High-throughput spectral phenotyping for classification of two beech subspecies

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Left: *Fagus orientalis*, right: *Fagus sylvatica*.

Background

Climate-smart forestry implies re-thinking the composition of our forests with the introduction of new potentially more drought tolerant tree species. Oriental beech (*Fagus sylvatica subsp. orientalis (Lipsky) Greut. & Burd*), which grows in drier regions compared to European beech (*Fagus sylvatica L.*), has been proposed as a candidate species for assisted migration (AM) at critical sites, due to its presumed higher drought tolerance. Moving forest tree provenances or closely related species beyond their current range can increase genetic diversity and thus the resilience of the forest, but could entail risks such as outbreeding depression. Mapping forest species composition is thus important for monitoring and performance assessment purposes, but common approaches relying on genetic screening are expensive and impractical.

Project description

This ongoing project aims:

(i) to investigate the potential of using leaf reflectance spectra to differentiate between two beech subspecies and their hybrids, and

(ii) to explore spectral leaf traits underlying subspecies phenotypic differences.

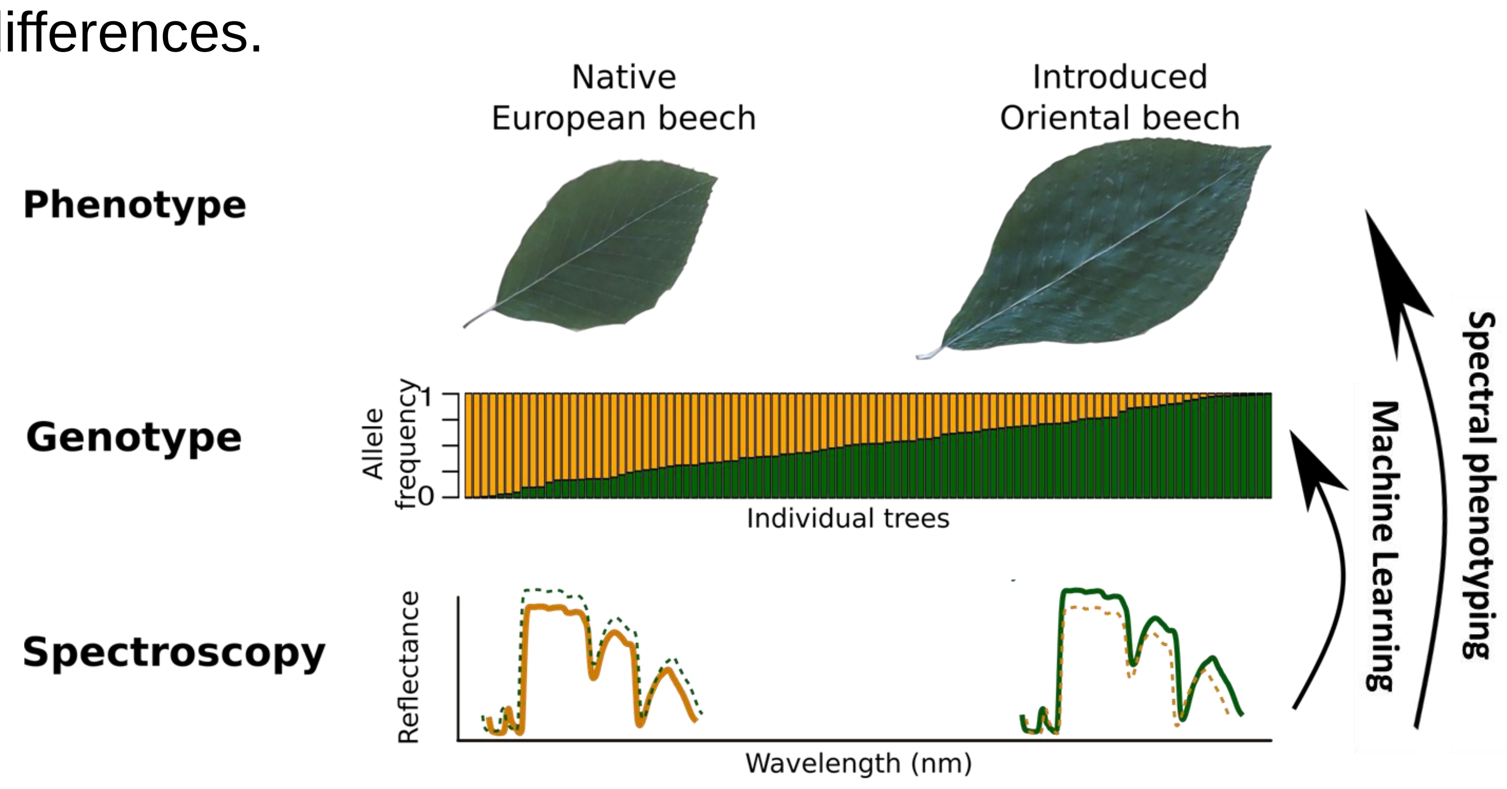

Fig. 1 Schematics of proposed subspecies classification and phenotyping approach.

In summer 2021 field campaigns were conducted at a rare 100-year-old oriental beech plantation (ALL, Fig.2) in France. In 2022 the approach will be rolled-out to other plantations in Germany and Switzerland, where the two beech subspecies coexist and regenerate through hybridization, representing living laboratories of AM (Fig. 2).

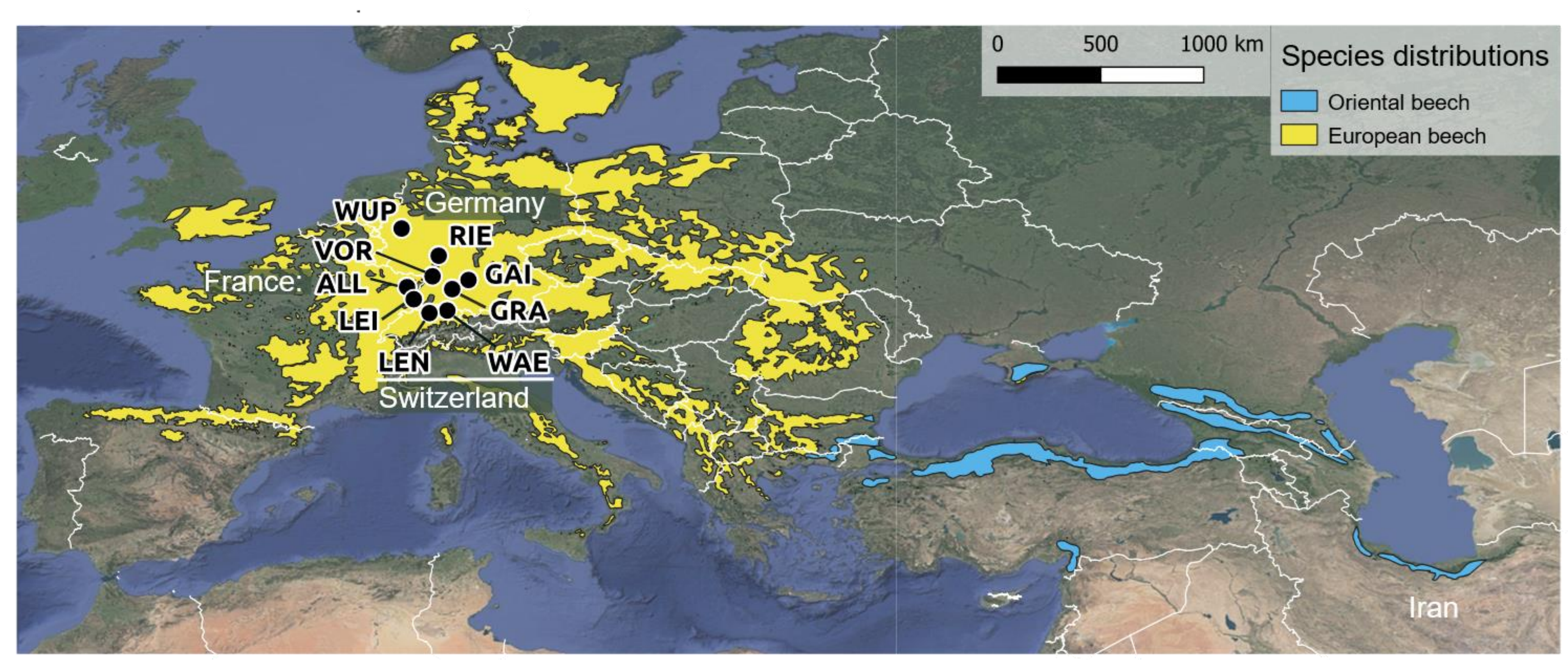

Fig. 2 Species distribution of European and Oriental beech and location of Oriental beech plantations in central Europe.

Results

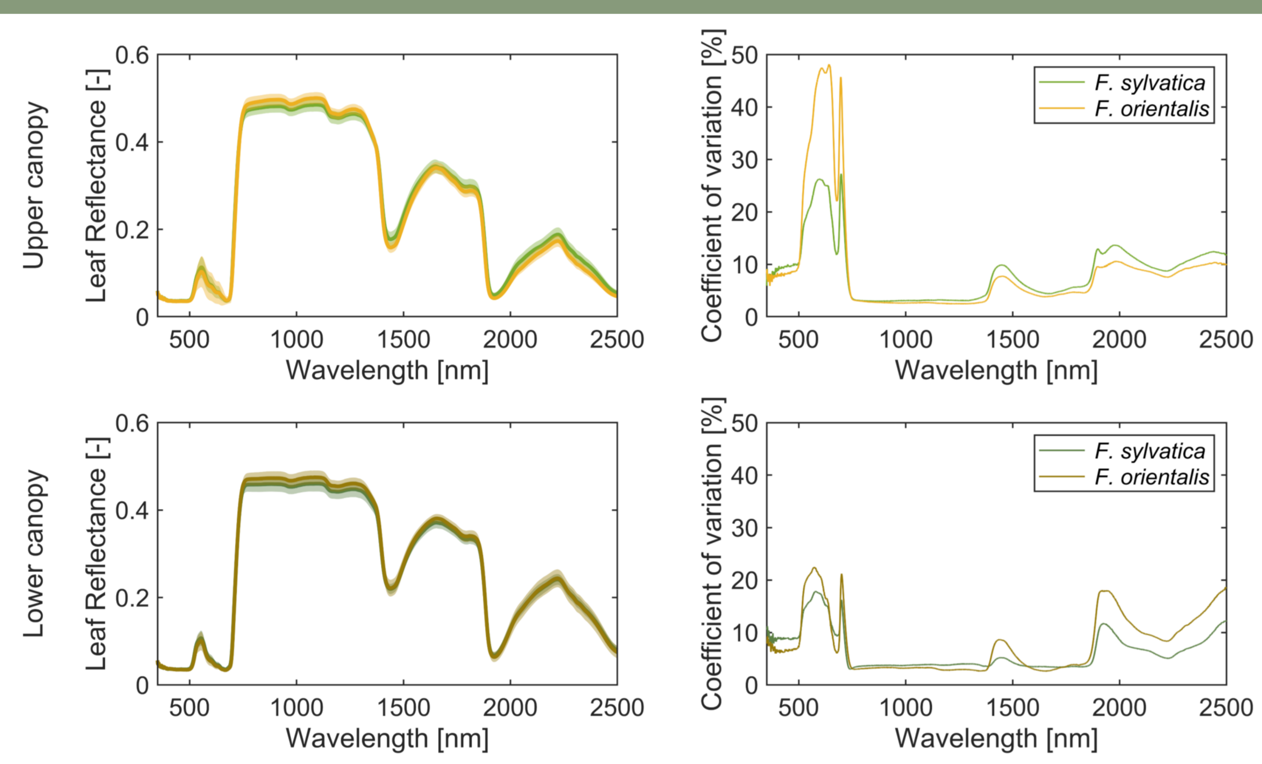

Fig. 3 Mean subspecies leaf reflectance spectra with shaded areas representing ± 1 standard deviation (left) and intra-specific (within subspecies) variance (right) of European and Oriental beech trees at the Allenwiller (FR) forest sampled in summer 2021.

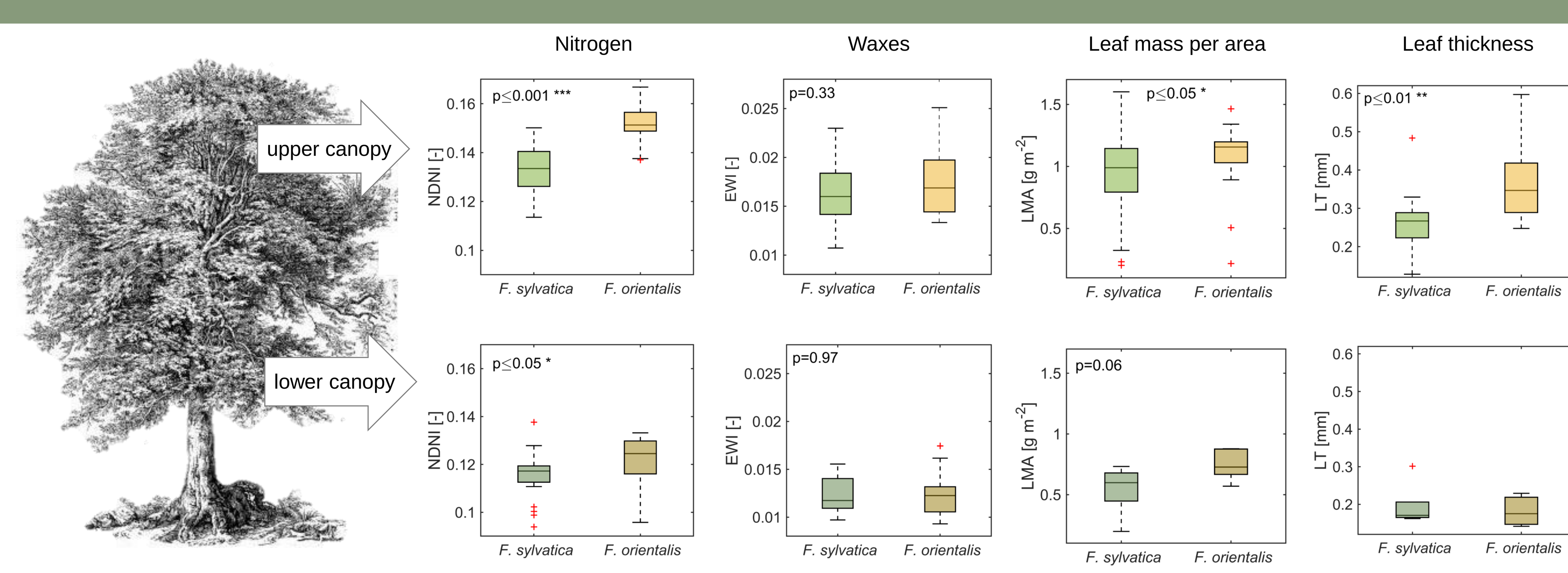

Fig. 4 Selection of leaf traits for two canopy positions and subspecies, including: nitrogen derived from the spectral Normalized Difference Nitrogen Index as NDNI = $(\log(1/R_{1510})-\log(1/R_{1680}))/(\log(1/R_{1510})+\log(1/R_{1680}))$; wax derived from the spectral Epicuticular Wax Index as EWI = $R_{625}(1/R_{736} - 1/R_{832})$; leaf mass per area (LMA) derived from leaf area scans and dry weight measurements and leaf thickness (LT) derived from micrometer measurements.

Confusion Matrix Cross Validation

Predicted \ Actual	F.sylvatica	F.orientalis	
F.sylvatica	303 37.9%	119 14.9%	71.8% 28.2%
F.orientalis	73 9.1%	305 38.1%	80.7% 19.3%
	80.6% 19.4%	71.9% 28.1%	76.0% 24.0%

Confusion Matrix Prediction

Predicted \ Actual	F.sylvatica	F.orientalis	
F.sylvatica	8 44.4%	2 11.1%	80.0% 20.0%
F.orientalis	1 5.6%	7 38.9%	87.5% 12.5%
	88.9% 11.1%	77.8% 22.2%	83.3% 16.7%

Fig. 5 Confusion matrix from the partial least squares discriminant analysis (PLS-DA) model discriminating leaf samples by beech subspecies, using as predictors light reflected by leaves from 350-2500 nm. Samples from the upper canopy of 46 trees were collected in summer 2021 at the Allenwiller forest site in France, of which 60% used for training (left) and 40% for testing (right) the model. Model training was based on cross-validation using a Monte Carlo approach with a 70%-30% data split and 100 iterations.
The diagonal cells correspond to observations that are correctly classified and the off-diagonal cells correspond to incorrectly classified observations (both number of observations and % of the total number of observations shown). The row at the bottom of the plot shows the true positive rate (in green) and the false negative rate (in red). The column on the far right of the plot shows the precision (in green) and the false discovery rate (in red). The cell in the bottom right of the plot shows the overall accuracy.

Outlook

Preliminary findings indicate the potential of an approach relying on spectral reflectance data to capture changes in forest composition at the subspecies level and compare tolerance of native and introduced species to environmental pressures. The employment of optical sensors carried by drone platforms holds the potential to scale this spectral monitoring approach to entire forests in a cost-effective way.