

# 使用不同季節作為基準估算紅樹林土壤碳 年變化量之結果差異分析

## Effect of Seasonal Baseline Selection on Estimated Annual Soil Carbon Change in Mangroves

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### 摘 要

紅樹林濕地土壤為藍碳生態系統中最關鍵且穩定的碳匯之一。隨著全球推動淨零碳排放政策，紅樹林碳匯之監測成為藍碳治理與碳匯盤查的重要課題。多項研究指出，紅樹林土壤碳儲在季節尺度下相對穩定，惟實際估算其跨年變化量時，仍存在一定的不確定性，值得進一步探討其潛在成因與估算策略。本研究於 2023–2025 年間，針對臺灣三處紅樹林樣區（關渡、塭子頭、芳苑）進行 0–30 cm 土壤碳含量調查，並採用相同季節的跨年資料進行年碳變化量估算。估算設計包括：(1) 2023 與 2024 年夏季、(2) 2023 與 2025 年春季，以及(3) 2024 與 2025 年冬季，涵蓋三地樣區之季節比較。結果顯示，關渡樣區在三個季節估算中皆呈現穩定的碳吸存 ( $14.85\text{--}30.30 \text{ Mg C ha}^{-1} \text{ yr}^{-1}$ )，而塭子頭與芳苑樣區則在不同季節估算下出現結果不一致的情形：兩地夏季估算為碳匯，冬季則呈碳排傾向，塭子頭於春季亦為碳排。此結果顯示不同季節估算下的碳收支可能存在差異。紅樹林土壤碳收支在不同季節下所呈現之差異，可能受到某些尚未量化之環境條件變動的影響。但本研究未進行相關環境因子的系統性驗證，未來仍需透過更長期且多層面的觀測資料，進一步釐清其對估算結果穩定性與解釋力的潛在影響。另一方面，2023 與 2024 年每季各樣區僅設置約 3 個樣點，而紅樹林土壤碳空間異質性大，3 個樣點無法代表各樣區，因此樣本數量不足也可能造成本次觀察的現象。短期（如一年或兩年）估算所觀察之變化，可能因監測誤差與取樣不確定性而產生偏差，但若持續長期監測則有助於辨識紅樹林土壤碳儲的真實累積趨勢。未來建議透過具代表性之樣點配置與空間分析方法，搭配多年度穩定調查，以建立具信度與解釋力之紅樹林藍碳監測策略。

關鍵詞：土壤碳年變化量，藍碳監測，紅樹林土壤碳

## Abstract

Mangrove wetland soils are among the most critical and stable carbon sinks within blue carbon ecosystems. As global efforts toward net-zero emissions intensify, the monitoring of mangrove carbon sinks has become a central issue in blue carbon management and carbon accounting. While numerous studies have indicated that mangrove soil carbon stocks tend to remain relatively stable across seasons, uncertainties remain in estimating their annual changes, highlighting the need to explore potential causes and improve estimation strategies. This study conducted surveys of 0–30 cm soil carbon content at three mangrove sites in northern and central Taiwan (Guandu, Wenzitou, and Fangyuan) between 2023 and 2025. Annual changes in soil carbon stock were estimated using cross-year data from the same season. The estimation design included three seasonal pairings: (1) summer 2023 vs. summer 2024, (2) spring 2023 vs. spring 2025, and (3) winter 2024 vs. winter 2025, allowing comparisons across seasons and sites. Results showed that Guandu consistently exhibited carbon sequestration across all three seasonal comparisons (14.85–30.30 Mg C ha<sup>-1</sup> yr<sup>-1</sup>). In contrast, results from Wenzitou and Fangyuan varied by season: both sites were carbon sinks in summer but shifted toward carbon sources in winter, with Wenzitou also exhibiting carbon emissions in spring. These findings suggest that seasonal baseline selection may influence carbon budget estimates. Such seasonal variability may be influenced by unquantified environmental conditions, although this study did not systematically investigate environmental factors. Future studies should integrate longer-term and multi-dimensional datasets to clarify their potential effects on the robustness of annual estimates. In addition, spatial heterogeneity in mangrove soils poses challenges for representation. The surveys in 2023 and 2024 were limited to only three sampling points per site per season, which are likely insufficient for spatially heterogeneous environments like mangroves. The observed inconsistencies may thus also reflect sampling limitations. Short-term (one- to two-year) estimates are subject to observational and sampling uncertainties, whereas long-term monitoring can better reveal the true trajectory of soil carbon accumulation. It is recommended that future work incorporate representative sampling designs and spatial analysis, supported by multi-year, consistent data collection, to establish a robust and interpretable blue carbon monitoring strategy for mangrove ecosystems.

Keywords: annual soil carbon change, blue carbon monitoring, mangrove soil carbon