擴大灌溉服務對茶園碳匯效益之影響：以密閉罩法實測 CO_2通量為例

Impacts of the Expanded Irrigation Service on Carbon Sequestration in Tea Plantations: A Case Study Based on CO_2 Flux Measurements Using the Static Chamber Method

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摘 要

人為溫室氣體排放，尤其是二氧化碳(CO_2)，已被廣泛認為是造成全球氣候變遷的主要因素之一。以自然為本的解決策略(如光合作用)提供了從大氣中移除 CO_2 的可行途徑，然而，農業相關碳匯的潛力仍有待深入探討與量化。農業部預定於 2040 年前將農業部門的溫室氣體排放量至少減少 50%，並推動「減量、增匯、循環、綠趨勢」四大政策，以邁向農業淨零與永續經營之目標。當減排措施達到技術與實務上的極限時，透過碳匯或碳捕捉機制以抵銷剩餘排放，已被視為實現淨零排放的可行策略之一。茶樹(*Camellia sinensis*)作為多年生木本經濟作物，具備生長週期長、生物量高等特性，顯示其具有潛在的碳吸收能力。現有文獻多以異速生長模型(allometric model)間接估算茶樹碳匯，然而此法往往受限於多項假設條件。本研究嘗試將密閉罩法(static chamber method)應用於茶樹碳通量的直接觀測，期望能提供較傳統模型更為準確的碳匯評估資料。本研究於宜蘭縣冬山鄉擴大灌溉服務推動區擇定三類農地進行 CO_2 通量監測：已建置灌溉系統且管理灌溉良好的茶園、雨養茶園 (rainfed tea plantation，看天茶園)與鄰近荒地，調查期間自 2024 年 11 月至 2025 年 9 月，每月擇一日於晴朗天氣下進行現地採樣。氣體樣本經冷藏保存，並於兩週內使用氣相層析－熱傳導檢測儀(GC-TCD)進行定量分析，以確保數據之準確性與時效性。初步結果顯示，灌溉良好的茶園具有較高的 CO_2 吸收量，雨養茶園次之，鄰近荒地則呈現淨排放。此結果顯示，農田水利署推動的擴大灌溉服務計畫除了有助於穩定作物產量外，亦具提升茶園碳匯潛力的潛在附加效益，其在氣候調適方面之潛在價值亦值得關注。雖然密閉罩法在本研究中展現出可行性，但在實務應用上仍面臨如數據波動、操作穩定性等技術挑戰，相關經驗可作為後續實驗設計與儀器應用的重要參考。整體而言，本研究顯示健全的農田水利設施及良好的灌溉管

理對茶園碳匯功能具有潛在正向影響，進一步強化農田水利於永續發展與氣候調適策略中的關鍵角色。

關鍵詞：碳匯，淨零碳排，茶樹，農田水利，灌溉管理，密閉罩法

Abstract

Human-induced greenhouse gas emissions, particularly carbon dioxide (CO_2), are widely recognized as major contributors to global climate change. Nature-based solutions such as photosynthesis offer viable pathways for atmospheric CO_2 removal; however, the carbon sequestration potential of agricultural systems remains underexplored and insufficiently quantified. The Ministry of Agriculture (Taiwan) aims to reduce greenhouse gas emissions from the agricultural sector by at least 50% by 2040, guided by four strategic pillars: mitigation, sequestration, circularity, and green transition. When emission reduction reaches technological and practical limits, carbon sequestration or capture is considered a viable strategy to offset residual emissions in the pursuit of net-zero goals. Tea (*Camellia sinensis*), as a woody perennial crop with high biomass and a long life cycle, presents a promising potential for carbon uptake. While existing studies often rely on allometric models to indirectly estimate carbon sequestration, such approaches are constrained by multiple assumptions. This study explores the application of the static chamber method—commonly used in rice paddies for greenhouse gas flux measurement—for directly assessing CO_2 flux in tea plantations. This method, though still relatively uncommon in tea-related studies, may provide more accurate and site-specific data than traditional estimation models. This study conducted CO_2 flux monitoring on three types of farmland within the Expanded Irrigation Service Promotion Area in Dongshan Township, Yilan County, Taiwan: (1) a tea plantation equipped with an irrigation system and managed with proper irrigation practices, (2) a rainfed tea plantation, and (3) adjacent fallow land. From November 2024 to September 2025, gas sampling was carried out monthly under fair weather conditions. Samples were stored under refrigeration and analyzed within two weeks using gas chromatography with a thermal conductivity detector (GC-TCD) to ensure data accuracy and reliability. Preliminary results showed that the well-irrigated tea plantation had greater CO_2 uptake than the rainfed one, while the fallow land exhibited net CO_2 emissions. These findings suggest that “Expanded Irrigation Service Policy” may enhance carbon sequestration in addition to their primary goal of improving crop yield stability, thus highlighting their ancillary benefits in climate mitigation. While the static chamber method proved feasible in this context, challenges such as data variability and operational limitations were encountered. These technical insights offer valuable guidance for improving future experimental designs and instrumentation protocols. Overall, this study demonstrates that well-developed farmland irrigation infrastructure and optimized irrigation management have the

potential to positively influence the carbon sequestration capacity of tea plantations, further underscoring the critical role of agricultural engineering and farmland water management in sustainable development and climate adaptation strategies.

Keywords: carbon sequestration, net-zero emissions, irrigation engineering and management, tea plantations, static chamber method