On the Role of Topography in the Water Use Efficiencies of Adjacent Rice Paddies: a Case Study in Northern Italy

S. Cesari de Maria[1], A.Mayer[1], M. Rienzner[1], E.A. Chiaradia[1], F. Buarnè[1], S. Silvestri[2], M. Romani[2], C. Gandolfi[1], A. Facchi[1]

[a] Department of Agricultural and Environmental Sciences (DiSAA), Universitá degli Studi di Milano, Milan, Italy

[b] Centro Ricerche sul Riso, Ente Nazionale Risi (ENR), Castello d'Agogna (PV), Italy

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EXTENDED ABSTRACT

Around 75% of the global rice production is provided by irrigated rice, which requires up to 2-3 times more water per hectare than other irrigated crops. Due to the high water requirements of flooded rice, irrigation efficiencies ranging between 20% and 60% are reported in the literature. However, there is evidence that water performance indicators may increase with increasing spatial scale because of water reuse. As a consequence, the overall efficiency of a group of rice paddies might be higher than what estimated on a field-level basis.

This study investigated the water balance terms and the water use efficiencies of a group of adjacent rice paddies characterized by different elevations, with a focus on both the single fields and on the group of rice paddies. The experiment involved a two-year monitoring activity conducted at the "Cerino Farm" (Semiana, PV, Northern Italy) during the agricultural seasons 2015 and 2016. Four rice fields (A, B, C and D) were instrumented with devices measuring water inflows, water outflows, water levels, soil moisture and groundwater depths. Alongside continuous measurements of water dynamics, we collected soil samples in each field to measure the retention curves of different horizons of soil profiles and to determine the saturated hydraulic conductivity (K_s) of the hardpan. Only fields A, C and D were adjacent, while B was separated by a deep drainage channel. Elevations were in the order A ≈ B > C > D. Groundwater depths at the site were within 1 m from the soil surface during the flooding period.

Water balances of year 2015 were computed at a daily time step from seeding till harvest. Irrigation (Irr), tail water drainage (D), rainfall (R) and changes in water storage (ΔS) were obtained from the collected measures, whereas crop evapotranspiration (ET) was computed by multiplying the reference evapotranspiration (ETo) by site-specific rice crop coefficient (K_c) determined in a previous study. The sum of seepage and percolation (SP) was obtained as the residual term of the water balance. During the flooding periods, SP of A tended to be equal to the percolation flux computed by applying the Darcy's law (P_{Darcy}) considering the laboratory measured K_s. The very good agreement confirmed the accuracy of both the water balances and the K_s measurements, and suggested that no subsurface lateral fluxes occurred in A. On the other hand, SP term of C and D deviated from P_{Darcy}, indicating the occurrence of seepage fluxes. Water amounts higher than 2,500 mm were required by A, whereas water inputs to C and D were less than 900 mm. The lower values of C and D were not only due less permeable soils (e.g., K_s-C = 0.12 cm/d against K_s-A = 1.02 cm/d), but also to the contribution given by lateral fluxes, which provided extra water inputs to C and D not measured by inflow meters. Water use efficiencies (WUE), i.e. ET/(R+I-D), of A, B, C and D amounted to 0.22, 0.28, 0.66 and 2.75, respectively. However, considering fields A, C and D as a group, the overall efficiency increases to 0.38 due to the subsurface lateral exchanges between fields that were promoted by the topographic gradient.

The results of the study highlights not only the relevance of the scale-effects when considering the efficiency of flooded rice systems, but also stresses the role of the topography in planning the spatial distribution of cropped fields.

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Key words: Water balance; Darcy's law; Percolation; Seepage; Water use efficiency