應用 SWAT 模式評估作物生產水足跡以及農民收益之轉作策略—以北港溪流域為例

林冠州[1]、**江莉琦**[2]
國立臺灣大學生物環境系統工程學系博士後研究員[1]
國立臺灣大學生物環境系統工程學系教授[2]

摘要

氣候變遷導致降雨時空分布日益極端，臺灣乾旱發生頻率與強度持續升高，將對高度依賴灌溉水源的水稻耕作構成顯著挑戰。在此背景下，如何有效配置有限水資源並規劃作物轉作策略，以成為近年來臺灣農業調適之核心課題。本研究以北港溪流域為研究區，應用 SWAT 水文模式模擬 2012 至 2022 年間流域作物的灌溉需水量與作物生產水足跡(包括: 藍、綠、灰水)，並設置三種灌溉水量情境(減少 20%、40%、60%的最大灌溉量)，評估水稻轉作耐旱雜糧作物（玉米、大豆、地瓜）之用水效益與環境污染風險(灰水足跡)。模擬結果顯示，水稻平均灌溉需水量約 2400 mm，其藍水-綠水足跡高達 2472 m^3/ton，顯著高於區域內之旱作及果樹。在不同灌溉水量情境下，若水稻轉作可為流域作物生產藍水-綠水水足跡降低約 7%~51%；與休耕補助相比，農民將能增加約 105%~675%的經濟收益。惟大豆與玉米雖具節水潛力，卻伴隨較高非點源污染輸出，造成灰水需求量增加約 5%~22%。相較之下，地瓜兼具較低水足跡與污染輸出量之優勢，且對農民收益增加幅度最高，為兼顧水資源利用效率與水質保育之適宜轉作選項。本研究整合 SWAT 模式與水足跡評估，提出作物轉作與灌溉策略調適分析方法，對強化農業氣候韌性與推動流域農業永續發展具實務應用價值。

關鍵字: SWAT 模式、作物生產水足跡、非點源汙染、作物轉作、北港溪流域

Evaluating Crop Production Water Footprints and Farmer Incomes under SWAT-Based Crop Conversion Strategies: A Case Study of the Beigang River Basin

Guan-Zhou Lin[1]、Li-Chi Chiang[2]

Postdoctoral Researcher, Department of Bioenvironmental Systems Engineering, National Taiwan University[1]

Professor, Department of Bioenvironmental Systems Engineering, National Taiwan University[2]

Abstract

Climate change has led to increasingly extreme temporal and spatial rainfall patterns in Taiwan, intensifying the frequency and severity of droughts and posing serious challenges to rice cultivation, which is highly dependent on irrigation. This study evaluates crop production water footprints and farmer incomes under alternative crop conversion strategies using the SWAT model, focusing on the Beigang River Basin from 2012 to 2022. Three irrigation scenarios were designed (20%, 40%, and 60% reductions in maximum irrigation) to simulate the irrigation demand and water footprints—blue, green, and grey—of rice and three drought-tolerant crops: maize, soybean, and sweet potato. Results indicate that rice has an average irrigation demand of 2400 mm and a blue-green water footprint of 2472 m^3/ton, much higher than that of upland crops and orchards. Crop conversion reduced blue-green water footprints by 7%–51% and increased farmer incomes by 105%–675% compared to fallow subsidies. However, soybean and maize resulted in 5%–22% increases in grey water footprints due to higher pollution loads. Sweet potato exhibited the best balance between water efficiency, environmental protection, and economic return. This study demonstrates the practical value of integrating SWAT-based simulation with water footprint analysis for improving climate resilience and promoting sustainable agriculture in Taiwanese watersheds.

Keywords: SWAT model, Crop production water footprint, Non-point source pollution, Crop conversion, Beigang River Basin