ERNST MORITZ ARNDT
UNIVERSITÄT GREIFSWALD

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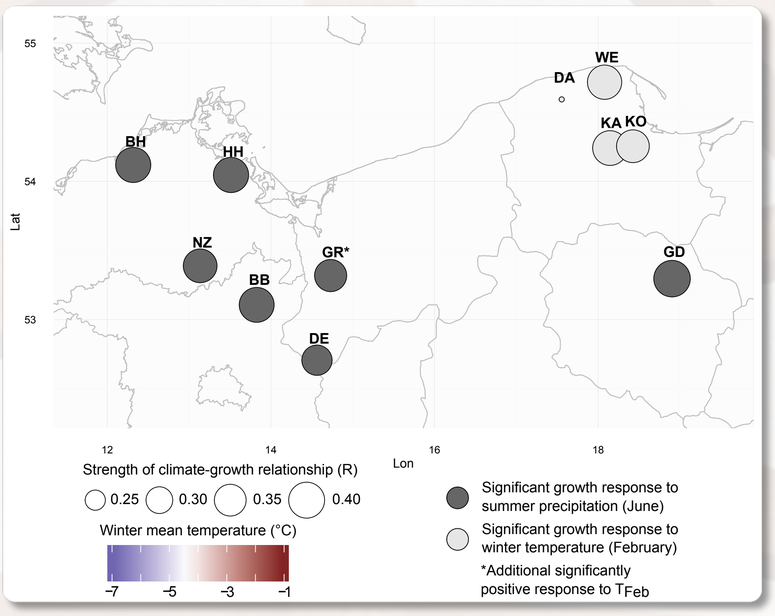
The importance of snow cover and winter soil temperature for soil biotic activity, nutrient availability, and plant growth in temperate forest ecosystems towards the cold distribution margin of European beech (*Fagus sylvatica* L.)

Robert Weigel[1], Gerhard Gebauer[2], Hugh Henry[3], Marcin Klisz[4], Lena Muffler[1], Ernst van der Maaten[1], Jürgen Kreyling[1]

[1]Institute of Botany and Landscape Ecology, University of Greifswald (D) • [2]Laboratory of Isotope Biogeochemistry, University of Bayreuth (D)
[3]Department of Biology, Western University, London (CAN) • [4]Forest Research Institute, Department of Silviculture and Genetics of Forest Trees, Raszyn (PL)

Background: Colder soils in a warmer world?

European beech reaches the margin of its closed distribution area in northern Poland. A dendroecological analysis showed that sensitivity of growth to winter cold increases along an ecological gradient of 10 study sites towards this cold margin. This cold sensitivity might be related to soil frost events, which might increase in future with a less frequent, insulating snow cover.



Soil temperature manipulation experiment

Hypotheses

- Changing soil temperatures in winter influence forest ecosystem processes in the following growing season (H1)
- Colder sites rely more on continuous snow cover and are more sensitive to altered winter conditions (H2)

Nitrogen retention

- Injection of ^{15}N tracer in soil cores in autumn and recovery in spring
- Calculation of **^{15}N excess rate** by standardizing to background ^{15}N of each site

Decomposer activity

- Burial of tea bags (litter bags) for one year (autumn to autumn)
- **Decomposition** (g/g) = $\frac{weight_{start} - weigth_{end}}{weigth_{start}}$

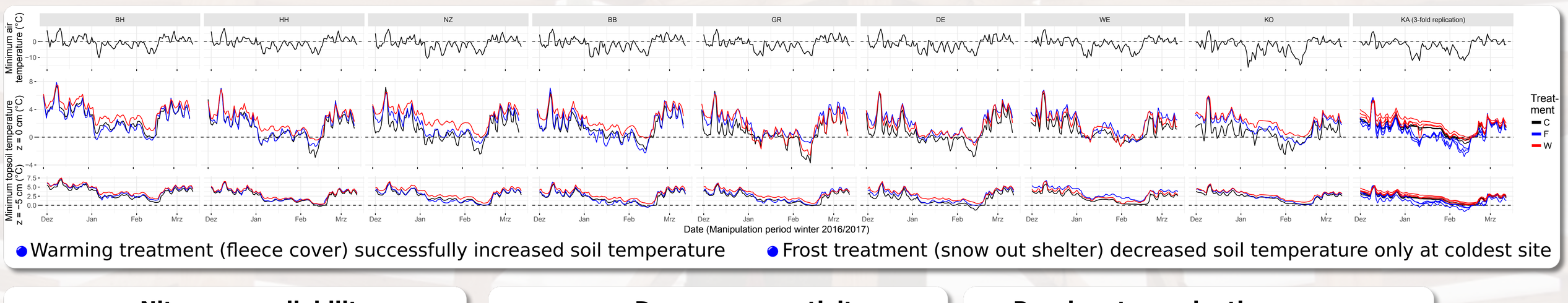
Rejuvenation (Germination trial)

- Beech nuts of 18 provenances of European beech sown in autumn
- Covered with leaf litter from juvenile beech stand
- Assessment of **germination success** (number of established sapplings at start of growing season (May)

Tree growth (Dendrometer)

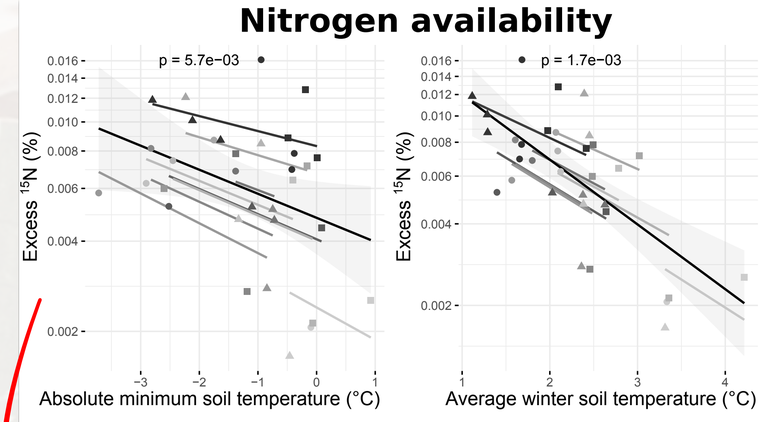
- Half-hourly measurements of stem size variation of mature beech trees
- Calculation of **stem increment for growing season** from difference between robust mean (mean of middle 50 % of data) of measurements before onset of growth and after cessation of growth

- Application of (generalized) linear mixed models to analyze relationship of response variables to manipulated soil temperature in winter
- Location included as random effect (random intercept and slope) to account for differences between sites

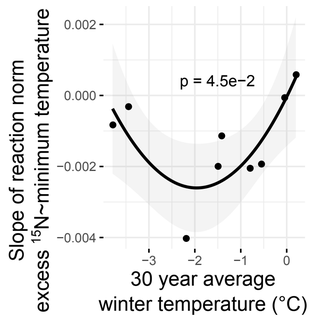


- Warming treatment (fleece cover) successfully increased soil temperature
- Frost treatment (snow out shelter) decreased soil temperature only at coldest site

Nitrogen availability

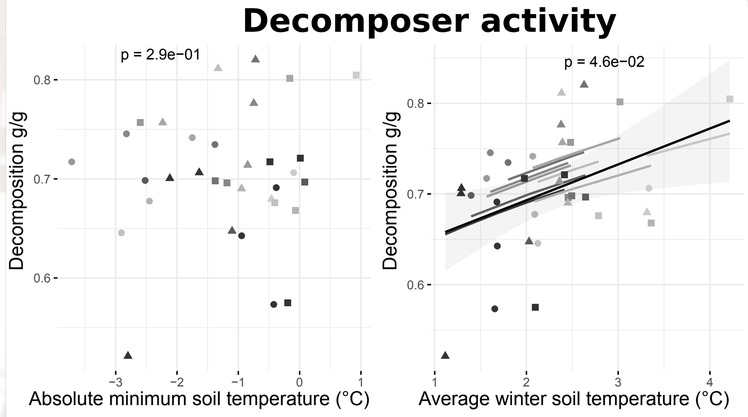


- More nitrogen is retained over winter with warmer soils (across plots within site and across sites)



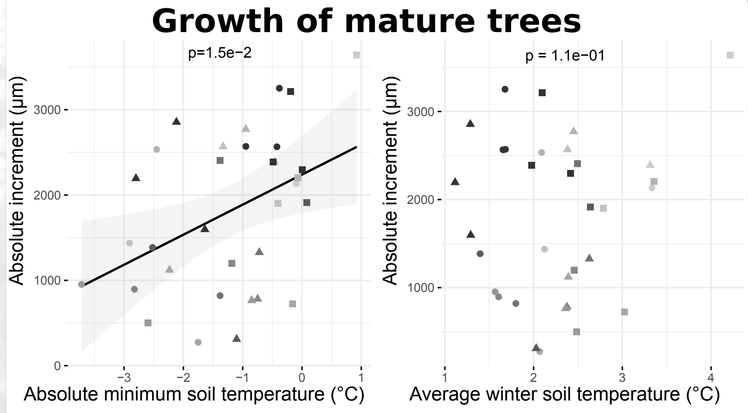
- Strongest (negative) temperature-nitrogen relationship at intermediate sites
- More detailed analysis on the fate of nitrogen input will follow based on ^{15}N tracer study

Decomposer activity



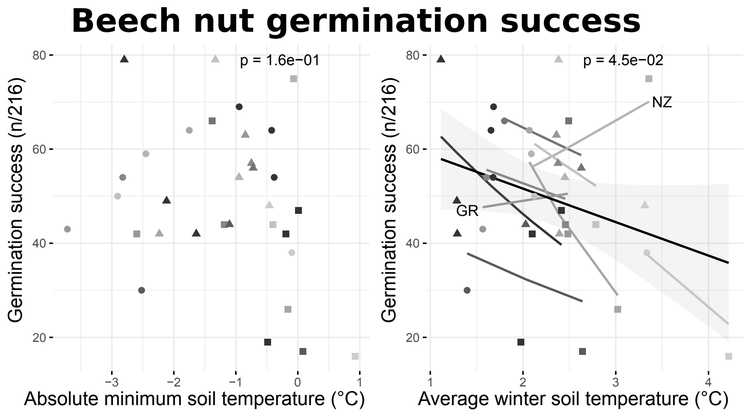
- More decomposition throughout the year with warmer soils (across plots within site and across sites)
- More microbial activity with warmer soils in winter

Growth of mature trees



- No effect of temperature manipulation within sites
- More growth with warmer soils across sites: climatic gradient more important predictor for tree growth

Beech nut germination success



- Germination success favoured by colder soils (across plots within site and across sites)
- Better chance to achieve chilling requirements to break seed dormancy

glm: *germination success ~ interaction of winter soil temperature*

Variable	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-0.46	0.13	-3.47	5.3e-4 ***
Soil temperature (during manipulation winter)	-0.29	0.048	-5.99	2.0e-9 ***
Interaction of average winter climate and soil temperature	-0.054	0.031	-1.73	8.3e-2
(Interaction of average winter climate and soil temperature)^2	-0.027	0.0078	-3.52	4.3e-4 ***

- Positive interaction of manipulated soil temperature and mean winter climate of site explaining germination success
- Intermediate sites even show positive slope (sites GR and NZ).
- Relationship of germination and soil temperature depends on site

Conclusion

- Ecosystem functioning during vegetation period influenced by winter conditions
- Within site and across site responses to different soil temperatures have same direction
- Effects of altered soil temperatures not more pronounced towards colder sites
- Colder soils in a warmer world due to missing snow cover only at coldest site

robert.weigel@uni-greifswald.de
http://www.botanik.uni-greifswald.de

#frozenbeech

Experimental Plant Ecology
University of Greifswald, Institute of Botany and Landscape Ecology
Soldmannstr. 15, 17487 Greifswald

Experimentelle Pflanzenökologie
ERNST MORITZ ARNDT
UNIVERSITÄT GREIFSWALD

RESPONSE