Testing different silviculture adaptation strategies for various climate change risks in Québec.

François Hébert, ing.f., Ph.D.
Research scientist
Direction de la recherche forestière (DRF)
Ministère des Ressources naturelles et des Forêts du Québec (MRNF)

Forestry Adaptation Practitioners’ Network webinar series

March 29th 2023

Votre gouvernement

Québec

Where to start ?

What is the best way to start a scientific presentation with the adaptation to climate change in forestry as the main subject ?

Starting a scientific presentation on adaptation to climate change in forestry requires a slightly different approach than a conference or public event. Here are some suggestions on how to begin your presentation:

1. Start with a title slide: The title should be clear, concise, and descriptive of the main topic of the presentation. It should include the main keywords related to adaptation to climate change in forestry.
2. Introduce yourself and your research: Provide a brief introduction of yourself, your

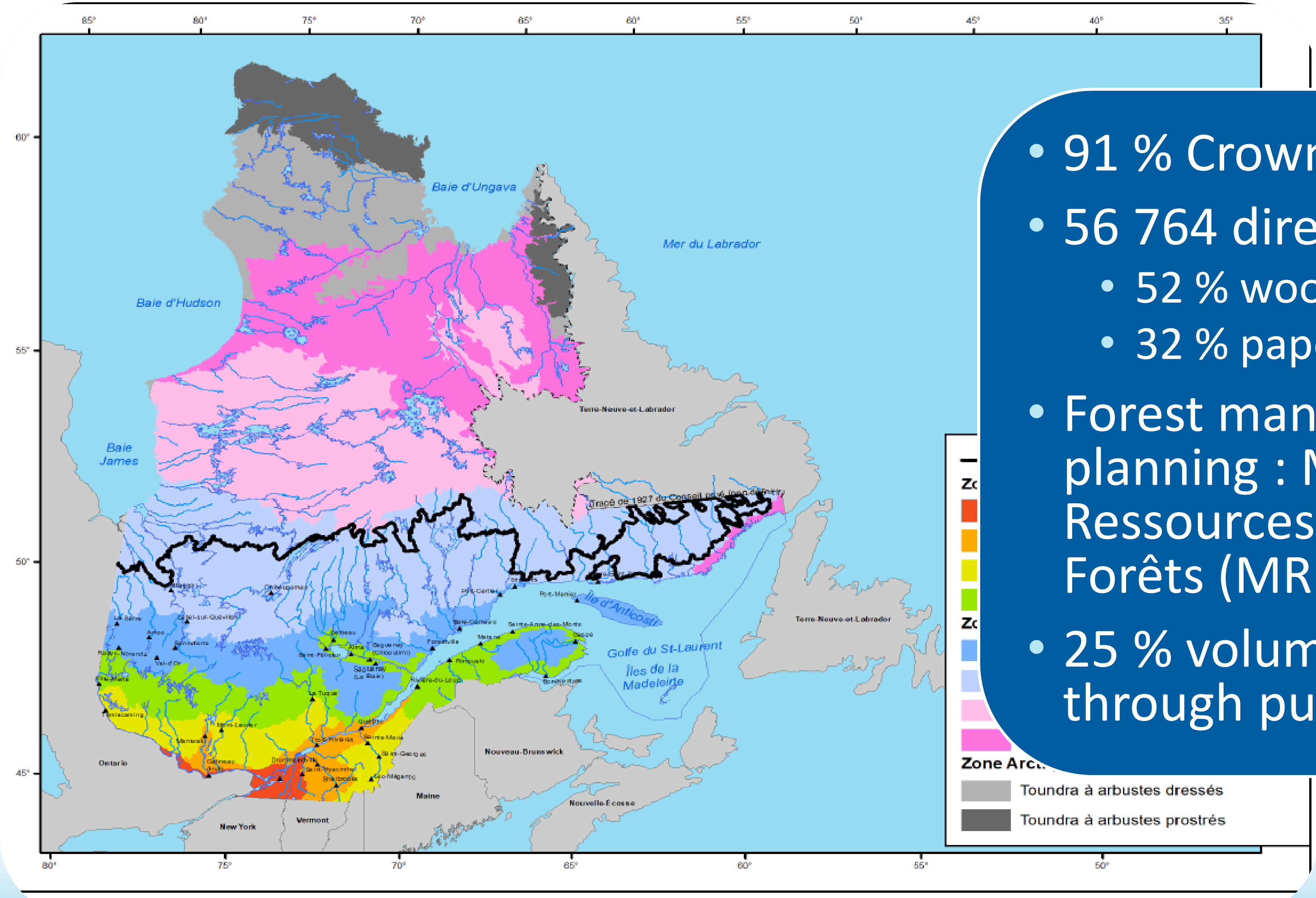
- Take-home message:
  - Do all these but keep your introduction brief, and focus on the main topic…which I'm not doing right now !

scope of your presentation.

6. Highlight the significance of the research: Emphasize the importance of your research in addressing the challenges of adapting to climate change in forestry. Discuss how your findings could contribute to the development of policies, practices, and strategies to mitigate and adapt to climate change.
7. Preview your presentation: Provide an overview of the key points that you will cover in your presentation. This will help the audience follow your talk and anticipate what they will learn from your research.

Remember to keep your introduction brief and focused on the main topic. Engage your audience by using visuals, graphs, and data to illustrate your points. And finally, provide a clear and compelling conclusion to summarize your main findings and their implications for the adaptation to climate change in forestry.

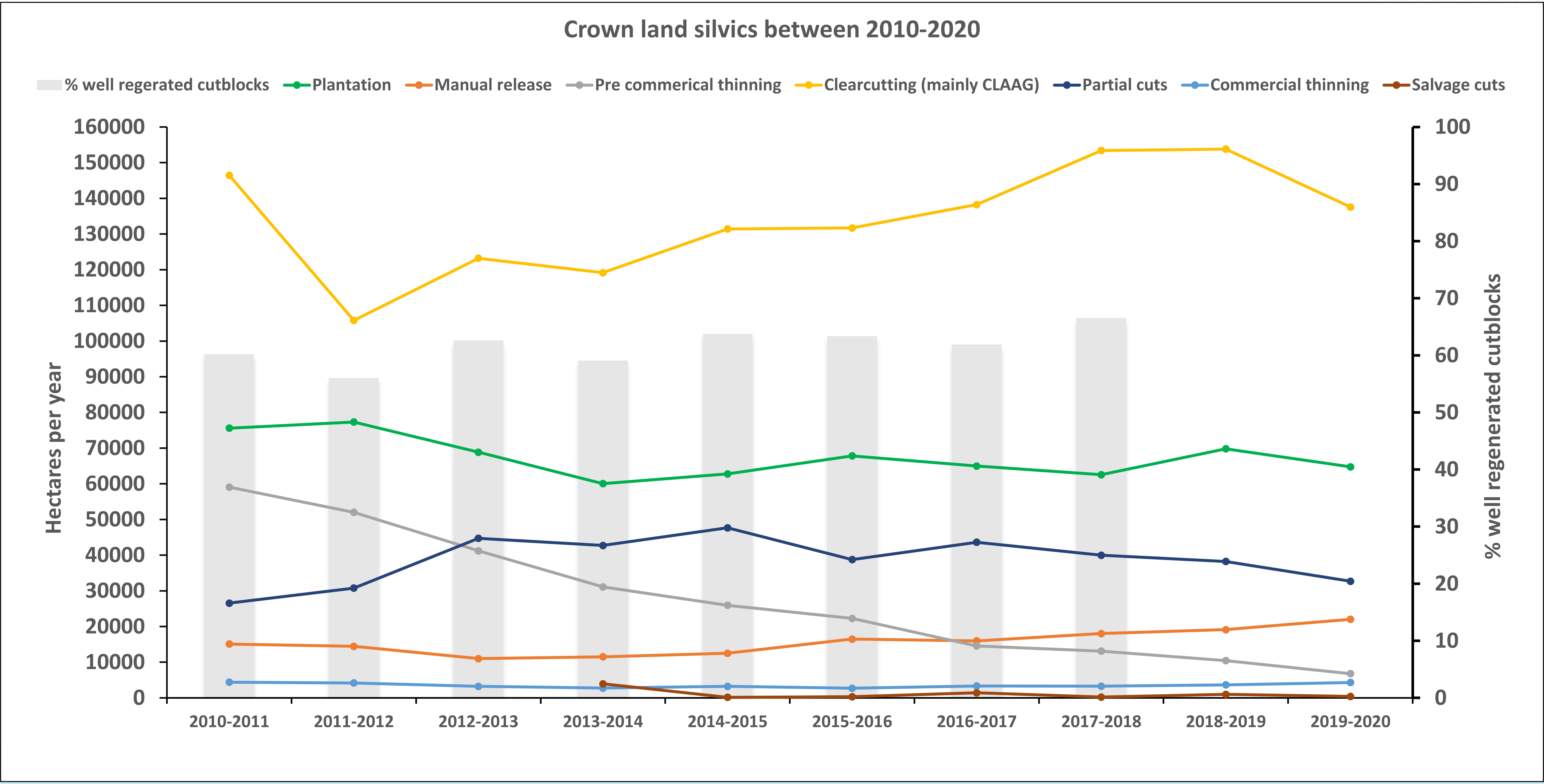
Québec's forest management



...: Ministère des Ressources naturelles et des Forêts, Direction du développement et de l'innovation de l'industrie

- 91 % Crown land
- 56 764 direct jobs
  - 52 % wood products
  - 32 % paper
- Forest management and planning : Ministère des Ressources naturelles et des Forêts (MRNF)
- 25 % volume per year allowed through public auction

Québec


Crown land silvics between 2010-2020
% well regerated cutblocks
Plantation
Manual release
Pre commerical thinning
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Salvage cuts
Hectares per year
% well regenerated cutblocks
160000
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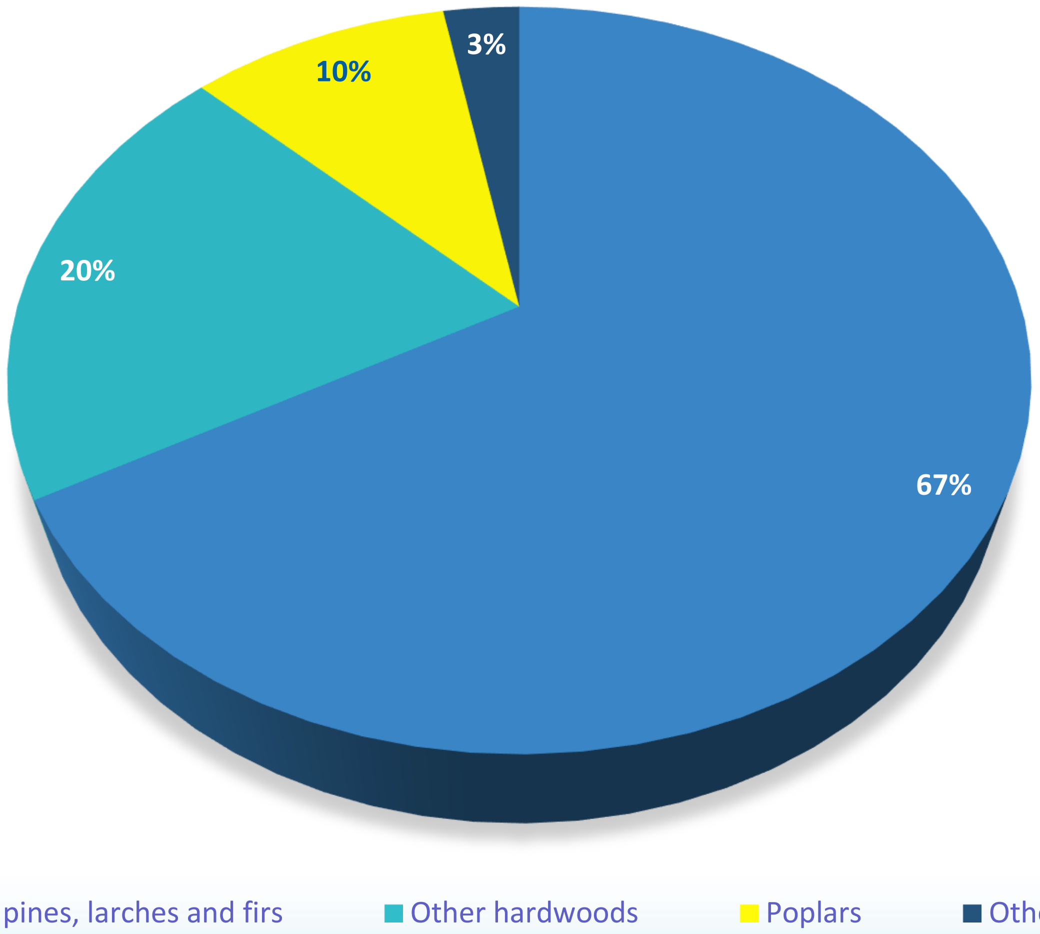
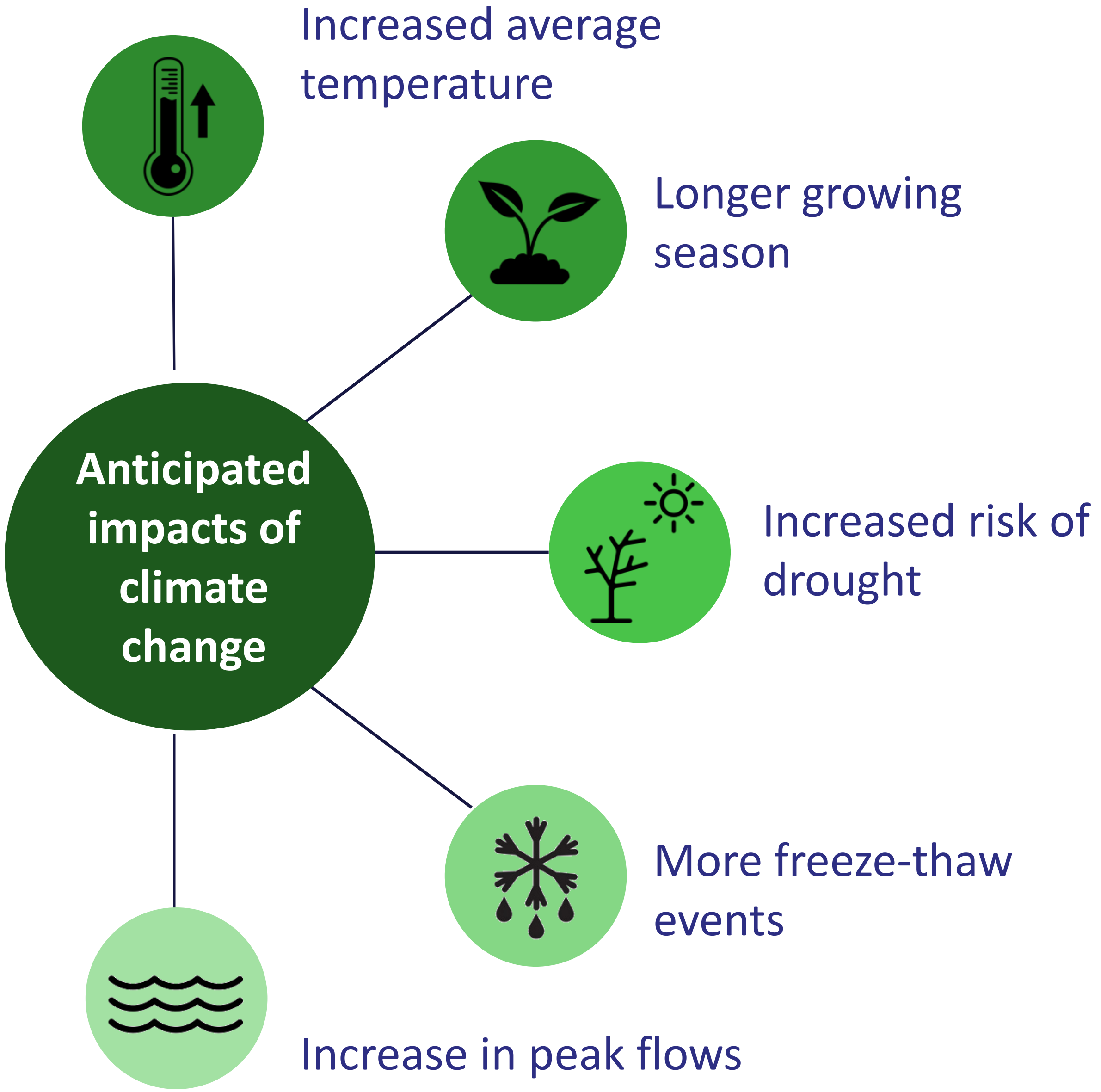
2019-2020

AAC by species groups on Crown land (2020-2023)



- Most planted species
  - Black spruce
  - White spruce
  - Jack pine

Climate change effects on forest ecosystems

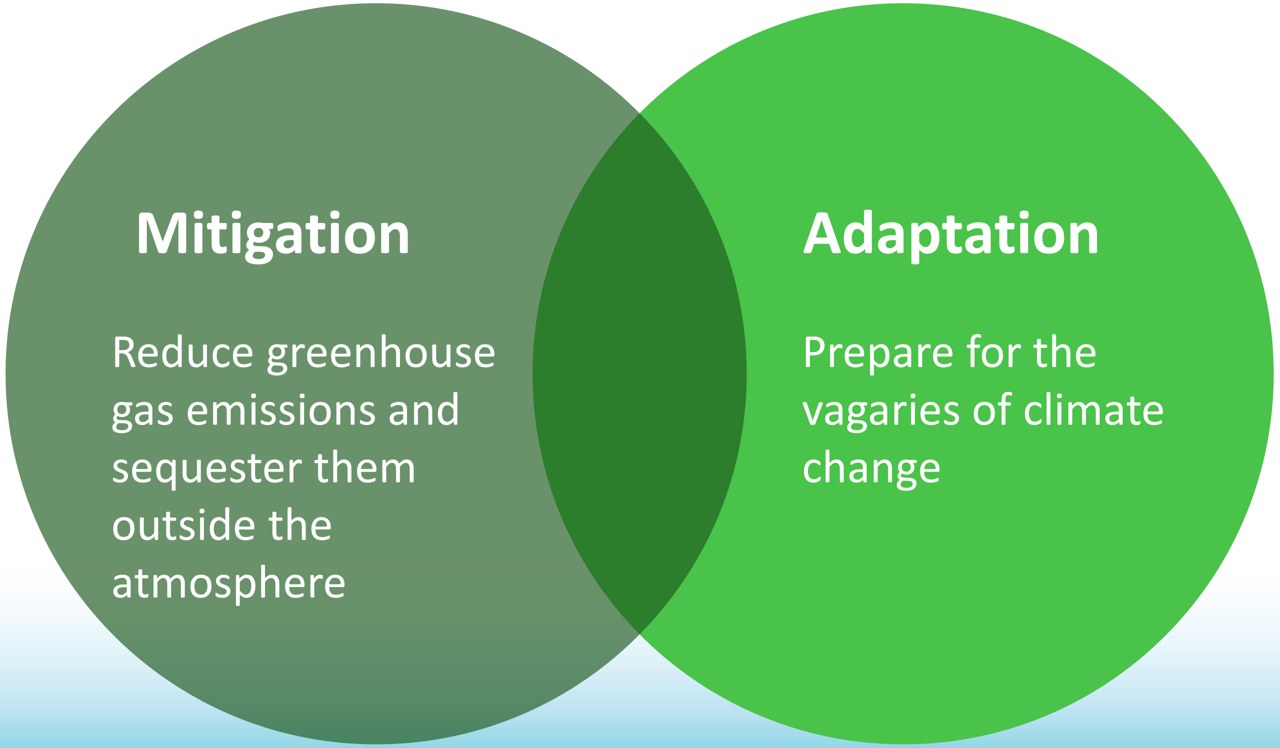


These changes may have impacts for:

- **Forest productivity**
- **Stand composition**
- Area burned by **wildfires** and the frequency of **regeneration failures**
- The duration and severity of **insect infestations**
- The emergence of **invasive exotic species**
- The **habitats of certain forest-dwelling wildlife species**
- **Land access** (integrity of infrastructures and multi-purpose roads)

The forest sector's role in the fight against climate change

- The forestry sector is recognized as a mitigation actor through its contribution to carbon sequestration in forest ecosystems, in wood products, and by using wood products to replace materials with a higher carbon footprint (IPCC).
- The forest sector's ability to contribute to climate change mitigation will be impacted by climate change itself.
- There is a need to adapt our forestry practices that will ensure consistency with mitigation measures being implemented.



Plan pour une économie verte

- Research projects financed by the **Plan pour une économie verte** (*Plan for a Green Economy*)
- Action 3.3.1.1:
  - Evaluate the impacts of climate change on the most vulnerable economic sectors (e.g., forestry) and support them through the implementation of adaptation solutions.

Adaptation options

Options

Resistance

Resilience

Transitions

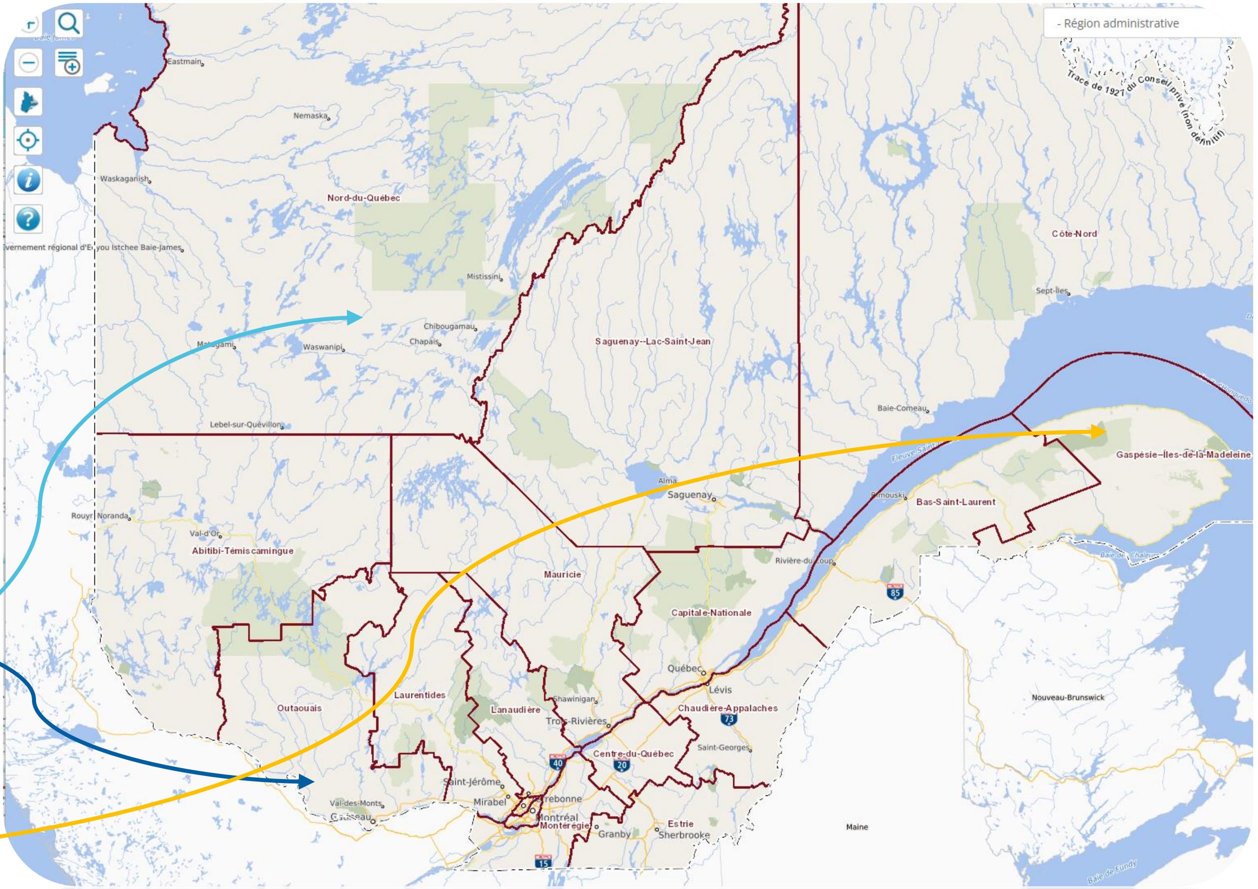
Management objective

Favor ecosystem persistence

Mangage the change

Phase one of research projects in adaptation sylviculture at the MRNF

- Workshops in 2020 with 3 pilot regions to assess risks associated with climate change
- One project per adaptation option
  - Resistance: Outaouais
  - Resilience: Nord-du-Québec
  - Transition: Gaspésie



- **Resistance**: Commercial thinning to improve water stress resistance in plantations in a context of climate change.
- **Resilience**: Mixed-species plantations to increase resilience to wildfire in boreal forests.
- **Transition**: Management of tree species composition in plantations and natural stands through enrichment planting and mixed-species plantations.

Resistance project

Collaborators: Emilie Champagne (DRF-MRNF),Catherine Périé (DRF-MRNF), Patricia Raymond (DRF-MRNF), Annie Deslauriers (Unviersité du Québec à Chicoutimi), François Girard (Unviersité de Montréal), Étienne Boileau (MRNF), Alexis Leroux (MRNF), Marcelle Falardeau (MRNF)

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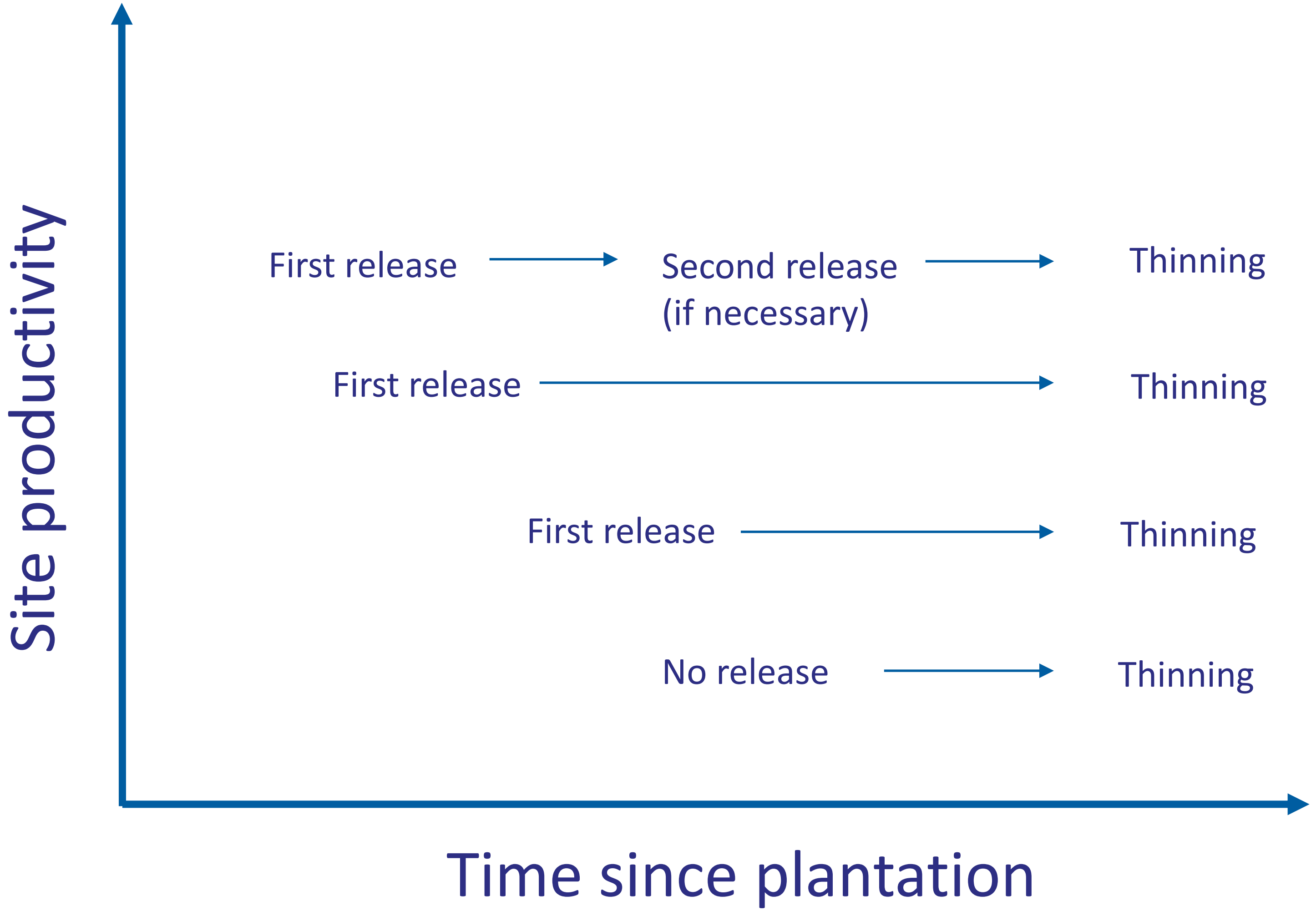
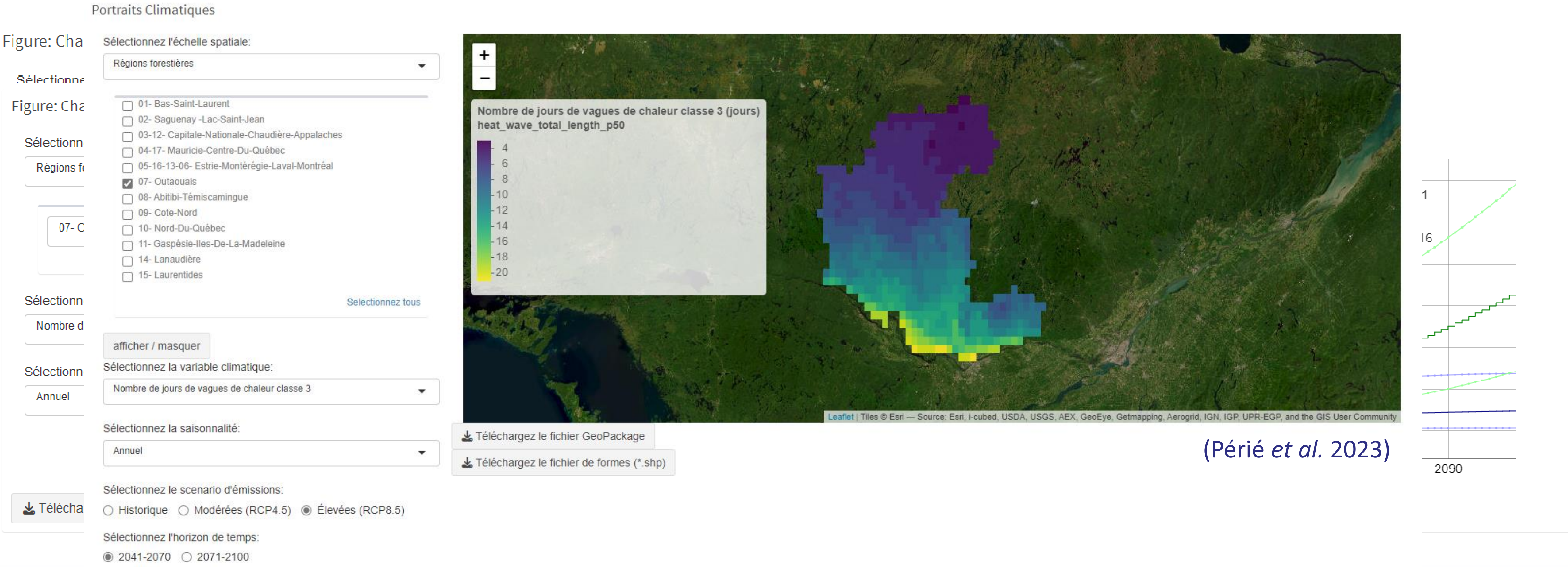


Adapted for Thiffault et al. (2003) and Jobidon (2000b)

Water availability

- A limiting factor for softwood radial growth
  - Lower number and size of cambial cells in the annual growth ring
- But is it the case in Québec ?
  - Many dendroclimatic studies show that water availability has a limited impact on tree productivity, especially in boreal forests.
  - However, under the 49th parallel, water availability influences black spruce's radial growth (D'Orangeville et al. 2016, Chagnon et al. 2022).

What about climate change ?



(Périé *et al.* 2023)

Article

Even modest climate change may lead to major transitions in boreal forests

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Published online: 10 August 2022

Check for updates

Peter B. Reich[1,2,3✉], Raimundo Bermudez[1], Rebecca A. Montgomery[1], Roy L. Rich[1,4], Karen E. Rice[1], Sarah E. Hobbie[5] & Artur Stefanski[1]

The sensitivity of forests to near-term warming and associated precipitation shifts remains uncertain[1–9]. Herein, using a 5-year open-air experiment in southern boreal forest, we show divergent responses to modest climate alteration among juveniles of nine co-occurring North American tree species. Warming alone (+1.6 °C or +3.1 °C above ambient temperature) or combined with reduced rainfall increased the juvenile mortality of all species, especially boreal conifers. Species differed in growth responses to warming, ranging from enhanced growth in *Acer rubrum* and *Acer saccharum* to severe growth reductions in *Abies balsamea*, *Picea glauca* and *Pinus strobus*. Moreover, treatment-induced changes in both photosynthesis and growth help explain treatment-driven changes in survival. Treatments in which species experienced conditions warmer or drier than at their range margins resulted in the most adverse impacts on growth and survival. Species abundant in southern boreal forests had the largest reductions in growth and survival due to climate manipulations. By contrast, temperate species that experienced little mortality and substantial growth enhancement in response to warming are rare throughout southern boreal forest and unlikely to rapidly expand their density and distribution. Therefore, projected climate change will probably cause regeneration failure of currently dominant southern boreal species and, coupled with their slow replacement by temperate species, lead to tree regeneration shortfalls with potential adverse impacts on the health, diversity and ecosystem services of regional forests.

Twenty-first century climate change will influence northern forests, through rising temperatures and altered precipitation patterns[1–9]. Higher temperatures associated with climate change may extend the growing season and alleviate enzymatic limits to the metabolic activities of plants when moisture is abundant. However, increased evaporative demand will probably lead to increased summertime soil water deficits, despite modest water savings due to elevated CO_2 (refs. [1,2,6–8]). Mid- to high-latitude plants are therefore likely to experience both positive and negative effects from climate warming—positive in cool and/or moist times and places, but negative in hot and/or dry times and places[1,9–14].

Observational and experimental evidence

Observational studies have shown both negative and positive trends in growth, survival and productivity in boreal forests[4,13–18]. Some reports suggest that tree growth and forest productivity have increased recently in central and eastern Canada[14,17,18], whereas others show declines in growth[4,13,16] and survival[4,15]. In all cases, disentangling the impacts of temperature and precipitation from one another and from other drivers, such as rising CO_2, remains challenging[13,14,19]. Whether such impacts are in aggregate positive or negative for fitness-related responses such as growth and survival is unclear at present, because direct tests of the effects of climate warming across a range of soil moisture conditions are rare. Moreover, such responses may be dependent on time, species, disturbance history, tree size and geography[13,19].

Some experiments have explored the interactive effects of temperature and moisture on tree performance, although all such experiments are limited in size, scope and duration. A study over a single growing season of temperate seedlings subject to warming and a 50% reduction in rainfall in the year of planting found that the survival responses of six species to warming were not inferior in low rainfall[20]. By contrast, in other 1-year studies, warming treatments in high-elevation forests adversely affected establishment of *Pinus* species by reducing soil moisture[21], and a greenhouse study found that *Picea mariana* had high mortality when exposed to both +6 °C warming and drought, but not to either alone[22]. In a prior study conducted from 2009 to 2011, we found that the response of juvenile boreal tree species to +3.4 °C warming differed, depending on whether the species had a more boreal or temperate distribution[23]. However, whether the results would have been similar under varying moisture conditions is unknown.

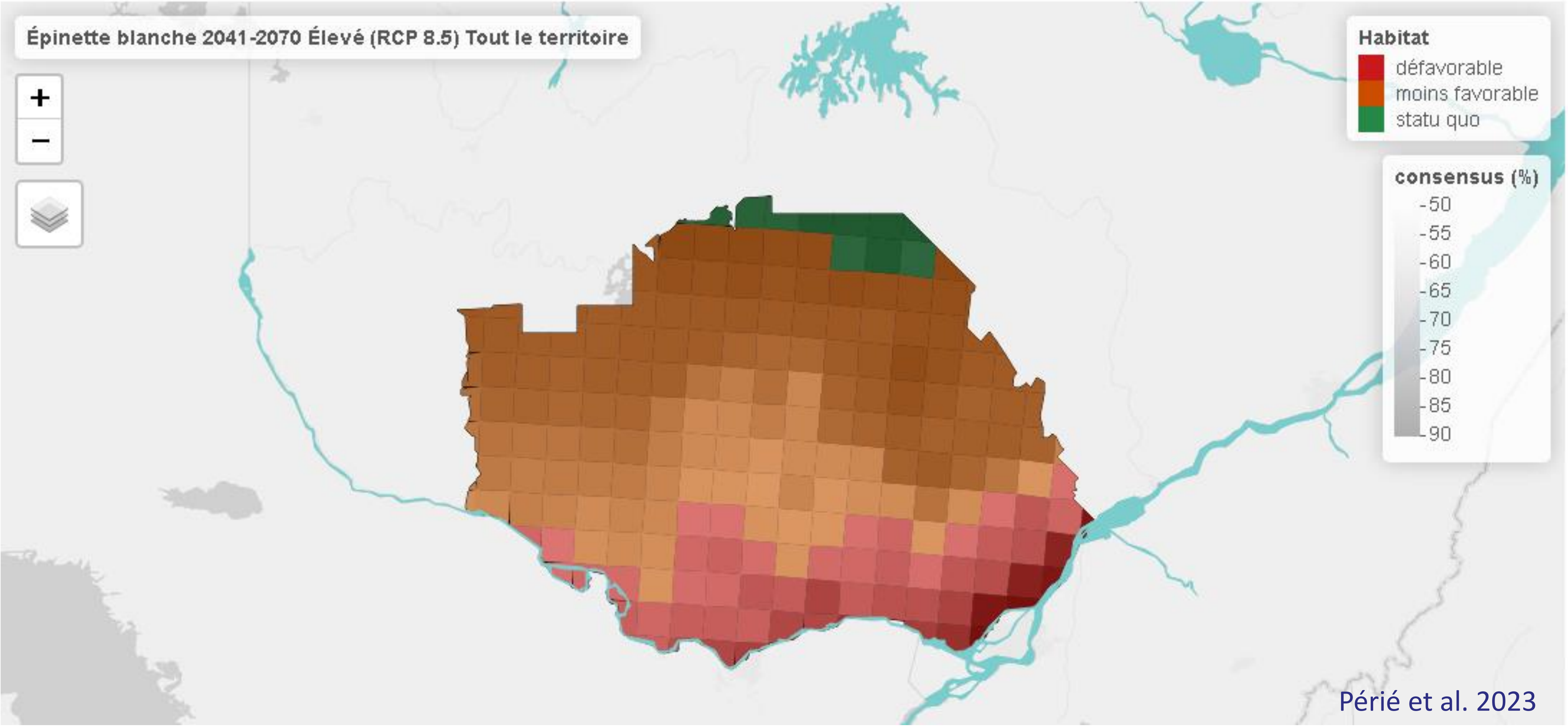
A 5-year warming and rainfall experiment

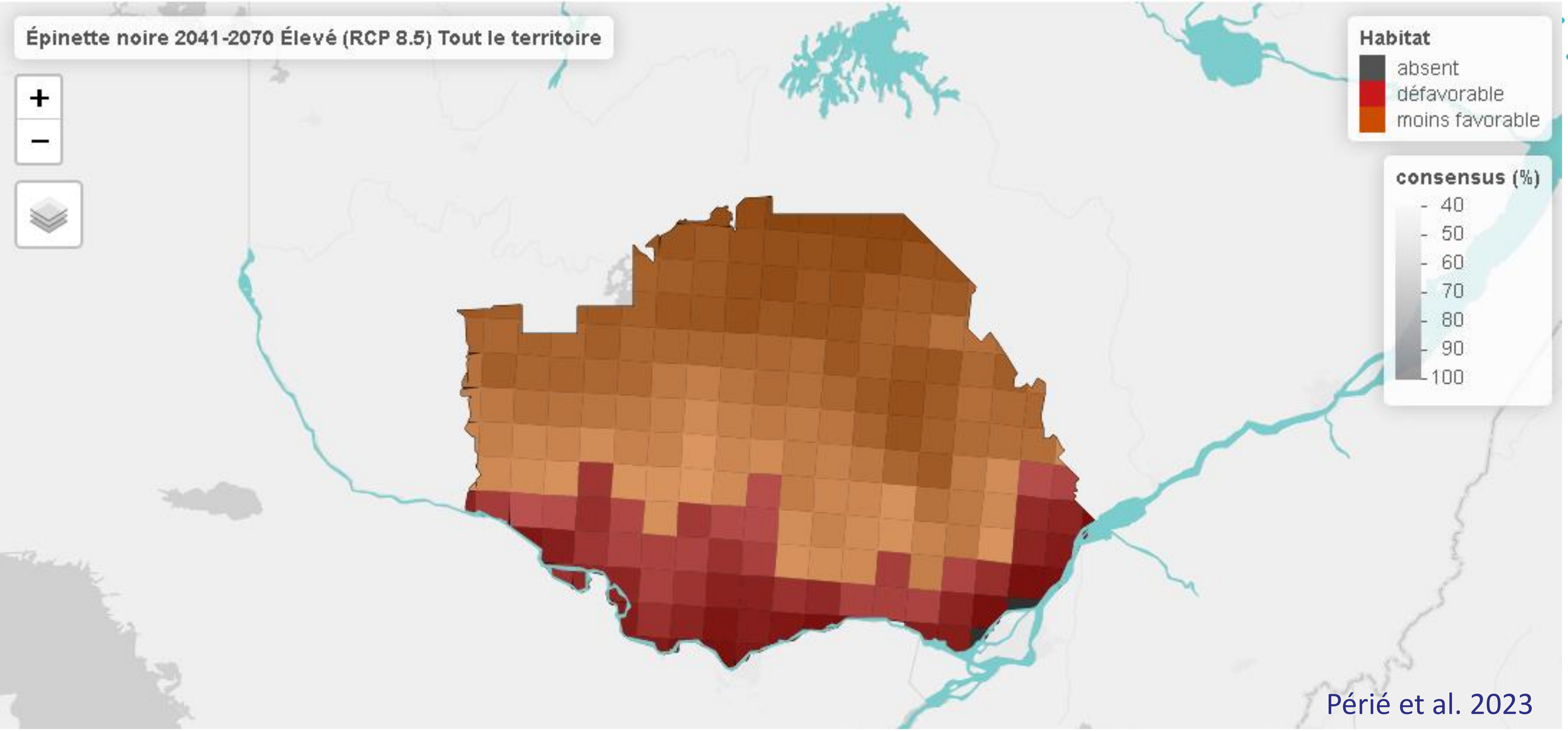
Herein we report on an independent open-air field experiment conducted from 2012–2016 with juveniles of nine tree species that included

[1]Department of Forest Resources, University of Minnesota, St. Paul, MN, USA. [2]Hawkesbury Institute for the Environment, Western Sydney University, Penrith, New South Wales, Australia. [3]Institute for Global Change Biology and School for Environment and Sustainability, University of Michigan, Ann Arbor, MI, USA. [4]Smithsonian Environmental Research Center, Edgewater, MD, USA. [5]Department of Ecology, Evolution and Behavior, University of Minnesota, St. Paul, MN, USA. ✉e-mail: preich@umn.edu

540 | Nature | Vol 608 | 18 August 2022

- Main findings:
  - Treatments where species were exposed to hotter and drier climate than their climate envelope had the most adverse effect on survival and growth.
  - Most sensible species: Jack pine and white spruce.
  - Even on mesic sites, white spruce and balsam fir will probably decline despite a modest increase in temperature.


Épinette blanche 2041-2070 Élevé (RCP 8.5) Tout le territoire
Habitat
défavorable
moins favorable
statu quo
consensus (%)
-50
-55
-60
-65
-70
-75
-80
-85
-90
Périé et al. 2023



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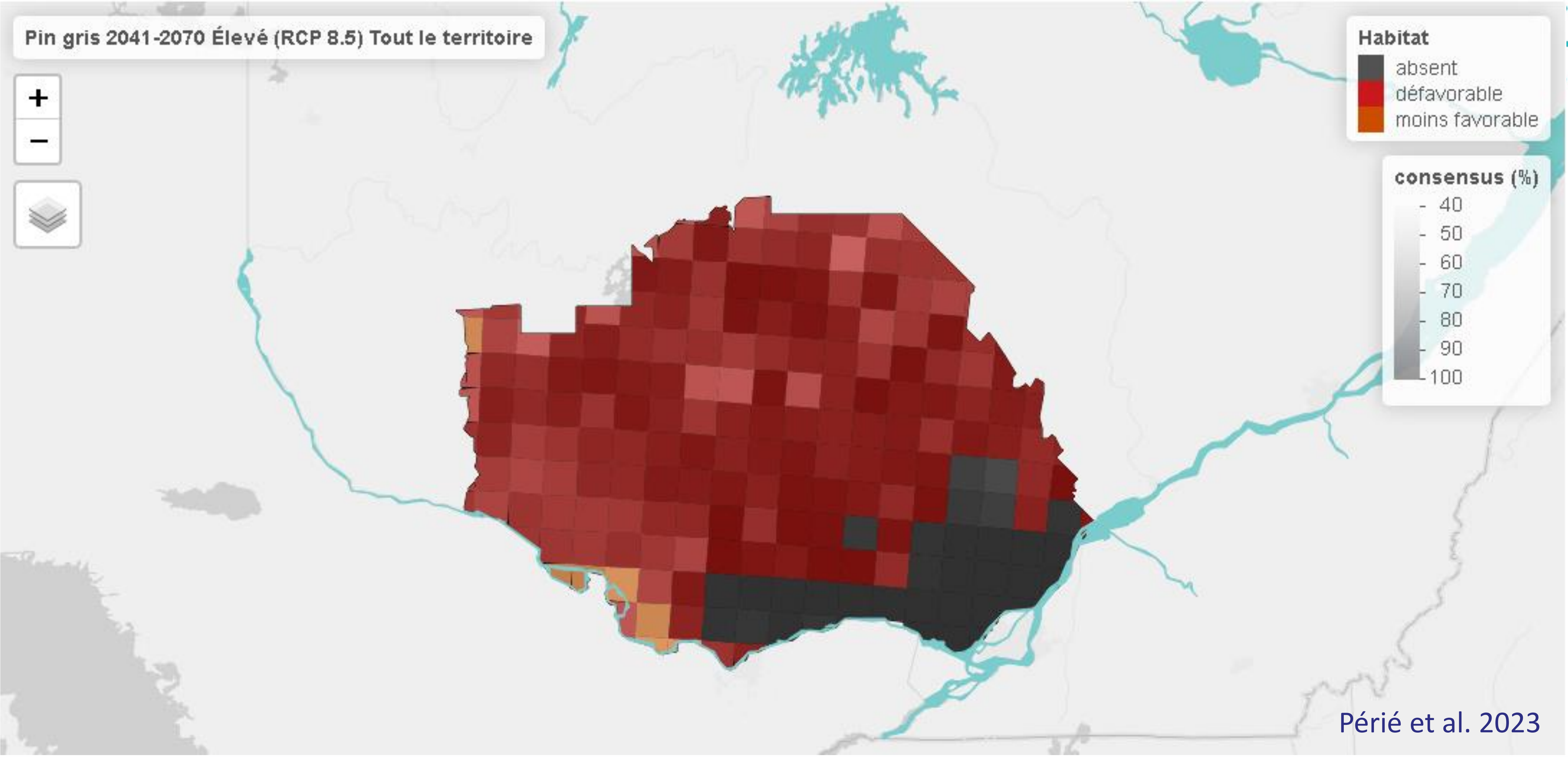
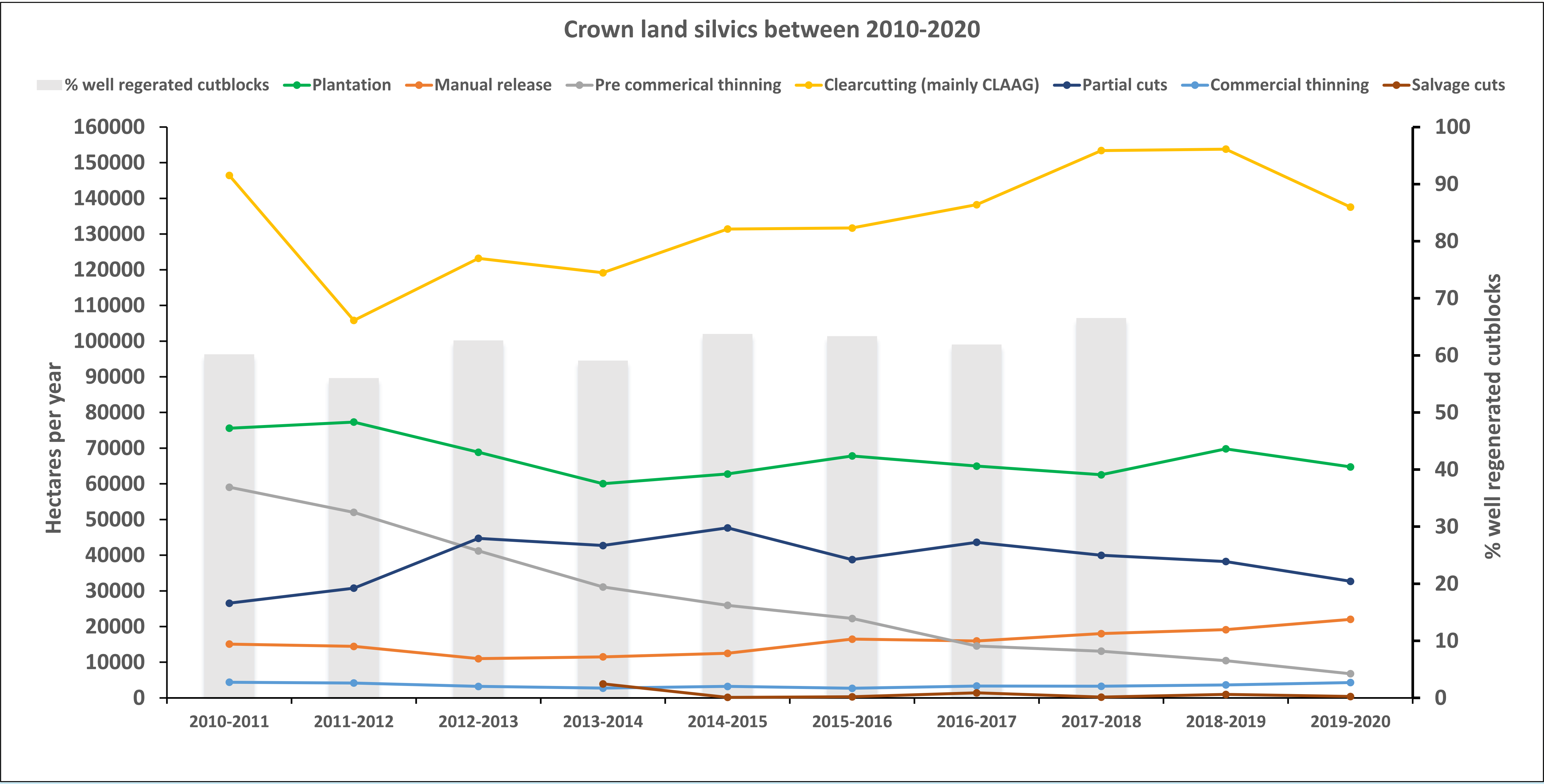

Pin gris 2041-2070 Élevé (RCP 8.5) Tout le territoire
+
−
Habitat
absent
défavorable
moins favorable
consensus (%)
40
50
60
70
80
90
100
Périé et al. 2023

Considered solution: commercial thinning

- Positive effects of thinning ↗ with intensity
- Thinning effect
  - Specific for each species
  - Decreases with time
  - Becomes negligible after 20 to 40 years
- For tree species at their water stress tolerance limit on dry stations, thinning could be insufficient to improve water stress resistance.
- Physiological mechanisms involved in the thinning response are still poorly understood.

Moreau et al. (2022)



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2010-2011
2011-2012
2012-2013
2013-2014
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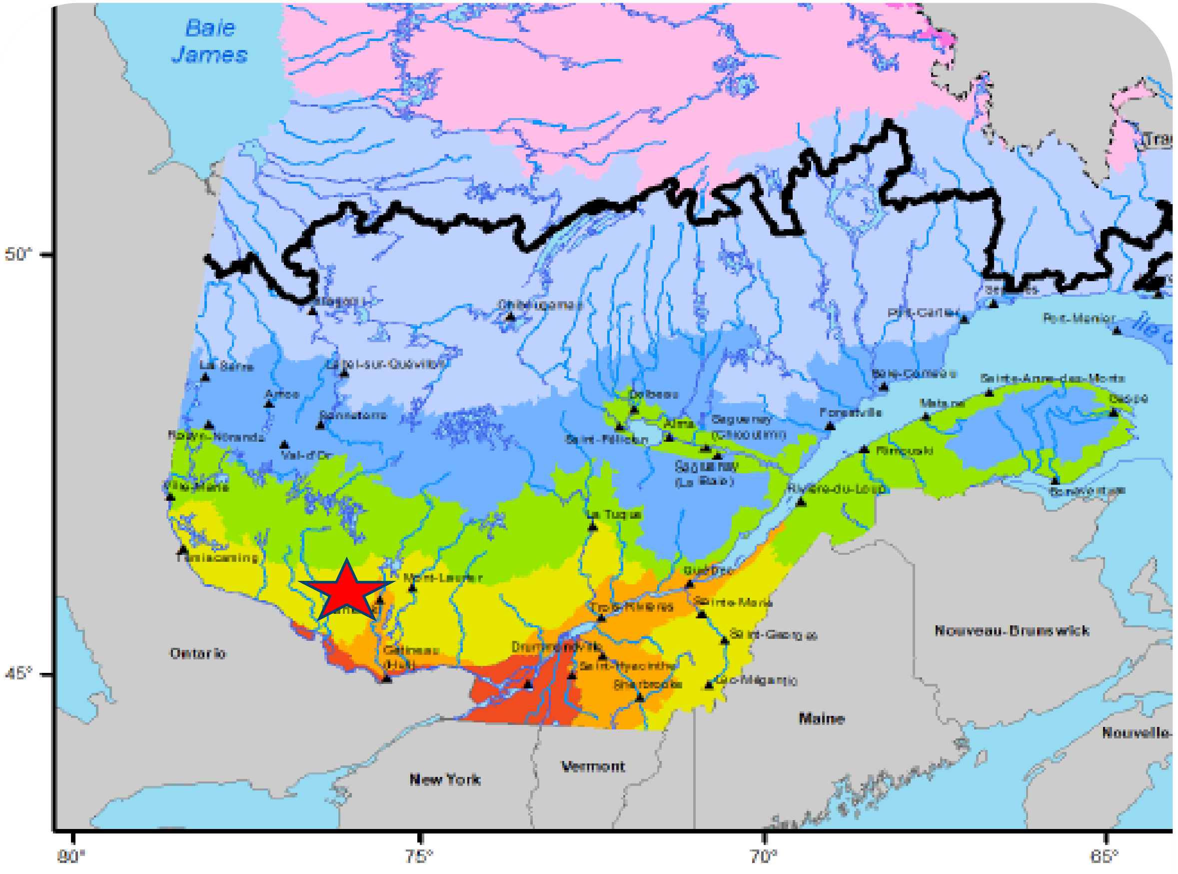
2018-2019
2019-2020

Objectives

- Evaluate the financial and the operational feasibility of various thinning intensities as a water stress management tool in softwood plantations in the context of climate change.
- Measure the growth and the physiology of the residual stems submitted to various thinning intensities.

Experimental design

- 2 trials
  - Jack pine (JP)
  - White spruce (WS)
- Western sugar maple-yellow birch bioclimatic subdomain
- Glaciofluvial outwash deposits
- 4 blocks
- Plantation in 1990
- Pre-commercial thinning in 2000 (JP), 2004 (WS)
- Thinning in 2023 (WS) and in 2024 (JP)



…rce : Ministère des Ressources naturelles et des Forêts, Direction du développement et de l'innovation de l'i…

Operational measurements and financial analysis

- Operational measurements
  - Harvested volume (m^3/ha), mean stem volume (m^3/stem) to harvest and prior to harvest (m^3/stem).
- Cost benefit analysis
  - MERIS model from MRNF
  - Lumber product assortment with StatSAW (Auty et al. 2014)

Studied variables

- Environment
  - Air and soil
  - Leaf area index
- Physiology
  - Sap flow, photosynthesis, water potential, cavitation, WUE
- Real time radial growth

Resilience project

Collaborators: Patricia Raymond (DRF-MRNF), Emilie Champagne (DRF-MRNF), Daniel Dumais (DRF-MRNF), Nelson Thiffault (NRCan), Jean-François Boucher (Université du Québec à Chicoutimi), Étienne Boileau (MRNF), Sonia Légaré (MRNF), Mélissa Lainesse (MRNF)

Votre gouvernement

Québec

Effects of climate change on wildfire regimes

13/08/2018 Wildfires will only get worse unless we learn how to live with them - The Globe and Mail

THE GLOBE AND MAIL

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OPINION

Wildfires wil

Environmental Research Letters

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E-mail: mike.wotton@utoronto.ca

PLOS | ONE

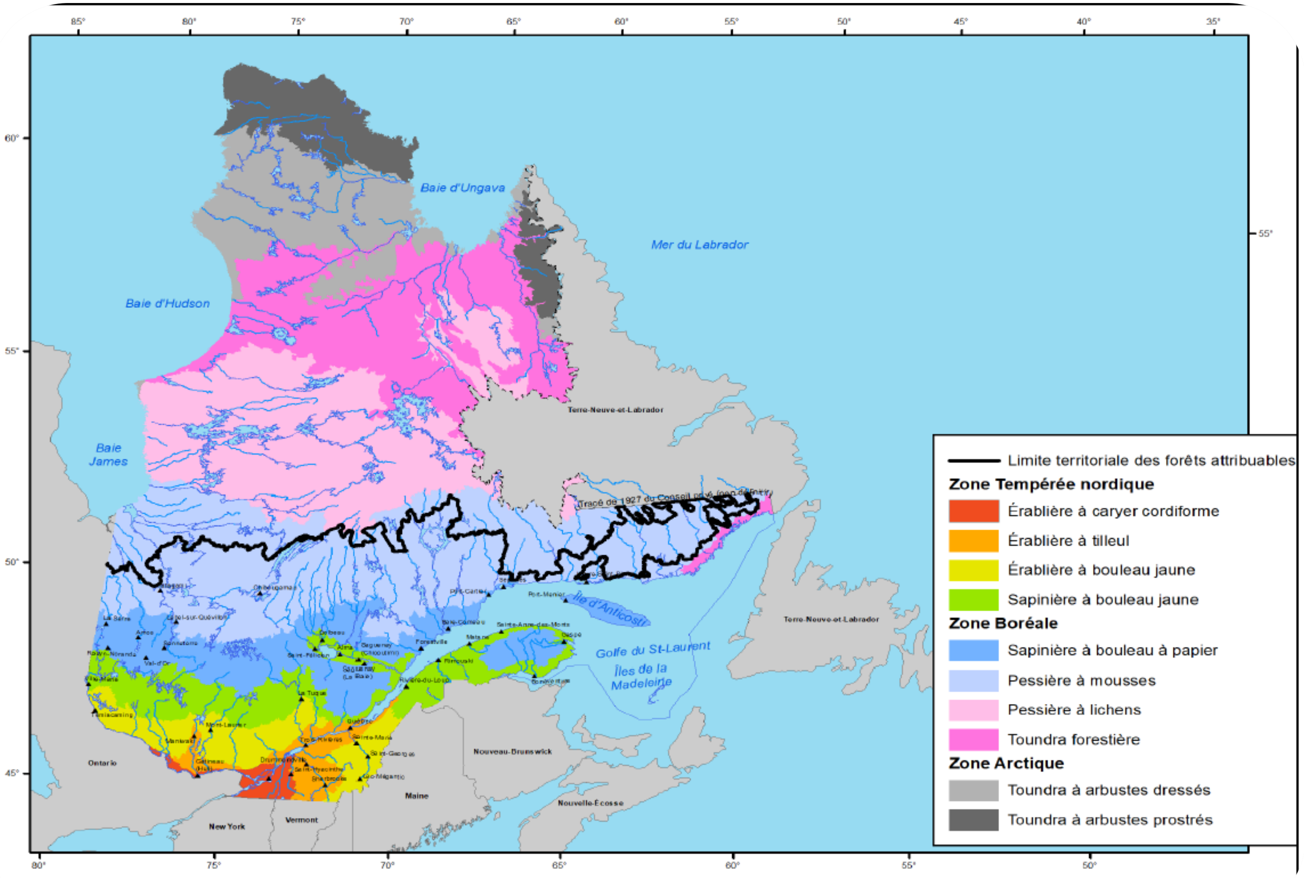
RESEARCH ARTICLE

Wildfire Suppression Costs for Canada under a Changing Climate

Emily S. Hope[1☯], Daniel W. McKenney[1☯*], John H. Pedlar[1☯], Brian J. Stocks[2‡], Sylvie Gauthier[3‡]

But is it the case in Québec ?

- Québec
  - ↗ surface area burned, fire season, number of fires and their intensity expected by the end of the 21st century
    - West > East
  - Most affected bioclimatic domains:
    - Lichen woodland
    - Spruce-feathermoss
    - White-birch-balsam fir



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Boulanger et al. (2014), Girardin et Terrier (2015)

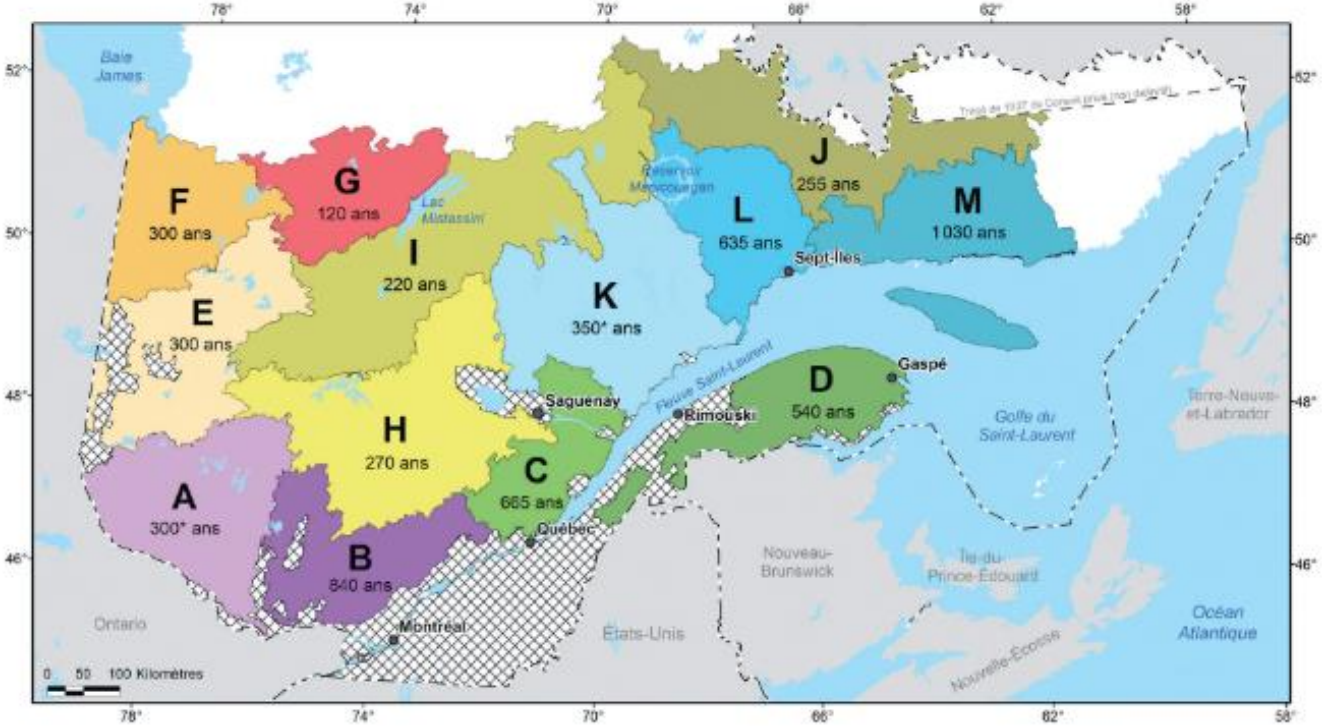


Figure 3. Zonage des régimes de feux du Québec méridional. Les valeurs représentent le cycle de feu calculé pour la période 1890-2020. Le cycle de feu des zones A et K (*) a été ajusté sur la base d'autres études réalisées dans ces régions.

Intégration des changements climatiques et développement de la capacité d'adaptation dans la détermination des niveaux de récolte au Québec

Novembre 2020

Bureau du forestier en chef

Québec

Votre gouvernement

- Main recommendation
  - Reduce the risk exposure time for our silvicultural investments

- How?
  - By using species with an early sexual maturity mixed with a desirable species (e.g., black spruce).

PNAS, vol 118 no 45 2021

Increasing fire and the decline of fire adapted black spruce in the boreal forest

Jennifer L. Baltzer[a,1], Nicola J. Day[a,b], Xanthe J. Walker[c,d], David Greene[e], Michelle C. Mack[c,d], Heather D. Alexander[f], Dominique Arseneault[g], Jennifer Barnes[h], Yves Bergeron[i], Yan Boucher[j], Laura Bourgeau-Chavez[k], Carissa D. Brown[l], Suzanne Carrière[m], Brian K. Howard[c,d], Sylvie Gauthier[n], Marc-André Parisien[o], Kirsten A. Reid[a,l], Brendan M. Rogers[p], Carl Roland[q], Luc Sirois[g], Sarah Stehn[q], Dan K. Thompson[o], Merritt R. Turetsky[r], Sander Veraverbeke[s], Ellen Whitman[o], Jian Yang[t], and Jill F. Johnstone[u,v]

Ajustement des stratégies de production de bois dans certaines portions sensibles de la forêt boréale

Rapport présenté au :

Ministère des Forêts, de la Faune et des Parcs

Chaire industrielle CRSNG - UQAT - UQAM en aménagement forestier durable

Version finale

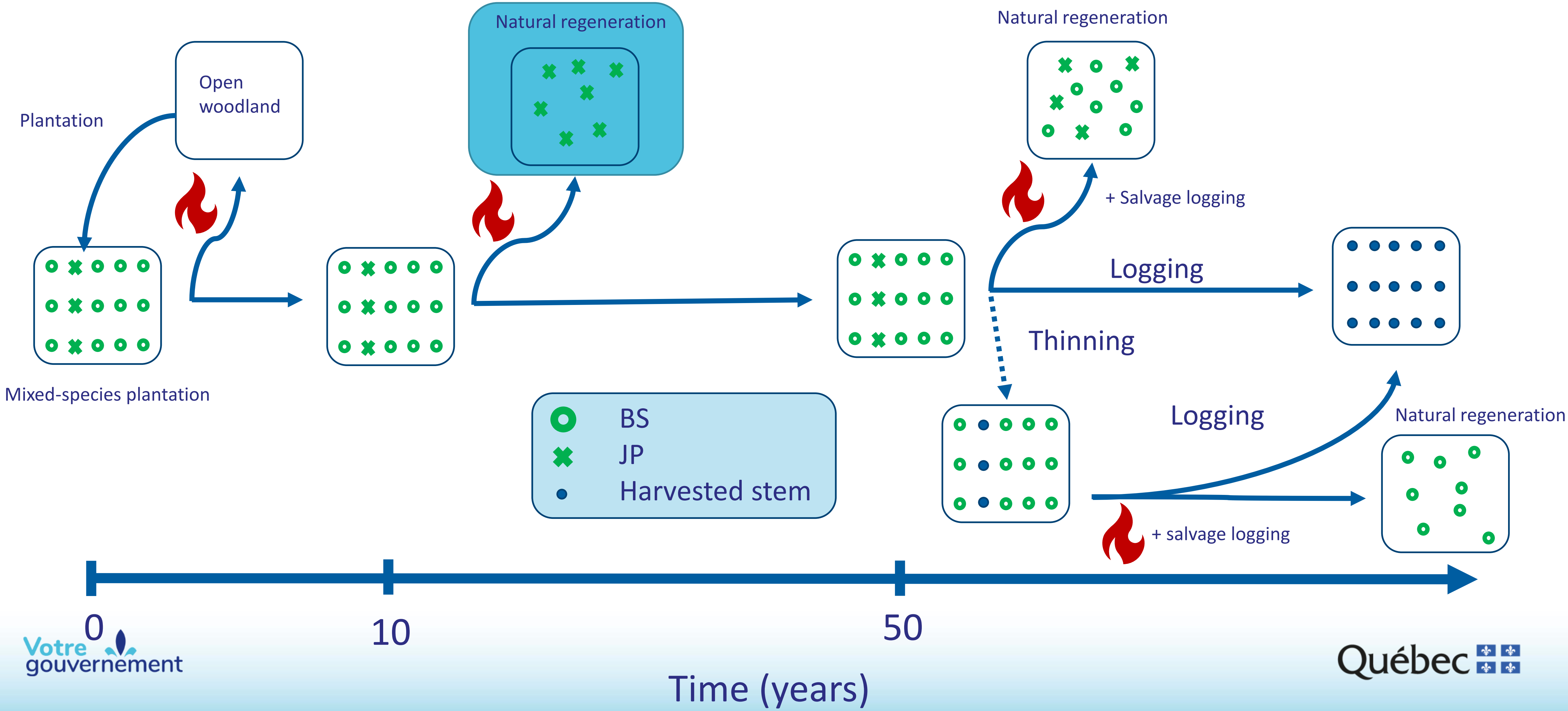
Québec, Mars 2019

A solution ? Mixed species plantations (BS-JP)

- 50% probability to bear cones at 30 years of age
- Seedling recrutement following wildfire limited by the number of seeds available for a period up to 50 years (Vigas et al. 2013).
- Anisohydric species

- Higher juvenile growth rate
- Cone production sufficient to regenerate a stand at around 10 years (Rudolph, 1979).
- Isohydric species.

Jack pine as an insurance policy



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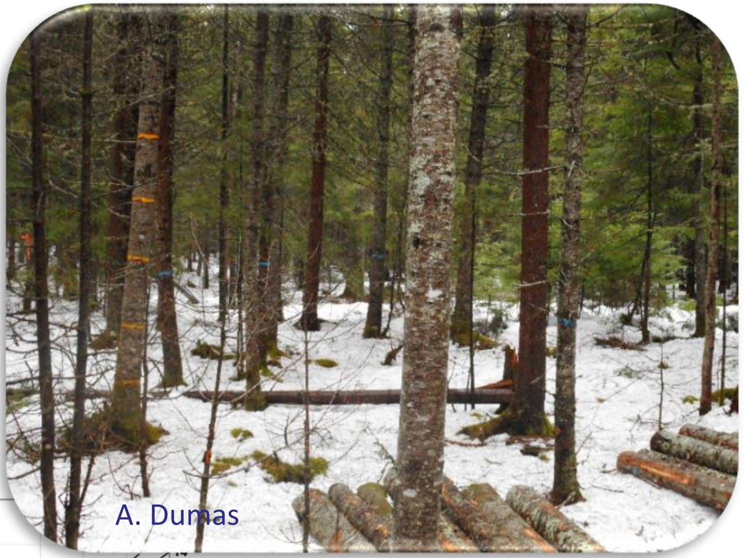
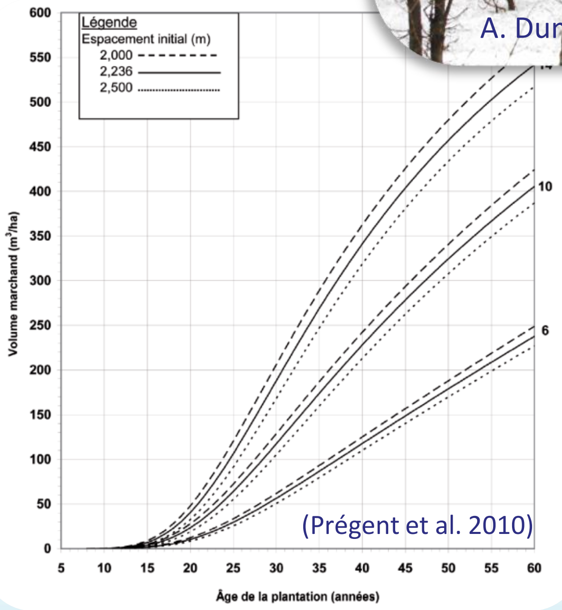
Challenges associated to mixed species plantations

- Establishment and growth of planted species
  - Facilitation or competition for resources?
- Is it operationally and economically feasible?
- Silvicultural and management challenges
  - Growth and yield tables calculations, plantation patterns, release and thinning treatment planning


A. Dumas



(Prégent et al. 2010)

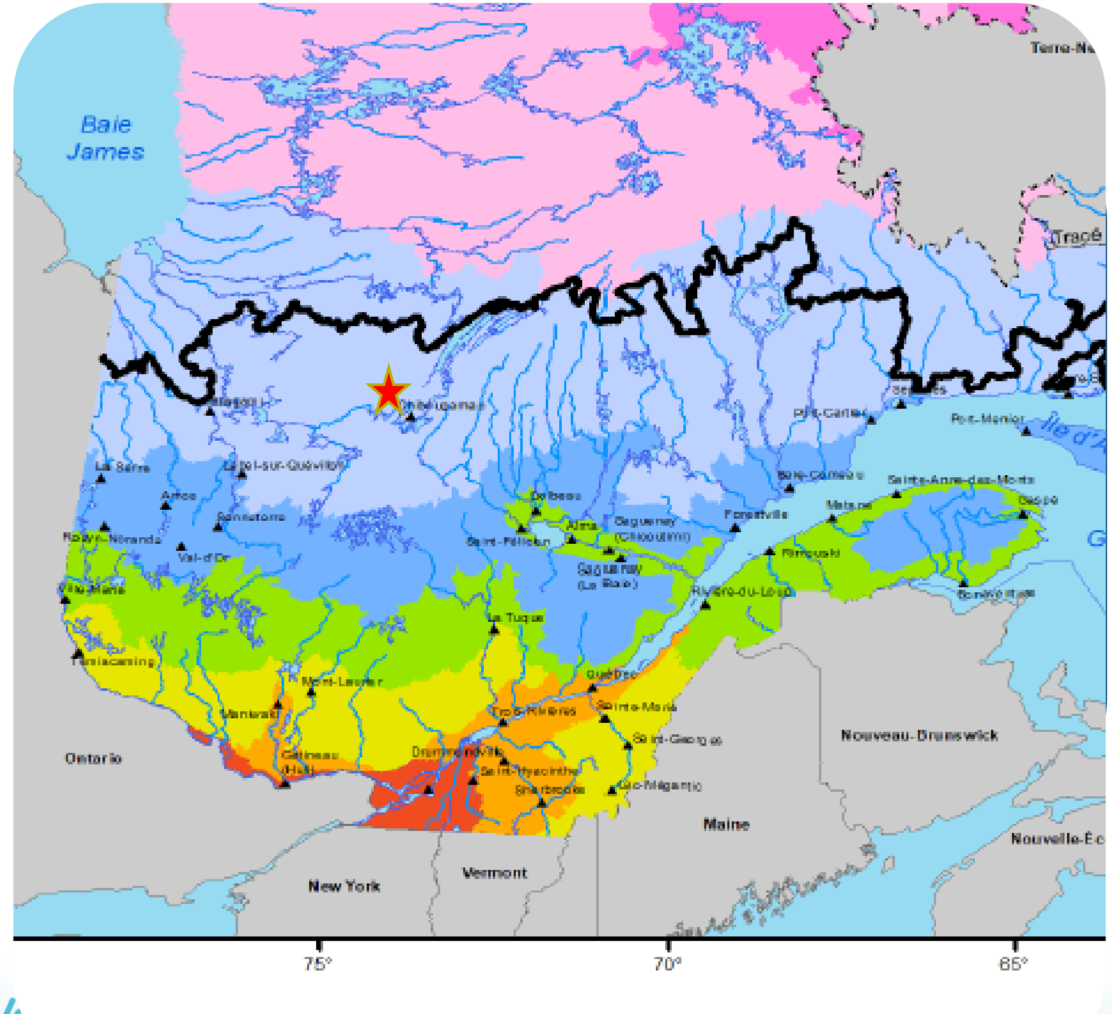
Objectives

Evaluate the operational feasibility and economic profitability of various mixed-plantation patterns by quantifying their effects on planters and on the seedling’s supply chain

Measure the initial success of planted seedlings in terms of their survival, growth and physiology as a function of their microsite

Measure the mid and long term success of planted seedlings in terms of survival, growth, physiology and on the carbon budget, and the influence of the competing vegetation on those variables

Experimental design



...re des Ressources naturelles et des Forêts, Direction du développement et de l'innovation de l'ind...

- 4 blocks
- Western black spruce-feathermoss subdomain
- Silvicultural scenario planned for mixed-species plantations:
  - Disk scarification + plantation at 1600 stems/ha + manual release + thinning (JP) + CLAAG
- No mix of species in the containers either at the nursery or at the planting site.

Studied variables

- Survival
- Physiology
  - Photosynthesis, water potential
- Functional traits
  - SLA, NUE, WUE.
- Plantation microsite characterization
  - Substrate type, planting position, humus thickness, soil temperature
- Carbon
  - Soil, snags and big woody debris
- Environmental variables

Studied variables

- Person-time measurements and cost of every step of plantation establishment
  - Site preparation,
  - Seedling freight, plantation, manual release, etc.
  - Goal: establish payment rates for mixed species vs monospecific plantations.

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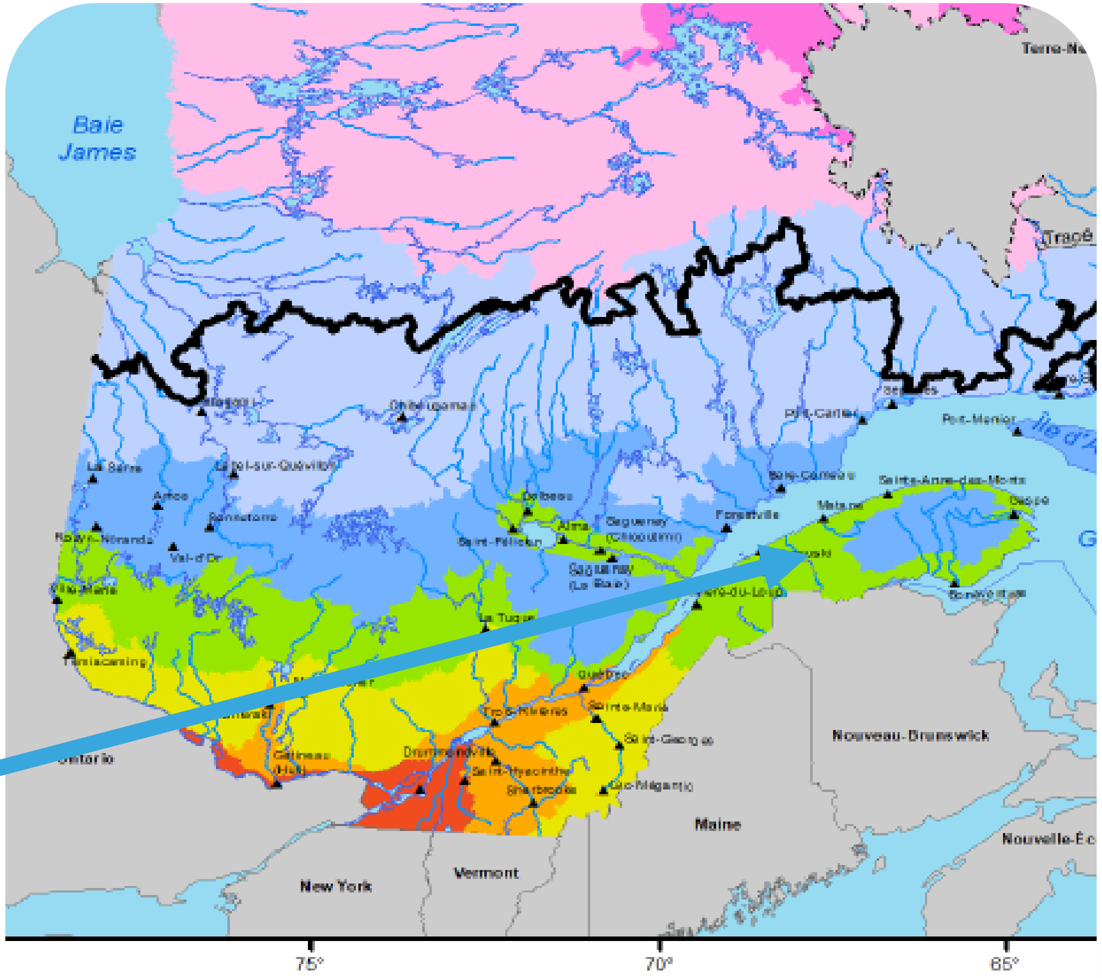
Transition project

Collaborators: Patricia Raymond (MRNF-DRF), Emilie Champagne (MRNF-DRF), Julie Godbout (MRNF-DRF), Marine Duperat (MRNF-DRF), Samuel Royer-Tardif (CERFO), Étienne Boileau (MRNF), Caroline Hamelin (MRNF), Greg St-Hilaire (MRNF), Mélanie Ruel (MRNF)

General objective

- Assist or facilitate the transition of species in order to maintain wood productivity in forest ecosystems where some species could be not adapted to new climatic conditions.
- Regions targeted : Bas-St-Laurent et Gaspésie.



...re des Ressources naturelles et des Forêts, Direction du développement et de l'innovation de l'ind...

Take-home message

- The impact of climate change on the Québec's forestry sector is a concern for the MRNF and for the Governement of Québec.
- Adaptation sylviculture in Québec is still at its development stage.
- A knowledge gap remains on the estimation of climate change risks on forest ecoystems and on their integration in forest management and planning in Québec.