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ORIGINAL ARTICLE

Changes in irrigation management and quantity and quality of drainage water in a traditional irrigated land

I. García-Garizabal · J. Causapé · R. Abrahao

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Abstract Irrigated agriculture allows for the increase of agrarian yields and stability in food supply and raw materials, being, at the same time, responsible for the reduction of water resources availability and for the pollution by salts and nitrate. This work aims to analyze the impact of changes in irrigation management (establishment of an on-demand flood irrigated system, assignment of irrigation allowances and water payment for surface and irrigation water consumption) in a traditional irrigated land on drainage flow, electrical conductivity and nitrate concentration in irrigation return flows between the year 2001 and the period 2005–2008. Changes in water management significantly modified quantity (lower drainage) and quality (electrical conductivity and nitrate) of irrigation return flows, keeping similar evolution paths during the year with water ameliorants in summer due to the use of good irrigation water quality. Salinity in irrigation return flows is not a current problem in the area as electrical conductivity values in water did not exceed the limit established for water used in irrigation or intended for human consumption. Despite the fact that changes in irrigation management and crop distribution have reduced nitrate concentrations in irrigation return flows by 43 %, the water still presents nitrate values exceeding the 50 mg NO_3^-/l. Thus, nitrate remains as the main agro-environmental problem in this irrigation area. However, the nitrate concentration trends detected in this work mark the possibility of reaching nitrate values below 50 mg NO_3^-/l in the case of maintenance of the conditions in this agricultural system.

Keywords Irrigation return flows · Electrical conductivity · Nitrate · Trend analysis

I. García-Garizabal (✉) · J. Causapé
Instituto Geológico y Minero de España (IGME),
C/ Manuel Lasala n° 44; 9° B, 50006 Zaragoza, Spain
e-mail: ikerggarizabal@gmail.com

R. Abrahao
Federal University of Paraíba (UFPB), Center of Alternative and Renewable Energy, Department of Renewable Energy Engineering, Cidade Universitária, João Pessoa, Paraíba 58051-900, Brazil

Introduction

Irrigated agriculture consumes 70 % of the world's freshwater withdrawals (FAO 2003), being considered the main factor of water resources shortage (FAO 2002). On the other hand, irrigation importance is clear: 40 % of agrarian yields are obtained in only 20 % of cultivated surface where irrigation is developed (FAO 2003).

In Spain, where irrigation area has increased by 24 % in the last 20 years (MAPA 2006), ratio yield-surface is even higher, generating over 50 % of national yields in only 14 % of agricultural land, consuming 75 % of country's hydric resources (INE 2008; MMA 2007). In Europe, Spain is the second country, after France, in agricultural area, and the first one in irrigated area (EU 2008).

Although irrigation volumes used by the agrarian sector are high, only 50 % of the withdrawn water is used by the plants and remaining water is lost as drainage or return flows through creeks, rivers or aquifers (FAO 2003). Water returned to water systems would help to reduce the impact of extractions, if it was not for the fact that water quality can be very different, due to the salts and agrochemicals carried from soil profile.

Removal of salts from the soil profile is a required action to avoid problems with crops and to obtain high yields. Water required for salt leaching may come from rainfall events or be applied with irrigation during the non-growing season, with rainfall water more recommended for use to optimize water use efficiency (Beltran 1999; Caballero et al. 2001).

Regarding the presence of agrochemicals in water, nitrate from nitrogenous fertilization is a very important issue, especially when the remarkable changes implemented in agriculture in the last decades are taken into consideration (WHO 2004). The use of inorganic fertilizers has led to increase and stability of agricultural yields (Fuentes 1999), but it has also increased the nitrate availability in soils and, under inadequate irrigation management or heavy rainfall, these nitrate loads end up in downstream rivers and in aquifers (Quílez et al. 2006).

Considering the approach "agrarian yields vs. water quality", we have to achieve a sustainable use of agricultural resources, optimizing the use and minimizing the impacts to environment. For this, it is necessary to develop agri-environmental studies to assess the management of agrarian inputs (water and agrochemicals) with the aim to avoid or reduce the impacts produced. Nevertheless, the short period of time covered in previous works did not allow the long-term analysis of the influence of agricultural changes in the quantity and quality of irrigation return flows (Basso et al. 1990; Tedeschi et al. 2001; Lasanta et al. 2002; Cavero et al. 2003; Causapé et al. 2004a, b, c; Isidoro et al. 2004, 2006a, b; Ribbe et al. 2008).

Thus, the objective of this paper is to analyze the impact of changes in irrigation management in a traditional irrigated land (establishment of an on-demand flood irrigated system, assignment of irrigation allowances and water payment for surface and irrigation water consumption) on quantity and quality of irrigation return flows during the years 2001 and 2005–2008.

Materials and methods

The study zone is located in the Middle Ebro River basin (Spain), and it corresponds to the hydrological basin of drainage ditch D-XIX-6, belonging to the Bardenas Canal Irrigation District no V (ID-V). The basin is located at 377 m.a.s.l., and has a north–south topographic gradient of 1 %. The irrigation canal network that surrounds the basin constitutes the divide line of waters, limiting a basin of 95 ha, 91 of them under irrigation. The remaining area corresponds to access roads and the drainage system. Irrigation system used was flood irrigation with good quality waters (electrical conductivity = 0.3 dS/m; nitrate concentration = 2 mg NO_3^-/l) diverted from Yesa reservoir (Fig. 1).

ITGE (1985) classifies the climate of the study zone as Mediterranean warm weather. Average precipitation was 460 mm/year, recorded during the study period (2001 and period 2005–2008), constituted by a rainy year (2001), a dry year (2005) and other 3 years with intermediate-low precipitations. Rain was seasonally distributed, with highs in autumn-spring and lows during winter-summer (Table 1). Year reference evapotranspiration (ET_0) was 1,068 mm, with a sharp seasonality, recording low values during winter and high in summer when it exceeded

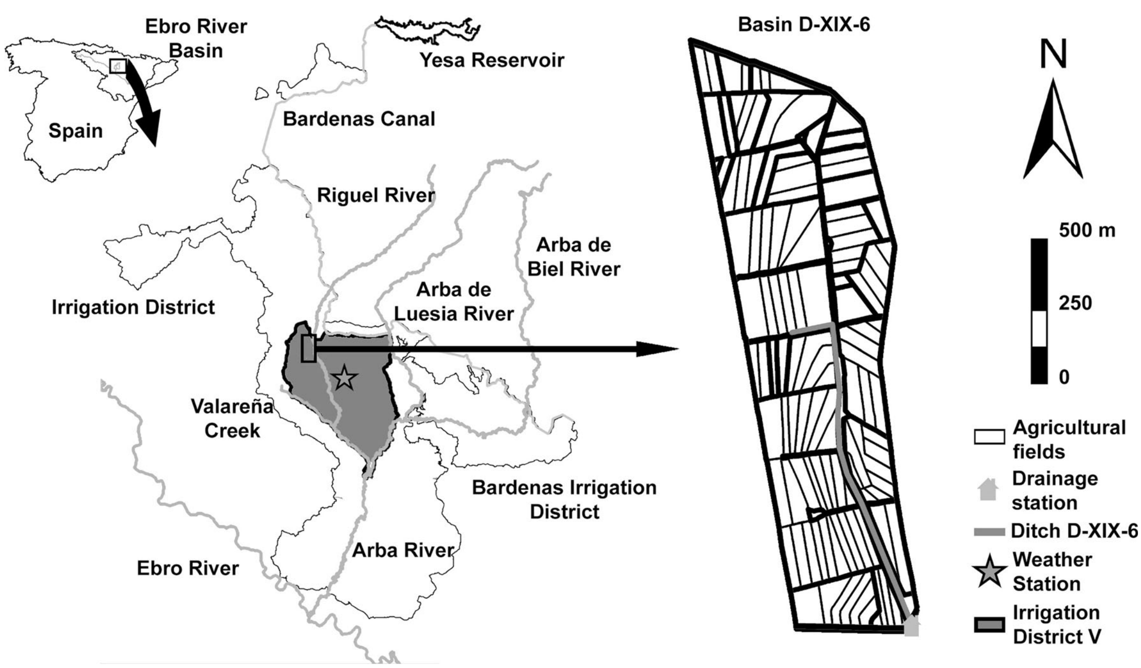

Fig. 1 Location of Bardenas canal irrigation district no V (ID-V) and the study basin D-XIX-6

precipitation (Table 1), being irrigation necessary for the adequate development of summer crops.

Geologically, the study basin is located on a quaternary glacis of gravel with loamy matrix that constitutes a free aquifer. Drainage ditch D-XIX-6 is located on the glacis, forming a valley where tertiary substratum appears. Regarding hydraulic characteristics of the aquifer, ITGE (1995) and SIAS (2009) estimate permeabilities of up to 90 m/day and transmissivities of up to 600 m^2/day, with effective porosity of 10–15 %. The agricultural soils developed on the area were characterized as Calcixerollic Xerochrepts and Typic Xerofluvent (Soil Survey Staff 1992; Lecina et al. 2005; García-Garizábal et al. 2011).

Regarding agricultural practices, irrigation management was the main difference between the two study periods (year 2001 vs. period 2005–2008). In 2001, the area presented a rotation irrigation system, changed after 2005 to an on-demand irrigation system, allowing farmers to choose timing and irrigation doses, being irrigation allowances assigned for each year according to water reserves in the reservoir. This fact influenced crop distribution, which changed between both periods. Thus, in 2001 alfalfa and corn were the main crops, but from 2005 on, due to the lower water availability, winter cereal started its expansion in detriment of alfalfa and corn (Table 2).

Irrigation doses showed significant differences between crops, due to its different potential evapotranspiration (ETc = ET0•Kc, Kc = crop coefficient; Allen et al. 1998). In 2001, alfalfa was the main irrigated crop, with 11 irrigation doses of 151 mm each, followed by corn with 7 irrigation doses of 137 mm, and winter cereal with 4 irrigation doses of 137 mm. From 2005 onwards, general irrigation doses applied to crops decreased, although volumes applied to alfalfa and corn remained the highest. Alfalfa presented 8-10 irrigation doses of 122 mm and corn 8 irrigation doses of 136 mm. On the other hand, winter cereal only received 2–3 irrigation doses of 128 mm, but regularly some farmers did not irrigate because precipitation was sufficient to satisfy the crop's water demands.

The change in crop patterns reduced nitrogen applied in the basin. Fertilization doses were high for corn (420 kg N/ha) compared to winter cereal (162 kg N/ha) or alfalfa (61 kg N/ha). It is important to note the fertilization of alfalfa in the area, although, for being a legume, it theoretically did not need any nitrogen fertilization. Nitrogen fertilizer was mainly applied as compound NPK fertilizers (8-15-15 and 15-15-15), urea (46 % N), nitrogenous solution N-32 (32 % N) and, to a smaller extent, ammonia nitrate (33.5 % N).

Methodology

The assessment of evolution and trends in irrigation return flows in the irrigated basin was carried out based on readings of water flows measured in a gauging station located at the outlet of the studied basin, and on the analysis of electrical conductivity and nitrate concentration of water samples collected at the station.

Characterization of irrigation return flows

Daily water flow through D-XIX-6 was calculated from the transformation of the 15 min water level readings (h) measured and recorded with an electronic limnigraph (Thalimedes, OTT) installed in a long throated flume-type canal with rectangular section. The rating curve was obtained from 9 propeller current meter measure, comprehending the variation of ranges in water level.

Table 1 Average monthly precipitation (P) and reference evapotranspiration (ET_0) in the study zone (GA 2011)

	Jan (mm)	Feb (mm)	Mar (mm)	Apr (mm)	May (mm)	Jun (mm)	Jul (mm)	Aug (mm)	Sep (mm)	Oct (mm)	Nov (mm)	Dec (mm)
P	31	38	32	45	57	44	24	27	31	42	46	39
ET_0	15	33	65	86	119	161	192	171	114	68	31	14

Table 2 Crops distribution (%), average irrigation doses (I; mm), nitrogenous fertilization (N; kg N/ha), total irrigation applied (I_T) and potential evapotranspiration (ET_C) in the basin of drainage ditch D-XIX-6 during the years 2001, 2005, 2006, 2007 and 2008

	Corn %/I/N	Alfalfa %/I/N	Winter cereal %/I/N	Other crops %/I/N	Fallow %/I/N	I_T mm	ET_C mm
2001	49/1,023/404	49/1,598/56	1/550/216	1/1,348/405	0/–/–	1,139	831
2005	11/737/445	39/924/59	25/415/152	17/561/86	8/–/–	570	1,031
2006	8/1,025/460	39/1,158/80	33/236/152	16/414/3	4/–/–	567	991
2007	3/1,152/428	31/1,054/43	51/141/164	14/396/462	1/–/–	512	846
2008	0/–/–	24/960/53	55/328/171	20/997/312	1/–/–	559	883

$Q\,(l/s) = 0.17\,\mathrm{h}^2(\mathrm{cm}) - 1.95\,\mathrm{h}\,(\mathrm{cm}) - 17.9;\ n = 9;$
$R^2 = 0.99;\ p < 0.01$

Regarding data for electrical conductivity (EC) in the drainage water, it was measured in a daily basis, using an auto-sampler collector (ISCO 3600) located in the outlet of the basin. Water samples ($n = 1{,}826$) were taken to the laboratory, EC at 25 °C was determined using an Orion five-star conductivity meter equipped with DuraProbe. Nitrate concentration (NO_3^-) in each water sample was analyzed in the laboratory by colorimetry (AutoAnalizer 3). Nitrate was the only form of nitrogen analyzed because it constitutes 98 % of the total nitrogen in the study zone drainage waters (Causapé 2004).

Due to the fact that data did not follow a normal distribution, the Mann and Whitney (1947) non-parametric method was utilized to compare water flow, electrical conductivity and nitrate concentration in drainage waters between the "rotation irrigation system" period (2001) and the period in which the on-demand irrigation system was implanted (2005–2008). The aim of this comparison was to understand the influence of changes in irrigation management to the aforementioned parameters. It was considered that the groups were significantly different for a probability of <5 % error ($p < 0.05$).

Cyclicity in irrigation return flows

The influence of irrigation water management in the basin of drainage ditch D-XIX-6 was analyzed through the identification of annual cycles in water flow, electrical conductivity and nitrate concentration. The identification of the cycle was made from the medians of the daily data for each month during the year 2001 and the period 2005–2008.

Trends in irrigation return flows

The Mann–Kendall (Mann 1945; Kendall 1975) non-parametric method was used to detect monthly trends in water flow, electrical conductivity and nitrate concentration for the period 2005–2008 (12 groups), and during the whole period 2005–2008 (1 group). It was considered that the groups were significantly different for a probability of <1 % error ($p < 0.01$), 5 % error ($p < 0.05$) and 10 % error ($p < 0.10$), applying the correlation coefficient (τ) of Kendall to analyze the temporal relationship and quantifying the trend magnitude based on the calculation of Sen's (1968) slope. The τ coefficient ranges between -1 and 1, establishing whether relationships are negative, positive or non-existent ($\tau = 0$), and the absolute value indicates the strength of the relationship and larger τ values indicate stronger relationships.

Results

Characterization of irrigation return flows

Flow

Water flow evolution through the drainage ditch presented a sharp seasonality (Fig. 2a) with significantly lower values during the unirrigated season (autumn–winter months) with respect to spring-summer ($p < 0.05$). The drainage values recorded during the year 2001 were larger than the measured during the period 2005–2008 ($p < 0.05$). However, there were flow peaks measured in the gauging station coinciding with heavy precipitation events or when irrigation was applied out of the specific irrigated season. Similar behaviors were observed in other irrigation areas were water exiting the agricultural basins increased during the beginning of irrigation season (Tedeschi et al. 2001; Cavero et al. 2003; Causapé et al. 2004a; Isidoro et al. 2004). Records of maximum water flow decreased from 220 l/s in year 2001 to 96 l/s in period 2005–2008, while minimum water flow remained constant (4 l/s).

Electrical conductivity

The EC of drainage waters ranged from 0.38 dS/m (similar to irrigation water values) to 1.57 dS/m (Fig. 2b). Thus, no sample exceeded the threshold limits for water intended for human consumption (2.5 dS/m: EU 1998) and the severe restriction level for water used in irrigation (3.0 dS/m: Ayers and Westcot 1994). Only 10 % of the water samples did not present any restrictions for irrigation use (EC < 0.7 dS/m: Ayers and Westcot 1994). The minimum EC values occurred during the irrigated seasons ($p < 0.05$), coinciding with irrigation applications that diluted the natural salinity of drainage waters (Causapé et al. 2004b; Tedeschi et al. 2001). Changes implemented in the agricultural basin between 2001 and the period 2005–2008 modified significantly ($p < 0.05$) the EC of drainage waters.

Nitrate concentration

Nitrate was detected in all water samples collected, ranging from 10 mg NO_3^-/l to 215 mg NO_3^-/l (Fig. 2c). 91 % of samples collected exceeded the 50 mg NO_3^-/l limit established for water intended for human consumption (EU 1998) and 5 % exceeded nitrate values established by Ayers and Westcot (1994) as harmful for sensitive crops. 8 % of waters ranged from 25 to 50 mg NO_3^-/l, and 5 % of waters collected are included in the control interval 40–50 mg NO_3^-/l established by MMA (2010).

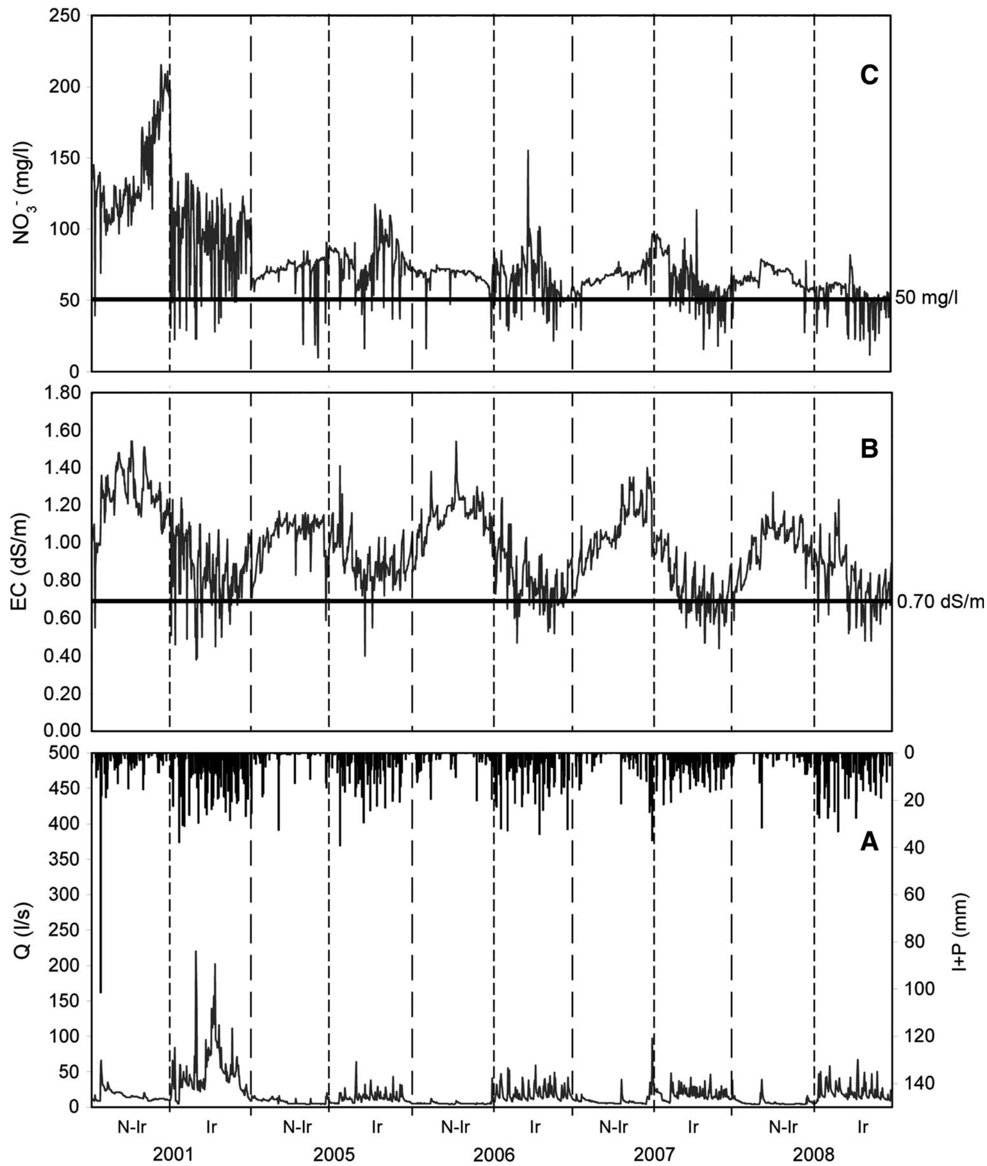

Fig. 2 **a** Daily water flow (Q) and inputs from irrigation and precipitation (I + P), **b** electrical conductivity (EC) and **c** nitrate concentration (NO_3^-) measured at the gauging station located at the end of the drainage ditch D-XIX-6 for the year 2001 and the period 2005–2008. *Solid horizontal lines* present slight to moderate restriction level for irrigation waters (EC: 0.7 dS/m) and limit for water intended for human consumption (NO_3^-: 50 mg/l). Large *vertical dashed lines* show the change of years and *small dashed lines* divide non-irrigation (N–Ir) from irrigation (Ir) seasons

Less than 1 % of water samples presented values below 25 mg NO_3^-/l, which could be defined as "not contaminant level". Despite the changes in irrigation and fertilization management carried out between 2001 and the period 2005–2008, the number of samples over 50 mg NO_3^-/l did not decrease. However, maximum nitrate concentration values decreased up to 62 %, so the ratio between monthly maximum and minimum decreased from 2.3 in 2001 to 1.5 during the period 2005–2008, so in this way, drainage waters presented significant differences in nitrate concentration between both evaluated periods ($p < 0.05$). Higher nitrate concentrations were detected in autumn–winter compared to spring-summer ($p < 0.05$), although high nitrate peaks were detected in between April and September (Fig. 2) as consequence of leaching of nitrogenous fertilizers applied to crops during the growing season.

Cyclicity in irrigation return flows

There is an annual cyclic behavior in the drainage water flows exported from the basin, with increases from March to July, being July the month with highest drainage values, a clear influence of irrigation applications (Fig. 3a). The behavior was similar for both irrigation management periods, but during 2005–2008 period, water volume exported was 61 % lower and $Q_{\text{month-max}}/Q_{\text{month-min}}$ ratio was 50 % lower, proving the influence of better irrigation management not only for reducing irrigation return flows, but also for stabilizing monthly flow variability.

Regarding water electrical conductivity, the exported flow presented seasonal cyclic EC, but with reverse pattern when compared to water flows exported. Thus, minimum EC values were measured in August, with a progressive increase until February, and from this date on EC values

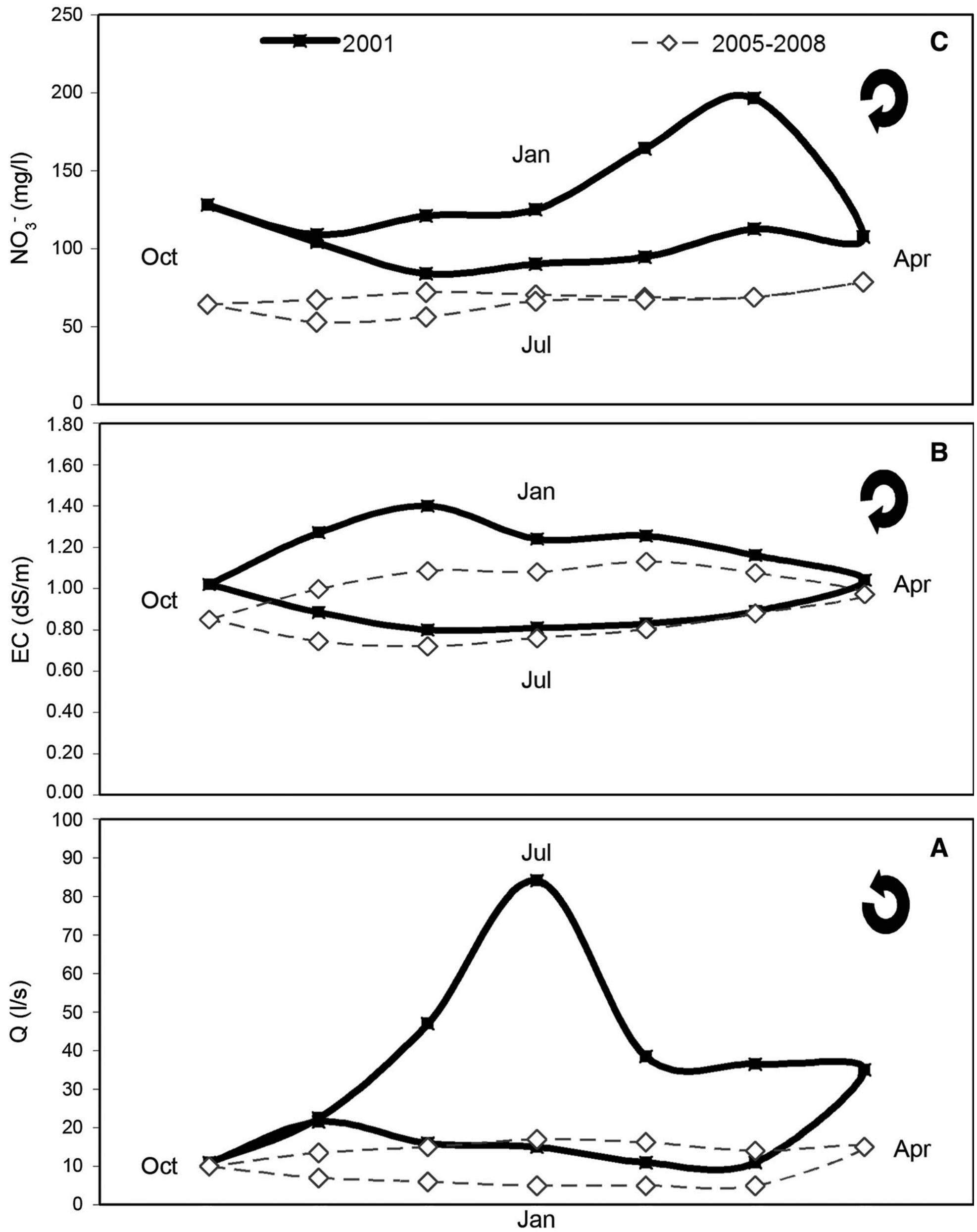

Fig. 3 **a** Monthly evolution in water flow (Q), **b** electrical conductivity (EC) and (C) nitrate concentration (NO_3^-) in drainage waters at ditch D-XIX-6 for the year 2001 and period 2005–2008

decreased up to closing the cycle (Fig. 3b). Even though there was similar monthly evolution observed in EC data during both periods (2011 vs. 2005–2008), the interval of increase in 2001 finished in December, while during 2005–2008 the increase lasts until February. This change is related to heavy precipitations occurred during December–January in 2001 (115 mm), generating drainage and consequently a sharp dilution effect on drainage waters. Low precipitation values during these months in 2005–2008 period did not generate soil water drainage and, therefore, no changes in EC of waters.

For nitrate, there were maximum values in March–April and a progressive decrease during summer months until November, coinciding with the end of irrigation applications, starting point for the increase of nitrate concentrations (Fig. 3c). This evolution is explained by the dilution effect of good quality waters used in irrigation mixed with water present in soil and aquifer, with high nitrate concentrations as a consequence of high nitrogenous fertilizer applications in the area, double as nitrogen necessities of the crops (Causapé et al. 2004b; García-Garizábal et al. 2012). In this way, some authors have found a decrease in soil nitrate leaching during irrigation season as a consequence of the initial leaching of nitrogenous fertilizers applied to crops during the first grown stage and nitrogen crop extractions during the growing season, achieving a lower nitrate availability in soil with time (Díez et al. 2006; Feng et al. 2005; Gehl et al. 2005).

Table 3 Trend test results for monthly evolution in drainage waters of the ditch D-XIX6 in years 2005 to 2008 and during the period 2005-2008 in water flow (Q), electrical conductivity (EC) and nitrate concentration (NO_3^-)

	Q	EC	NO_3^-
Oct			
p	0.73 ns	0.17 ns	0.50 ns
τ	−0.18	−0.67	−0.33
m	–	–	–
Nov			
p	0.17 ns	0.17 ns	0.31 ns
τ	−0.67	−0.67	−0.55
m	–	–	–
Dec			
p	0.73 ns	0.5 ns	0.73 ns
τ	−0.18	−0.33	0.18
m	–	–	–
Jan			
p	1.00 ns	0.73 ns	0.50 ns
τ	0	−0.18	−0.33
m	–	–	–
Feb			
p	0.73 ns	1.00 ns	0.31 ns
τ	−0.18	0	−0.71
m	–	–	–
Mar			
p	0.73 ns	1.00 ns	0.17 ns
τ	0.24	0	−0.67
m	–	–	–
Apr			
p	0.50 ns	0.17 ns	0.50 ns
τ	0.33	−0.67	−0.33
m	–	–	–
May			
p	0.09*	0.73 ns	0.17 ns
τ	0.91	−0.18	−0.67
m	0.0032 l/s year	–	–
Jun			
p	0.50 ns	1.00 ns	0.17 ns
τ	0.33	0	−0.67
m	–	–	–
Jul			
p	0.73 ns	0.31 ns	0.00***
τ	0.18	−0.55	−1
m	–	–	−11 mg/l year
Aug			
p	0.50 ns	0.17 ns	0.00***
τ	0.33	−0.67	−1
m	–	–	−10 mg/l year
Sep			
p	1.00 ns	0.50 ns	0.17 ns
τ	0	−0.33	−0.67
m	–	–	–
2005–2008			
p	0.09*	0.02**	0.00***
τ	0.17	−0.24	−0.41
m	0.08 l/s month	−0.004 dS/m month	−0.38 mg/l month

p Probability values (* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$, *ns* non-significant), τ Kendall's coefficient, *m* Sen's slope

The reduction in values of EC and nitrate in drainage water is maximum in August–September, as consequence of lower irrigation efficiency reached at the end of months of the irrigation season (García-Garizábal et al. 2011) related with the last irrigation doses applied at the end of the campaign on corn and alfalfa due to the availability of water reserves. In the case of nitrate concentrations, values at the end of the irrigation season were lower too due to the low availability of nitrate in soil, since crops were at the end of growing stage. A survey conducted with all farmers of the basin revealed that major fertilizer supplies were applied during the initial growing stage of crops, coinciding with higher nutrient demands of plants (MICT 2007). In this way, timing and fertilizer applied have an important role in nitrate leaching, being easier to leach nitric than ammoniacal fertilizers (Quílez et al. 2006). In D-XIX-6 basin, ammoniacal fertilizers were major (up to 86 % of N supplies), and applied mainly in February–May (66 % of yearly N). Therefore, due to the impossibility of a better application of nitrogen fertilizer and water supplied in flood irrigation systems, higher nitrate concentrations in drainage waters were measured at the beginning of the irrigation season.

Trends in irrigation return flows

Water flow trend analysis detected an increase in water flow in May (Table 3). This trend is related to heavy precipitation events occurred in 2008, when rainfall doubled the historical average precipitation during this month (107 mm), increasing by 85 % the water flow exported from the basin, when compared to previous years. On the other hand, it was detected a weak increasing trend ($\tau = 0.17$) for monthly flow during the 2005–2008 period, with a slope calculation of 0.08 l/s month.

For EC, no monthly trend was detected. Nevertheless, during the monthly period 2005–2008 it was detected a weak ($\tau = -0.24$) EC downward trend in drainage waters, with a slope calculation of −0.004 dS/m month. This downward trend is related to the significant increase in water flow measured during the 4 years of the study, in the same way of water flow-electrical conductivity inverse relationship observed in other agricultural areas irrigated with good quality waters (Causapé et al. 2004b; Isidoro et al. 2006a; García-Garizábal and Causapé 2010).

Finally, there was a downward trend in nitrate values for July and August, coinciding with the final months of irrigation season. As mentioned in "Cyclicity in irrigation return flows", the lower nitrate availability in soil at the end of the irrigation season resulted in lower nitrate concentrations in drainage water. The reason was the change in crop distribution (winter cereal instead of corn), with consequent decrease in nitrogenous fertilization (Orús and Sin 2006) and a shorter growing season. In global terms, growing season during year 2005 finished in October (corn) while during 2005–2008 it finished in July (winter cereal; Martínez-Cob 2004). A weak decreasing trend of −0.38 mg NO_3^-/l month was detected during the 2005–2008 period, so in the case of maintenance of agronomic system conditions (winter cereal as main crop, fertilization doses and irrigation efficiency), drainage waters would present nitrate concentrations below 50 mg NO_3^-/l in next years.

Trends in water flow, electrical conductivity and nitrate concentration observed in this irrigated basin were inverse to those observed in other studies carried out in the Ebro River basin (CHE 2006; Lassaletta et al. 2009). In this way, water trends in Arba River (tributary of Ebro River; Fig. 1), collector of our study basin drainage waters (Fig. 1), presented decreasing values in water flows and increasing values for electrical conductivity and nitrate (period 1975–2004; CHE 2006). However, García-Garizábal and Causapé (2010) observed flow reduction and improvement in water quality in Riguel River (tributary of Arba River; Fig. 1) as a consequence of decrease in electrical conductivity and nitrate values of irrigation return flows belonging to ID-V. Even so, the short period of time of the previous works (2 years) did not allow for the development of trend analysis in this irrigated area, after changes in irrigation and crop management.

Although the management changes performed in the area have been efficient, only the continuous monitoring would permit the understanding of current status and future possibilities for this and other irrigated lands, to reduce risks for the surrounding environment, specifically downstream water resources. This is necessary considering the ecological status that water bodies must reach according to the Water Framework Directive (EU 2000) and it will allow fast decisions, avoiding important deterioration of water quality.

Conclusions

Changes in irrigation management imposed by the Irrigation District between years 2001 and during the period 2005–2008 (establishment of an on-demand flood irrigated system, assignment of irrigation allowances and water payment for surface and irrigation water consumption) have caused significant changes in drainage waters of basin belonging to ditch D-XIX-6.

After changes in water management, yearly water flows decreased 61 %, although maximum water flows decreased up to 56 % while minimum water flows did not present variations during the 5 years. For electrical conductivity, reduction in water drainage has increased the electrical conductivity of water samples. Nevertheless, the good quality of water used in irrigation and the low salinity of agricultural soils did not cause water samples with electrical conductivity values above the restriction level for waters used in irrigation. Regarding nitrate, despite the 43 % reduction in nitrate values of the drainage waters, water samples still present yearly nitrate concentrations above 50 mg NO_3^-/l.

Therefore, the change to an on-demand flood irrigated system has significantly changed irrigation return flows. A similar behavior in water flow, electrical conductivity and nitrate concentration was detected with similar evolution along the year. Decrease in irrigation volumes and agronomic changes implemented (crops and fertilization) has caused a lower variability in irrigation return flows. Drainage waters still present nitrate values exceeding 50 mg NO_3^-/l, so nitrate contamination persists as the main agro-environmental problem related to this irrigation land. Thus, farmers have to focus their work in reducing nitrate leaching, being nitrate availability in soil irrigation doses and timing of irrigation the key factors to minimize nitrate leaching. In this way, a reduction in fertilization doses adjusting nitrogen applications with nitrogen demands of the crops would ameliorate nitrate impact, although it is difficult in this traditional irrigated system being a better option the fertilizers applications through pressurized irrigation systems.

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