学　位　論　文　内　容　の　要　旨

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学　位　論　文　題　名

The Efficiency-level Inconsistency of the SIF–GPP Relationship in a Subtropical Evergreen Forest in Japan

（日本の亜熱帯常緑樹林における SIF-GPP 関係の効率レベルにみられる不一致性）

Abstract

Terrestrial forests play a central role in the global carbon cycle and convert solar energy into chemical energy through photosynthesis, quantified as gross primary productivity (GPP). Monitoring photosynthetic activity is therefore crucial for understanding forest carbon dynamics, especially in ecosystems that are structurally stable but physiologically dynamic, such as subtropical evergreen broadleaf forests, which have received relatively little attention despite their importance in the carbon cycle. Solar-induced chlorophyll fluorescence (SIF) provides near real-time insights into photosynthesis because it responds more directly to physiological activity than reflectance-based vegetation indices. SIF, defined as the red to far-red (650–850 nm) emission from excited chlorophyll a following solar radiation absorption, represents one of the three main pathways of excitation energy dissipation alongside photochemical and non-photochemical quenching. Its close relationship with GPP arises from their shared dependence on absorbed photosynthetically active radiation (APAR), which makes SIF a robust proxy for assessing photosynthetic activity via remote sensing.

In this study, we investigated the seasonal and diurnal dynamics of far-red and red SIF using the spectral fitting method (SFM), together with synchronous GPP measurements, vegetation indices including the normalized difference vegetation index (NDVI), enhanced vegetation index (EVI), and leaf area index (LAI), and radiation data (e.g., APAR), in a subtropical evergreen broadleaf forest in Okinawa, Japan, based on ground-based observations from 2020 to 2022. Our results show that, despite the structural stability of the canopy (as indicated by minimal interannual variation in vegetation indices), both SIF and GPP exhibit pronounced and synchronous seasonal variability. This finding confirms that SIF can reliably track long-term vegetation physiological dynamics in subtropical evergreen forests. However, at a half-hourly scale, SIF shows a linear response to APAR, whereas GPP exhibits a saturation pattern. By further quantifying SIF and GPP efficiencies using APAR, we found that SIF yield and light-use efficiency (LUE) diverge during noon and afternoon periods: SIF yield remains suppressed, whereas LUE shows signs of recovery. Random Forest analysis further demonstrated that this divergence is associated with the differing relative importance of environmental drivers including photosynthetically active radiation (PAR), vapor pressure deficit (VPD), and air temperature (TA) across various periods of the day.

Overall, this study provides three years of continuous ground-based observations in a subtropical evergreen broadleaf forest, a region where surface measurements remain scarce, and examines the relationships and variations between SIF and GPP across multiple timescales and at both the flux and efficiency levels. These findings refine the interpretation of SIF-based indicators in dense evergreen canopies and highlight the need to improve SIF-based GPP models for subtropical ecosystems.