（学位第３号様式）

学 位 論 文 要 旨

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題　目	Enhancing Sustainability in Sugarcane Production via Process-Based Crop Modeling, Fertilizer-Based Emission Mitigation, and a Life Cycle Assessment Approach (プロセスベースの作物モデリング、肥料ベースの排出削減、ライフサイクル評価アプローチによるサトウキビ生産の持続可能性の強化)

Sugarcane is an important crop for sugar and bioenergy worldwide. However, climate change-mediated spatial and temporal yield variability makes it difficult to manage strategies in the sugarcane sector. Greenhouse gas emissions and non-renewable fossil fuel usage in both sugarcane cultivation and processing phases have raised concerns about the sustainability of the sector. Therefore, the present study focused on comprehensive analysis encompassing process-based crop modeling, optimization strategies, and environmental impact assessments to contribute to the sustainable development of sugarcane sectors in diverse geographic regions, including Khon Kaen, Thailand, Okinawa, Japan, and Sri Lanka.

In the first study, a comprehensive evaluation of the Agricultural Productions System Simulator (APSIM)-Sugar model in Khon Kaen, Thailand, is conducted using global sensitivity analysis based on Gaussian process (GP) emulation. The study identifies key trait parameters influencing sugarcane dry weight as *radiation_use_efficiency*, *green_leaf_no*, *transp_eff_cf*, *tt_emerg_to_begcane*, and *cane_fraction* (which explained more than 90% of the total variance on the simulator output), revealing their sensitivity under varying soil types and rainfed and irrigated conditions. The results provide insights for refining modeling accuracy and devising effective management strategies to address temporal and spatial variability in sugarcane yield.

The second study focuses on optimizing cultivar-specific parameters in the APSIM-Sugarcane model for three Thai sugarcane cultivars under rainfed and irrigated conditions. Employing GP emulation and the differential evolution algorithm, the study achieves successful parameterization (validation results between simulated and observed yields: R^2 0.93–0.98; normalized root mean squared error: 5–22%; Willmott's agreement index: 0.87–0.99), yielding simulations closely approximating observed biomass and cane dry weight. This study emphasizes the efficiency of GP emulation in handling computationally expensive simulators, particularly under water-stressed conditions.

The third study evaluates the ability of controlled-release N fertilizers (CRFs) to reduce N_2O emissions compared to standard N fertilizer in Okinawa, Japan. Laboratory experiments reveal significantly lower N_2O emissions from CRFs (in winter season emission factor [EF]: 0.4% and in spring season EF: 1.9%) compared to standard fertilizers (in winter season EF: 3.9% and in spring season EF: 4%). The findings underscore the significance of careful fertilizer choice and soil moisture management in mitigating N_2O emissions and nutrient leaching.

The fourth study investigates the Sri Lankan sugar sector's energy usage and greenhouse gas (GHG) emissions using the Life Cycle Assessment approach. A comparison between two major sugar factories established at different time scales highlights variations in energy consumption and GHG emission, with sugarcane cultivation and harvesting phases identified as major contributors to energy consumption [66.5%–73.5%] and GHG emission [62.5%–76.8%]. Enhancing millable cane yield, optimizing machine use, and increasing machine use efficiency were identified as the major phases that should be concerned when achieving the sustainable development of the sugarcane sector in Sri Lanka.