学　位　論　文　内　容　の　要　旨

博士の専攻分野の名称：　博　士（食資源学）　　　　氏名　　範　良賢

学　位　論　文　題　名

Data assimilation of solar-induced chlorophyll fluorescence improves gross primary production estimation by a process-based VISIT-SIF model in a rice paddy
（水田におけるプロセスベースモデル VISIT-SIF を用いた太陽光誘起クロロフィル蛍光の統計的データ同化による総一次生産（GPP）推定精度向上）

Understanding gross primary production (GPP) is crucial for the global carbon cycle, and many studies have shown that solar-induced chlorophyll fluorescence (SIF) is a reliable proxy for GPP. This study integrates SIF data into the process-based Vegetation Integrative Simulator for Trace gases (VISIT-SIF) model to enhance GPP simulations in a rice paddy field in Tsukuba, Japan. Using data assimilation techniques (Bayesian Optimization) with ground-based SIF data and satellite-derived SIF (CSIF) from June 2019 to September 2020, I optimized key model parameters to improve GPP simulation accuracy. Sensitivity analysis via SHapley Additive exPlanations (SHAP) revealed that absorbed photosynthetically active radiation (APAR)-related parameters are most critical for SIF simulations, while nitrogen-related parameters associated with the maximum rate of carboxylation (Vcmax) strongly influence GPP.

The optimization significantly improved the VISIT-SIF model's performance across multiple timescales. At the half-hourly scale, SIF R^2 increased from 0.37 to 0.60, while GPP R^2 improved from 0.47 to 0.68, with substantial reductions in relative errors. Similar improvements were observed at daily and weekly scales, demonstrating the model's enhanced ability to capture diurnal and seasonal variations. Comparisons between sunny and cloudy conditions highlighted the model's stronger performance under direct sunlight, with reduced accuracy under diffuse light. Notably, the optimized model showed improved correlations between SIF and GPP at all temporal scales,

achieving R^2 values as high as 0.99 at the weekly scale. However, Stage II of the growing season presented challenges, with relatively weaker SIF-GPP relationships even after optimization.

I further investigated the relationship between SIF and GPP and the impacts of environmental factors. Results showed that the SIF-GPP correlation strengthened with increasing temporal aggregation, from half-hourly to weekly scales, reflecting the integration of short-term variations over longer periods. Environmental conditions, particularly light variability, played a significant role in shaping this relationship. The model performed better under stable, direct sunlight, while cloud cover introduced complexities that reduced simulation accuracy. These findings underscore the importance of considering environmental factors, such as light quality and cloud effects, in improving SIF-GPP modeling.

Overall, this study demonstrates the value of using SIF as a proxy for GPP and highlights the effectiveness of integrating ground-based and satellite SIF data into process-based models. While data assimilation significantly improved model performance, challenges such as SIF overestimation and limitations under cloudy conditions remain. These findings contribute to advancing the understanding of SIF-GPP dynamics and emphasize the potential of SIF for enhancing GPP estimations across varying environmental conditions.