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CENTRO DE INVESTIGACIÓN Y TECNOLOGÍA AGROALIMENTARIA DE ARAGÓN

Long-term evolution of the salt balance in the Flumen irrigation district (Spain)

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Presentation Outline

- Introduction
  - Irrigation [modernization] and water resources in Spain
  - The Ebro River Basin
  - Objectives
- Methodology
  - The Flumen Irrigation District (FID) in the Ebro River Basin
  - Historical data series
  - Salt balance estimation and trends
- Results and Discussion
  - Salt balance dynamics
  - Salinity Trends
- Conclusions
  - Main concerns and future work

Irrigation and Water resources in Spain

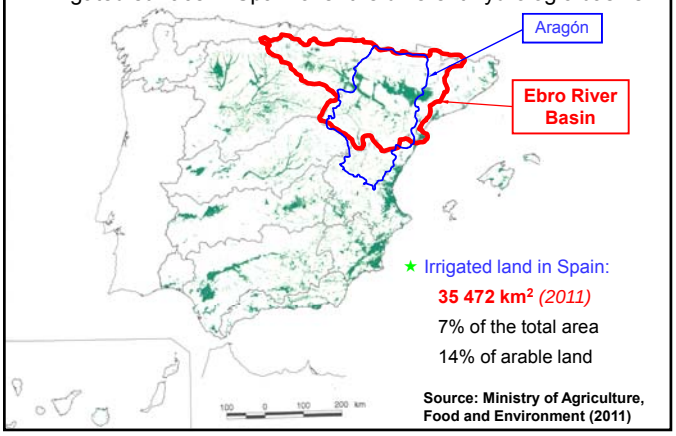
- Climate in Spain:
  - ★ Mediterranean with dry-hot (Csa) or dry-warm (Csb) summer mixed with areas of warm summers and no dry season (Cfb) and big areas of steppe (BSk)
  - ★ More varied than northern European countries
  - ★ Dry steppe areas (BSk) where irrigation is required for enhanced agricultural production (SE and NE)

Source: Hammond, 1970

Australia and Spain

- Latitude comparison between Australia and Spain (and Ebro basin)
  - ★ Australia:

❑ Irrigated surface in Spain over the different hydrologic basins



★ Irrigated land in Spain:
35 472 km² *(2011)*
7% of the total area
14% of arable land

Source: Ministry of Agriculture, Food and Environment (2011)

	Spain	Ebro River Basin
Irrigated land km² (%)	**35472 (7%)**	**7387 (9%)**
Type of irrigation (%)		
Surface	**59**	**62 ↓**
Sprinkler	**24**	**28 ↑**
Drip	**17**	**10**
Water source (%)		
Suface water	**69**	**91**
Groundwater	**19**	**9**
Recycled	**1**	**0**
Mean water supply (m³/ha)	**7042**	**8033 ↓**
Population		
Total population (est. 2012)	**47 042 984**	**3 019 176**
Population density (hab/km²)	**93.1**	**35.5**

Source: Ministry of Agriculture, Food and Environment (2011) and CHE

❑ Irrigation in Spain

★ In Spain, all irrigation schemes are bound to constitute a ***Water Users Association*** (Comunidades de Regantes) that is the legal speaker for the farmers before the Basin Authority

★ **Basin Authorities** (Confederaciones Hidrográficas) were established since the 1920's and are the entities responsible for water use and quality issues within the basin

➢ Today a requirement in the European Water Framework (Directive 2000/60/EC)

➢ The ***Confederación Hidrográfica del Ebro*** was createded in 1927

★ There is an ongoing modernization effort throughout all the territory:

Affected surface area (ha) Horizon 2008			
New irrigation		Amelioration and modernization	
Spain	**Aragón**	**Spain**	**Aragón (NE Spain, Ebro Basin)**
652 277	**55 660**	**1 134 891**	**142 332** Infrastructure amelioration: 115 693 Change of the irrigation system: 67 029

Source: National Irrigation Plan (PNR)

❑ The strengths of irrigation or why irrigation?

★ Production under irrigation is much higher than in dry-land conditions in Spain [Productivity ratio: Irrigated land/dry-land = 6.38]

★ Agriculture and related activities adds up to 6.8% of GDP; 14% of the exports and provides labor for 1.5 million people

★ Irrigated agriculture accounts for 14% of the arable land; but contributes to 55% of the agricultural production

★ Irrigation is the key to **maintaining the population** in rural areas with an adequate standard of living

Counties with % irrigated to cultivated	Population growth (1981-1990)	Population density (hab/km²)
< 20%	-0.5	71
20% to 50%	7.9	88
> 50%	5.4	133
Spain	1.9	80

Source: National Irrigation Plan (PNR)

Irrigation and Water resources in Spain

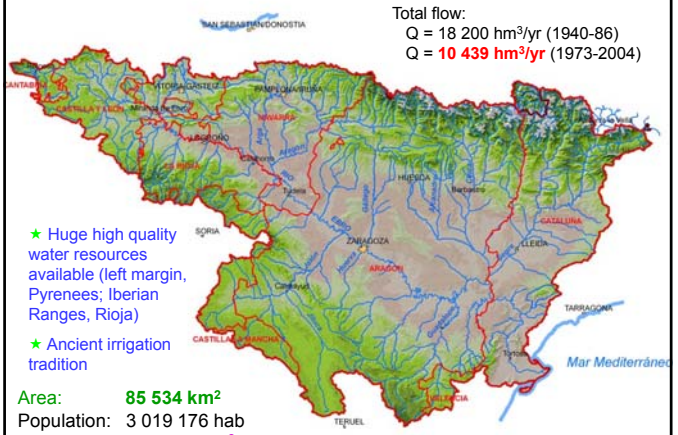
- Why irrigation in Aragón (Ebro River basin, NE Spain)?
  - ★ Fixing population in rural areas

Aragón (excluding province capitals)		
Irrigation by municipality (% agricultural area)	Density 2001 (cap/km²)	Δ Density 1970-2001 (%)
> 50	36	+0.2
25 – 50	21	-10.8
9.4 – 25	17	-13.1
< 9.4	7	-27.9

  - ★ Maintaining the standard of living of farmers
    - ➢ Aragón (2000): 34700 farmers
      7% of active population [Δ = -30% (∇)]
    - ➢ Aragón (1991-2000): Δ PFA = -5.7% (∇)
      Δ Rent = -12.5% (∇) [**Rent per capita: Δ=20%**]

Source: CESA (2002, 2003)

The Ebro River Basin



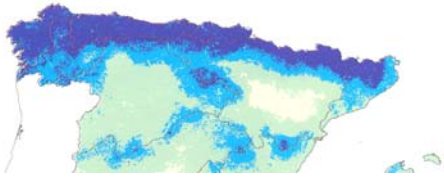
Total flow:
Q = 18 200 hm³/yr (1940-86)
Q = **10 439 hm³/yr** (1973-2004)

★ Huge high quality water resources available (left margin, Pyrenees; Iberian Ranges, Rioja)

★ Ancient irrigation tradition

Area: **85 534 km²**
Population: 3 019 176 hab
Density: 35.5 hab/km²

- Ratio of actual ET (ET_a) to reference ET (ET_o) in Spain



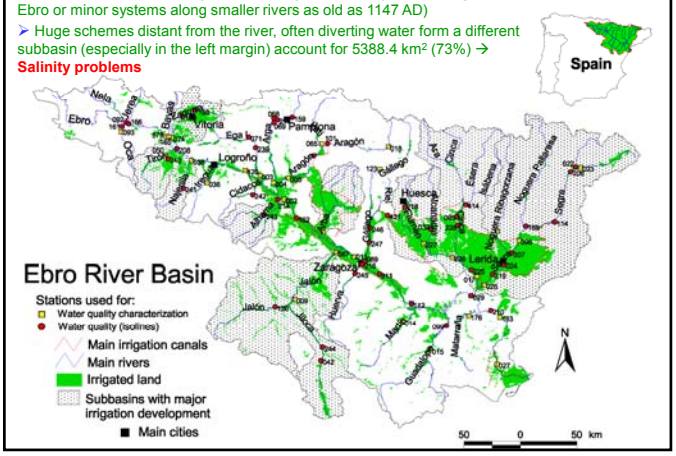
The Ebro River Basin

★ Kind of irrigation schemes

➢ Traditional schemes along the rivers (big state-built systems along the Ebro or minor systems along smaller rivers as old as 1147 AD)

➢ Huge schemes distant from the river, often diverting water form a different subbasin (especially in the left margin) account for 5388.4 km² (73%) →

Salinity problems

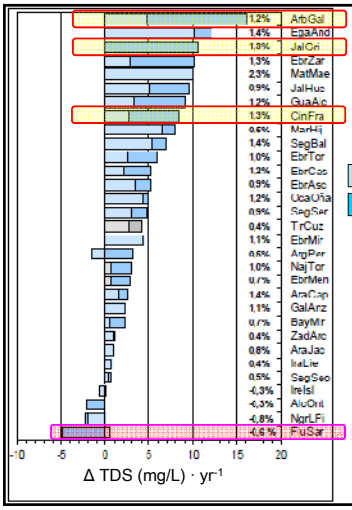


The Ebro River Basin

❑ Soil degradation induced by irrigation in the Ebro Basin

Salinity (CE_e>4dS/m) or sodicity (PSI>15) asffected land		
Irrigation Scheme	ha	%
Bardenas Canal 1st section	13500	41.8
Bardenas Canal 2nd section	13284	20.1
Cinca Canal (sectors 23-37)	5569	14.4
Cinca Canal (sectors 1-22)	13458	23.7
Aragón & Cataluña Canal	34700	25.5
Flumen Canal	12883	46.9
Monegros Canal, 1st Part (tracts 2-3)	6178	17.2
Monegros Canal, 1st Part (tract 4)	4645	52.8
Monegros Canal, 2nd Part	46479	34.7
TOTAL	**150696**	**28.1**

Soure: Herrero and Aragüés (1988)



Objectives

… why the Flumen River Watershed?

❑ Salinity increase (TDS) in 31 WQ stations in the Ebro River Basin (1975-2004)

Increase due to flow decrease

Total salinity increase

❑ Salinity affected area: Soil salinity decrease 1975-1999 (Herrero and Pérez Coveta, 2005)

1. **Explain the decrease in concentration in FRW**
2. **On-going modernization process: What will be its effect on water quality and salt loads?**

Source: CHE-CITA (2007)

Objectives

❑ To assess the historical salt balance in the FID

➢ Characterize the salt balance in FID-FRW (seasonality)

★ Under traditional surface irrigation

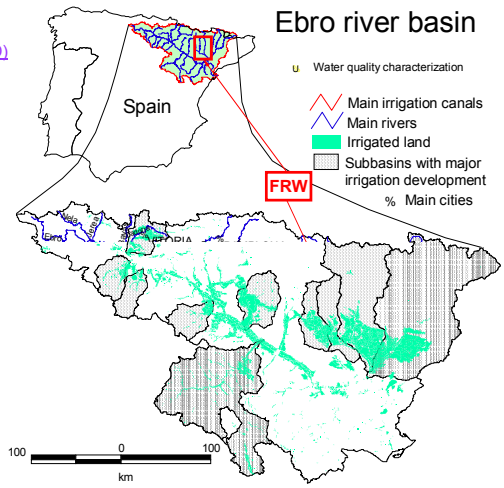
★ To anticipate changes after change to sprinkler irrigation systems

➢ Establish the TRENDS in the salt balance

➢ Determine the usability of water flow and quality records from CHE to establish the long-term salt balance

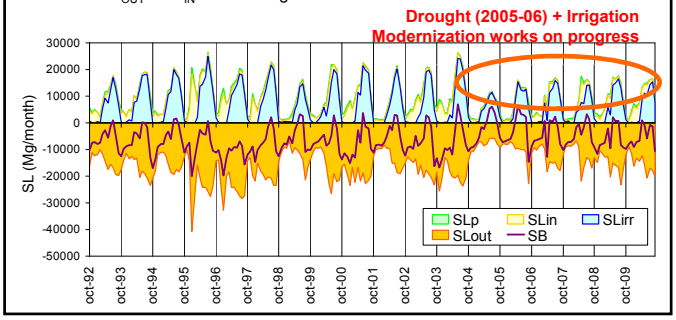
➢ Test the use of basic crop information (statistical sources by municipalities) to establish the relationship between land use and salt exports/salt balance

Flumen
Irrigation
Distrcit (FID)

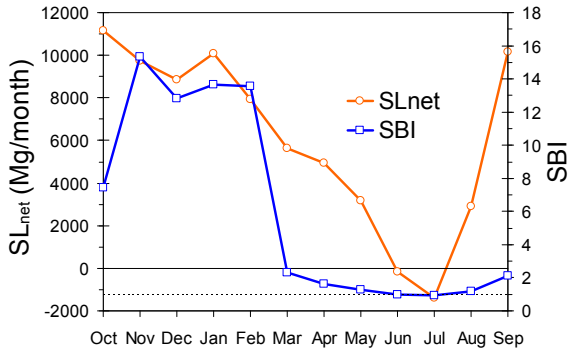


- Data submitted to conference: up to 2008
  - In this presentation: up to 2010
    - ★ Drought in 2005-06 might induce a decrease in SB (extend the time series)
- Results:
  - How is leaching taking place?
  - How is it related to crop patterns in FID?
  - Trends in salinity of irrigation resources and volume of irrigation
  - Trends in the salt balance: future implications

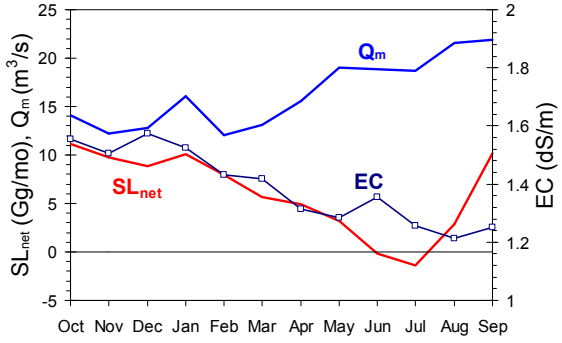
- Salt inputs:
  - SL_{IRR} → IS
  - SL_{IN} (Flumen+Isuela) → NIS
  - SL_P → Negligible
- Salt output (Flumen thorugh Sariñena):
  - $SL_{OUT} > SL_{IN}$ → Leaching
- SB < 0 (salt removal from the system)
  - Except in summer months
  - Winter Leaching dominant
  - SB decreasing in absolute value along time (?)



- SB seasonality: Most leaching (73%) is taking place in the NIS
  - In the mean, there was no leaching in July-August → Monitor the increase of salinity along the IS

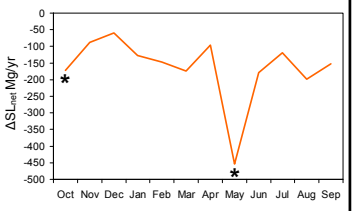


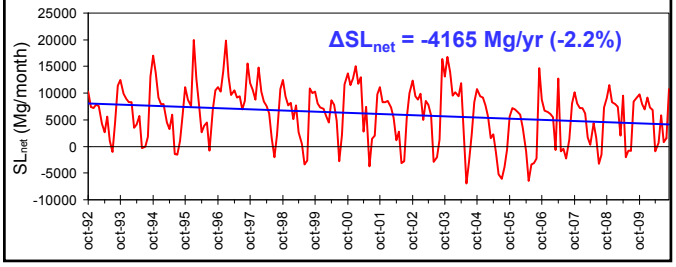
- SB seasonality: Higher flow (Q_m) in the IS with a diluting effect (EC ↓)
  - High volumes of relatively diluted tailwaters may increase water level in the drainange lines and reduce soil drainage and leaching during the IS → SL_{net} ↓



Results and discussion

- Significant decreasing trend in SL_{net} (-SB) (P<0.05)
  - Homogeneous for all months
  - Decrease in inputs: SL_{IRR}, SL_{IN}, SL_P?
  - Related to crop pattern and type of irrigation?
  - SL_{out}=188.9 Gg/yr; SL_{net}=73.0 Gg/yr





Results and discussion

- Trends in water and salt inputs (1993-2010)
  - Only significant slopes are shown: P<0.05; P<0.10; Homogeneous trend

	O	N	D	J	F	Mr	Ap	My	Jn	Jl	Au	S	Year
Trends in water flows (m^3/s)/year													
Irr	·	·	·	·	·	·	-1.3	·	·	·	·	·	**-0.3**
P	·	·	·	·	·	·	·	·	·	·	-0.6	·	**NS**
Q_{out}	-0.34	-0.20	·	-0.29	·	·	·	·	·	·	·	·	**-5.15**
-WB	·	·	·	·	0.49	·	0.57	·	·	·	-0.53	·	**NS**
Trends in salt loads, SL Mg/year													
SL_{IRR}	·	·	·	·	·	·	-406	·	·	·	·	·	**-91**
SL_P	·	·	·	·	·	·	·	·	·	·	-0.6	·	**NS**
SL_{OUT}	-267	-175	·	-252	·	·	·	·	·	·	·	·	**-4165**
SL_{net}	-173	·	·	·	·	·	·	-454	·	·	·	·	**-2300**
Trends in EC (dS/m)/year													
EC_{OUT}	·	·	·	0.02	·	·	·	·	·	·	·	·	**NS**
EC_{cmoalm}	·	·	·	·	·	·	·	·	·	·	·	·	**NS**
EC_{cciemb}	·	·	·	·	·	·	·	·	·	·	·	·	**NS**

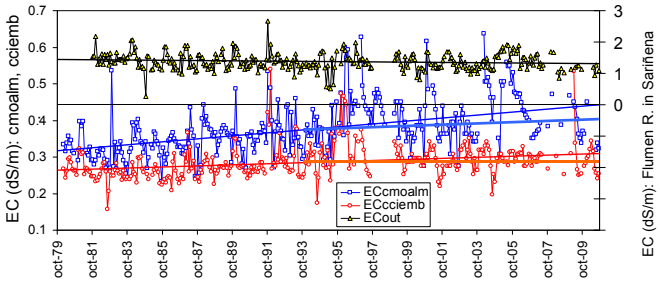
Results and discussion

- No trends in salinity (EC) for 1993-2010 → Longer series?
  - Reported decrease in soil salinity (1975-1985/86-1999) → Is there no decrease in salinity (EC) in the longer data series?
  - P<0.05; P<0.10; Homogeneous trend; Non-homogeneous trend

Trends in EC (·10^{-3} dS/m)/year	O	N	D	J	F	Mr	Ap	My	Jn	Jl	Au	S	Year
Flumen River in Sariñena (Outflow) [Oct 81-Sep 10]													
EC_{OUT}	·	·	-13	·	·	·	·	·	-8	·	·	·	**-4**
Irrigation water (Monegros and Cinca Canals) [Oct 79-Sep 10]													
EC_{cmoalm}	5	5	5	3	4	4	4	3	4	3	3	4	**4**
EC_{cciemb}	1	2	2	2	1	2	3	2	·	·	·	1	**1**
Upstream inflows (Flumen R. [Oct 91] and Isuela R. [Oct 79])													
EC_{fluqui}	·	·	·	·	·	·	·	-13	-9	·	·	·	**-5**
EC_{isupom}	-10	21	·	·	·	·	·	·	-7	·	·	·	**NS**

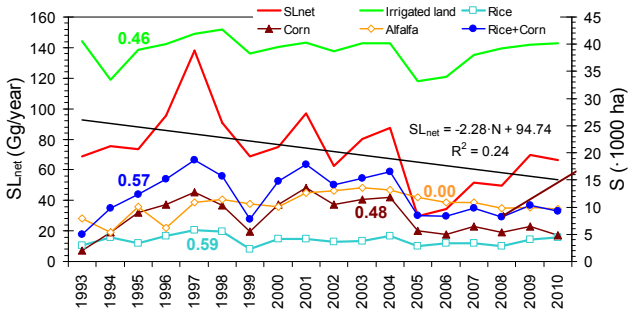
Results and discussion

- Salinity (EC) trends in the period 1979-2010
  - The increase in salinity in irrigation water was steeper before 1993
  - No trends detected for the main ions in Q_{out} except HCO_3 [+2.5 (mg/L)/year —by regression]



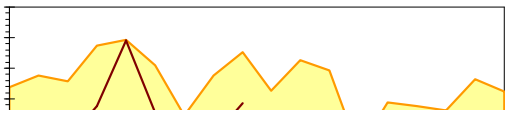
Results and discussion

- Annual SL_{net} was related to cropping patterns
  - Rice – Irrigated Land – Corn ↑ → SL_{net} ↑
  - ΔSL_{net} = -2283 Mg/year —regression estimate



Results and discussion

- Annual SL_{net} was related to irrigation and rainfall
  - Better related to total salt mobilizing flows (Irr+P)



- Trends in the salt balance
  - ΔSL_{net} = -2300 Mg/year (-3.1%)
  - Partially induced by the transformation to sprinkler irrigation in recent years (but not only) and drought in 2005-06.
    - Decrease in irrigation (-0.3 Mm^3/yr) was much lower than the decrease in outflow (-5.5 Mm^3/yr)
    - ΔSL_{IRR} = -91 Mg/yr much lower than ΔSL_{out} = -4165 Mg/yr
  - Trends in EC of irrigation water (increasing)
    - Undetected for 1993-2010, but clear for 1979-2010
  - Decreasing trend in drainage salinity (Q_{OUT}) for 1981-2010
    - ΔEC_{OUT} = -0.004 (dS/m)/yr or ΔTDS_{OUT} = -3.1(mg/L)/yr
    - Only significant for HCO_3 [+2.5 (mg/L)/yr] among the main ions (established by regression)
    - Not significant for the period 1993-2010
  - **Need to assess the evolution of the SB and the implications of the modernization of the system**

- What is to be expected after changing the irrigation system?
  - Expected changes with modernization:
    - Reduced Irrigation volume (-33%)
    - Increased efficiency (consumption)

    → Lower leaching → SB↓
    - Reduced tailwaters and operational losses

    → Lower levels in the drainage system → Enhanced leaching
  - The result from both hydrologic changes is uncertain, but
  - **The detected decreasing trend in SL_{net} and the original salinity problems in the FID point to the need for continuing the monitoring of the Salt Balance**

- **For further information (in Spanish)**
- About the Ebro River Basin (Data, Hydrologic Basin Plan, Reports):

  http://www.magrama.gob.es/es/agua/temas/planificacion-hidrologica/planificacion-hidrologica/default.aspx
- About the assessment of irrigation on water quality in the Ebro River Basin (Reports):
  - http://oph.chebro.es/ContenidoAgronomico.htm
  - Isidoro D. and R. Aragüés (2007), **River Water Quality and Irrigated Agriculture in the Ebro River Basin: An Overview**, *International Journal of Water Resources Development, 23 (1):91-106*
- About the Spanish National Irrigation Plan:

  http://www.magrama.gob.es/es/agua/temas/gestion-sostenible-de-regadios/plan-nacional-de-regadios/

Results and discussion