Hyperspectral leaf spectroscopy reveals the response of beech (*Fagus sylvatica*) seedlings from across the species' range to simulated drought

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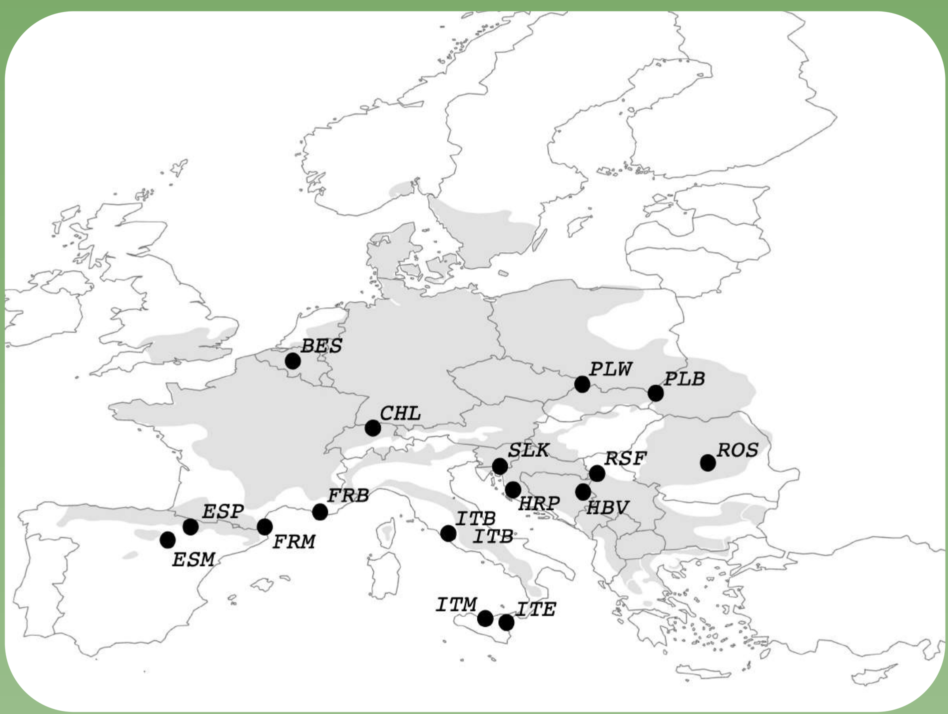
Beech (*Fagus sylvatica*) is common in Europe and commercially important. However, climate change, including droughts and heatwaves, is likely to change the distribution of beech and lead to local population declines. For beech to persist, it relies on phenotypic variation underpinned by intraspecific genetic variation. **We conducted a common garden experiment with 184 beech seedlings from 16 European beech populations with known population genetic structure and exposed a subset of the seedlings to a short but intense drought lasting two weeks.**

Seed collection

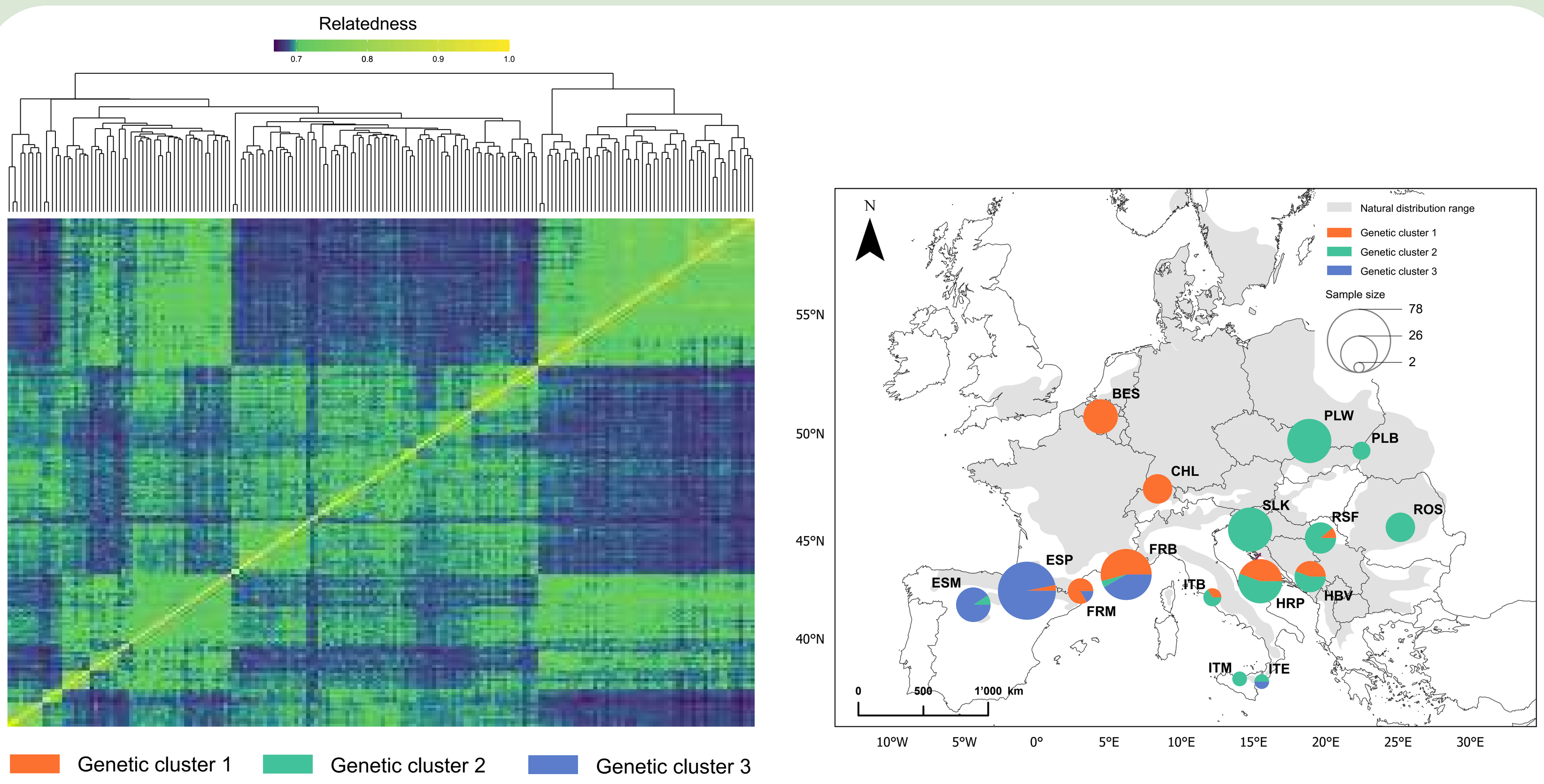


Seeds were collected **from 16 beech populations across Europe**, germinated in 2021, and placed in a common garden in Switzerland in 2023. All seedlings were two years old when we carried out the common garden experiment.

Common garden experiment

We asked

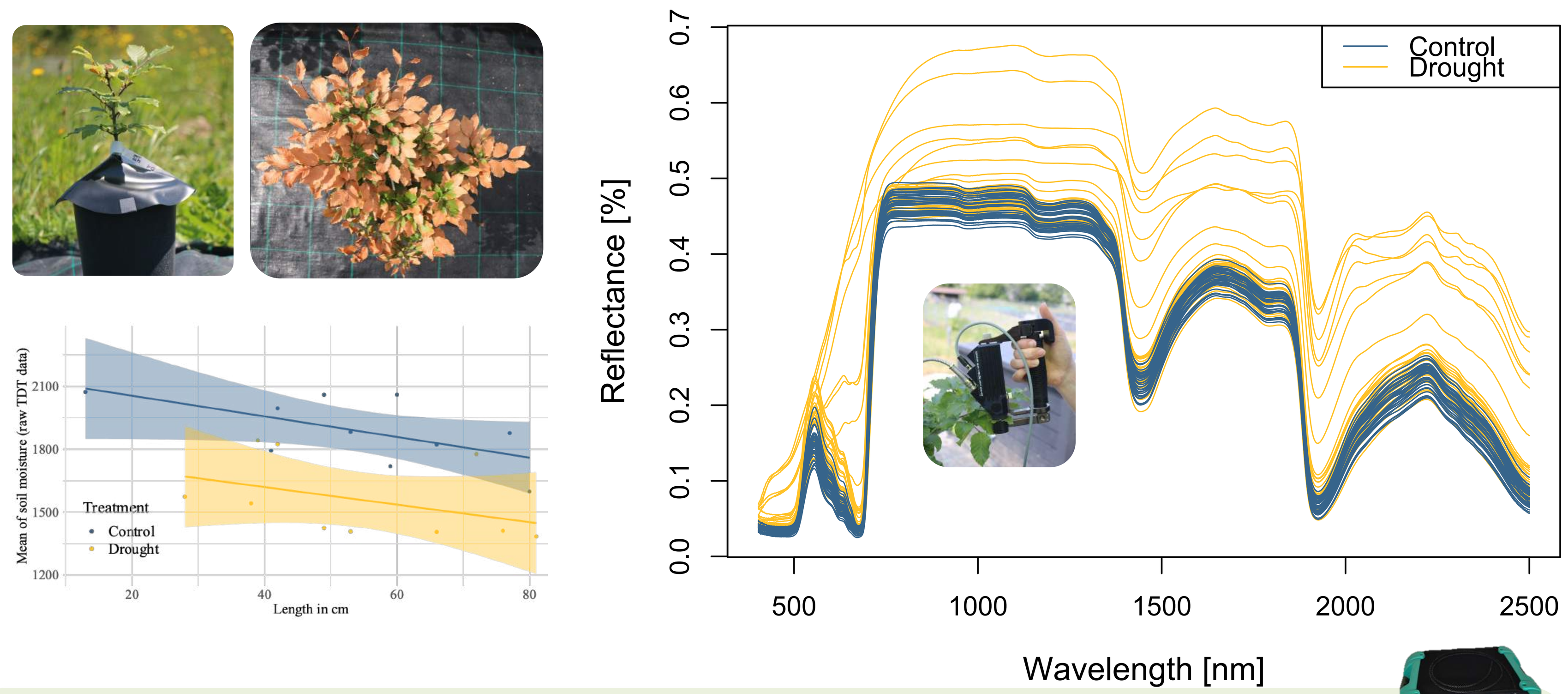
1. What are the physiological effects of a **short and intensive drought** on beech tree seedlings grown in a common garden?
2. How do **spectrally derived traits** and constituents differ among drought-treated seedlings from various provenances?



Population genomic structure

Kinship matrix based on whole-genome sequencing of all individuals in the study (yellow: high relatedness, blue: low relatedness). We identified three main genetic clusters each encompassing multiple provenances (see dendrogram). Therefore, we analyzed our data using the genetic clusters as predictors instead of the individual provenances. Genetic cluster 1 is a mix of central European provenances, genetic cluster 2 mostly consists of Eastern provenances, genetic cluster 3 is dominated by Spanish and French provenances.

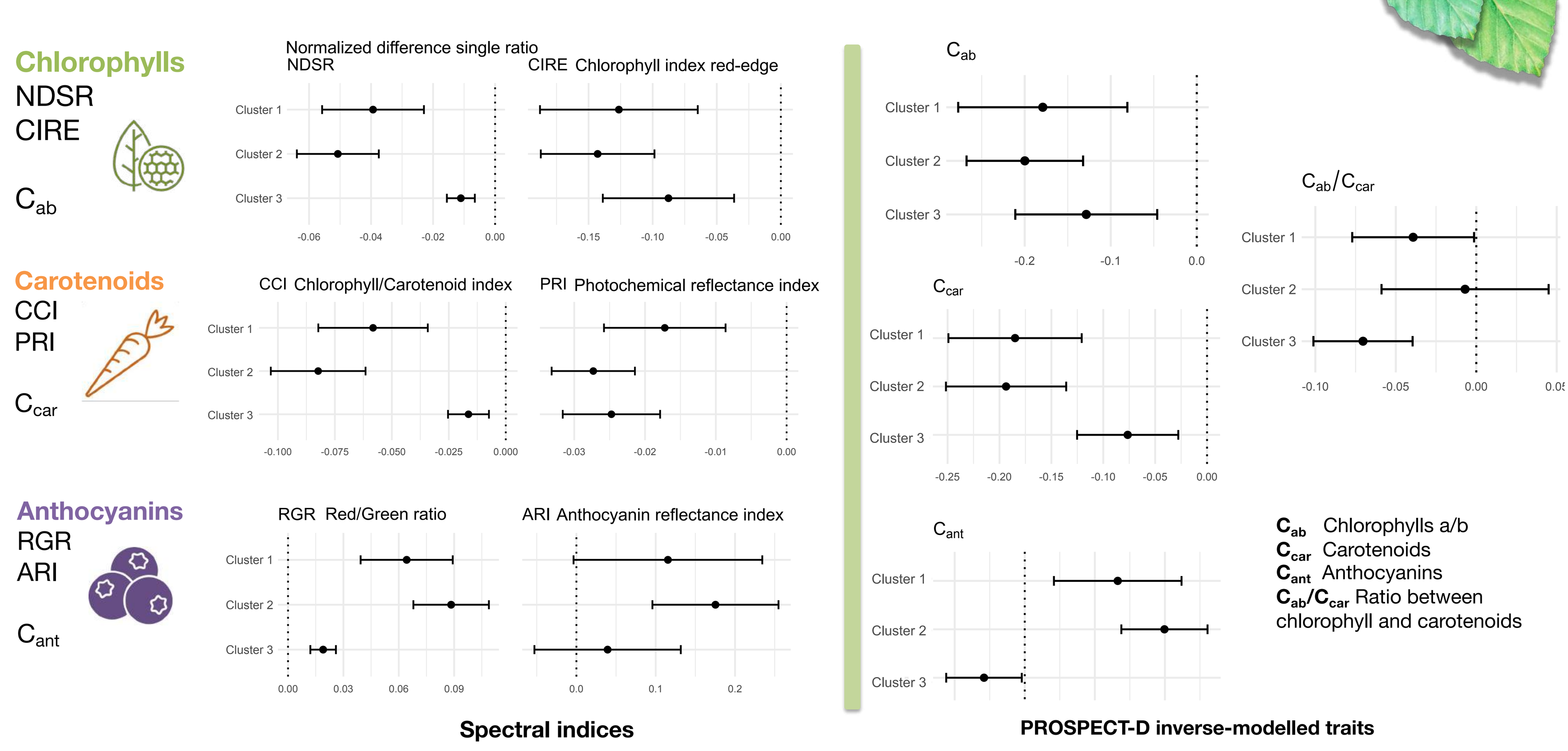
Results



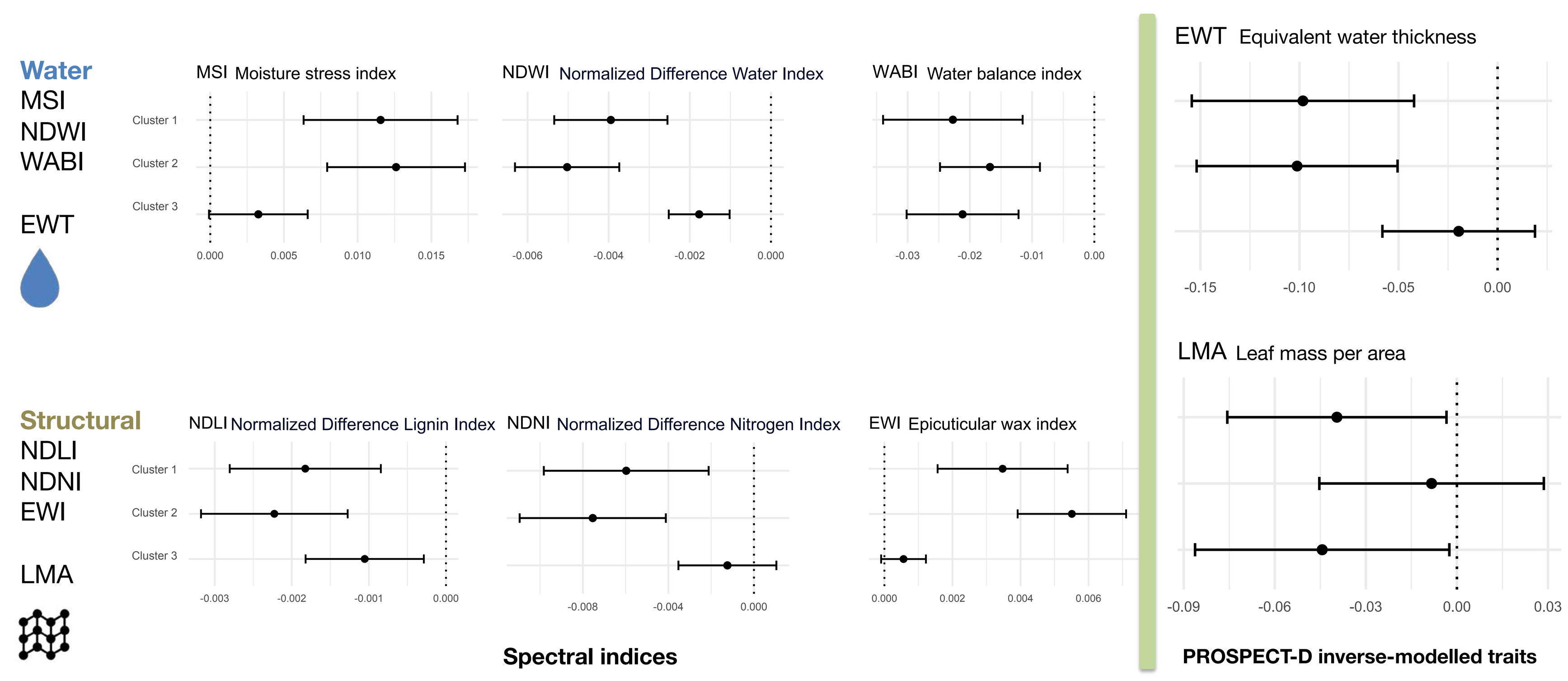
Leaf reflectance spectra

Left: Photo of rain cover used to simulate drought and example seedling with strong leaf discoloration. The TMS-4 soil moisture sensors showed lower soil moisture for the drought treatment (yellow) compared to the control group (blue). We also observed larger trees had drier soil on average. Right: Leaf spectra measured with an ASD FieldSpec 4 and a leaf clip. Spectra strongly varied between provenances and treated *vs* control seedlings. The spectral data was used to derive spectral indices and PROSPECT-D inverse modelled leaf constituents.

Drought response in leaf pigments



Drought response in leaf traits related to water and leaf structure



Leaf spectral indices and PROSPECT-D constituents

Leaf spectra may pick up multiple physiological leaf changes. We derived log response ratios (LRR) of spectral indices and PROSPECT-D modelled leaf traits during the drought period for the three identified genetic clusters (n=170 seedlings). Three pigment classes and several water and leaf structural indices reveal differences in response magnitude between the genetic clusters, though not in directionality. The PROSPECT-D inverse modelled constituents revealed the strongest effect for anthocyanins, carotenoids and equivalent water thickness. Negative values indicate a reduction in the respective trait in response to the drought treatment, positive values an increase. Genetic cluster three showed significant differences in magnitude of the response in several traits. Shown are effect sizes +/- SD.

We conclude that leaf spectroscopy is a valuable tool to assess the integrated response of beech seedling to drought.

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