FACULTY OF SCIENCE

BECC

EGU26 GENERAL ASSEMBLY

Tundra Root Responses to Environmental Change - A Meta-Analysis

Jiahui Lin[1], Kimberly Montañez[2], and Wenxin Zhang[1,3]

[1]Department of Earth and Environmental Sciences, Lund University, Lund, Sweden
[2]Department of Economic History, Lund University, Lund, Sweden
[3]School of Geographical and Earth Sciences, University of Glasgow, Glasgow, United Kingdom

Sharing is encouraged

Background

- Definition: The Arctic tundra refers to low-growing vegetation north of the Arctic treeline (Walker et al., 2005).
- The most rapid climate change;
- A disproportionately large fraction of plant biomass belowground;
- Poorly studied;
- Various experimental evidence across study sites, conditions and focuses.
- **Objective:**
  - **To quantify effects of environmental change on tundra roots**
  - **To incorporate tundra root dynamics into ecosystem models**

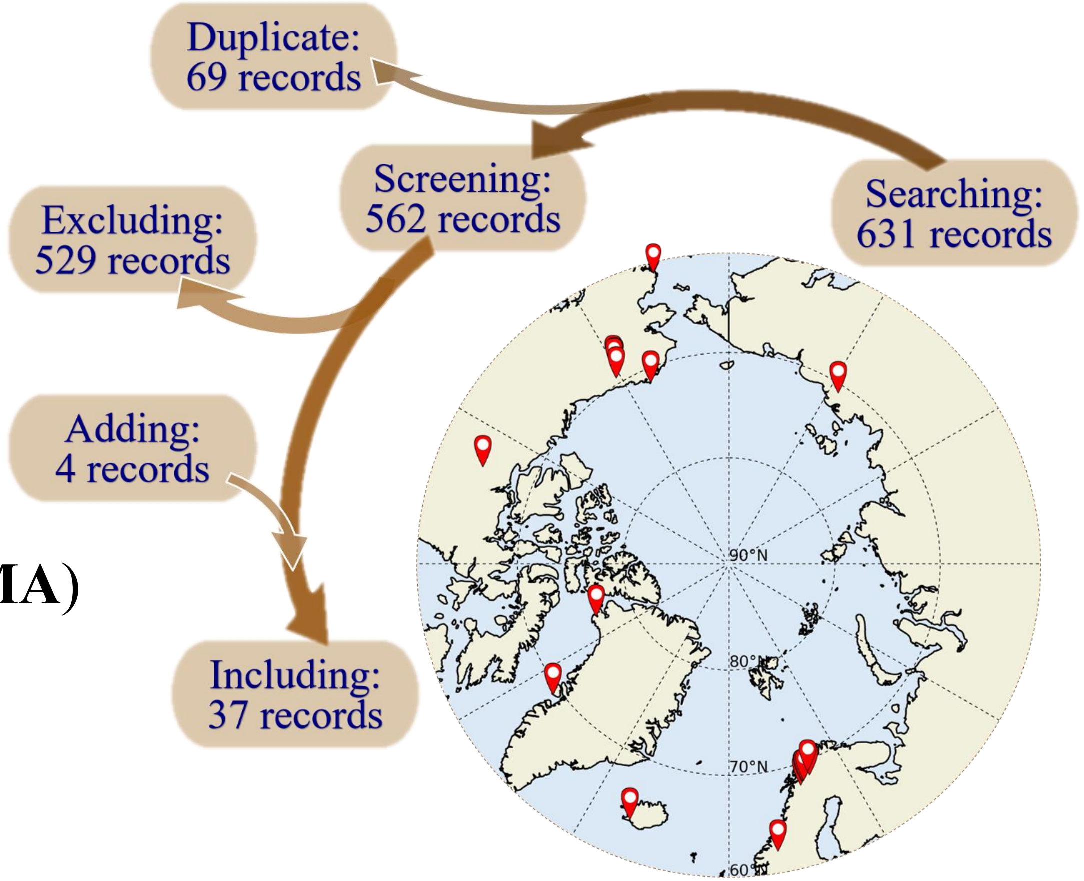
Walker DA, Raynolds MK, Daniëls FJA, et al. 2005. The Circumpolar Arctic vegetation map. Journal of Vegetation Science 16(3):267-282.

Method

- Integrated experimental evidence from **37** studies across the pan-Arctic region, and collected **14** root-related traits and their responses to **7** different types of treatments and **8** environmental moderators, respectively.

- Incorporated plants of **4** plant functional types (PFTs) and with **4** types of mycorrhizal associations.

- Based on a comprehensive framework combining:
  - Network Meta-Analysis (**NMA**)
  - Component Network Meta-Analysis (**CNMA**)
  - Meta-Regression: **Linear & Spline**
  - Bootstrap



Result: Linear Root Responses to Environmental Drivers

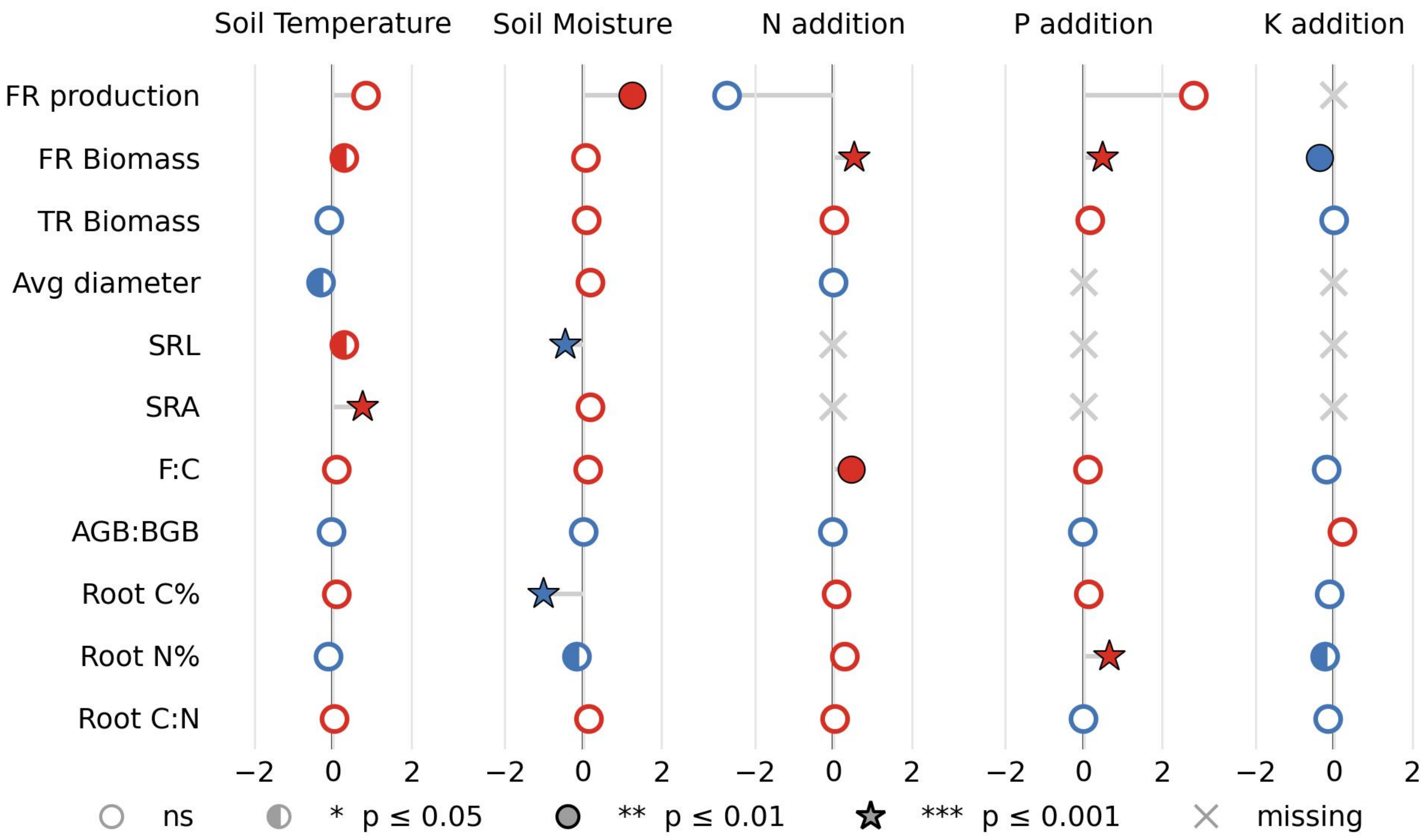
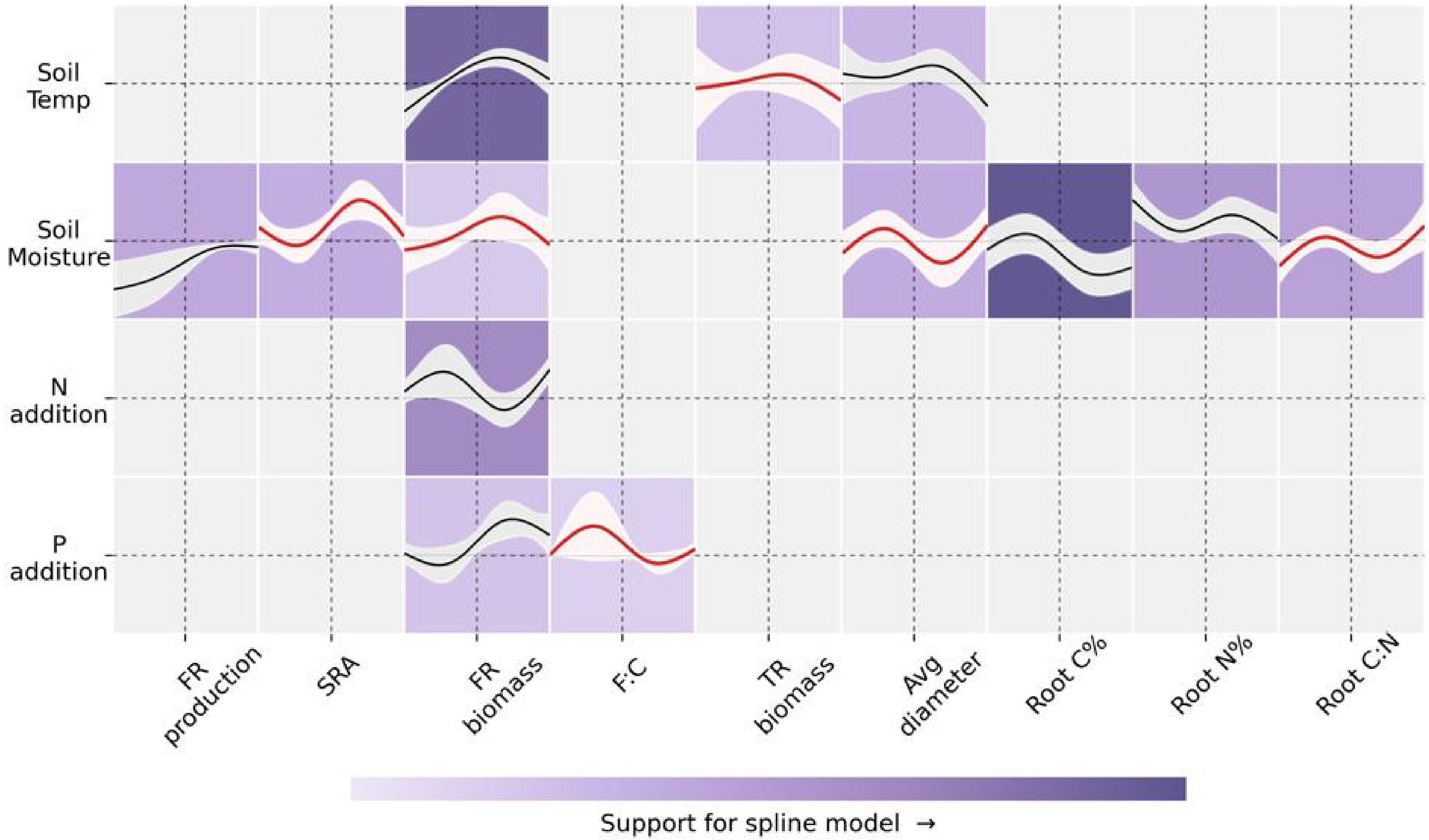


Figure 2 Effects of environmental drivers based on meta-regression.

- Higher temperature led to **thinner** roots.
- Wetter soil promoted **fine root production**.
- Nutrient effects were element-specific.
    - N&P: **fine root** ↑↑
    - K: often **opposite** to N and P effects
    - P: an unexpectedly **key role** in root N content
- Individual-level biomass allocation remained **stable**.

Result: Nonlinear Patterns in Root Responses



- **Undetected** patterns in linear meta-regression
- **Hump-shaped** responses to **soil temperature**
- **Wave-like** responses to **soil moisture**
- **Opposite oscillation** patterns between **N** and **P** effects

Figure 3 Significant nonlinear root responses to environmental moderators.

Result: Effects of environmental drivers on roots vary across PFTs.

- **AGB:BGB** responses to **soil temperature**: between forbs and other PFTs
  - **Forb:** A substantial shift **towards belowground** allocation under increasing soil temperature
  - **Shrub & Graminoid:** A relatively stable allocation strategy on the individual level
- **Root diameter** responses to **soil moisture**: between graminoids and shrubs
  - **Graminoid:** A significant **increase** in average root diameter with increasing soil moisture
  - **Shrub:** A weak and non-significant trend

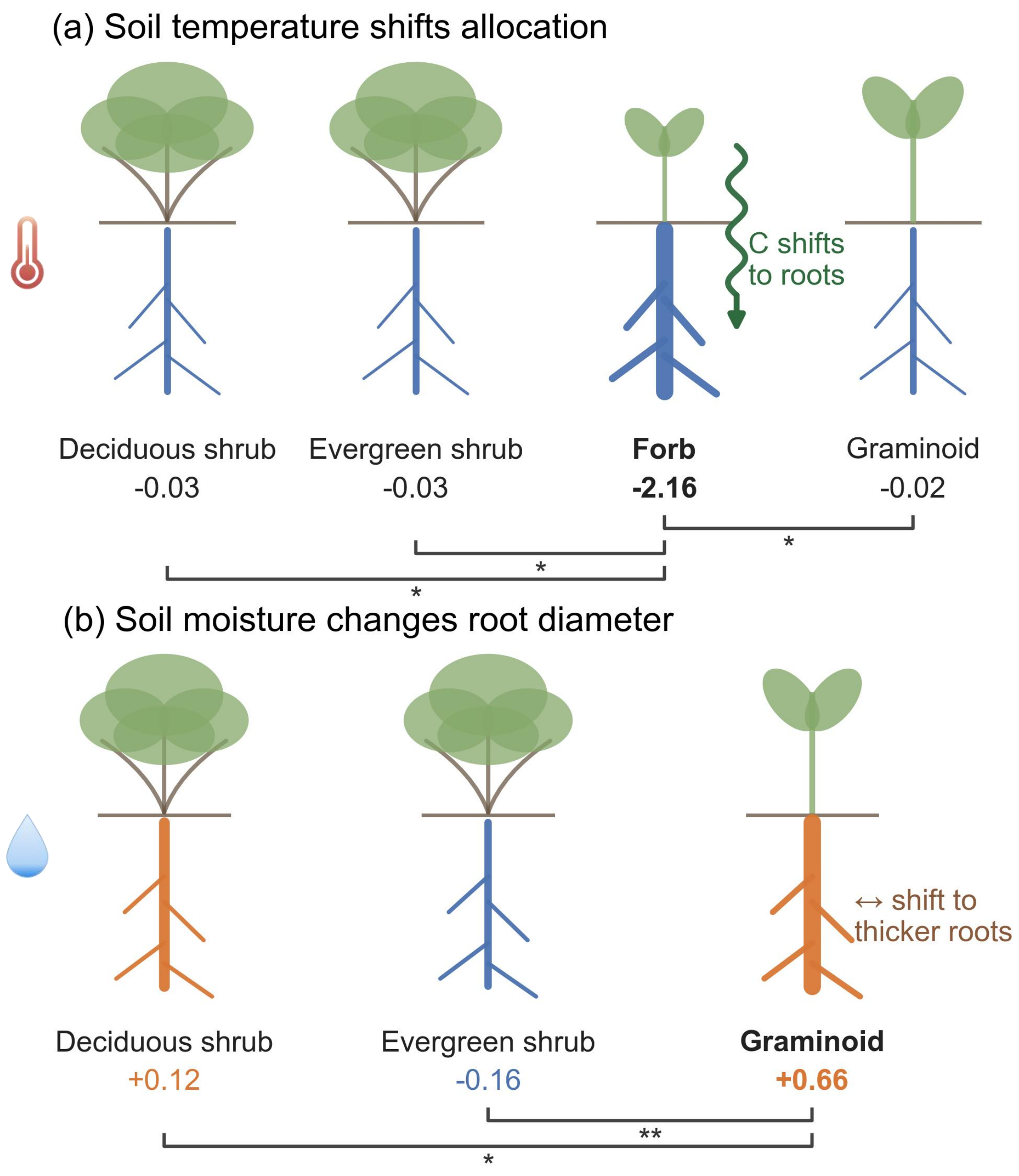


Figure 4 Significant differences in root responses to environmental drivers across PFTs.

Result: Effects on fine root biomass vary among mycorrhizal association types.

- NM: Non Mycorrhiza
- ErM: Ericoid Mycorrhiza
- EcM: Ectomycorrhiza
- AM: Arbuscular Mycorrhiza

- **Soil temperature**: between AM and other mycorrhizal species
  - AM: A negative response
  - Non-AM species: strong temperature-driven fine root investment

- **N addition**: between NM and EcM species
  - EcM: A significant increase in fine root biomass
  - More advantages to EcM and AM species under elevated N availability

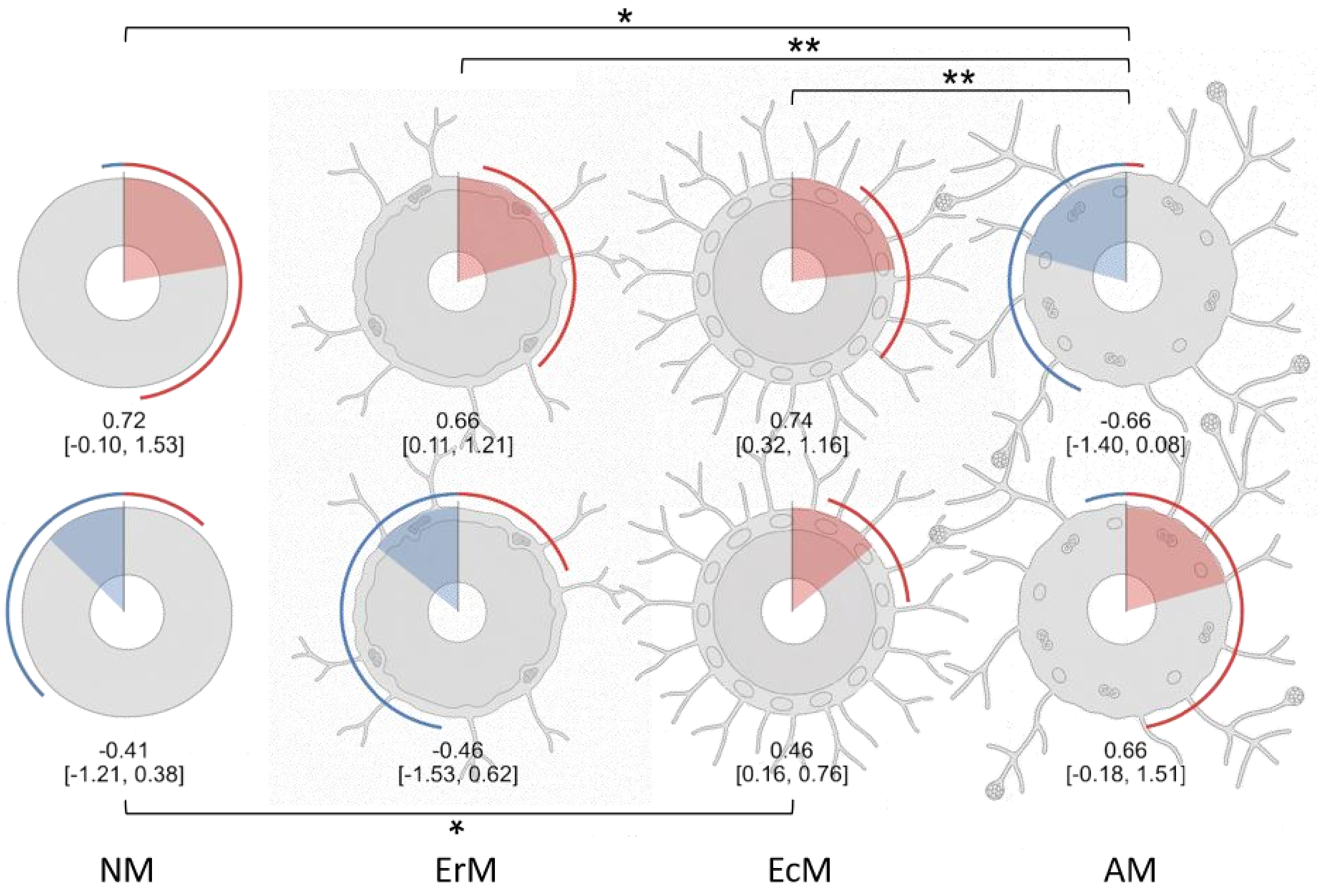


Figure 5 Significant differences among mycorrhizae species in fine root biomass responses to soil temperature and N addition. Outer rings denote the 95% CI.

Result: Root responses change with time, and temporal patterns depend on the magnitude of environmental change.

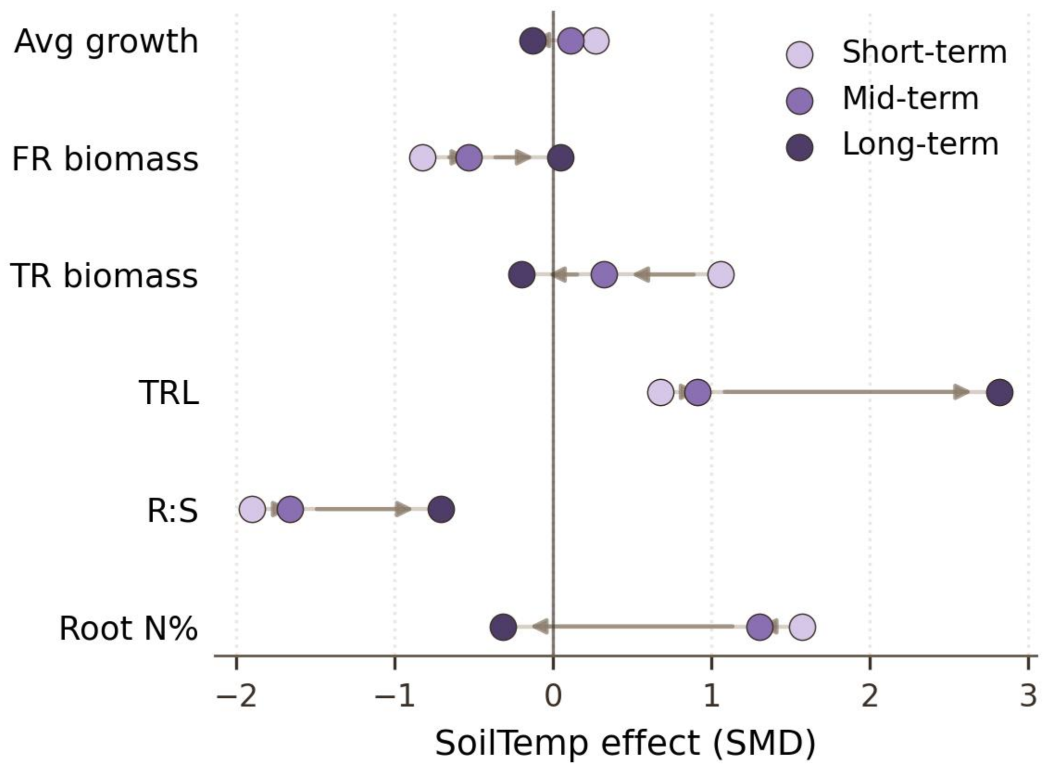


Figure 6 Soil temperature effects over durations. Short-, mid-, and long-term denote the 25th, 50th, and 75th percentiles of the exposure duration.

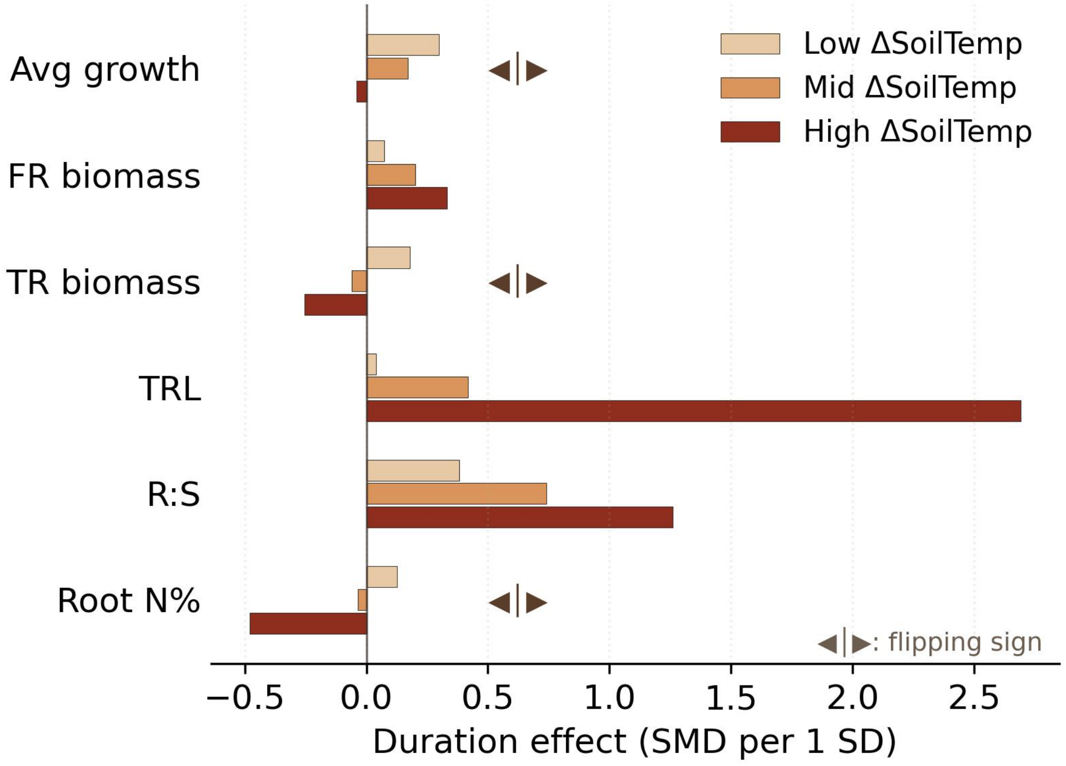


Figure 7 Duration effects over soil temperature increases. Low, mid, and High ΔSoilTemp denote the 25th, 50th, and 75th percentiles of the soil temperature increase.

Conclusion

- In a **warmer** and **wetter** Arctic, tundra roots are likely to adopt an **acquisitive** strategy with higher absorption efficiency and turnover rate.
- Root responses are **co-regulated** by **N** and **P availability** in Arctic tundra.
- **Threshold** effects are commonly found in root responses to environmental change.
- Different **PFTs** and **mycorrhizal species** generally have different belowground strategies in resource acquisition, competition, and adaptation.
- **Exposure duration** and the **magnitude of environmental change** together control the dynamic of root responses.
- We highlight the need to incorporate **multi-element** nutrient constraints, **non-monotonic** root responses, **species-specific** strategies, and **temporal** patterns into Arctic ecosystem models to improve predictions of climate-carbon feedbacks.

Thank you for your attention!

Contact: Jiahui.Lin@mgeo.lu.se