学 位 論 文 内 容 の 要 旨

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学 位 論 文 題 名

Linking Solar-Induced Chlorophyll Fluorescence to Gross Primary Productivity Across Terrestrial Ecosystems
（陸域生態系における太陽光誘起クロロフィル蛍光と総一次生産量の関係の解明）

Terrestrial ecosystem photosynthesis plays a crucial role in the global carbon cycle, as plant photosynthesis represents the largest sink of atmospheric CO_2. Accurate estimation of terrestrial gross primary productivity (GPP) is therefore essential for understanding ecosystem-scale carbon dynamics and land–atmosphere CO_2 exchange. Solar-induced chlorophyll fluorescence (SIF) has emerged as a state-of-the-art proxy for ecosystem photosynthesis because it is directly linked to photosynthetic processes at the leaf level. Although satellite-derived SIF has been shown to correlate with GPP at regional and global scales, its coarse spatiotemporal resolution requires validation using ground-based observations to better capture short-term and ecosystem-specific variations in carbon uptake by plants.

The capability of SIF to track and predict GPP across terrestrial ecosystems with increasing canopy structural complexity was evaluated using ground-based SIF measurements in combination with eddy covariance observations. Three contrasting ecosystems in Japan were investigated: a structurally simple rice paddy ecosystem, a cool temperate bog ecosystem, and a mixed larch–Sasa sparse forest characterized by a vertically complex, multi-layer canopy. Analyses were conducted at diurnal and seasonal scales to assess how canopy structure, vertical heterogeneity, and environmental conditions regulate SIF–GPP relationships.

In the rice paddy ecosystem, SIF showed strong relationships with ecosystem-scale GPP, demonstrating that red SIF (F687) can effectively track GPP under homogeneous canopy conditions with limited chlorophyll reabsorption. In the cool temperate bog ecosystem, integrating SIF with key environmental variables further improved the prediction

of GPP, highlighting the importance of environmental controls such as radiation and moisture on the SIF–GPP relationship. In contrast, in the mixed larch–Sasa forest, overstory larch vegetation contributed more substantially to ecosystem GPP than understory Sasa bamboo. Under these structurally complex canopy conditions, far-red SIF (F760) exhibited a stronger and more consistent relationship with GPP than red SIF, reflecting enhanced chlorophyll reabsorption and multiple scattering effects within the canopy.

Overall, the results demonstrate that SIF can robustly track ecosystem GPP across diverse terrestrial ecosystems, while the optimal interpretation of SIF depends strongly on canopy structure and environmental conditions. These findings provide important insights for improving the application of both ground-based and satellite SIF observations in estimating terrestrial ecosystem productivity and advancing global carbon cycle research