Centro de Investigación y Tecnología Agroalimentaria de Aragón

“Regadío y calidad físico-química de las aguas superficiales en la cuenca del río Ebro”

Huesca, 28 de febrero de 2019

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GOBIERNO DE ARAGON
Departamento de Innovación, Investigación y Universidad

INTRODUCCIÓN

Calidad de agua: tendencias

Efecto de la agricultura:

- Incremento del consumo de agua
- Lavado de suelos y salinización de las aguas
- Aportes por disolución de fertilizantes y pesticidas
- Temperaturas

OBJETIVOS:

Caracterizar la calidad del agua en la Cuenca del Ebro y su relación con los cambios en los usos del suelo y en particular el regadío

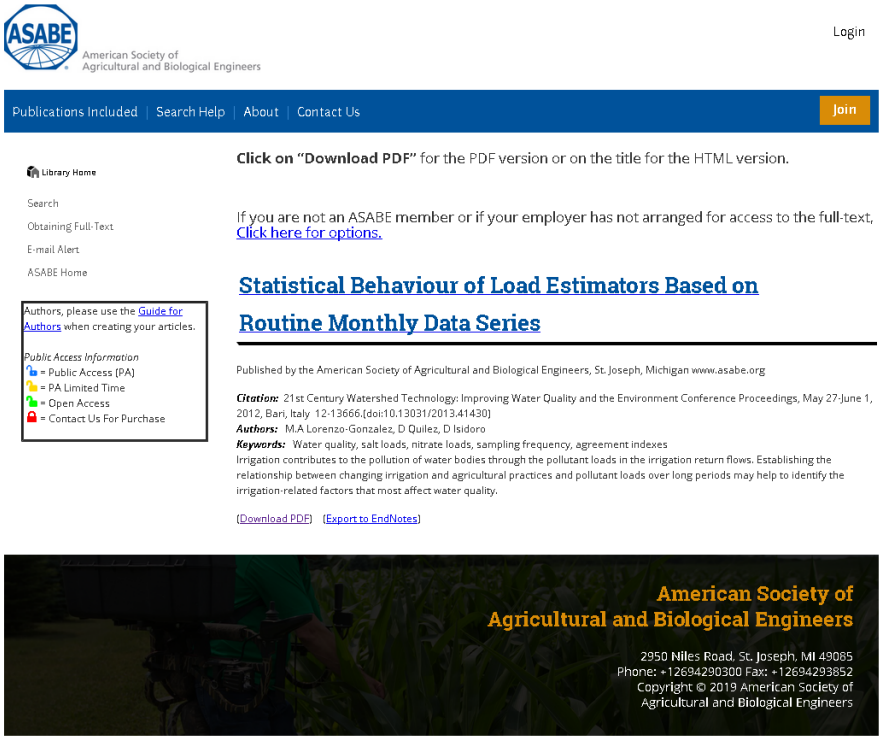
1. "*Statistical behaviour of monthly load estimators*". Desarrollo de metodologías apropiadas para el cálculo de masas de sal y nitrato en cuencas.
2. Balance de agua y salinidad en la cuenca del río Arba y su relación con el desarrollo de la agricultura a lo largo de los últimos 40 años y previsiones futuras de desarrollo.
3. Análisis estadísticos de las tendencias de salinidad del río Ebro y su proyección para el 2027.
4. Análisis espacio-temporal del incremento de la temperatura del eje del río Ebro y principales tributarios (Aragón y Cinca).

Regadío y calidad físico-química de las aguas superficiales en la cuenca del río Ebro

1. Statistical behavior of monthly load estimators

21st Century Watershed Technology Conference and Workshop (ASABE)

Bari (Italy) May 27th- June 1st, 2012



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Statistical Behaviour of Load Estimators Based on Routine Monthly Data Series

Published by the American Society of Agricultural and Biological Engineers, St. Joseph, Michigan www.asabe.org

Citation: 21st Century Watershed Technology: Improving Water Quality and the Environment Conference Proceedings, May 27-June 1, 2012, Bari, Italy 12-13666.[doi:10.13031/2013.41430]
Authors: M.A Lorenzo-Gonzalez, D Quilez, D Isidoro
Keywords: Water quality, salt loads, nitrate loads, sampling frequency, agreement indexes
Irrigation contributes to the pollution of water bodies through the pollutant loads in the irrigation return flows. Establishing the relationship between changing irrigation and agricultural practices and pollutant loads over long periods may help to identify the irrigation-related factors that most affect water quality.

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STATISTICAL BEHAVIOR OF MONTHLY LOAD ESTIMATORS

M. A. Lorenzo-Gonzalez, D. Quilez, D. Isidoro

international watershed technology

ABSTRACT. *Agricultural activities are important contributors to the pollution of water bodies. In this context, the establishment of relationships between changes in irrigation and agricultural practices and pollutant loads over long periods may help to diagnose the agriculture-related factors with higher influence on water quality. To this end, the first step is to generate robust, long-term pollutant load series with the available data. This article aims to ascertain the statistical performance of five mean monthly salt (MS) and nitrate (MN) load estimators based on the long-term records of the Surface Water Quality Control (SWQ) network of the Ebro Basin Authority (CHE) in Spain. The five loads estimates were compared with reference loads calculated with the more complete, daily frequency data of the irrigation return flows network (Recor-Ebro, or R-E) available at a sampling point on the Arba River at Tauste for the period April 2004 to September 2010. Three interpolation methods that make use of total dissolved solids (TDS_{swq}) and nitrate concentrations (NO_{3swq}) of samples taken once a month in the SWQ network were multiplied by flows at the sampling time (Q_{swq}), mean daily flow of the sampling day (Q_d), and mean monthly flow (Q_m). Two regression-based methods established the relationships between flow and TDS and between TDS and NO_3 concentration to estimate daily and monthly TDS and NO_3 concentrations, which were then multiplied by mean daily flow (Q_d) or mean monthly flow (Q_m), respectively, to estimate loads. Six statistical indexes were used to determine the fit of the five proposed methods to the reference load: the coefficient of determination (R^2), mean bias (MB), root mean square error (RMSE), mean absolute error (MAE), Nash-Sutcliffe efficiency (NSE), and Nash-Sutcliffe efficiency modified (E1). Mean bias was not significant for the five MS and MN estimators (<7.5%), but the other statistical indexes showed different behavior for the MS and MN estimators. The RMSE and MAE were in general higher for the MS interpolation methods (RMSE ≈ 6,000 to 11,000 Mg per month; MAE ≈ 4,000 to 7,000 Mg per month) than for the regression-based methods (RMSE ≈ 5,000 Mg per month; MAE ≈ 4,000 Mg per month). The errors for the MN estimators were similar for the regression and interpolation methods when using the mean monthly flow or mean daily flow of the sample day (RMSE ≈ 30 Mg per month; MAE ≈ 20 Mg per month). The NSE and E1 for the three interpolation methods for MS were not satisfactory (NSE < 0.5; E1 < 0.3), while the interpolation methods for MN using daily or monthly average flow presented satisfactory NSE and E1 values (NSE > 0.5; E1 > 0.3), performing just as well as the regression methods. For the short period analyzed (six years), regression-based estimators presented the best reliability for the estimation of monthly salt and nitrate loads, along with interpolation methods that applied the mean daily flow (Q_d) or mean monthly flow (Q_m) for the estimation of monthly nitrate loads, provided that the data series were complete.*

Keywords. *Agreement indexes, Irrigation, Nitrate loads, Salt loads, Sampling frequency, Water quality.*

The European Water Framework Directive (WFD) (EU, 2000) aims to protect and enhance the status of aquatic ecosystems, prevent further deterioration, and promote sustainable water use based on long-term protection of available water resources. According to the WFD, member states will implement the necessary measures to prevent deterioration of the status of water bodies to reach a good ecological status of European water bodies by 2015. New basin hydrologic plans are required to collect and maintain information on the type and magnitude of the significant anthropogenic pressures to which the surface water bodies in each river basin district are subject. These pressures include diffuse agricultural pollution, with identification of long-term anthropogenic trends in pollutant concentrations and the response of the identified trends to the correction measures applied.

A complete assessment of the effects of agricultural drainage on water quality must focus on pollutant loads in addition to pollutant concentrations, as it is the mass of pollutants that will degrade the quality of the receiving water bodies (Lecina et al., 2010), as recognized by the total maximum daily load (TMDL) approach used in the U.S. and elsewhere (Elshorbagy et al., 2005). In the Ebro River basin (northeast Spain), salt and nitrate loadings have been identified among the main water pollution problems

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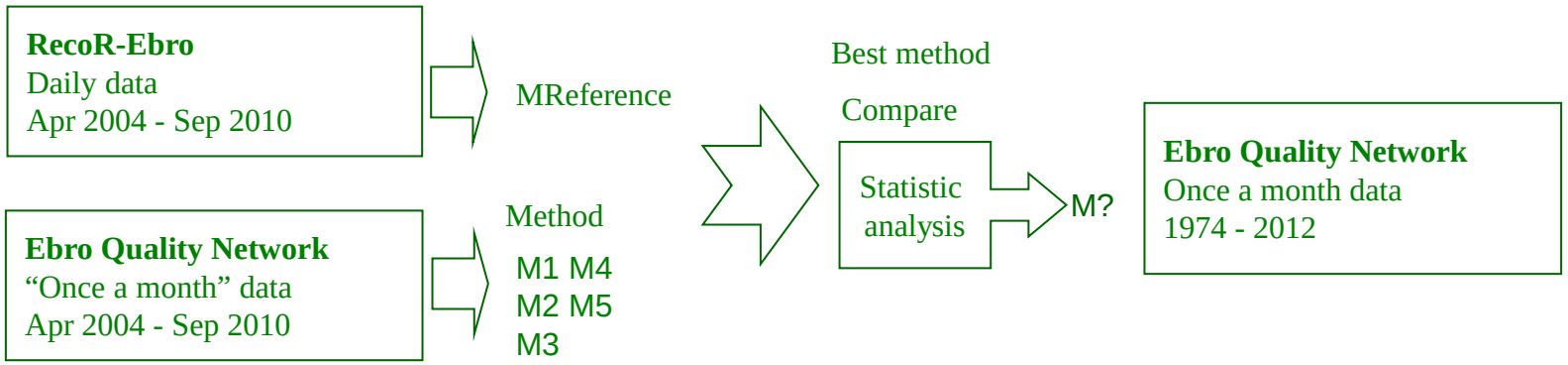
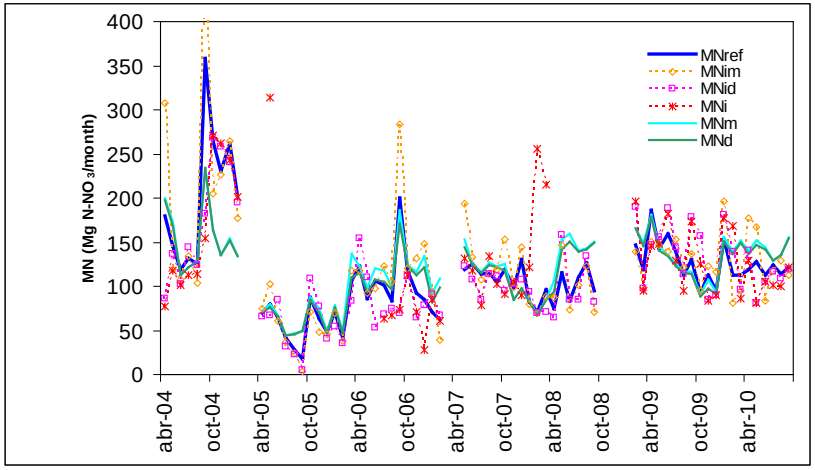
The authors are **María Ángeles Lorenzo-Gonzalez**, Graduate Student and Postdoctoral Fellow, **Dolores Quílez**, Agricultural Researcher, and **Daniel Isidoro**, Agricultural Researcher, Department of Soils and Irrigation, Agrifood Research and Technology Center of Aragón, Zaragoza, Spain. **Corresponding author:** M. A. Lorenzo-Gonzalez, Centro de Investigación y Tecnología Agroalimentaria de Aragón, Avenida Montañana No. 930, 50059 Zaragoza, Spain; phone: +34-976-716-282; e-mail: malorenzog@aragon.es.

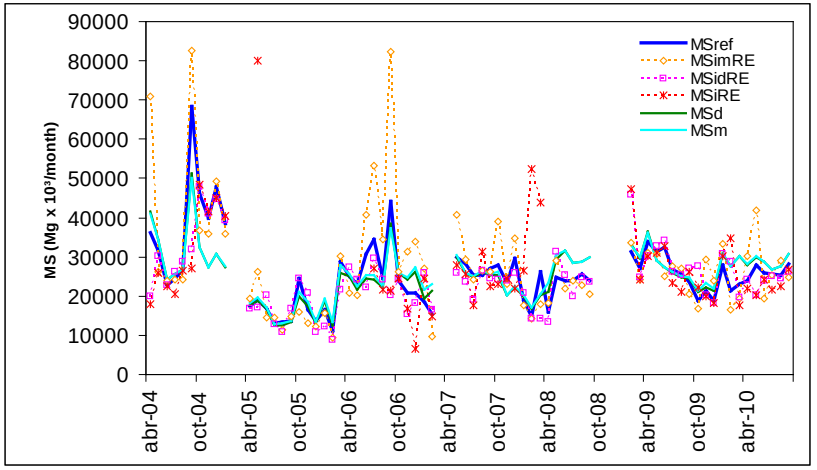
Objetivo: Comparar diferentes métodos de estimación de la carga de sal y nitrógeno a partir de series con frecuencia mensual aportados por la CHE con series de cadencia diaria obtenidas en las estaciones de RecoR-Ebro.



	Métodos basados en datos instantáneos						Métodos de regresión			
	MSi	MNi	MSid	MNid	MSim	MNid	MSd	MNd	MSm	MNm
Caudal	Qi		Qd		Qm		Qd		Qm	
	Caudal instantáneo del muestreo		Caudal del día de muestreo		Caudal medio mensual		Caudal medio diario		Caudal medio mensual	
Concentración	TDSi y NO_3i		TDSi y NO_3i		TDSi y NO_3i		TDSd y NO_3d		TDSm y NO_3m	
	Dato instantáneo		Dato instantáneo		Dato instantáneo		Obtenido a partir del caudal medio diario		Obtenido a partir del caudal medio mensual	
	1 dato/mes		1 dato/mes		1dato/mes		∑mes		Media del mes	

Resultados:





- Métodos **regresivos** son los que representan mejor la variabilidad de la carga de sal y nitrato a lo largo del tiempo. Estos métodos solo necesitan una buena relación entre el caudal y la concentración de sal/nitrato.

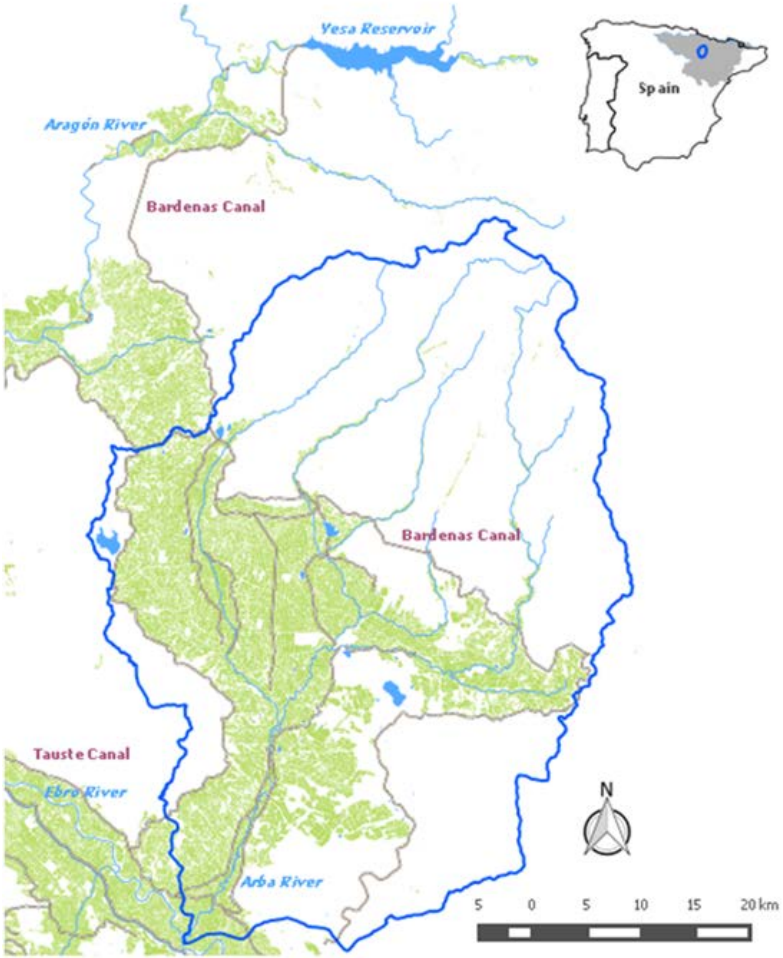
- Hay que tener en cuenta **tres factores** importantes:

  - Solo en ríos con buena relación Q/TDS o NO3

  - Esta relación debe ser estable en el tiempo.

  - Las tendencias de ambos parámetros están fuertemente vinculados a las tendencias de los caudales

2. Balance de agua y salinidad en la cuenca del Arba



Objetivo: Análisis de tendencias de salinidad en la cuenca del río Arba y su relación con el desarrollo de la agricultura a lo largo de los últimos 40 años.

Implementación de distintos escenarios.

Cuenca del río Arba:

- Riegos desde los años 60´: 20.000 ha ⟶ 62.000 ha (28%). Canal de Bardenas – Canal de Tauste.

- Agua de riego: Río Aragón (Embalse de Yesa). CE: 0.35 dS/m

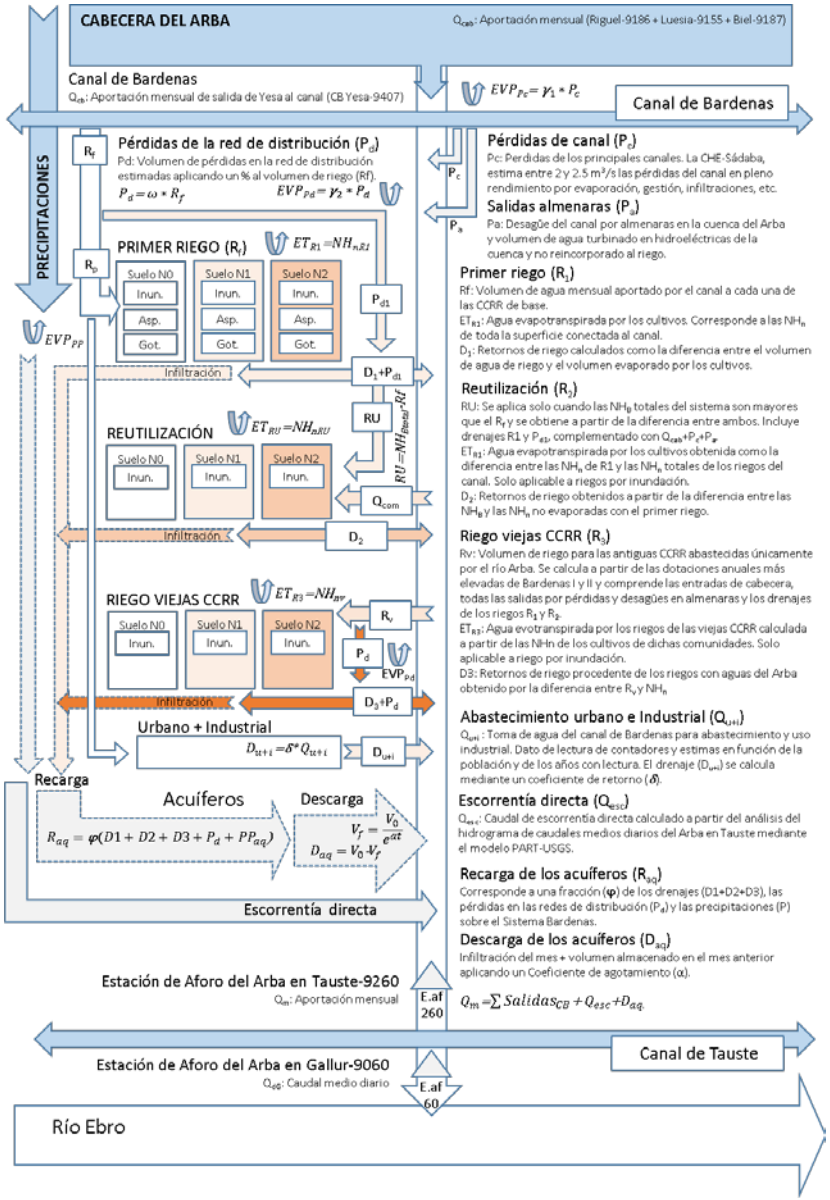
- Caudal en regimen natural 172.8 hm^3/año (máximos en primavera y mínimos en verano)

- Riego incrementa en 160 hm^3/año (máximos en verano y minimum otoño e invierno)

- Suelos ricos en formaciones salinas.

- Datos de caudal y salinidad en desembocadura desde 1973

Regadío y calidad físico-química de las aguas superficiales en la cuenca del río Ebro



Datos conocidos (1973-2014)

ENTRADAS	SALIDAS
Naturales: - Caudal cabecera - Precipitaciones **Canal de Bardenas:** - Volumen de riego - Volumen urbano e industrial - Desagües almenaras e hidroeléctricas - Pérdidas de canales	- Evapotranspiración de los cultivos - Caudal del Arba en Tauste (E. Af. 260)

Usos del suelo	Calidad
- Superficie de riego - Sistema de riego - Litologías regadas	- SDT cabecera - SDT C. Bardenas - SDT Arba (E. Af. 260)

Parámetros de ajuste

Eficiencia del sistema	Acuíferos
- Eficiencia de riego en parcela - Pérdidas en las redes de distribución - Evaporación de las pérdidas	- Infiltración en acuífero - Coeficiente de agotamiento

$$Q_m = \sum Salidas_{CB} + Q_{esc} + D_{aq.}$$

ESCENARIOS FUTUROS:

Previsiones del Plan Hidrológico de la Cuenca del Ebro: 2015-2021 (Real Decreto 1/2016, de 8 de enero)

- Ampliación de la superficie de riego
- Modernización de los regadíos
- Incremento de la demanda: cultivos con requerimientos hídricos mayores (dobles cosechas, forrajeras o maíz)
- Cambio climático: reducción del recurso natural 5% (PHE)

3. Análisis estadísticos de las tendencias de salinidad del río Ebro y su proyección para el 2027.

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Orals HS2.4.1

HS2.4.1
Hydrological change: Regional hydrological behaviour under transient climate and land use conditions
Convener: Stefan Hagemann | Co-Conveners: Axel Bronstert, Harald Kunstmann
Orals / Tue, 19 Apr, 13:30–15:00 / Room C
Posters / Attendance Tue, 19 Apr, 17:30–19:00 / Hall A

Tuesday, 19 Apr 2016
Room C
Chairperson: Stefan Hagemann

13:30–13:45 EGU2016-12184
Separation of land-use change induced signals from noise by means of evaluating perturbed RCM ensembles: Assessing the potential impacts of urbanization and deforestation in Central Vietnam
Patrick Laux, Phuong N. B. Nguyen, Johannes Cullmann, and Harald Kunstmann

13:45–14:00 EGU2016-2288
Storylines of socio-economic and climatic drivers for land use and their hydrological impacts in alpine catchments – the STELLA project example
Ulrich Strasser, Herbert Formayer, Kristian Forster, Thomas Marke, Gertraud Meißl, Markus Scherner, Friederike Stotten, and Matthias Themessl

14:00–14:15 EGU2016-9218
Recent Trends in the Ebro River Basin: Is It All „Just" Climate Change?
Stefanie Lutz and Ralf Merz

14:15–14:30 EGU2016-13810
Salinity trends in the Ebro River (Spain)
Mª Angeles Lorenzo-Gonzalez, Daniel Isidoro, and Dolores Quilez

14:30–14:45 EGU2016-14597
Decrease in hydroclimatic conditions generating floods in the southeast of Belgium over the last 50 years resulting from changes in seasonal snow cover and extreme precipitation events
Coraline Wyard and Xavier Fettweis

14:45–15:00 EGU2016-16337 | presentation | presentation
Assessing the impact of climate change on water resources in a tropical West African catchment using an ensemble of CORDEX climate simulations (Dano, Burkina Faso)
Yacouba Yira, Bernd Diekkruger, Gero Steup, and Aymar Yaovi Bossa

Geophysical Research Abstracts
Vol. 18, EGU2016 13810, 2016
EGU General Assembly 2016

Salinity trends in the Ebro River (Spain)

Mª Angeles Lorenzo Gonzalez, Daniel Isidoro, and Dolores Quilez
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In the Ebro River Basin (Spain), the increase in water diversion for irrigation (following the increase in irrigated area) and the recovery of natural vegetation in the upper reaches, along with climate change have induced changes in the river flow and its associated salt loads. This study was supported by the Ebro River Basin Administration (CHE) and aimed to establish the trends in the salt concentrations and loads of the Ebro River at Tortosa (no 027, the extreme downstream gauging station).

The CHE databases from 1972 73 to 2011 12, including mean monthly flows (Q) and concentration readings (electrical conductivity converted to total dissolved solids TDS by regression) from monthly grab samples, have been used. The trends were established by (i) harmonic regression analysis; (ii) linear regression by month; and (iii) the non parametric Mann Kendall method. Additionally, (iv) the regressions of TDS on Q in the current and previous months were established, allowing for analyzing separately the trends in TDS linked to (TDSq) and independent of (TDSaj) the observed changes in flow. In all cases, the trends were analyzed for different periods within the full span 1973 2012 (1973 to 2012, 1981 to 2012, 1990 2012 and 2001 2012), trying to account for periods with sensibly similar patterns of land use change.

An increase in TDS was found for all the periods analyzed that was lower as shorter periods were used, suggesting that lower salinity changes might be taking place in the last years, possibly due to the reduction in the rate of irrigation development and to the on going irrigation modernization process. The higher seasonal TDS increases were found in autumn and winter months and the increase in TDS was linked both to intrinsic changes in salinity (TDSaj) and to the observed decrease in flow (TDSq). On the other hand, the salt loads decreased, especially in autumn, as a result of the observed flow decrease.

These results are based on the observed evolution of flows and salinity in 1973 2012 and can only be extrapolated into the future if the drivers of this evolution (climate and land use changes) remain unchanged in the following years, what is uncertain. A more comprehensive methodology to estimate the effects of irrigation on water salinity has been developed based on a mass balance approach. Using actual data on volumes and concentrations of return flows observed in the basin (dependent on the actual salinity of soils and waters and the irrigation systems, among other factors), the return flows of the irrigated areas are aggregated to match the actual flows and loads observed in the Ebro River. Once this balance is satisfied, the effect of new irrigated areas, drainage water reuse, irrigation modernization, or climate change would be incorporated to the balance yielding salinity forecasts based on planned irrigation developments and modernization or climate change predictions. A priori, irrigation modernization would produce lower, more concentrated volumes of return flows with lower salt loads that would result in lower TDS concentrations in the Ebro River.

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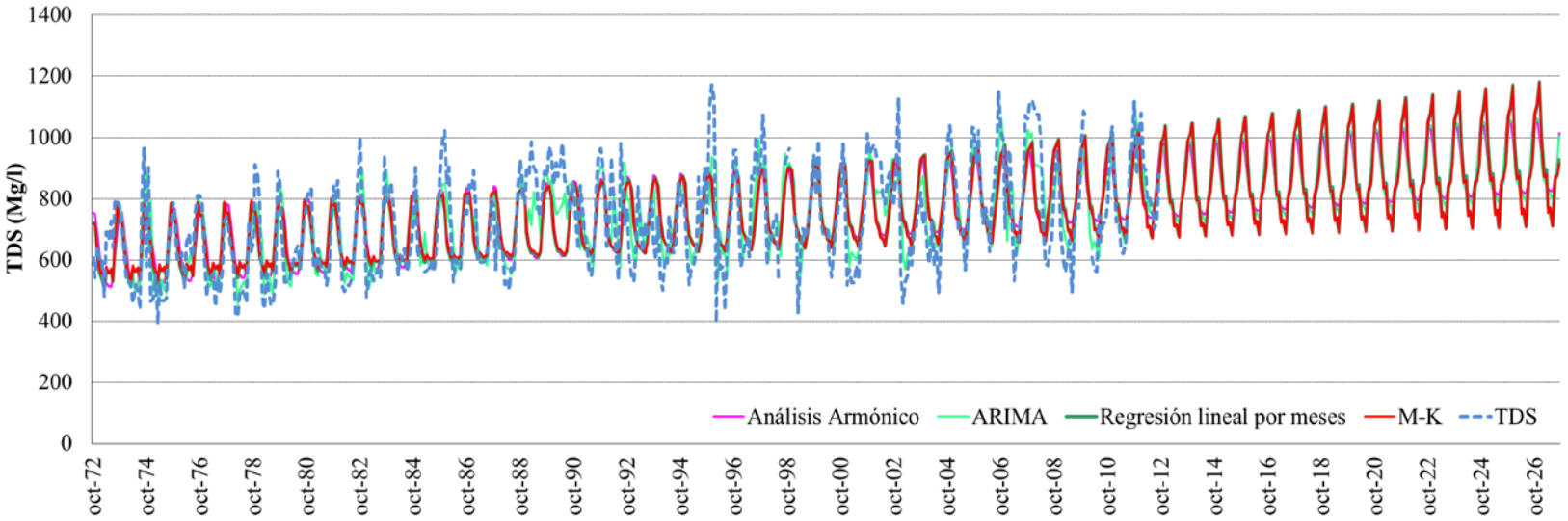
Regadío y calidad físico-química de las aguas superficiales en la cuenca del río Ebro

Objetivo: Definir las tendencias de salinidad del río Ebro en desembocadura y realizar proyecciones de concentraciones de sal para 2027

Statistical Methods:

1. **Análisis de tendencias de salinidad**: Análisis armónico, ARIMA, regresion lineal por meses y M-K
2. **Análisis estadístico basado en la relación salinidad – caudal** : TDS_{caudal} + $TDS_{ajusado}$

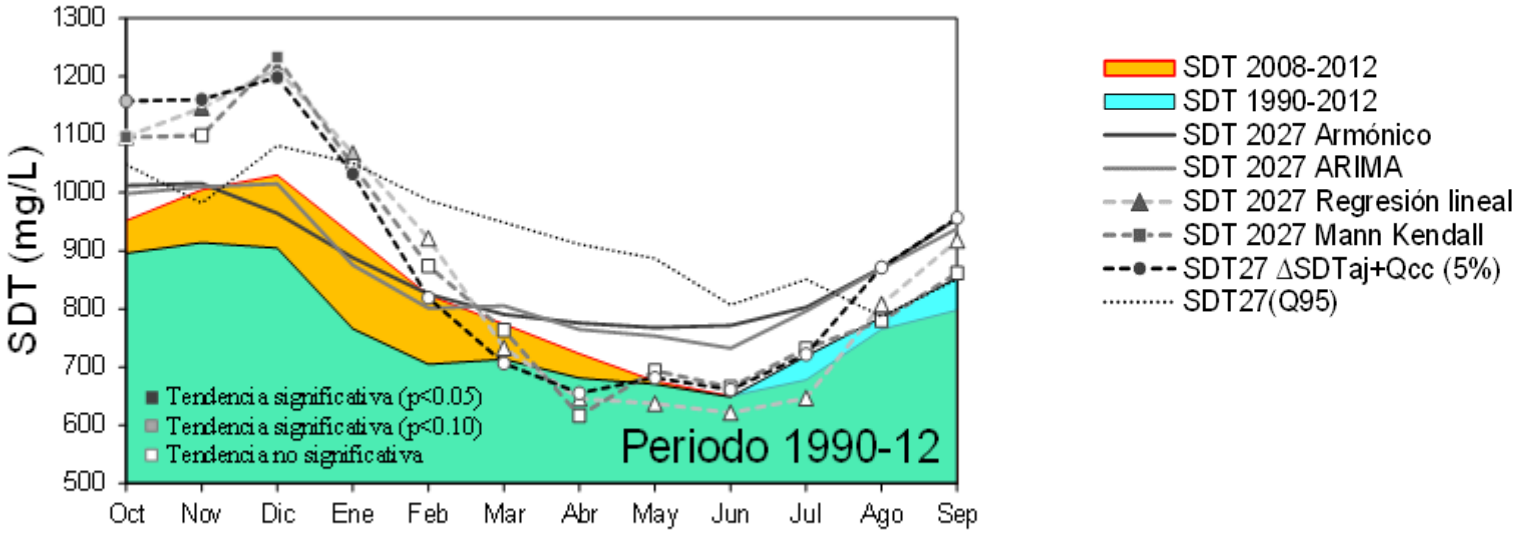


Periodos	Criterio	Años	Datos
1973-2012	Serie complete de CE	40	480
1981-2012	PHE planificación	32	384
1990-2012	Cambio en el régimen de caudal	23	276
2001-2012	Comienzo de los grandes planes de modernización	12	144

Resultados 2027: Predicciones anuales

	Observados	SDT 2027 (mg/L)				
		Armónico	ARIMA	Reg. lineal	M-K	SDT_{aj}+Qcc
2008-2012	817					
1973-2012	721	920	917	920	913	884
1981-2012	749	896	894	896	894	883
1990-2012	772	870	863	871	872	885
2001-2012	793	968	947	973	1003	879

Predicciones mensuales



4. Análisis espacio-temporal del incremento de la temperatura del eje del río Ebro y principales tributarios (Aragón y Cinca)

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Orals HS2.4.5

HS2.4.5
Hydrological change: Regional hydrological behaviour under transient climate and land use conditions
Convener: Stefan Hagemann | Co-Conveners: Axel Bronstert, Harald Kunstmann
Orals / Wed, 30 Apr, 08:30-12:00 / Room R1
Posters / Attendance Wed, 30 Apr, 17:30-19:00 / Red Posters

Wednesday, 30 Apr 2014
Room R1
Chairperson: Axel Bronstert

The role of land use for hydrological change

10:30-10:45 EGU2014-14883
Water availability and demand in West Africa in the 21st century: impacts of climate change and population growth
Dominik Wisser, Ganiyu Oyerinde, Moussa Ibrahim, and Boubacar Ibrahim

10:45-11:00 EGU2014-5713
Evaluation of Med-CORDEX regional climate model simulations for hydrological impact studies in Morocco
Yves Tramblay, Samuel Somot, Csaba Zsolt Torma, Erika Coppola, Raquel Romera, Marca Dominguez, Miquel Ángel Gaertner, Denis Ruelland, Redouane Bouaicha, and Eric Servat

11:00-11:15 EGU2014-3751
High-resolution distributed evaluation of climate and anthropogenic changes on the hydrology of an Alpine catchment
Paolo Scalondo and Simone Fatichi

11:15-11:30 EGU2014-10838
Modeling impacts of climate change on evapotranspiration and soil moisture spatial patterns in an alpine catchment
Johannes G. Brenner, Giacomo Bertoldi, Stefano Della Chiesa, Georg Niedrist, Ulrike Tappeiner, and Axel Bronstert

11:30-11:45 EGU2014-14980
Using a stochastic hydrological model to study the sensitivity of flood frequency to climate change [France]
Philippe Caballet and Patrick Arnaud

11:45-12:00 EGU2014-1210
Trend analysis of river water temperatures in the Ebro River Basin [Spain]
Mª Angeles Lorenzo-Gonzalez, Dolores Quilez, and Daniel Isidoro

Uncertainties and various aspects of hydrological change

Geophysical Research Abstracts
Vol. 16, EGU2014-1210, 2014
EGU General Assembly 2014

Trend analysis of river water temperatures in the Ebro River Basin (Spain)

Mª Angeles Lorenzo-Gonzalez, Dolores Quilez, and Daniel Isidoro
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Water temperature is an important factor conditioning physical, biological and chemical processes in water courses. The huge changes along the last 50 years in land and water use (dam construction, urban development, nuclear power plants (NPP), riparian alteration, irrigation development, and return of agricultural lands to forests), along with climate change, call for the study of their influence on river water temperatures.

This work analyzed the trends (1973-2010) in water temperature (T_w) along the Ebro River (14 water quality stations) in North-East Spain and its main tributaries (6 water quality stations), as a first step to assess its possible relationships with land use changes, climate change, and other factors. Water temperature trends (ΔT_w) were estimated by two different methods: (1) multiple regression incorporating year seasonality and linear trend; and (2) non-parametric Mann-Kendall seasonal trend estimator. A cluster analysis based on principal components (performed upon the variables T_w, ΔT_w, annual T_w range, lag of the T_w annual cycle, coefficient of correlation between water and air temperature (T_a), and station altitude) allowed for grouping stations with similar behaviour in T_w (along the year, seasonality, and throughout the study period, trend).

Trend analysis by the regression and Mann-Kendall methods produced similar results. They showed significant ($P<0.05$) annual upward trends in T_w in all the stations but for the 2 headwater stations of the tributaries Aragón and Segre. However, there were significant differences in ΔT_w among stations and seasons. The lower reach of the Ebro River, downstream the Ascó NPP, showed the highest ΔT_w with an increase of 3.5°C in 40 years (~0.09°C/year). In contrast, the stations located on dams or on the lower reaches of the tributaries showed the lowest trends: 1.3°C in 40 years (~0.03°C/year). Generally, the ΔT_w were significant from April to June, but in the lower reach of the Ebro River (downstream from Ascó station), ΔT_w was significant from December to September.

The cluster analysis identified four kinds of stations: (i) headwaters with low T_w and generally low ΔT_w and close relationship between T_a and T_w; (ii) stations on dams, downstream the Garoña NPP, or downstream the main tributaries, with the weakest relationship between T_a and T_w; (iii) the stations in the mean reaches of the Ebro River and outlets of the main tributaries showing the closest relationship between T_a and T_w; and (iv) stations downstream from Ascó NPP that showed the highest ΔT_w and T_w (2°C higher than contiguous stations).

Altogether, a noticeable increase in T_w was observed throughout the Ebro River Basin (up to 2°C in 40 years) which may affect physic-chemical and biological in-stream processes. Although climate change should be contributing to this increase, the contribution of other anthropogenic factors (particularly related to land use, as irrigation development and reforestation) is likely to be important in this basin and its effect on T_w should be studied in detail.

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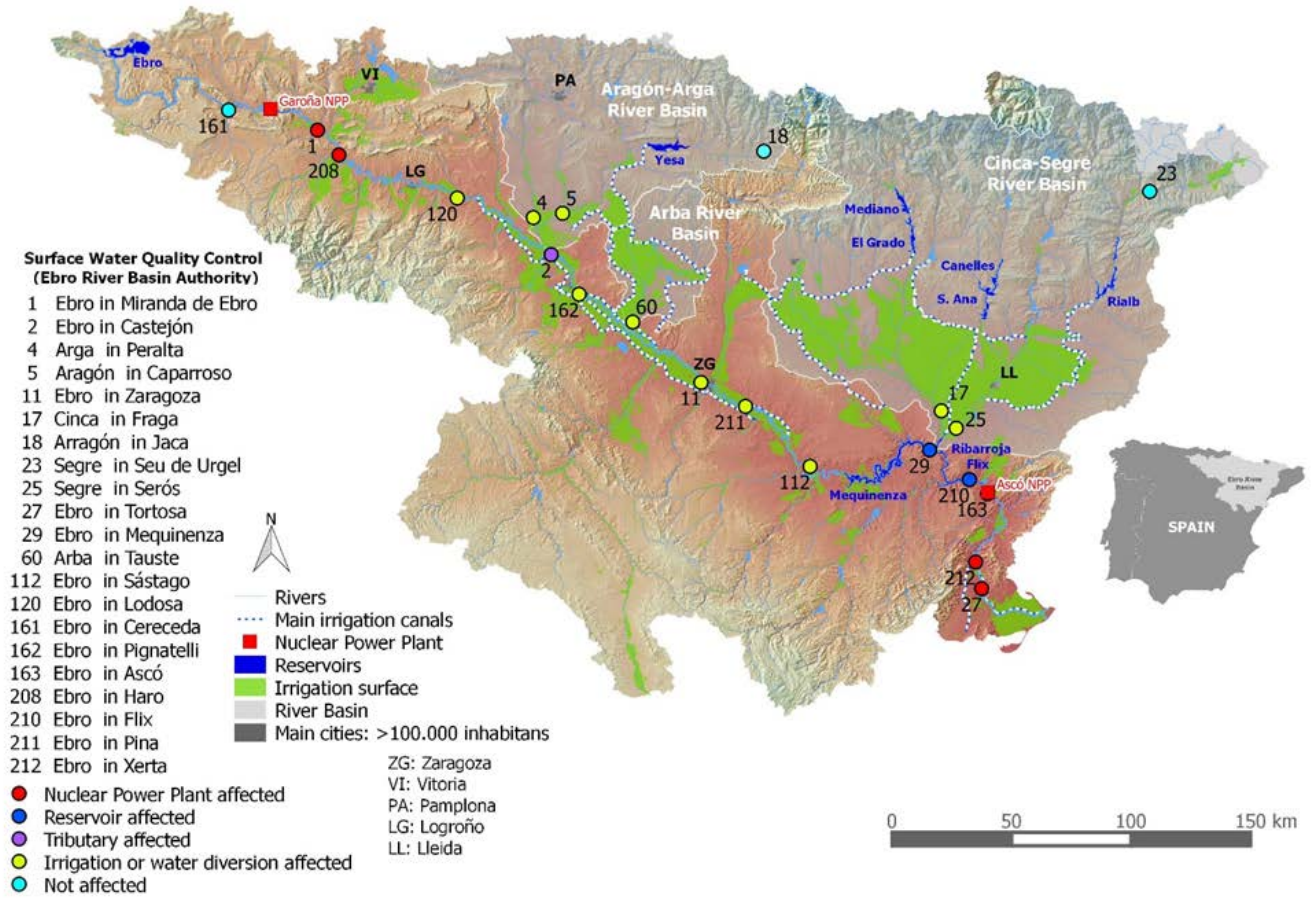
cita
CENTRO DE INVESTIGACIÓN Y TECNOLOGÍA AGROALIMENTARIA DE ARAGÓN

Regadío y calidad físico-química de las aguas superficiales en la cuenca del río Ebro

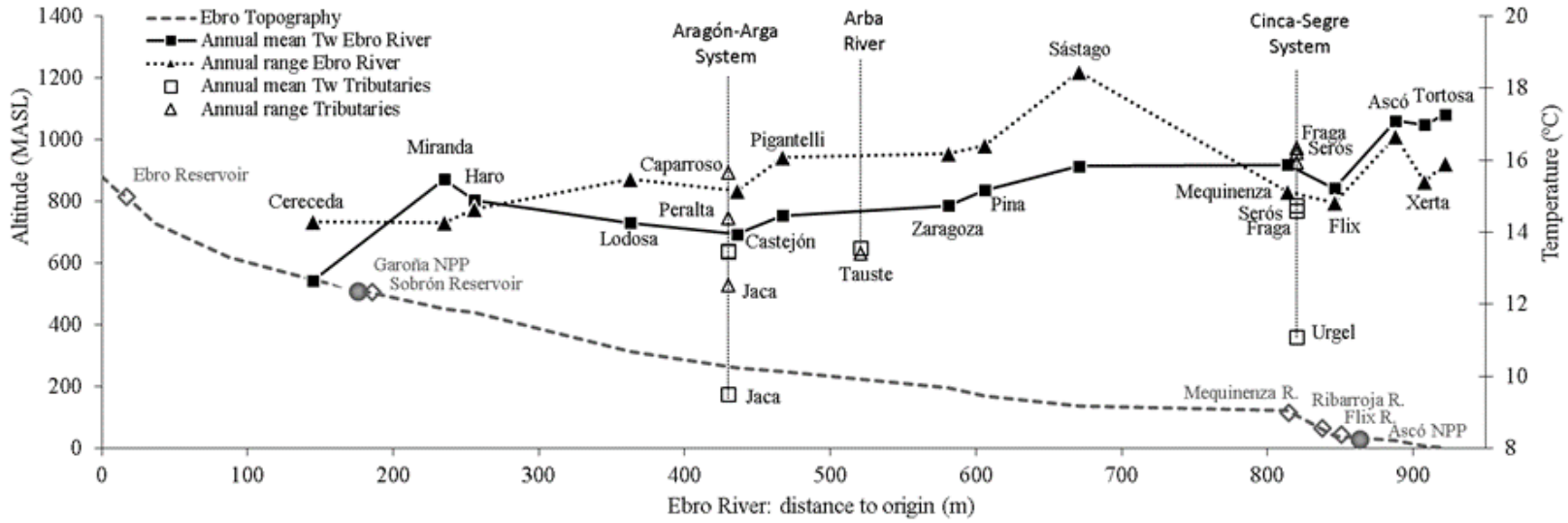
Objetivo: Analizar la tendencia de la temperatura del agua del río Ebro y principales tributarios (1973 - 2012) como un primer paso para definir posibles relaciones entre los cambios en los usos del suelo, el cambio climático y otras posibles causas.

Estaciones de la red de calidad (CHE). October 1973 - September 2012

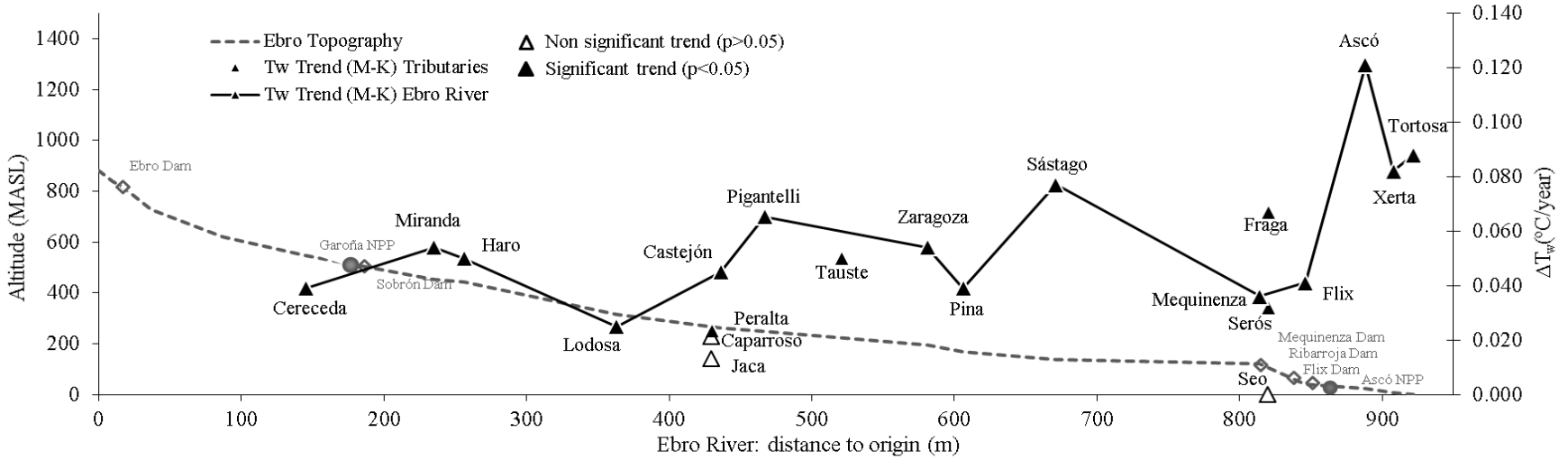


Regadío y calidad físico-química de las aguas superficiales en la cuenca del río Ebro

RESULTADOS: Longitudinal profile of the annual mean T_w and annual range



Longitudinal profile of the annual trend



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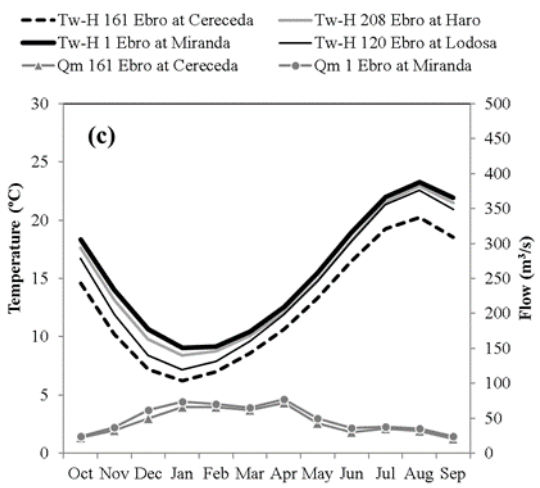
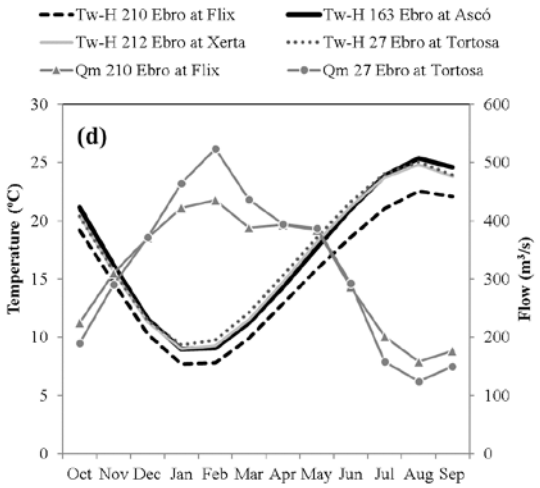
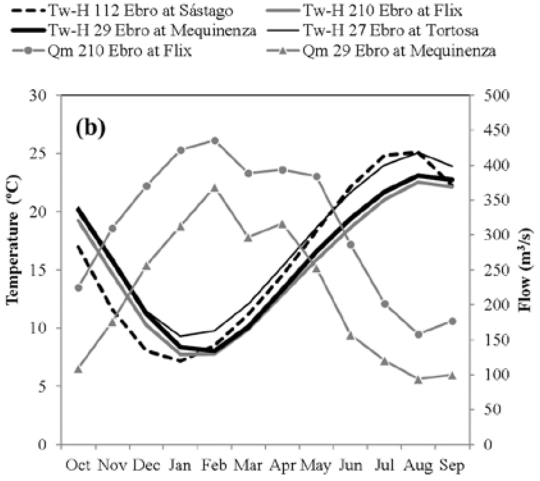
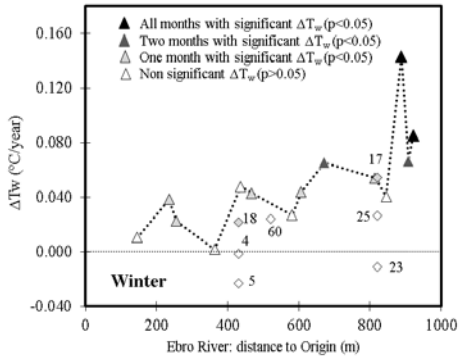
Seasonal mean Tw

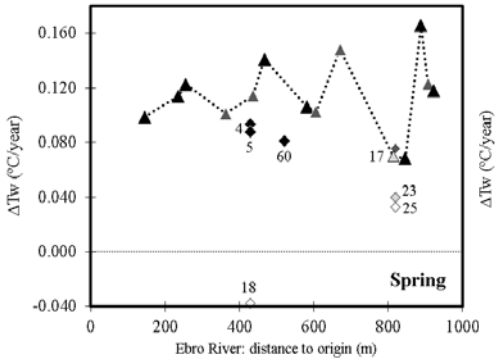


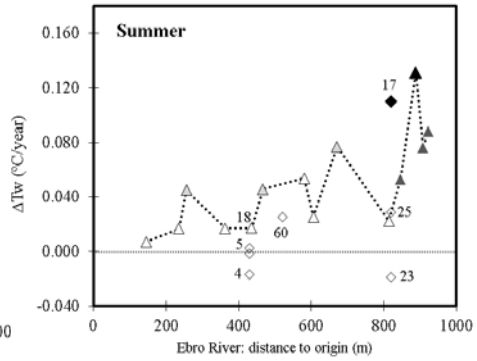


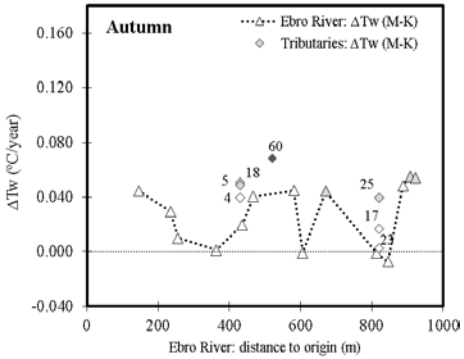


Seasonal trends









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ACTIVIDADES DEL DOCTORADO

	Requerimientos	Realizado	
Seminarios de iniciación a la investigación	48h 4h imp.	77 h 5h	Seminarios RAMA.
Participación en congresos	80h	90 h	- 21st Century Watershed Technology Conference and Workshop (ASABE) Bari (Italy) May 27th- June 1st, 2012 - European Geosciences Union General Assembly 2014 Vienna | Austria | 27 April – 02 May 2014 - European Geosciences Union General Assembly 2016 Vienna | Austria | 17–22 April 2016
Elaboración de manuscritos y publicación de resultados	200h	>200h	- M.A. Lorenzo-González, D. Quílez y D. Isidoro. 2012. "*Statistical behaviour of load estimators based on routine monthly data series*". 21st Century Watershed Technology Conference and Workshop: Improving Water Quality and Environment. Bari (Italia) 28-30 May 2012. - M.A. Lorenzo-González, D. Quílez, D. Isidoro. 2014. "*Trend analysis of river water temperatures in the Ebro River Basin (Spain)*". European Geosciences Union, General Assambly. Vienna (Austria) 28 April - 2 May 2014. - M.A. Lorenzo-González, D. Quílez, D. Isidoro. 2014. "*Long term salinity trends in the Ebro River (Spain)*". 3rd Salinity Forum, 2014. University of California Riverside (USA) 16-18 June 2014. - M.A. Lorenzo-González, D. Quílez, D. Isidoro. 2016. "*Salinity trends in the Ebro River(Spain)*". European Geosciences Union, General Assambly. Vienna (Austria) 19 April 2016.
Estancia en otros centros de investigación	80h	3 m	Oct-Dic 2014: Civil and Environmental Engineering Dept., Colorado State University (Fort Collins-USA). "*Characterization of the salt loads of the Irrigation Return Flows in the Arba River Basin*"

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