学　位　論　文　要　旨

Sustainable land management with biochar application in the dry tropical cropland of southern India: improvement of soil organic carbon stock and crop productivity

熱帯半乾燥地の南インドの畑作地におけるバイオ炭施用を用いた持続的な土地管理法の創出：土壌有機炭素蓄積と作物生産性の向上

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Soils in the dry tropical croplands of southern India are critically low in soil organic carbon (SOC) stock, resulting in severe land degradation and subsequent low crop productivity. Biochar application has gained attention as potential land management to enhance SOC stock and crop productivity. The objectives of this doctoral thesis were to develop sustainable land management practices with biochar application to improve SOC stock and crop productivity in southern India. To achieve the above objectives, the following four studies were conducted in a farmer's field (soil type; Inceptisols, SOC; 3.2 g C kg^{-1}, pH; 8.5), in Tamil Nadu state in southern India with an annual rainfall of 800 mm and mean air temperature of 24.7 ℃.

【1; CHAPTER 3】 Local farmers in India traditionally make farmyard manure (FYM) from livestock excreta, which is then applied to the soil, though the sustainability of the traditional cultivation management is unclear in terms of soil C budget, despite its importance for proper SOC management. In this chapter, a 2-year field experiment was conducted from 2015 to 2017, to estimate annual CO_2 flux and soil C budget. The total CO_2 flux for two years as C output was estimated at 2.4 Mg C ha^{-1}, while C input as FYM (1.1 Mg C ha^{-1}) and root biomass-C (0.4 Mg C ha^{-1}) were 1.5 Mg C ha^{-1}. These results suggest that it is necessary to apply larger or more frequent C inputs to prevent land degradation.

【2; CHAPTER 4】 Biochar application is currently considered as an effective SOC management to enhance SOC stock, though few studies evaluated the effect of biochar application on *in-situ* CO_2 flux and associated microbial responses in the

tropical alkaline soil. In this chapter, to evaluate the effect of land management (control (C), biochar (B; 8.2 Mg C ha^{-1}), FYM (M; 1.1 Mg C ha^{-1} yr^{-1}), chemical fertilizer (F), and mixture of them (BM and BF)) on CO_2 flux, microbial biomass C (MBC) and metabolic quotient (qCO_2), a 27-month field experiment was conducted from 2017 to 2019. Cumulative CO_2 flux was 2.4, 2.7, 4.0, 2.8, 3.7, and 3.3 Mg C ha^{-1} in the C, B, M, F, BM, and BF treatments, respectively. The combined application of biochar and FYM did not increase CO_2 flux compared to FYM alone, resulting from no difference of MBC and slightly decreased qCO_2. Moreover, the SOC increment over the experiment (8.9 Mg C ha^{-1}) and the rate of C-input retention in soil (0.78) was the largest in the BM treatment. These results indicate that the combined application of biochar and FYM could be effective land management for increasing SOC stock.

【3; CHAPTER 5】 Microbial carbon use efficiency (CUE) has recently been considered as a critical indicator of soil microbial function for evaluating soil C dynamics. Microbes with high CUE generally contribute to effective microbial growth and soil C sequestration. However, the relationship between CUE and associated microbial community with biochar and FYM application is not fully understood in tropical alkaline soil such as India. In this chapter, to evaluate the effect of biochar and FYM application on microbial CUE and community structure, a short-term incubation experiment was conducted with biochar and/or FYM application. There were no significant differences in CUE between treatments, and CUE in all treatments was low over the incubation (0.36 — 0.42) compared to previous studies. In contrast, the bacterial community such as gram-positive bacteria was strongly related to microbial CUE. These indicate that neither biochar nor FYM application shifted microbial community to the extent which causes a significant change in microbial function such as CUE.

【4; CHAPTER 6】 In dry tropical India, crop production is vulnerable to soil nitrogen (N) availability and annual rainfall, causing low crop productivity. In this chapter, to evaluate the effect of land management (same treatments as CHAPTER 4) on soil water and N dynamics and crop production, three times cultivation experiments were conducted from 2017 to 2019. Biochar application increased soil water holding capacity, contributing to better crop N use efficiency and subsequent crop production in the BF treatment, only in the wet years. In contrast, B or BM application did not affect soil N dynamics, causing little improvement of crop productivity. These results indicate that it is necessary to improve both water and N availability to significantly increase crop productivity in nutrient-poor soil.

In conclusion, in the dry tropical cropland of southern India, biochar application would be sustainable land management for improving SOC stock, while another nutrient management such as chemical fertilizer is also necessary to improve crop productivity.