Modeling hydraulic failure of spruce and larch

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Background: Hydraulic failure—defined as the loss of water transport capacity due to embolism in xylem conduits—is a key mechanism driving tree mortality under global warming. Yet, the combined effects of warming and elevated CO_2 (eCO_2) remain largely untested in boreal peatland conifer species. Here, we modelled mortality risk using the PLC (percentage loss of hydraulic conductivity) within the Ecosystem Experiment.

Question: How will elevated CO_2 (eCO_2) and warming influence mortality in boreal peatland conifer species?

Hypothesis: eCO_2 is expected to reduce tree mortality, whereas warming is expected to increase it.

Method:

- A hydraulic-process based model (SurEau) integrating vegetation traits from root to crown, soil hydraulics, stand parameters and climate data.
- Sapfow data is perfect data for benchmarking

Fig.1 Input parameters for the SurEau model include vegetation, soil, stand, and climate characteristics

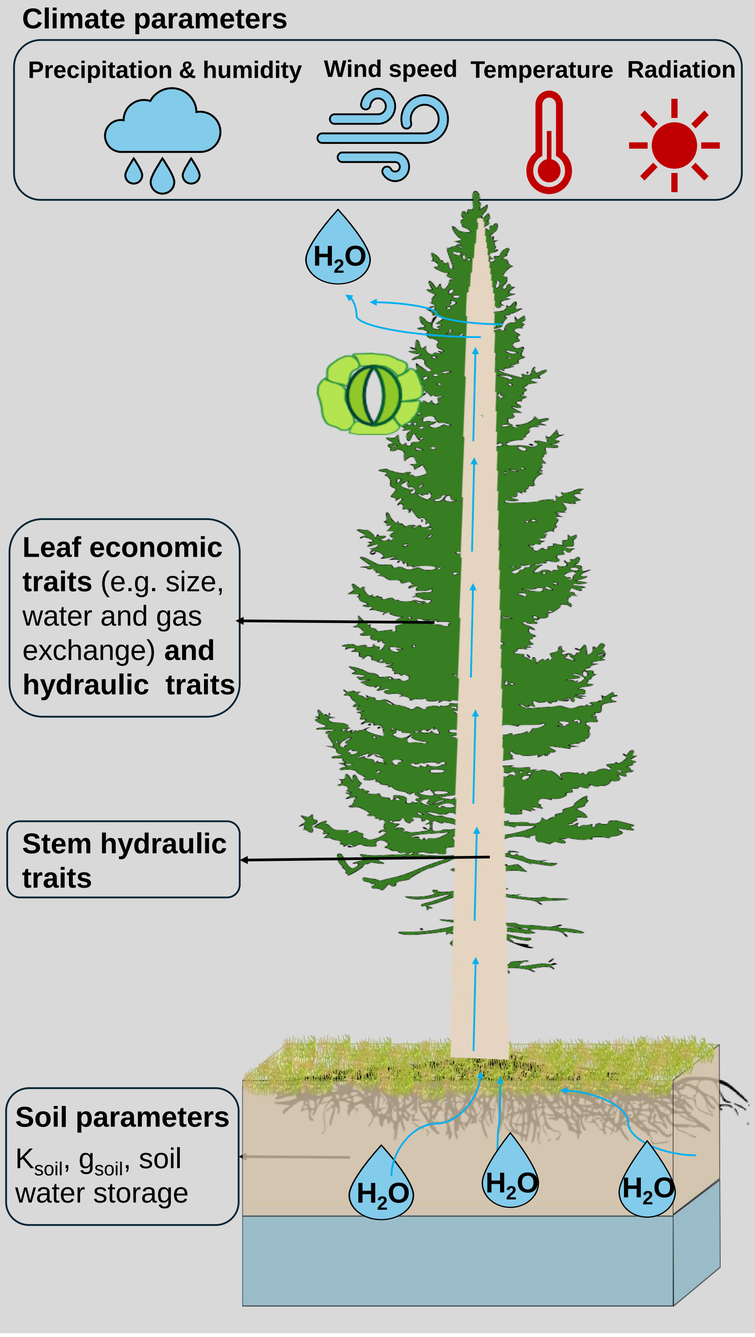
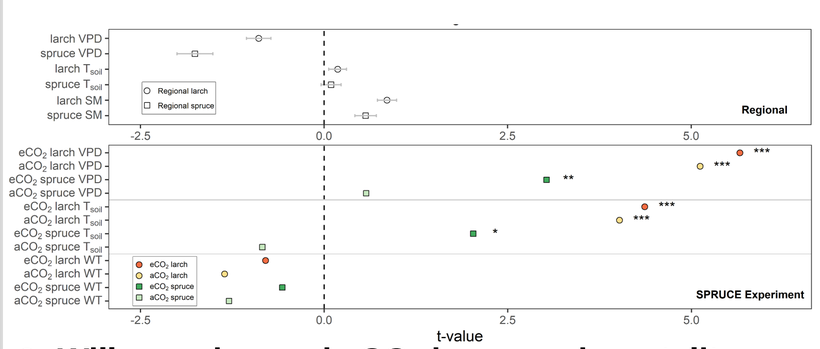
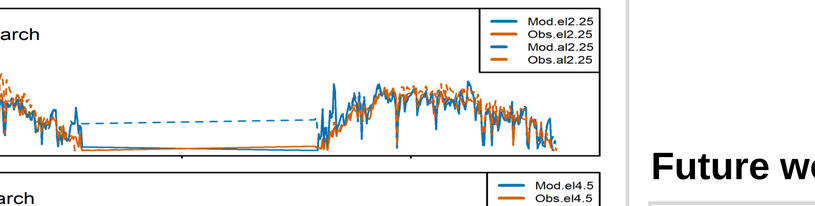


Fig.2 VPD (vapor pressure deficit) positively (*t>0*) affected growth in the SPRUCE site, but negatively (*t<0*) affected growth in regional Canada (Song et al. 2025, in Preparation).



- **Will warming and eCO_2 increased mortality or decrease mortality?**
- **Will mortality pattern differ between regional scale and SPRUCE sites?**

Fig.3 VPD affects functional traits related to gas and water exchange, as well as hydraulics. Ψ_{pre}, predawn water potential; Ψ_{min}, minimum water potential; Ψ_{50}, xylem water potential inducing 50% loss of hydraulic conductivity; Hydraulic safety margin was calculated as Ψ_{min} -Ψ_{50}.

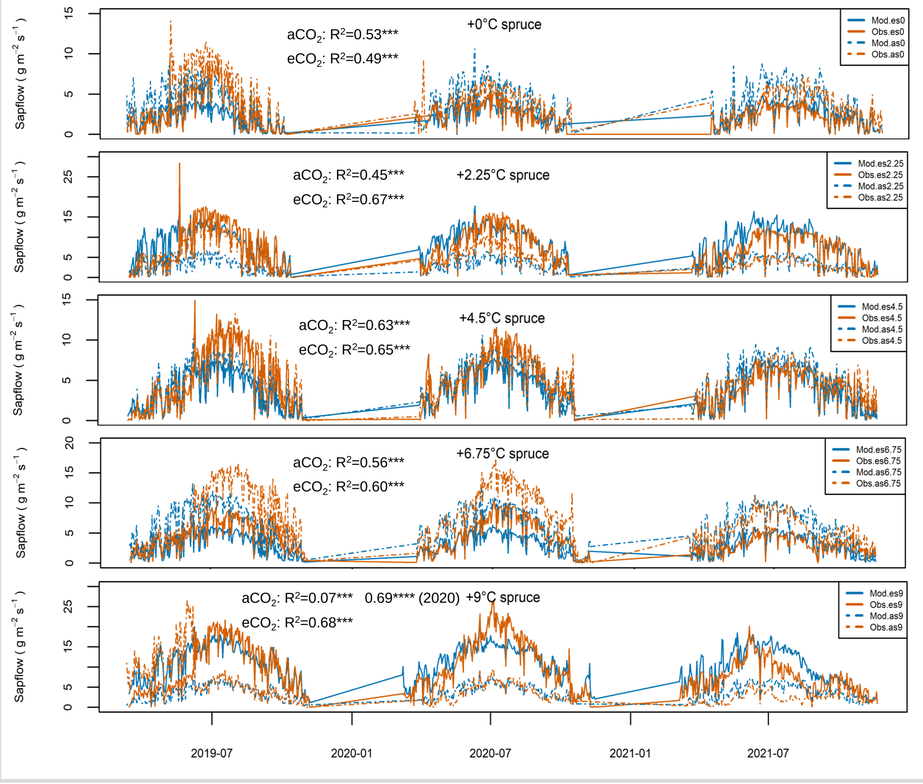


- High VPD increased gas exchange in both species, water transport in larch.
- High VPD decreased water-use efficiency in larch due to its anisohydric strategy.
- Spruce maintained higher hydraulic safety margin than larch due to its isohydric strategy.

Do the divergent species differ in mortality ?

Results I: Model validation

Fig. 5 Spruce: Model validation based on sapflow



Results II: Modelled mortality risk

Fig.6 Modelled results of daily PLC (percentage loss of hydraulic conductivity) from 2019 to 2021. Higher PLC values indicate greater mortality risk.

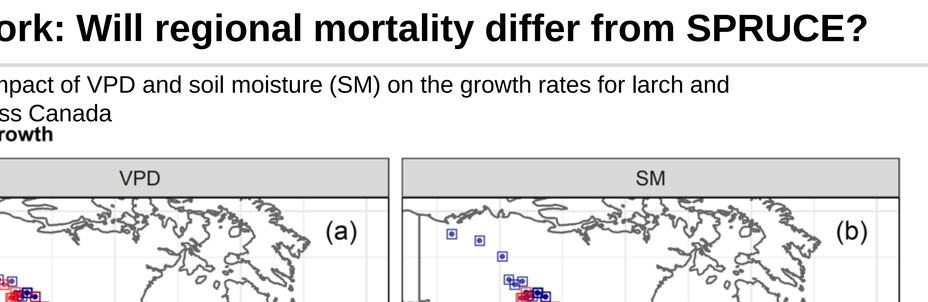
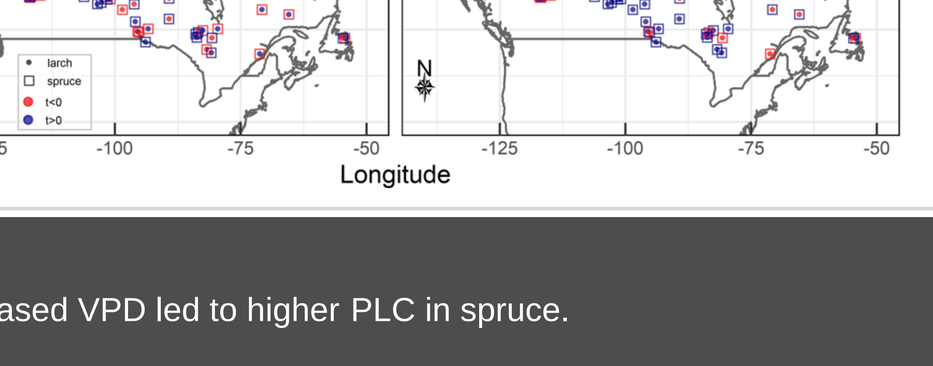


Fig.7 Relationships between PLC, VPD and BAI.



Results I: Model validation

Fig. 4 Larch: Model validation based on sapflow

Future work: Will regional mortality differ from SPRUCE?

Fig.8 The impact of VPD and soil moisture (SM) on the growth rates for larch and spruce across Canada

Take home messages

- Both larch and spruce maintained low PLC values and survived well under rising VPD, although the increased VPD led to higher PLC in spruce.
- Elevated CO_2 increased mortality risk in larch, despite PLC remaining below 20%.
- Boreal peatland species can maintain both high growth and low mortality risk at the same time.

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