Salt balances in a pre- and post-modernized irrigation district

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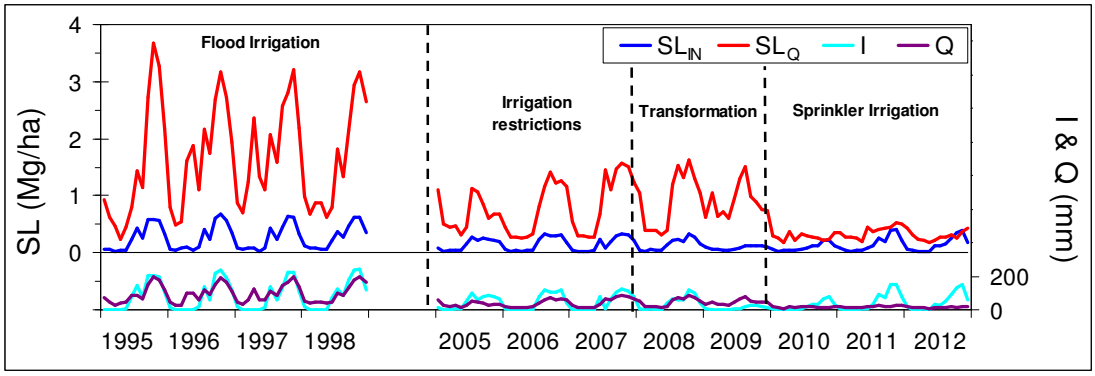
Salt loads in irrigation return flows (IRF) may salinize the receiving water bodies and become a relevant environmental problem when they originate from saline areas. In contrast, when the amount of salts removed from an irrigated area is smaller than the amount of salts incorporated (mainly with irrigation water), the soil and water resources may become salinized. Thus, a sensible equilibrium must be achieved between salts leaving and entering the system to cope with these potential on-site and off-site salinization problems.

Typically, pre-modernized and inefficient flood-irrigated districts have higher IRF volumes and salt loads than post-modernized and efficient pressure-irrigated districts. Accordingly, the on-going irrigation modernization process in Spain (converting 1.1 Mha of traditional surface irrigation into pressurized systems) should have a positive impact on the salinity of the water bodies receiving those IRF. The aim of this work was to quantify the volumes, salt concentrations and loads in the IRF of La Violada Irrigation District (VID; about 4200 irrigated ha) before (1995-98 and 2005-07), during (2008-09) and after (2010-12) its modernization from flood to sprinkler irrigation. Under flood irrigation, the main crops were corn, alfalfa and winter cereals, with years 2005-07 showing a lower cropping intensity due to irrigation restrictions and the impending transformation works. The first year after modernization (2010) was dominated by winter cereals, followed by a more intensive cropping (2011-12) with the introduction of double crops (cereal-corn mainly) along with corn, alfalfa and winter cereals.

The daily flows measured in La Violada Gully (VG), the only surface drainage exit of VID, were combined with the daily measurements of the electrical conductivity [converted into Total Dissolved Solids (TDS) by regression] to obtain the daily salt load outputs from VID (SL_Q). The volumes of precipitation (P), irrigation (I), and La Violada canal seepage (CS) along with their concentrations measured periodically, allowed to establish the salt load inputs into VID ($SL_{IN} = SL_I + SL_P + SL_{CS}$). From these data, the net salt load (SL_{net} = -Salt Balance) was calculated monthly as $SL_{net} = SL_Q - SL_{IN}$ and related to the cropped area, types of crops, and hydrologic indices.

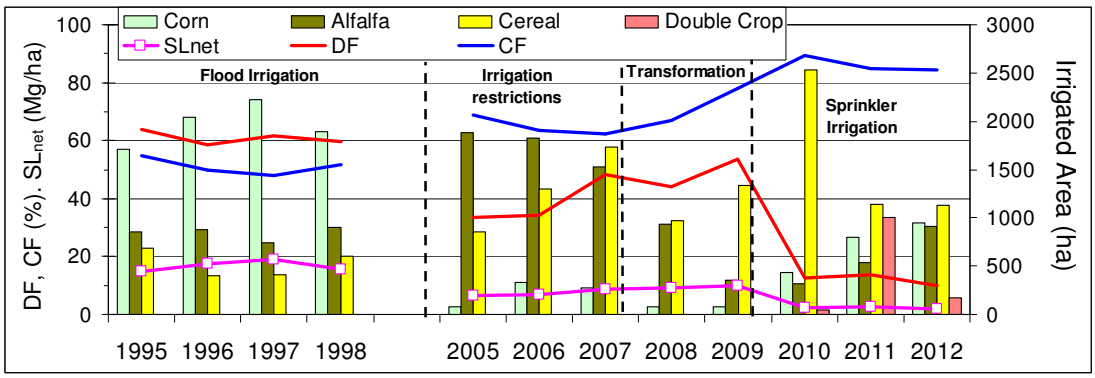
The transformation of VID from flood to sprinkler irrigation significantly decreased the annual water [from 10017 m^3/ha (1995-98) to 4837 m^3/ha (2010-12)] and salt [(SL_{IN} = 3.2 Mg/ha and 1.6 Mg/ha, respectively)] inputs and, particularly, the annual water (IRF = 8965 m^3/ha and 1009 m^3/ha, respectively) and salt (SL_Q = 19.9 Mg/ha and 3.8 Mg/ha, respectively) outputs;

whereas the TDS of IRF remained almost constant (1.7 g/l and 1.8 g/l, respectively) because the main salt source in this district was gypsum dissolution. Accordingly, SL_{net} decreased from 16.7 Mg/ha (flood irrigation, 1995-98) to 2.2 Mg/ha (sprinkler irrigation). In the lower cropping-intensive flood irrigated years 2005-09 SL_{net} was 8.3 Mg/ha. The hydrologic indices were also significantly affected by irrigation modernization, with lower drainage and higher consumptive fractions under sprinkler than under flood irrigation.



VID monthly average salt load inputs (SL_{IN}) and outputs (SL_Q), irrigation (I) and outflow (Q).

Therefore, although SL_{net} depended on the cropping pattern, it was mostly affected by the irrigation system. Under flood irrigation, salt leaching ($SL_{net} > 0$) took place mainly during the irrigation season due to excessive irrigation depths. Under sprinkler irrigation, salt leaching took place mainly during the non-irrigation season due to winter rains and lower ET, with slightly negative SL_{net} values (i.e., potential risk of soil salinization) obtained occasionally during the irrigation season (July 2012).



Net salt loads (SL_{net}), drainage fraction (DF), consumptive fraction (CF), and irrigated area for main crops in VID.

These results indicate that the VID modernization significantly decreased IRF salt loads without any significant increases in TDS because of the gypsum-rich soils in this area. However, in other gypsum-free areas TDS could be higher and the off-site benefits lower. Although SL_{net} was very low in some summer months, pointing to a potential risk of soil salinization and foreseeable salinity effects on sensitive crops, the overall annual SL_{net} values were positive, indicating that the long-term salinization of the sprinkler-irrigated VID is negligible.