学位論文の要旨

Abstract of Thesis

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学位論文題目 Title of Thesis（学位論文題目が英語の場合は和訳を付記）

Influences of land-use changes and water management strategies for water availability of coffee cultivation in the Srepok River Watershed, Vietnam

ベトナム・スレポック川流域における土地利用の変化と水管理戦略がコーヒー栽培の水資源利用可能性に与える影響

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Coffee is one of the most widely consumed beverages globally, with demand increasing annually. This crop not only makes a significant contribution to economic development but also has potential implications for water resource management. A comprehensive understanding of the water demand-supply dynamics and the hydrological balance responses of watersheds to anthropogenic activities, including irrigation and land-use changes, is crucial for effective water planning and management. The primary objective of this study was to evaluate the impacts of management strategies and transitions in coffee cultivation on hydrological balance and water shortages in the Srepok River Watershed. Specifically, the study investigated the effects on water availability by considering water demand priorities and irrigation methods from 2006 to 2019, as well as the alterations in coffee cultivation in 2016, 2020, and 2024 in the Srepok River Watershed, Vietnam.

The Soil and Water Assessment Tool (SWAT) model was employed to simulate streamflow within the study area. Utilizing available spatial and temporal datasets, including the Digital Elevation Model, land-use, soil, and climatic characteristics, the model was configured and calibrated against observed monthly streamflow data. The calibration and validation results demonstrated that the SWAT model was able to simulate streamflow with a high degree of accuracy. The monthly simulated runoff closely corresponded with observed data, with $NSE > 0.51$ and $R^2 > 0.65$ at five stations (Ban Don, Krong Buk, Cau 14, Giang Son, and Duc Xuyen) during both the calibration (2000 – 2020)

and validation (1983 – 1999) periods. Subsequently, based on the simulated results, drought characteristics were investigated using the modified surface water supply index ($MSWSI$) which considers the contributions of surface runoff, precipitation, reservoir inflow, and groundwater to streamflow to define the wet, normal, and dry years during the period of 2006 – 2019. According to the $MSWSI$ results, the Srepok River Watershed experienced drought events in 2012, 2015, and 2018, while wet conditions were identified in 2007 and 2009, following the hydrological years (from May to April of the following year). To quantify the unmet water demand, the Water Evaluation And Planning (WEAP) model was utilized, with the study area being divided into six sub-regions. Two scenarios, including water priorities and transition from hose irrigation to sprinkler irrigation for coffee cultivation, were considered in the Srepok River Watershed. In this context, water priorities assigned the highest order of water use to domestic and industrial consumption, followed by livestock and other crops in descending order. The shift in irrigation methods could potentially reduce water consumption for coffee irrigation by 25% annually. The results indicated that coffee irrigation in the Srepok River Watershed accounted for 40.6–79.1% of unmet water demand between 2006 and 2019, particularly during the latter dry season in sub-regions I and V. Furthermore, the transition from hose irrigation to sprinkler irrigation demonstrated enhanced efficacy compared to demand prioritization, specifically with an approximate 37.8 million cubic meter reduction in unmet water demand during dry years, considering in both the impacts of water priorities and changing in irrigation methods.

To examine the alterations in coffee-producing areas within the Srepok River Watershed, Google Earth Engine (GEE) was employed to generate land-use maps with a coffee category, for the years 2016, 2020, and 2024. These land-use maps were categorized into ten cover types: water, urban, rice, coffee, other crops, shrubs, bare land, evergreen broadleaf forest, deciduous forest, and plantation forest. The 2024 land-use map was validated using ground-truth data. The findings indicated that the quantity and distribution of training data significantly influenced classification accuracy, whereas ancillary data showed less influence but substantial computation. However, texture serves as important ancillary data for crop-specific mapping. The results indicated that the overall accuracy exceeded 0.8, and the Kappa coefficient surpassed 0.78 for all three land-use maps. Transition changes were considered based on these reliable classification maps. The primary transformation in the Srepok

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River Watershed involved the interchange between coffee and non-coffee crops and the conversion from shrubs to agriculture. The coffee area in the Srepok River Watershed expanded by approximately 67,000 ha from 2016 to 2020, followed by a reduction of around 30,000 ha from 2020 to 2024. Moreover, the middle of the watershed was identified as the most dynamic region.

The impacts of irrigation and coffee cultivation changes on the water balance in the Srepok River Watershed were assessed using the SWAT model. The changes were considered in the years 2016, 2020, and 2024, combining with the coffee water requirements to reflect the contrasting changes in the different intervals. Initially, streamflow was validated in three projects with the same parameter values. The simulation results showed good agreement between the observation and simulation data. Hydrological simulations indicated that irrigation applications for coffee cultivation in the Srepok River Watershed caused a reduction in surface runoff, ranging from -7.9% to -37.6%; a slight increase in soil moisture, between 2.7% and 4.3%, and a significant increase in evapotranspiration, from 62.9% to 158.5%. In terms of the impacts of both coffee irrigation and cultivation changes, evapotranspiration consistently increased throughout the study period, surface runoff exhibited minor variations with a similar trend to coffee area changes, and soil moisture showed a comparable increase in the three target years. In which, soil moisture decreased by approximately 12.8% from 2016 to 2020 and increased 1% from 2020 to 2024. Surface runoff increased 9.8% from 2016 to 2020 and decreased 39.8% from 2020 to 2024.

The obtained results in this study are expected to provide more comprehensive understanding of the impacts of coffee cultivation on water usage, and to provide information that managers need in order to promote water resources planning efforts. Besides, this study will also contribute a basic framework for assessing the coffee producing on hydrology that can be applied in other basins in Vietnam and around the world.