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Biochar addition leads to more soil organic carbon sequestration under a maize-rice cropping system than continuous flooded rice

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ABSTRACT

Crop rotation of flooded rice with an upland crop like maize on previous continuous paddy soils is an emerging cropping system in South China. A four-year experiment was conducted at a research area in Hunan province, having a long history of double paddy-rice cropping throughout the year. Maize was introduced as an upland crop in rotation with paddy rice, thus providing two parallel cropping systems i.e., the previous flooded rice-rice (R–R) and the new maize-rice rotation (M–R) systems. We used three treatments in both cropping systems; namely, farmer's practice (without external C input) as a control, straw addition, and biochar addition. The straw and biochar were added to soil in late rice season on an equal C input basis (3000 kg C $ha^{-1}yr^{-1}$). In the R–R plots, rice straw was added while in M–R plots maize straw was added during late rice field preparation. Our results show that there were no changes in soil organic carbon (SOC) concentration when R–R was replaced by M–R rotation. Straw addition had no effect on SOC but improved late rice yield. Biochar addition significantly increased SOC and late rice yield in both cropping systems. Moreover, biochar addition resulted in a more significant accumulation of SOC (9% higher) in M–R than R–R. Among soil aggregates, only the 0.25–2 mm fraction had a significantly higher SOC concentration with biochar relative to the control and straw return; and this increase was significantly more pronounced under M–R (28% higher) than R–R cropping system. In general, a significantly higher proportion of small macro-aggregates (0.25–2 mm) were found under M–R, while smaller aggregates (0.05–0.25 and < 0.05 mm) were more abundant under R–R. $\delta^{13}C$ analyses from M–R plots reveal that the quantity of maize-derived C was marginally higher in the straw treatment than control, but this was not reflected in any significant impact on total SOC of the bulk soil or of aggregates. In conclusion, no detectable changes in SOC were observed over four years experimental period following shift from R-R to M-R cropping system. M-R system with biochar addition led to higher productivity and environmental benefits.

1. Introduction

Rice (*Oryza sativa* L.) is the main daily staple food for over 3.5 billion people (World Rice statistics, IRRI, 2018a). China is the largest producer of rice, accounting for 30% of total global production, cultivated on over 29.5 million ha of its mainland (World Rice statistics, IRRI, 2018b). However, looming water crises and climate change bringing drought (Huang et al., 2014) are considered as main barriers to future paddy rice production in China (Fan et al., 2005; Steduto et al., 2012). Also, socio-economic development, such as labor migration to cities, and increasing livestock production (Cheng et al., 2012; Xu et al., 2013; Zhang et al., 2017c) are possible drivers of a shift from rice farming to other crops. Maize on other hand has an advantageous position compared to rice as it can save irrigation water, feed livestock, provide raw materials for food items, and be taken as both cash and cereal crop (Timsina et al., 2010; Meng, 2006). As a result, maize is increasingly introduced in paddy soils, especially in the double rice system (R–R) in the south of China (Jiang et al., 2020), and maize-rice (M–R) rotation has been recognized as an example of a 'Save and Grow' policy by the FAO for sustainable intensification of cereal production (FAO, 2016).

Although paddy soils are considered as net emitter of greenhouse

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