Estimation of Canopy Photosynthetic Productivity by Remote Sensing

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CO$_2$ flux in deciduous forests

CO$_2$ flux shows seasonal and inter annual variation.

It is important to consider the seasonal and yearly variation.

Ohtsuka et al. 2009 Global Change Biology
GPP estimated by satellite RS

Satellite remote sensing is a powerful tool for ecosystem observation. However it is difficult to detect the seasonal changes of carbon flux by RS.

GPP product of MODIS (MOD17)
8-day composite, 1 km resolution

Eddy covariance-based GPP

Muraoka et al. 2010  Journal of Plant Research

We have revealed the relationship between RS data and canopy photosynthetic productivity.
Multi-scale remote sensing of canopy processes

Satellite optical obs.  ↓  ↑  In-situ optical obs.  ↓  ↑  Ecological data

MS700 Spectro-radiometer
ADFC Digital camera
MS712 Spectro-radiometer

Phenological Eyes Network

Global PEN sites

Mul#-scale remote sensing of canopy processes
Takayama super-site (long-term, multidisciplinary obs.)

TKY site
Deciduous broadleaf forest
36°08’N, 137°25’E, 1420 m a.s.l.

JaLTER / ILTER-EAP
JapanFlux / AsiaFlux

Eddy covariance
(Since 1993)

Soil respiration
Litter fall
Tree growth
Leaf physiology

Betula ermanii
Quercus crispla
Sasa senanensis

Canopy phenology

PEN (since 2003)
Photosynthetic productivity of the canopy

Leaf area index

Photosynthetic capacity in single-leaf level

Daily total GPP

Daily maximum GPP

Muraoka and Noda et al. 2012 Journal of Plant Ecology
Vegetation indices of the canopy

Normalized Difference Vegetation Index

\[ NDVI = \frac{NIR - R}{NIR + R} \]

Enhanced Vegetation Index

\[ EVI = G \times \frac{NIR - R}{NIR + C1 \times R - C2 \times B + L} \]

Green-Red Vegetation Index

\[ GRVI = \frac{G - R}{G + R} \]

Muraoka and Noda et al. 2012 Journal of Plant Ecology
Relationship between VIs (NDVI, EVI and GRVI) and canopy photosynthetic productivity

○ spring to midsummer (DOY 090-210), ● midsummer to early winter (DOY 211-330)

Muraoka and Noda et al. 2012 Journal of Plant Ecology
Vegetation indices of the canopy

Chlorophyll Index

\[ CI = \frac{R_{750} - R_{705}}{R_{750} + R_{705}} \]

Canopy Chlorophyll Index

\[ CCI = \frac{D_{720}}{D_{700}} \]

Muraoka and Noda et al. 2012 Journal of Plant Ecology
Relationship between VIs (CI and CCI) and canopy photosynthetic productivity

○ spring to midsummer (DOY 090-210), ● midsummer to early winter (DOY 211-330)

Muraoka and Noda et al. 2012 Journal of Plant Ecology
Regional estimate of photosynthetic capacity ($GPP_{\text{max}}$)

Empirical model at TKY site

\[ y = 87.033x^2 - 18.634x + 0.20938 \quad R^2=0.88 \]
\[ y = 78.767x - 15.301 \quad R^2=0.95 \]

Muraoka and Noda et al. 2012 Journal of Plant Ecology
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Muraoka and Noda et al. 2012 Journal of Plant Ecology
Spectral vegetation indices as the indicator of canopy photosynthetic productivity in a deciduous broadleaf forest

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Abstract

Aims
Understanding of the ecophysiological dynamics of forest canopy photosynthesis and its spatial and temporal scaling is crucial for revealing ecological response to climate change. Combined observations and analyses of plant ecophysiology and optical remote sensing would enable us to achieve these studies. In order to examine the utility of spectral vegetation indices (VIs) for assessing ecosystem-level photosynthesis, we investigated the relationships between canopy-scale photosynthetic productivity and canopy spectral reflectance over seasons 5 years in a cool, temperate deciduous broadleaf forest at ‘Takayama’ super site in central Japan.

Methods
Daily photosynthetic capacity was assessed by in situ canopy leaf area index (LAI), [LAI × V_{max} (single-leaf photosynthetic capacity)].

Important Findings
Our in situ observation of leaf and canopy characteristics, which were analyzed by an ecosystem carbon cycling model, revealed that their phenological changes are responsible for seasonal and interannual variations in canopy photosynthesis. Significant correlations were found between the five VIs and canopy photosynthetic capacity over the seasons and years; four of the VIs showed hysteresis-type relationships and only CCI showed rather linear relationship. Among the VIs examined, we applied EVI-GPP_{max} relationship to EVI data obtained by Moderate Resolution Imaging Spectroradiometer to estimate the temporal and spatial variation in GPP_{max} over central Japan. Our findings would improve the accuracy of satellite-based estimate of forest photosynthetic productivity in fine spatial and temporal resolutions, which are necessary for detecting any response of terrestrial ecosystems to climate change.
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