UNBC

# From Simulation Models to Management: Quantifying Projected Drought Resistance

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# Key Question

Where and when will drought cause the largest impacts on forest stands in Interior and Northern British Columbia, and how should forest management adapt to reduce those impacts?

Current forest management

P1

Short-term

P2

Long-term

# Overview

- Ecological drought in interior & northern BC
- Drought resistance framework
- Objectives
- Methodology
- Projected resistance dynamics
- Impact of silviculture treatments
- Management implications

# Ecological drought in interior & northern BC

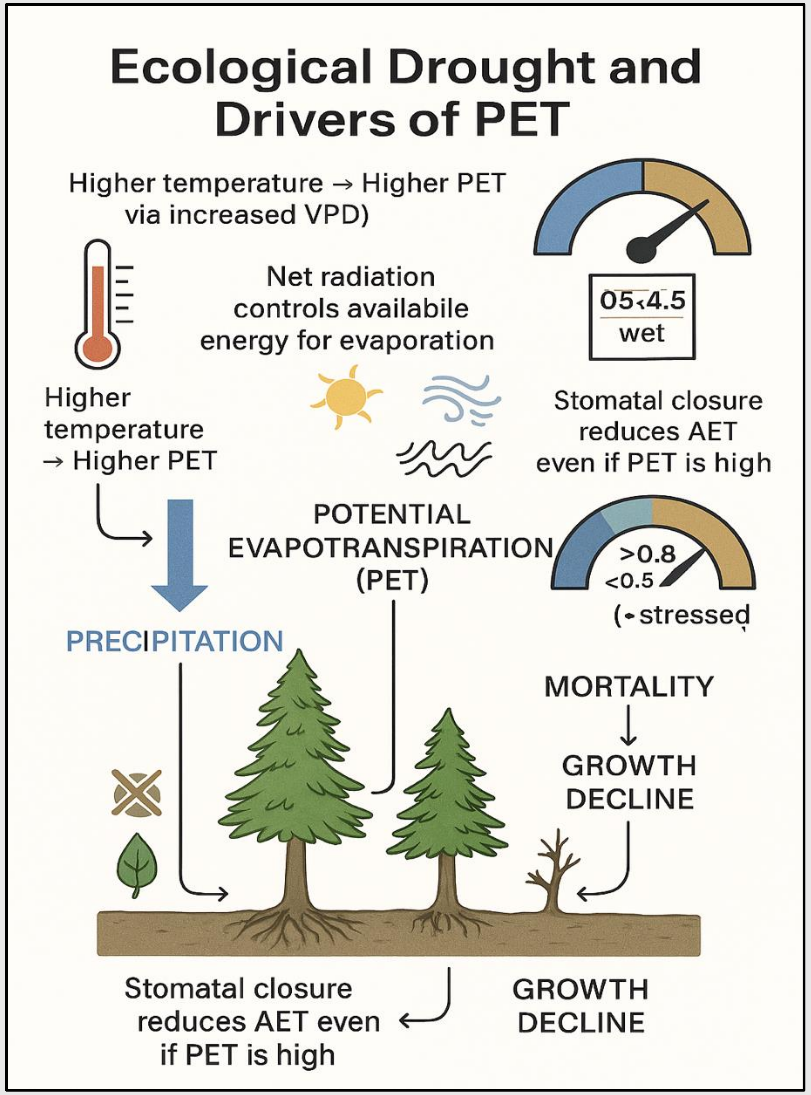
Ecological drought is defined as the period when **actual evapotranspiration (AET)** drops far below **potential evapotranspiration (PET)** because soil moisture becomes insufficient, often leading to increased tree mortality and ecosystem breakdown.

## Different from meteorology/hydrology drought

# Ecological drought in interior & northern BC

## Why AET/PET Matters

When AET ≪ PET, ecosystems cannot meet water demand → trees reduce transpiration → close stomata → growth declines → ecological processes break down → mortality



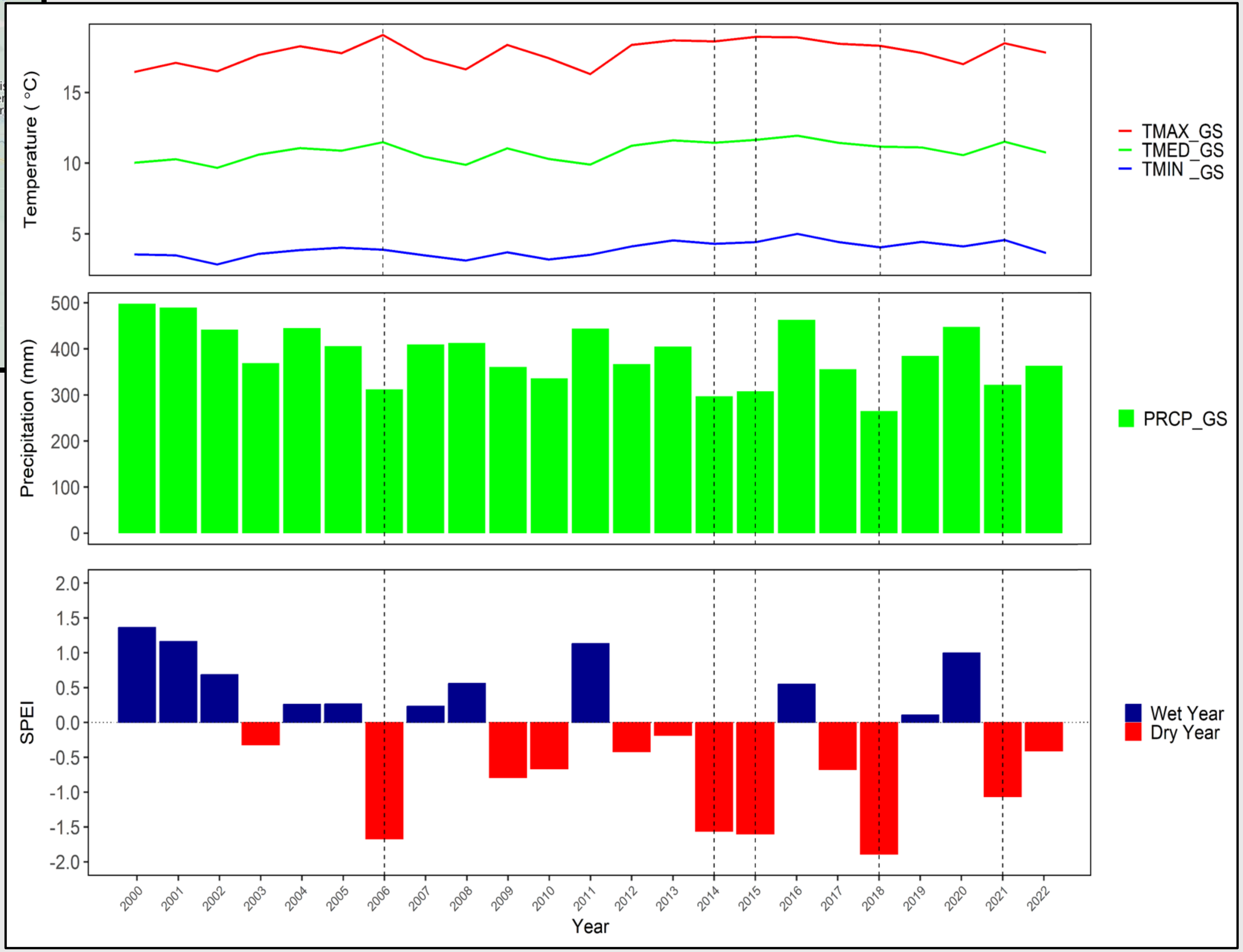

Conceptual figure

# Ecological drought in interior & northern BC


**SPEI:** Standardized Precipitation-Evapotranspiration Index

Five moderate to severe drought years between 2000- 2022

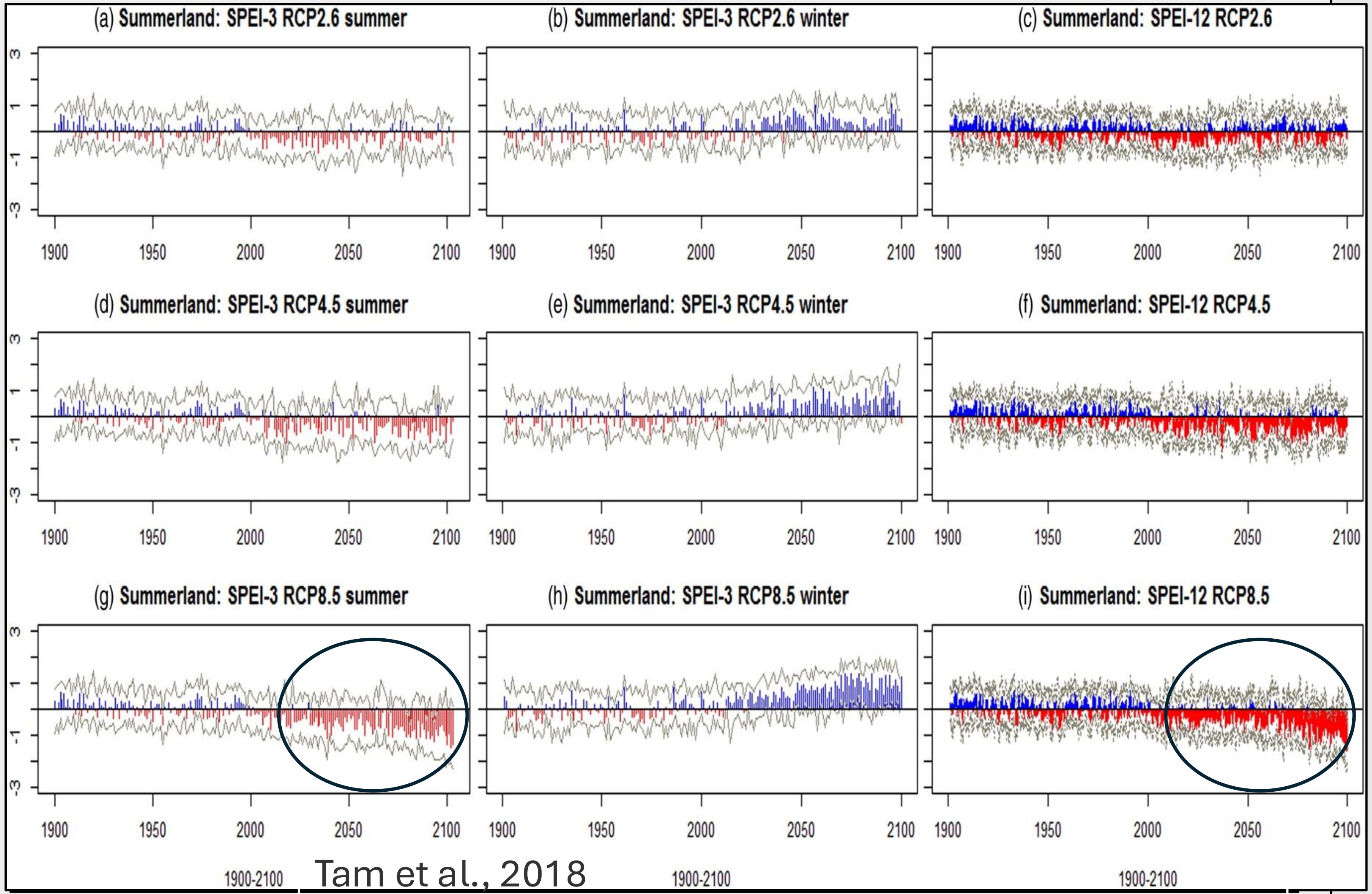
2006, 2014, 2015, 2018, 2021



# Ecological drought in interior & northern BC

With global warming, drought severity and duration are expected to increase

Significantly affect tree growth, carbon sequestration, and timber supply




Tam et al., 2018

# Drought resistance framework

Need a Resistance Framework to quantify the current and future drought resistance capacity

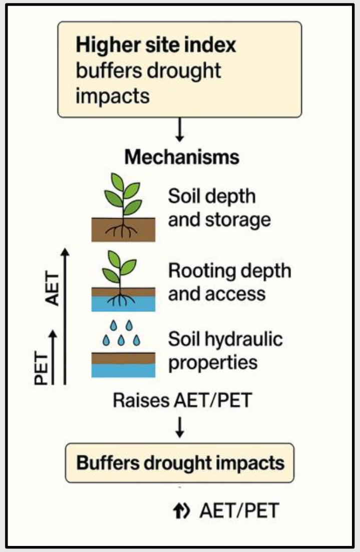
To quantify the future drought resistance capacity of a stand, we need to grow the stand in future

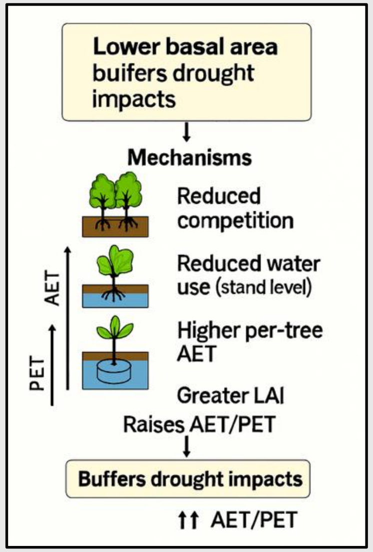
The Forest Vegetation Simulator (FVS) simulate forest vegetation changes over time in response to natural succession, disturbances, and management activities

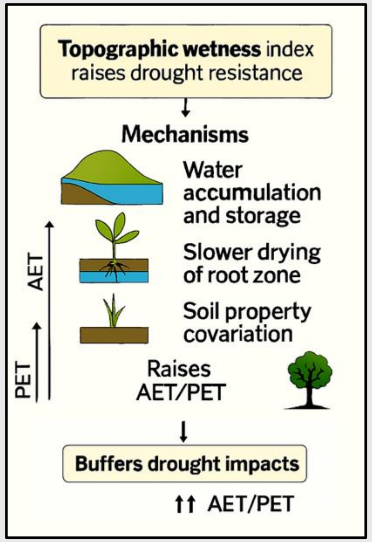
# Drought resistance framework

Drought resistance is the stand-level capacity to maintain structure and function during a drought event, quantified here as a composite score that integrates four stand and site indicators.

- Site index: Proxy of site productivity
- Stand Basal area: Proxy of resource competition
- TWI: Topographic Wetness Index: Proxy of soil water accumulation capacity
- DRAT (Drought Risk Assessment Tool): Species-specific drought mortality risk



# Drought resistance framework

## Drought Risk Assessment Tool (DRAT)

### Inputs

- BEC unit (climate regime) + soil moisture regime (ASMR: xeric–subhygric) + ClimateBC projections

### Water Balance Calculation

- PET: atmospheric water demand
- AET: water available to plants (soil moisture-limited)
- AET/PET ratio: Lower = greater drought stress

### Site × Species Risk Adjustment

- Risk scaled by species' drought tolerance (Low, Medium, High and Very high)

### Temporal Projections

- 1961–1990 baseline → climate projection 2020s (2011–2040), 2050s (2041–2070), and 2080s (2071–2100) (RCP 4.5)
- Identifies which species–site combinations remain viable vs. become unviable under climate change

# Drought resistance framework

Each indicator has a maximum resistance score of 1 and a minimum of 0, based on the lower and upper thresholds.

**For example:**

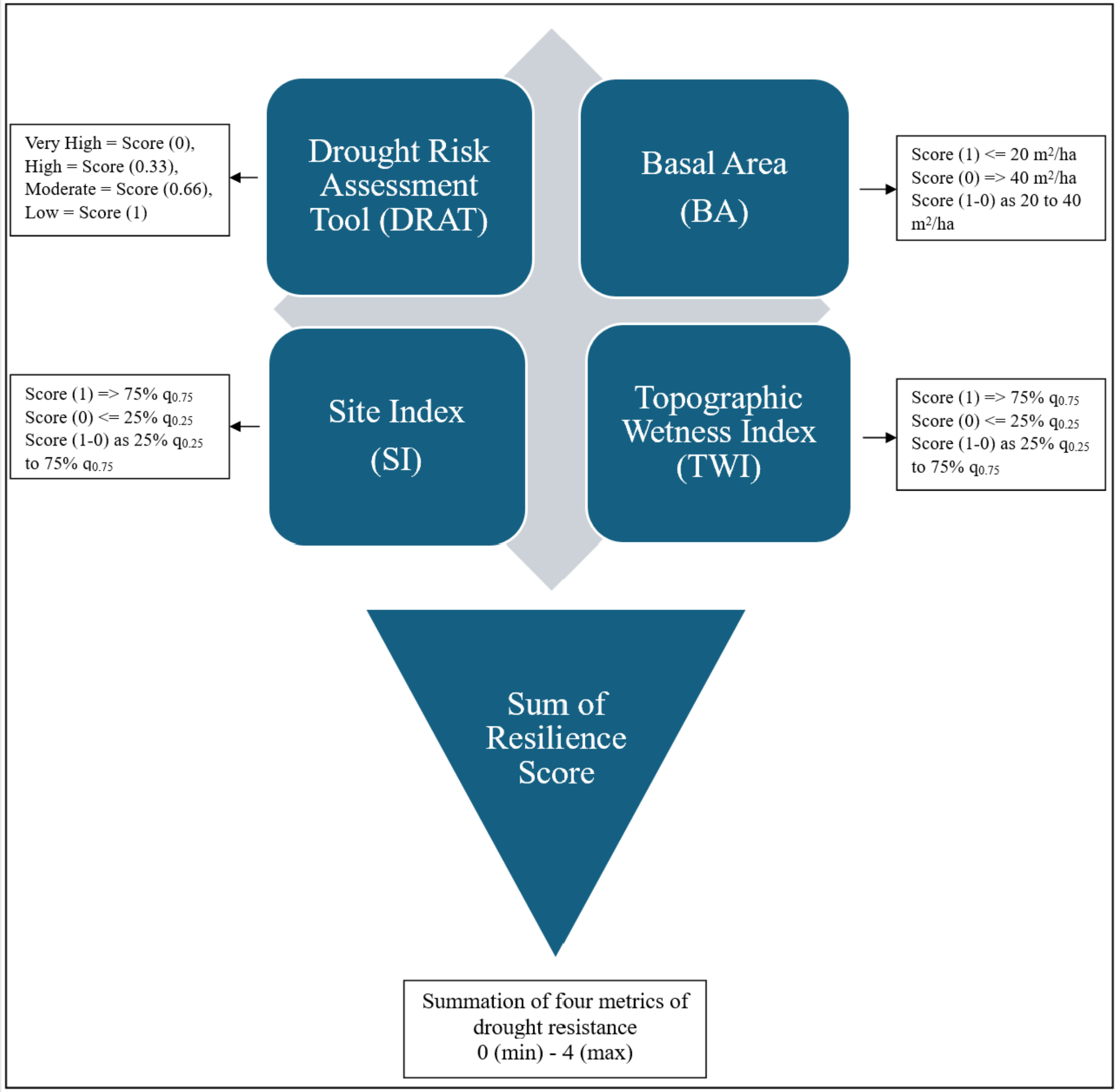
Stand Basal Area

Lower threshold 20 $m^2/ha$ = 1

Upper threshold 40 $m^2/ha$ = 0

From lower to upper threshold = 1 ~ 0

$$\mathbf{Drought_{resistance} = R_{SI} + R_{BA} + R_{TWI} + R_{DRAT}}$$



# Objectives

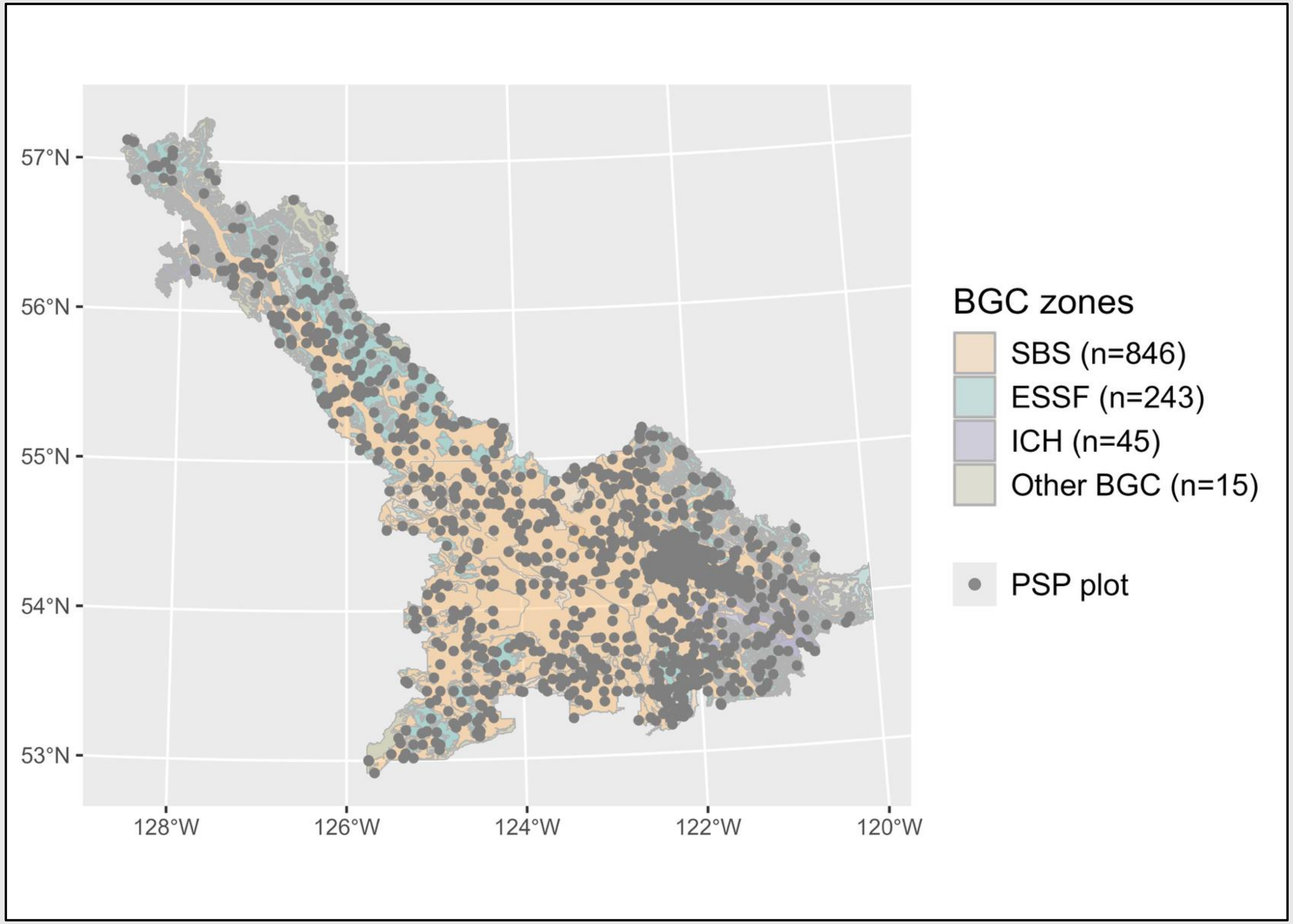
Projected drought resistance across biogeoclimatic zones up to 2100

Effect of different thinning intensities on projected drought resistance

How thinning alters projected drought resistance across stand types

# Methodology: Study area

- Prince George Timber Supply Area (PG TSA)
- Total 1149 Permanent Sampling Plots
- Data collected between 1998-2018
- Subalpine fir, hybrid spruce, lodgepole pine dominant stands

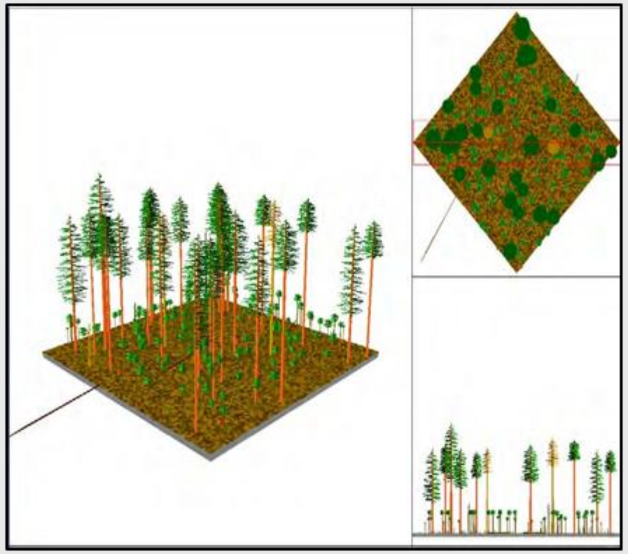


# Methodology: FVS-BC

- Individual-tree, distance-independent growth and yield model.

- Responsive to site, structural differences and silviculture treatments; thinning, pruning, species plantation, harvesting, etc.

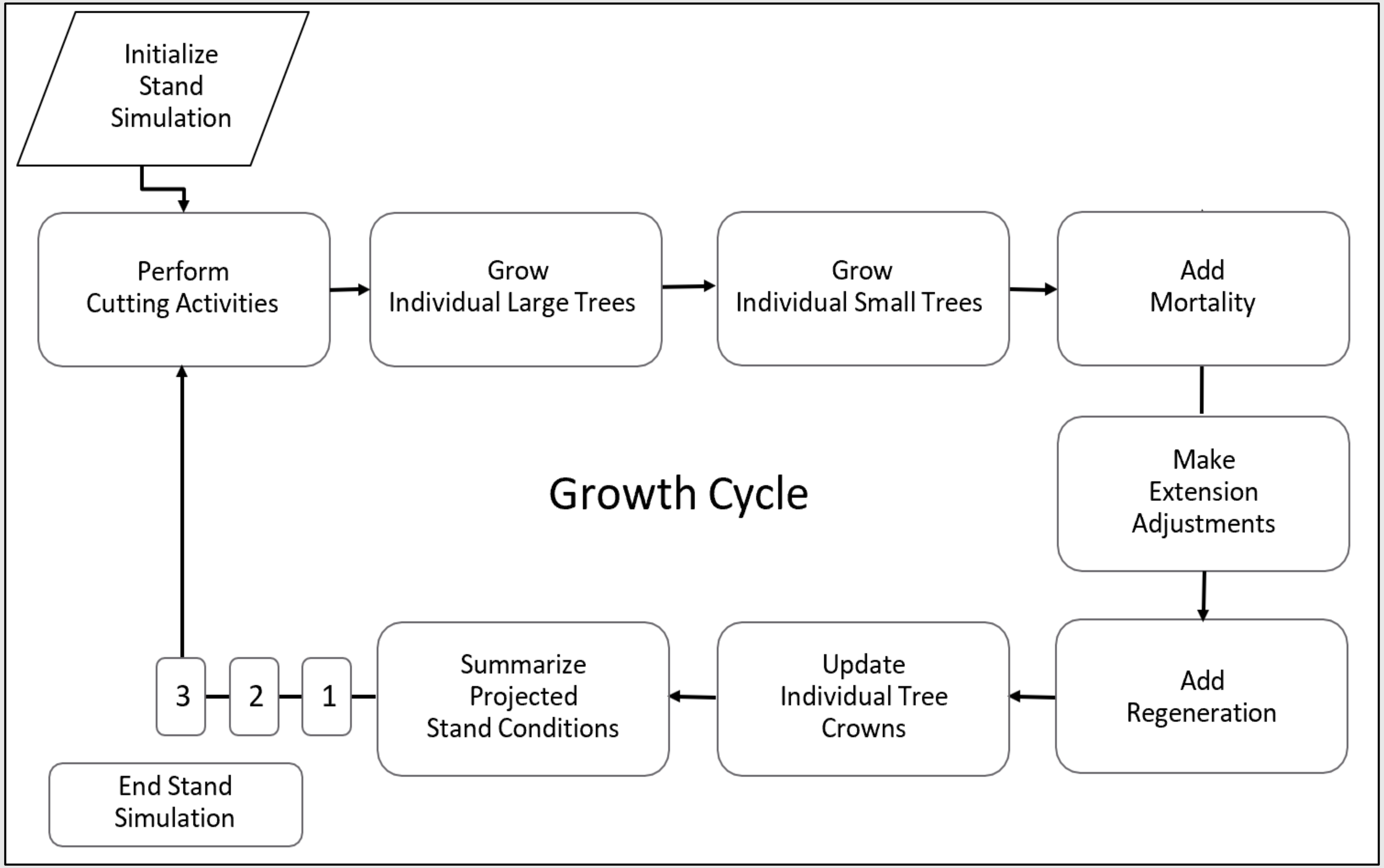
- Inventory-based system that can accommodate a variety of inventory designs in projecting stand development.



# Methodology: FVS-BC

Two Datasets

- FVS TreeInt
- FVS StandInt



# Methodology: FVS-BC

## TreeInit (Tree Characteristics)

- Species
- DBH
- Height (total)
- Crown Ratio
- Tree Count (Per Hectare Factor) (from inventory design)

## StandInit (Stand Characteristics)

- Location (Latitude and Longitude
- Inventory Year
- Slope
- Aspect
- Elevation
- **Ecoregion**
- **Carrying Capacity (BAMAX)**

Simulation performed from 2020-2100 for all the stands

# Methodology: Thinning treatments

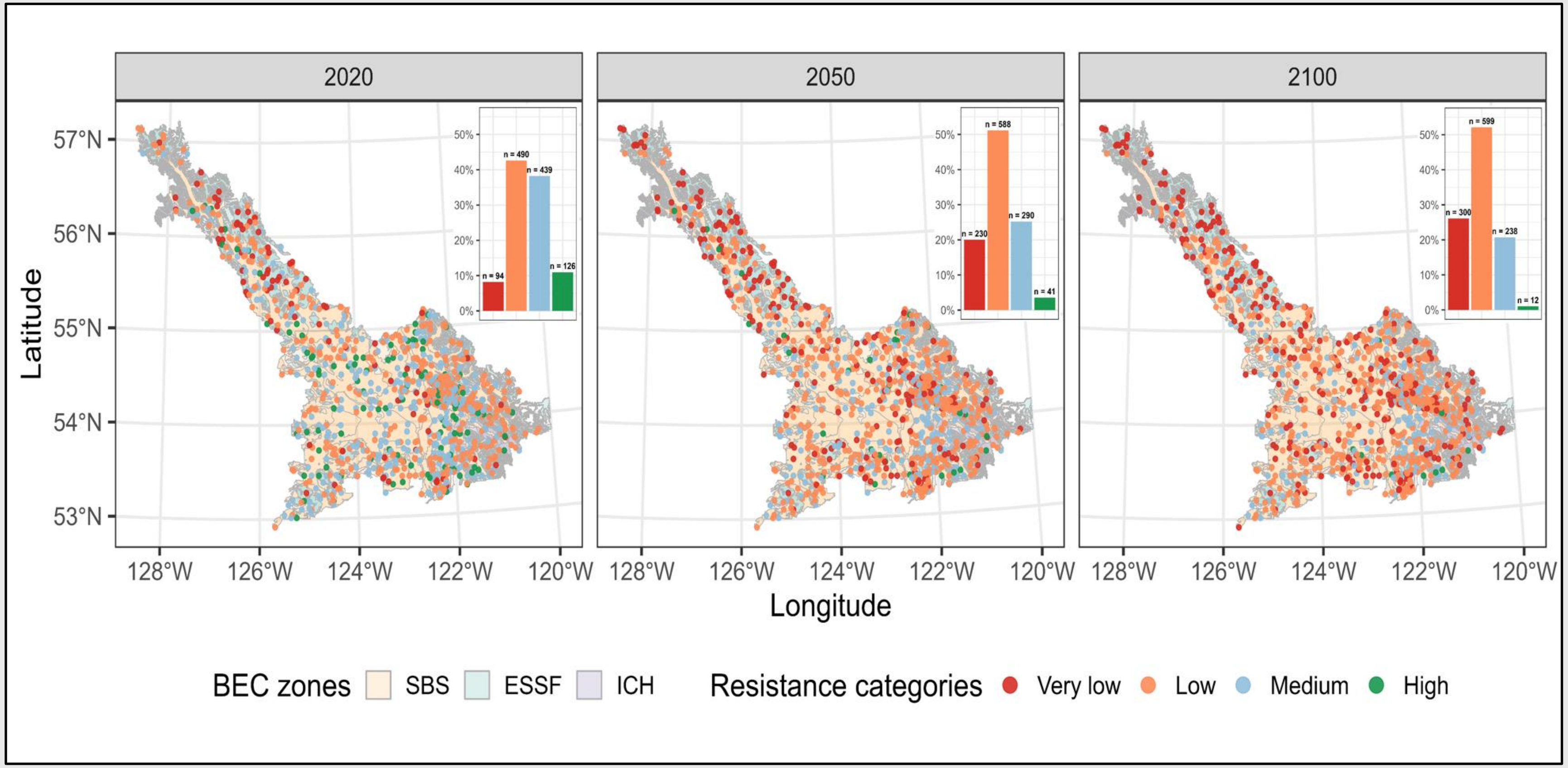
**Five treatments**

- Control : No thinning treatment
- Thin_25 $m^2$/ha : Thinning to 25 $m^2$/ha residual Basal Area
- Thin_20 $m^2$/ha : Thinning to 20 $m^2$/ha residual Basal Area
- Thin_15 $m^2$/ha : Thinning to 15 $m^2$/ha residual Basal Area
- Thin_10 $m^2$/ha : Thinning to 10 $m^2$/ha residual Basal Area

Thinning was applied in 2030, from below, removing the smallest trees with a minimum DBH of 5 cm, with priority given to removing species known to have lower drought resistance, including subalpine fir and spruce (all species).

# Results: Projected drought resistance

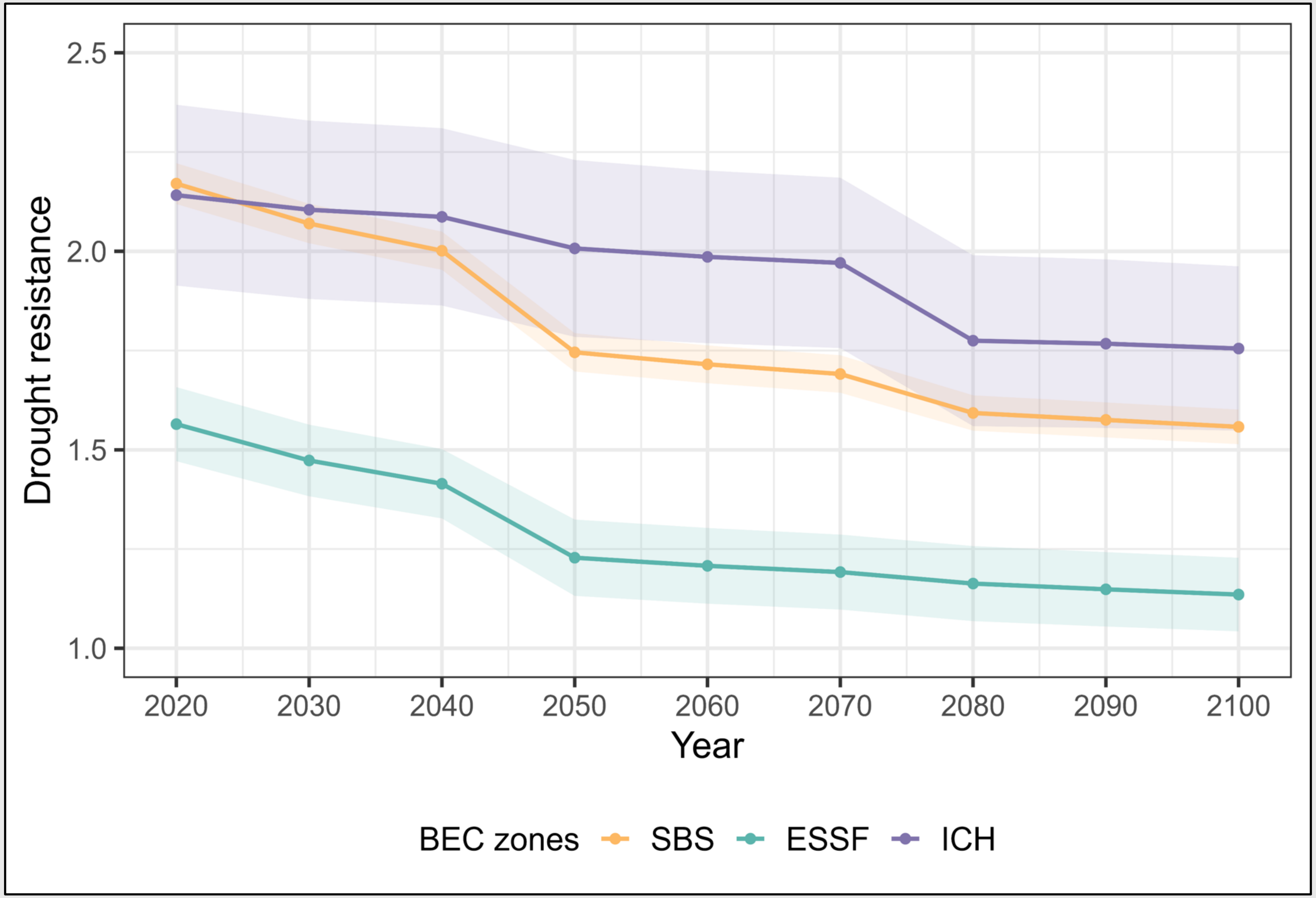
- 2020: Low & Medium categories are dominant.
- 2050, Medium category dropped, Low category increased.
- 2100, Low category dominated, High category disappears.




Very-Low (<1), Low (1–1.99), Medium (2–2.99), High (>3)

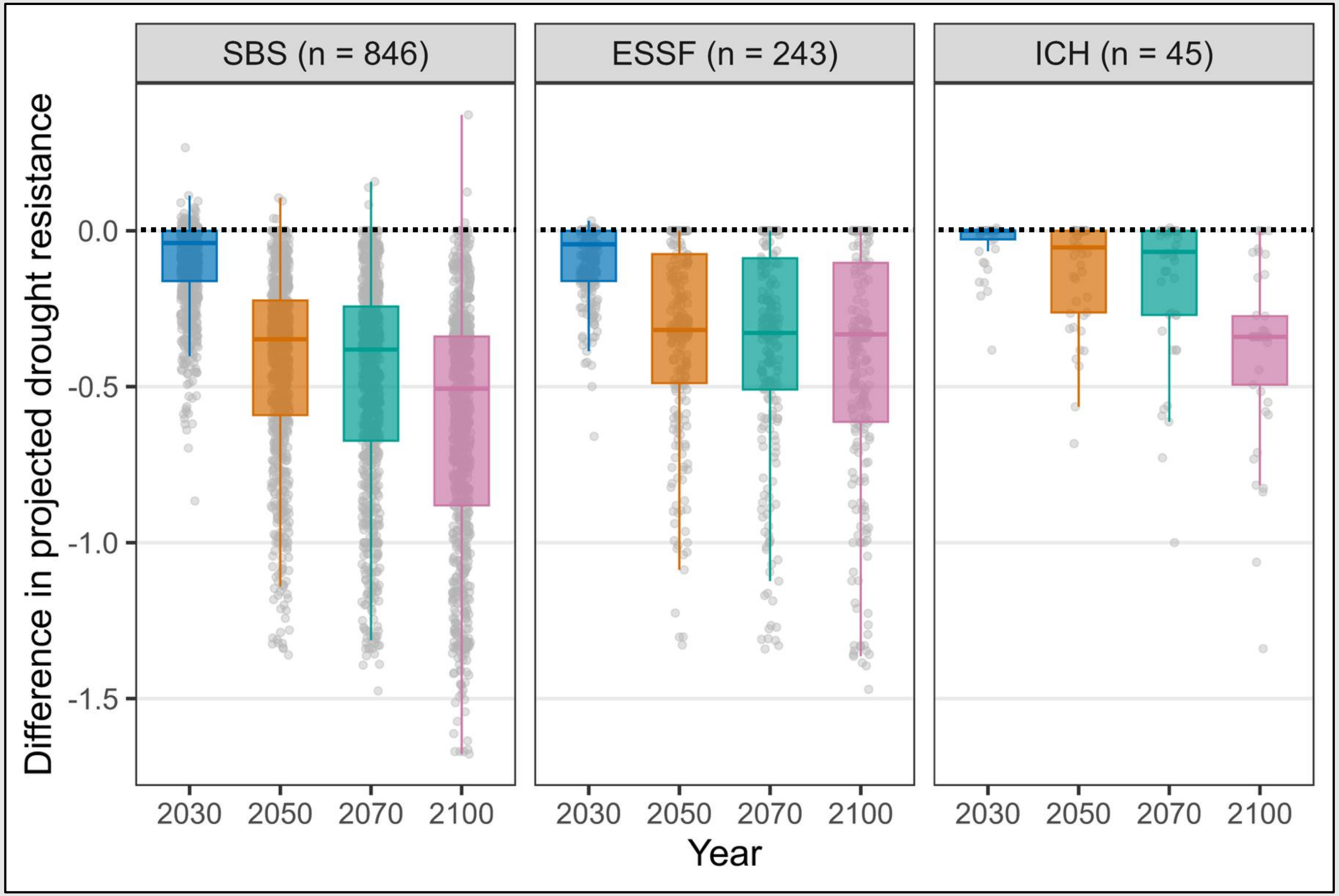
# Results: Projected drought resistance

- ESSF showed the lowest projected resistance, followed by SBS and ICH.
- SBS declined 28% from 2020-2100 (highest).
- ESSF declined by 26.9%
- ICH declined by 17.8% (lowest).



# Results: Projected drought resistance

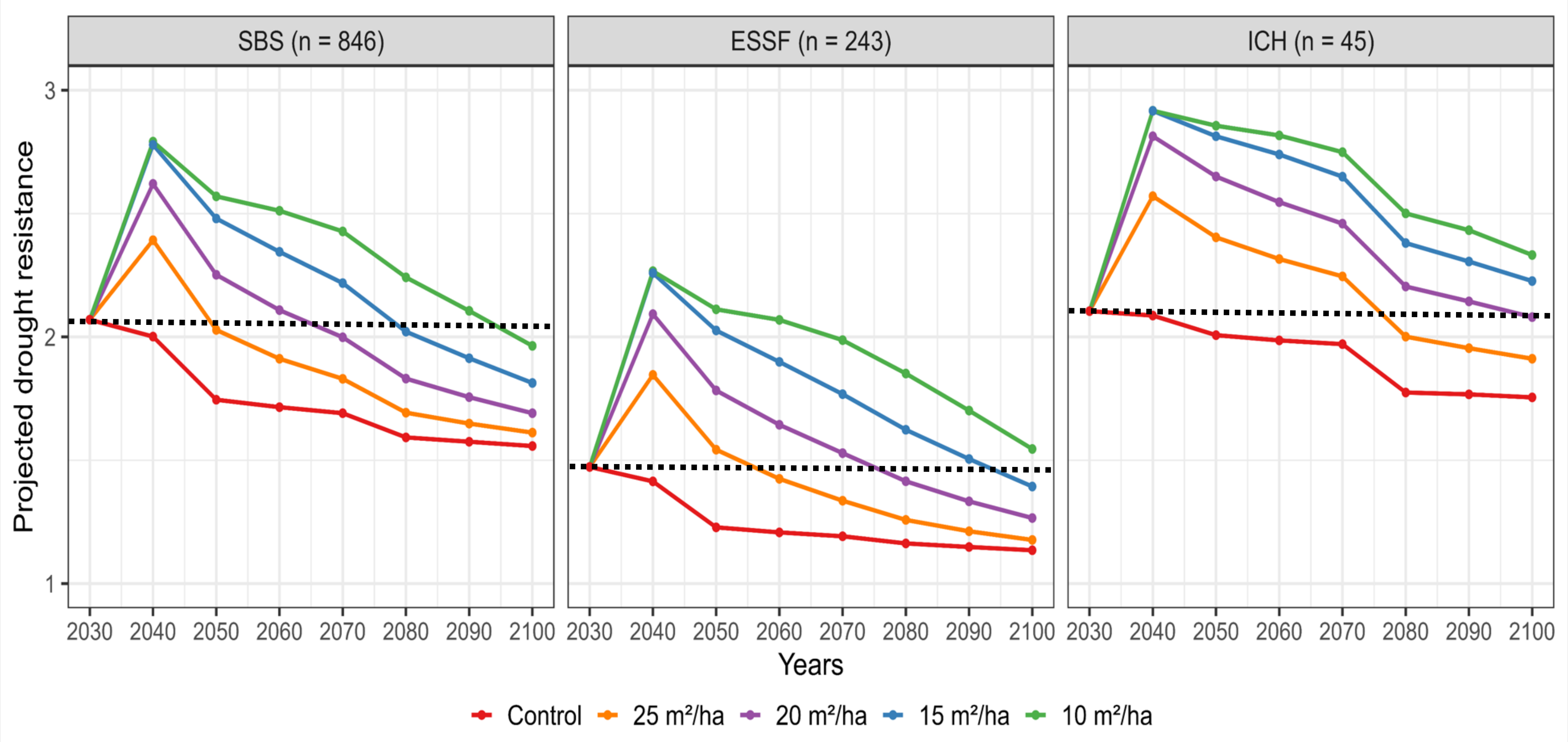
- Large amount of variance driven by stand structure within each BEC.
- Highest variance in SBS, then ESSF, then ICH.
- Amount of variance peaks after the 2070s.



# Results: Silviculture treatments impact

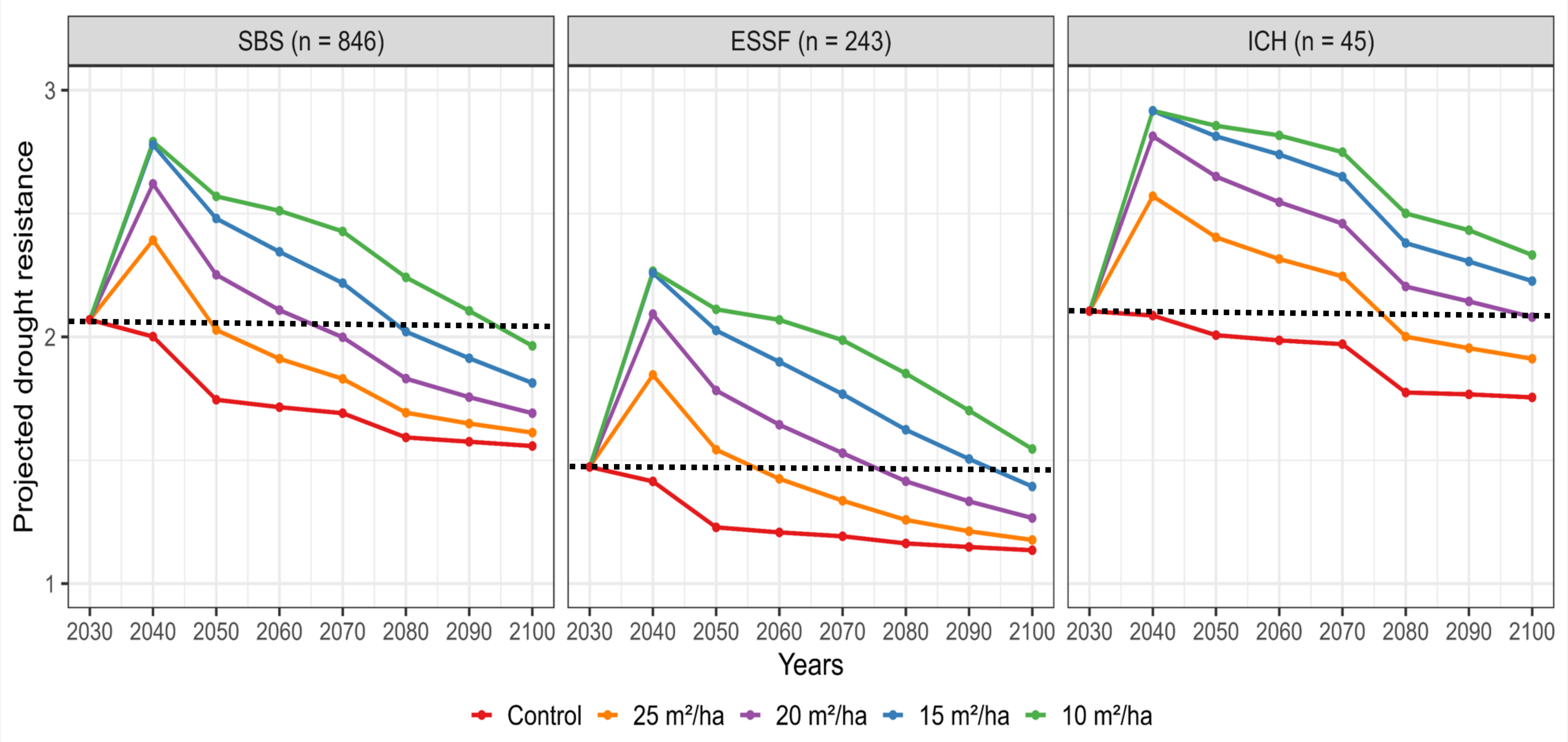
- Thinning increased the projected resistance in all three BECs.

- However, the magnitude and persistence of projected resistance gains vary by BEC and thinning intensity.



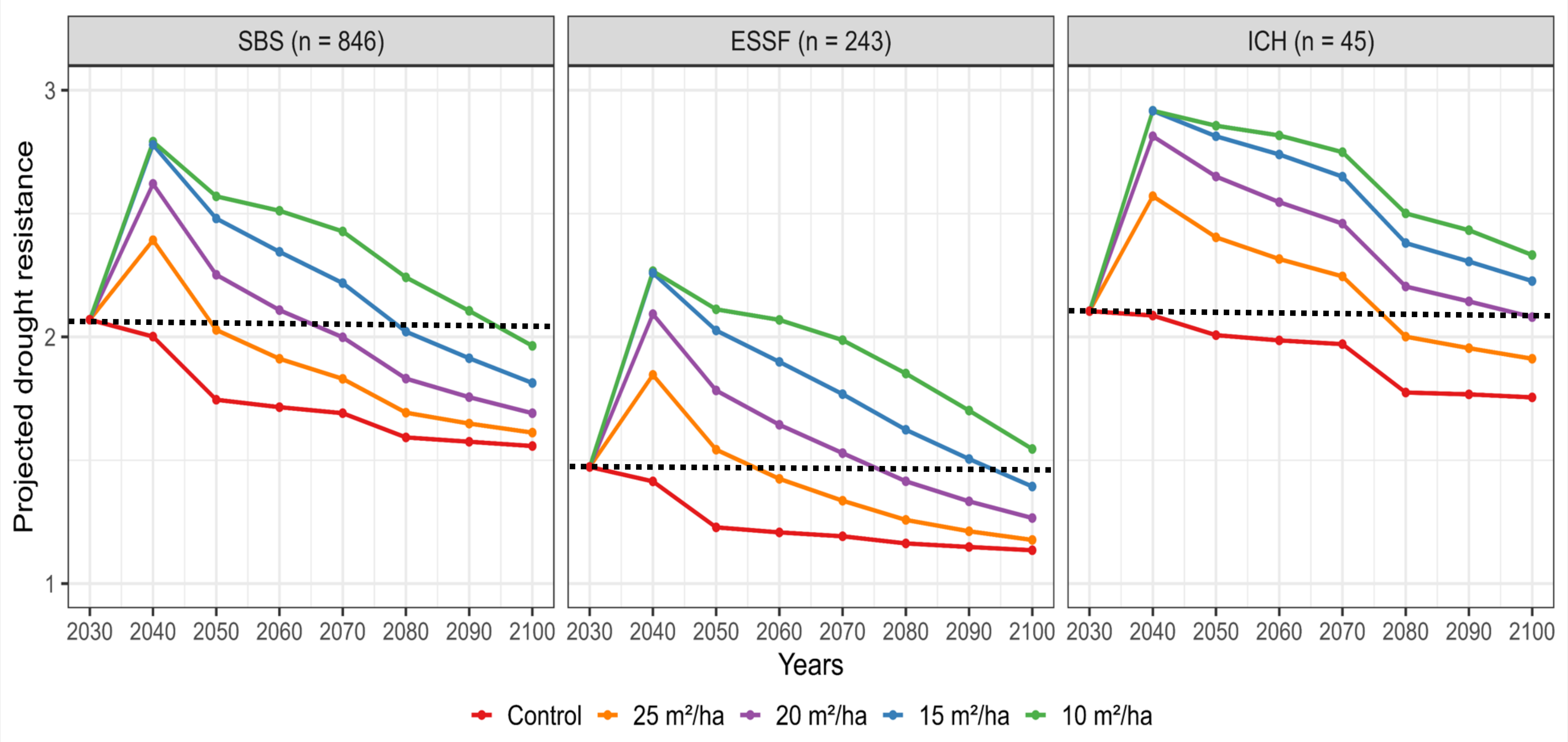
# Results: Silviculture treatments impact

- ICH showed the longest gain in projected resistance, followed by ESSF and SBS.



# Results: Silviculture treatments impact

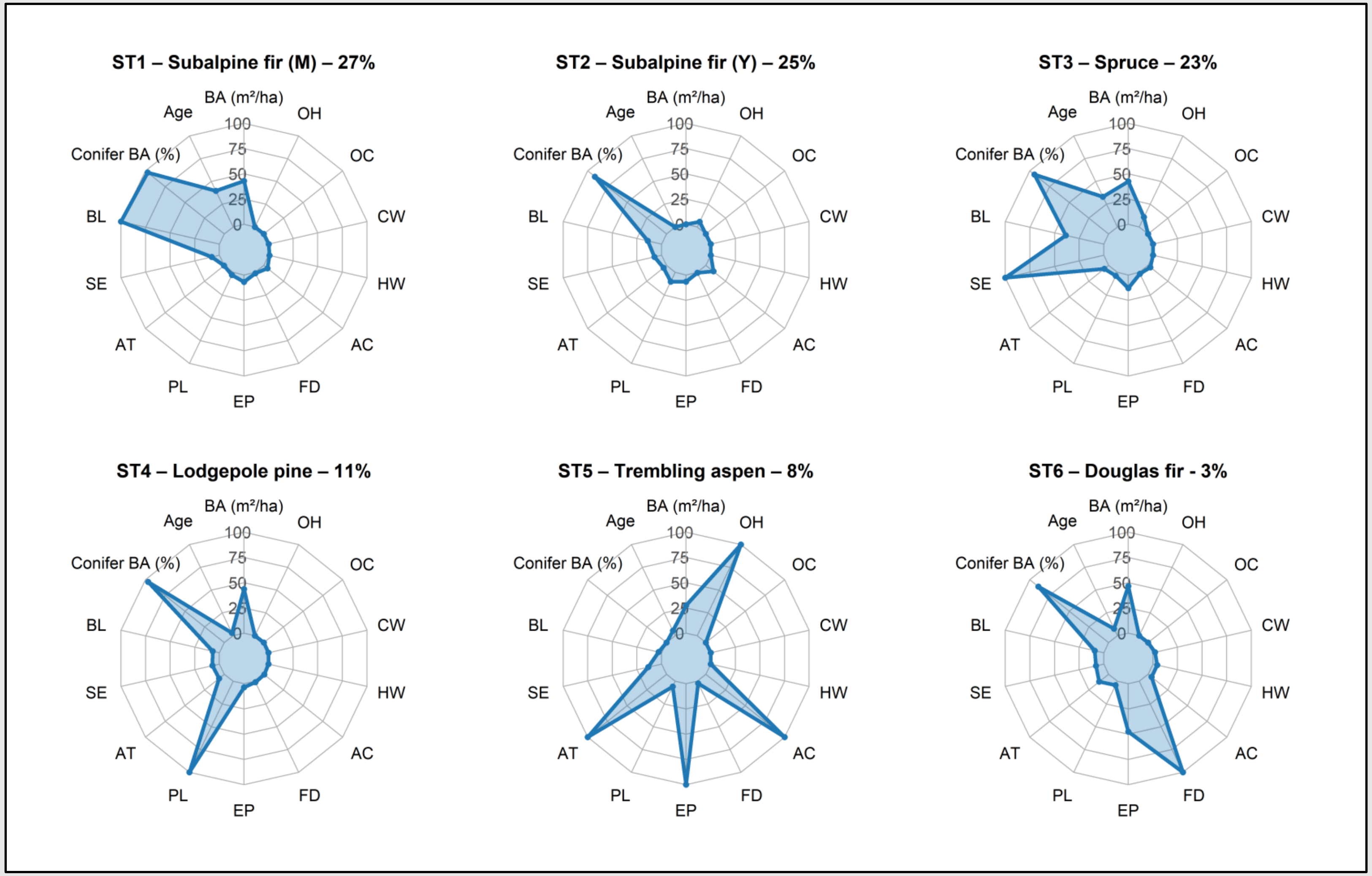
- Very heavy to heavy thinning yields the highest and longest gains in projected resistance, sustained for 50–70 years relative to the baseline (2020).



# Results: Stand types

- 9 stand types identified by cluster K-means analysis.

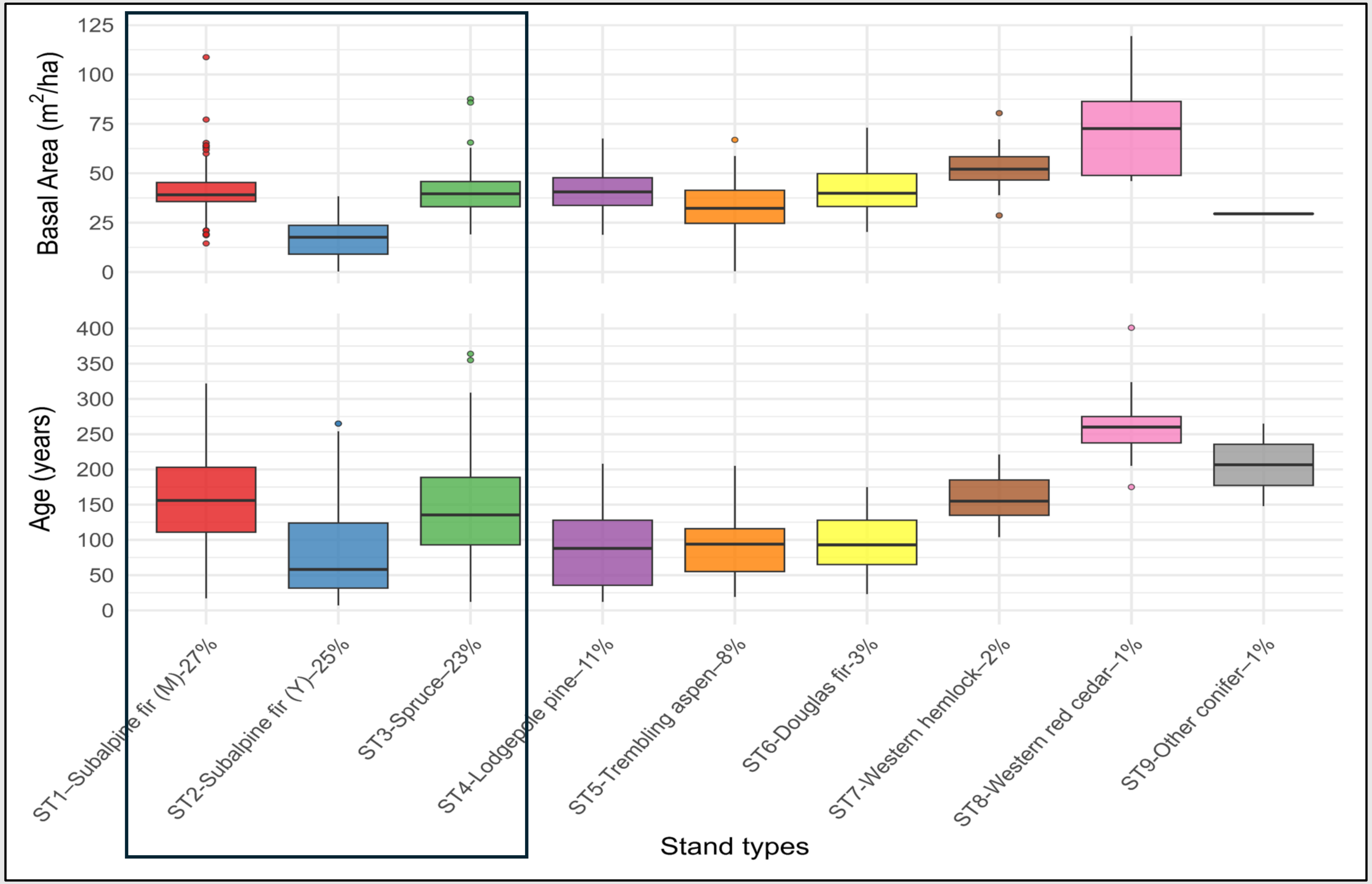
- Stand basal area, age, % of conifer species BA and individual species BA (11 species) were used to define the number of clusters.



# Results: Stand types

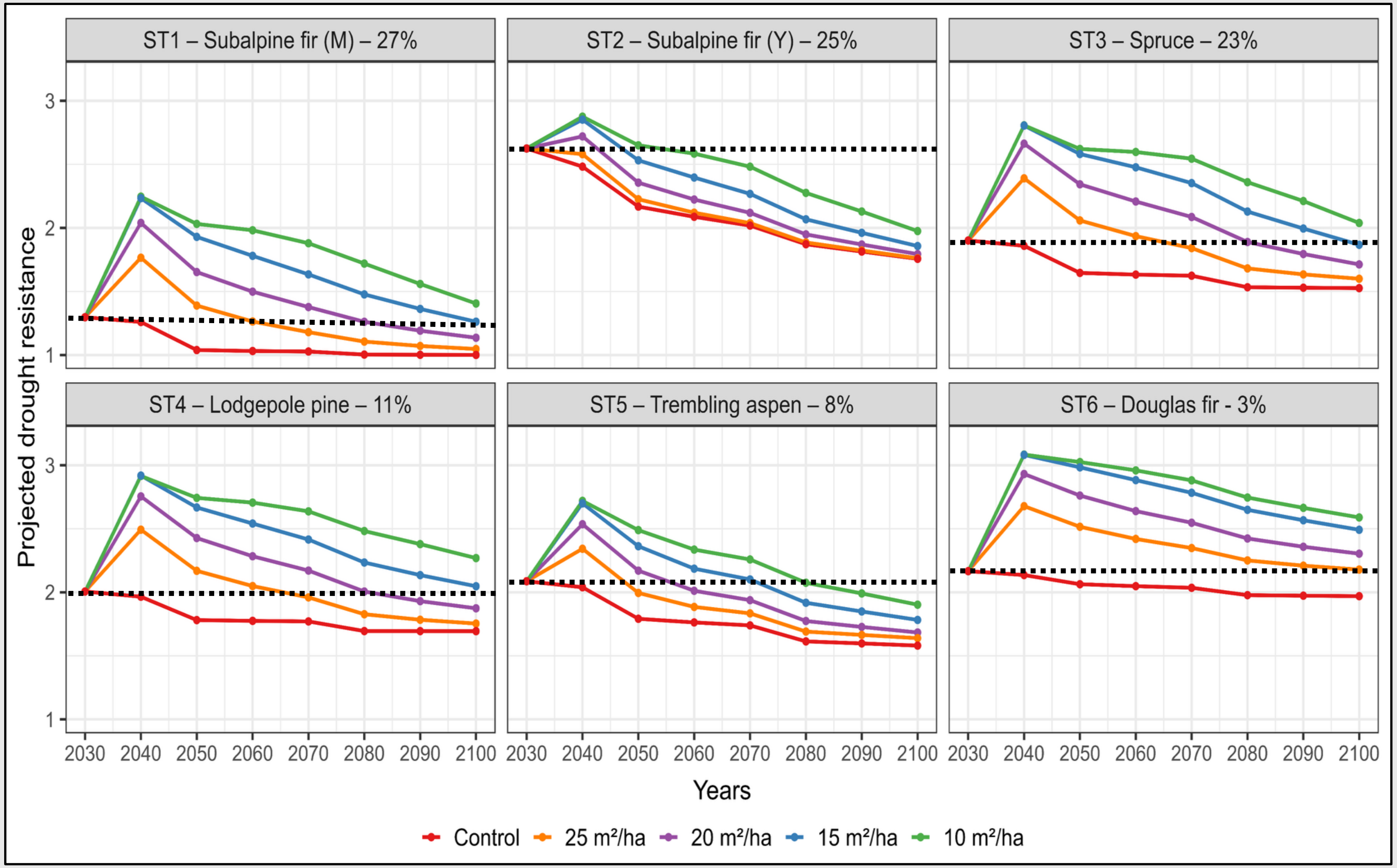
- ST1 and ST3 represented the mature and dense stands, dominated by subalpine fir and spruce (all species).

- ST2 represents the young stands of subalpine fir, spruce and other conifer species.



# Results: Stand types

- ST2 showed the highest decline in projected resistance.
- ST1, ST3, ST5 and ST6 showed the highest gain in projected resistance.
- Very heavy/heavy thinning most effective in ST1, ST3, ST4, ST6.



# Management implications

Management implications to increase drought resistance

- Prioritize thinning: Apply heavy to very heavy thinning in SBS and ESSF over the next 5–10 years, and in ICH by 2050–2060.
- Target mature stands and dense subalpine fir (ST1) and spruce (ST2) stands to secure long-term gains in resistance.
- Retain drought-resilient species during thinning.
- Shift stand composition from conifer monocultures to mixed stands where ecologically suitable based on the BEC zone after thinning.

# Key takeaways

- Drought resistance in interior and northern BC forests is declining; projected ~26% decline by 2100.
- Young subalpine fir and spruce stands showed the largest declines in projected drought resistance.
- Thinning increases projected drought resistance across stand types and BEC zones.
- Mature subalpine fir and spruce stands gain the largest benefit from heavy to very-heavy thinning.
- Convert to mixed species (conifer + broadleaf) guided by BEC to improve and sustain long-term drought resistance.
- FVS-BC is an appropriate tool for stand simulation and scenario testing across BEC zones (SBS, ESSF, ICH, IDF).

# Acknowledgements

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# Questions?

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