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Narrowband vegetation indices in boreal forest LAI estimation: the effect of reflectance seasonality

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Understanding the seasonal dynamics of boreal ecosystems and linking its different phases to satellite-measured reflectance data are crucial for efficient monitoring and modeling of northern hemisphere vegetation dynamics and productivity trends. The seasonal reflectance course of a boreal forest is a sum of the temporal reflectance cycle of both the tree canopy and the understory layers. Seasonal reflectance changes of the two layers are explained by the complex combination of changes in optical and structural properties of the different tree species as well as variation in solar illumination. Leaf area index (LAI), the hemi-surface area of all leaves or needles in the vegetation canopy divided by the horizontal ground area below the canopy, is closely linked to the spectral reflectance of the canopy in the shortwave range of solar radiation. LAI is one of the key biophysical parameters in the global monitoring of vegetation by satellite remote sensing since it describes the surface for the energy and gas exchange between vegetation and atmosphere. Imaging spectroscopy (hyperspectral remote sensing) has opened up new possibilities for investigating the spectral changes of forests throughout the seasons, and for estimating and monitoring vegetation status and structure, including LAI.

In this study, our objective was to analyze the role LAI as a driving factor of reflectance seasonality in boreal forests. The more specific objectives were 1) to link the field reference measurements of LAI to narrowband Hyperion data, 2) to analyze which narrowband vegetation indices perform the best in estimating boreal forest LAI, and 3) to assess how the performance of the indices changes during the snow free period. In particular, we were interested in how the selection of optimal bands for vegetation indices depends on the season. Our study area is located at Hyytiälä in southern Finland, where 20 forest stands were monitored throughout the snow free period of 2010 for LAI. The field measurements were paralleled with three EO-1 Hyperion images for 5 May, 2 June and 3 July, which represent the vegetation dynamics from the earliest vegetation development after snow melt to fully-developed canopy and understory vegetation. The results suggest that most VIs are sensitive to tree species composition (coniferous versus broadleaved). However, the VIs based on spectral bands sensitive to the water absorption in NIR and SWIR were the least sensitive to species composition and provided the strongest linear relationship over the seasons.