



Effect of irrigation modernization on water and nitrogen use efficiency

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The growing pressure on water resources and water quality conservation demands a better and more efficient use of irrigation water and fertilizers, particularly nitrogen (N). Irrigated agriculture is the main water consumer, contributing to the reduction of available water resources and the degradation of water quality by contaminants exported in drainage waters. In Spain, the 1.1 Mha on-going modernization program (from surface to pressurized systems) prompts for the assessment of its impact on water availability and quality. Our goal was to analyze the changes in water and N use in the Almodóvar Irrigation District (Spain) derived from its modernization from traditional flood irrigation (T-Irr) to sprinkler irrigation (S-Irr). Irrigation (I), actual crop evapotranspiration (ET_a , calculated through a soil water balance), yield (Y) of the main crops (alfalfa, cereals (wheat and barley) and corn), fertilizer N (N_F) and crop N uptake (N_U) were obtained for the pre-modernization (T-irr) and post-modernization (S-Irr) scenarios. The I was 31% lower in S-Irr (20.7 Mm^3/yr) than in T-Irr (30.2 Mm^3/yr) ($P < 0.05$), but modernization increased ET_a only by 7% (26.1 and 24.3 Mm^3/yr in S-Irr and T-Irr, respectively) ($P > 0.05$). After modernization, the irrigation water use efficiency ($WUE_I = Y/I$) increased in corn (1.21 to 1.88 kg/m^3), alfalfa (1.38 to 1.87 kg/m^3), and cereals (1.71 to 3.63 kg/m^3), whereas the consumptive water use efficiency ($WUE_{ET} = Y/ET_a$) increased in corn (1.36 to 1.78 kg/m^3) and slightly decreased in alfalfa (1.76 to 1.46 kg/m^3) and cereals (1.31 to 1.14 kg/m^3). After modernization, N_F applied to corn decreased from 431 to 338 $kg N/ha$, yield increased from 10.2 to 13.9 Mg/ha , and nitrogen use efficiency ($NUE_y = Y/N_F$) increased from 23.8 to 41.1 $kg DM/kg N$. Alfalfa yield (mean of 14.2 Mg/ha), alfalfa N_F (47 $kg N/ha$), cereal yield (5.1 Mg/ha) and cereal NUE_y (41.6 $kg DM/kg N$) were similar in T-Irr and S-Irr, but cereal N_F decreased from 154 to 110 $kg N/ha$. Reductions in N_F after modernization were due to the ability of sprinkler irrigation to apply water and N timely, but also to increases in fertilizer price. Crop N uptake relative to N_F ($NUE_u = N_U/N_F$) significantly increased after modernization in corn (38% in T-Irr and 66% in S-Irr) and alfalfa (73% to 93%), but remained fairly constant in cereals (72% to 77%). Overall, modernization reduced the water diverted for irrigation by 9.5 Mm^3/yr , while the foreseeable increases in ET_a were not presently observed, and increased water and nitrogen use efficiency, particularly in corn. The lower I and higher WUE should increase N concentrations in drainage waters. In contrast, the lower N_F and higher NUE_u should decrease N losses in drainage waters, counteracting the previous effect. Therefore N concentrations and loads in irrigation return flows and the concomitant N concentrations in the receiving water bodies depend on the conjunctive water and N management and should be assessed on a case by case basis.