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Water fluxes and balance in a toposequence of rice paddies in Northern Italy

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Paddy soils are the most widespread example of hydromorphic soils having an economic value. They are present in land devoted to rice growing, where submersion and waterlogging conditions occur during all or part of the cropping season. Rice is cropped on about 160 million hectares worldwide, with a production close to 700 million tons. European production is quantitatively modest (about 3 million tons of paddy rice) and concentrated in a few areas including Italy, which is the largest European producer with over half of the total production grown on an area of 220 thousand hectares, predominantly located on the left bank of the Po River (Northern Italy). This area is characterized by many peculiarities: a historical abundance of surface water, an ancient and extensive network of unlined irrigation and drainage channels, a complex geo-morphologic and hydro-geologic structure formed by wide fluvioglacial conoids (Pleistocene) cut by river valley lowlands (Holocene), and the presence of one of the largest aquifers in Europe. Phreatic water level varies in space and time and it rises up to the soil surface in some areas as a consequence of the summer flooding of paddies. Soils are generally loam/sandy-loam developed on sandy alluvial sediments, with coarser textures occurring along river valleys and finer granulometries in the older (paleo)soils in the northernmost area. Thus, soils are generally moderately permeable, and only the peculiar agricultural practices adopted in rice cultivation (mainly flooding) lead to the formation of a dense and low permeable layer below the ploughed horizon, which strongly influences vertical percolation. Additionally, in paddy areas, local topography activates lateral water exchanges in the unsaturated zone. In particular, in a toposequence of paddy fields, lower paddies may receive seepage and runoff from paddies located upslope. This study (funded by Fondazione Cariplo, grant n° 2014-1260), investigates the hydrology and water use efficiency of a group of four paddies located in Northern Italy and characterized by different elevations (A $\approx$ B > C > D) during two years (2015-2016). Water fluxes and storages were quantified by coupling field monitoring and hydrological modelling. The main outcomes are: i) the Darcy's law, applied considering lab-measured soil hydraulic conductivities of the most impervious horizons and field monitored data (soil profile description, ponding water and groundwater levels), is a valuable tool for the estimation of vertical percolation in flooding conditions; ii) significant variations of vertical percolation in time may be observed even for the same paddy due to fluctuations in groundwater table depth; iii) surface and subsurface lateral water exchanges activated by the slope provide extra water supply to paddies at the bottom of the toposequence; iv) none of the paddies in a toposequence is representative of the whole area; thus, the spatial scale of monitoring must be enlarged when computing water balances of rice areas.