SWAT-pothole 與 SWAT+ Paddy 模式於水稻田水文模擬之比較—以烏溪流域為例

Comparison of SWAT-pothole and SWAT+ Paddy Approaches for Simulating Hydrological Processes in Paddy Fields: A Case Study of the Wu River Basin

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摘 要

水稻田因具長期蓄水與灌排調控特性，水文行為顯著異於旱作農田。SWAT (Soil and Water Assessment Tool) 模式在農業管理中主要針對旱作設計，在面對水田區域時，多以 pothole (壺穴)模組進行模擬，將田區視為圓錐形靜態蓄水空間。然而此模組缺乏對水稻不同生育期水位控制、定期灌排與灌溉來源管理等細部水文過程的描繪，對於灌溉制度發達且水田分布廣泛的地區，例如台灣中部的烏溪流域，模擬精度與實用性皆有所不足。

為提升水稻田區的模擬能力，本研究應用 SWAT+ 模式中所整合之 paddy 模組進行改進，重建具農田管理邏輯之灌溉流程。SWAT+ Paddy 架構允許使用者針對水田區域建立獨立灌溉管理單元，透過灌溉排程定義不同生長過程之目標灌溉深度與頻率，且可明確指定灌溉來源，包括水庫、渠道或河川等，並模擬灌溉與排水的再利用流程，使整體水資源收支與田間動態更趨合理與物理一致。

本研究以烏溪流域為例，比較 SWAT-pothole 與 SWAT+ Paddy 兩種模式於 2020 至 2022 年間的模擬表現，資料涵蓋土地利用、土壤類別、氣象紀錄與實際灌排作業資訊。模擬結果顯示，SWAT+ Paddy 模式在田間水位、水稻生育期灌溉需求與流域水文過程變化均優於傳統 pothole 模式，特別是在雨灌交替頻繁與乾濕變化劇烈的生長季節，其模擬能力尤為顯著。此外，SWAT+paddy 更能真實反映農田對下游流量的調節與蓄洪功能，進而提升整體水收支評估的準確性。

本研究結果指出，SWAT+ 架構下整合之 paddy 模組在模擬具灌溉與積水管理需求之水稻田區具有顯著優勢，亦提供更靈活且符合實際管理操作的模型結構。此一進展對於未來執行農業灌溉規劃、水資源調度、水質模擬及氣候變遷下農業水管理調適策略評估，具有重要應用潛力。

關鍵詞：SWAT+、水稻田、水文模擬、農業水資源管理

Abstract

Paddy fields have unique hydrological characteristics due to prolonged ponding and active irrigation and drainage operations, which differ significantly from upland croplands. The SWAT (Soil and Water Assessment Tool) model, originally designed for dry farming, typically simulates paddy fields using the pothole module. However, this approach oversimplifies key processes such as growth-stage-specific water level control, irrigation scheduling, and source assignment, limiting its accuracy in intensively managed rice areas like Taiwan's Wu River Basin.

This study applies the paddy module in the SWAT+ to improve paddy field simulation by enabling dynamic irrigation management, flexible water depth settings, and source-specific inflows. A comparison between SWAT-pothole and SWAT+ Paddy was conducted using data from 2020 to 2022, including land use, soil types, weather data, and irrigation records.

Results show that SWAT+ paddy better represents field water levels, irrigation demand, and hydrological responses, particularly during alternating rainfall and irrigation periods. It also captures the buffering effect of paddy fields on downstream flows more accurately, enhancing water balance assessment at the basin scale.

Overall, the SWAT+ paddy module provides a more realistic and adaptable approach for modeling irrigated rice fields and has strong potential for supporting future agricultural water management and planning under changing environmental conditions.

Keywords: SWAT+, paddy fields, hydrological modeling, irrigation, Wu River Basin