Assessing the Sustainability of Irrigation Practices in the Ebro Basin under Climate Change

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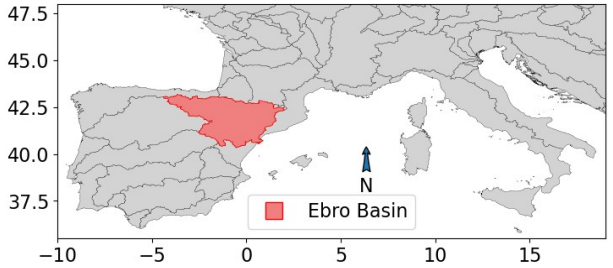
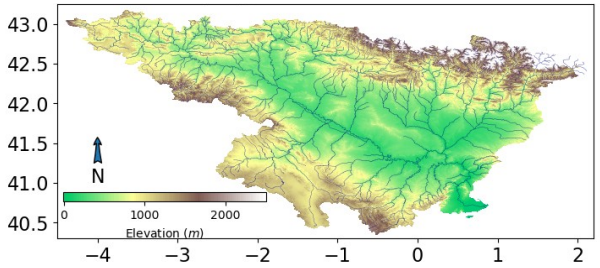
The Ebro River basin

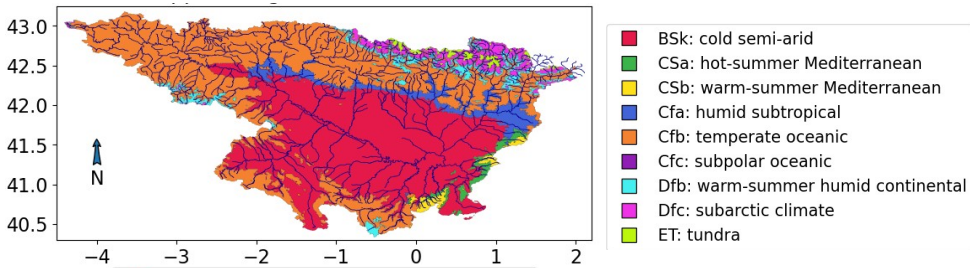
1. Ebro basin in Western Med.



2. Digital elevation model

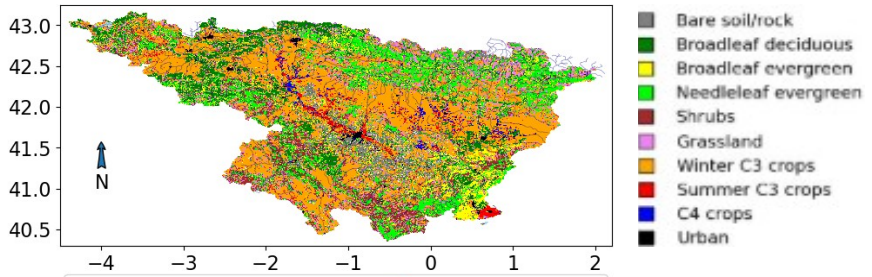


3. Köppen-Geiger climate classification

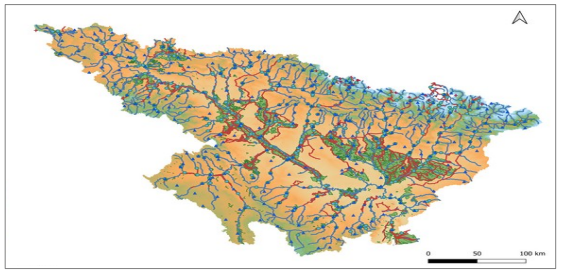


- The Ebro basin is the largest Mediterranean basin in Spain and one of the largest in Europe.
  - According to the Ebro Hydrographic Confederation (CHE), six main climatic zones can be distinguished.
  - Precipitation unevenly distributed: wet (mountainous areas, 1800 mm/y); dry (central valley, 200 mm/y).
  - The Ebro basin is highly anthropized.
    - Irrigated agriculture and farming represent 92% of the basin's total water consumption (CHE).

4. Land Cover / Land Use



5. Hydraulic infrastructure

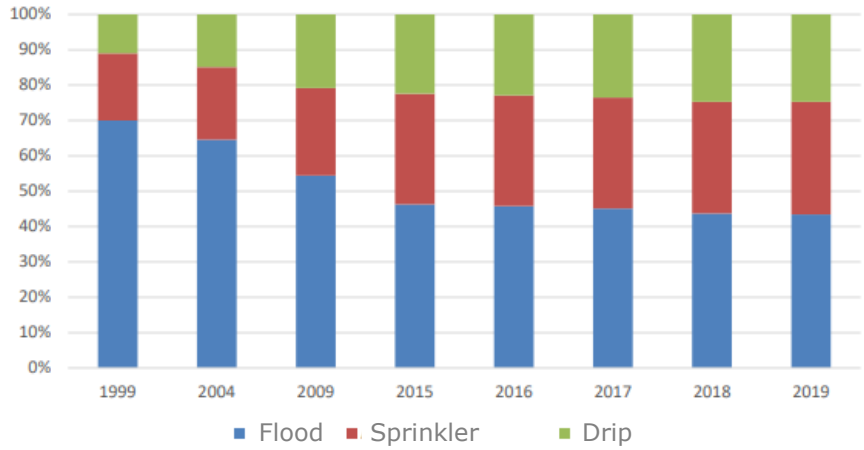


Irrigated areas in the Ebro basin

Hydrological Plan for the Spanish part of the Ebro River Basin (Revision for the third cycle: 2022-2027):

- Of the 3 million hectares cultivated each year, approximately 25% are irrigated.
- In 2019, the main irrigated crops by area were:

Crops	Area (%)	ECOCLIMAP-SG classification
Grain cereals	45	• Summer/Winter C3 crops • C4 crops
Non-citrus fruit trees	16	Temperate broadleaf deciduous
Forage crops	16	Summer/Winter C3 crops
Vineyards	7	Temperate broadleaf deciduous
Olive groves	5	Temperate broadleaf evergreen



Evolution of the percentage distribution of irrigation methods in the Ebro basin.

- Certain crops (non-citrus fruit trees, industrial crops, and vegetables) are only viable in this basin if grown under irrigation.
- In 2015, irrigated farming accounted for approximately 65% of the over €5000 million in agricultural production value within the basin.

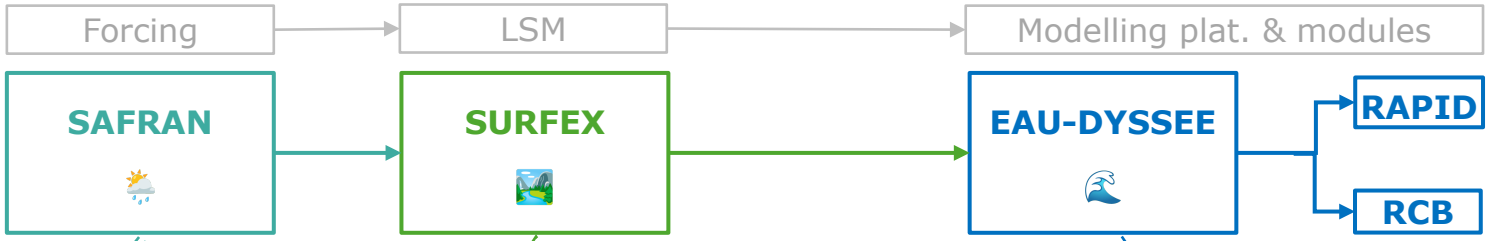
Study different irrigation strategies over the Ebro basin with focus on the Algerri-Balaguer region using the SASER modelling chain.

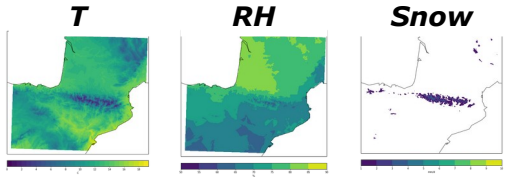
SASER hydrometeorological modelling chain

The Ebro Observatory developed the SASER (Safran – Surfex – Eaudyssee – Rapid) modelling chain.

To simulate irrigation:

- Used SURFEX V9 with an irrigation scheme (Druel et al., 2022)
- Created a 1 km grid over the Ebro basin
- Generated a new SAFRAN versión (V3)
- Improved agricultural physiography over the basin

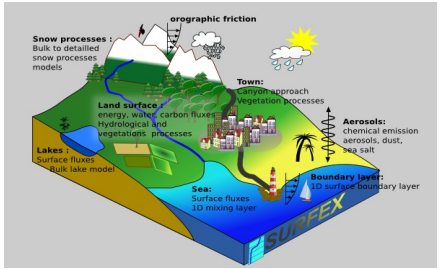




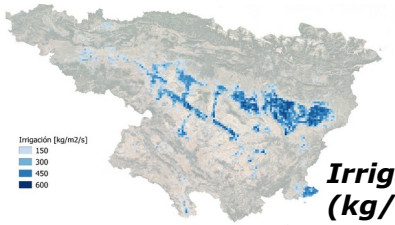
- Precipitation
- Cloudiness
- Wind speed
- Radiation

Versions	V1	V2	V3
Regions	I.P.	Pyrenees	Ebro
Resol. (km)	5	2.5	1
Periods	79-21	80-13	08-20
Data	AEMET		• AEMET • SMC

SURFEX scheme

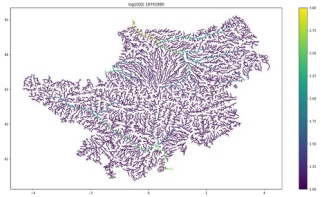


- Version V9
- Water and energy balance
- Irrigation scheme



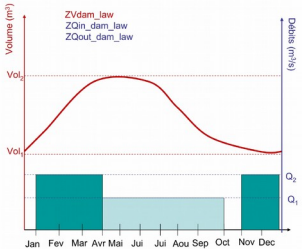
Irrigation (kg/m²s)

RAPID : river routing scheme



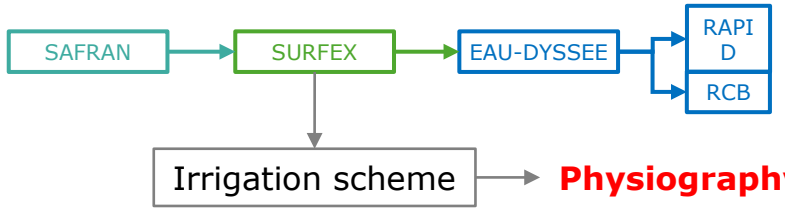
Streamflow (m³/m³)

RCB : dam management rules



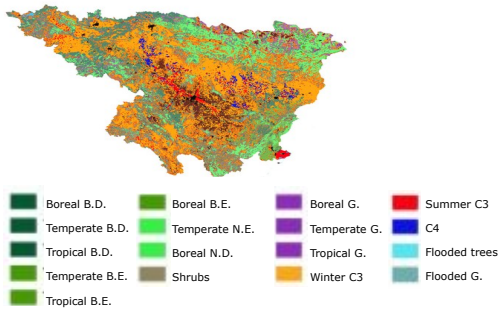
- No link between irrigation and dam management

Irrigation scheme: scenarios physiography



SURFEX's default physiography was improved over the Ebro basin

Land Cover Map (LCM)

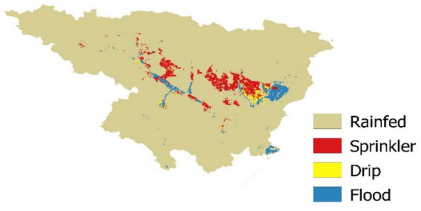


- Basis: crops per plot from SIGPAC *(Agricultural Plot Geographic Information System from the Spanish Administration).*
- SIGPAC crops were classified into ECOCLIMAP-SG covers and replaced in ECOCLIMAP-SG LCM (SURFEX's default map).

(Actual) Irrigated Areas Map (IAM)

- Basis: SIGPAC potentially irrigated areas.
- SIGPAC was combined with LDAS-Monde LAI Assimilation Increments, computed for 2 summer days.

Irrigation Methods per Area Map (IMM)

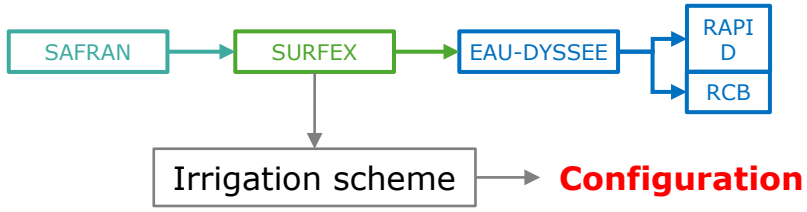


- Basis: LCM and IAM.
- IAM-irrigated areas were classified as traditional or modern.

Traditional	Modern	
	Sprinkler	Drip
Flood	Trees	Herbaceous

- The improved LCM was used to differ between herbaceous and tree crops.

Irrigation scheme: scenarios configuration



Three irrigation scenarios where considered: Default, Realistic, and Optimal.

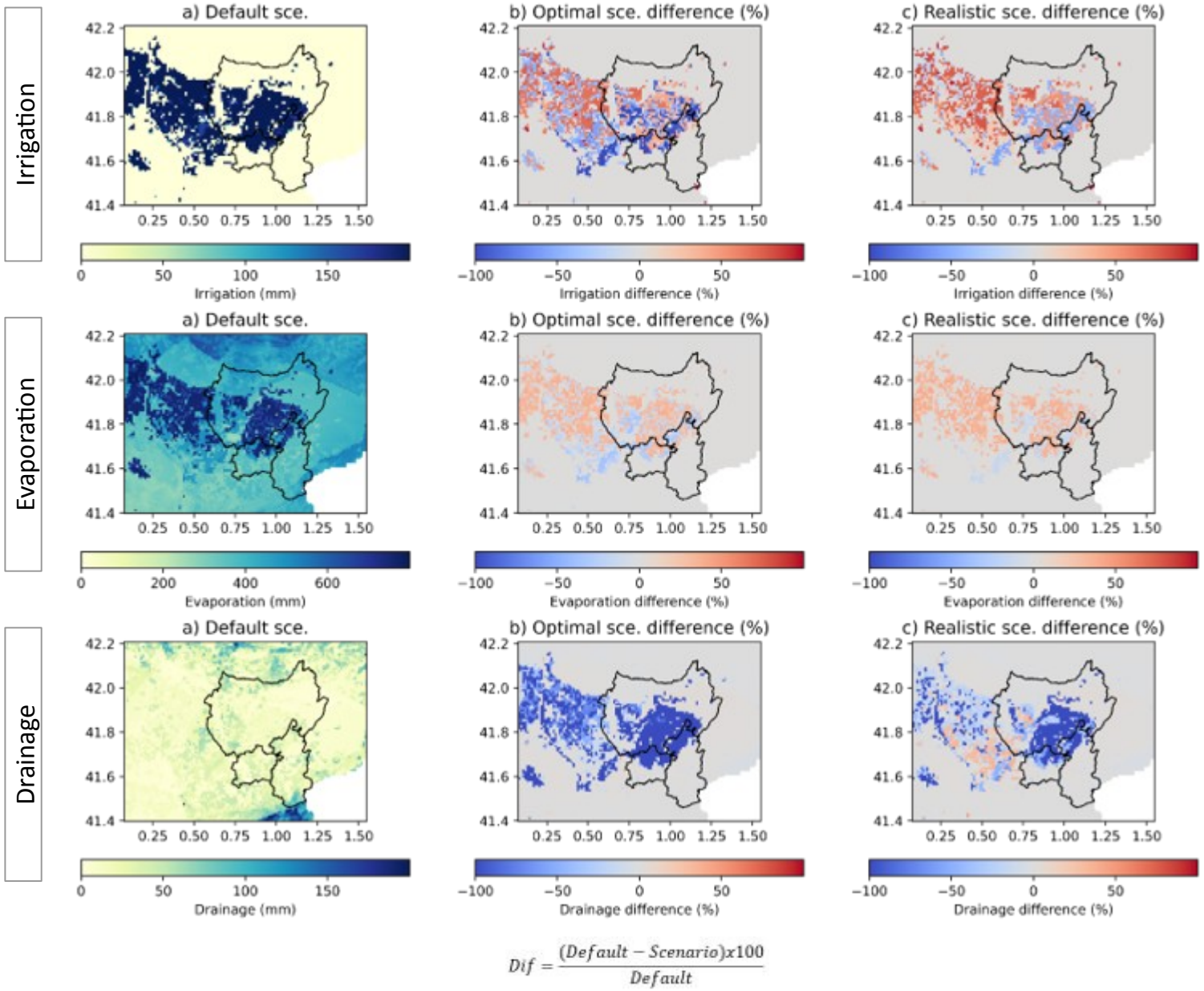
- The Default scenario uses the irrigation scheme's default parameters.

- Both the Realistic and Default scenarios use the same irrigation parameters defined after a pole performed to farmers (Algerri-Balaguer region). The only exception is the irrigation trigger:
  - Realistic scenario: Triggers based on SWI for 5 vegetation classes* (obtained from a threshold for triggering irrigation developed by Luis Oliveira and the evolution of the roots per class). (Olivera-Guerra et al., 2023).
  - Optimal scenario: Triggers based on SWI for 5 vegetation classes* (obtained from threshold for triggering irrigation from FAO and the evolution of the roots per class). Allen et al. (1998) & Pereira et al. (2021).

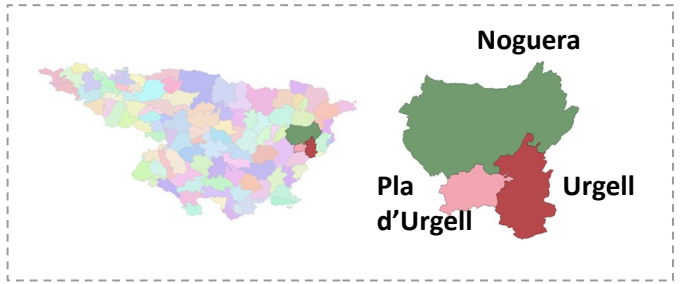
PARAMETERS	Default scenario	Realistic and Optimal scenarios (pole)			
		Classes*	Methods		
			Flood	Sprinkler	Drip
Sowing and harvesting dates	15/04 – 15/09	C3 crops	15/02 - 15/06		
	15/05 – 30/10	C4 crops	15/05 - 30/10		
Duration of an irrigation event	8 h	C3, C4 crops	2 h	1.25 h	
		T.B. trees	2.5 h		1 h
Amount of water used in an irrigation event	30 mm	C3, C4 crops	75 mm	8.75 mm	
		T.B. dec.			7 mm
		T.B. ever.			6 mm
Minimum time between 2 irrigation events	sprinkler & flood = 14 d drip = 0	C3, C4 crops	12 d	1 d	
		T.B. trees	7 d		0.5 d
Nº days since the end of irrigation and	14 d	C3, C4 crops	14 d	14 d	14 d

Vegetation classes: temperate broadleaf deciduous, temperate broadleaf evergreen, winter C3 crops, summer C3 crops, C4 crops.

Scenario comparison over three districts: Annual results



$$Dif = \frac{(Default - Scenario)x100}{Default}$$

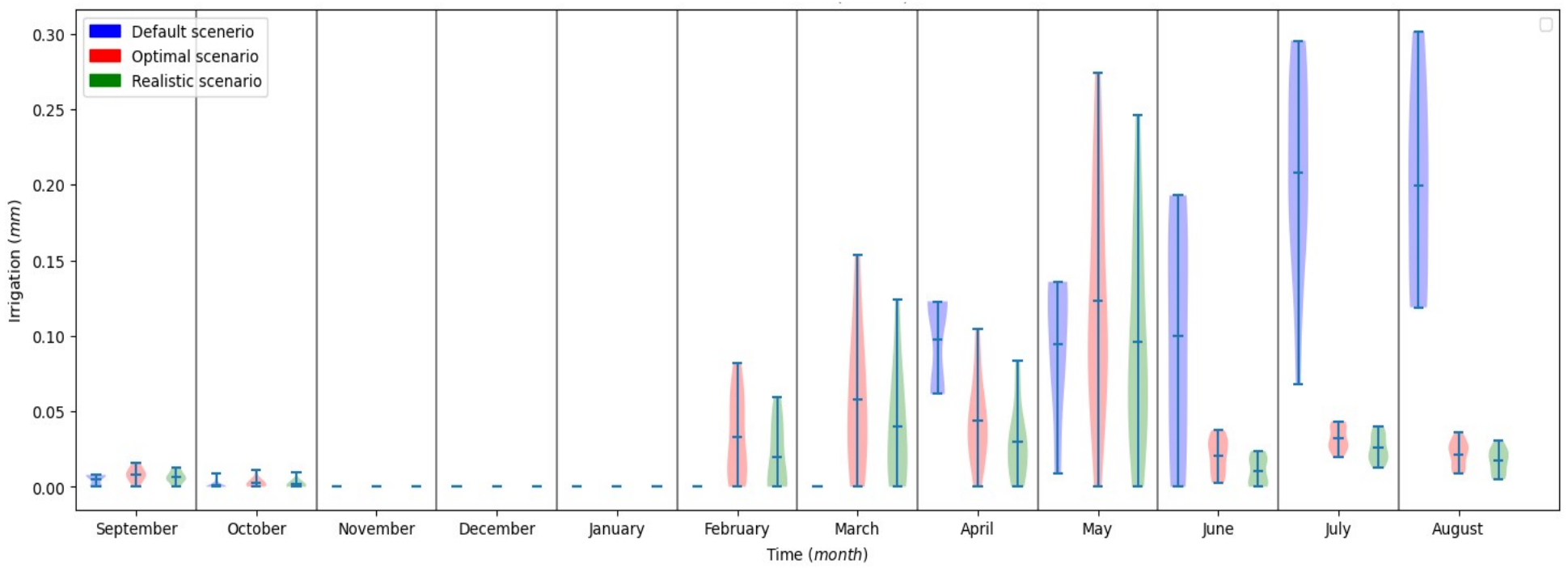


Compared to the default irrigation scenario the optimal and realistic scenarios:

- Result in higher **irrigation** over drip and surface irrigated areas, and lower **irrigation** over sprinkler irrigated areas.
- Show an increase in **evaporation** over drip and flood (at a lesser extent) irrigated areas.
- The optimal irrigation scenario produces more **drainage** than the default one. However, the realistic scenario shows lower **drainage** than the default one over drip irrigated areas.

Scenario comparison over three districts: Monthly distribution

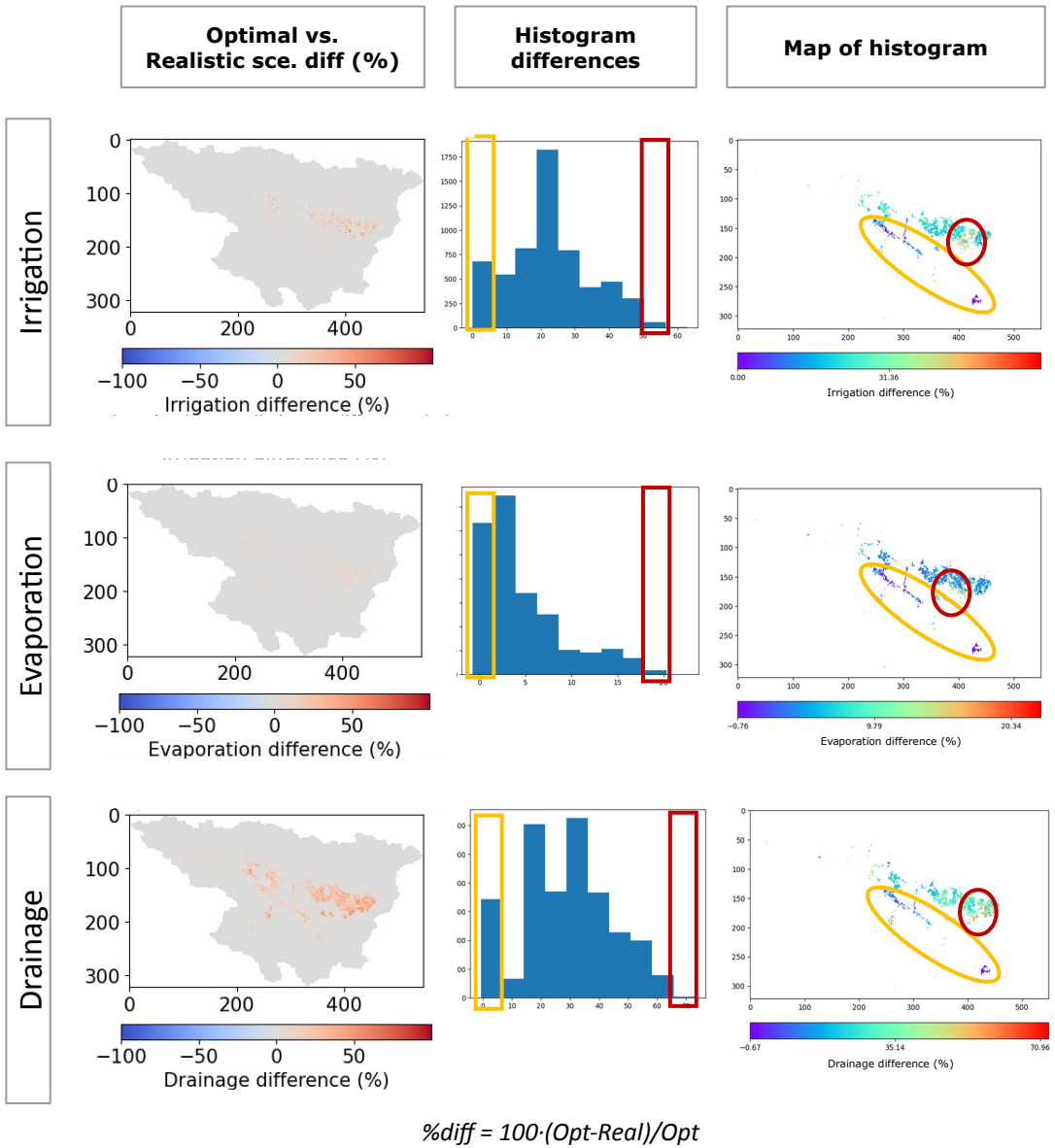
Monthly irrigation distribution for the three scenarios in the Cinca-Segre irrigation areas (2008-2020)



Irrigation monthly distribution: Default vs. Optimal vs. Realistic scenarios

- Default scenario mainly irrigates during summer months while realistic and optimal scenarios irrigate during spring.
- The three scenarios irrigate in a similar way during fall.
- There is no irrigation during winter, exept in february for optimal and realistic scenarios.

Scenario comparison over the Ebro basin: Annual results



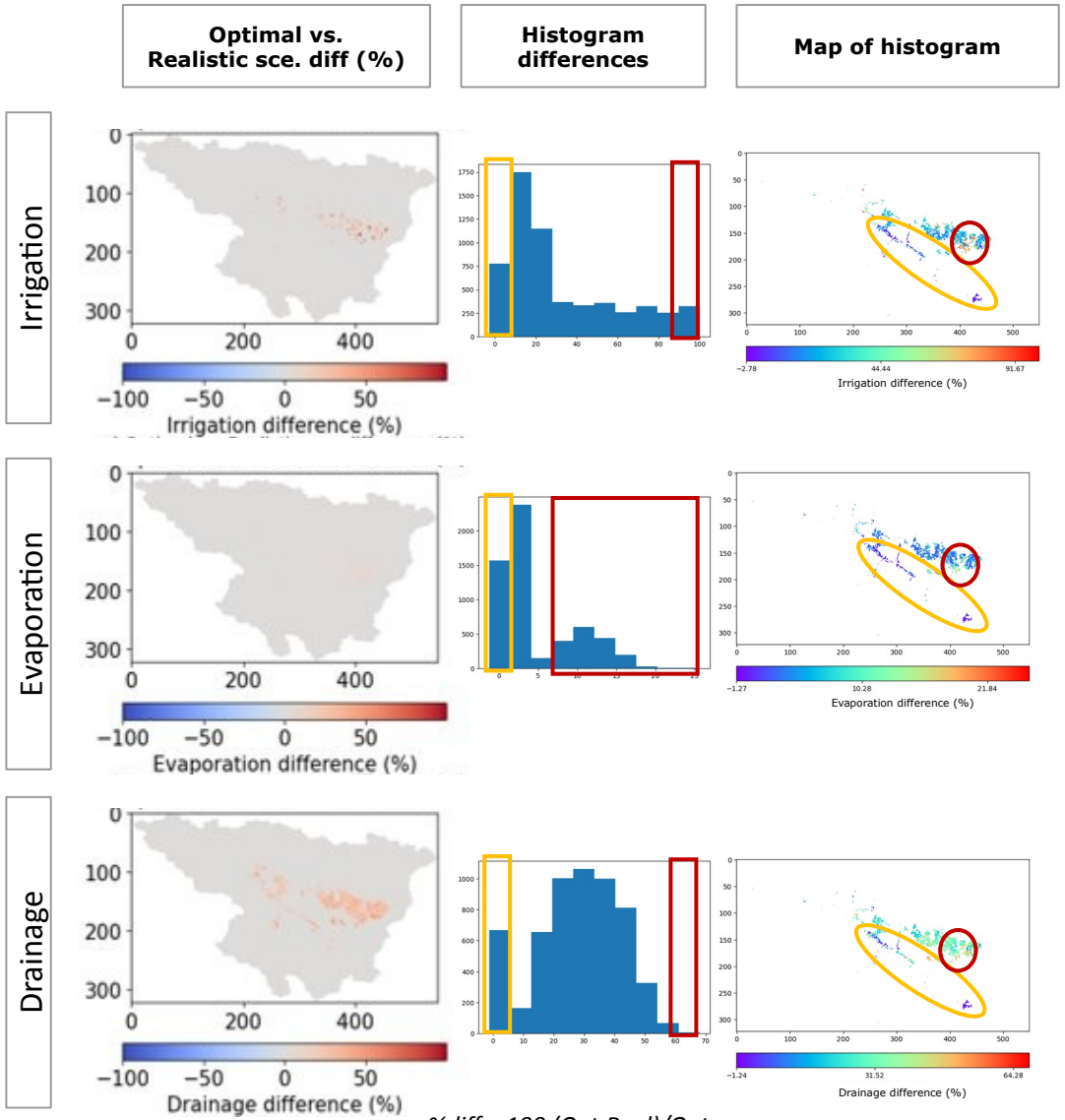
%diff = 100·(Opt-Real)/Opt

- The distribution can be divided into 3 groups:
  - Lower values: Ebro river and delta.
  - Higher values: Cinca and Segre confluence.
  - Rest of the values.

- The scenarios show differences in irrigation, evaporation, and drainage.
  - In general, they coincide with the spatial distribution of the irrigation methods.
    - Irrigation: difference of 20%
    - Evaporation: Less than 5%
    - Drainage: between 20% and 30%

Scenario comparison over the Ebro basin: Seasonal results

Optimal vs. Realistic scenario differences in spring



%diff = 100·(Opt-Real)/Opt

- The distribution previously shown was also observed in the fall, winter, and spring.
  - Lower values: Ebro river and delta → **Flood**
  - Higher values: Cinca and Segre confluence → **Drip**
  - Rest of the values.

- During summer:
  - Irrigation: both scenarios show similar irrigation
  - Evaporation: same pattern as the rest of the seasons
  - Drainage: same pattern as the rest of the seasons regarding lower values.

Conclusions

- **Improved SASER modelling chain**:
  - Updated to latest version of SURFEX LSM with new irrigation scheme
  - The default physiography is not good over the Ebro basin → New physiographic maps have been developed to describe irrigated areas over the Ebro basin.
  - Important step towards a realistic simulation of the water cycle in the Ebro basin.

- **Impact of different irrigation scenarios using SASER:**
  - The optimal and realistic scenarios show differences in irrigation, evaporation, and drainage which, in general terms, coincide with the spatial distribution of the irrigation methods used.
    - Overall, irrigation shows a 20% difference, evaporation in irrigated areas is under 5%, and drainage varies between 20% and 30%.
    - The optimal scenario generally resulted in higher values compared to the realistic scenario.
    - Differences between scenarios are lower over flood irrigated zones located in the Ebro riverbed and in the delta.
    - The greatest differences between the scenarios occur in the drip-irrigated areas where the Cinca and Segre rivers meet.

Thank you for your attention

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