Utility of spectral vegetation indices for estimation of light use efficiency in Japanese larch and Japanese cypress forests

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To clarify the utility of spectral vegetation indices (VIs) for estimating light use efficiency (LUE) in Japanese coniferous forests, we investigated the relationships between six VIs (NDVI, EVI, SAVI, PRI, CI, and CCI) and LUE in two mature monospecific forests of deciduous conifer (Japanese larch) and evergreen conifer (Japanese cypress) and one young mixed stand of deciduous conifer with evergreen undergrowth (hybrid larch and dwarf bamboo).

In this study, we hypothesized that CCI and EVI would give higher positive correlations between LUE and VI in deciduous forests than the other VIs. This expectation is based on the fact that the foliar chlorophyll contents and leaf mass of deciduous tree species, which show dramatic variations in these variables with spring green-up and autumn senescence, are strong driving factors of canopy photosynthesis. In contrast, in evergreen coniferous forests, where the seasonal variations in leaf mass and chlorophyll concentration are relatively small, the correlation of LUE and VIs would be stronger by PRI than by the other leaf-mass- and chlorophyll-related VIs. Furthermore, we hypothesized that SAVI would be more strongly correlated with LUE in the young plantation with an open canopy and exposed soil, but that this index would likely not represent an improvement over the other indices in the closed-canopy stands.

In each forest canopy, we measured seasonal variations in CO_2 flux, radiation environment, and visible-near-infrared spectral reflectance during 1 or 2 growing seasons. We calculated LUE as gross primary production (GPP) divided by the difference between incoming and reflected photosynthetically active radiation (PAR). VIs and LUE under clear skies were averaged between 11:00 and 13:00 JST and their relationships were analyzed.

In the larch forest, all calculated VIs were positively correlated with LUE, and the highest correlation was that with CCI. In the cypress forest, on the other hand, no significant correlation was found except with PRI and CCI. The highest correlation in this forest was that with PRI, suggesting that the leaf biomass-related VIs based on near-infrared reflectance are not sufficient for estimating LUE of evergreen forest. In the mixed forest, with relatively sparse vegetation cover, all VIs were significantly correlated with LUE, but the best correlation was that with SAVI, possibly owing to the reduction in the effect of the reflectance from background soil. Correlation analysis of the pooled data from all forests showed the highest correlation between LUE and PRI. These results indicate that PRI is an effective VI in the remote estimation of LUE in both deciduous and evergreen forests, although there are some sensitivity differences between vegetation types. The test estimation of GPP using PRI and PAR could trace the seasonal variation in GPP well, and the root mean square error (RMSE) of the estimated GPP was 5.46 micromol m^{-2} s^{-1}(rRMSE=27%).