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Variation in structural and optical properties of sun exposed and shaded leaves: A model based approach

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Highlights: A database of optical, structural and biochemical properties of leaves of boreal species was established. The database was used to validate simulations of leaf spectra with the PROSPECT model. The relationships between leaf spectra and structure were similar for all species but the strongest for birch. The spectra of coniferous needles were more dependent on canopy position than birch spectra.

Keywords: leaf optical properties, structure, leaf radiative transfer model, boreal forest, PROSPECT

Leaf and needle (further commonly referred to as leaves) reflectance and transmittance convey information about the structure and biochemical constituents of leaf tissues (e.g. chlorophylls, carotenoids) and can be directly linked to the photosynthetic processes of plants via the light use efficiency. Both leaf structure and biochemical composition respond to decreasing light levels at deeper canopy positions and depend thus directly on canopy structure. Reliable information on leaf pigment and nutrient content and its variation, obtainable from reflectance and transmittance spectra, is required in detailed models of canopy functioning, estimation of canopy light absorption, as well as the interpretation of remote sensing data. Both structural and biochemical properties of leaves respond to decreasing light levels reaching deeper canopy positions and also to plant phenological stages.

We measured the reflectance and transmittance spectra of leaves of typical tree species in boreal Europe – Scots pine (*Pinus sylvestris* L.), Norway spruce (*Picea abies* (L.) Karsten) and Silver birch (*Betula pendula* Roth) – using a spectroradiometer coupled with an integration sphere. Measurements were calculated to hemispherically integrated reflectance and transmittance factors. Simultaneously, we measured leaf biochemical composition, water content and specific leaf area. Two different canopy positions (sunlit and shaded) were sampled. To generalize our measurements, we used the leaf-level radiative transfer model PROSPECT (Jacquemoud and Baret, 1990). The model requires only few input parameters of leaf biochemistry (e.g. chlorophyll a+b content, dry matter content, equivalent water thickness) and structure (leaf structure parameter) to simulate leaf reflectance and transmittance from 400 to 2500 nm in 1 nm step. When run in inverse mode, the model can be used to retrieve leaf structural and biochemical parameters from leaf spectra. The model allowed us to parameterize relationships between leaf spectra, biochemistry and structure for different irradiance conditions and canopy structures.

For both coniferous species transmittance was lower than reflectance whereas for birch it was similar. The relationships between the optical and structural properties of leaves and needles were similar for all species but the strongest for birch. The coniferous species, in turn, showed higher dependency of transmittance and reflectance spectra on canopy position. The results presented in this study will be part of the database of optical, structural and biochemical properties of tree species in the European boreal zone.

LITERATURE CITED

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