Integrating climate change uncertainties into boreal timber supply determination through spatially referenced replanning: Implications for decision-making in Québec

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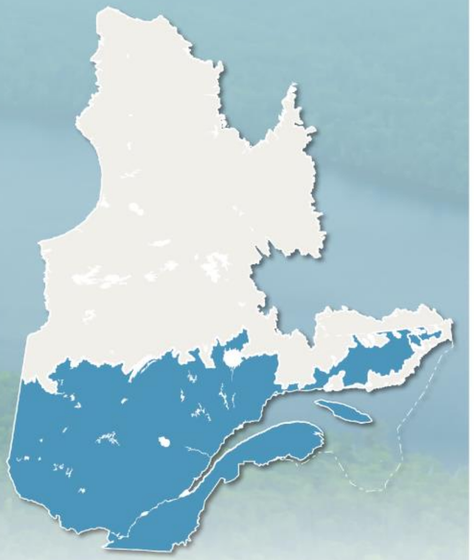

IBFRA − Québec − 27th August 2026

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Introduction

Who we are :

Office of the Chief Forester in Québec is an independent public office

- Mission :
  - Determine the annual allowable cut (AAC) for Québec's public forests (as required by the *Sustainable Forest Development Act* (RLRQ, c.A-18.1, s.48))

Main question :

- How can science support decision-making under uncertainty ?

Our goals :

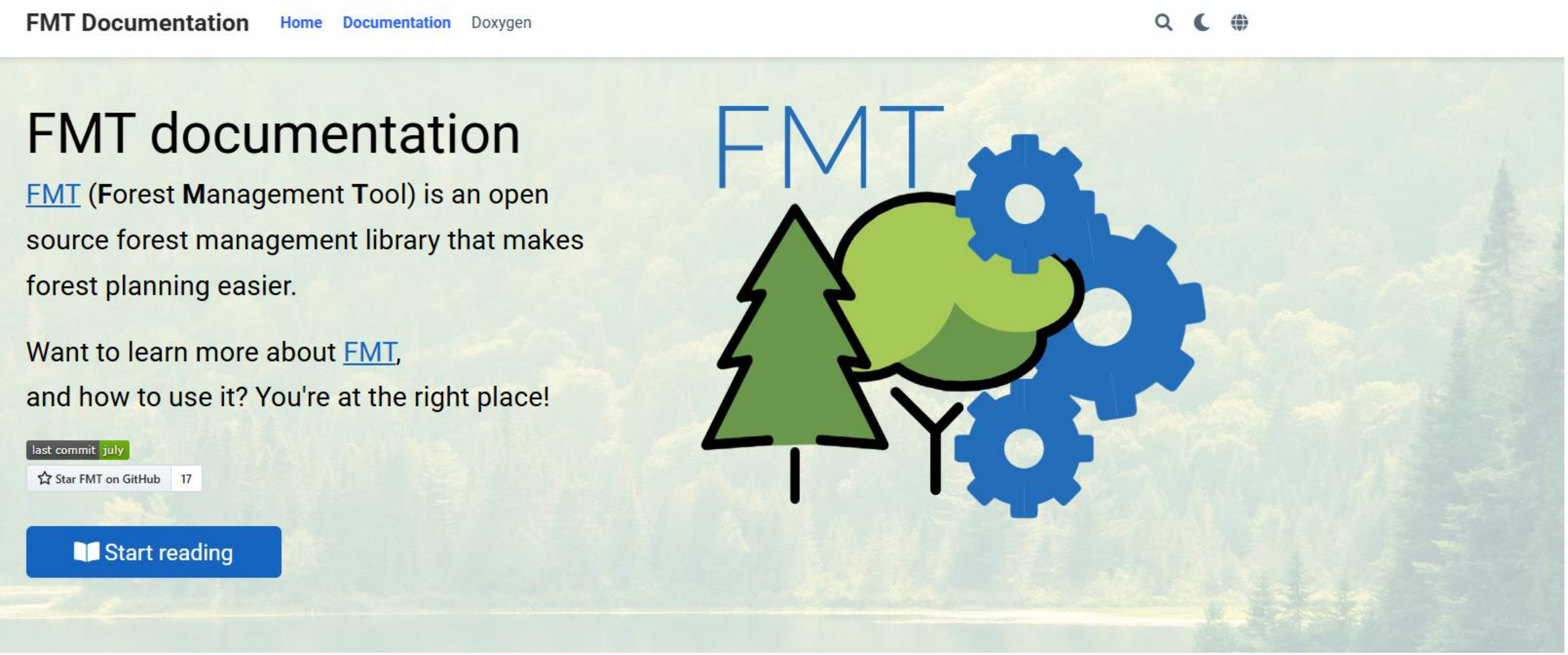
- Develop an integrated modeling framework that combines climate change, future natural disturbances and adaptation management strategies
- Support the Chief Forester's decision making from stochastic analyses

Methods: Study area in North Shore Region

- One model was developed and applied to the North Shore region (5 management units, ~8 M ha)
- Based on management strategies and budget from the 2023-2028 AAC calculation

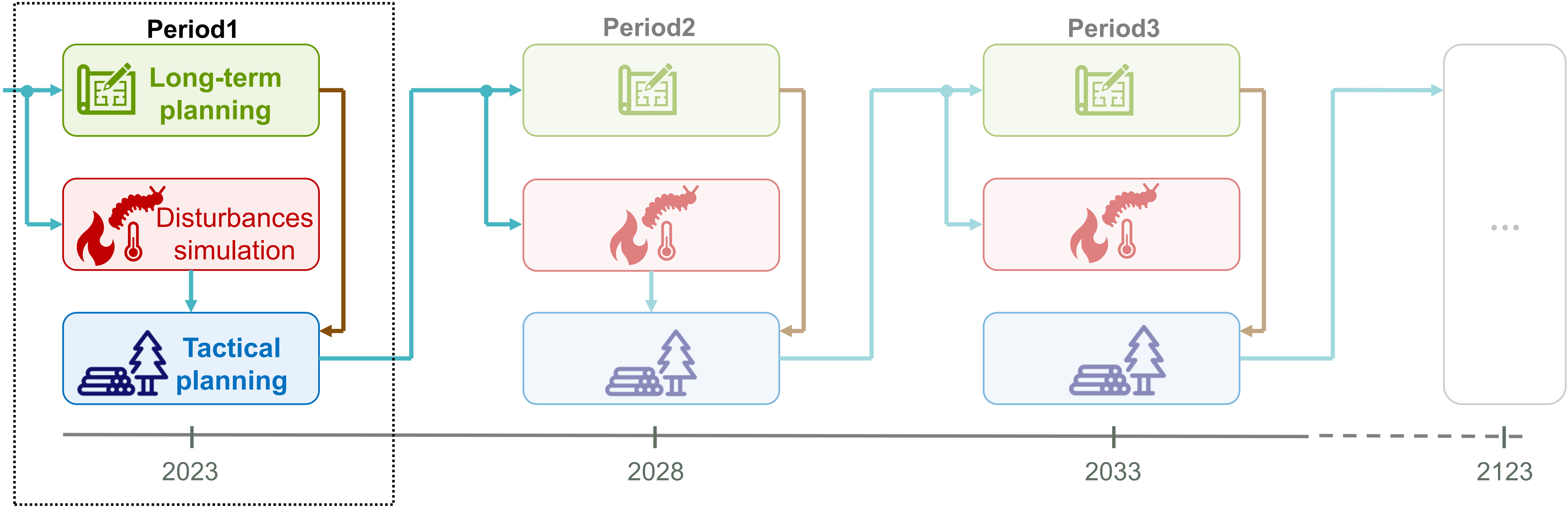
Methods: Modelling approach

- What's new ? A new tool for optimization/simulation: **Replanning**
- OpenSource on https://github.com/Bureau-du-Forestier-en-chef/FMT



Methods: Modelling approach

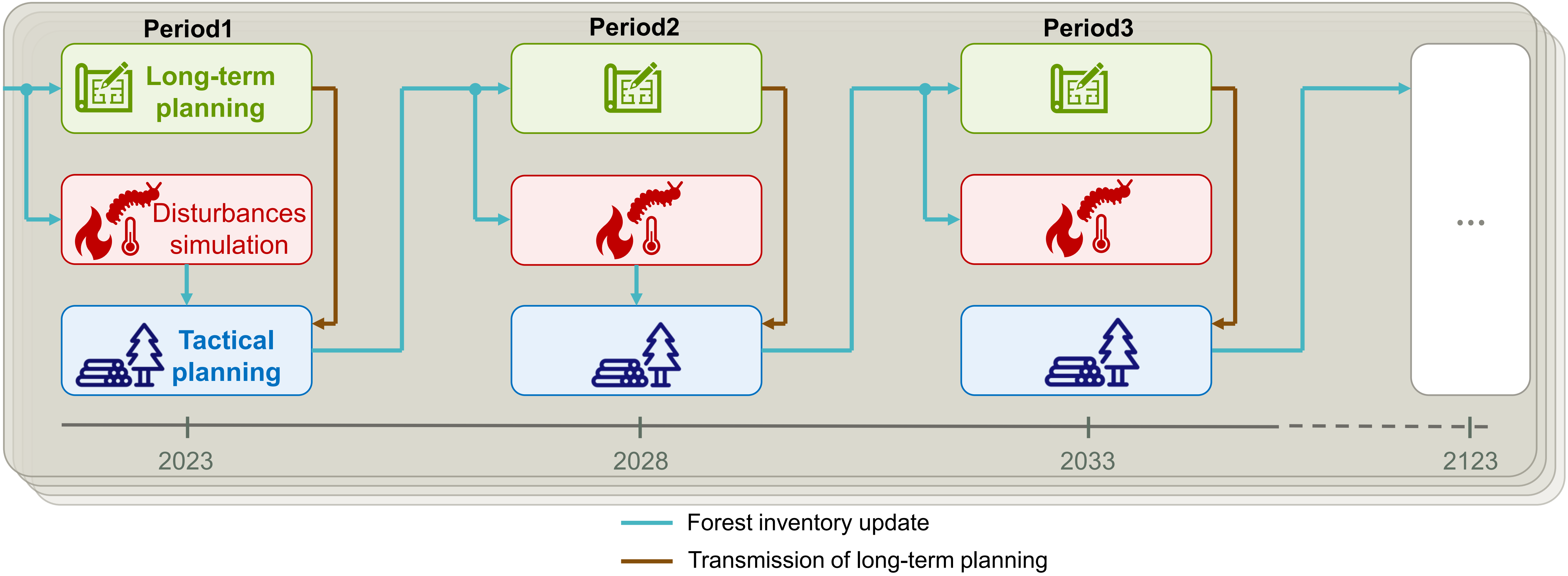
- **Replanning : how ?**
  - *Each time step represents a 5-year period, repeated until the end of the planning horizon*



This is one complete cycle: *it plans long-tem, simulates disturbances, re-optimizes, then moves on to the next period.*

Methods: Modelling approach

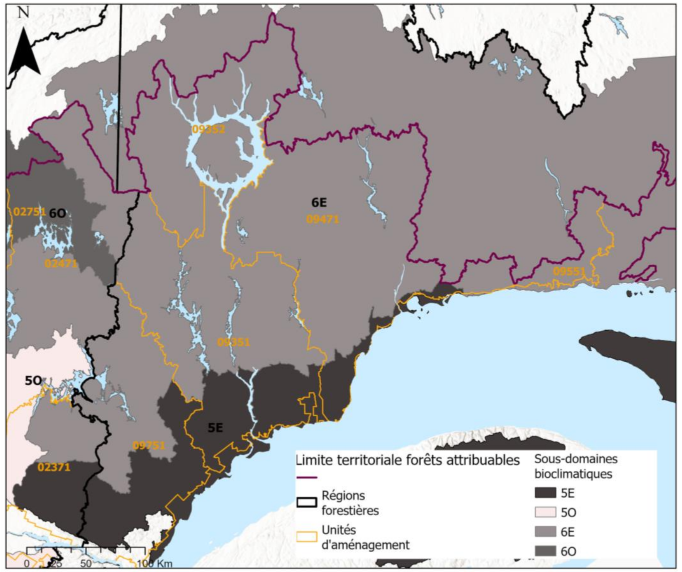
- **Replanning : how ?**
  - *Each time step represents a 5-year period, repeated until the end of the planning horizon*



Methods: Modelling approach

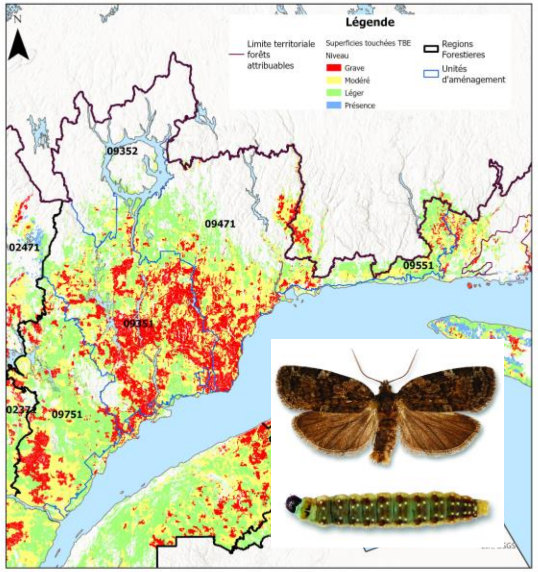
Climate effects and natural disturbances were included in the modelling process

Climate effects on productivity



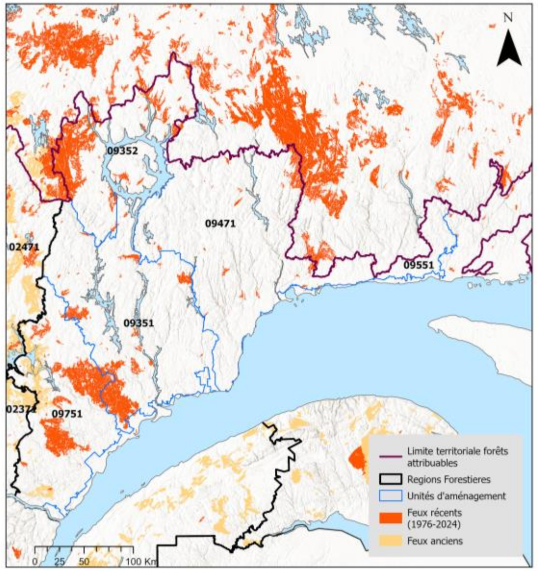
D'Orangeville et al., 2018; Power. et Auger, 2019; Power et al., 2025; Wang et al., 2022

Spruce budworm



Bauce et al., 2024, Bouchard et Auger, 2016, Boulanger et al., 2016; DRF, 2024; Houdonde et al., 2021, Régnière et al., 2012

Wildfire



Bernier et al, 2006; Couillard et al., 2022; Cyr et al., 2022; Metsaranta et al., 2023; NRCan, 2016; Bouchard et al., 2023; Splawinski et at., 2014, 2016, 2019.

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Methods: Modelling approach

- **Climate :** comparison of the historical baseline *versus* a moderate climate scenario (SSP2-4.5)

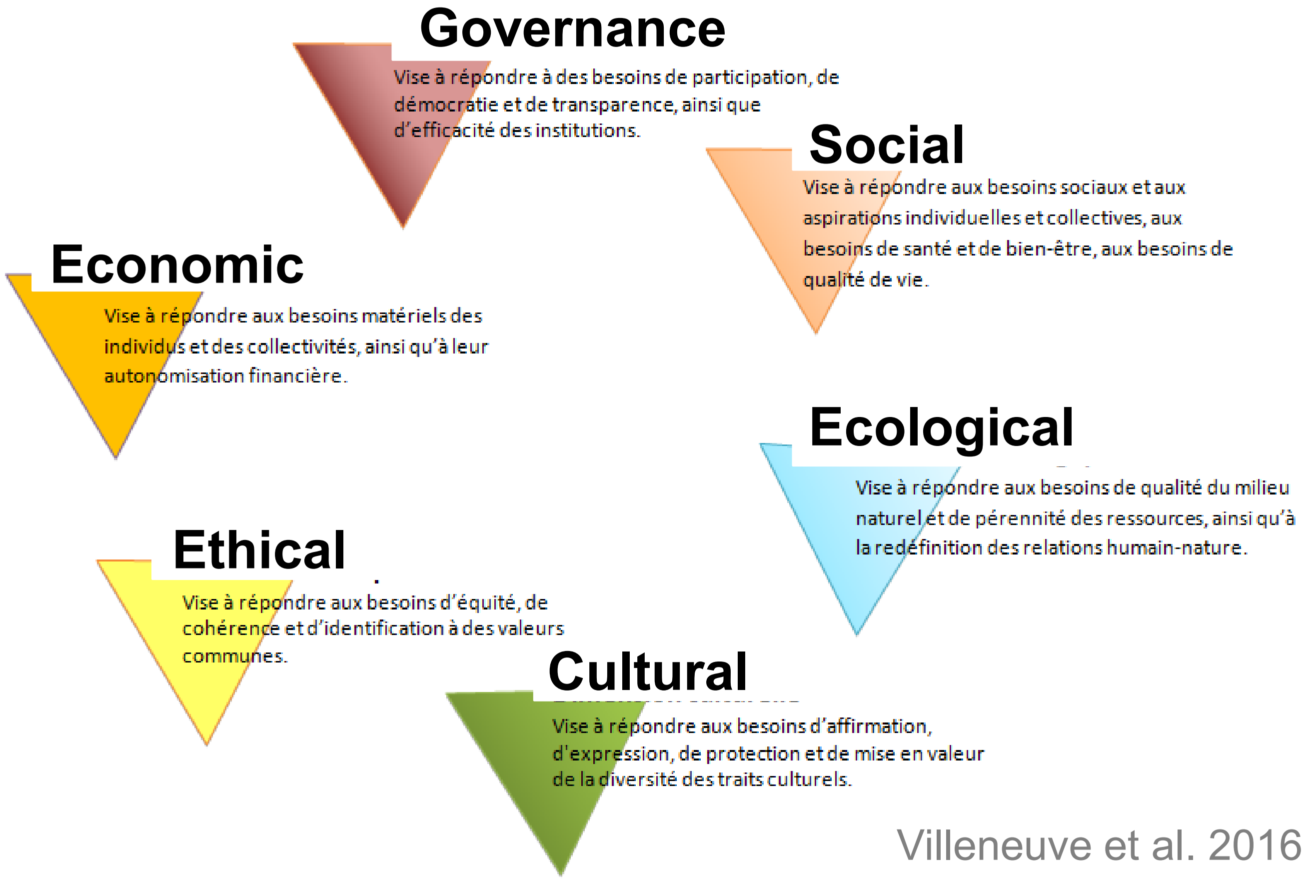
- **Scenario categories** :
  - Natural evolution (no intervention)
  - Managed forest ***without*** adaptations
  - Managed forest ***with*** adaptations (different salvage logging rates, seed cutting, mixed conifer planting, different buffer stock rates)

- **Various indicators :** e.g. AAC sustainability, standing volume, natural disturbance areas, regeneration failure, etc.

Methods: How to use our model indicators to support decision making?

- **Sustainable Development Analysis Grid** : a multi-dimensional sustainability assessment tool (UQAC and UN SDG Acceleration Toolkit)

- Used to **compare scenario replicates across six dimensions**, based on forest management indicators from our modelling.

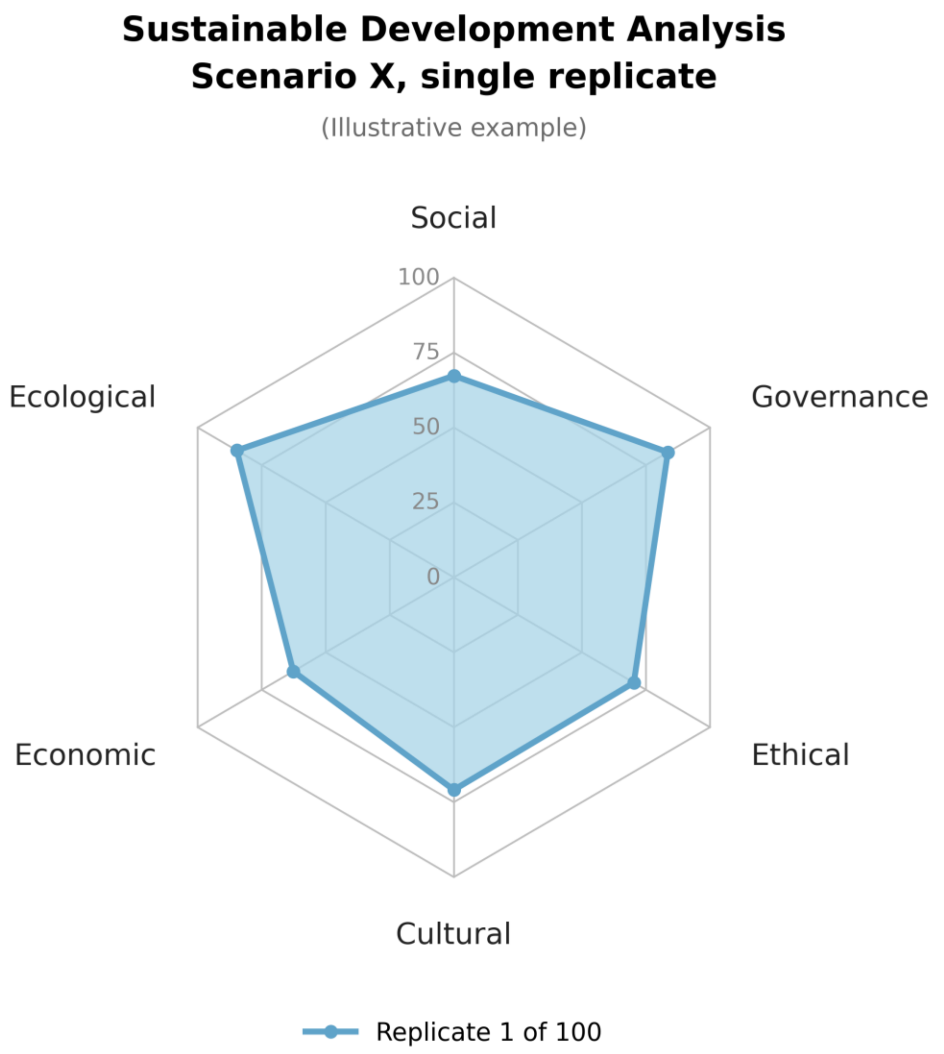


Villeneuve et al. 2016

Methods: Decision Support accounting for Uncertainty

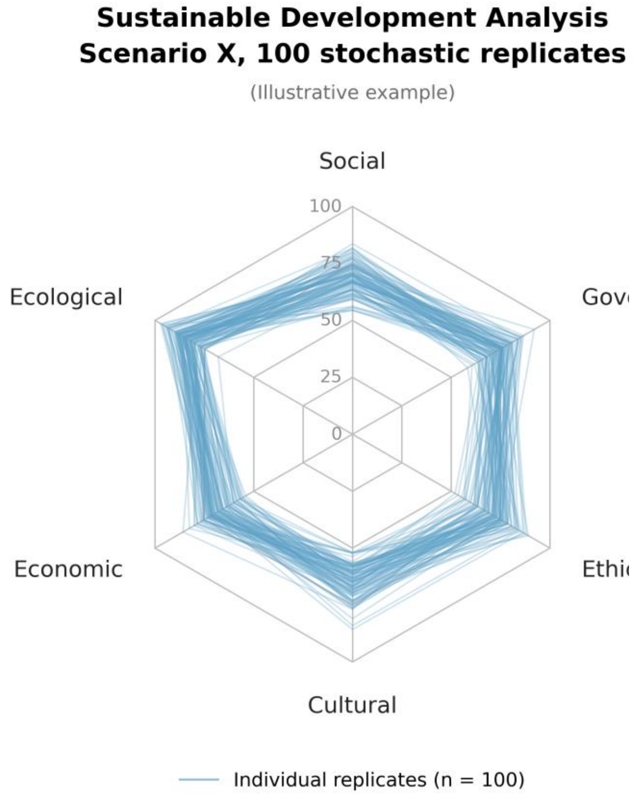
- Normalisation and dimensional score calculation

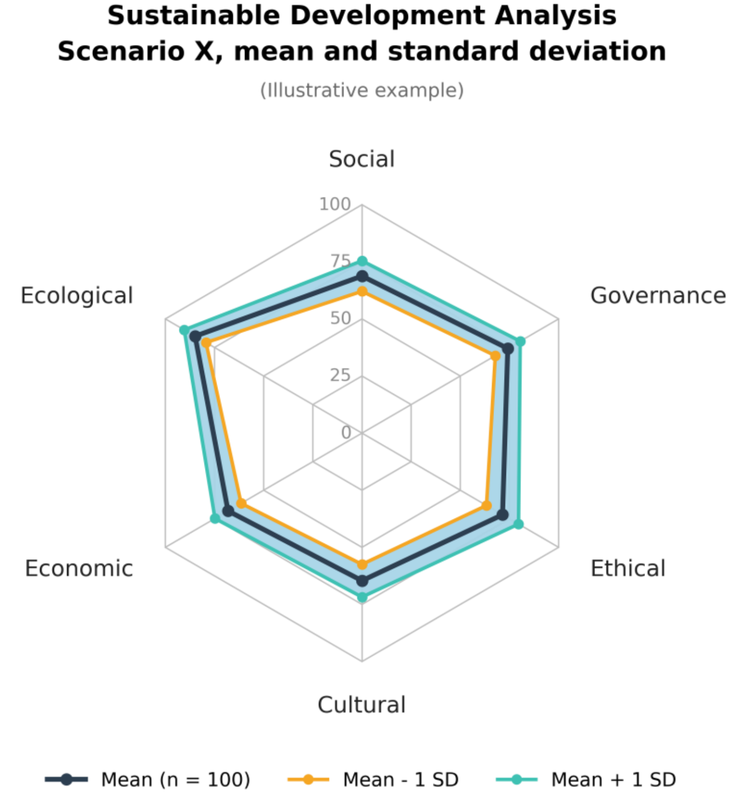
- Replicate overall performance = Hexagon area



Methods: Decision Support accounting for Uncertainty

- Normalisation and dimensional score calculation
- Replicate overall performance = Hexagon area
- Scenario ranking based on overall performance under uncertainty
- 3 periods (up to 2050, 2050-2080, 2080-2128)

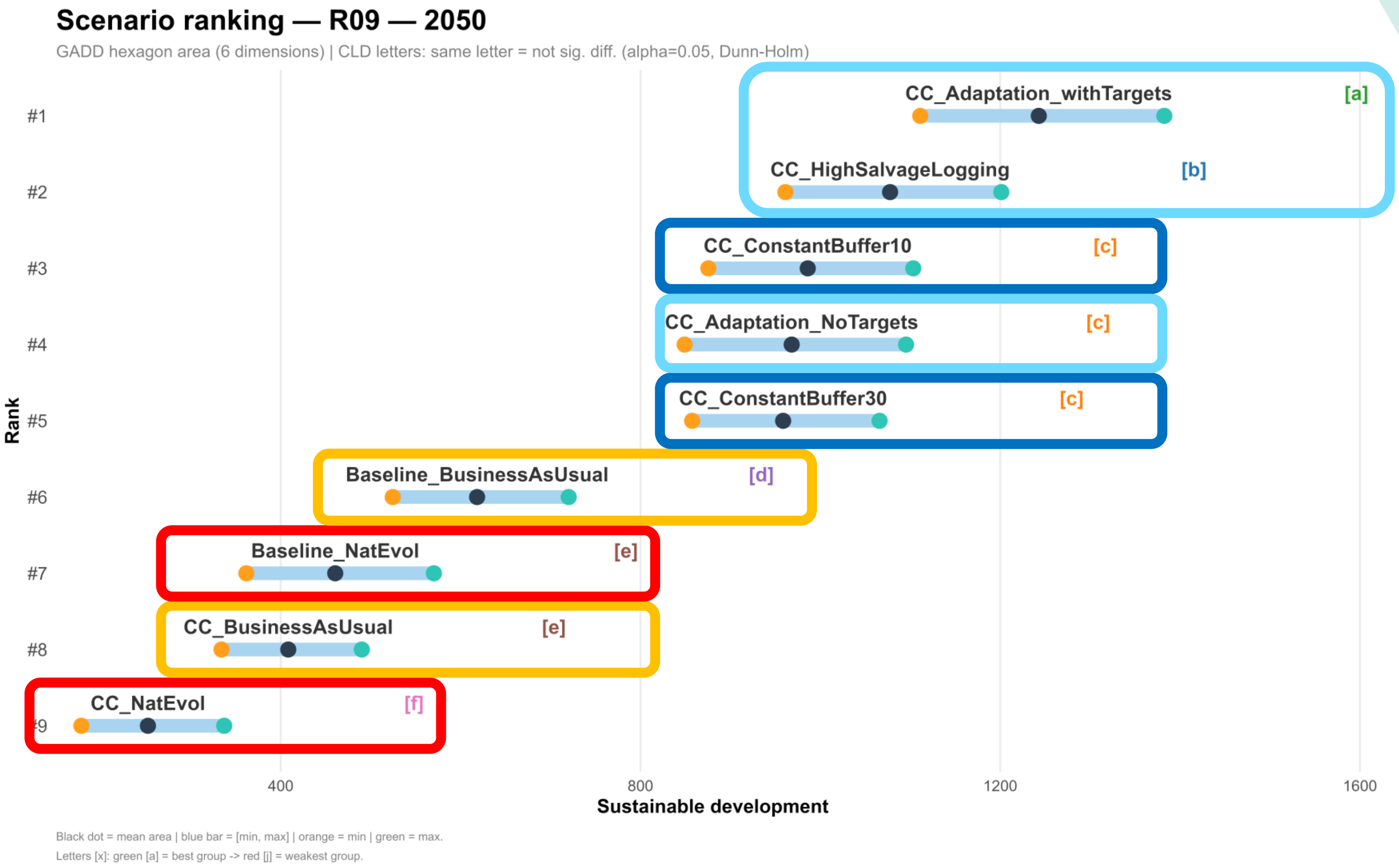




Results: Decision Support

Short term (Today–2050)

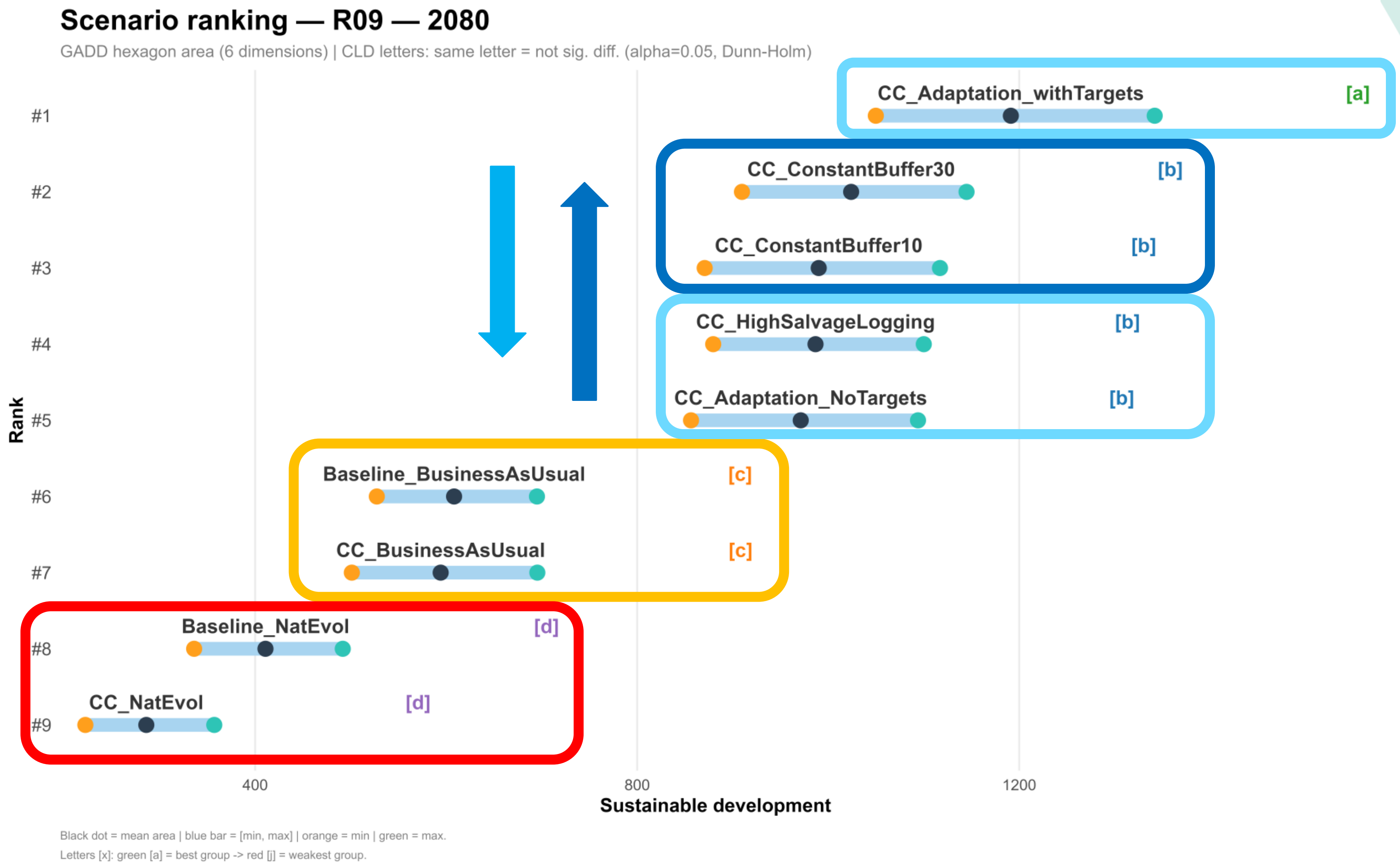
Focus on immediate actions and near-term impacts



Results: Decision Support

Medium-term (2050–2080)

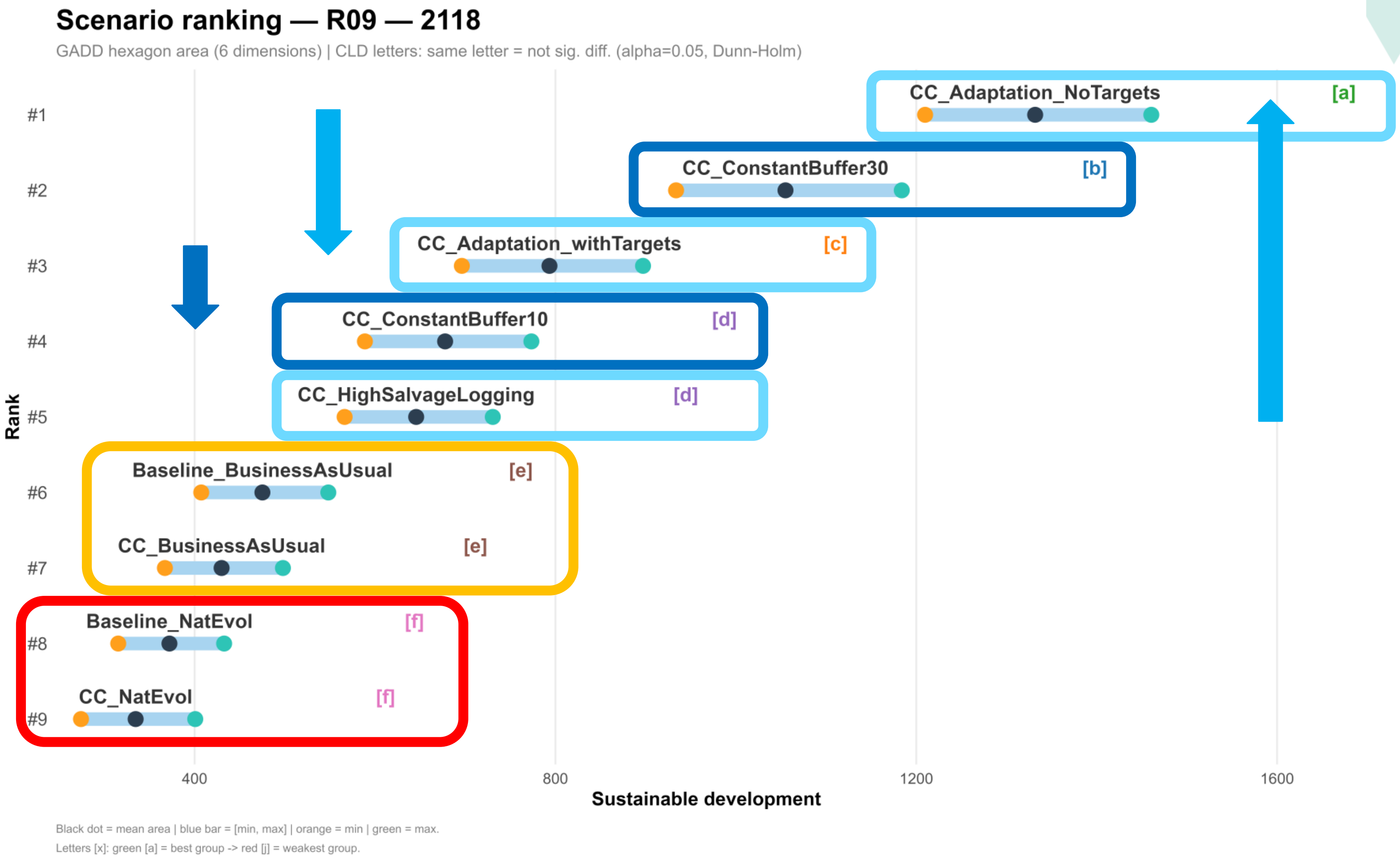
Assessment of medium-term adaptation and transition pathways



Results: Decision Support

Long-term (2080–2100)

Evaluation of long-term sustainability and resilience



Take-home messages

1. We built a new modeling framework that integrates impacts of climate change on productivity, natural disturbances and adaptation management strategies to support decision-making.
2. Adaptation scenarios *outperformed* the historical baseline during the whole simulated horizon.
3. But there is no universal best scenario : the right choice depends on the dimensions prioritized and the time horizon, not a single ranking.
4. First step : translate complex issues into simple message to inform decision-makers.

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Visit our website:
http://www.forestierenchef.gouv.qc.ca
https://github.com/Bureau-du-Forestier-en-chef

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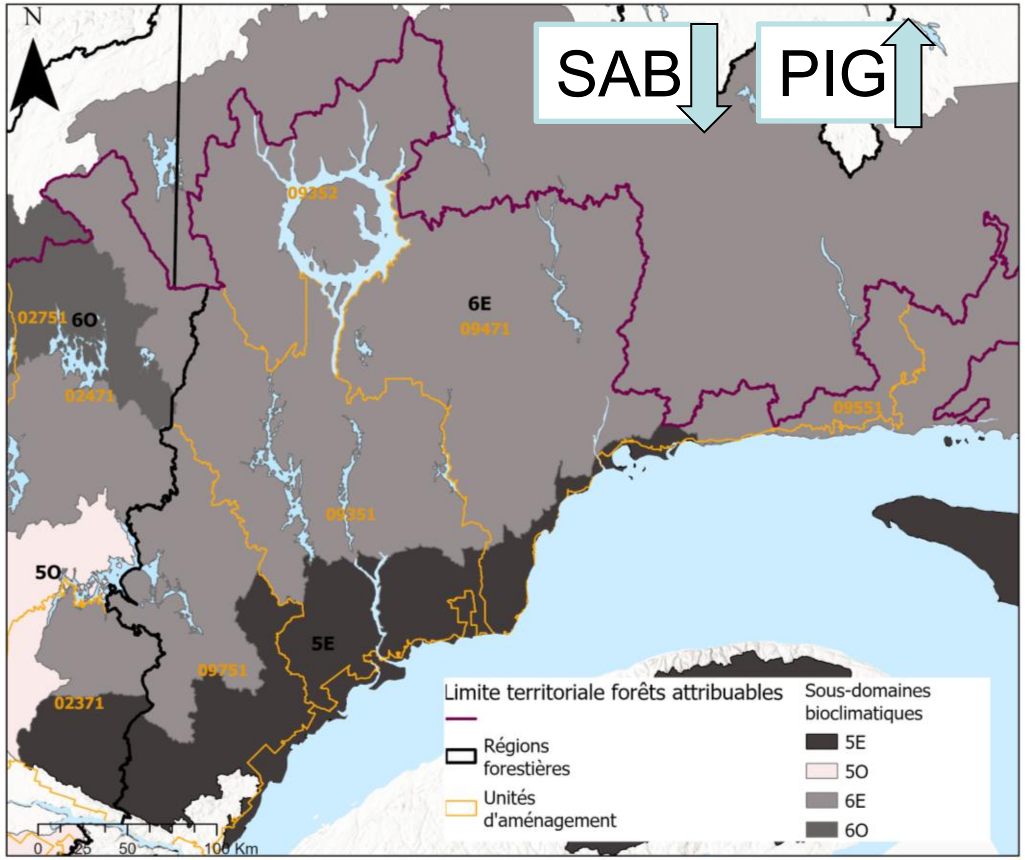
THANK YOU! MERCI!
QUESTIONS?

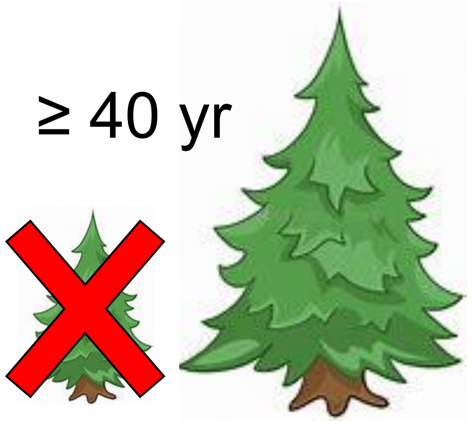
Methods : Climate effects on Productivity



- Volume modifiers (Power, DRF, 2025)
  - Ratio of mean volume under climate change / mean volume under historical climate
- Based on previously published models
  - Two DBH-increment growth models (D'Orangeville et al. 2018, Wang et al. (2022))
  - Senescence assessed with mortality model (Power et al. 2025)
- Modifiers were incorporated *a priori* into model inputs
- Linked to BFEC 2023–2028 CPF growth curves

Methods : SBW dynamics

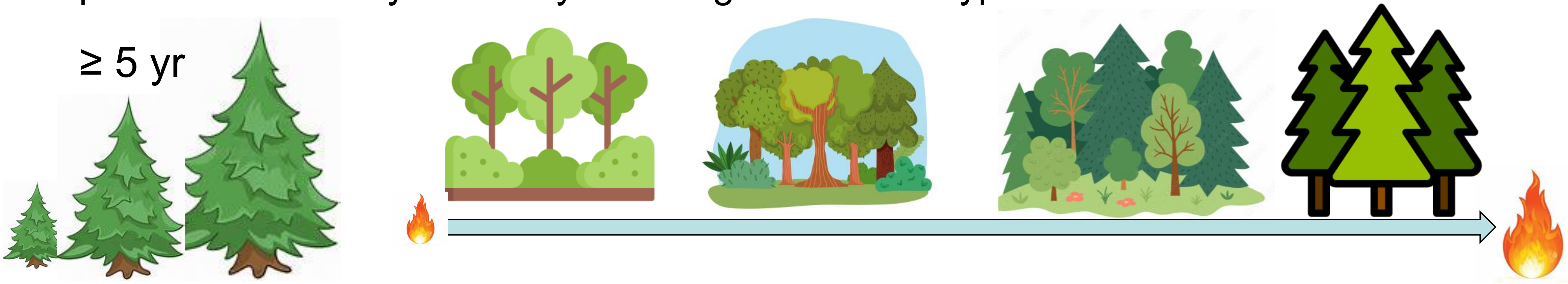
- *Biological components*
  - **Host species** (vulnerability driven by age and presence of balsam fir)



  - **SBW**: insect growth rate and outbreak duration/severity (baseline vs SSP2-4.5)

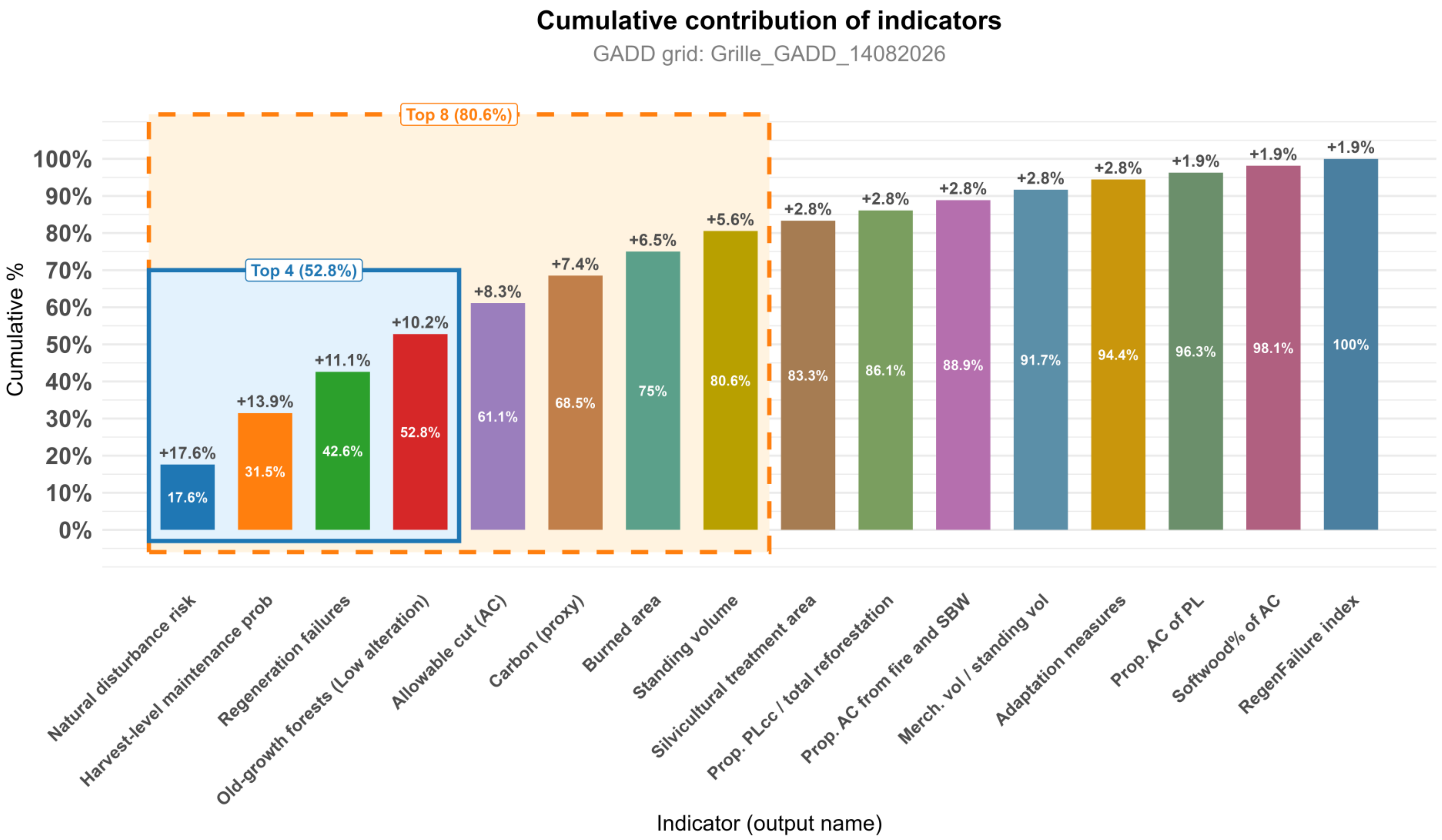
Methods : Wildfires

- *Biological components*
  - Species vulnerability driven by stand age and cover type

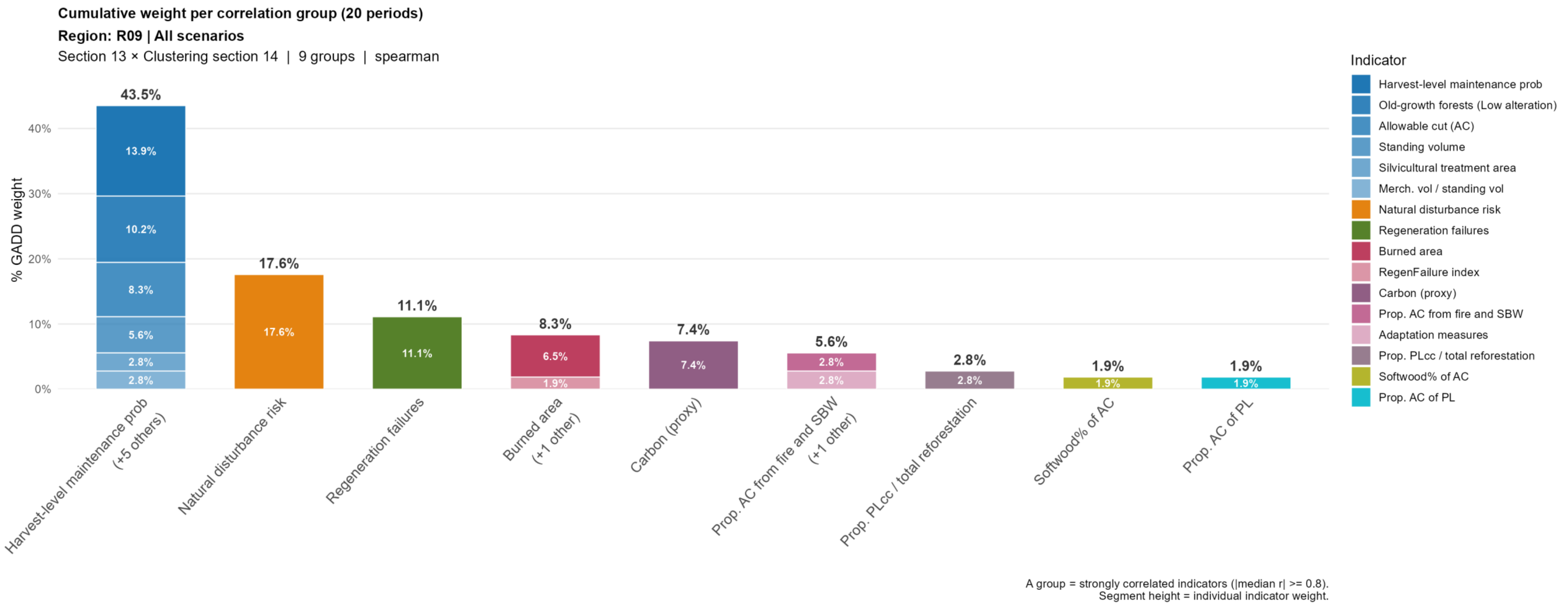


- *Physical environment :* surperficial deposit and homogeneous vegetation units
- *Wildfire components*
  - Fire history (size and number of fires),
  - Québec fire regime zones (Couillard et al., 2022)
  - Projections of fire season duration under RCP4.5 (NRCan, 2016, 2022)

Results : Decision Support



Results : Decision Support



Results : Decision Support