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Dissolved carbon and nitrogen dynamics in paddy fields under different water management practices and implications on green-house gas emissions

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The alternation of oxidizing and reducing conditions in paddy soils results in considerable complexity in the biogeochemical cycling of elements and their interactions, influencing important soil processes. Water management practices may play an important role in controlling the loss of nutrients from rice paddies to surface and subsurface waters, as well as soil organic matter (SOM) stabilization and the emission of green-house gases (GHG) such as methane and nitrous oxide. The aim of this study was therefore to evaluate the interaction between changes in soil redox conditions and element cycling in temperate paddy soils as a function of different water management practices.

The research was carried out within an experimental platform (1.2 ha) located at the Rice Research Center of Ente Nazionale Risi (Castello d'Agogna, PV, NW Italy) where three water management practices are being compared with two plots for each treatment. These included (i) rice cultivation under traditional submerged conditions (FLD); (ii) seeding under dry soil conditions and flooding delayed by about 40 days (DRY); (iii) seeding under dry soil conditions and rotational irrigation (IRR). Surface and subsurface (25, 50 and 75 cm) water samples were collected at regular intervals over the cropping season from V-notch weirs and porous ceramic suction cups installed in each plot, and subsequently analyzed for DOC, SUVA, Fe(II), ammonium and nitrate-N. Moreover, methane and nitrous oxide fluxes were measured in situ by the closed-chamber technique.

DOC concentrations in soil solutions were generally higher in FLD and DRY treatments with respect to IRR throughout the cropping season. Higher DOC contents after field flooding in FLD and DRY treatments also corresponded with greater concentrations of reduced Fe, higher SUVA values, lower Eh values and higher pH values, suggesting that desorption of more aromatic, mineral-associated SOM could be responsible for the observed increase in DOC. These trends were not observed in the IRR treatment. The differences in DOC contents and in Eh trend between treatments could possibly explain the increasing trend in cumulative methane emissions in the order IRR«DRY<FLD. Water management practices also resulted in different N dynamics, principally resulting from their influence on nitrification-denitrification processes, losses to surface waters and leaching. Under the predominantly reducing conditions of the FLD treatment, limited nitrification resulted in lowest nitrate concentrations in solution at all depths. However, when flooding was delayed (DRY) or substituted with rotational irrigation (IRR), greater nitrification and nitrate leaching along the soil profile were observed possibly resulting in important N losses. Differences in soil redox conditions between treatments also influenced nitrous oxide emissions with IRR showing the highest fluxes and cumulative emissions.

The results of this field study show that alternative water management practices may have important implications on nutrient availability, fertilizer efficiency, losses of DOC and nitrates to surface and subsurface waters, soil C stocks as well as GHG emissions. Suggesting alternative management practices therefore requires a holistic evaluation of the extent of all the processes involved.

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