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Estimation of ecosystem photosynthesis parameters using normalized difference spectral indexes from hyper-spectral images

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1. Introduction

Nowadays, the increased global CO_2 concentration leads to various kinds of environmental impacts. Thus it is important to estimate the carbon dynamics of terrestrial ecosystems through photosynthesis (Gross Primary Production: GPP). To do it for a wide area and know a spatial variation, satellite remote sensing with optical sensors could be a powerful tool. For example, the parameters of the light curve of GPP were determined using the reflected radiance of two broad wavebands in shortwave radiation from the ecosystem surface. To improve the accuracy of the GPP estimation, it is necessary to measure the spectral reflectance for a narrower waveband and to explore the best combination of wavelengths, which are highly correlated to the parameters. Therefore, field experiments were conducted at three different ecosystems in Hokkaido using a spectral camera.

2. Materials and Methods

The field study was conducted in a snow-free period at three sites: Teshio experimental forest of Hokkaido University in 2016 to 2018, Bibai Mire in 2016 and Tomakomai national forest in 2015. At each site, the spectral images of the plant canopy were taken every 15 min in the daytime from 460 to 780 nm at intervals of 10 nm with a liquid crystal tunable filter (LCTF) camera installed on a tower. The reflected radiance at each pixel was converted to reflectance (R_i: i denotes a wavelength) using spectral solar irradiance measured with a spectro-radiometer. The reflectance at each wavelength was averaged within the region of interest (ROI) set in the image. For every combination of two wavelengths, normalized difference spectral indices (NDSI[i,j] = $(R_i - R_j) / (R_i + R_j)$) were calculated. Simultaneously, net ecosystem CO_2 exchange (NEE) was measured continuously by the eddy covariance technique. After quality control, NEE was partitioned into GPP and ecosystem respiration (RE) using an empirical method. Using a 5-day-long moving window, a non-rectangular hyperbola was fitted to the relationship of GPP with photosynthetic photon flux density (PPFD), and the two parameters of initial slope (φ) and maximum GPP (GPP_{max}) were determined every day. Then, to explore the best combination of two wavelengths, correlation between NDSIs and the parameters were analyzed.

3. Results and Discussion

The best combination of wavelengths with the highest coefficient of determination (R^2) to determine the parameters was 780 nm in near infrared and 710 nm in red edge at every site and in every year. Using NDSIs of this combination, it is possible to estimate the initial slope (φ) and GPP from solar radiation. After the comparison of observed GPP and estimated GPP, the R^2 of Teshio in each year was 0.89, 0.90 and 0.90, and those of Bibai and Tomakomai were 0.85 and 0.86, respectively. This result showed that there is possibility to estimate GPP with high accuracy from NDSI determined hyperspectral images taken with the LCTF camera. Also, interannual variations and inter-site differences in phenology between plant species could be confirmed through NDSI[780,710] of different periods of plant respectively.

4. Conclusions

In this study, the best combination of two wavelengths that highly related to the light curve of GPP is the same despite different ecosystems in different years. The result may provide useful insights for the assessment of radiation use efficiency and photosynthetic capacity in ecosystems using spectral data.