Geophysical Research Abstracts
Vol. 18, EGU2016-4043, 2016
EGU General Assembly 2016

Changes in carbon stability and microbial activity in size fractions of micro-aggregates in a rice soil chronosequence under long term rice cultivation

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Recent studies have shown soil carbon sequestration through physical protection of relative labile carbon intra micro-aggregates with formation of large sized macro-aggregates under good management of soil and agricultural systems. While carbon stabilization had been increasingly concerned as ecosystem properties, the mechanisms underspin bioactivity of soil carbon with increased carbon stability has been still poorly understood. In this study, topsoil samples were collected from rice soils derived from salt marsh under different length of rice cultivation up to 700 years from eastern China. Particle size fractions (PSF) of soil aggregates were separated using a low energy dispersion protocol. Carbon fractions in the PSFs were analyzed either with FTIR spectroscopy. Soil microbial community of bacterial, fungal and archaeal were analyzed with molecular fingerprinting using specific gene primers. Soil respiration and carbon gain from amended maize as well as enzyme activities were measured using lab incubation protocols. While the PSFs were dominated by the fine sand (200-20μm) and silt fraction (20-2μm), the mass proportion both of sand (2000-200μm) and clay (<2μm) fraction increased with prolonged rice cultivation, giving rise to an increasing trend of mean weight diameter of soil aggregates (also referred to aggregate stability). Soil organic carbon was found most enriched in coarse sand fraction (40-60g/kg), followed by the clay fraction (20-24.5g/kg), but depleted in the silt fraction ($\sim$10g/kg). Phenolic and aromatic carbon as recalcitrant pool were high (33-40% of total SOC) in both coarse sand and clay fractions than in both fine sand and silt fractions (20-29% of total SOC). However, the ratio of LOC/total SOC showed a weak decreasing trend with decreasing size of the aggregate fractions. Total gene content in the size fractions followed a similar trend to that of SOC. Bacterial and archaeal gene abundance was concentrated in both sand and clay fractions but that of fungi in sand fraction, and sharply decreased with the decreasing size of aggregate fraction. Gene abundance of archaeal followed a similar trend to that of bacterial but showing an increasing trend with prolonged rice cultivation in both sand and clay fractions. Change in community diversity with sizes of aggregate fractions was found of fungi and weakly of bacterial but not of archaeal. Soil respiration ratio (Respired CO_2-C to SOC) was highest in silt fraction, followed by the fine sand fraction but lowest in sand and clay fractions in the rice soils cultivated over 100 years. Again, scaled by total gen concentration, respiration was higher in silt fraction than in other fractions for these rice soils. For the size fractions other than clay fraction, soil gene concentration, Archaeal gen abundance, normalized enzyme activity and carbon sequestration was seen increased but SOC- and gene- scaled soil respiration decreased, more or less with prolonged rice cultivation. As shown with regression analysis, SOC content was positively linearly correlated to recalcitrant carbon proportion but negatively linearly correlated to labile carbon, in both sand and clay fractions. However, soil respiration was found positively logarithmically correlated to total DNA contents and bacterial gen abundance in both sand and clay fractions. Total DNA content was found positively correlated to SOC and labile carbon content, recalcitrant carbon proportion and normalized enzyme activity but negatively to soil respiration, in sand fraction only. Our findings suggested that carbon accumulation and stabilization was prevalent in both sand and clay fraction, only the coarse sand fraction was found responsible for bioactivity dynamics in the rice soils. Thus, soil carbon sequestration was primarily by formation of the macro-aggregates, which again mediated carbon stability and bioactivity in the rice soils under long term rice cultivation.