SPECTROMETRIC DETERMINATION OF NORWAY SPRUCE *(PICEA ABIES)* STAND LIGHT USE EFFICIENCY - COMPARATIVE STUDY OF REFLECTANCE OPTICAL INDICES

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INTRODUCTION

We evaluate the ability of three parameters computed from blue-green reflectance to track changes in photosynthesis performance of spruce stand:

-the most traditional approach, the Photochemical reflectance index **(PRI = (R531-R570)/(R531+R570))** introduced by Gamon et al. (1992),
-continuum removal based indicator called Area Under Curve Normalized to Maximal Band Depth between 510 and 557 nm **($ANMB_{511-557}$)** used successfully for tracking xanthophylls transformations in spruce needles (Kováč *et al.*, 2012; 2013),
-and the ANMB indicator calculated from reflectance between 531 and 593 nm **($ANMB_{531-593}$)**. Reflectance in this interval is sensitive to thylakoid energization (Nichol *et al.*, 2002) and changes in chlorophyll content.

MATERIAL AND METHODS

All measurements were conducted at the forest stand located at the experimental study site **Bílý Kříž in NE of the Czech Republic** (Beskydy Mountains, 18.54°E, 49.49°N, 908 m asl.)

REFLECTANCE MEASUREMENTS

Reflectance is measured with **spectroradiometer** consisting of two **JAZ modules (Ocean Optics, Dunedin, USA)**. The instrument is mounted on the eddy-covariance tower, one JAZ module measures down-welling sun radiance and the second module measures up-welling radiance reflected from the forest. FWHM = 1nm, spectral resolution varies from 0.375 nm (at wavelength 400 nm) to 0.25 nm in near-infrared area. Optical fibre measuring down-welling radiance is equipped with cossine corrector CC-3, whereas the fibre measuring radiation reflected from the canopy is not equipped with this device. With FOV of 23° and optical fibre placement 20 m above the top of the canopy, projected area is approximately 50 m^2. Spectra are measured once a 5 minutes, continually between 8 am and 4:30 pm. Reflectance is not corrected for the atmospheric effects, which are usually neglected for such close to canopy observations.

STAND PHOTOSYNTHESIS MEASUREMENTS

Daily changes in Net Ecosystem Exchange (NEE) are being measured continuously using **eddy-covariance system**. **Light use efficiency (LUE)** represents **NEE** per amount of incoming **photosynthetically active radiation (PAR)**. Data were transformed to grams of carbon accepted per mega joule of incoming PAR. Low quality data have not been put in consideration for analyses.

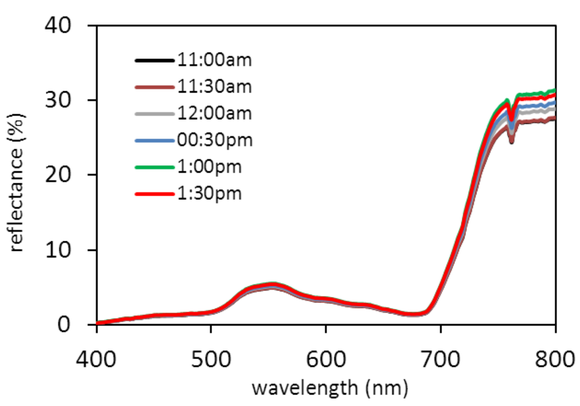

Fig. 1 Sample reflectance curves obtained during the noon at the experimental forest site using JAZ spectroradiometer. Time represents time when data collection in 5 minutes intervals over 30 minutes long period ended and data were averaged.

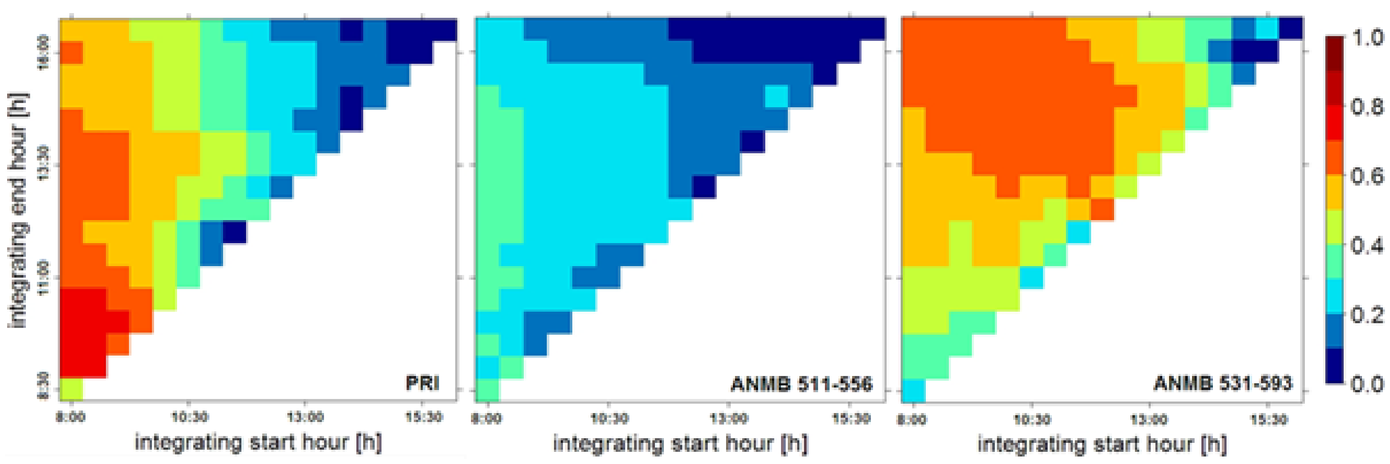

Fig. 2 Matrix showing relationship (coefficients of determination R^2) between light use efficiency and optical indices: PRI, $ANMB_{511-556}$ and $ANMB_{531-593}$ as averaged for time intervals defined by integrating start and end hour. X axis shows time when data integration started, Y axis rows show integrating end hour. N = 48.

RESULTS

- Data obtained between the beginning of the June (instrument installation) and the end of the August 2012 are shown to provide impressions about each parameter behaviour. In specific time intervals during this part of the growing season, the daily sun elevation is changing within the range of 10°.
- Sample reflectance curves measured using the instrument are shown in **Fig. 1**.
- **Fig. 2** shows coefficients of determination (R^2) of linear regressions established between LUE obtained and three optical indices computed within the time intervals defined by the integrating start and end hour throughout three months of daily measurements.
- A strong relationship between **PRI** and LUE, with the highest R^2 close to 0.8, was found for the early morning measures. However, R^2 gradually declined during the later hours, particularly during midday.
- **$ANMB_{511-556}$** showed the same pattern, but R^2 for the $ANMB_{511-556}$ – LUE relationship did not reach value higher than 0.4.
- Regression matrix for the **$ANMB_{531-593}$** – LUE relationship shows R^2 higher than 0.6 almost regularly spread around the matrix diagonal. The part closer to the centre of the matrix, are data acquired when the sun elevation angle was above 50°.
- In **Fig. 3** we considered only the hourly averaged spectral data acquired when the sun elevation angle was above 50° (N = 264) to investigate temporal behaviour of optical indices.

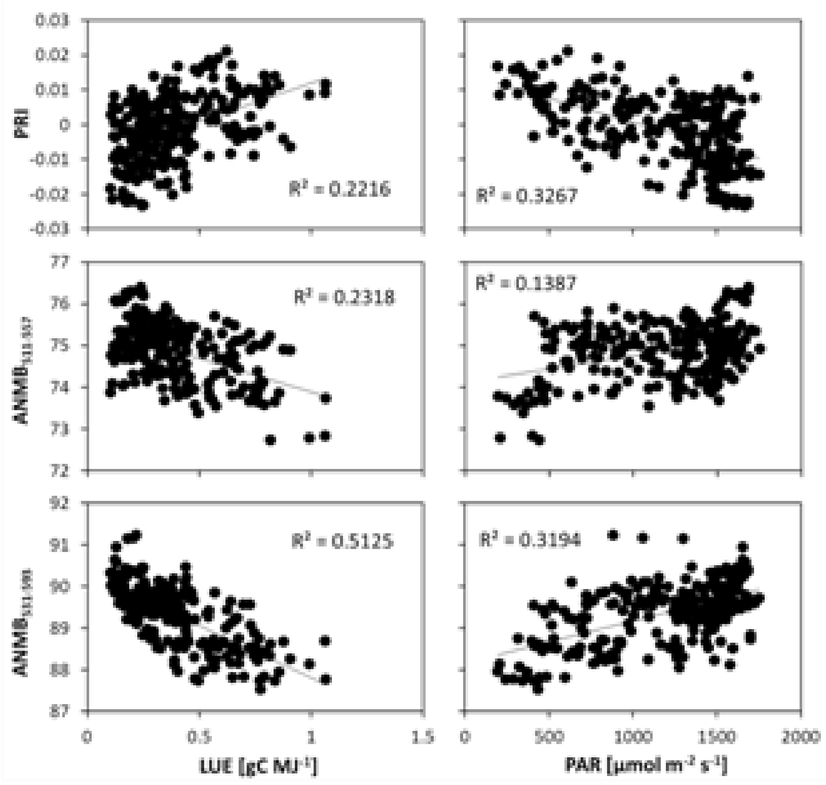

Fig. 3 Relationship between hourly averaged light use efficiency (left handed panes), amount of photosynthetically active radiation coming to the forest (right handed panes) and hourly averaged values of reflectance parameters PRI, $ANMB_{511-556}$ and $ANMB_{531-593}$. Only data acquired for sun elevation angle above 50° are included. N = 264.

DISCUSSION

- **PRI** responds to differences in LUE during early morning hours = as stated by Gamon *et al* (1997) and many others indicative ability of PRI can be confounded by physiological processes of Mehler reaction, photorespiration or nitrate reduction, all of which compete with carboxylation for reductant generated by electron transport.
- Although at the leaf level the **$ANMB_{511-556}$** index helped us to understand link between leaf reflectance and xanthophyll deepoxidation processes (Kováč *et al.*, 2012; 2013), at the canopy level we did not find a statistically significant link between $ANMB_{511-556}$ and LUE, yet.
- The strongest relationship between LUE and the canopy reflectance information was obtained after applying ANMB transformation between the wavebands 531 and 593 nm. **$ANMB_{531-593}$** combines seasonal information on canopy chlorophyll content with a thylakoid energisation (Nichol et al., 2002). However, causality of this relationship still needs further investigation.
- **$ANMB_{531-593}$** is able to track LUE changes even under irradiances higher than 1000 µmol m^{-2} s^{-1} , under such high irradiances **$ANMB_{511-556}$** may behave unpredictably as shown in Kováč *et al.* (2013). Due to lack of space figure is not shown.
- It would be more appropriate to compare reflectance information with LUE computed from GPP

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