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ORIGINAL ARTICLE

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Drought as an agri-environmental determinant of irrigation land: the case of Bardenas (Spain)

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Abstract Irrigated agriculture is causing certain deterioration of the quality of rivers and aquifers. The objective of this study is to analyse the agri-environmental repercussions caused by climatic changes in a typical irrigated land in the Ebro valley (Spain). The irrigation efficiency and agri-environmental impact in a basin of irrigated land (95 ha) were compared for two hydrological years with different pluviometry [October 2000/September 2001 (526 mm/year) vs. October 2004/September 2005 (211 mm/year)]. For this end, water balances were carried out in every plot and the quantity and quality (salinity and nitrates) of the water circulating through the drainage of the basin were gauged. The results indicate that in 2004/2005 farmers adjusted the irrigation doses better on each irrigation occasion, thus diminishing the fraction of drainage of the same (50% vs. 31%) and increasing the consumptive water use efficiency (56% vs. 79%). Nevertheless, the drought of 2004/2005 determined inappropriate irrigation management as the crops suffered a greater hydric deficit (3% vs. 23%). In 2004/2005, drainage waters presented higher electric conductivity (0.92 dS/m vs. 0.94 dS/m) and smaller nitrate concentration (96 mg/l vs. 74 mg/l). Last year, 55, 54 and 65% less of water, salts and $N–NO_3^-$, respectively, were exported in the drainage. The lesser environmental impact in the year 2004/2005 was influenced by more appropriate use of water and agrichemical resources. Nevertheless, it is necessary to continue optimizing agricultural practices, mainly irrigation and fertilization, in order to minimize nitrate pollution and to confront years of drought.

Keywords Water · Irrigation · Fertilization · Pollution · Salt · Nitrate

Introduction

Efficiency in the use of irrigation water and diffuse contamination caused by irrigation are topics of great concern in semi-arid countries which, like Spain, have limited water resources subject to progressive deterioration in quality. Irrigated agriculture, like any other activity which makes use of water and returns it in part to the natural environment, contaminated to a greater or lesser degree, causes certain deterioration in the quality of the water of rivers and aquifers.

In the Ebro basin (Spain), during recent decades, a series of studies have been undertaken designed to quantify irrigation efficiency and the environmental impact (salinization and contamination of the drainage waters by nitrates) of small irrigation basins (between 100 and 5,000 ha).

On this scale of study, representative values of the Ebro basin verify low-to-moderate irrigation efficiency in areas with flood irrigation on inappropriate soils (51%), moderate-to-high efficiency in areas with flood irrigation on appropriate soils (79%) and high efficiency in areas with highly modernized sprinkler irrigation (94%) (Causapé et al. 2006).

Saline areas which present low irrigation efficiency and nitrogen fertilization can export up to 20 Mg/ha of salts and 200 kg N–NO_3^-/ha per year. However, smaller salt (3 Mg/ha·per year) and nitrogen loads (25 kg N–NO_3^-/ha·per year) exported in areas with high irrigation and nitrogen fertilization demonstrate the possibility of reducing the environmental impact of the most contaminating irrigation districts.

Many of the studies undertaken in order to identify and quantify the main environmental problems of irrigation land have been carried out by monitoring a single hydrological year, which has hindered analysis of the effect of the climatic and agronomic seasonal variability on the problems mentioned. This work compares the external environmental impact on a small hydrological irrigation basin in two hydrological years (October 2000/September 2001 and October 2004/September 2005) which were very different in pluviometry, availability of water for irrigation, crop patterns and fertilizer management.

Description of the area and years of study

The basin drained by D-XIX-6 ditch (94.5 ha) is located in the Irrigation District no. V (CR-V) of Bardenas (Aragón, Spain). It is located in a small valley originated from the Miraflores glacis towards the alluvial of the River Riguel. The soil developed on the glacis (calcisol) occupies 67% of the surface of the basin and it is characterized as stony, shallow soils (presence of petrocalcics) which have a low water holding capacity (WHC = 85 mm; Causapé et al. 2004). On the other hand, the soils developed on the alluvial (fluvisols—33% of the surface) do not have stones or superficial petrocalcic horizons limiting their depth; so they have a larger WHC (176 mm; Causapé et al. 2004).

The annual average precipitation in the area is 419 mm, registered mainly in the spring and summer seasons. Nevertheless, the annual pluviometric variability is high, as is illustrated in the differences between the two hydrological years studied (2000/2001 and 2004/2005). The precipitation in 2000/2001 was 25% higher than the historical average while 2004/2005 was an extremely dry year in which the annual precipitation (211 mm) was only half of the historical average and 40% of the precipitation registered in 2000/2001 (526 mm).

As for the evapotranspiration reference (ET_0), the historical average is 1,084 mm/year reaching maximum values in summer. The ET_0 of the hydrological year 2000/2001 (1,093 mm) was similar to the historical average while for the year 2004/2005, the annual ET_0 was 25% higher (1,363 mm).

A majority of the basin (95% of the surface) was occupied by flood-irrigated plots while the rest of the surface of the basin (5% of the total surface) was occupied by barren land, roads, canals, drainages and farm sheds. The irrigation water was of good quality [electric conductivity (EC) = 0.3 dS/m and [NO_3^-] < 2 mg/l] proceeding from Yesa reservoir (River Aragon, Central Pyrenees).

The drought of 2004/2005 reduced the capacity for irrigation considerably in the CR-V (6,300 m^3/ha in 2004/2005 as opposed to the 11,000 m^3/ha in 2000/2001) and this caused changes in crop pattern planning on the part of the farmers. Thus, whereas in 2000/2001 the basin was almost completely occupied by corn (47% of the surface area) and alfalfa (46% of the surface area) with a small percentage of winter cereal (1%) and leeks (1%), in 2004/2005, the surface areas of alfalfa (37%) and especially of corn (11%) were noticeably smaller, while the percentage of crops needing less irrigation was higher (winter cereal—24%, sunflower—8%, grass—7% and peas—2%). The surface area left fallow, non-existent in 2000/2001, accounted for 7% of the surface area of the basin in 2004/2005 (Fig. 1).

There were also significant changes between the two periods studied as regarding water management. While in 2001, the CR-V billed irrigation water to its farmers for the irrigated surface area, and the farmers irrigated using a rotation surface irrigation system, in 2005, the CR-V used a binomial rate (payment for irrigated surface area and water consumption) and the farmers requested the date and volume of each irrigation application (on-demand surface irrigation system). These water management changes were made in order to achieve a more rational and efficient use of the water.

Objectives

This work analyses and quantifies the external environmental repercussions caused by irrigation in two hydrological years with strong climatic and agronomic contrasts. To be precise, an analysis is made of the agri-environmental effects induced by irrigation in the basin of the D-XIX-6 drainage in two hydrological years (2000/2001 and 2004/2005) with different precipitations, crop patterns and water management.

Methodology

The Soil Water Balance computer application (BAS) was used in each plot of the basin drained by the D-XIX-6 ditch in the hydrological years 2000/2001 and 2004/2005. The Soil Water Balance application, described thoroughly in Causapé et al. (2004), is based on the equation:

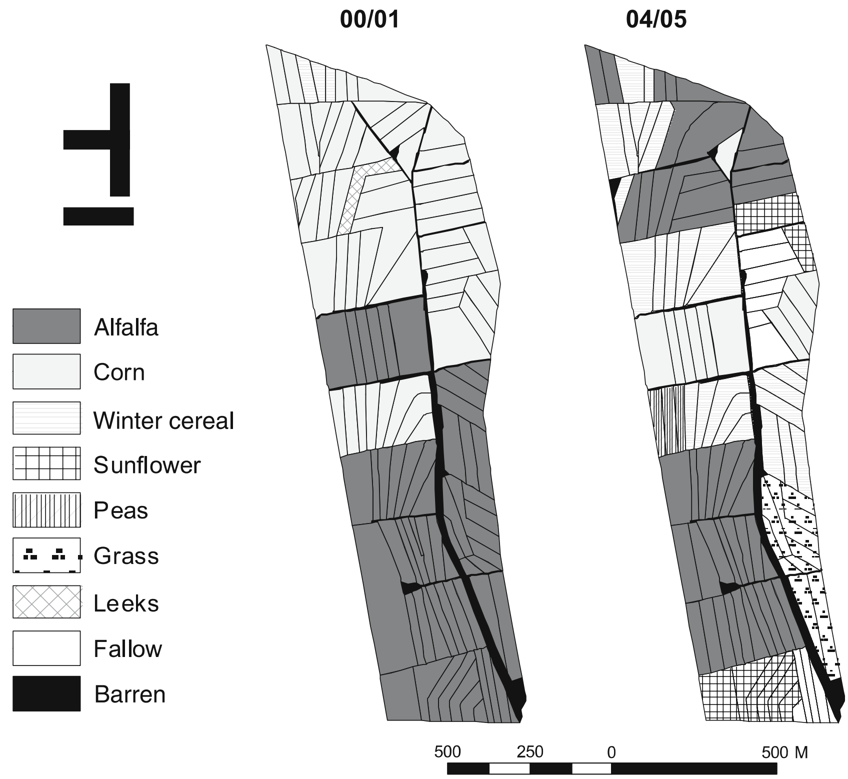

Fig. 1 Crop pattern in D-XIX-6 basin in 2000/2001 and 2004/2005 hydrological years

$$(I + P) - (\mathrm{ET_a} + D) = \Delta W$$

where the water apported by irrigation (I) and precipitation (P) minus the output through actual evapotranspiration ($\mathrm{ET_a}$) and drainage (D) equals the soil water variation (ΔW).

The program assumes that all irrigation water and rain infiltrates into the soil. This approach is valid for the study area because the plots are terraced and limited by ridges which impede surface runoff.

The daily irrigation and precipitation volumes for each plot were obtained from the CR-V database and from the meteorological station which the SIAR network has in the study area (http://www.oficinaregante.aragon.es). The daily $\mathrm{ET_0}$ (http://www.oficinaregante.aragon.es), together with crop coefficients (K_C) and agronomic information of the area (CHE 2004), enabled the calculation of the potential daily evapotranspiration ($\mathrm{ET_C}$) in each plot:

$$(\mathrm{ET_C} = \mathrm{K_C} \times \mathrm{ET_0}).$$

For the days and plots without cultivation, a coefficient of the bare soil was considered following the methodology proposed by Allen et al. (1998) to estimate the initial K_C of the crops.

Therefore, BAS generated water balances for each plot in the basin estimating soil humidity, the actual evapotranspiration and daily drainage, based on the $\mathrm{ET_C}$, of the soil water parameters ($\mathrm{WHC_{calcisol\text{-}plots}}$ = 85 mm and $\mathrm{WHC_{fluviosol\text{-}plots}}$ = 176 mm) and the initial humidity (humidity on 1 October) which, if unknown, was estimated at half its WHC.

On the other hand, the quantity and quality (salts and nitrate) of the water circulating through the D-XIX-6 ditch were measured. For this, a flume gauging station was installed at the outlet of the D-XIX-6 drain, equipped with an electronic water level recorder (Thalimedes) and an automatic water sampler (ISCO 3700C).

The electronic water level recorder was programmed to read water levels (h) every 15 min. These readings were converted to flow (Q) using the flowmeter equation:

$$Q(\mathrm{m^3/s}) = 1.728[h(\mathrm{m}) + 0.003469]^{1.624}.$$

The autosampler was programmed to take a sample of daily water. These samples were collected every 21 days and transported to the laboratory, where the electric conductivity at 25°C was determined and its nitrate concentration ($[NO_3^-]$) was measured by colorimetry with the Autoanalyser 3 equipment.

Also, in several water samples of the D-XIX-6 drainage, the dry residue (DR) was decided and the concentration in bicarbonate ($[HCO_3^-]$) necessary for the estimate of the total of dissolved solids (TDS) was calculated as:

$$\mathrm{TDS(mg/l)} = \mathrm{DR(mg/l)} + \tfrac{1}{2}\left[\mathrm{HCO_3^-}\right]\mathrm{(mg/l)};$$
(Custodio and Llamas, 1983).

The transformation equation of EC to TDS was the following:

$$\mathrm{TDS(mg/l)} = 749\mathrm{EC(dS/m)} + 41;\ R^2 = 0.96.$$

Irrigation management indices

To evaluate water use in the basin, the indices of consumptive water use efficiency (CWUE) and the hydric deficit (HD) have been calculated for each cultivated plot during the vegetative cycle of the crops.

Consumptive water use efficiency is defined as the percentage of the crop's water which has actually evapotranspired (ET_a) over the total water available for this evapotranspiration (irrigation—I, precipitation—P and available water present in the soil at the beginning of the vegetative cycle—AW_{sowing}). This index refers to the degree to which the water available for the crops is used.

$$\mathrm{CWUE} = \frac{\mathrm{ET_a}}{I + P + \mathrm{AW_{sowing}}} \times 100.$$

The HD is defined as the percentage of potentially evapotranspirable water which did not evapotranspire because of the absence of available water in the soil, over the potentially evapotranspirable water. The HD evaluates to what extent the hydrological needs of the crops were not satisfied.

$$\mathrm{HD} = \frac{\mathrm{ET_C} - \mathrm{ET_a}}{\mathrm{ET_C}} \times 100.$$

These indices depend on natural (climate and soil) and antropic factors. If the rains do not exceed the field capacity of the soils (null drainage) and there are no important rains in the last days of the vegetative cycle, "ideal" irrigation management would make it possible for a CWUE of 100% and an HD of 0% to be achieved.

Finally, drainage irrigation fraction (D_IF) was calculated as the volume of water drained through irrigation events ($D_I = \sum D$ of each plot on irrigation days only), with respect to the volume of irrigation water applied (I).

$$D_IF = \frac{D_I}{I} \times 100.$$

This index refers to the "loss" of irrigation water through deep percolation, so that in an area with low leaching necessities, efficient irrigation management will be determined by low D_IF values.

Nitrogen management index

The nitrogen fertilization efficiency of the basin (NE) was calculated by means of the relationship between the theoretical necessities of nitrogen fertilization of the crops (NF) and the nitrogen applied by the farmers (NA).

$$\mathrm{NE} = \frac{\mathrm{NF}}{\mathrm{NA}} \times 100.$$

The nitrogen applied to each plot was taken from surveys carried out on all the farmers in the basin while the needs of nitrogen fertilization were obtained from the extractions of N of each crop and the average production in Aragón (Spain) (Orús et al. 2001). The fertilization needs of the alfalfa and pea crops, which are able to fix nitrogen symbiotically, were considered to be 30 and 20 kg N/ha·per year, which corresponds to the maximum values allowed by the effective legislation of Aragón (Boletín Oficial de Aragón 2004) concerning the application of nitrogen fertilizers in areas vulnerable to nitrate contamination. Although the index does not take into account aspects such as the N accumulated in the soil or introduced with the irrigation water, it is considered to be an appropriate index for the objectives of this study.

Results and discussion

Water balance in the soil

The largest amount of water contributed to the basin was by way of irrigation in both the years studied (Table 1). The average irrigation application for the whole basin in 2005 was 49% lesser to that of 2001 (570 mm compared to 1,112 mm). This important difference was due to a great degree to the crop patterns made necessary by the drought.

In alfalfa, the main crop in both years, an average of 13,949 m^3/ha was applied in 11 irrigation applications in 2001, while in 2005, the average irrigation application was only 9,224 m^3/ha, distributed between 8 irrigation applications. Thus the unitary volume for irrigation in 2005 (1,153 m^3/ha per irrigation event) was 9% lesser to that of 2001 (1,268 m^3/ha per irrigation event). On the other hand, for corn, the same number of irrigation applications was carried out in both years (eight irrigation events); however, the average irrigation application in 2005 (8,199 m^3/ha) was 21% lesser to that of 2001 (10,363 m^3/ha). These data indicate that in 2005 the volume of applied unitary irrigation decreased for both alfalfa and corn. Also, in 2005, the farmers decided to irrigate with less frequency and to do without the last irrigation applications for the alfalfa, sacrificing the last harvest in favour of saving the corn production.

Table 1 Soil water balance during hydrological years 2000/2001 and 2004/2005: volume of irrigation (*I*), precipitation (*P*), actual evapotranspiration (ET_a), drainage (*D*) and the difference between inputs and outputs (ΔW)

Hydrological year	Inputs				Outputs				Input–output	
	I		*P*		ET_a		*D*		ΔW	
	Dam^3	mm	Dam^3	mm	Dam^3	mm	Dam^3	mm	Dam^3	mm
2000/2001	1,055	1,112	499	526	816	860	717	755	22	23
2004/2005	539	570	200	211	629	665	155	164	−45	−48

The water introduced by rain was in both years approximately half that introduced by irrigation. Nevertheless, in 2004/2005, the contribution of the water from precipitation decreased by 60% compared to 2000/2001.

As for outputs, evapotranspiration was the main contributor in both years. In 2004/2005, water evapotranspiration in the basin decreased by 23% (from 860 to 665 mm) compared to 2000/2001. The presence of crops with smaller water demands in 2004/2005 was counteracted by a greater ET_0 that year (1,093 compared to 1,363 mm) causing an ET_C similar to that of 2000/2001 (880 compared to 882 mm). Therefore, the decrease in the ET_a for 2004/2005 compared to that of 2000/2001 was mainly determined by a greater HD in the soils.

The difference in the volume of water drained in both years was even larger. The drainage in 2004/2005 (164 mm) was 78% lesser to that of 2000/2001 (755 mm) due mainly to the considerable reduction of the volumes introduced by irrigation and rain.

The slight difference estimated between the input and output (23 and −48 mm) regarding the value of the remaining components of the balance demonstrate that in an annual balance of this type, the error in the estimate of the initial soil humidity as half of the WHC of the soil is not significant, and therefore, it justifies the lack of measurement of the initial soil humidity in each plot.

Irrigation quality

The CWUE in 2004/2005 was 79% compared to 56% in 2000/2001; in 2004/2005, a larger percentage of the water available for the crops was used in evapotranspiration. This percentage increased partly because the crops suffered conditions of greater hydric stress (irrigation deficit), such that in 2004/2005, the average HD of the basin stood at 23% compared to only 3% in 2000/2001. As an extreme case in 2005, mention must be made of a plot of peas which did not get watered (CWUE = 99.8%, HD = 68%). In contrast, in the same year, the most irrigated plot was of alfalfa on alluvial soil which scarcely obtained an HD of 6% and whose CWUE ascended to 96%. The limited HD of this alfalfa plot on fluviosol soils (HD = 6%) contrasts with the higher HD of the rest of alfalfa plots located on calcisol soils (HD = 21%) emphasizing the importance of the soil factor. Also, for the same year, the average HD of the corn plots on calcisol soils was less (14%), thus demonstrating the farmers' preferences to save the corn crop at the cost of relative losses in the annual alfalfa production.

Fortunately, the change in flood irrigation from the rotation surface system to on-demand surface system allowed the farmers a greater margin for action, in such a way that despite the water shortage in 2004/2005, they increased irrigation frequency in the corn plots in fluviosol soils from every 14 days in 2001 to every 13 days in 2005. In the same year, they maintained higher intervals between irrigation applications for alfalfa plots on calcisol soils (every 16 days), even higher if the alfalfa was on fluviosol soils (every 19 days).

In the 2 years of study, the D_IF presented a parallel evolution (Fig. 2). At the height of the irrigation period (from June to September), the D_IF reached its minimum values (44% in 2000/2001 and 21% in 2004/2005) indicating that irrigation in this period is more efficient than at the beginning of the irrigation period (from March to May). This is due to the fact that during the summer, before each irrigation application, the soil contains very little water available for plants and so the flood irrigation application, always above the WHC of the soil, accumulates in the soil to a greater degree than in

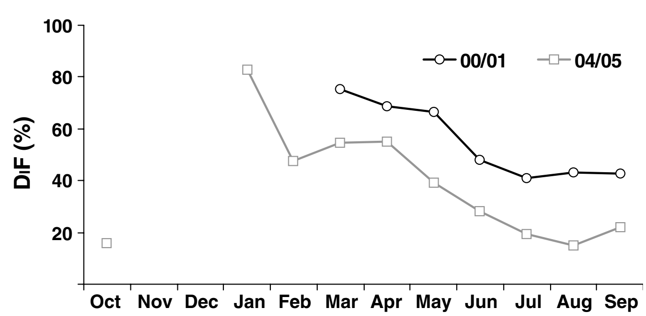

Fig. 2 Monthly drainage irrigation fraction (D_IF, %) in D-XIX-6 basin in 2000/2001 and 2004/2005 hydrological years

irrigation applications in the rest of the year, when the soil is more humid and it reaches its field capacity more quickly on irrigation. Also, in spring, presowing irrigation was used for corn, where watering the crop is not the objective, and therefore its consumptive use is inefficient. Nevertheless, although the farmer does not have unlimited influence over flood irrigation doses, an improvement was detected in the adjustment of the amount of water used at each irrigation application in 2004/2005, as the average D_IF 2004/2005 diminished from 50 to 31% compared to 2000/2001.

Quantity and quality of drainage water

The volume of water measured in flowmeter was slightly higher than the BAS estimate in the 2 years of study. Therefore, the drainage estimated by BAS in 2000–2001 was 67% of that measured in the flowmeter, while in 2004/2005, it was only 32% of that measured. This fact is justified by the hydrogeology of the basin, whose higher limits are situated on a glacis, where the aquifer associated to it contributes external underground flows which later drain into the D-XIX-6 ditch. That is to say, the drainage does not only drain water introduced into the basin through irrigation and the rain, but also water and pollutants proceeding from the exterior and introduced via the aquifer.

Awareness of this circumstance led to the installation of a network of piezometers in the basin in the summer of 2005. In this way, in future studies it will be possible to estimate the input of salts and pollutants in underground flows, and so close balances of masses to allow the assignation of unitary loads of pollutants exported in the drainage of the basin.

Despite not having been able to obtain unitary values of exported water and pollutants in this study, the comparison of the temporal evolution of the quantity and quality of the water circulating through the D-XIX-6 ditch offers interesting information (Fig. 3). Almost all of 2004/2005 presented smaller flows than 2000/2001, in such a way that the average flow in 2004/2005 (15 lps) was less than half that of 2000/2001 (34 lps), determined mainly by smaller flows during the irrigation period (51 lps in 2001 compared to 18 lps of the year 2005). In both years, the irrigation period flows (51 and 18 lps) were greater than those of the non-irrigation periods (17 and 12 lps). Nevertheless, the differences in flow

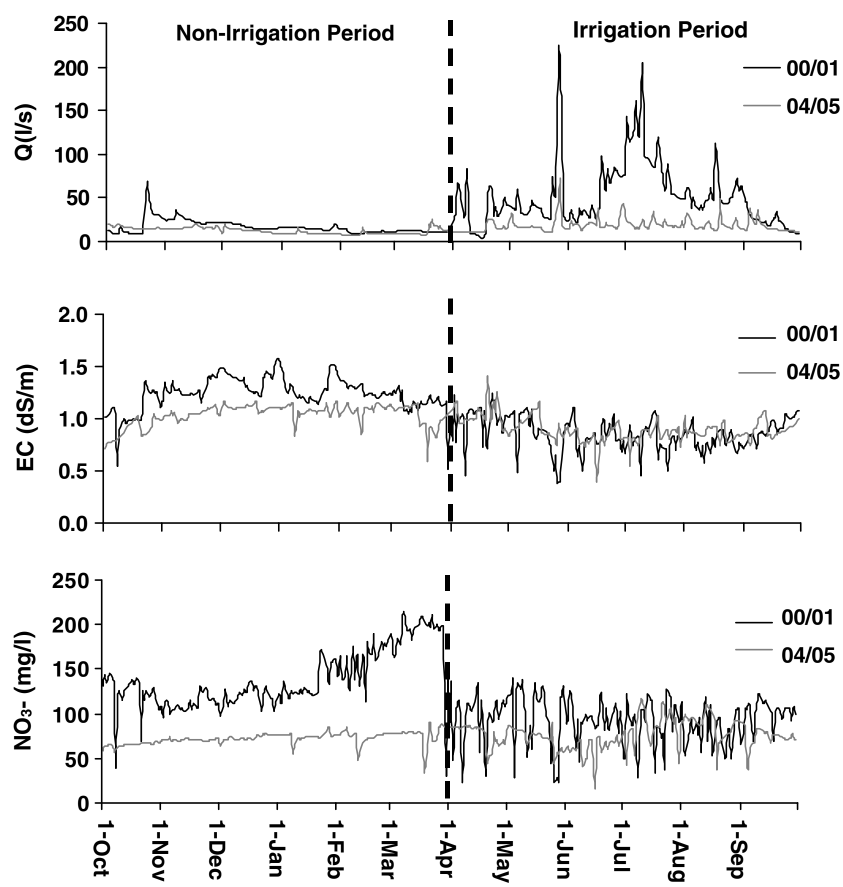

Fig. 3 Daily flow (Q, lps), electrical conductivity (EC, dS/m) and nitrate concentration (NO_3^-, mg/l) in the D-XIX-6 ditch during the hydrological years 2000/2001 and 2004/2005

between the two periods of 2004/2005 (6 lps difference) were much smaller than those of 2000/2001 (34 lps difference).

The evolution of EC was determined by flow variations (Fig. 3). In both years, the ECs of the non-irrigation period (1.26 dS/m in 2000/2001 and 1.02 dS/m in 2004/2005) were greater than the EC of the irrigation period (0.81 dS/m in 2000/2001 and 0.89 dS/m in 2004/2005). Nevertheless, the EC of the non-irrigation period in 2004/2005 (1.02 dS/m) was smaller than that of the non-irrigation period in 2000/2001 (1.26 dS/m), while in the irrigation period, the opposite happened (0.81 dS/m in irrigation in 2001 opposed to 0.89 dS/m in irrigation in 2005). In the yearly calculation, the average EC adjusted by flows in the year 2004/2005 (0.94 dS/m) was slightly greater than that of the year 2000/2001 (0.92 dS/m). This fact is coherent with the greater CWUE in the year 2004/2005, which causes irrigation returns of a higher salinity, smaller drainage volumes and a smaller salt load exported in drainage (360 Mg in 2004/2005 compared to 779 Mg in 2000/2001; Table 2).

As for [NO_3^-], practically the whole year 2004/2005 registered values lower than those registered in 2000/2001 (Fig. 3). The differences were more acute in the non-irrigation period mainly because of the high values registered in 2000/2001. Therefore, while in the non-irrigation period of 2000/2001 the [NO_3^-] average was 131 mg/l, in the same period in 2004/2005, the [NO_3^-] average was only 71 mg/l. On the other hand, in the irrigation season, although the [NO_3^-] in 2005 was lower, the resemblance between the [NO_3^-] averages was greater (85 mg/l in 2001 compared to 75 mg/l in 2005).

As happens with the EC, it is worth noting that while in 2000/2001, the [NO_3^-] of the non-irrigation season (131 mg/l) was higher than that of irrigation season (85 mg/l), in 2004/2005, the opposite happened (71 mg/l in the non-irrigation season compared to 75 mg/l in that of irrigation season). Thus , in 2001, inefficient irrigation application with good quality water produced a dilution of the drainage water while in 2005, it did not. Thus , the maximum concentration values in 2004/2005 are identified as being on 9th July and 26th July (Fig. 3), coinciding with the irrigation application in the only two corn plots in the basin. From then on, the maximum peaks did not reach such high values as the nitrate accumulated in the soil available to be leached was on the decrease.

In 2004/2005, the fertilization needs of the crops in the basin were 37% lesser (145 kg N/ha in 2000/2001 opposed to 91 kg N/ha in 2004/2005) and the doses of applied nitrogen fertilizer were better adjusted to the necessities (NE in 2000/2001 was 62% compared to 72% in 2004/2005). This, together with the decrease in the drainage volume as a consequence of the smaller irrigation-rain volume and the greater CWUE, caused the drainage water to have a [NO_3^-] 23% lesser (96 mg/l in 2000/2001 compared to 74 mg/l in 2004/2005) and 65% less N–NO_3^- was exported in the drainage (23 Mg in 2000/2001 compared to 8 Mg in 2004/2005).

Conclusions

Although in 2004/2005, the farmers adjusted the doses of each irrigation application better ($D_IF_{2000/2001}$ = 50% > $D_IF_{2004/2005}$ = 31%) considerably increasing the CWUE ($CWUE_{2000–2001}$ = 56% < $CWUE_{2004–2005}$ = 79%), irrigation management was not handled adequately, as the crops suffered a larger HD ($HD_{2000–2001}$ = 3% < $HD_{2004–2005}$ = 23%).

The study indicates that the change to on-demand irrigation system made the irrigation schedule more flexible, allowing prioritization in the irrigation according to the hydric necessities of the crops in function of the soil and the crop productivity. Nevertheless, the farmers were afflicted by the extreme drought which, as well as determining the implantation of crops needing less water, would have required more frequent irrigation applications.

In the year 2004/2005, 54% fewer salt loads were exported (779 Mg in 2000/2001 vs. 360 Mg in 2004/2005) and 65% less of N–NO_3^- load (23 Mg in 2000/2001 vs. 8 Mg in 2004/2005) through the drainage of the D-XIX-6 ditch, and its waters showed higher EC (0.92 dS/m in 2000/2001 vs. 0.94 dS/m in 2004/2005) and lower [NO_3^-] (96 mg/l in 2000/2001 vs. 74 mg/l in 2004/2005).

The lesser environmental impact in the year 2004/2005 was influenced by more appropriate agronomic management (greater irrigation efficiency and fertilizer application). Nevertheless, the climatic conditioning

Table 2 Drainage estimated by BAS (D_{BAS}), drainage measured in D-XIX-6 ditch ($D_{Flowmeter}$), consumptive water use efficiency (CWUE), electrical conductivity (EC), salt load (*S*), necessities of nitrogen fertilization (NF), nitrogen applied by the farmers (NA), nitrogen fertilization efficiency (NE), nitrate concentration ([NO_3^-]) and nitrogen load exported (N–NO_3^-) by D-XIX-6 ditch during 2000/2001 and 2004/2005 hydrological years

Year	D_{BAS} Dam^3	$D_{Flowmeter}$ Dam^3	CWUE %	EC dS/m	*S* Mg	NF kg N/ha	NA kg N/ha	NE %	[NO_3^-] mg/l	N–NO_3^- Mg
2000/2001	717	1,070	56	0.92	779	145	234	62	96	23
2004/2005	155	484	79	0.94	360	91	127	72	74	8

masks the effectiveness of the changes in irrigation management proposed by the irrigation district authority, the evaluation of which will require comparison of climatically similar years.

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