

Potentiality of DIGITAL TWINS representing the Soil-Plant-Atmosphere Continuum as a tool for automatically scheduling irrigation and forecast seasonal crop's water demand at irrigation district level

Joaquim Bellvert

IRTA - Efficient Use of Water in Agriculture

Key Figures

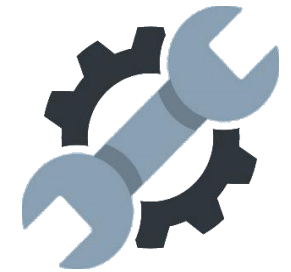
Growers



- How much water crops need
- When to be applied
- Where (in what irrigation sector)



Precision Irrigation



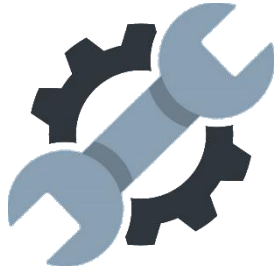
Irrigation District Managers



- How much water I have available now
- How much water I will have available throughout the growing season
- How much is crop's water demand now
- What is the potential crop water demand throughout the growing season

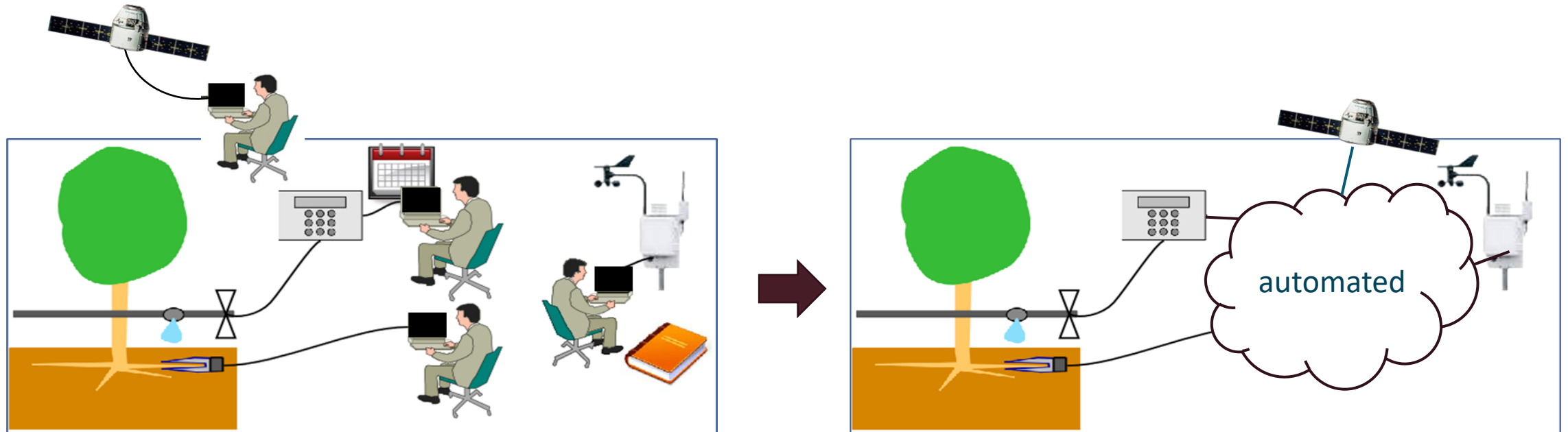


Water demand forecast

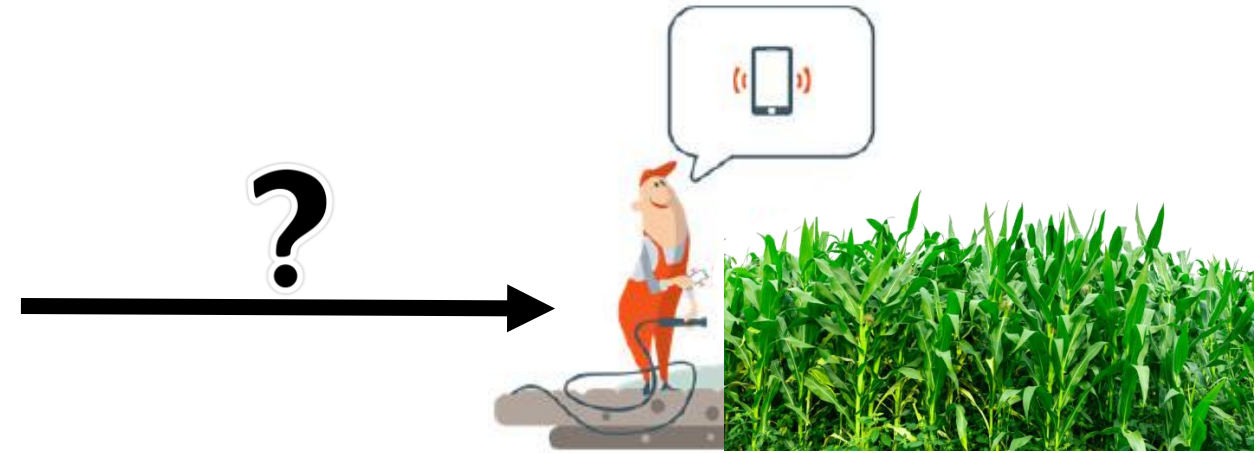
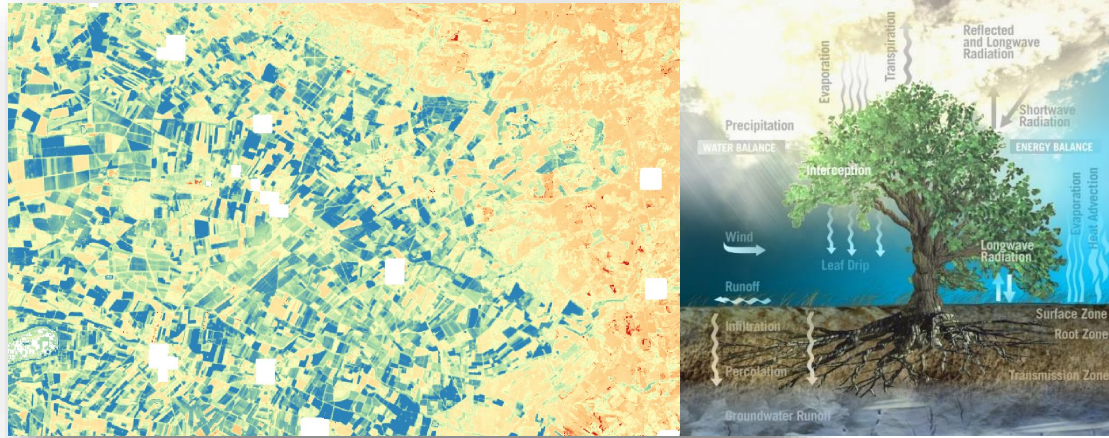


The problem to solve:

- Irrigation requirements vary with time and between sites
- Efficient irrigation requires knowledge and dedication
- Partial solutions exist but better integration is required



Remote sensing for ET

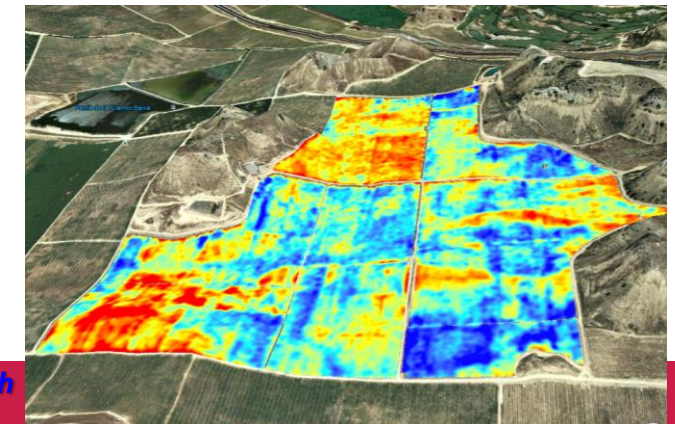


Then, let's the plants ask for water?

Need for a more complete model:

- complementary to ET
- vision of the whole irrigation season
- ability to interpret and forecast
- Knowledge about crop's water response to stress

- Only sometimes
- Not the right solution if:
 - Limited water allocation
 - Concerns on fruit quality/excess crop vigor
 - Issues of spatial variability



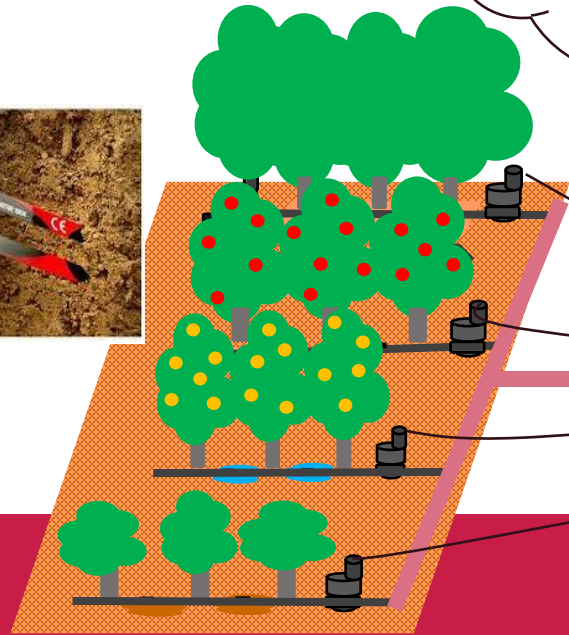
The professional tool for precision Irrigation

www.irridesk.com

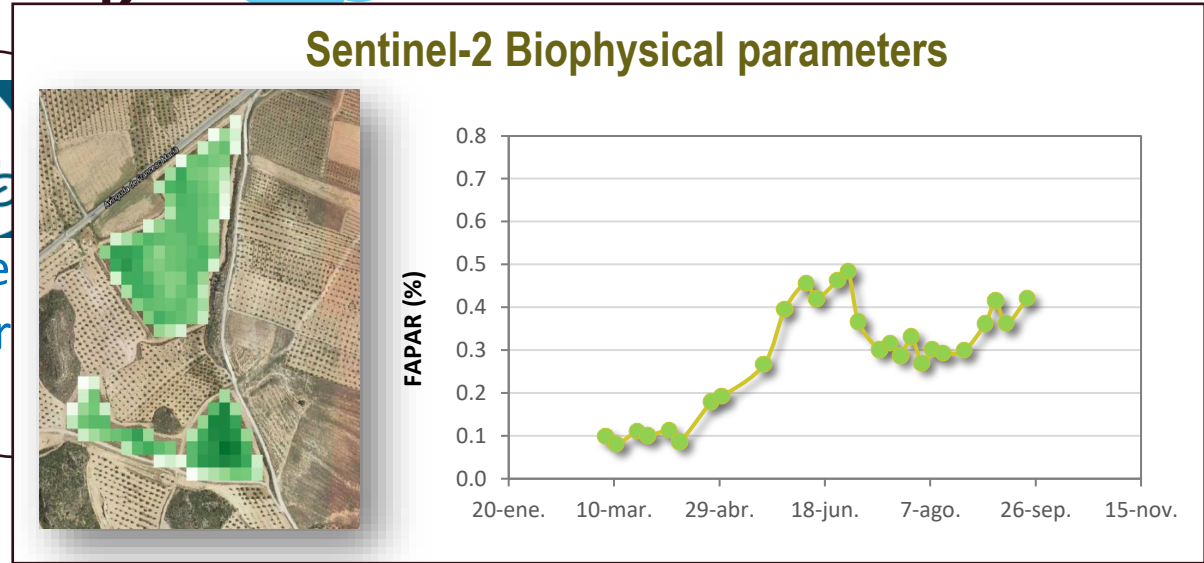
Digital twin



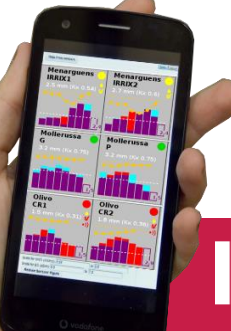
Sensor data

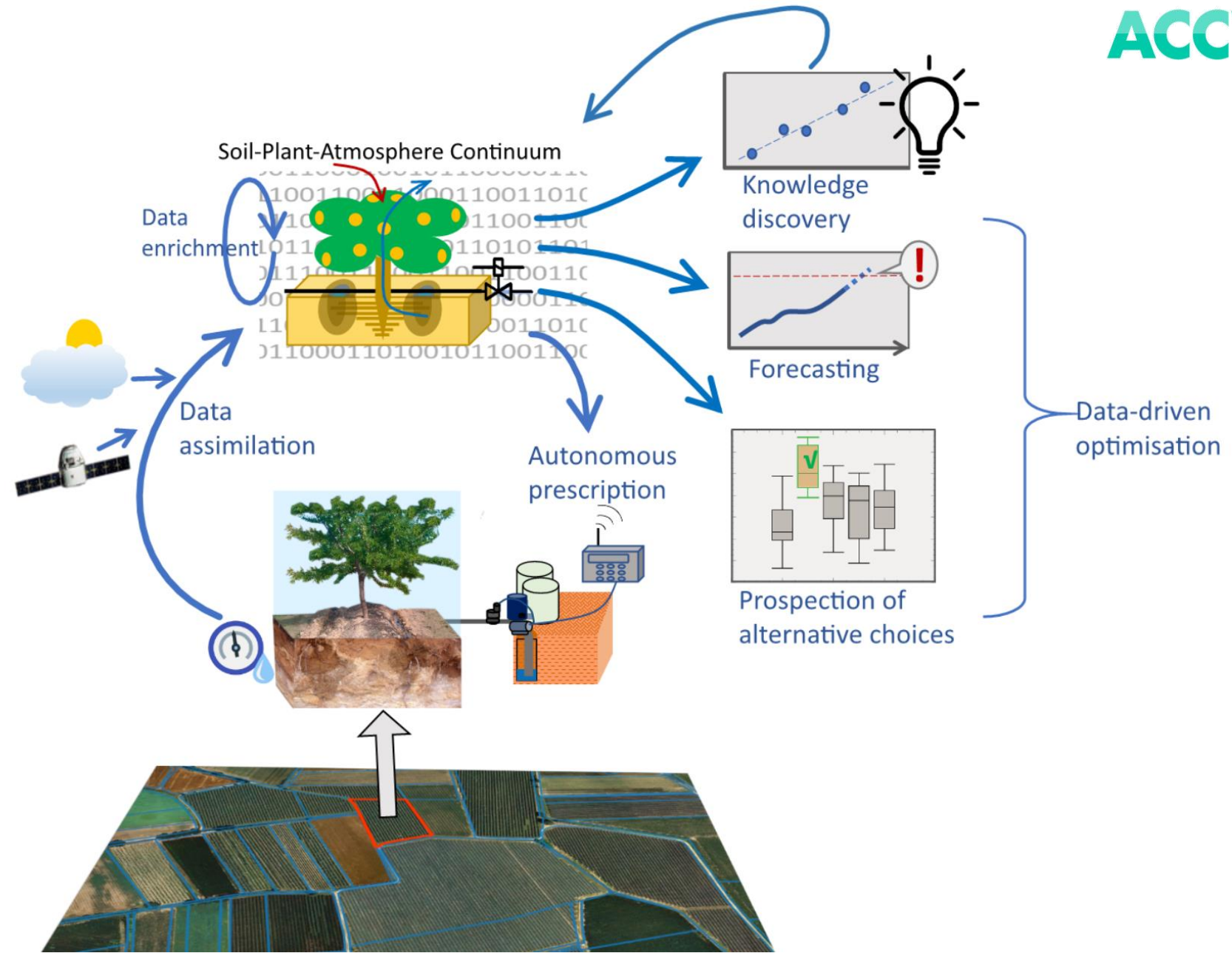


API



API







WELCOME TO IRRIDESK

A professional tool for precision irrigation

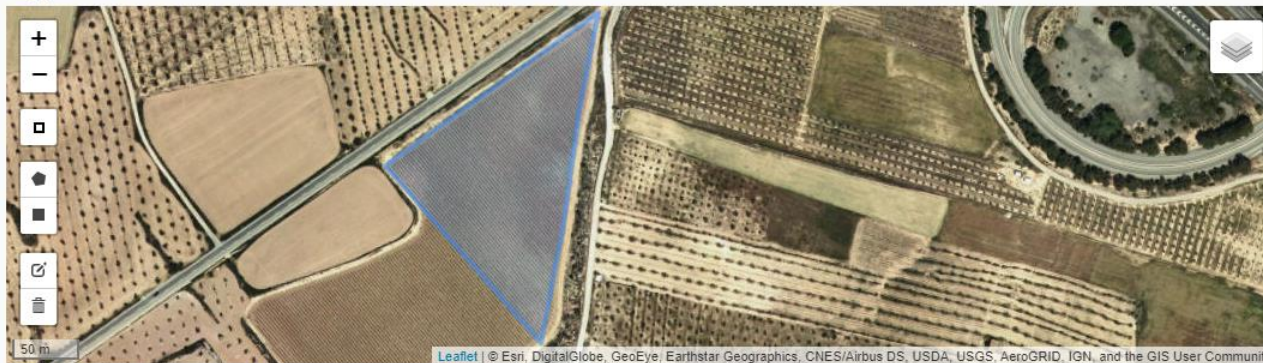
ENTER

User tasks: 1 of 4. Describe the Agronomical Scenario

IrriDesk

- Home
- Farm
- Crop & Soil
 - crops
 - Soils
- Irrigation
- Measurements
- Planning
- Supervision
- simulation
- Data I/O
- Tools
- Profile

- Name:** Name identifying this soil description in the farm
- TexturalClass:** Textural class for this soil, from USDA classification
- Polygon:**

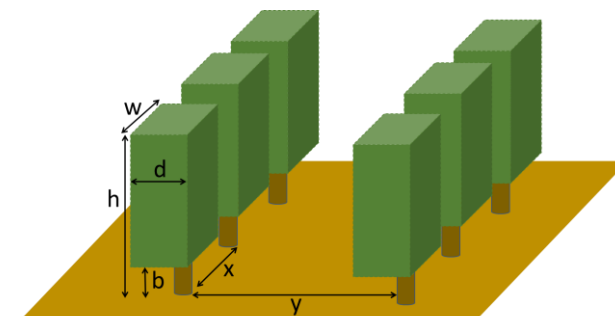


Zone in the farm covered by this crop description. Multipolygon

- Depth:** Soil depth, m
- Slope:** Mean soil slope, %
- Infiltration rate:** Infiltration rate at this soil, mm/h
- Clay:** Relative content of clay, as fraction between 0.0-1.0
- Sand:** Relative content of sand, as fraction between 0.0-1.0
- Silt:** Relative content of silt, as fraction between 0.0-1.0
- Coarse elements:** Relative content of coarse elements, as fraction between 0.0-1.0
- SWC_FC:** Volumetric soil water content at field capacity, m3/m3
- SWC_WP:** Volumetric soil water content at wilting point, m3/m3
- Bulk density:** Soil bulk density, g/cm3
- Ks coef.:** Ks coefficient, saturated hydraulic conductivity, cm/h
- Cover crop:** Whether there is a grass cover between tree rows
- Mulching:** Fraction of soil surface covered by mulching

Save

Back to the list

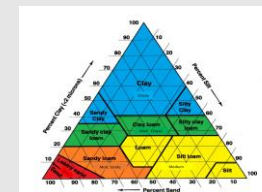


Agronomical Scenario

Crop



Soil



Irrigation System



User tasks: 2 of 4. Configure devices and sensors

IrriDesk


- Home
- Farm
- Crop & Soil
- Irrigation
- Measurements
 - Weather
 - Water meters
 - Soil water sensors
 - Manal sampling
 - Raster series
- Planning
- Supervision
- simulation
- Data I/O
- Tools
- Profile

- Name:**
- Property:**
- Datastream:**
- Raw units:** Units in which IrriDesk will receive these data
- Offset:** Coefficient for transforming the imported data, as $Y = \text{offset} + \text{slope1} * X + \text{slope2} * X^2$
- Slope1:** Coefficient for transforming the imported data, as $Y = \text{offset} + \text{slope1} * X + \text{slope2} * X^2$
- Slope2:** Coefficient for transforming the imported data, as $Y = \text{offset} + \text{slope1} * X + \text{slope2} * X^2$
- Min filter:** Minimum reasonable value. Smaller values will be considered outliers
- Max filter:** Maximum reasonable value. Smaller values will be considered outliers
- Max noise:** Maximum acceptable noise
- Max reliability:** The highest reliability that can be attributed to these data when automatically analysed
- Min reliability:** The lowest reliability that can be attributed to these data when automatically analysed
- Max weight:** Maximum weight that can be automatically assigned to these data
- Is accum?:** Whether the data to import is accumulative
- M3 per pulse:** If the imported units are pulses, what are the m3 per pulse
- Area serviced:** Field area irrigated from this water meter


[Back to the list](#)

Sensors


Water meters



Soil sensors



Weather sensors



User tasks: 3 of 4. Plan the irrigation season

IrriDesk

- Home
- Farm
- Crop & Soil
- Irrigation
- Measurements
- Planning
- Seasonal plan
- Supervision
- simulation
- Data I/O
- Tools
- Profile

Seasonal plan

Seasonal plan

Farm: Aranyó Prescription channel: Divisio_nord submit options

Calendar

Event	Day	
Season start	<input type="text" value="2021-05-15"/>	First day when irrigation is possible
Season end	<input type="text" value="2021-10-31"/>	Last day when irrigation is possible

- Irrigation strategy:** Smart recipe Strategy for deciding the right amount of irrigation
- Max annual volume:** Maximum allowed annual accumulated irrigation volume
- Min annual volume:** Minimum reasonable annual accumulated irrigation volume
- Target vigor:** Desired vigor for this crop at the moment of maximum development in this season

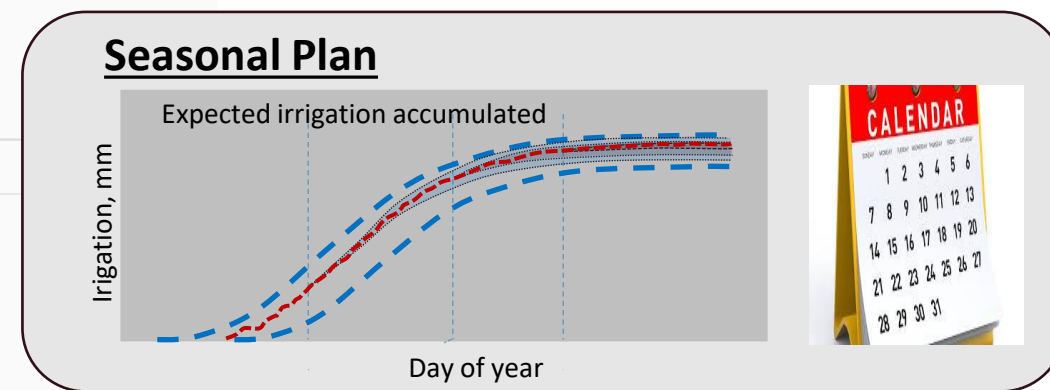
Save changes

recalculate seasonal plan

Use the multiplier curve as a recipe

Irrigation accumulated along the season, mm

upper limit - blue dashed line, lower limit - orange line, observed - green line



User tasks: 3 of 4. Plan the irrigation season

IrriDesk

- Home
- Farm
- Crop & Soil
- Irrigation
- Measurements
- Planning
- Seasonal plan
- Supervision
- simulation
- Data I/O
- Tools
- Profile

Seasonal plan

Seasonal plan

Farm: Aranyó Prescription channel: Divisio_nord submit options

Calendar

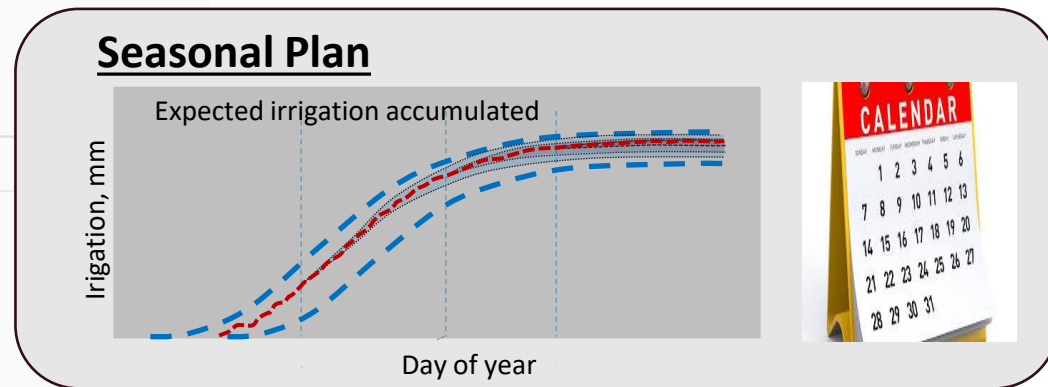
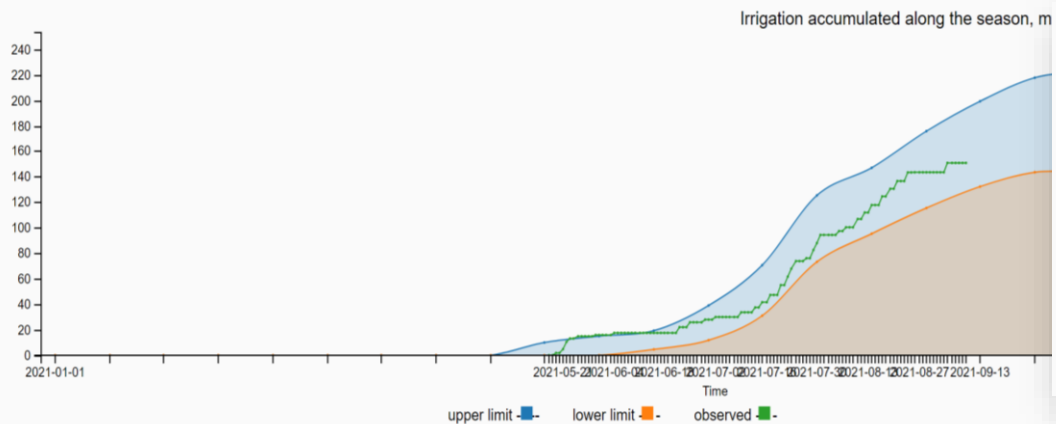
Event	Day	
Season start	2021-05-15	First day when irrigation is possible
Season end	2021-10-31	Last day when irrigation is possible

- Irrigation strategy:** Smart recipe Strategy for deciding the right amount of irrigation
- Max annual volume:** 230.0 Maximum allowed annual accumulated irrigation volume
- Min annual volume:** 150.0 Minimum reasonable annual accumulated irrigation volume
- Target vigor:** 1.0 Desired vigor for this crop at the moment of maximum development in this season

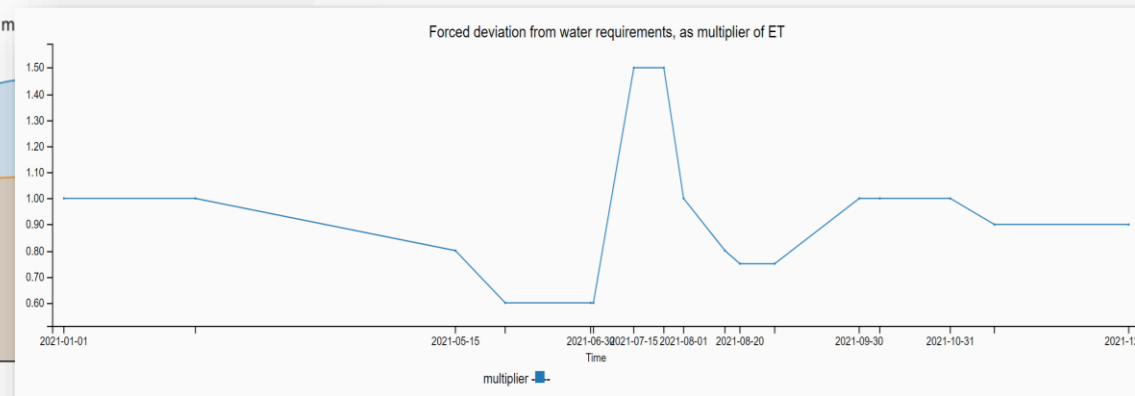
Save changes

recalculate seasonal plan

Use the multiplier curve as a recipe



Adoption of RDI strategies



User tasks: 4 of 4. Supervise periodically the absence of anomalies

IrriDesk

- Home
- Farm
- Crop & Soil
- Irrigation
- Measurements
- Planning
- Supervision**

Grid view

- Programmed
- Sensors view
- Seasonal view
- Digital Twin
- Prescriptions

- simulation
- Data I/O
- Tools
- Profile

Fast Supervision

Grid of panels for each prescription channel

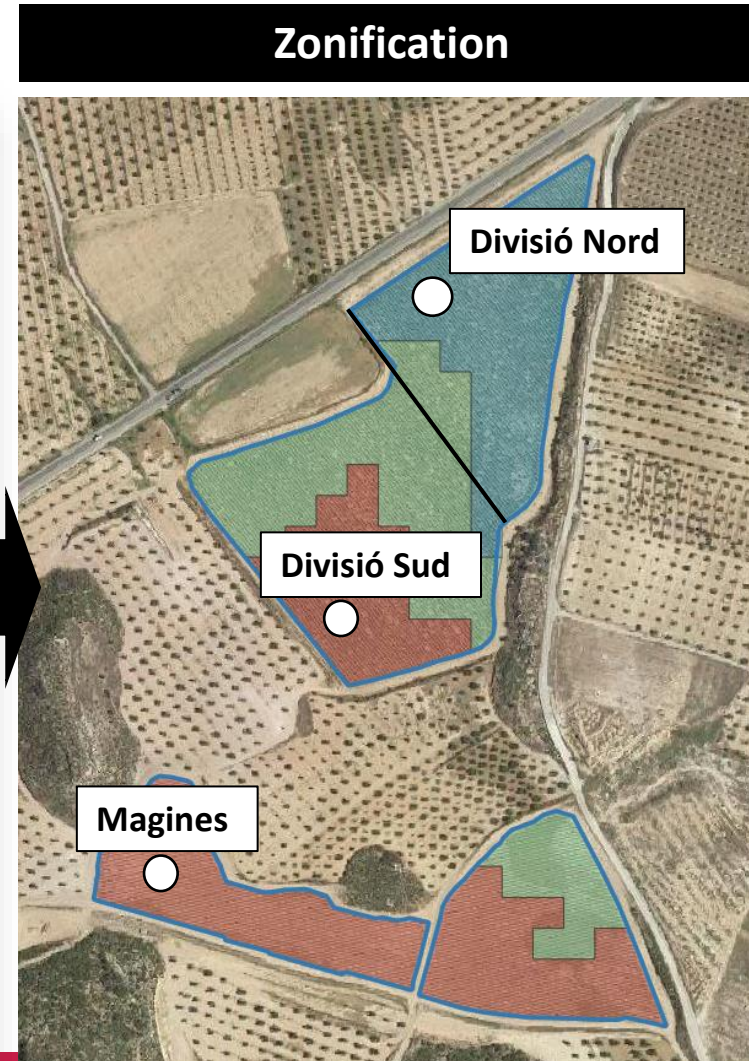
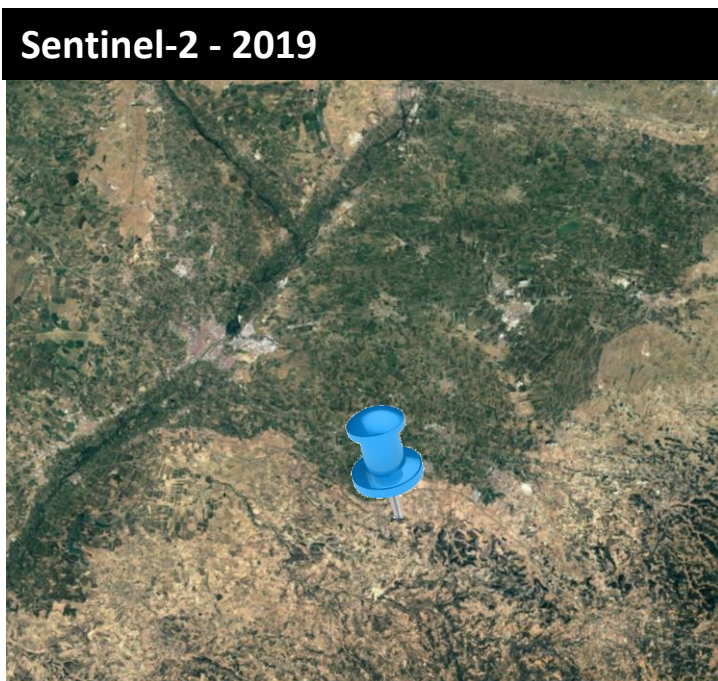
08/06/2021

<p>Divisio_nord@Aranyó</p> <p>0.84mm/day (Kx 0.01)</p>	<p>Divisio_sud@Aranyó</p> <p>0.28mm/day (Kx -0.06)</p>	<p>Magines@Aranyó</p> <p>0.37mm/day (Kx -0.04)</p>	<p>Guara_DN@Daroeira Norte</p> <p>0.0mm/day (Kx -1.0)</p>	<p>Lauranne_DN_1@Daroeira Norte</p> <p>0.0mm/day (Kx -1.0)</p>
<p>Lauranne_DN_2@Daroeira Norte</p> <p>0.0mm/day (Kx -1.0)</p>	<p>Penta_DN@Daroeira Norte</p> <p>0.0mm/day (Kx -1.0)</p>	<p>Ametllers@Farm_almond</p> <p>0.0mm/day (Kx -0.12)</p>	<p>Vinya@Farm_vinya</p> <p>60.88mm/day (Kx 14.49)</p>	<p>1@Viñedo</p> <p>1.2mm/day (Kx -0.05)</p>
<p>2@Viñedo</p> <p>0.96mm/day (Kx -0.09)</p>	<p>3@Viñedo</p> <p>0.87mm/day (Kx -0.11)</p>			



Case study (vineyard):

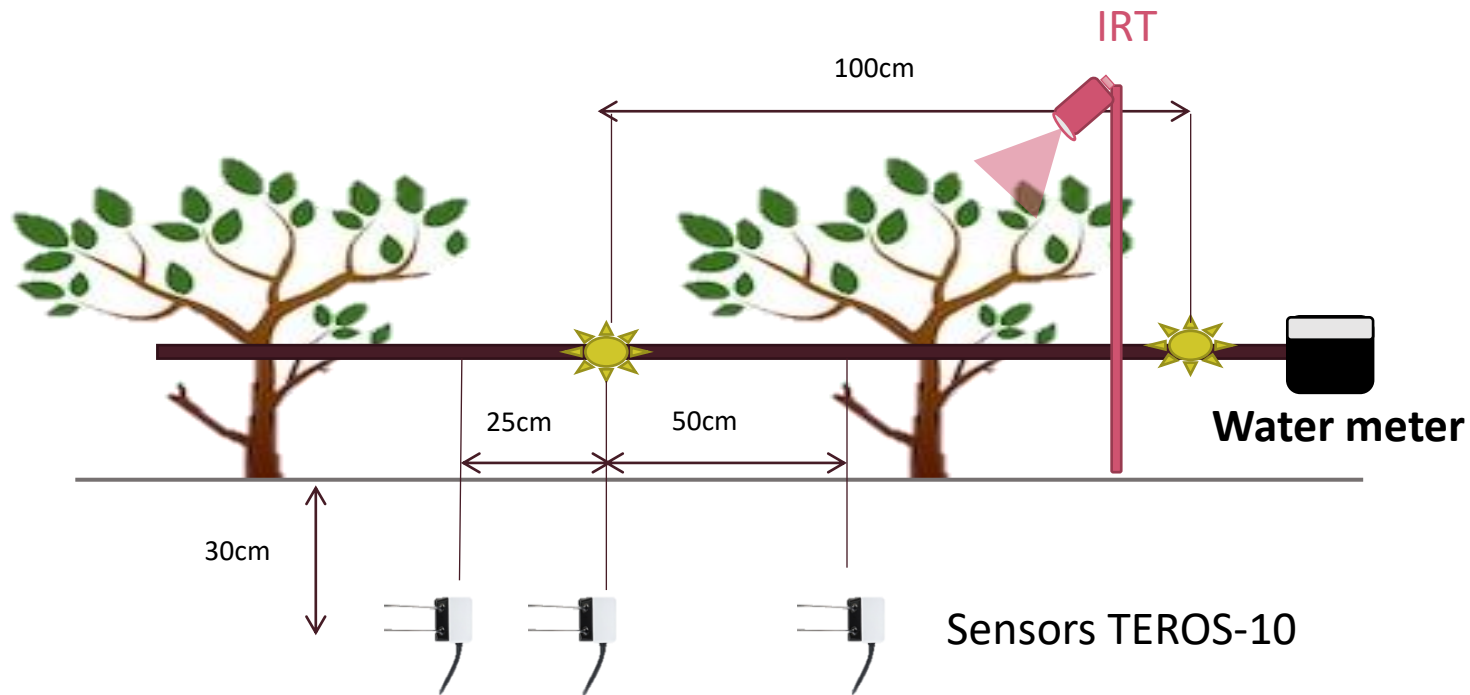
- To select 'Smart points' to install sensors



Kit of sensing

Points at **DIVISIO NORD, DIVISIO SUD & MAGINES**: Datalogger ZentraCloud (x4):

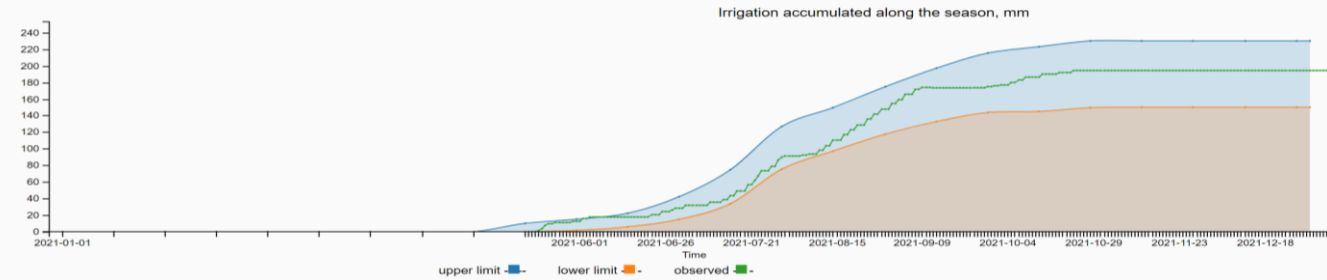
- 3 TEROS-10 a 30 cm
- 1 Water meter Zenner
- 2 Thermal Infrared sensors (IRT)



vista estacional

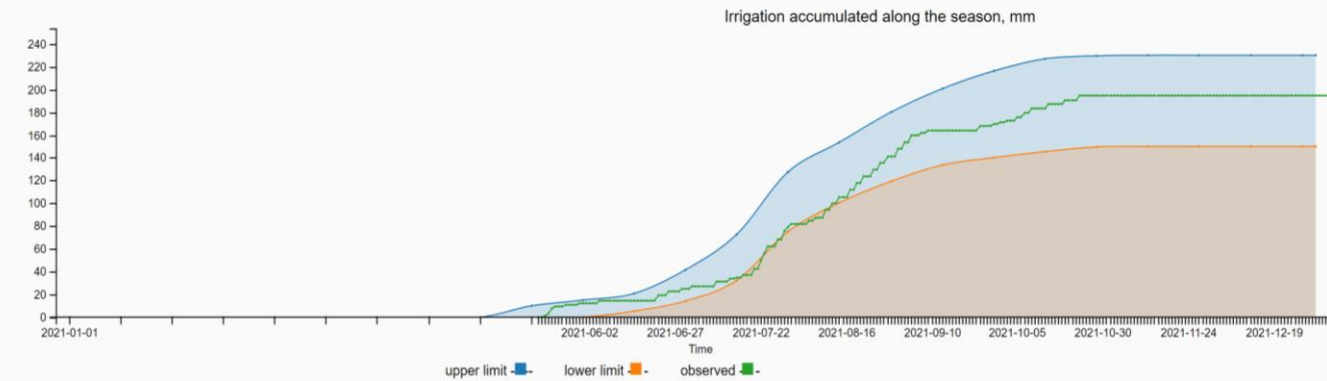
Dinámica estacional

finca: Aranyó Canal de Prescripción de Riego: Divisio_nord Enviar



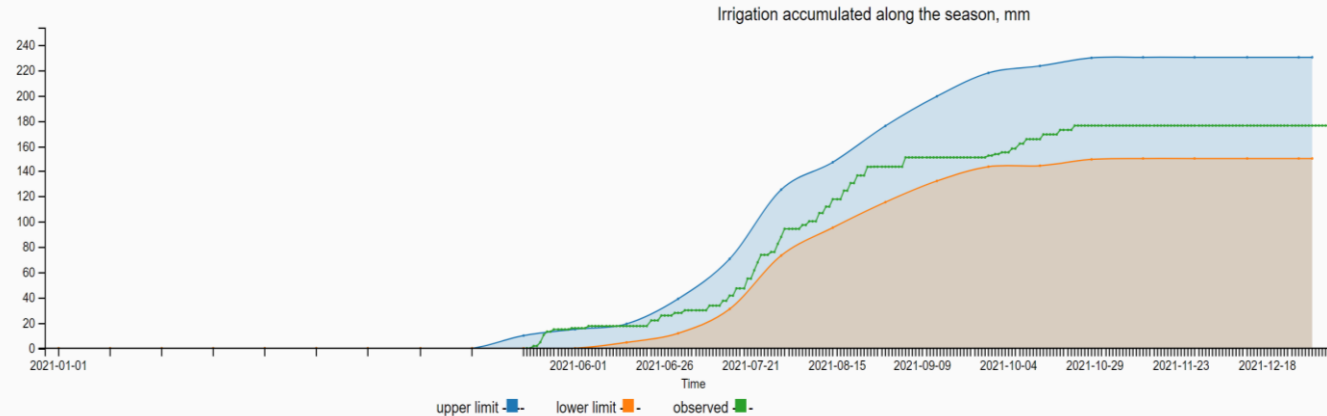
194 mm

finca: Aranyó Canal de Prescripción de Riego: Divisio_sud Enviar

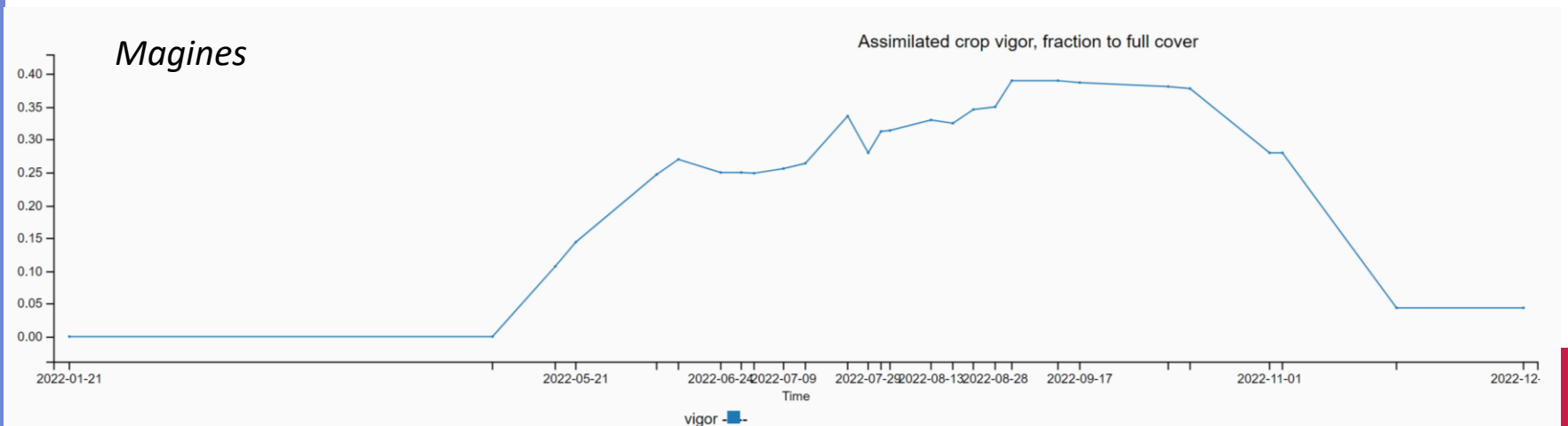
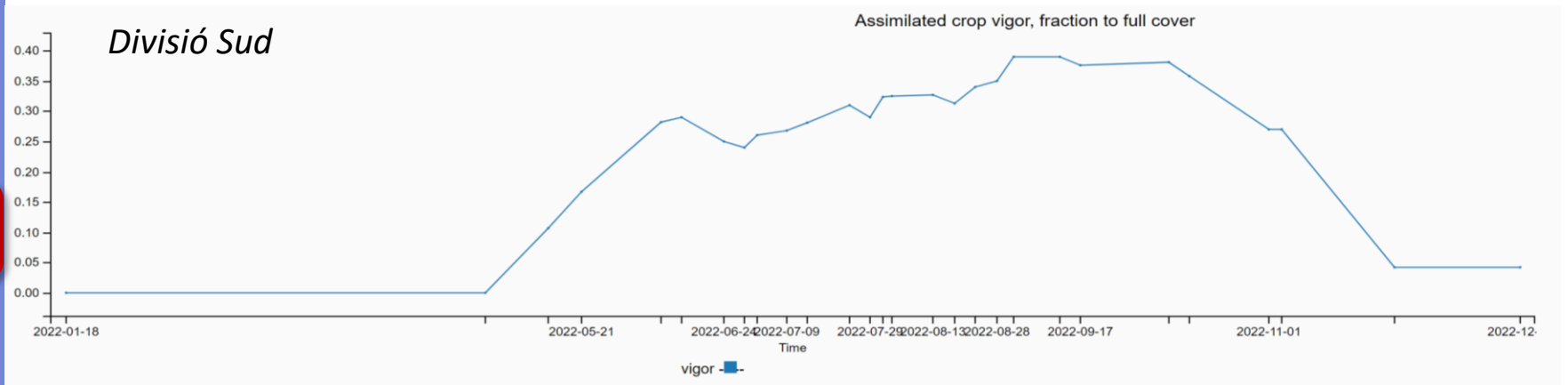
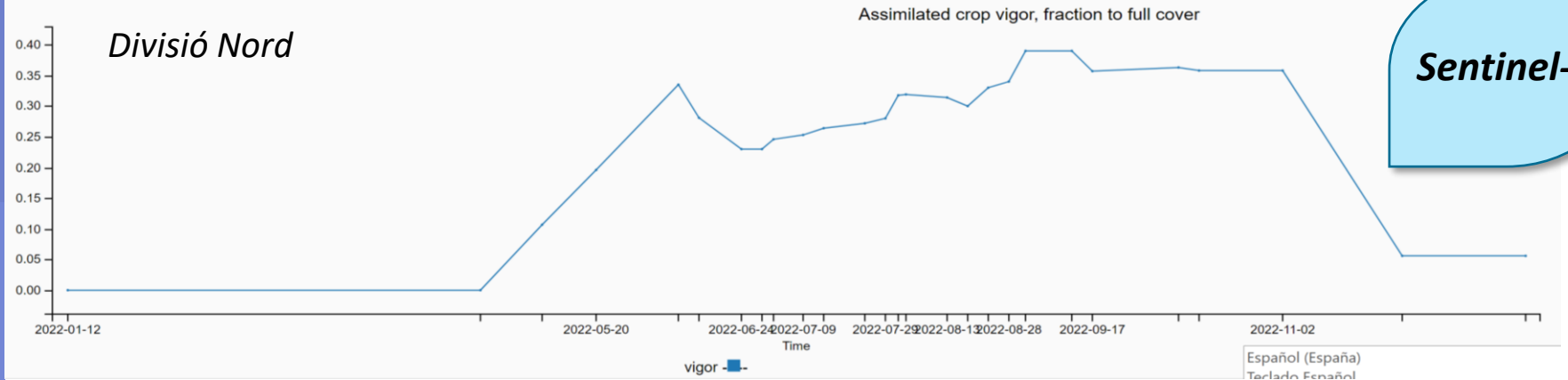


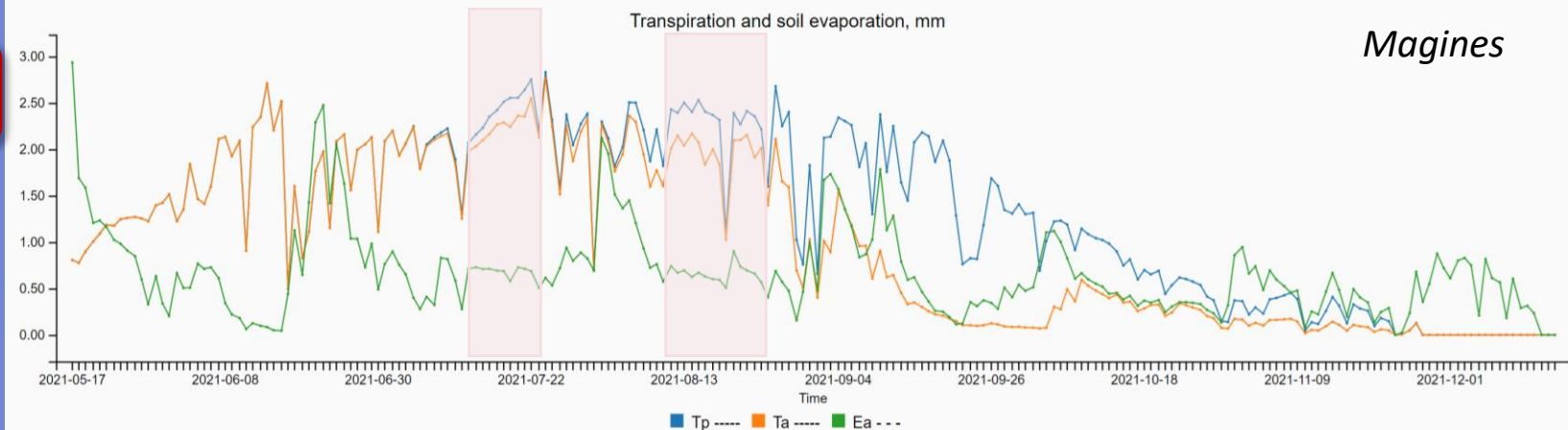
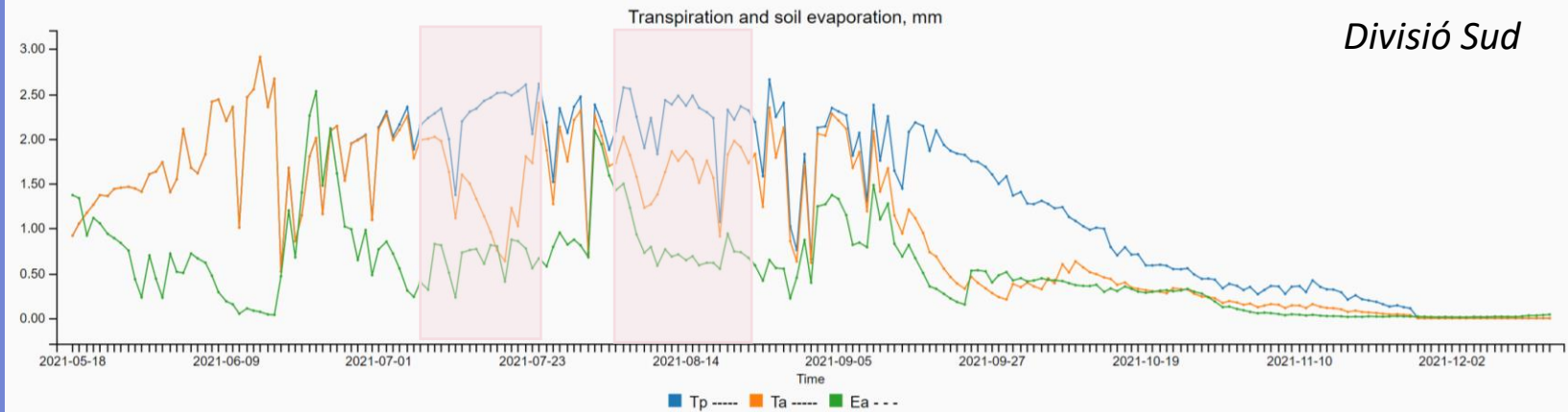
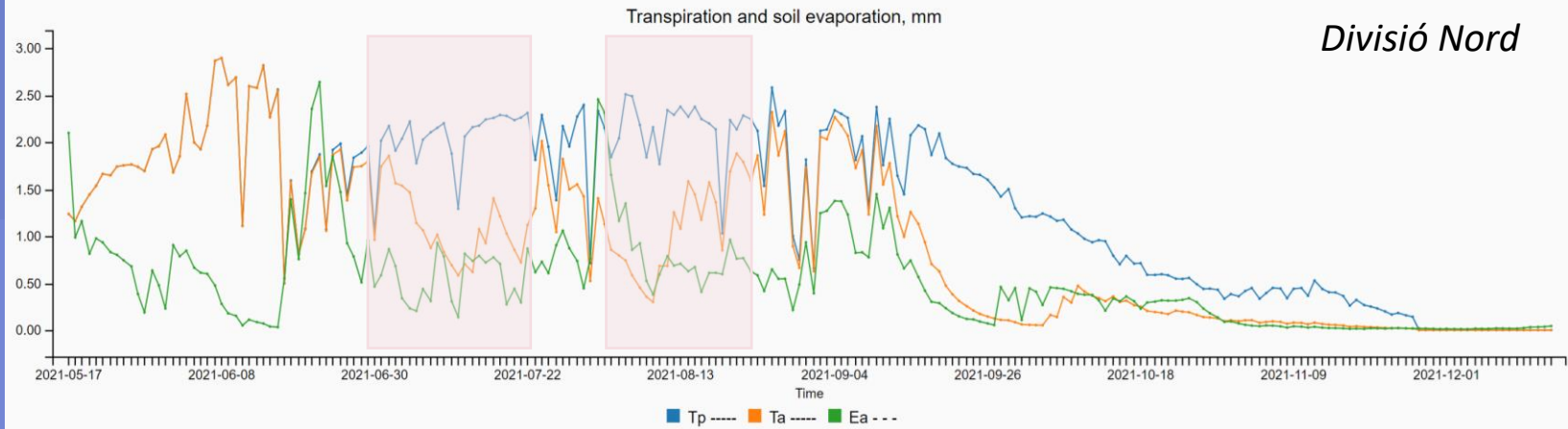
194 mm

finca: Aranyó Canal de Prescripción de Riego: Magines Enviar



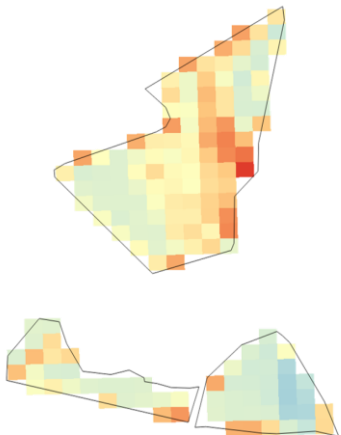
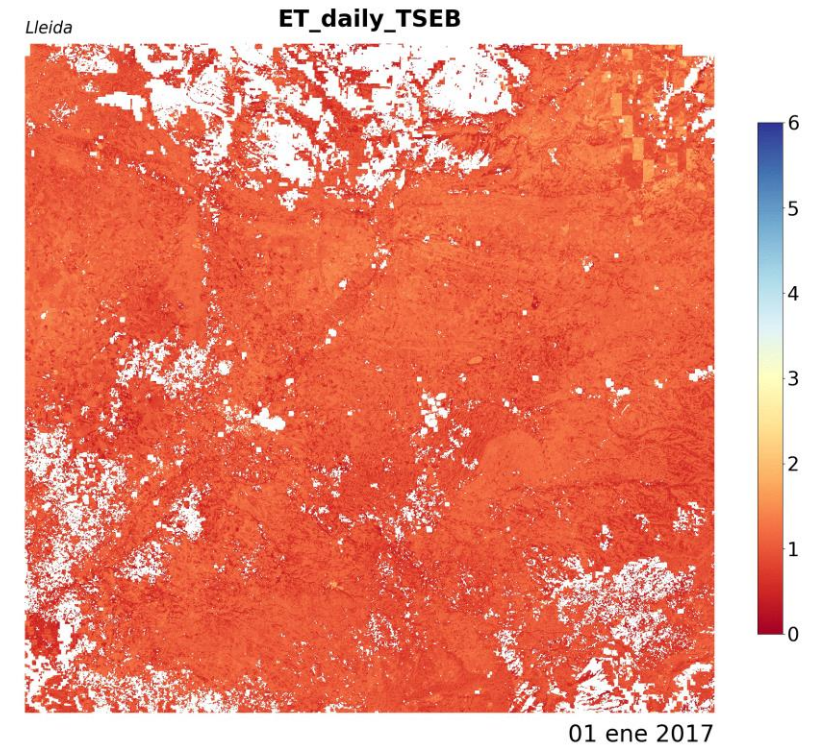
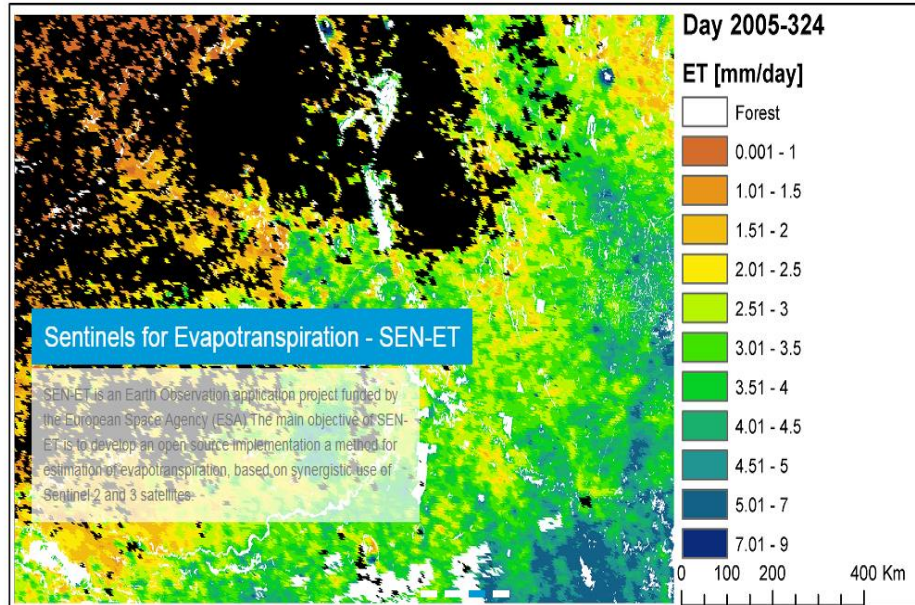
176 mm



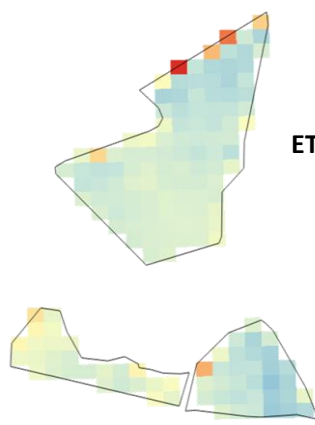
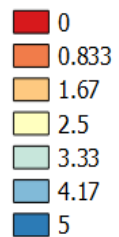


Monitoring ETa with TSEB_{S2+S3}

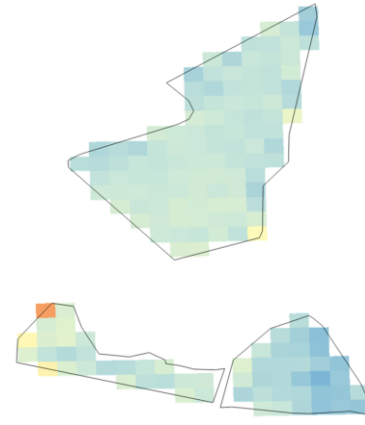
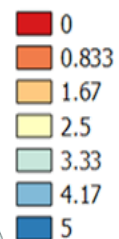
www.esa-sen4et.org



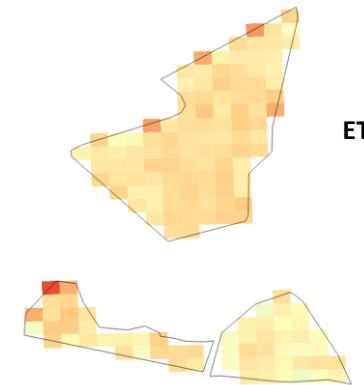
ET_{daily}—30/05



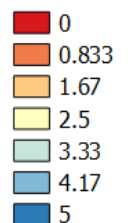
ET_{daily}—23/07

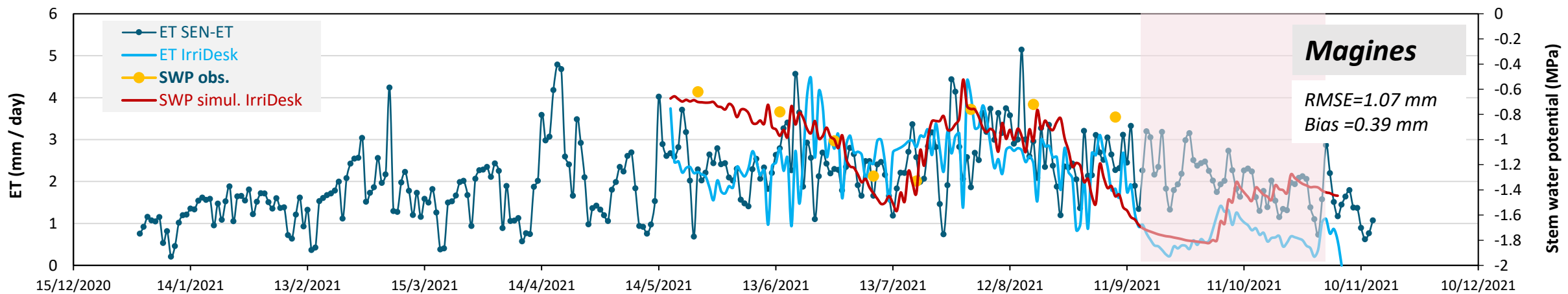
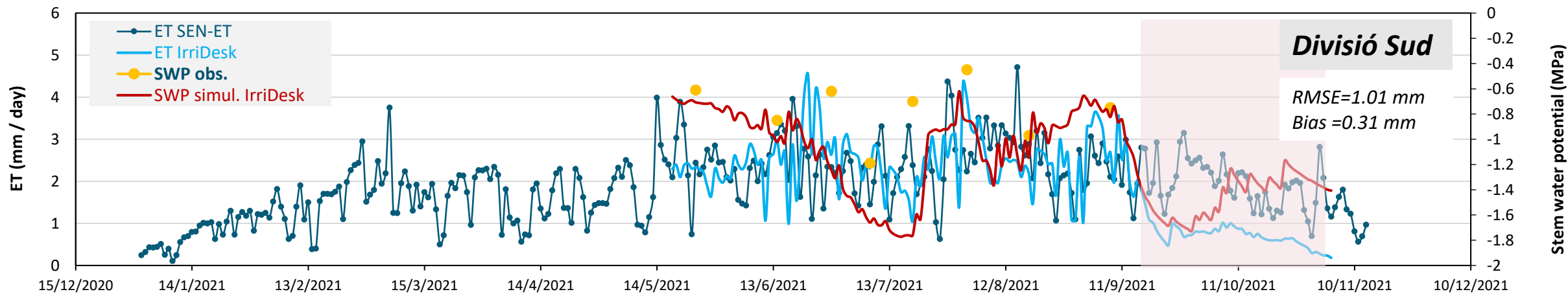
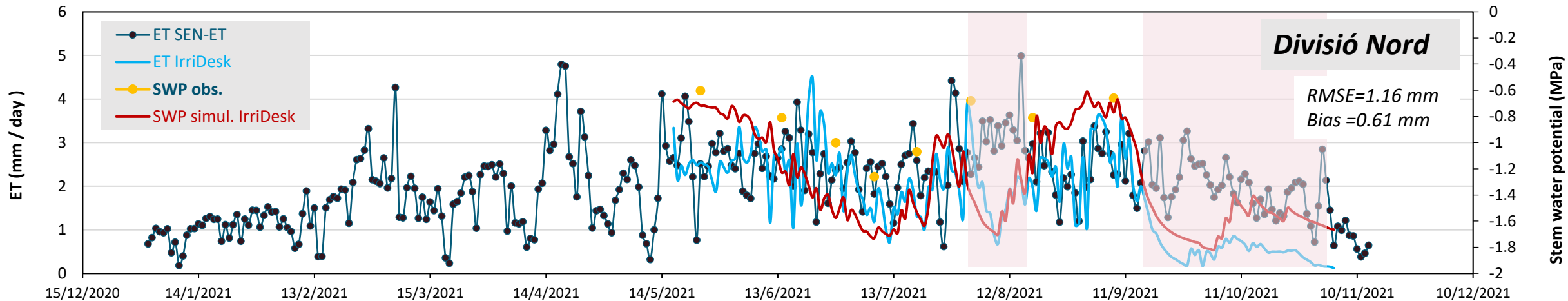


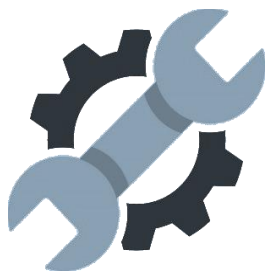
ET_{daily}—24/08



ET_{daily}—02/10

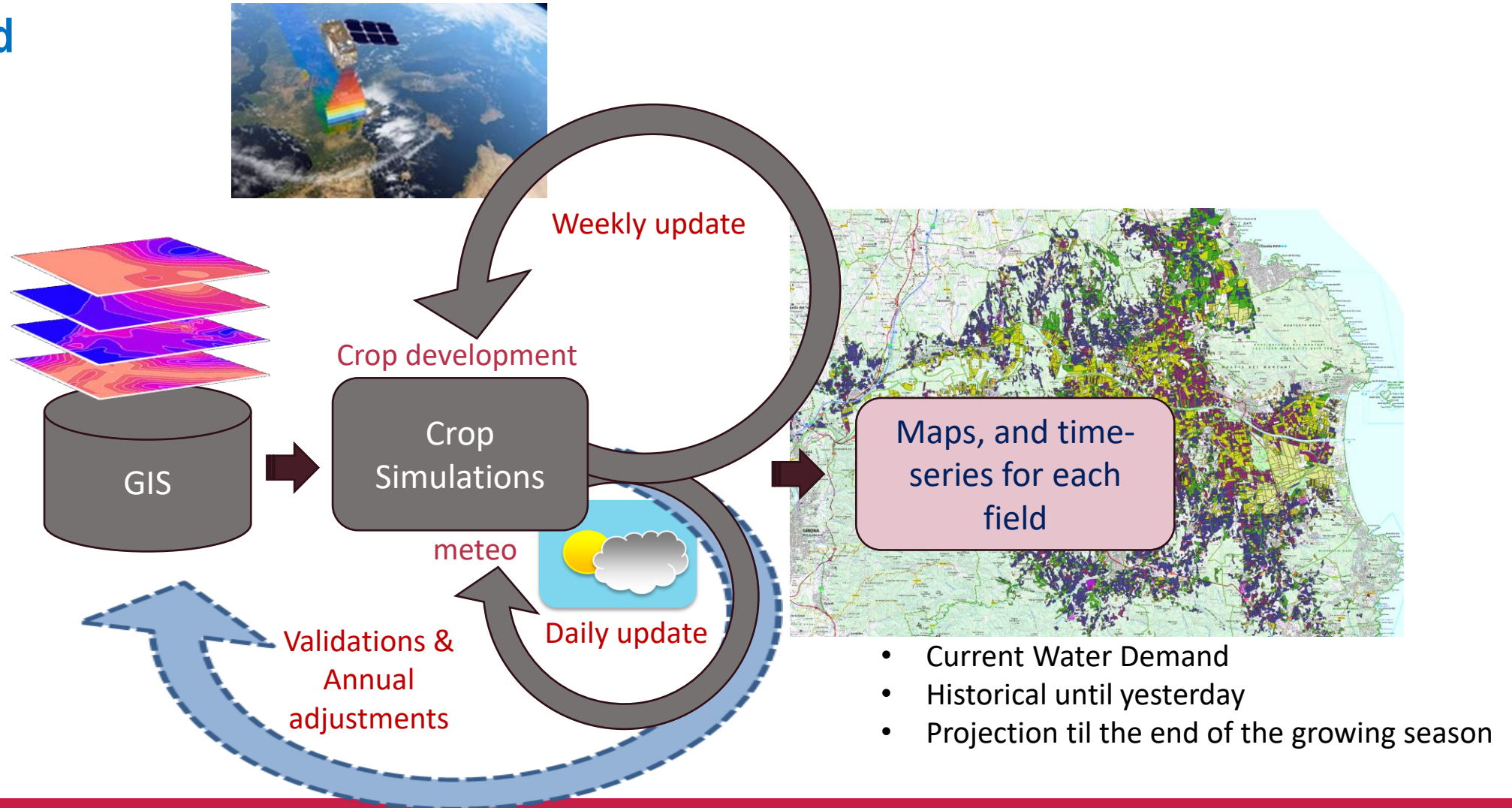


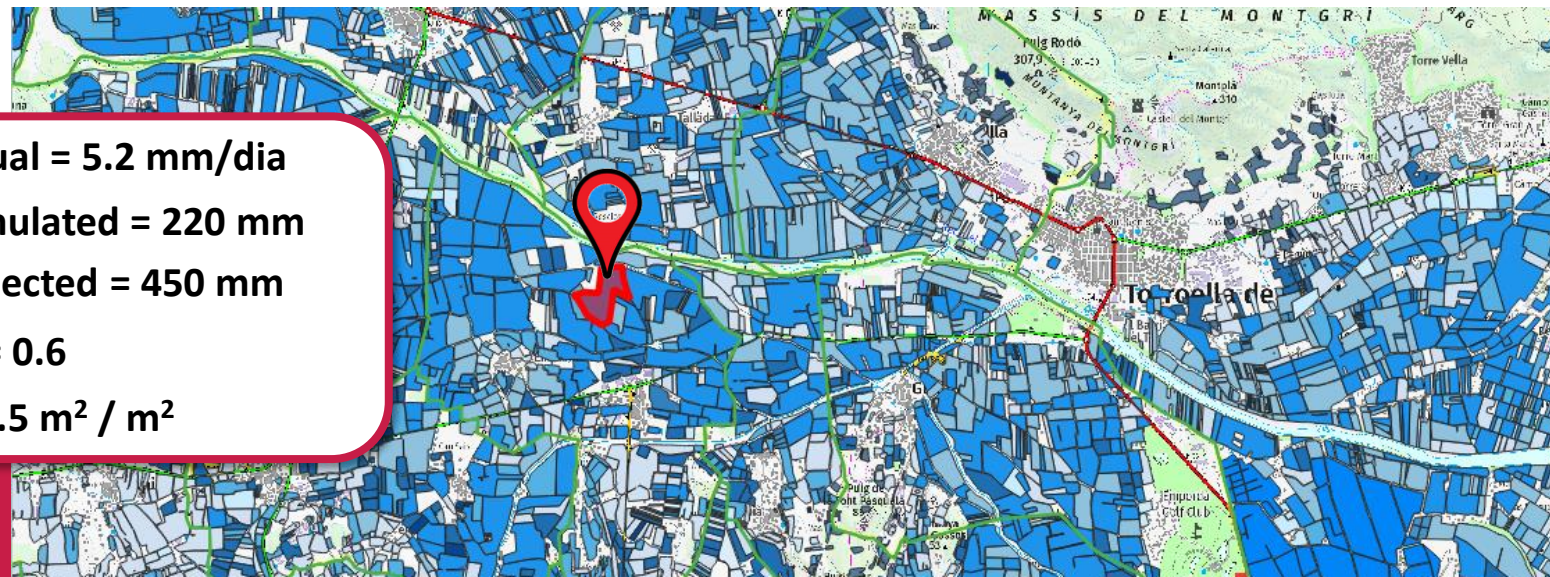
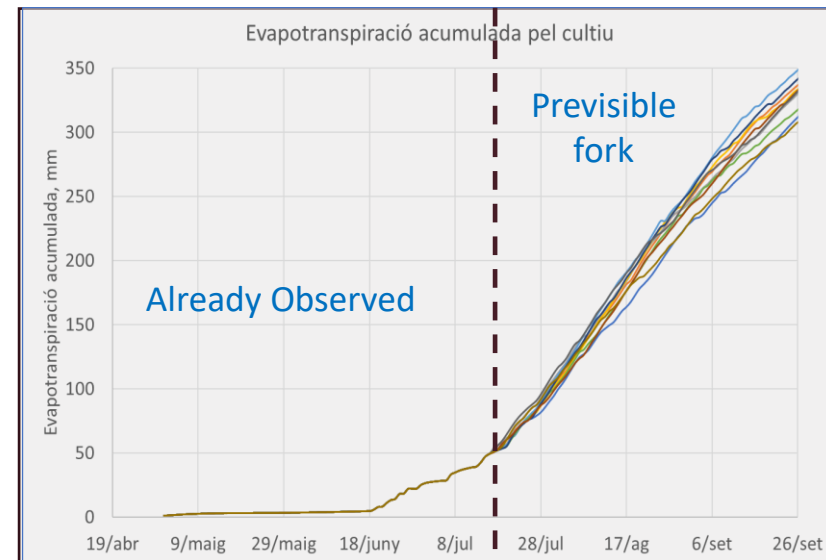
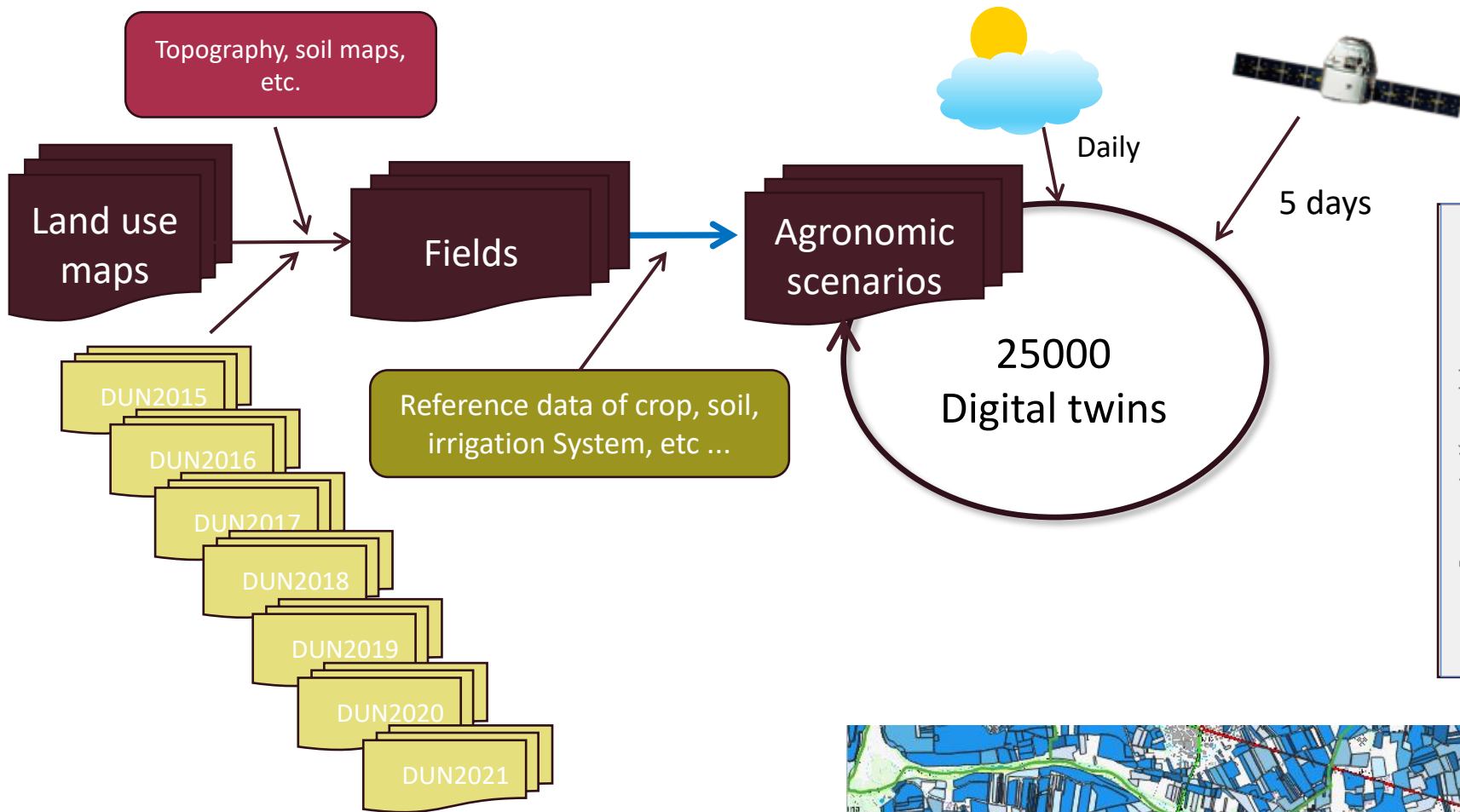




Water demand forecast

Simulations of crop water balance dynamics in real-time







ET actual = 5.2 mm/dia
ET cumulated = 220 mm
ET projected = 450 mm
CWSI = 0.6
LAI = 2.5 m² / m²

Variable selection

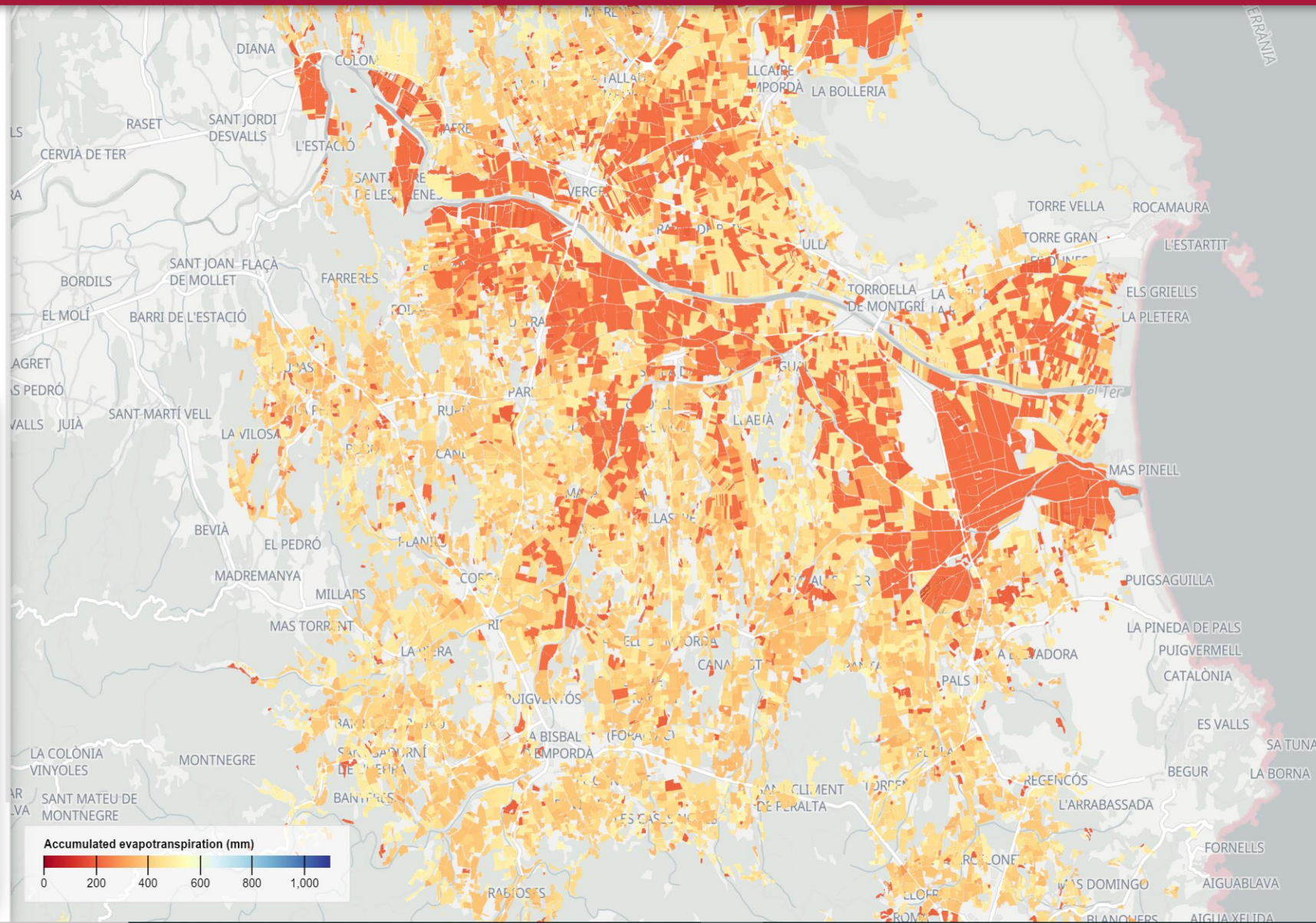
This Week 

Accumulated to date 

Min predictable to the end 

Max predictable to the end 

- Accumulated drainage
- Vegatative vigour (crop)
- Vegatative vigour (total)
- Transpiration (crop)
- Available soil water
- Minimum predictable drainage
- Maximum predictable drainage
- Potential Yield Fraction
- Water stress index

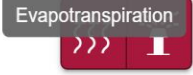


Variable selection

This Week



Accumulated to date



Min predictable to the end



Max predictable to the end

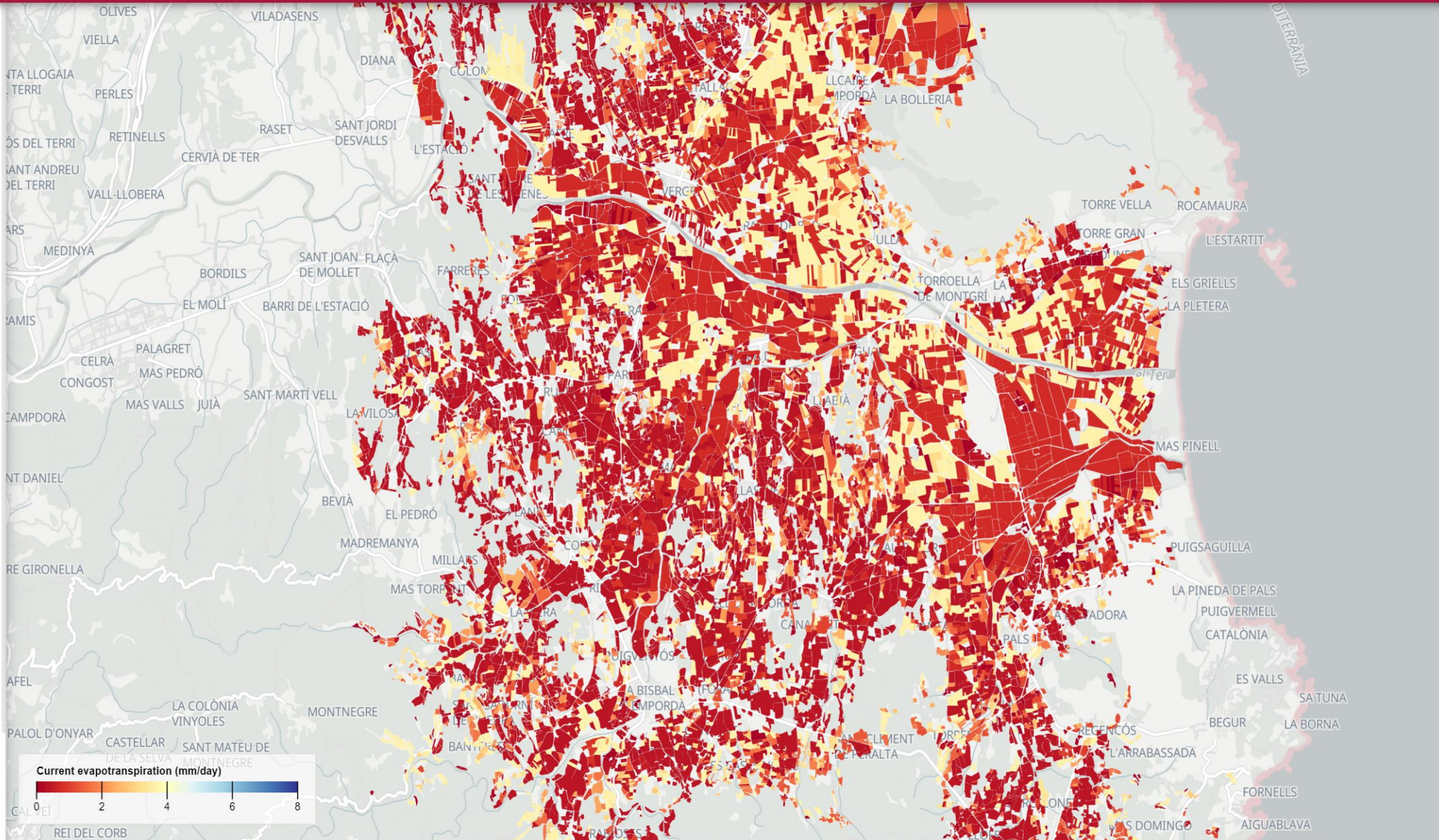


Date of the data

Jul 15, 2030

Base Map Style

- Positron
- Full Dark
- OSM Bright
- Híbrid



Variable selection

This Week



Accumulated to date



Min predictable to the end



Max predictable to the end



Available soil water



Date of the data

Jul 15, 2030

Base Map Style

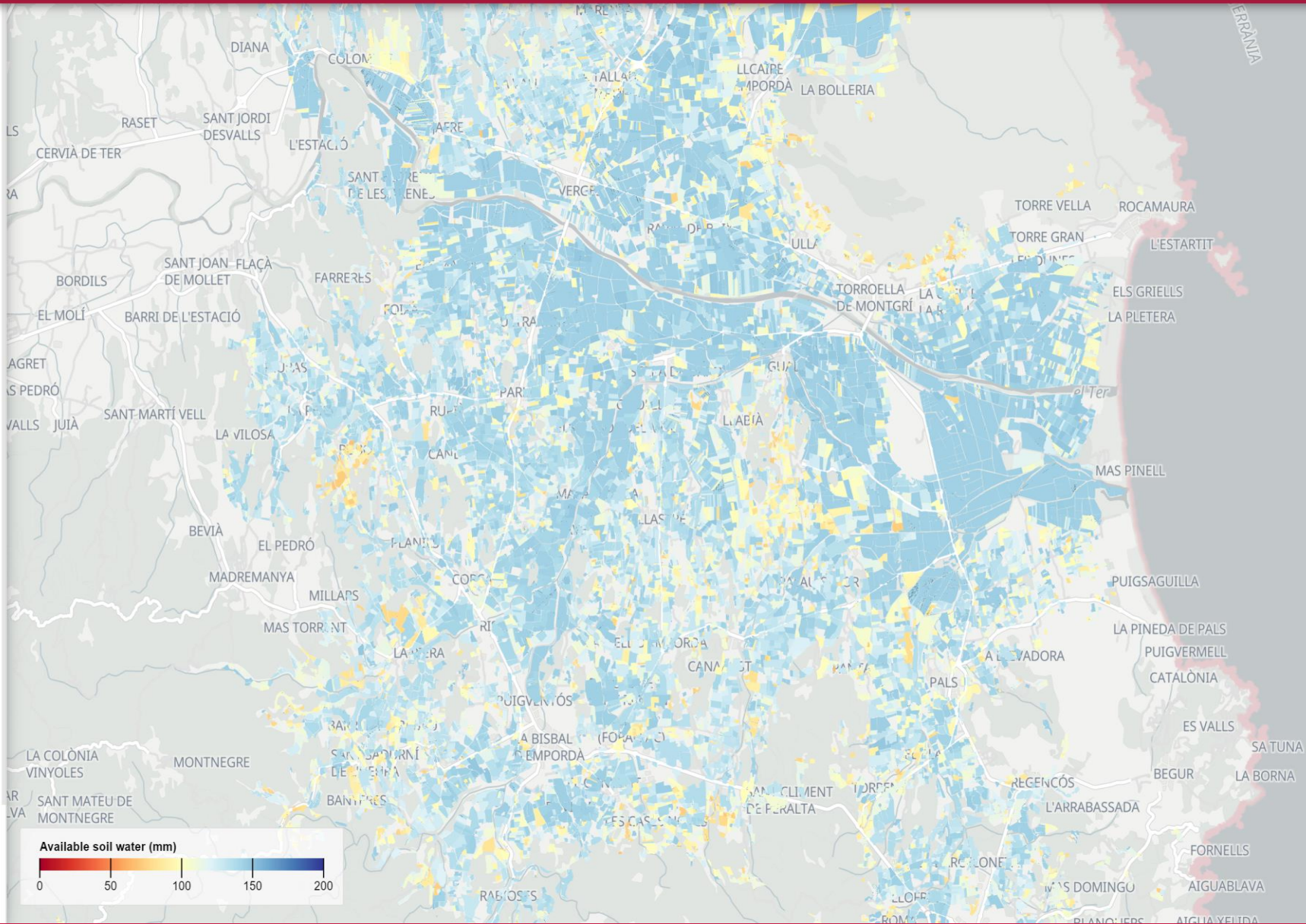
Positron

Positron

Full Dark

OSM Bright

Híbrid



Variable selection

This Week



Accumulated to date



Min predictable to the end



Max predictable to the end



Date of the data

Jul 15, 2030

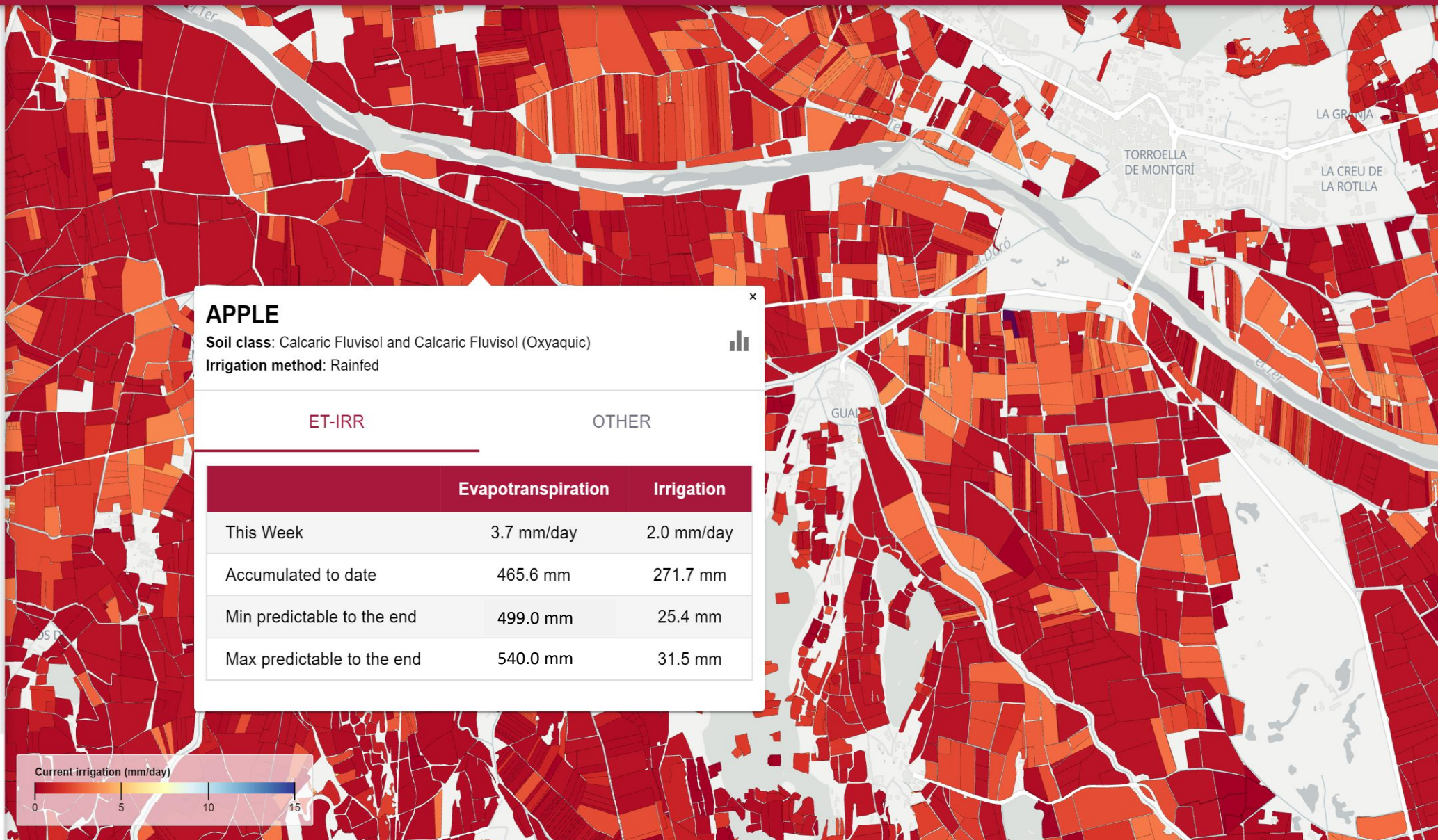
Base Map Style

Positron

Full Dark

OSM Bright

Hibrid

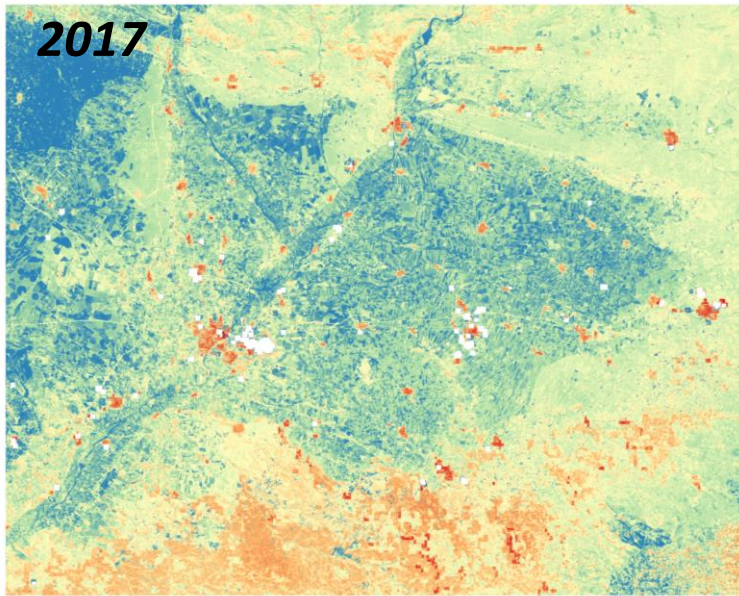


APPLE

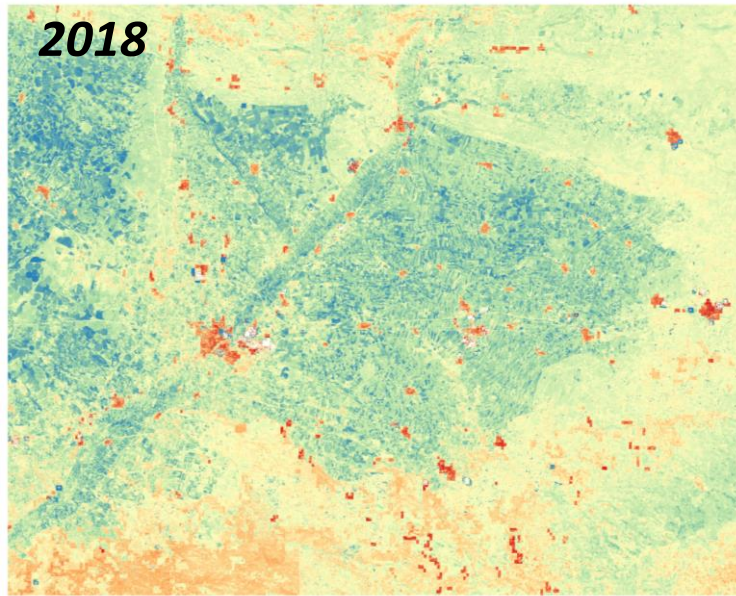
Soil class: Calcaric Fluvisol and Calcaric Fluvisol (Oxyaquic)
Irrigation method: Rainfed

	ET-IRR	OTHER
This Week	3.7 mm/day	2.0 mm/day
Accumulated to date	465.6 mm	271.7 mm
Min predictable to the end	499.0 mm	25.4 mm
Max predictable to the end	540.0 mm	31.5 mm

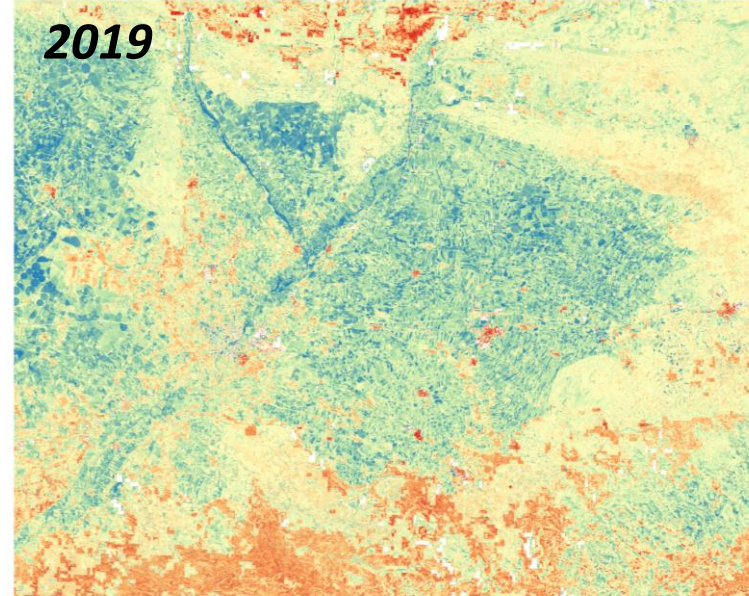




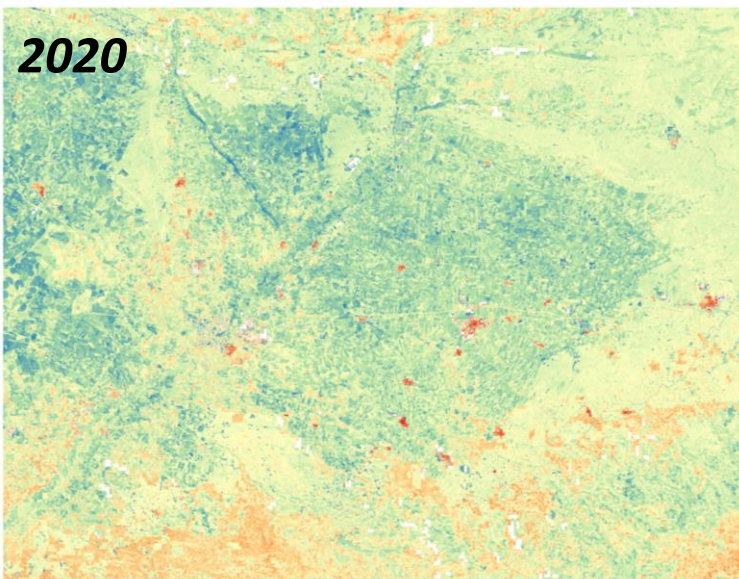
0 5 10 km



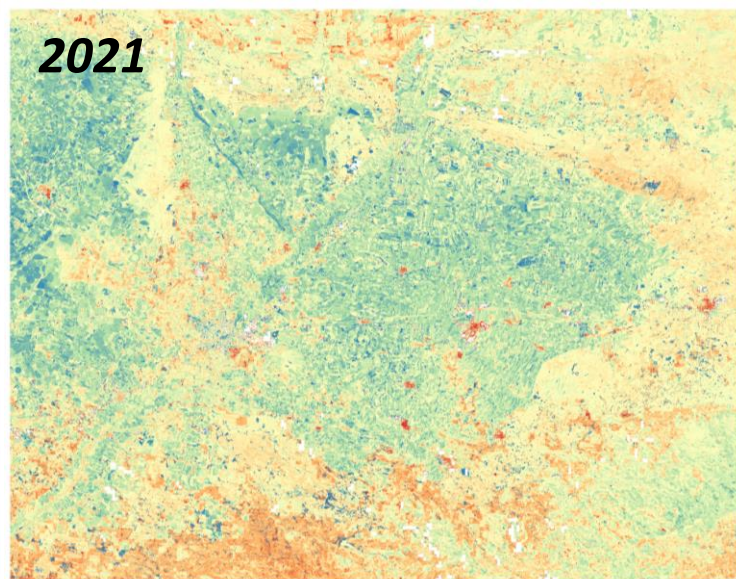
0 5 10 km



0 5 10 km



0 5 10 km



0 5 10 km

ETa (mm)

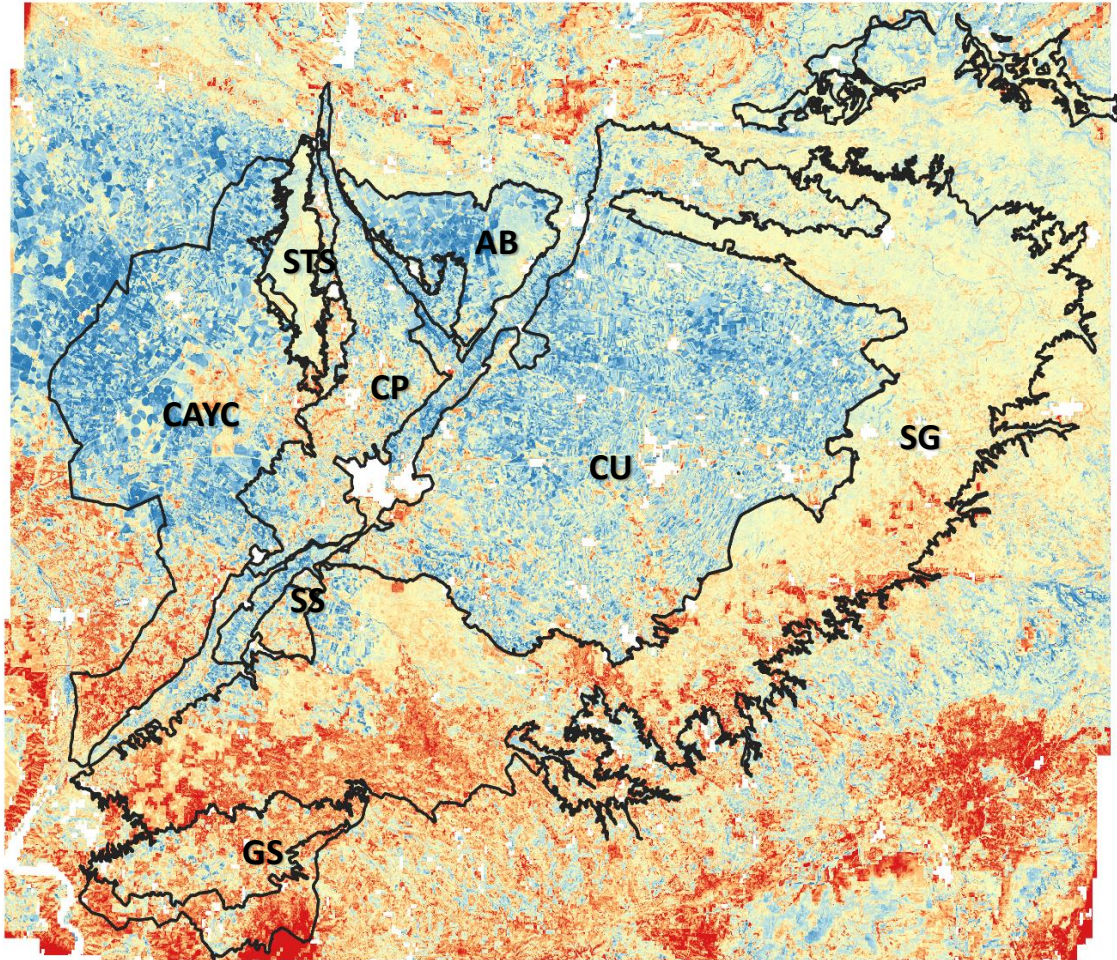
1200

200

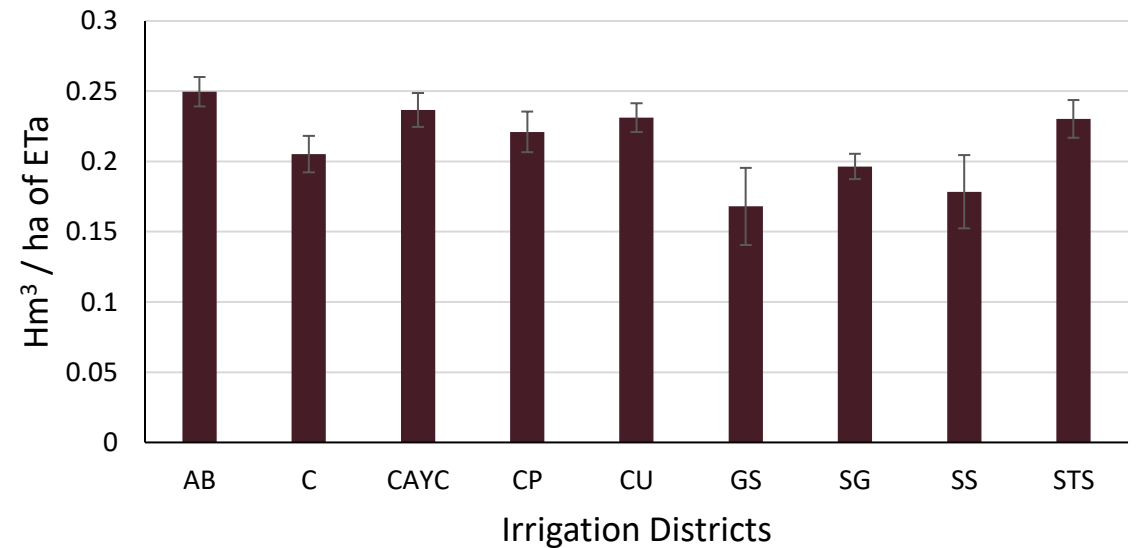
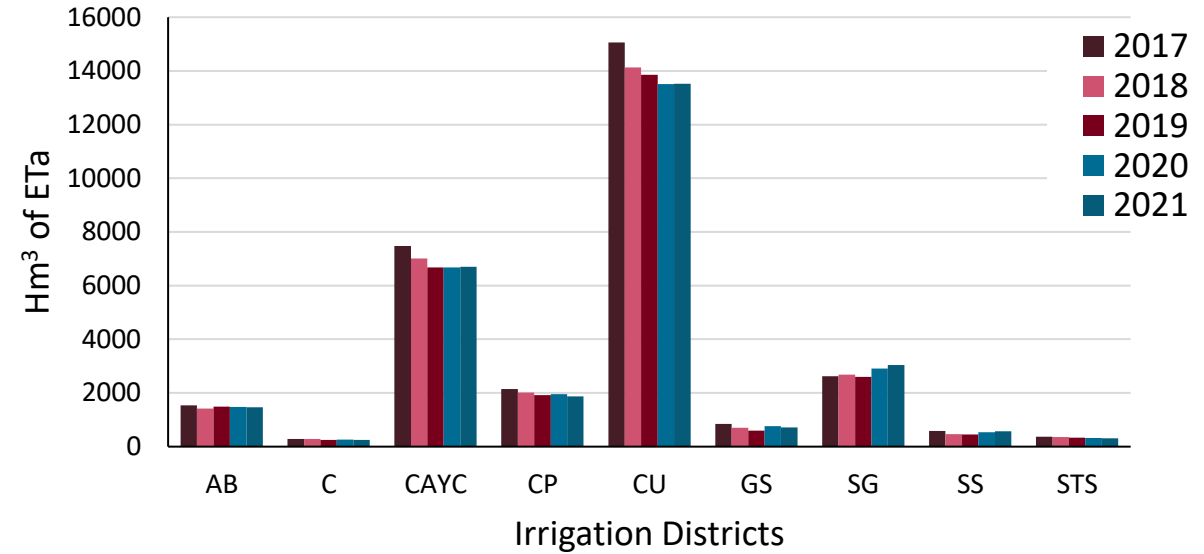


sen-et
sentinels for evapotranspiration

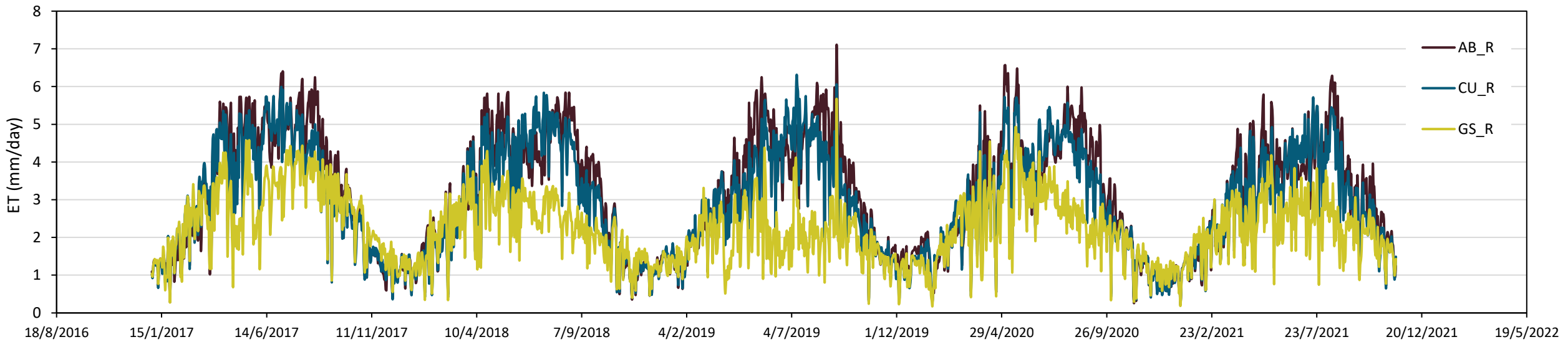
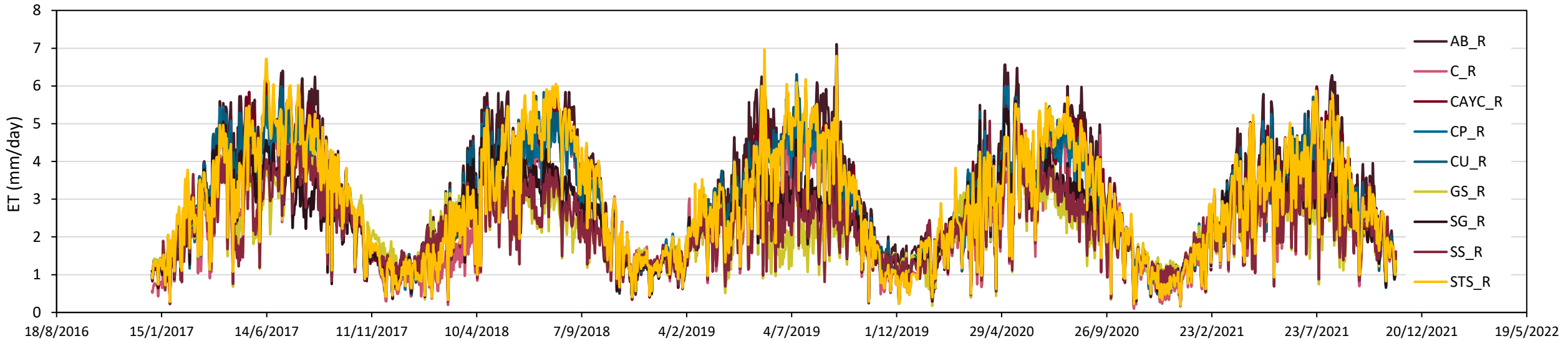
SEN-ET -> Crop's Water Use & demand by irrigation districts (Lleida, Spain)



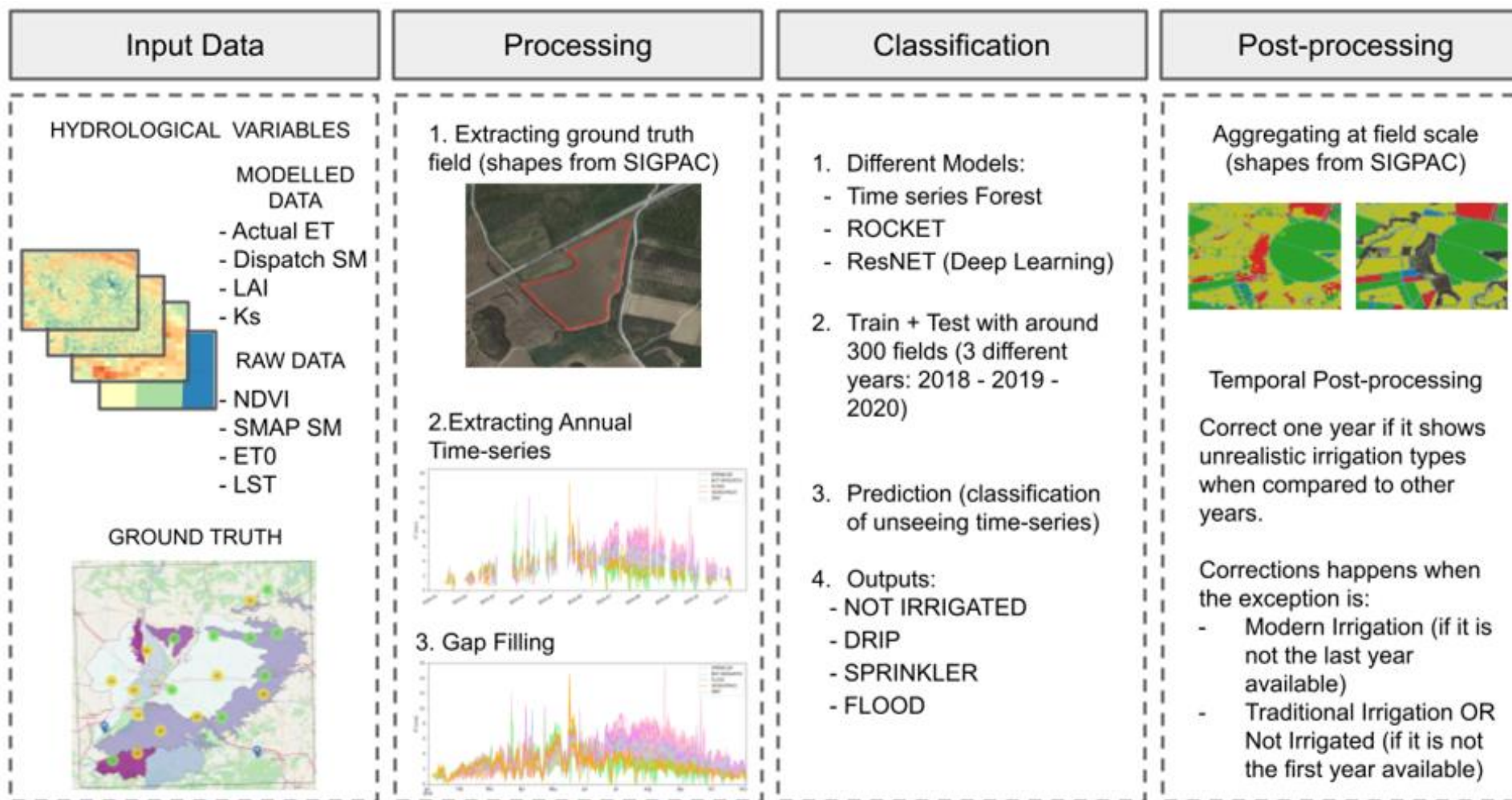
ET_a (mm)
1.232
562



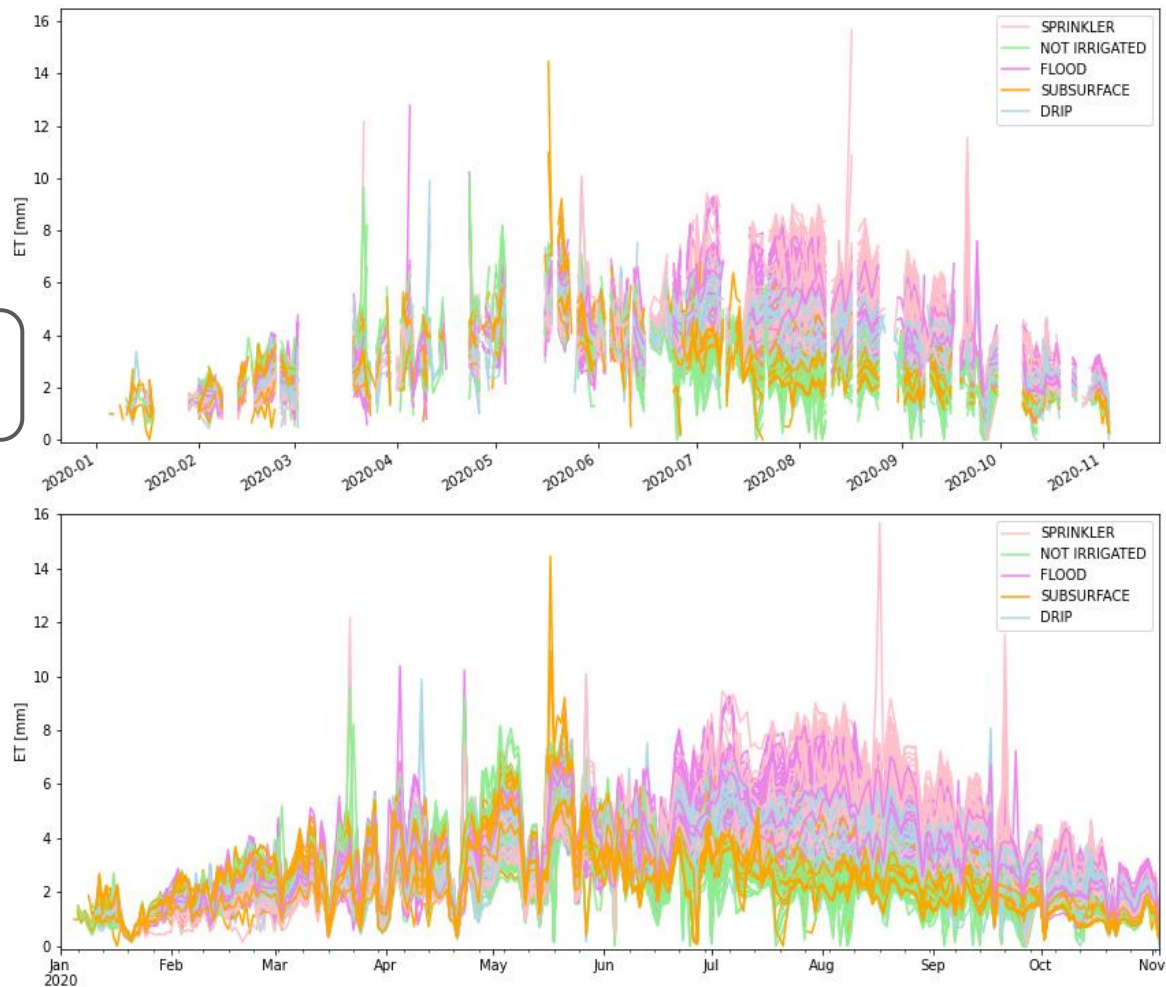
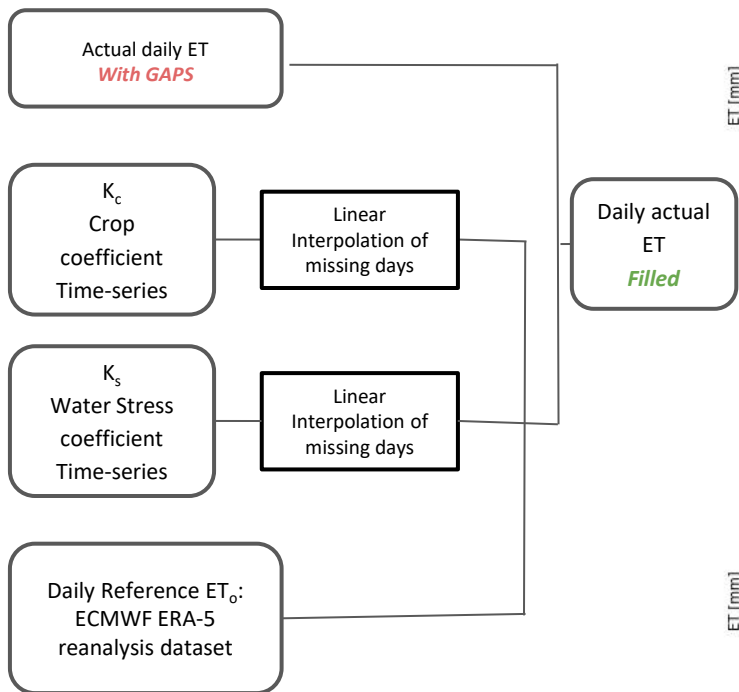
Seasonal pattern of ET by irrigation district



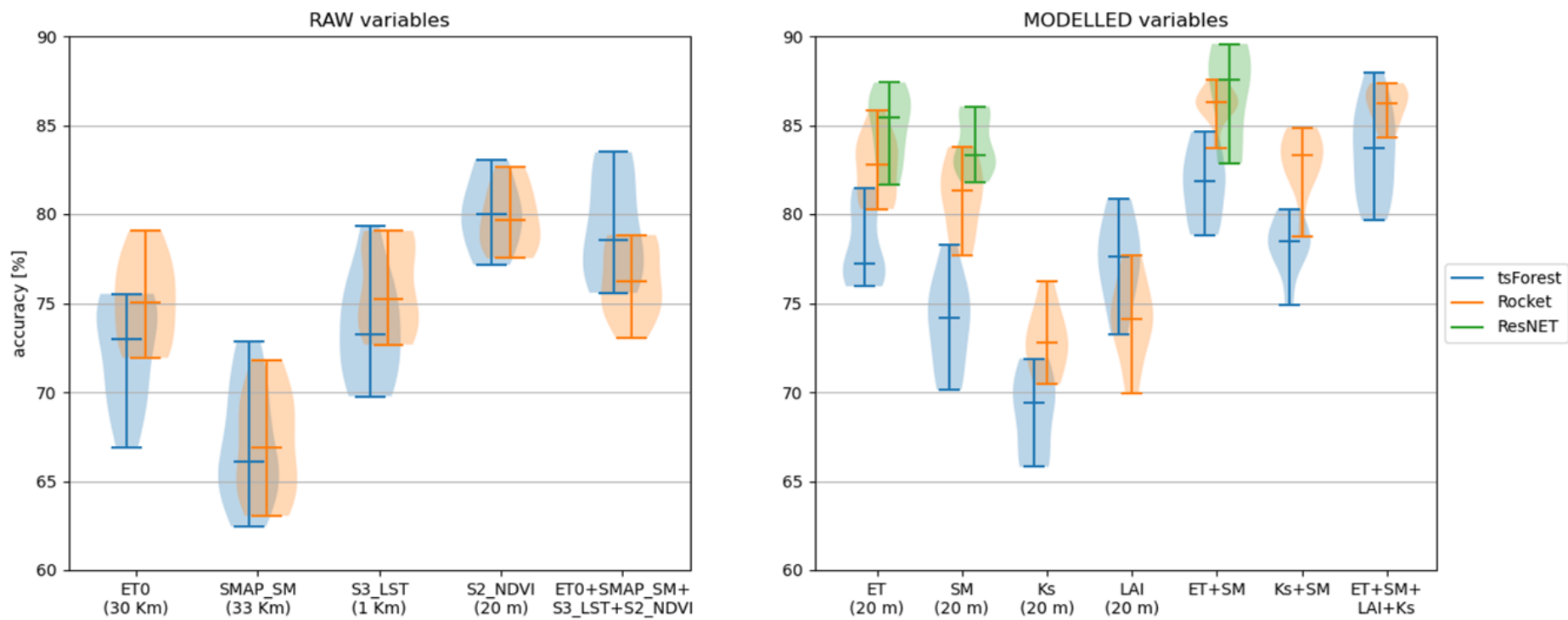
Framework



Input ETact

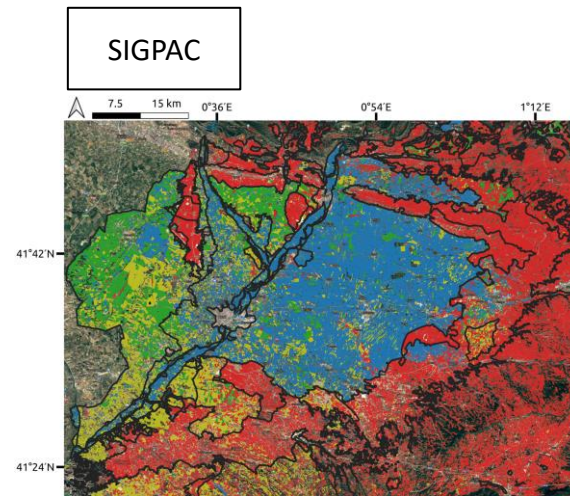
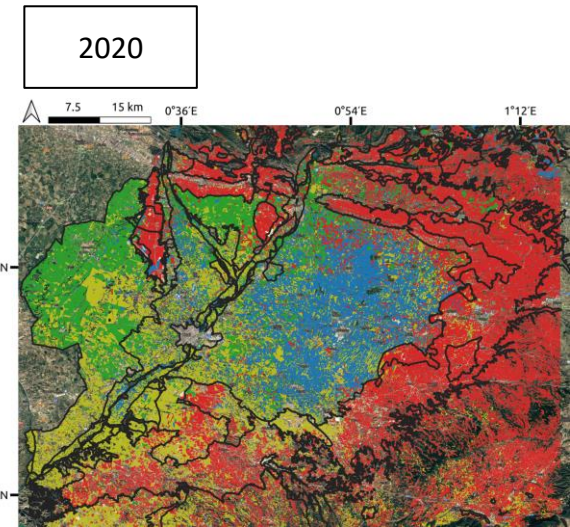
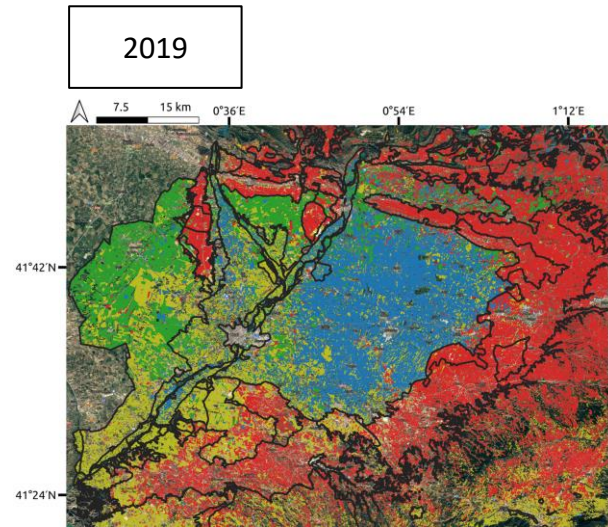
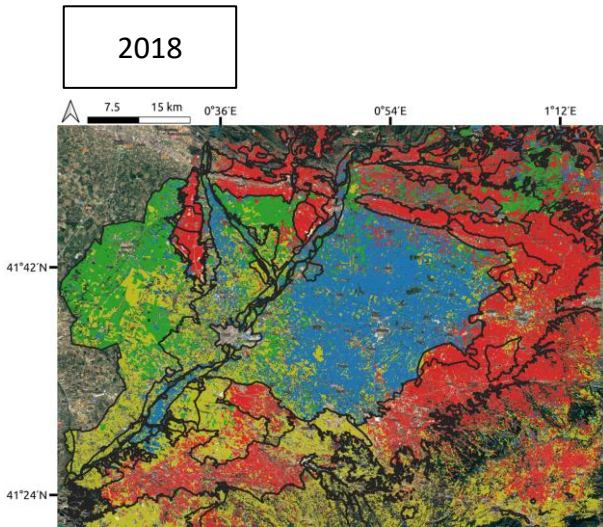


Results III



METRICS (%)	MODELS		
	tsForest	ROCKET	ResNET
Accuracy	81.59 +/- 2.14	82.45 +/- 1.62	86.59 +/- 2.79
Precision	81.73 +/- 1.90	83.28 +/- 1.62	87.39 +/- 2.26
Recall	81.59 +/- 2.14	82.45 +/- 1.62	86.59 +/- 2.79
Kappa	73.77 +/- 2.84	74.64 +/- 2.33	81.30 +/- 3.61

Results IV



ACCWA



Thank you very much!

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