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Transformation of marine sediment to paddy soil: Primary marine, lacustrine, and land plant lipids

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More than fifty percent of the world's population feeds on rice. The continuous population increase and urban sprawl leads to an ever-increasing demand for new rice cultivation area, in particular China. For centuries suitable coastal areas in China have been exploited for land reclamation, i.e. conversion of coastal marine and lacustrine marshlands into rice paddy fields. Flooded rice paddies are considered one of the major biogenic sources of methane into the atmospheric. Methane is thought to be about 30 times more efficient as greenhouse gas, when compared to carbon dioxide. Overall, rice fields are assumed to contribute app. 10–25% to global CH4 production. It is thus paramount importance to study the effects of increasing rice cultivation and land reclamation in China. For global carbon cycle investigation, it is crucial whether paddy soils, due to their large extent and higher carbon turnover, serve as carbon (CO2) sinks or sources.

Here we present results from a chronosequence study of paddy soils with different and well known starting dates of cultivation, in the Zhejiang province (Yangtze River delta) by land reclamation through the building of protective dikes over the past 2000 years. Two end members of natural sediments subjected to land reclamation, a marine tidal mudflat in the Yangtze delta and a coastal lake, represent the substrate on which the paddy soil evolution started. Dike systems were constructed 2000, 1000, 700, 300, 100, and 50 years before present. We are thus able to follow the evolution of rice paddy soils developed on marine sediments using eight well defined tie-points. This chronosequence is then used for assessing the relative proportion of primary marine or lacustrine organic matter preserved in present day soils and to identify the amount and composition of organic matter added since cultivation started. Paddy soil management introduces rice plants debris and exudates as well as rice-associated microbial biomass (covered in a separate contribution) into soils. Management practises involve burning of rice straw on fields, thus adding biomass combustion residues that either may be particularly stable (e.g. PAH) or highly reactive (alkenes resulting from dehydration of alcohols).

Bulk parameters reveal that the five field replicates taken at each site are highly compatible, with standard deviations usually between 0.1 to 5.0 % depending on site and/or parameter. This is better than expected and proves that the samples are representative for each cropping site. The n- and isoalkane composition also proved to be very systematic and reproducible. The marine end-member shows a broad n-alkane envelope from nC13 to nC40, with a maximum of nC31 and low abundance of nC17 and nC32+ alkanes. The lacustrine site also reveals a broad n-alkane envelope and a maximum of nC31 but shows higher relative abundance of nC17, nC23 and nC25 alkanes in addition to a C20-HBI. These biomarkers for aquatic macrophytes and diatoms were also found in minor proportions in paddy soils due to flooding with lacustrine water. Paddy n-alkane patterns were dominated by nC29 which systematically increased in abundance for older paddy soils. Paddy soil n-alkane patterns from the chronosequence are similar and related to the marine pattern. Combustion of rice straw on the field is a common management practise for nutrient return to soils. A rice straw ash sample collected in the field revealed a series of nC13 to nC37 n-alkane/alkene doublets with low odd over even predominance. As no alkenes were found in paddy soils, very fast diagenetic conversion of reactive alkenes must occur. Soil organic matter and aliphatics content increased six fold over a cultivation time of 2000 years, identifying paddies as CO2 sinks in the global carbon cycle.