探討不同施肥策略在農田源頭控制非點源污染中的控制與碳排放減量效益

Exploring the control effectiveness and carbon emission reduction benefits of different fertilization strategies for source control of non-point source pollution in agricultural farmlands

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摘　要

農業活動是臺灣及全球重要的非點源（Non-Point Source, NPS）污染來源之一。特別是化學肥料過度施用，導致氮與磷等養分滲漏，進而污染鄰近河川與水庫。本研究以石門水庫集水區果園為研究對象，評估不同施肥策略對非點源污染控制的效果，以及其減碳潛力，並結合農業廢棄物再利用技術，探討其對永續農業的貢獻。透過在地田間試驗，本研究比較傳統全量施肥與減量施肥，並搭配生物炭與微生物接種劑的處理。結果顯示，施用生物炭與微生物製劑可在維持作物產量的同時，降低氮素流失 36.9%–50.8%。此外，生物炭改善了酸性砂質壤土（pH 5–6）的酸鹼值及養分有效性，而微生物接種劑則促進有機質分解與作物養分吸收。稻殼、玉米桿與竹材等農業剩餘物經熱解轉換為生物炭。碳足跡分析與生命週期評估（LCA）確認此方法具備碳封存潛力與減排效益，同時達到污染源頭控制與資源循環再利用的效果。研究結果不僅提出農業非點源污染減緩的新策略，也提供一條邁向碳中和與循環經濟發展的可行途徑。

關鍵詞：非點源污染，生物炭，施肥策略，碳排放減量，永續農業

Abstract

Agricultural activities are among the significant sources of non-point source (NPS) pollution in Taiwan and worldwide. In particular, the excessive application of chemical fertilizers leads to the leaching of nutrients such as nitrogen and phosphorus, which in turn pollute nearby rivers and reservoirs. This study focuses on orchards in the Shimen Reservoir watershed to evaluate the effectiveness of various fertilization strategies in controlling NPS pollution and their potential for reducing carbon emissions. It also incorporates agricultural waste reuse technologies to explore their contributions to sustainable agriculture. Through local field trials, the study compares conventional full-dose fertilization with reduced fertilization schemes integrated with biochar and microbial inoculants. The results indicate

that the application of biochar and microbial agents can reduce nitrogen losses by 36.9% to 50.8% while maintaining crop yields. In addition, biochar improved the pH value and nutrient availability of acidic sandy loam soils (pH 5–6), while microbial inoculants enhanced organic matter decomposition and nutrient uptake by crops. Agricultural residues such as rice husks, corn stalks, and bamboo waste were converted into biochar using pyrolysis. Carbon footprint analysis and life cycle assessment (LCA) confirmed the carbon sequestration potential and emission reduction benefits of this approach, achieving both source control of pollution and resource recycling. The findings of this study not only provide an innovative strategy for agricultural NPS pollution mitigation but also offer a practical pathway toward carbon neutrality and circular economy development.

Keywords: Non-point source pollution, Biochar, Fertilization strategy, Carbon emission reduction, Sustainable agriculture