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Irrigation and Drainage monitoring by remote sensing for Ecosystems and Water resources management

A water accounting system of irrigation districts including downstream rivers

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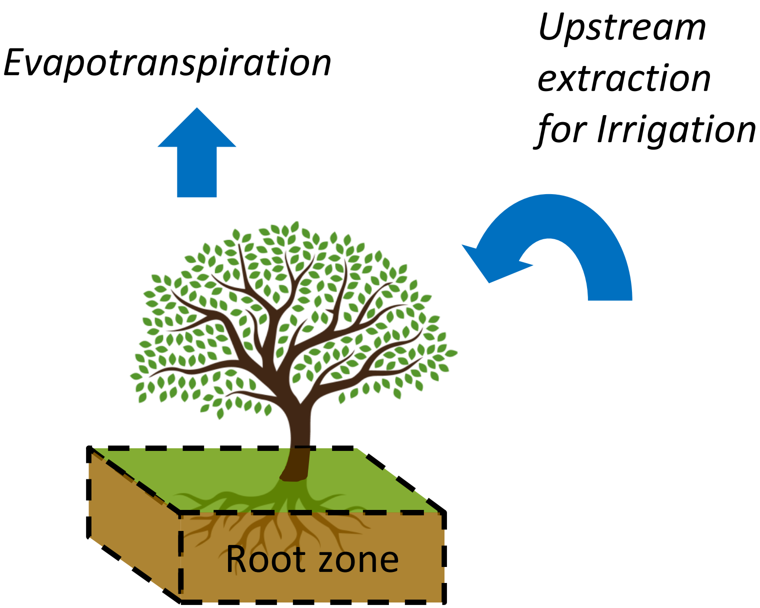
CESBIO isardSAT® Universitat de Lleida imaa observatori de l'Ebre UNIVERSITE CADI AYYAD MARRAKECH

PRIMA PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

H2020-PRIMA-S2-2019, 2020-2023, GA# ANR-19-P026-0003

Why are we focusing on drainage?



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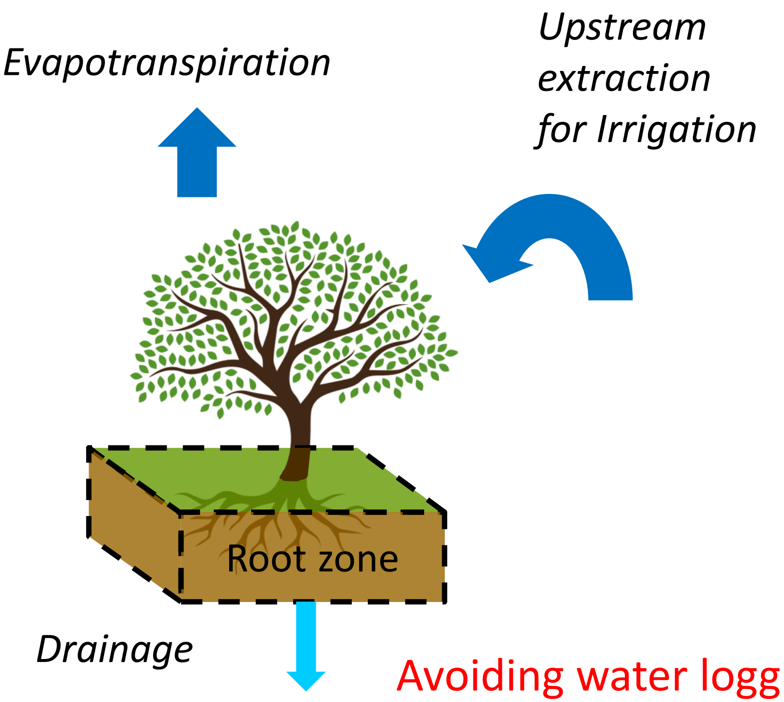
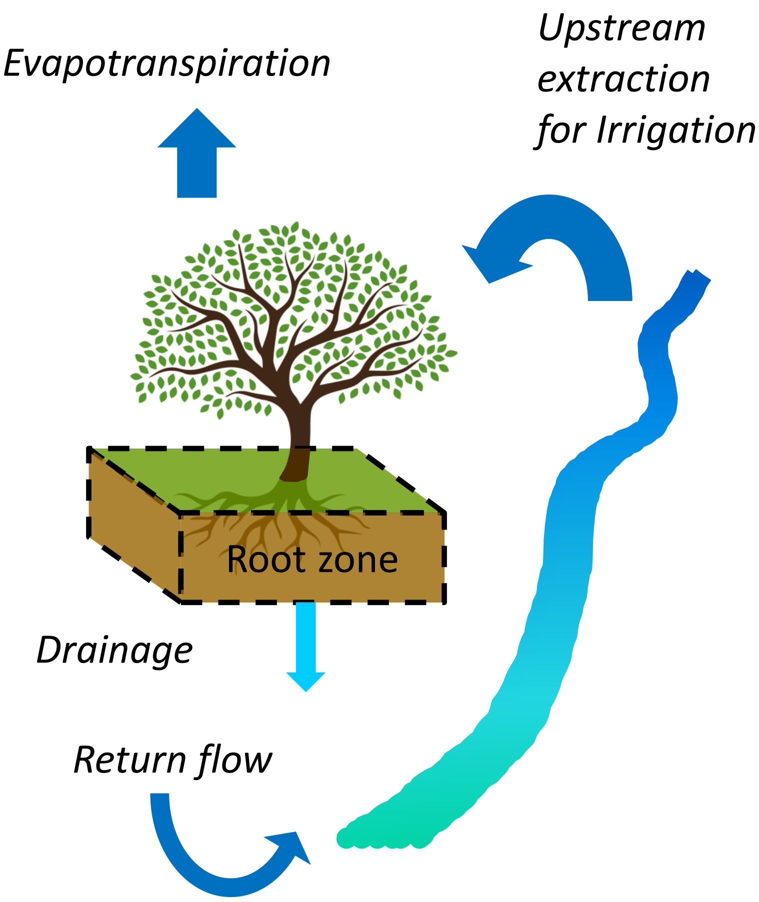


Drainage :

- ✓is necessary for agricultural soils
- ✓is a loss for crops

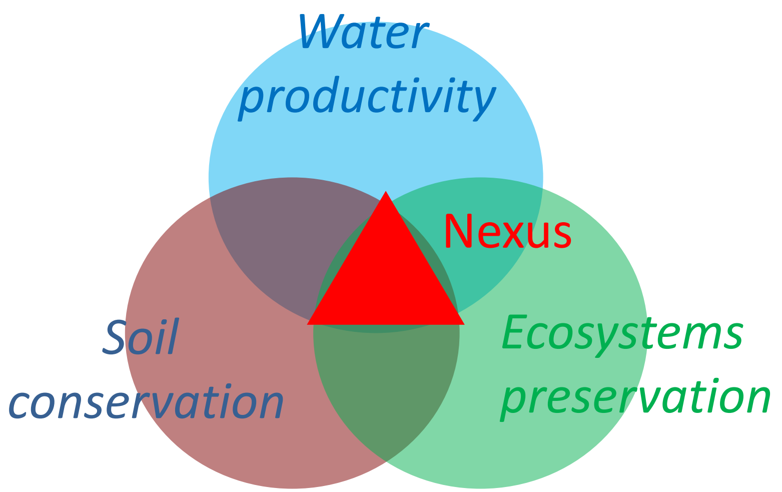
Avoiding water logging and salt build-up

Why are we focusing on drainage?



Drainage :

- ✓ is necessary for agricultural soils
- ✓ is a loss for crops
- ✓ may affect the quality of downstream rivers



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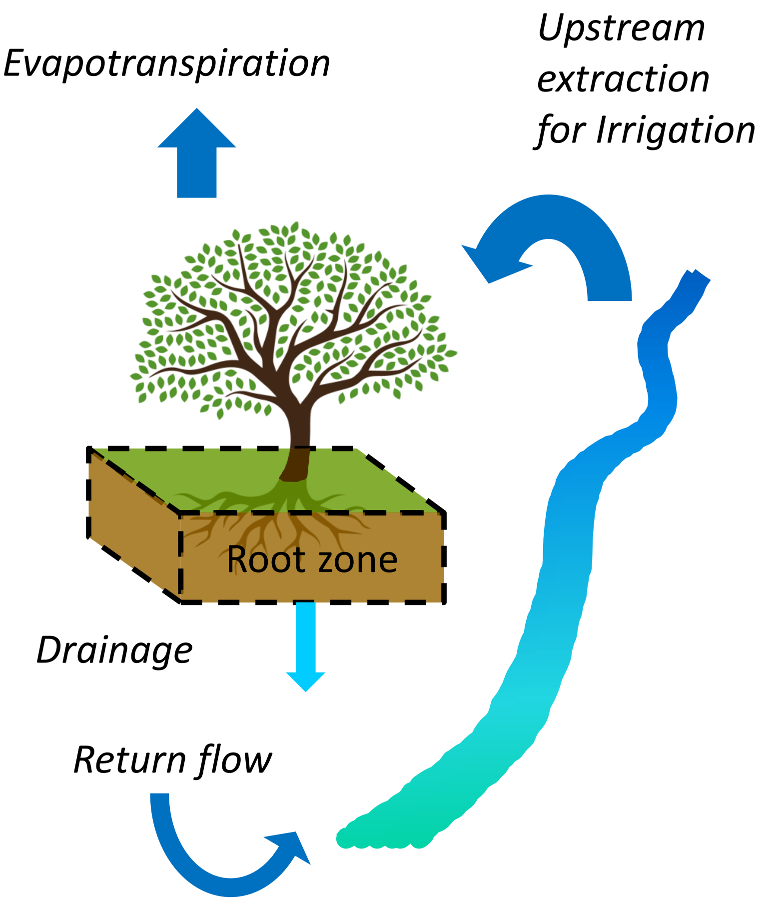
Addressing 3 science questions

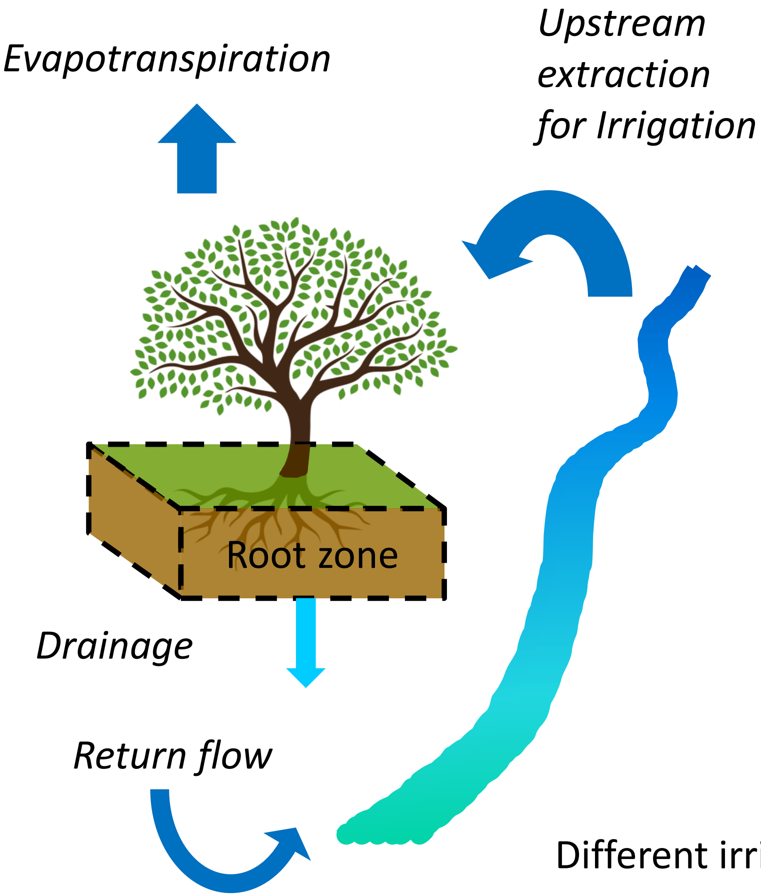


What is the water discharge by drainage of an irrigation district?

What is the impact of the drained irrigation water on the quality of downstream rivers?

How to adjust irrigation and fertilisation practices to ensure a minimum drainage ?

Addressing 3 science questions



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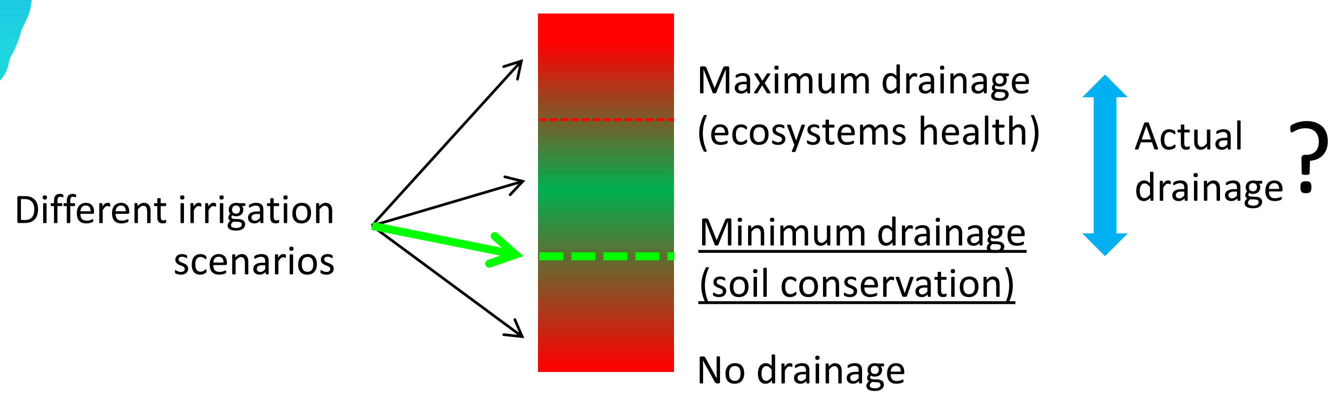

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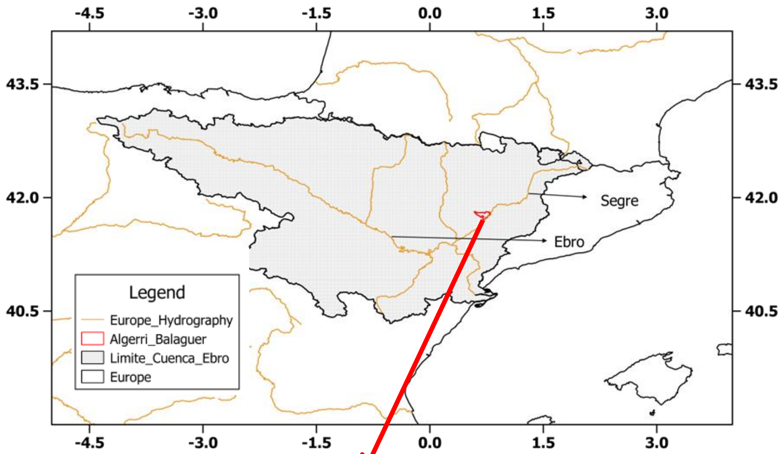
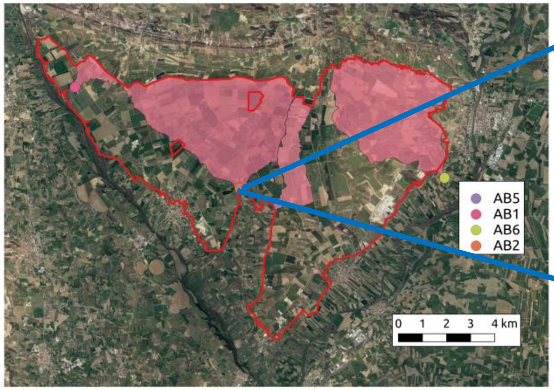
Two study areas

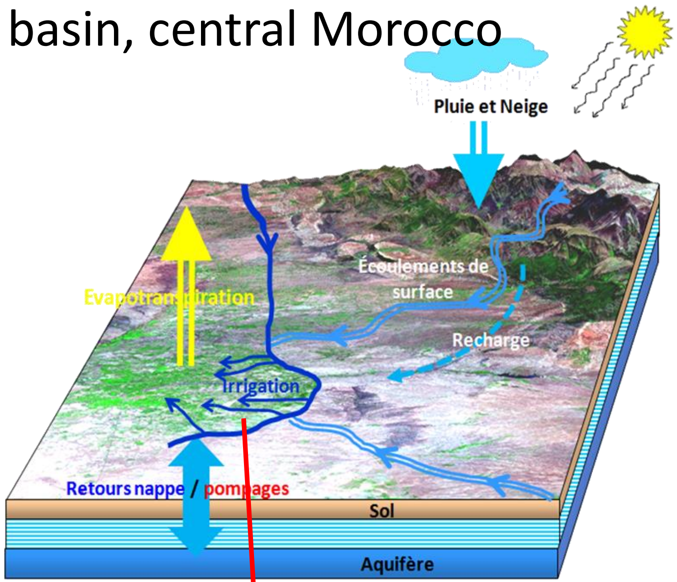
Ebro basin, Northeastern Spain



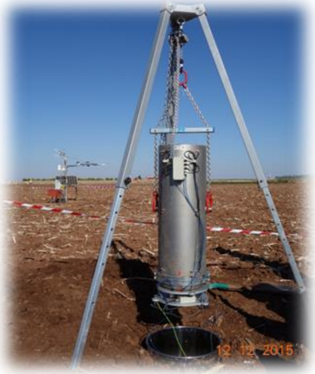
Algerri-Balaguer district



Tensift basin, central Morocco



Experimental fields



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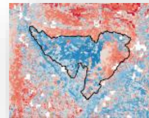
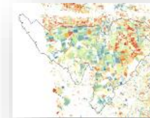
Project implementation

Vegetation index

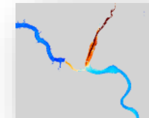
Evapotranspiration



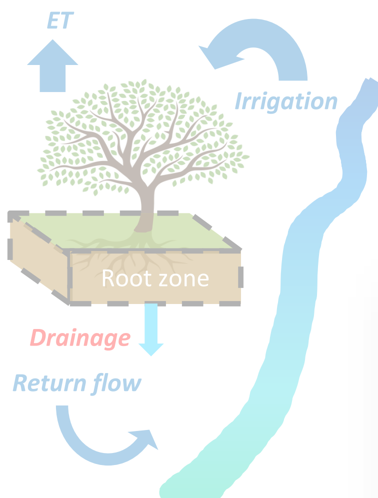
Soil moisture



Water quality index



Multi-sensor EO data

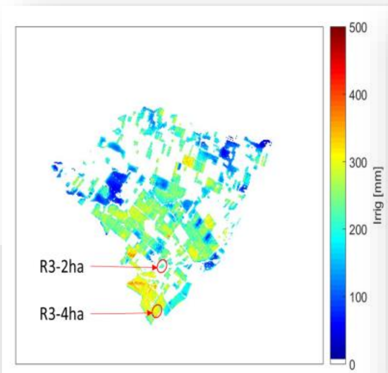


Drainage

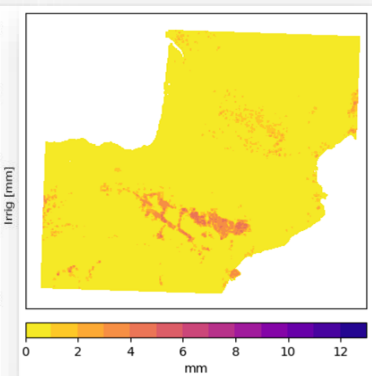
Evapotranspiration

Field measurements

Irrigation estimates at irrigation district scale (SAMIR model)

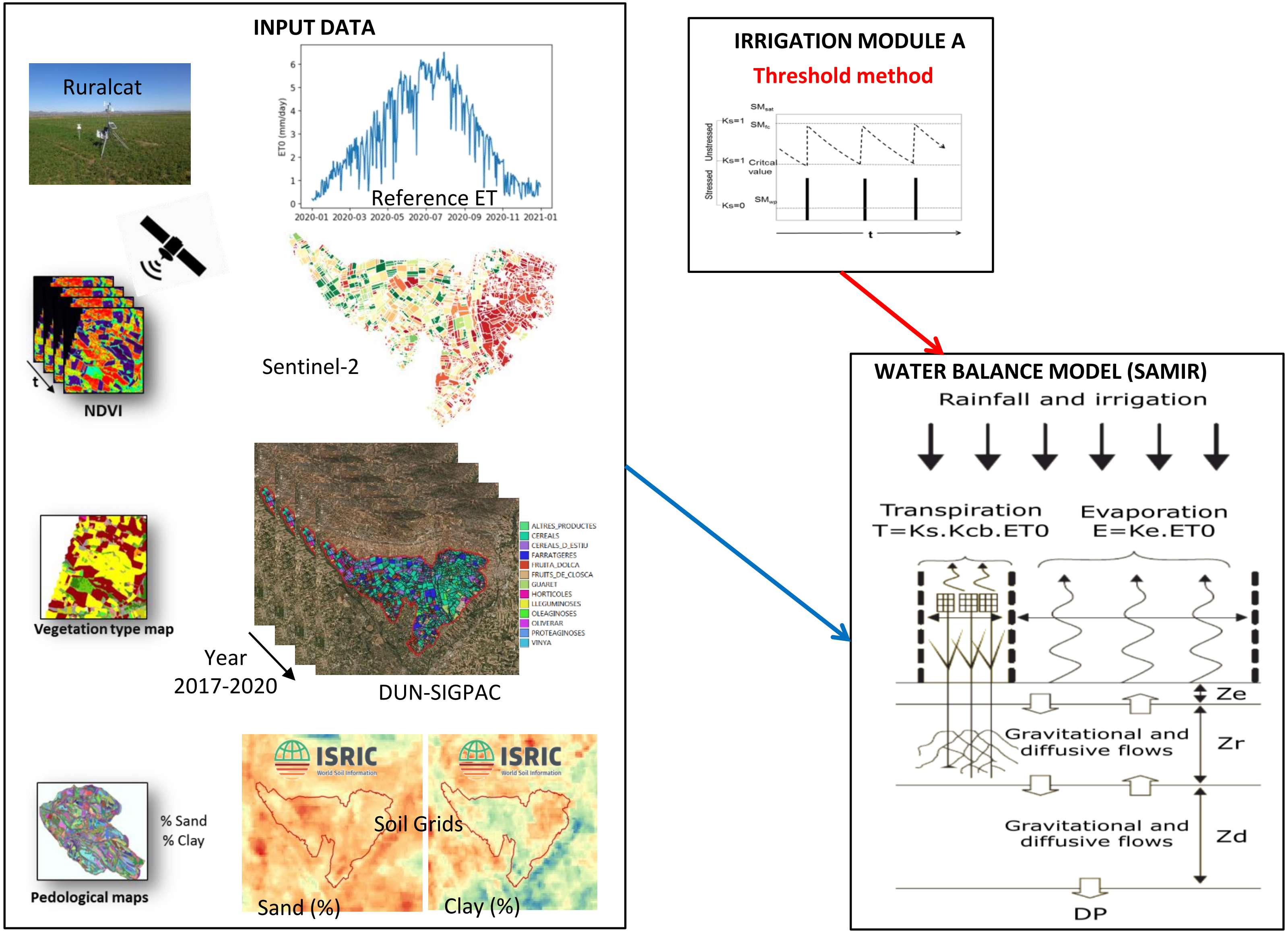


Irrigation estimates at basin scale (SURFEX model)

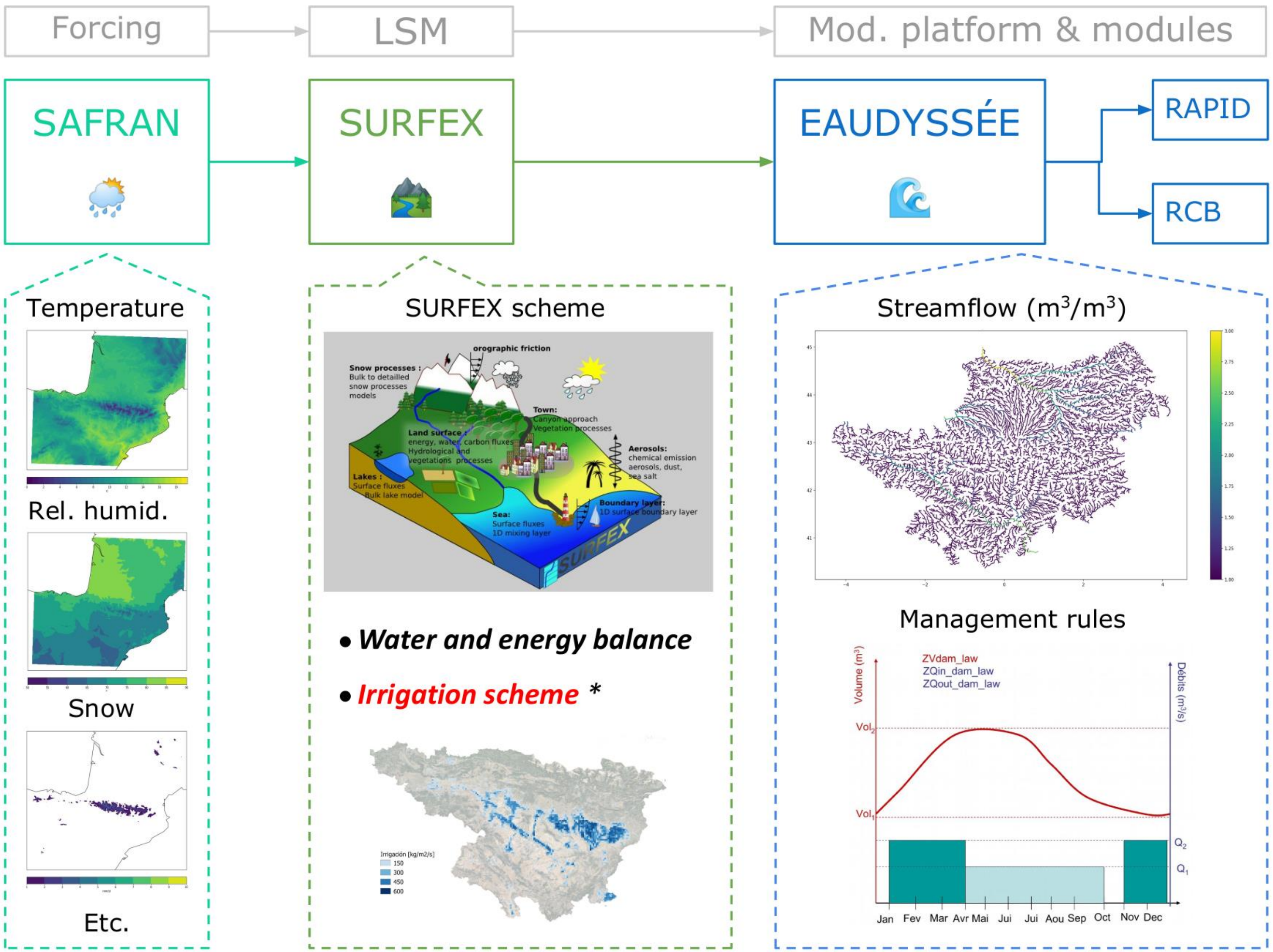


Multi-scale modeling

Crop water balance model (SAMIR)

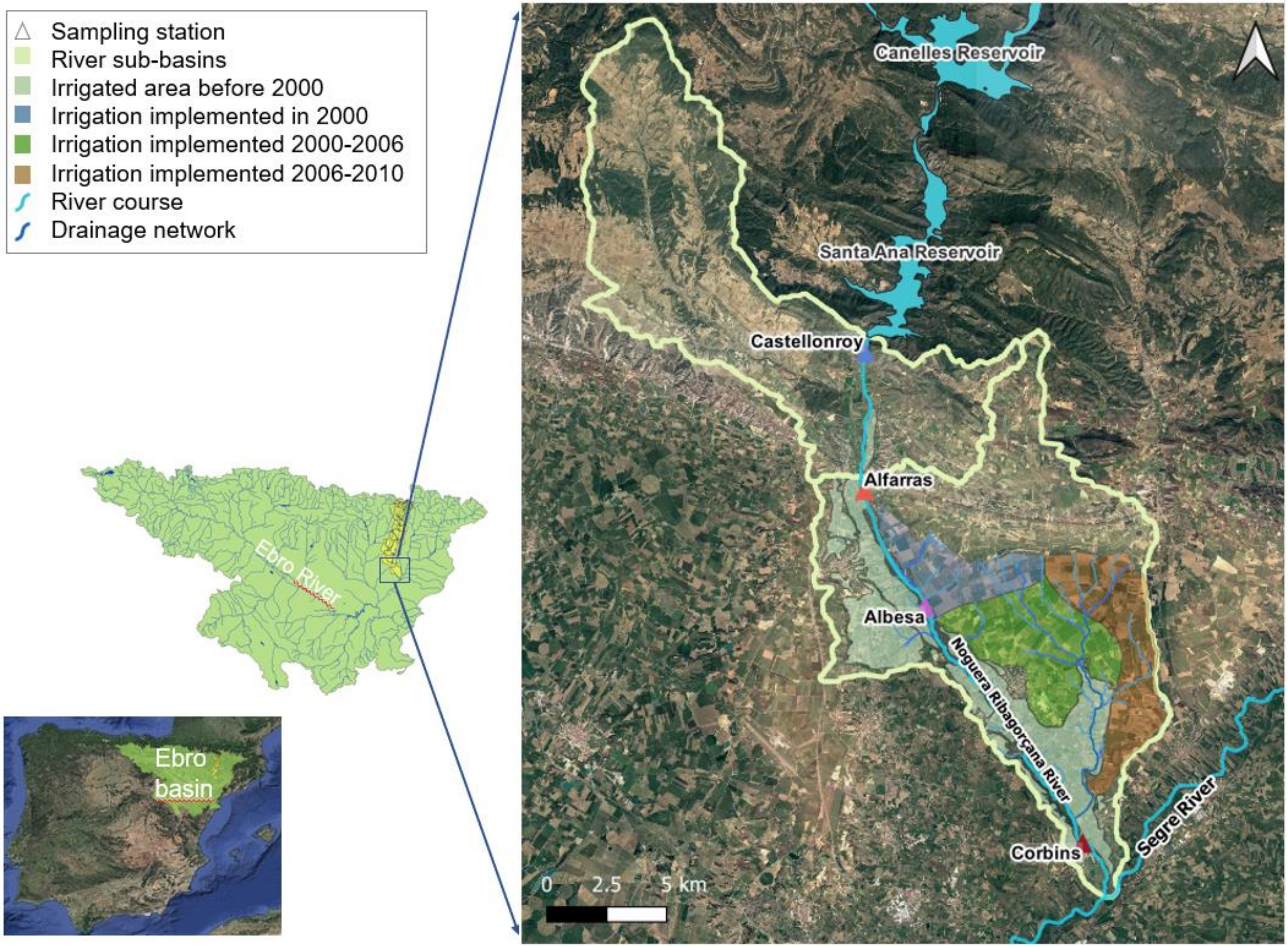


Hydrological model (SASER)



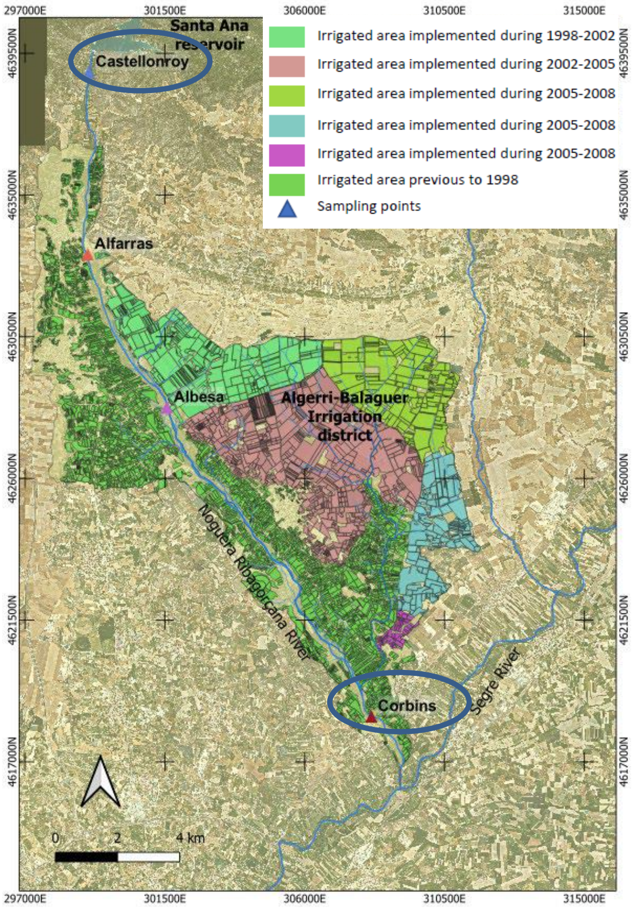
** No link between irrigation and dam management*

Algerri Balaguer Study area



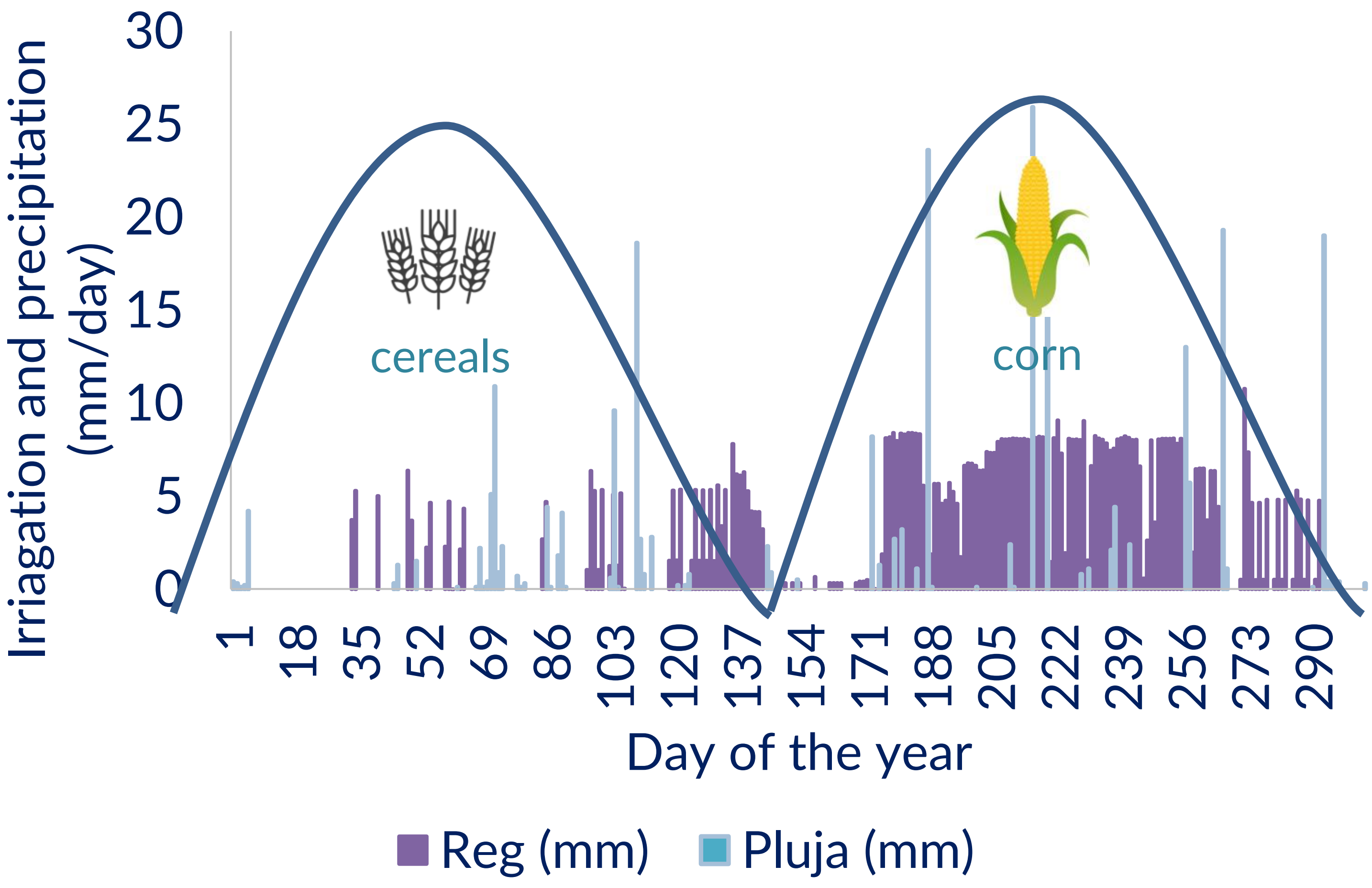
Algerri Balaguer Study area

- The lower basin of Noguera Ribagorçana River (Ebro basin, NE Iberian peninsula)
- Irrigation was implemented in 4000ha from 2002 to 2008
- Two different sampling points:
  - **Upstream** → Santa Ana Reservoir, Castellonroy ("clean water")
  - **Downstream** the IRF→ Corbins
- Monthly quality analysis have been performed for 20 years (2002-2022) in Castellonroy and Corbins
- Focus on concentration of NO_3^- and PO_4^{3-} (mg/L) as main nutrients involved in plant fertilization



Water Use and fertilisation

- Average water use 5950 m³/ha
- Average water use double crops 7010 m³/ha
- Fertilització nitrogenada promig de 300 kg N/ha



Methodology

- Data sampling
  - According the methodology proposed by the WFD (2000/60/EC) collected by the Hydrographic Confederation of Ebro (CHEbro)
- Land use evolution
  - Provided by the Algerri-Balaguer irrigation district
- Statistical analysis
  - **Mann-Kendall (MK)** trend analysis in Castellonroy and Corbins during the 20 years (XLSTAT)
  - **Spearman's ρ** and **Kendall's τ** to stablish possible correlations between irrigated area or rain episodes and analysed parameters (JMP)

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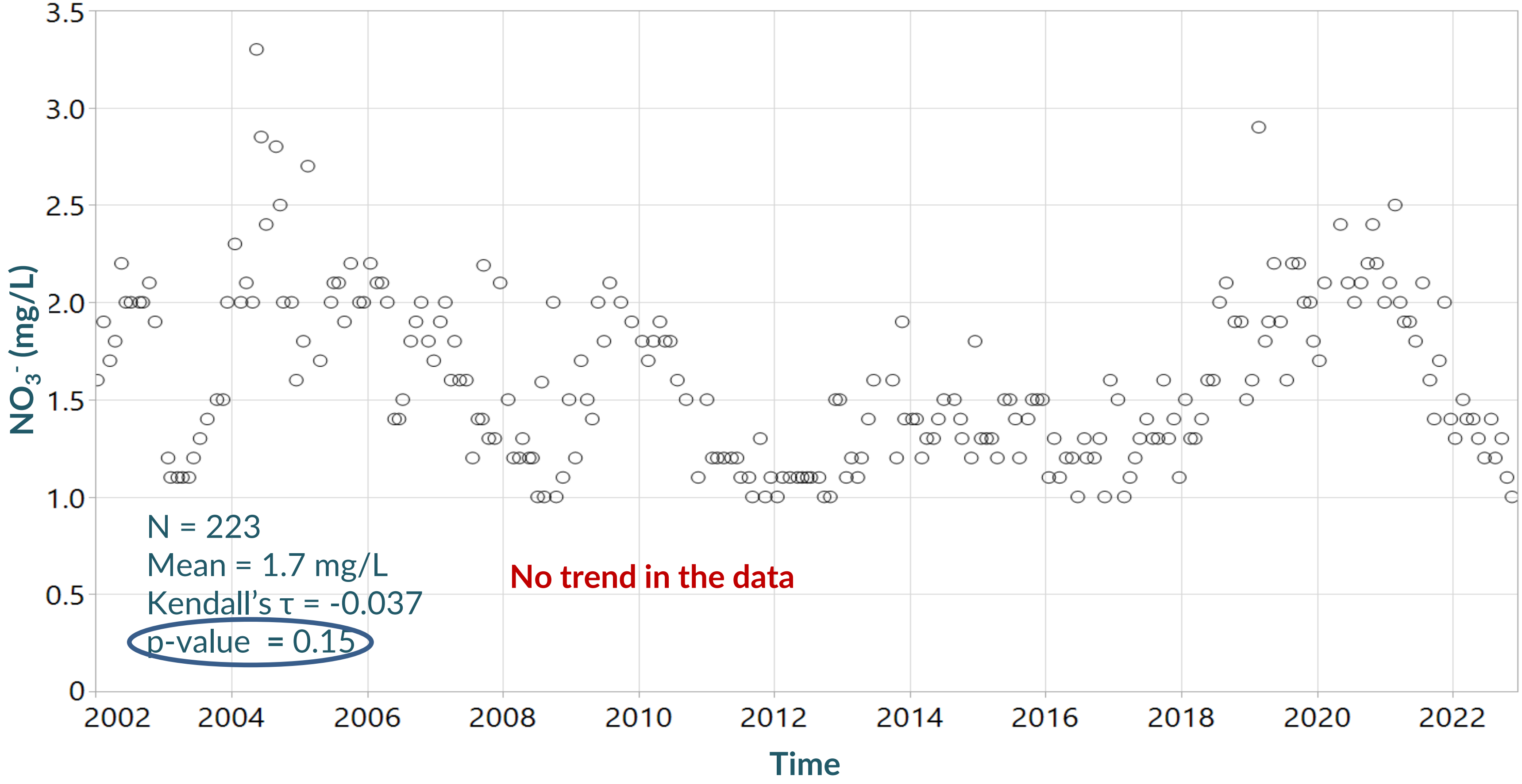
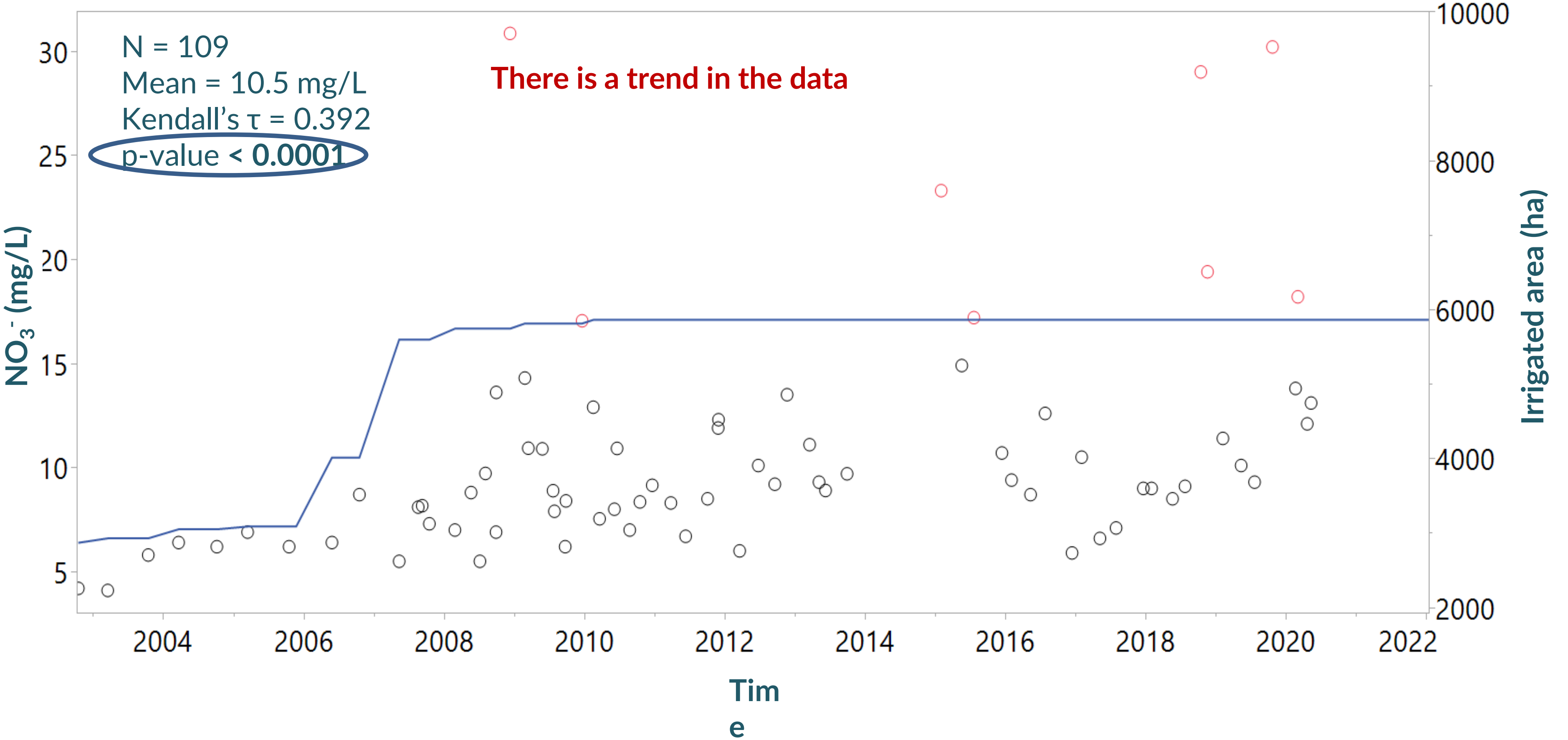
Nitrate (NO_3^-) seasonal MK in Castellonroy (upstream)



Nitrate (NO_3^-) Mann-Kendall trend in Corbins (after IRF)



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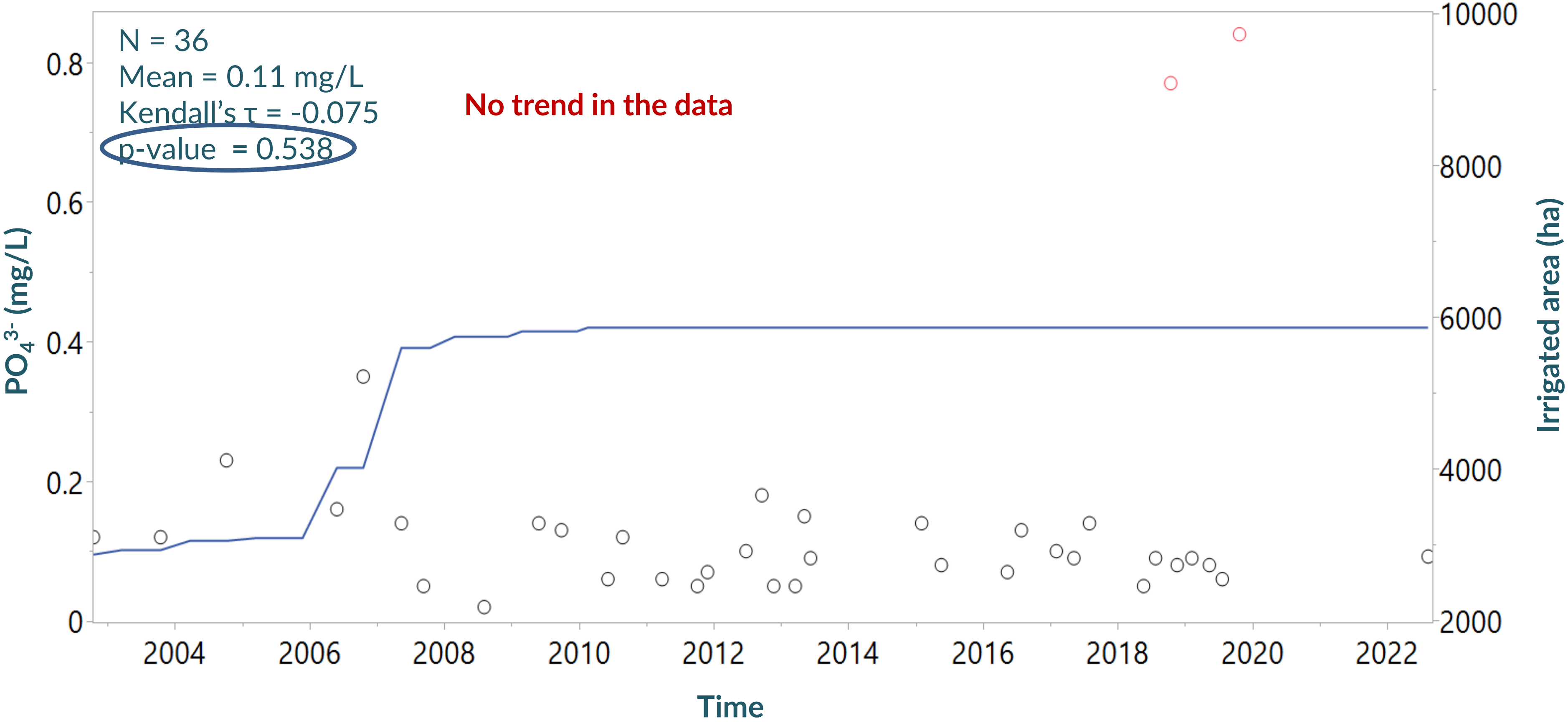
Phospates (PO_4^{3-}) MK trend in Corbins (after IRF)



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Seasonal trends

	NO_3^- ($mg \cdot L^{-1}$)		EC at 20 ºC ($\mu S \cdot m^{-1}$)		O_2 ($mg \cdot L^{-1}$)		PO_4^{3-} ($mg \cdot L^{-1}$)	
Season	UP	DOWN	UP	DOWN	UP	DOWN	UP	DOWN
Spring	1.58^{a}	9.38^{ab}	297^{ab}	641^{c}	10.50^{a}	9.95^{bc}	0.05^{a}	0.08^{a}
Summer	1.85^{a}	9.14^{b}	287^{b}	651^{bc}	9.28^{c}	9.44^{c}	0.07^{a}	0.09^{a}
Autumn	1.59^{a}	**12.42**^{a}	302^{a}	710^{ab}	9.70^{b}	10.51^{b}	0.07^{a}	**0.19**^{a}
Winter	1.75^{a}	**10.61**^{ab}	305^{a}	725^{a}	10.70^{a}	12.68^{a}	0.07^{a}	0.06^{a}

Mean seasonal values (2002-2022) of the parameters studied at Castellonroy (upstream IRF) and Corbins (downstream IRF). Means not connected by the same letter are significantly different ($\alpha = 0.05$).

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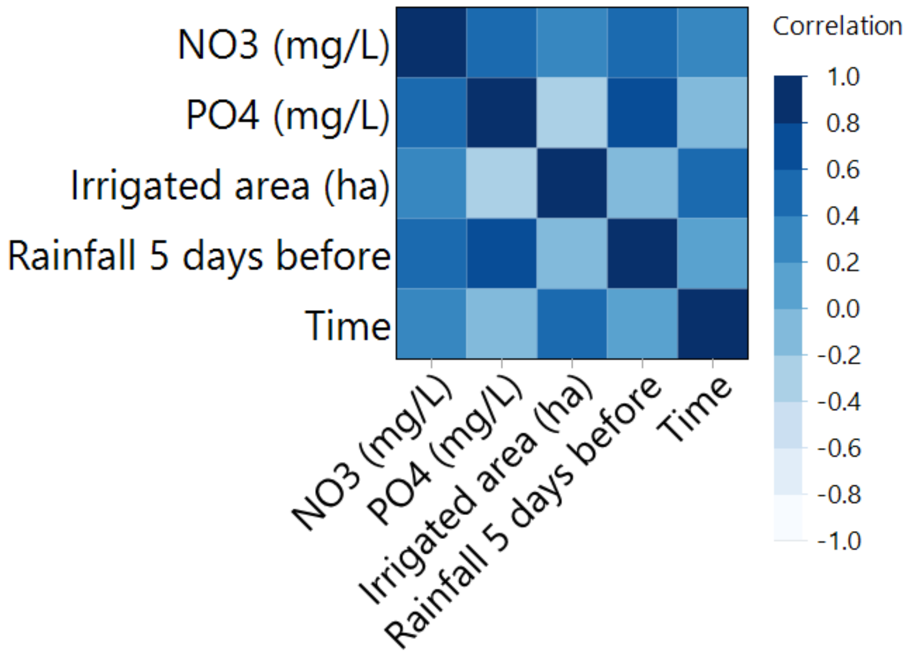
Does rainfall and irrigation affect the values in Corbins (after IRF)? Spearman's ρ and Kendall's τ analysis

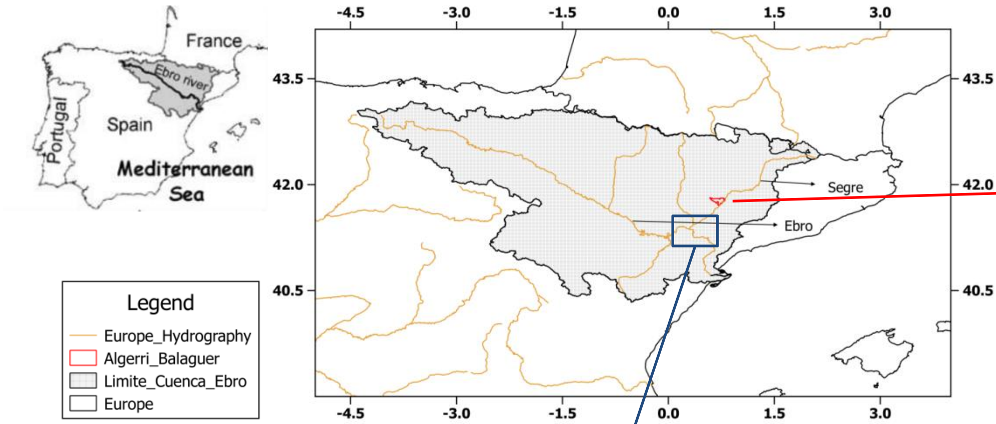


Variable	by Variable	Prob>|ρ|	Prob>|τ|
NO_3^- (mg/L)	Irrigated area (ha)	<.0001*	<.0001*
NO_3^- (mg/L)	Rainfall 5 days before	0.0311*	0.0367*
NO_3^- (mg/L)	Time	<.0001*	<.0001*

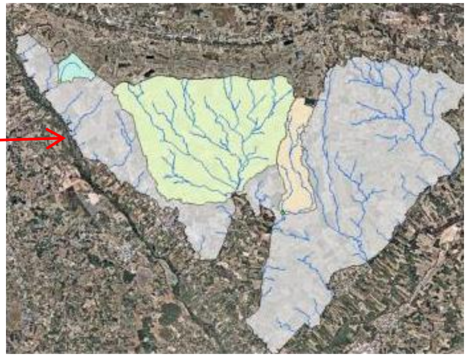
Water quality monitoring by EO data

Study Area: Ebro-Segre confluence (Ebro basin, Northeastern Spain)

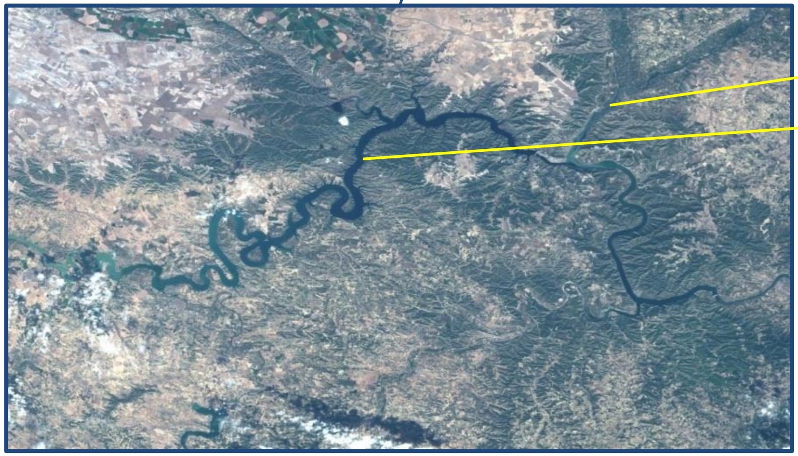
Ebro basin



Algerri-Balaguer district



Study area: Ebro-Segre rivers confluence



Segre river

Ebro river

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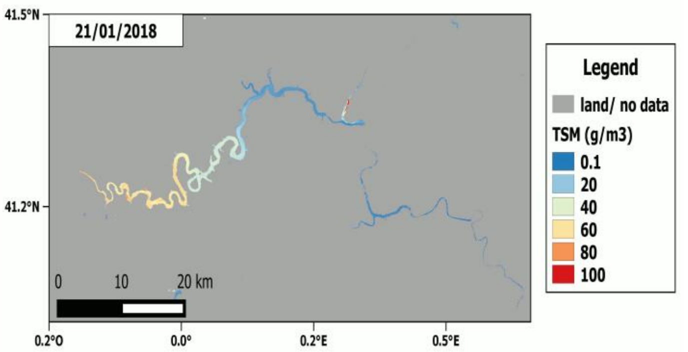
Water quality monitoring by EO data

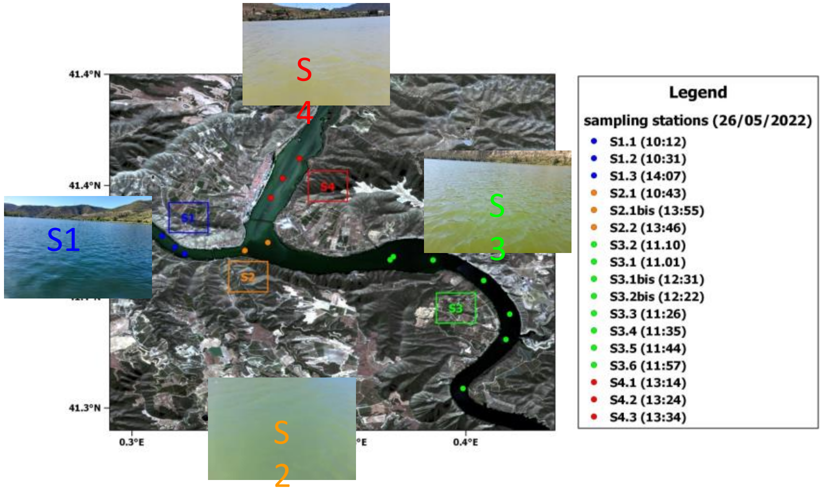
Processing of monthly Chl-a/TSM concentration maps derived from Sentinel 2A/B-MSI data

Preliminary analysis of the seasonal variability of WQ indices



One year (one image for month in 2018) of Sentinel2-MSI Total Suspended Material concentration

Rivers samplings collection and analysis



Sub-surface (0–1 m depth) water samples for lab analysis (Chl-a and TSM); above-water radiometric measurements by a portable spectroradiometer

Five campaigns were carried out: 26 May 2022; 29 June 2022; 20 April 2023; 22 Jun 2023; 31 July-03Aug 2023

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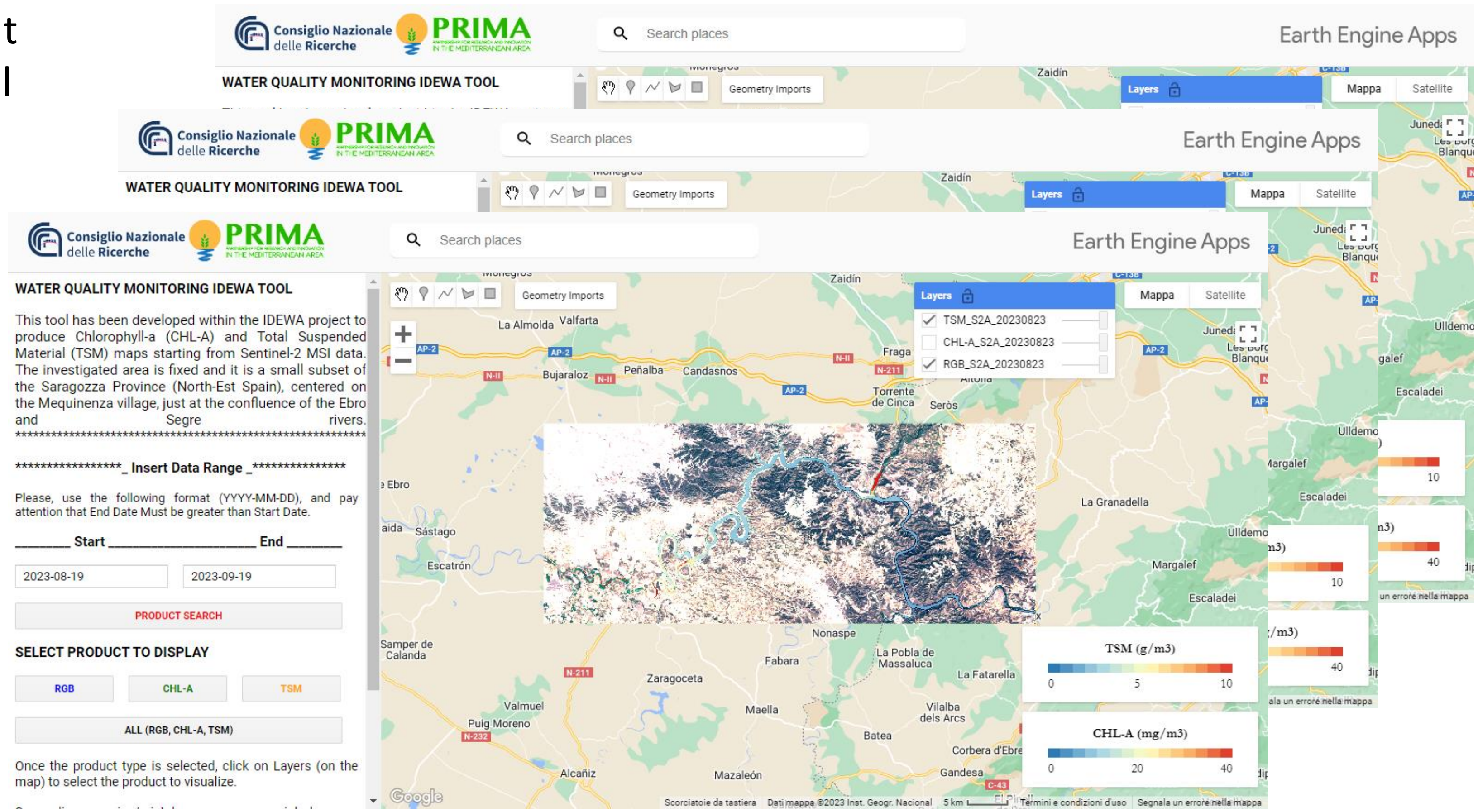
Water quality monitoring by EO data

Development of a GEE tool based on calibrated/ validated data

Chl-A

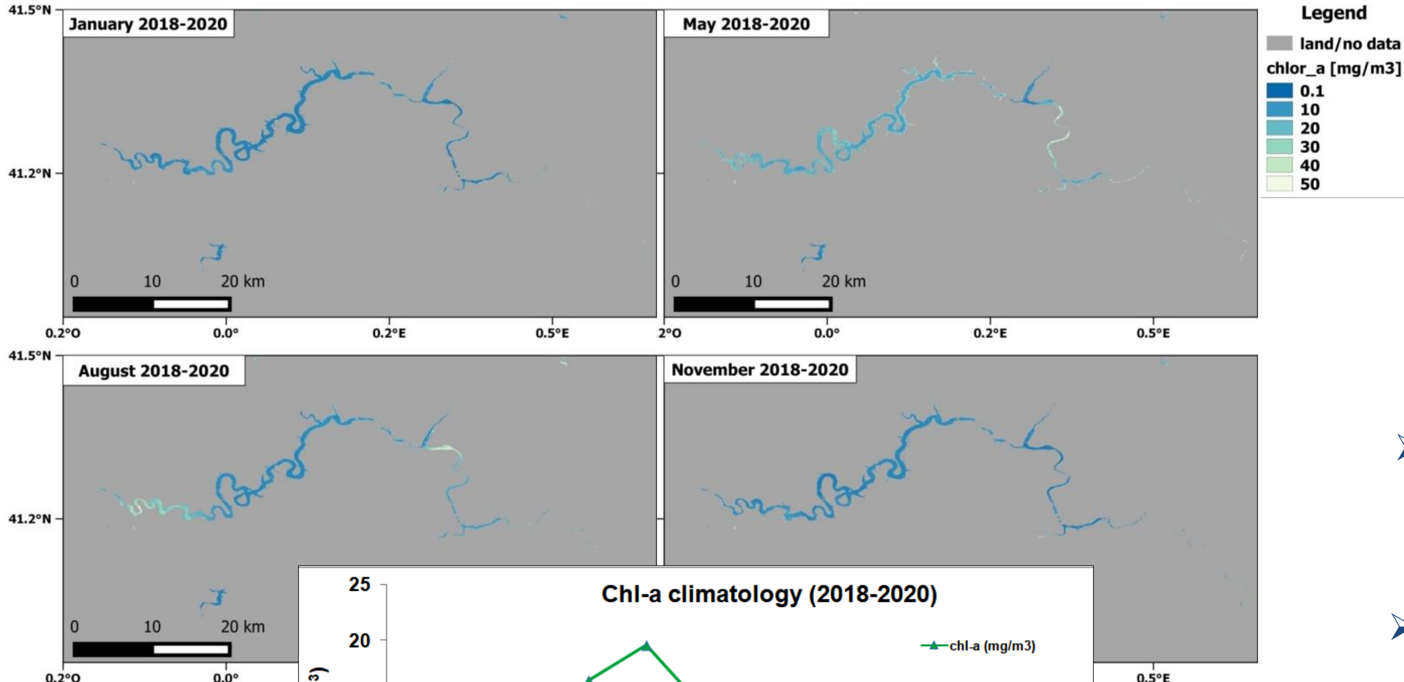
TSM

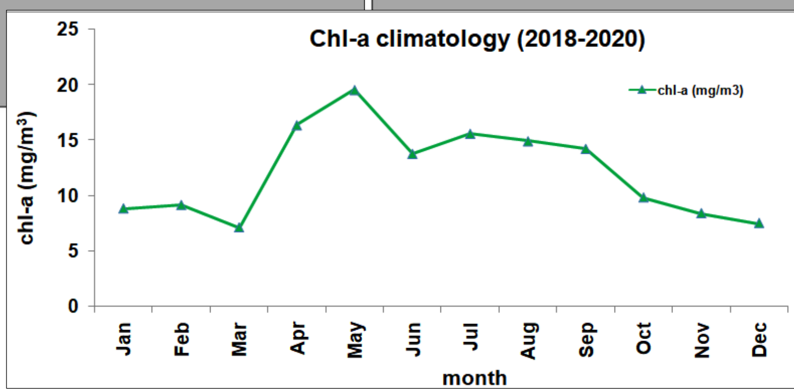


http://idewa.isardsat.space/

Chl-a climatology

S2-MSI Preliminarly results: 3-year (2018-2020)





Chl-a based on Normalized Difference Chlorophyll-a Index **(NDCI)**

$$Chl-a \propto \frac{[\rho NIR(704) - \rho VIS(665)]}{[\rho NIR(704) + \rho VIS(665)]}$$

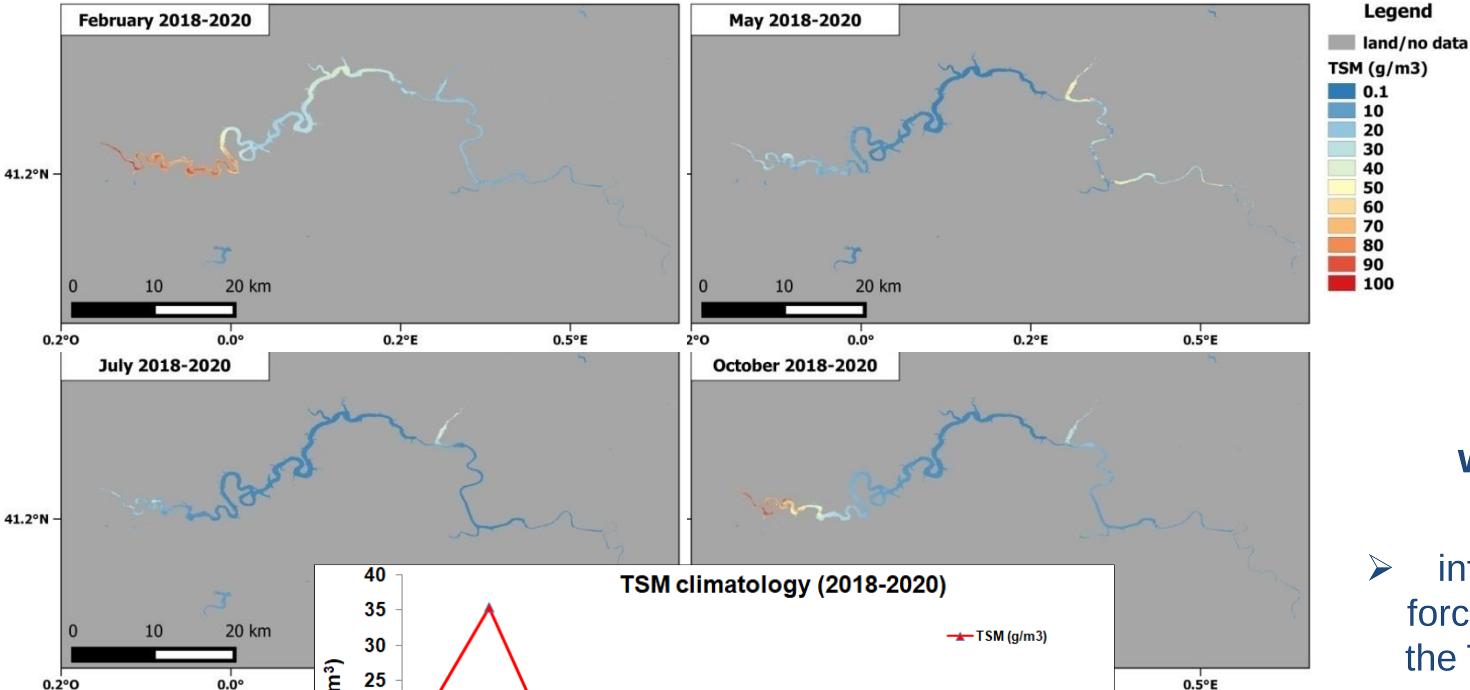
Mishra et al. 2012

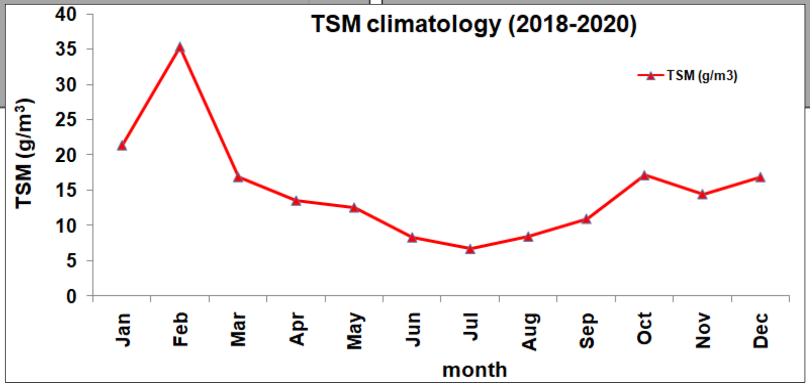
Chl-a increase in spring-summer

- low flow and high water residence time;
- meandering zone;
- high nitrates due to agricultural inputs

TSM climatology

S2-MSI Preliminarly results: 3-year (2018-2020)





TSM based on RED **(665 nm) band via the Nechad algorithm**

$$\mathrm{TSM} = \frac{A_p(\lambda) \times \rho_w(\lambda)}{1 - \frac{\rho_{w(\lambda)}}{C_p(\lambda)}}$$

Nechad et al. 2016

TSM peak in winter (February)

- influence of hydrological forcing (river discharges) on the TSM seasonal variability

Conclusions

- Implementing irrigation in 4000 ha increased $[NO_3^-]$ downstream from 4.7 ppm in 2002 to 10.8 ppm in 2022, on average
- During 22 km the river is enriched from 1.7 ppm to 10.5 ppm $[NO_3^-]$, on average, exclusively due to irrigation
- The $[PO_4^{3-}]$ downstream keeps similar to upstream values, the naturally present, with no trend to increase
- The highest values observed are related to episodes of rainfall, which leach the soil of nutrients
- The highest values are observed in autumn.

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Conclusions

- The 3-year (2018-2020) chl-a climatology based on S2-MSI data shows a chl-a increase within the spring and summer seasons (from April to September), probably due to agricultural and hydrological forcing, such as use of fertilizers and water level fluctuations;
- The 3-year (2018-2020) TSM climatology based on S2-MSI data shows a marked peak in February followed by a progressive decrease in TSM values from April to September, thus revealing the strict link with hydrological variables (i.e. river discharges);
- The N seasonality in AB (max in autumn) is different from the Chl-a seasonality observed at the Ebro-Segre confluence where the highest values of Chl-a are observed during the irrigation season.
- Our hypothesis is that ferti-irrigation is better managed in AB and only after the growing season there are significant losses whereas when looking at the Ebro confluence the impact of several not optimised irrigation districts is observed with significant losses across the entire irrigation season.

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Image from Espais naturals de ponent

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