occur at lower elevations in the lower foothills

Modeling climate change – main observations

- Moderate increases in **Frost Free Period** and **Growing Degree Days** by the 2020s are projected to accelerate towards the 2080s across Alberta

- Changes in **Growing Season Precipitation** are more variable across Alberta
  - Storm track will continue to bring precipitation to central and eastern boreal ecosystems, however there will be less available moisture
  - Moderate decreases projected for northern boreal and lower elevation Rocky Mountain Foothills ecosystems
  - More significant decreases expected for southern boreal ecosystems

Modeling climate change – main observations

- **Generally, climate change in Alberta is predicted to include**
  - High spring and summer heat (growing degree days > 5^{o}C)
  - Decline or small increases in annual and growing season precipitation
  - Decline in available moisture for tree growth in the boreal forest –**drought and decline in forest productivity**
  - Increase in spring and summer heat in mountainous areas that currently have high precipitation but low heat –**longer growing season** and **high forest productivity**.

Modeling climate change – main observations

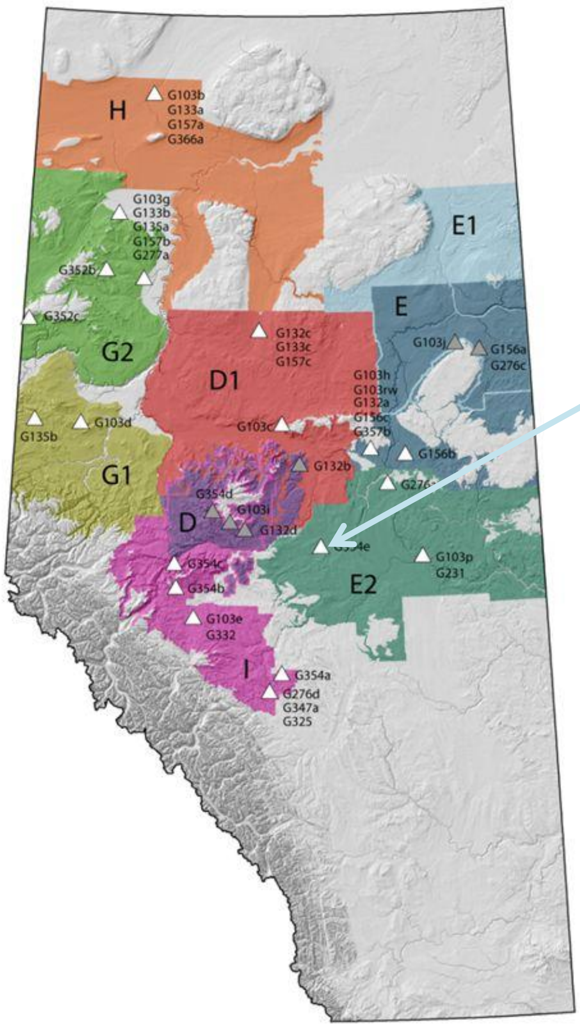
- For climate change adaptation the challenges are:
    - How to sustain forest health and productivity in a drier boreal forest region?
    - How to increase forest productivity in the mountain regions by bringing in more productive populations?

Biological response to climate change – white spruce and lodgepole pine

- The Alberta government and forest companies have **field experiments** linked to breeding programs and provenance trials for province-wide adaptation research
- **White spruce** and **lodgepole pine** makes up over **80%** of tree planting in Alberta
- **Climate change adaptation** in these two species will do a lot to adapt Alberta's forests and the forestry industry to climate change.
- The existing field experiments for white spruce and lodgepole pine provided data for analyzing genetic response to climate change
- How we can modify the **current standards** to consider climate change adaptation by potentially transferring seed among breeding regions?

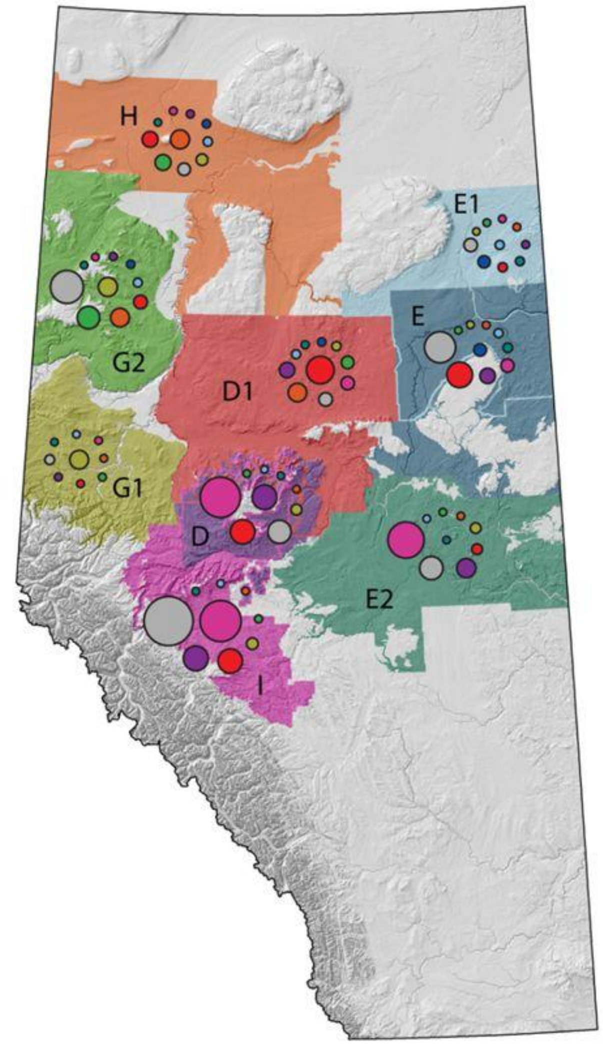
White spruce breeding regions & field testing (experiments)

Provenance & progeny test sites



- 44 provenance & progeny trials
- 25 test sites
- 1170 white spruce parents
- 133,791 individual trees
- Age 10 – 32 (relative height analyzed)

Seed transfers

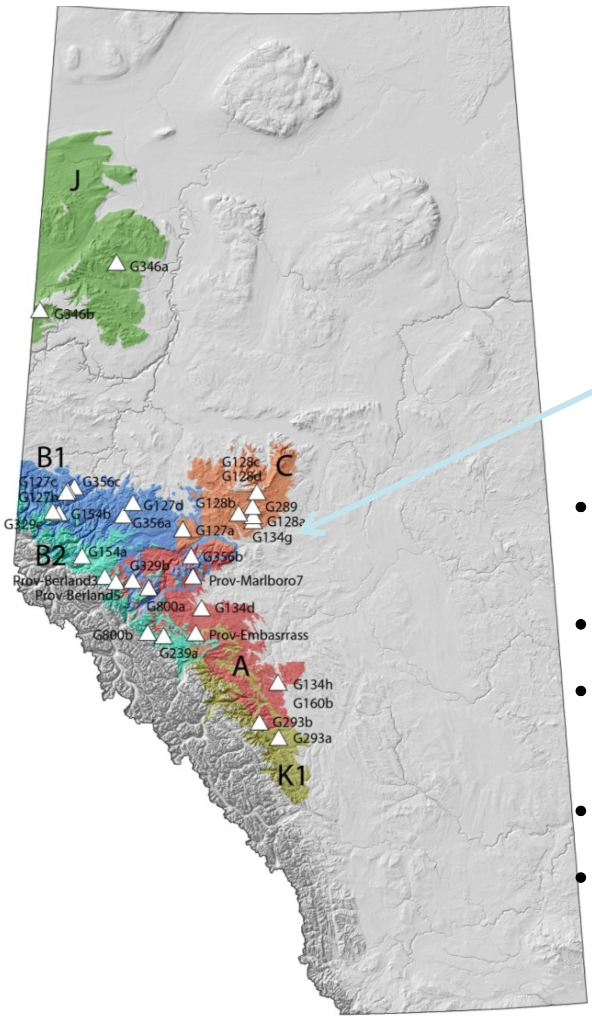


Images and analysis details provided in report:

Climatic Adaptation of White Spruce and Lodgepole Pine in Alberta CPPs

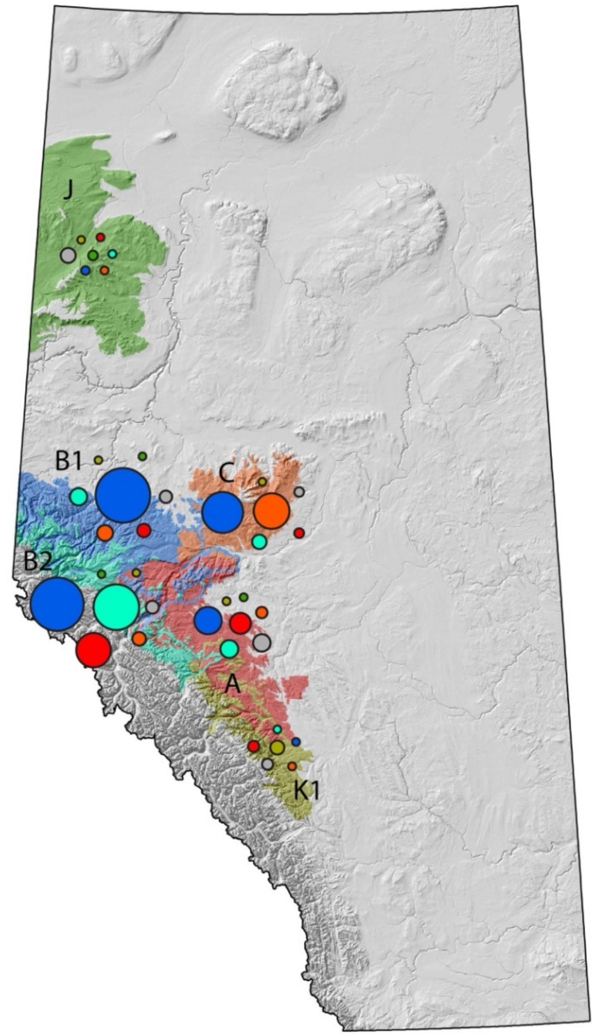
Lodgepole pine breeding regions & field testing (experiments)

Provenance & progeny test sites



- 43 provenance & progeny trials
- 28 test sites
- 1713 lodgepole pine parents
- 135,379 individual trees
- Age 10 – 35 (relative height analyzed)

Seed transfers



Images and analysis details provided in report:

Climatic Adaptation of White Spruce and Lodgepole Pine in Alberta Controlled Parentage Programs

Biological response to climate change – white spruce and lodgepole pine

LEFT: White spruce provenance trial near Edson, Alberta (37 years old)
RIGHT: Lodgepole pine provenance trial near Edson, Alberta (31 years old)

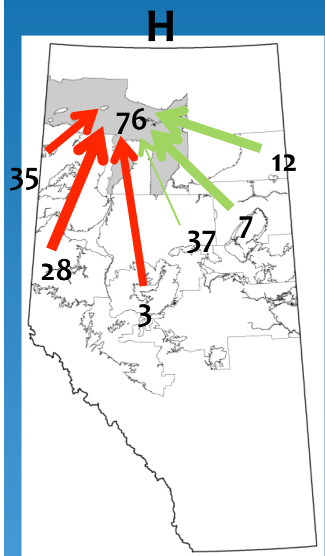
Biological response to climate change – white spruce and lodgepole pine

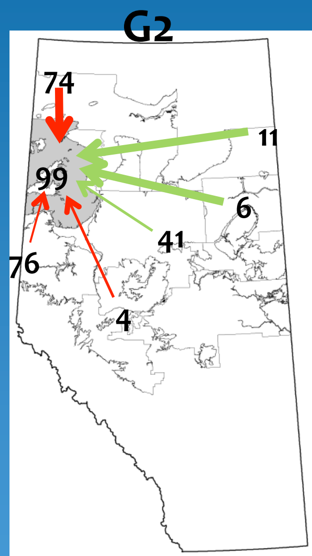
What we did:

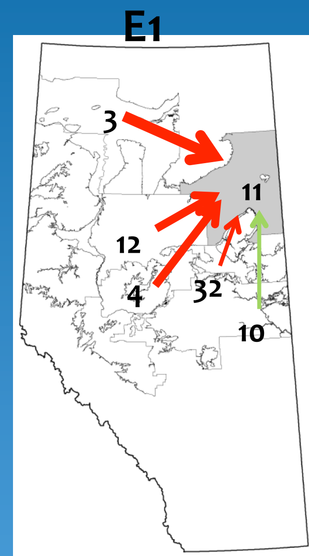
- Measured all field experiments.
- Analyzed **height growth** to see how **populations** and **families** from outside the breeding region grow compared to populations from within the breeding region (**local population**).
- Choose preferred direction of seed transfer based on comparative growth between introduced and local populations.
- **NOTE: This was completed for both white spruce and lodgepole pine.**

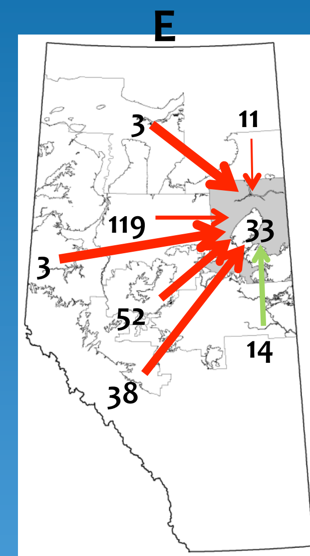
- **Present an example of white spruce analysis**

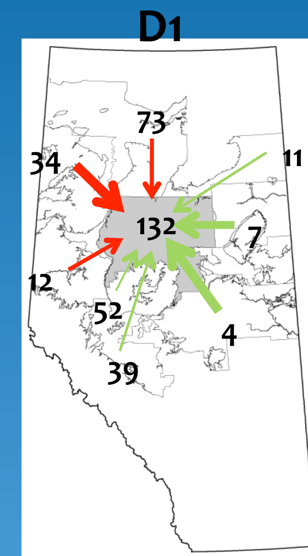
Which of the breeding regions can share seed in part or whole?

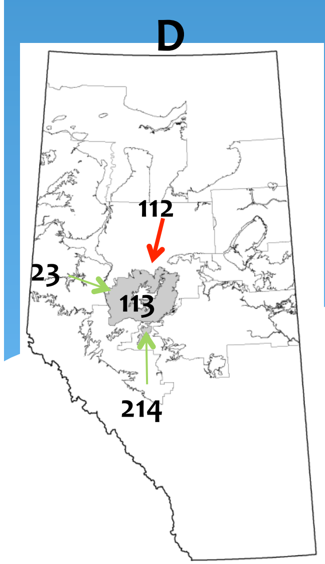


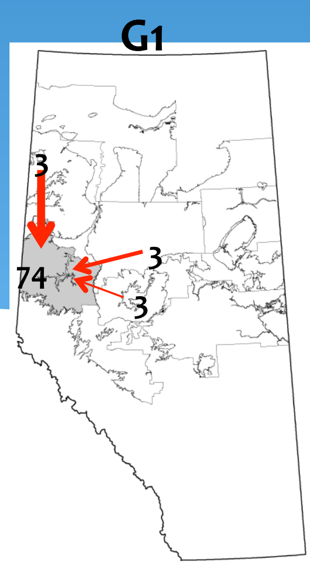


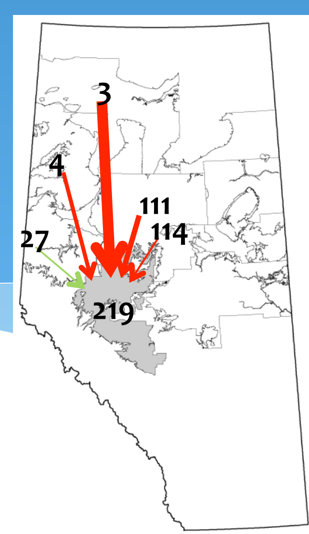












White spruce (*Picea glauca*)

RED = Poor performer compared to local sources

GREEN = Good performer compared to local sources

Thickness of arrow indicates magnitude of performance

Number of genotypes at arrow base

Biological response to climate change – white spruce

- Genetic variation among populations for growth is more related to **cool season temperatures** rather than precipitation
    - Slow growing populations are from the **northern boreal region** (**cold and continental**)
    - Slow growing populations are from the **Rocky Mountains (Short growing season due to low spring and summer heat)**
    - Fast growing populations are from the southern boreal region (**relatively moist and warmer; less continental than northern boreal**)
    - In the mountain regions, fast growing populations are from **lower elevations** (**warmer**) and slow growing populations are at **higher elevations** (**cooler and low heat**)

Biological response to climate change – white spruce

General conclusions,

1) Transferring seed from a **high latitude** to a **lower latitude** breeding region will **reduce productivity** compared to a local population

2) Transferring seed from a **high elevation** to a **lower elevation** breeding region will **reduce productivity** compared to a local population

3) Transferring seed from a **lower** to a **higher latitude** OR a **lower to a higher elevation** will **increase productivity** compared to a local population (**only to a certain extent**)

Biological response to climate change – lodgepole pine

Results of lodgepole pine analysis

1) Results from lodgepole pine analysis are not presented here but are similar to white spruce

2) Lodgepole pine is largely found in the foothills and Rocky Mountains areas – genetic variation related to climate and related to change in altitude (elevation).

3) Seed transfer to maintain or increase productivity under climate change can be managed through control of elevation transfer.

Potential future climate change adaptation areas

1) **Establishing experiments (trials) on sites developed under the current CCEMC project**

   - This needs to happen in the next 2-3 years before the sites are recolonized by wild plants
   - The value of these sites is realized when something is planted there.

2) **Insects and diseases of major Alberta conifers are increasing possibly due to warmer weather**

3) **Provenance trials for reclamation shrubs**

   - Starting 2015, seed transfer for reclamation shrubs will be regulated in the same way as reforestation seed
   - Government is developing a provenance trial plan for shrubs to generate data that will enable development of seed transfer standards for shrubs
   - In the interim, shrubs will be regulated by reforestation standards.

Potential future climate change adaptation areas



Acknowledgements

- CCEMC – funding and guidance
- Harry Archibald – Project Advisor (CCEMC)
- fRI Research – hosted the project
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- Leonard Barnhardt – project applicant; former TIA Board & Steering Committee member
- Richard Briand – former TIA Board & Steering Committee member
- The late Bruce Macmillan – project applicant; former TIA Board & Steering Committee member