Irrigation management based on models and remote sensing

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Terra Alta

Area of **crops that have traditionally been dry land**: vineyard, olive, almond, …

~20 years ago irrigation was introduced into the area.

- More than 7.000 hectàrees
- Batea, Bot, Caseres, Gandesa, Corbera d'Ebre, la Fatarella, Vilalba dels Arcs i la Pobla de Massaluca.

Benefits of irrigation:
- "It rains" when appropriate.
- Avoid losses in case of drought.
- Economic stabilization.
- Curbing population loss.

Risks of irrigation:
- Generates dependency
- It increases the fragility of the crop in case of not being able to satisfy the need for irrigation.

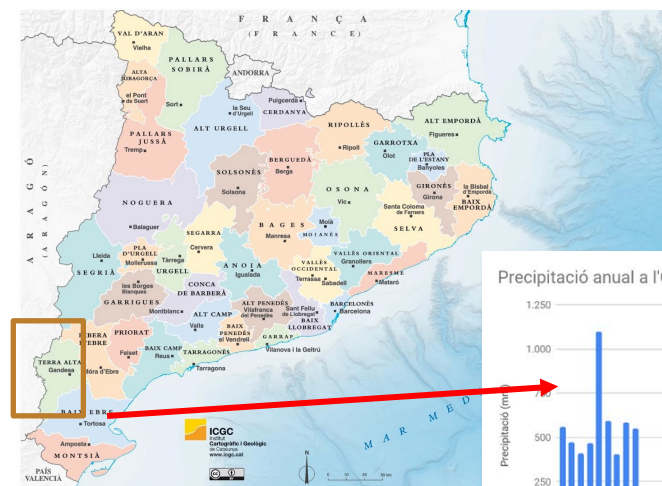**Irrigation is a good measure of adaptation if we have enough water to irrigate.**

We need to maximize the benefits and reduce the risks: support irrigation.

We will irrigate only when strictly necessary, quantitatively monitoring the water available in the soil.
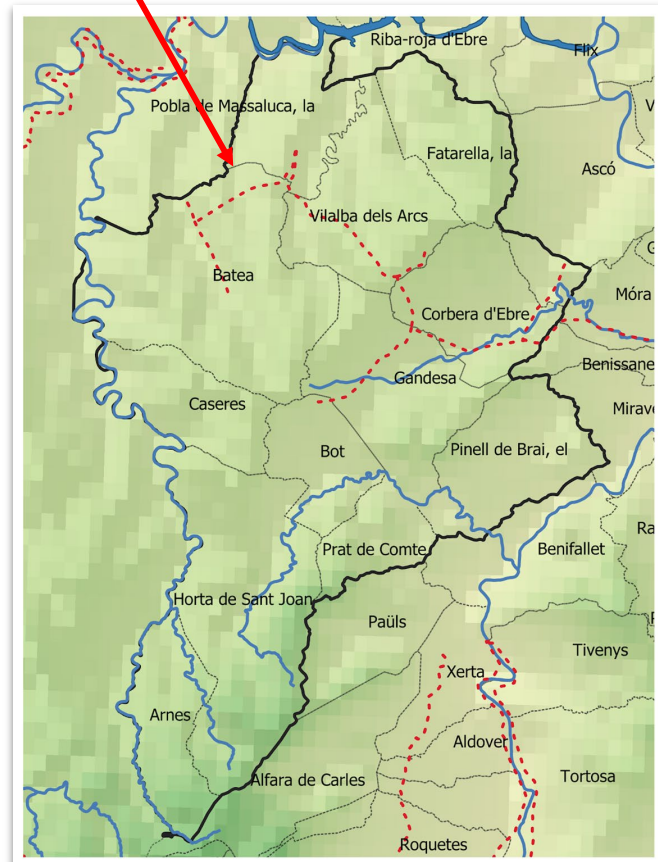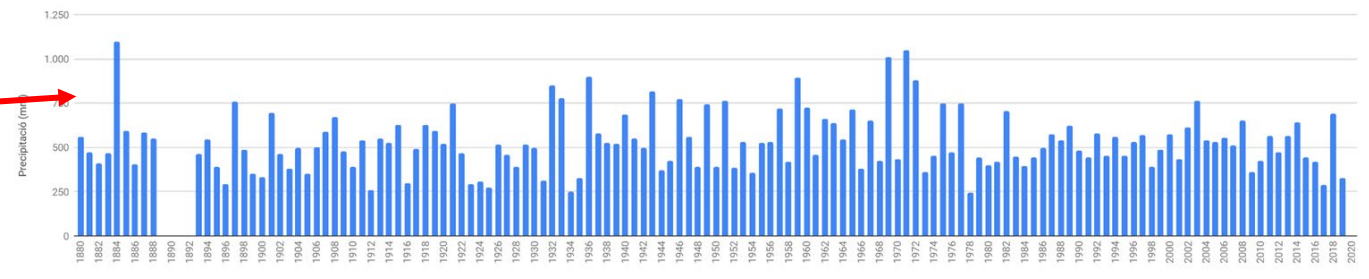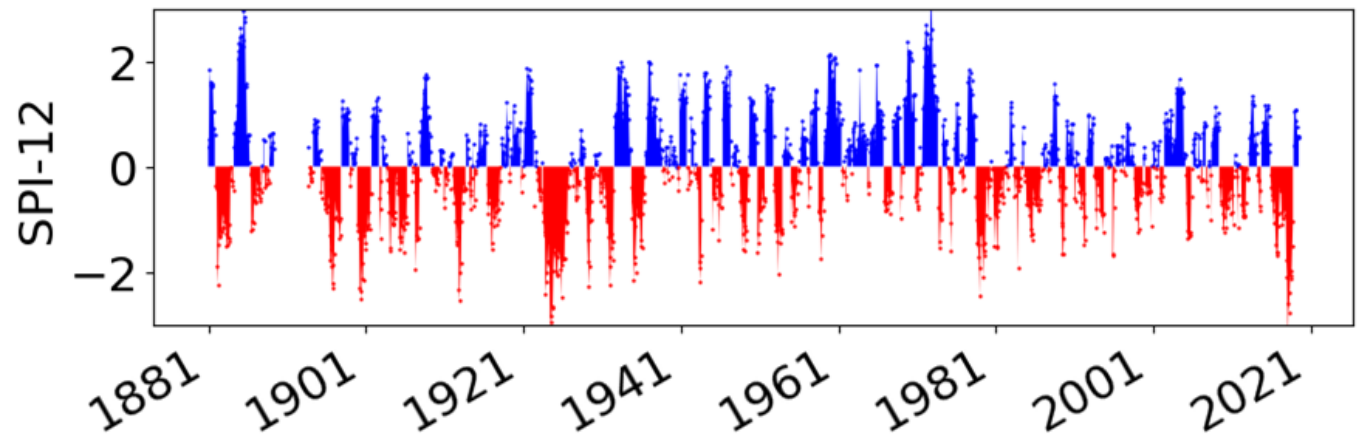
Mediterranean climate

Mean annual precipitation at Ebro Observatory (Roquetes, Baix Ebre)

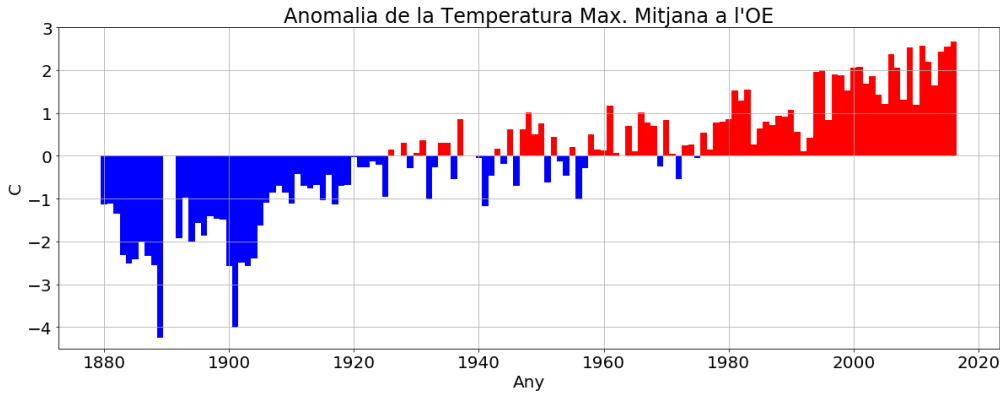**Drought index calculated at the Ebro Observatory.**

- High annual and intra-annual variability, frequent drought periods which may become intense.
- Human memory is not reliable, people often misjudge the current status ("This never happened before!")
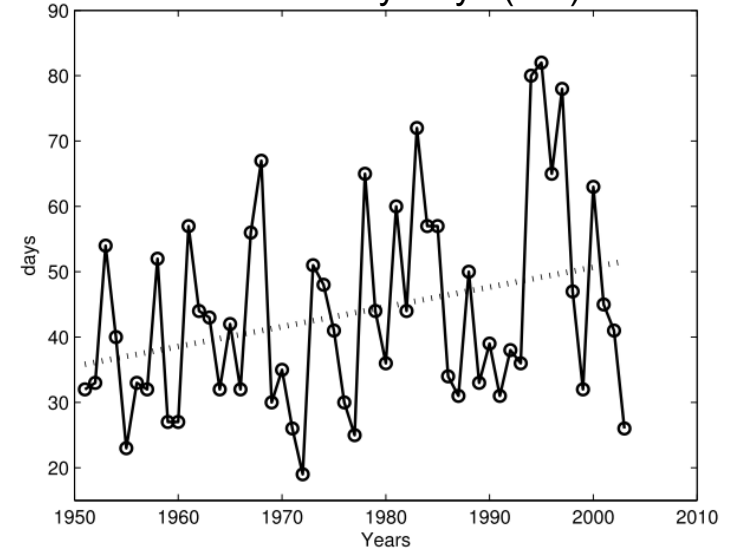
There is a need to provide farmers with accurate quantitative information on the state of their fields. Is this a serious drought? How does it compare with previous ones?
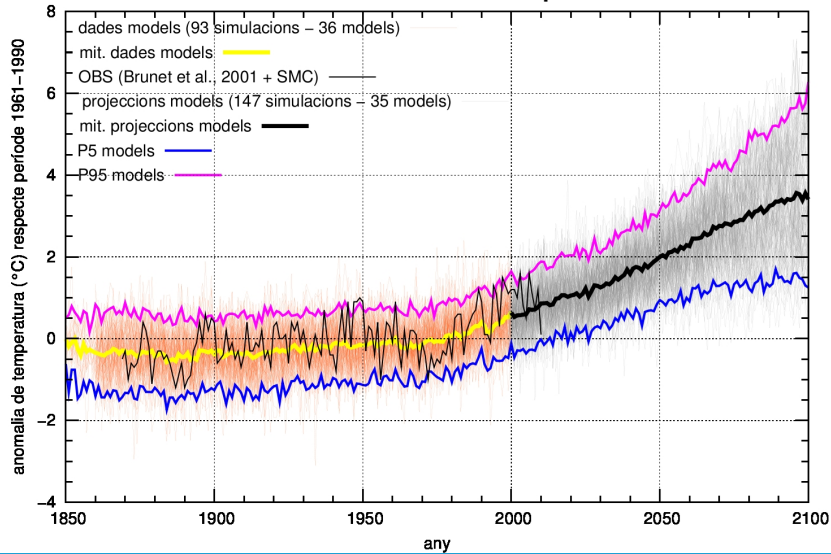
Climate is changing

Observations

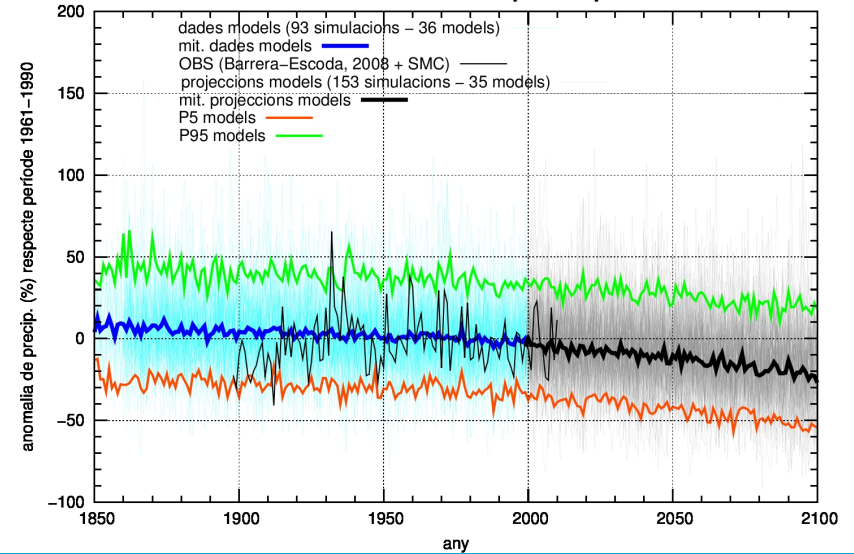Evolution of the observed Maximum Temperature at Roquetes (Baix Ebre).

Anomalia de la Temperatura Max. Mitjana a l'OE

Consecutive Dry Days (OE)

Projections for Catalonia

Future scenarios of temperature

- dades models (93 simulacions – 36 models)
- mit. dades models
- OBS (Brunet et al., 2001 + SMC)
- projeccions models (147 simulacions – 35 models)
- mit. projeccions models
- P5 models
- P95 models

Future scenarios of precipitation

- dades models (93 simulacions – 36 models)
- mit. dades models
- OBS (Barrera–Escoda, 2008 + SMC)
- projeccions models (153 simulacions – 35 models)
- mit. projeccions models
- P5 models
- P95 models

The Terra Alta Drought Observatory

Objectives:

1. Provide agrometeorological information for rainfed crops (vineyards).

Provide a <u>quantified</u> perspective of the actual state of the agrosystem in relation to its own historical variability (Meteorological and agronomical <u>drought</u>).

2. Provide <u>support irrigation recommendations</u> for irrigated vineyards.

The objective is to irrigate the minimum necessary to provide a good equilibrium between benefits and costs of irrigation.

Our irrigation recommendations are soil moisture based. Irrigation is triggered only if the reserve of the soil is too low.

Generic irrigation recommendations:

- Our users are farmers with small properties, who are not very technified and who are often old.

- We cannot provide irrigation recommendation tailored to each farmer, but we can provide something accurate enough.

The drought observatory
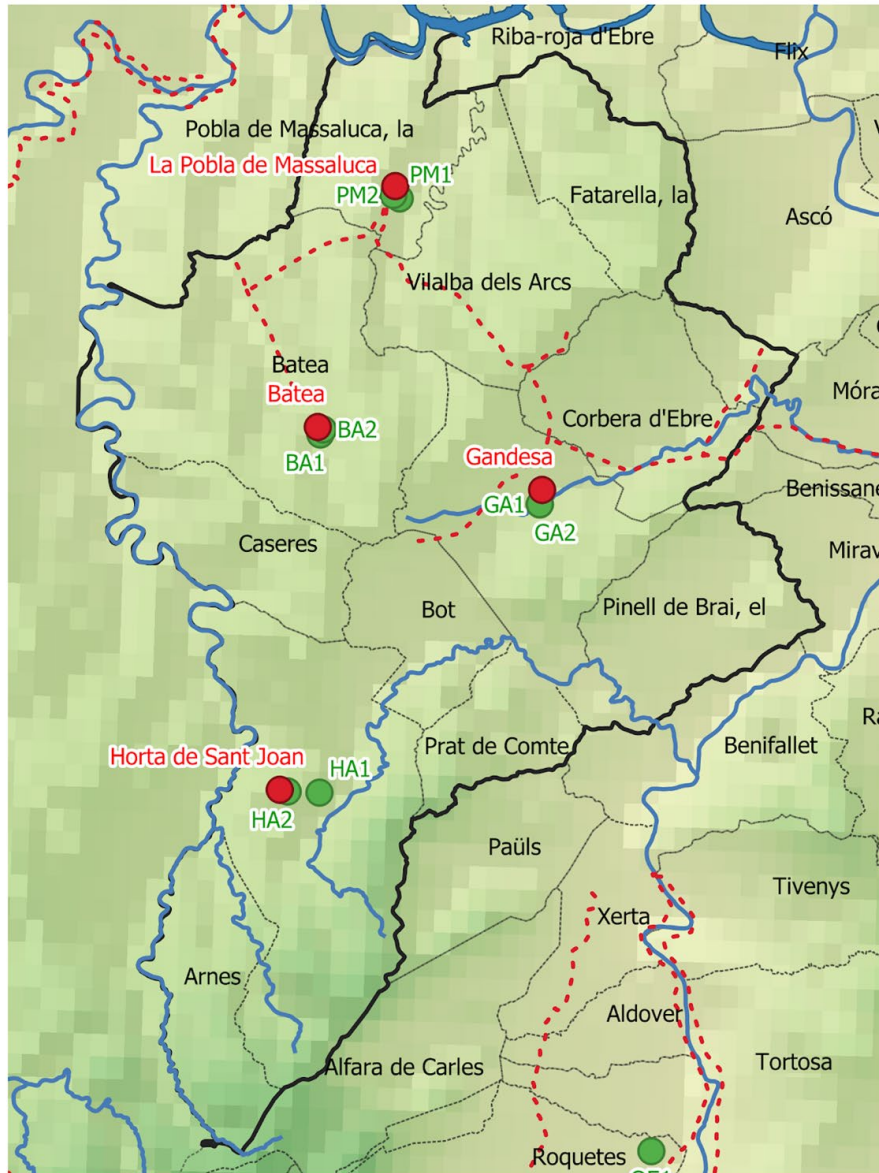
1. **Meteorological observations (with historical time series)**
   a. 4 stations of SMC and AEMET.
   b. Meteorological drought.
   c. Data to feed a model..

2. **Soil moisture observations (since 2019).**
   a. Selected plots
      a. 3 irrigated vineyards.
      b. 5 rainfed vineyards.
      c. Close to the meteorological stations.
      d. Representative of the area.
   b. Quantification of soil moisture status.
   c. Calibration and validation of model..

3. Model
   a. Quantification of other variables.
   b. Reconstruction of historical soil moisture time series.
   c. Agronomical drought.

Model results in rainfed field.

HA2: Horta de Sant Joan (2020)
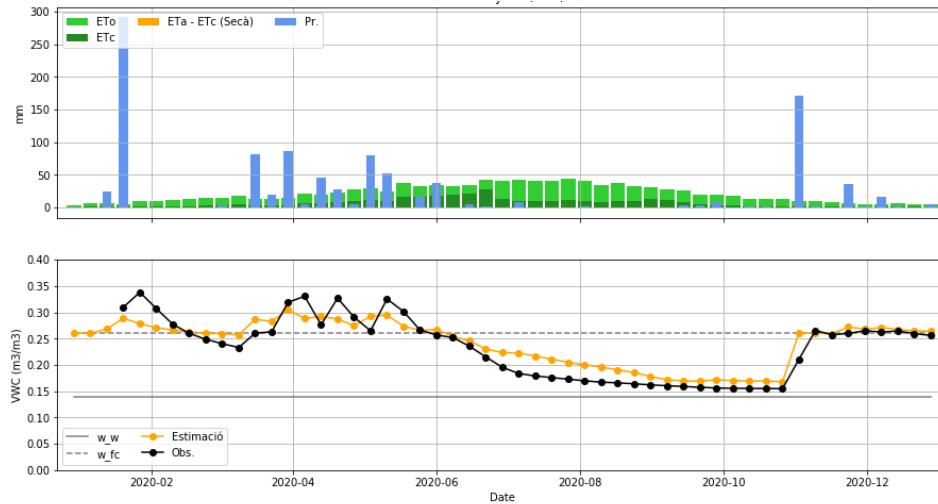
**FAO-56 model (with some additions).**
- Simulated water balance.
- Simulated soil moisture.
- Calculation of drought index, exploiting long meteorological time series.

Now rainfed farmers are able to quantify if the soil moisture is normal or not compared to the past. They can thus compare with previous years and make decisions based on their own experience in those years.
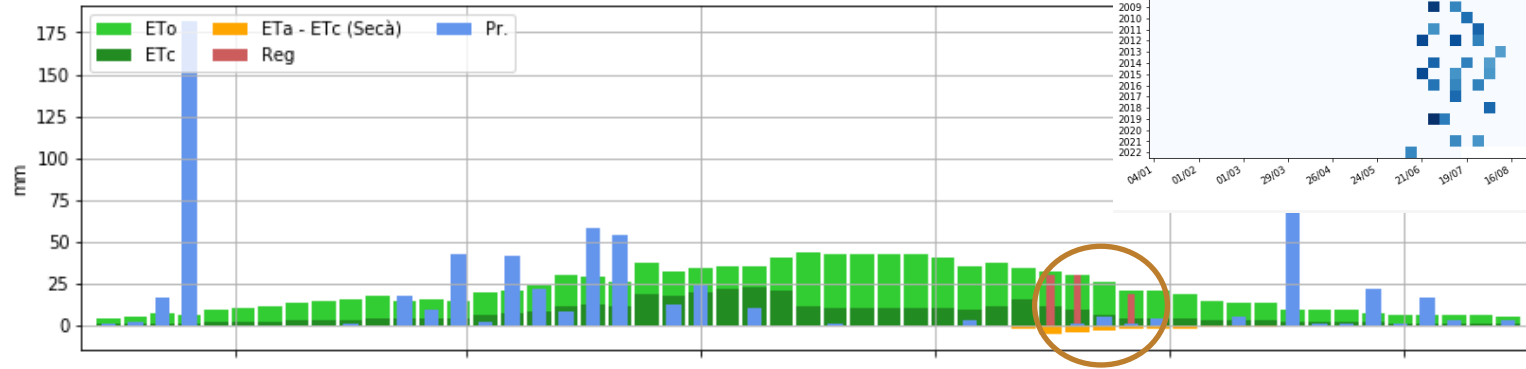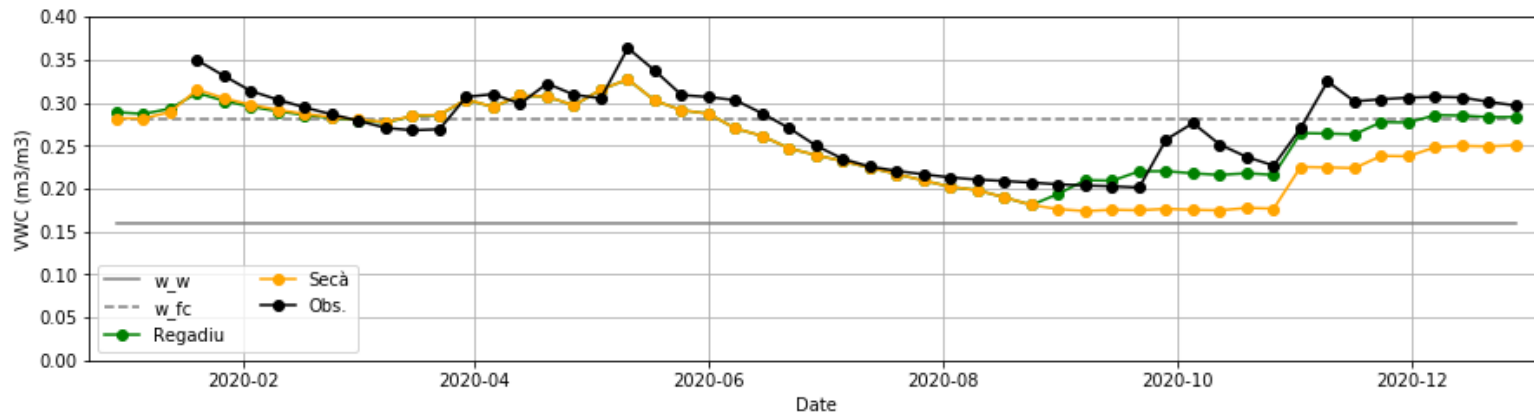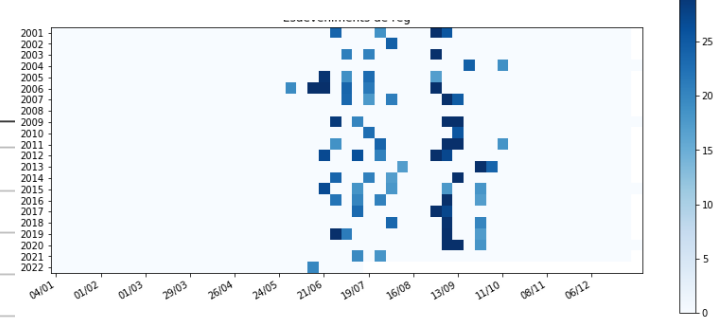
Simulated soil moisture
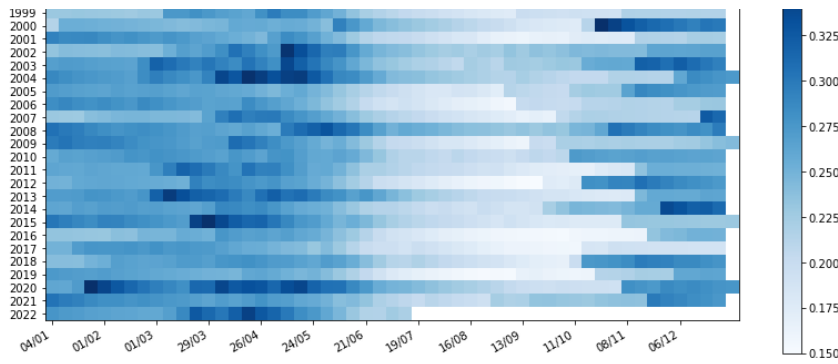
Drought index
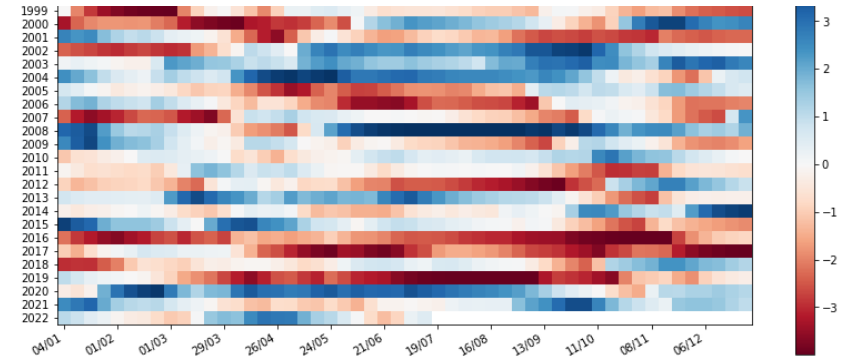
Irrigation recommendations

Batea (irrigated vineyard)

Simulated irrigation events

- This is an irrigated field, the observations reflect the actual soil moisture (with farmer's irrigation).

- The three irrigation events are the ideal according to our approach.

- The farmer irrigates too much as soil moisture goes higher than our ideal.

Weekly drought and irrigation bulletin.

Published every Monday.:

🌐 http://www.obsebre.es/ca/agrometeorologia

📱 https://t.me/os_ta

The bulletin is very simple and easy to read.

- Meteorological drought status.

- Agronomical situation of rainfed vineyards, with agronomical drought indicator.

- Agronomical situation of irrigated fields and irrigation recommendations.

Isn't this meeting about remote sensing?

Soil moisture obsevations

Anomalia de la humitat del sòl (Novembre 2017)
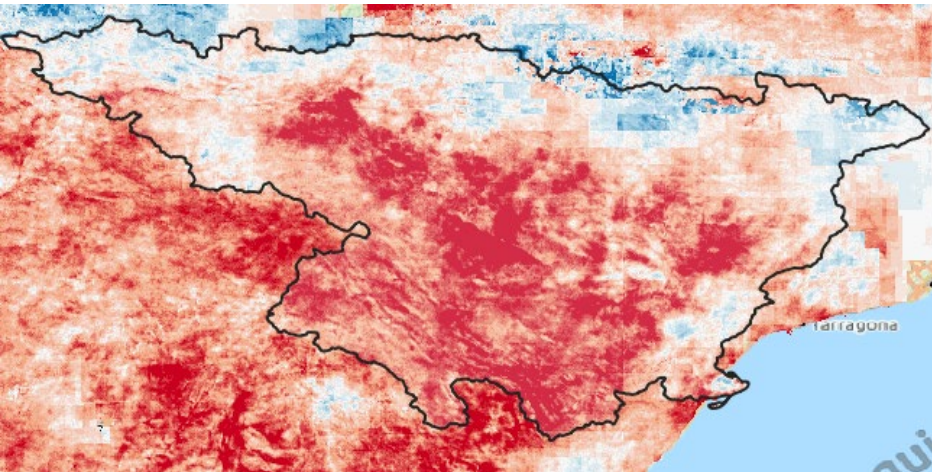
Anomalia de la humitat del sòl (Abril 2018)
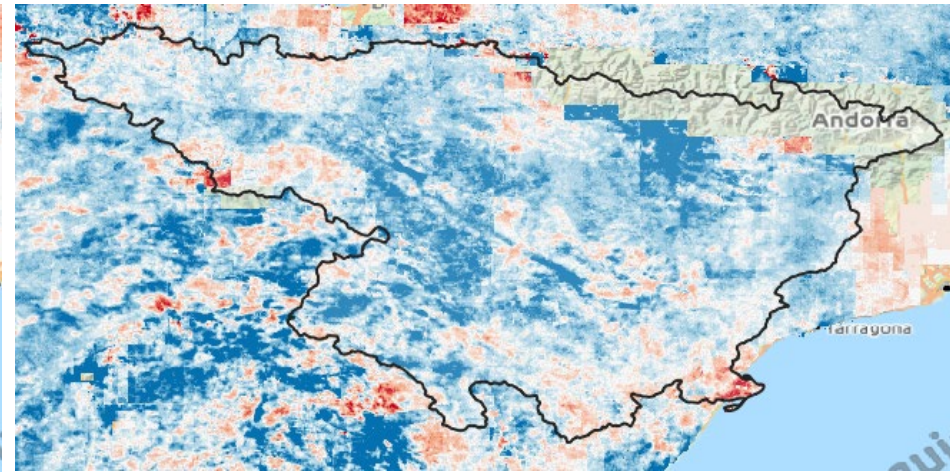
- Remote Sensing Surface Soil Moisture.

    ○ Weekly SMOS/SMAP downscaled to 1 km resolution using MODIS or Sentinel 1 (NDVI i LST) using the DISPATCH algorithm.

    ○ Provided by isardSAT.

- Spatialization of the drought status.

- Weekly drought indices

27/06/2021-03/07/2021

La Pobla de Massaluca

Batea

Gandesa

Horta de Sant Joan

isardSAT

-4 -3 -2 -1 0 1 2 3 4
SMDI

isardSAT®
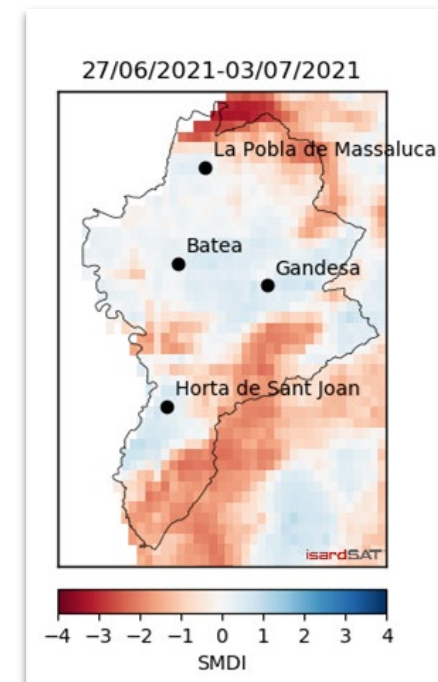
Drought evolution at Terra Alta
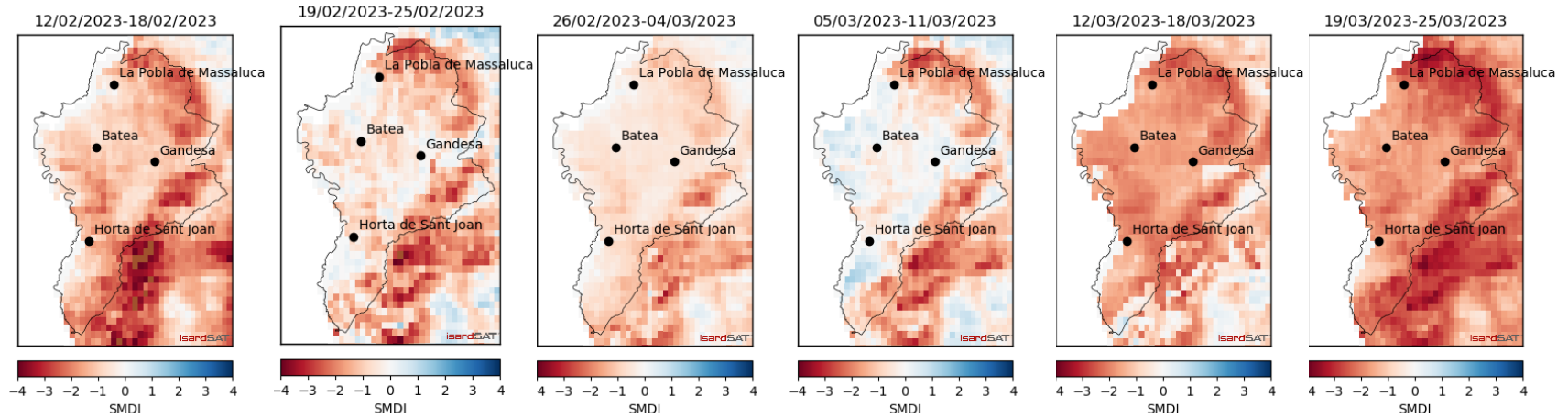
- With these data we can spatialize the drought status information.
- Some limitations:

    - SMOS time series are not as long as we would desire.

    - This is surface soil moisture, which does not correctly inform about what happens at the root zone, which is what we need.

Next step: RS Root Zone Soil Moisture

- Stefan et al. (2021) 10.3390/rs13061112
- Exponential filter.
- Parameters derived from ISBA LSM simulation.
- It can be applied anywhere in Catalonia.
- It manages estimate a soil moisture deeper than the standard product.
- Next step: improve our weekly map with this produc.

Root Zone SM method applied to ISBA LSM data.

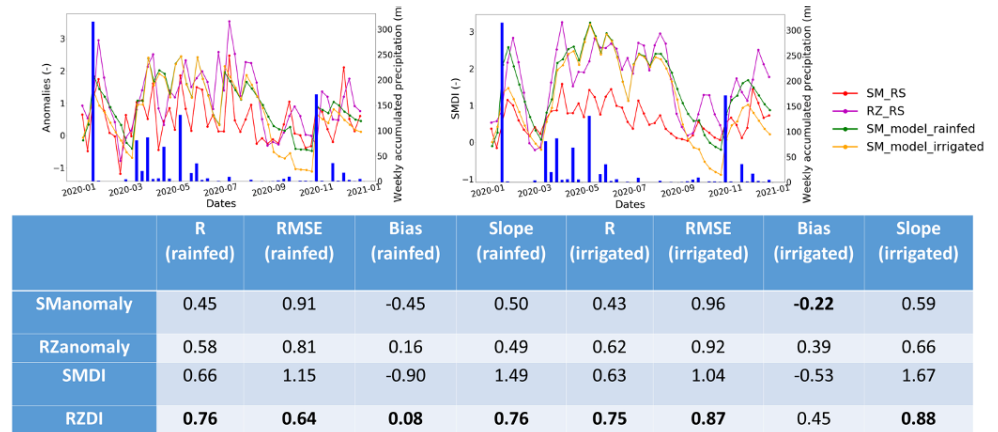|	R (rainfed)	RMSE (rainfed)	Bias (rainfed)	Slope (rainfed)	R (irrigated)	RMSE (irrigated)	Bias (irrigated)	Slope (irrigated)
SManomaly	0.45	0.91	-0.45	0.50	0.43	0.96	**-0.22**	0.59
RZanomaly	0.58	0.81	0.16	0.49	0.62	0.92	0.39	0.66
SMDI	0.66	1.15	-0.90	1.49	0.63	1.04	-0.53	1.67
RZDI	**0.76**	**0.64**	**0.08**	**0.76**	**0.75**	**0.87**	0.45	**0.88**

Root Zone SM method applied to SMAP and compared to in-situ observations.

Next step: RS Root Zoone Soil Mositure

Root Zone Soil Moisture estimated at Terres de l'Ebre (climatology) Stefan methodology.

Using an LSTM to simulate soil moisture
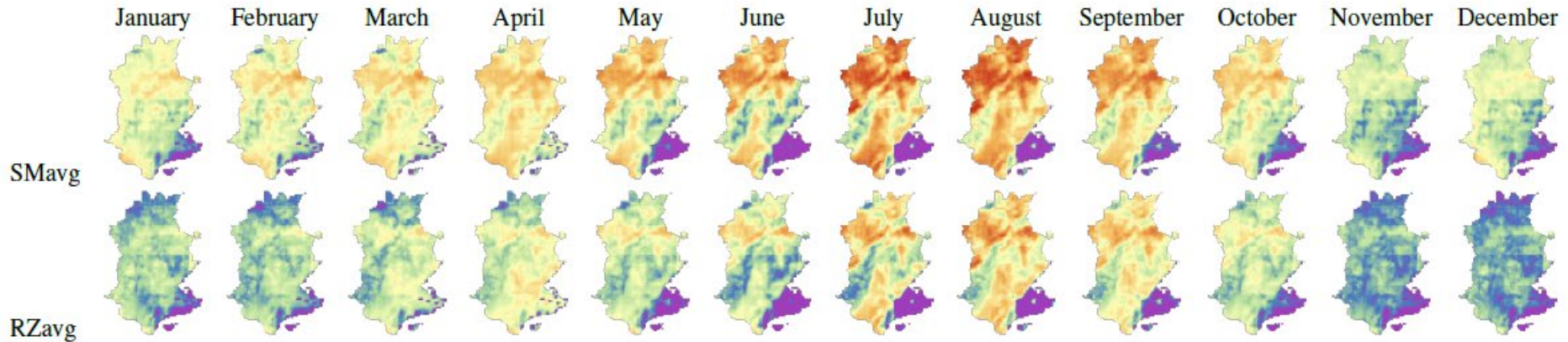
Machine learning

- We are currently exploring the possibility to build a Machine Learning model in order to estimate root zone soil moisture.
- The model would be trained with our observations or could also be trained with ISBA LSM simulations.
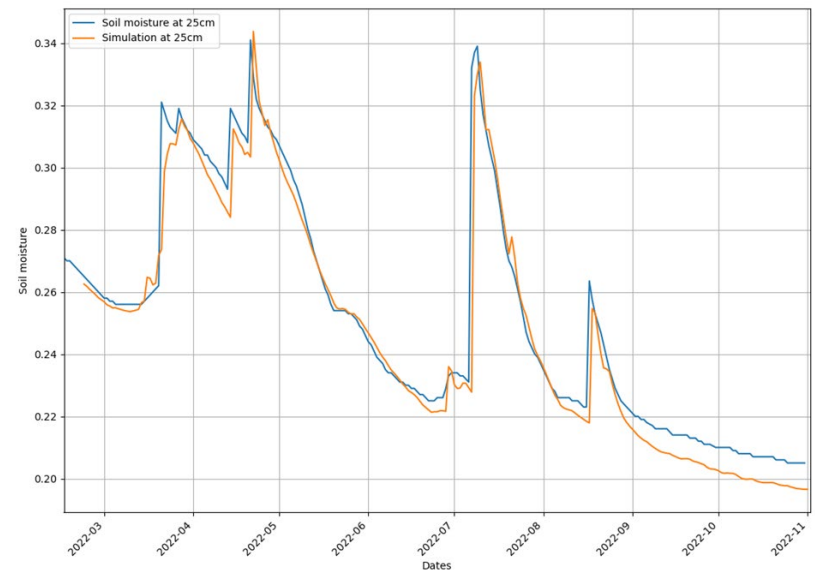
Next step: crop coefficients based on NDVI
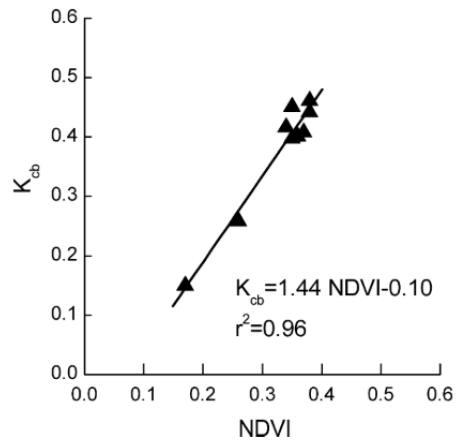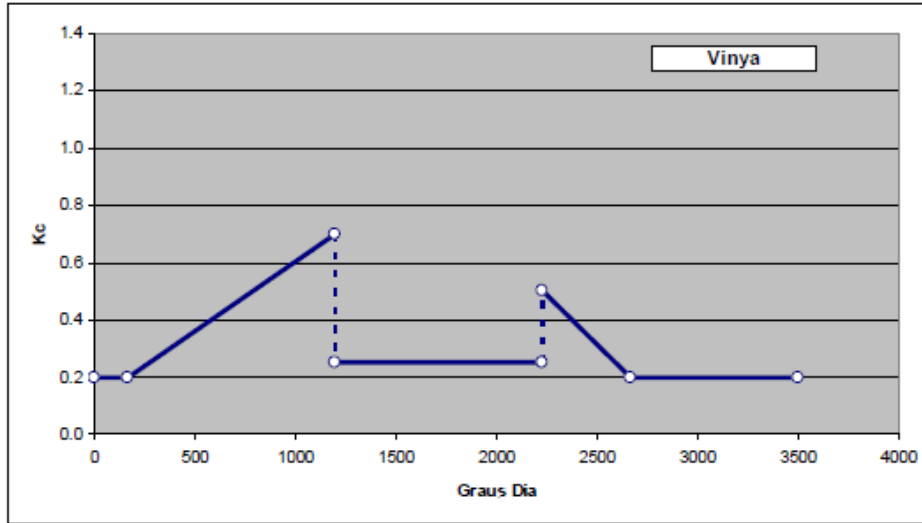
IRTA and ACA crop coeficient (2008)

Campos et al (2010)

The FAO-56 model estimates actual ET by means of the crop coefficient.

ET = Ks * Kc * ETo.

where Ks(w) is a stress coefficient and Kc is the crop coefficient.

Kc depends on the phyisology of the plant.

We are using crop coefficients calculated by IRTA and ACA that depend on the accumulated degree days.

They work well, but they do not necessary follow the in-situ agricultural practices.

We plan to try NDVI derived Kc.

● Evolves with actual phyisiology.

Other possibilities: actual ET from space

Can we bypass the FAO model and calculate the water balance using remote sensing ETa?

$$\Delta S = P - \boldsymbol{ETa} - Runof - Drainage$$

Within the ACCWA project we collaborate with IRTA, who developed an actual ET product.
- Very high spatial and temporal resolution!
- The product is not yet operational and does not cover Terra Alta.
- But we would like to try to perform the water balance using actual ET from this product.

Evaporation - Po Valley - 2017.05.17 10:30 AM
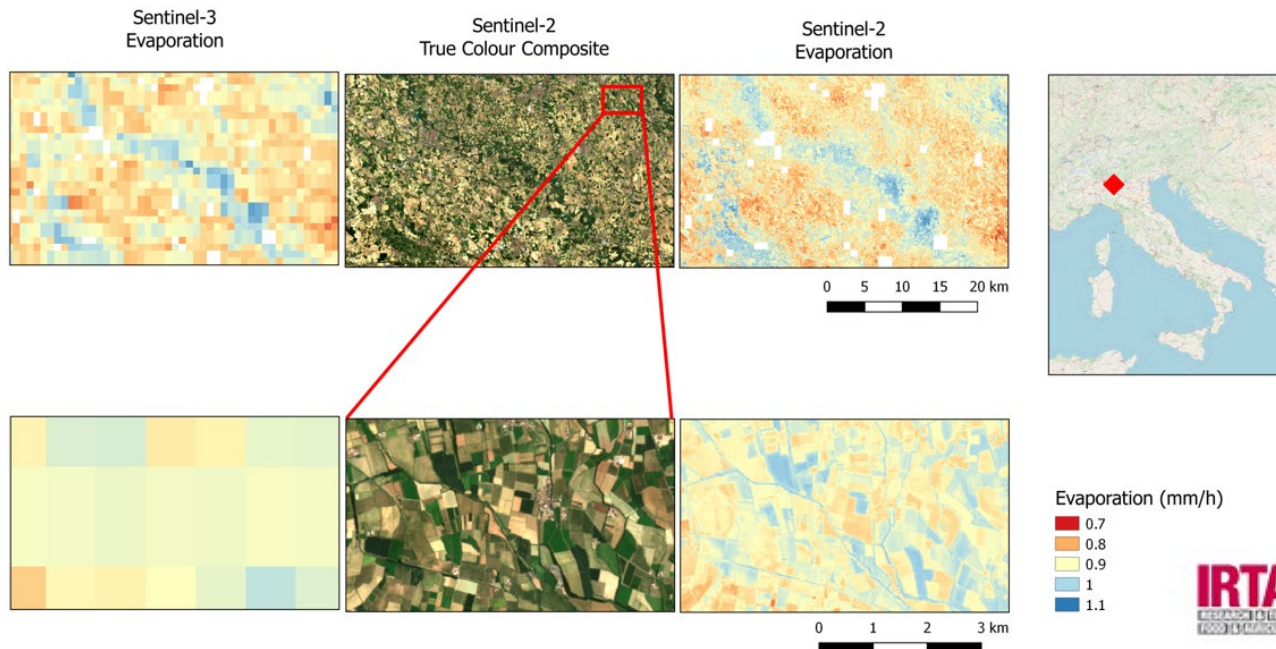
We hope that actual ET products will improve.

In ESA 4DMED we will be able to try other products.

ESA Sen-ET (esa-sen4et.org)

Conclusions and perspectives

The Observatory
- The Terra Alta is an agricultural area of Catalonia in the process of depopulation.
- Limiting the impacts of droughts will help make farming more attractive to the younger generation.
- The Drought Observatory of Terra Alta provides quantified drought information and irrigation recommendations.
- This is an adaptation to climate change.

The Methodology
- A FAO-56 based methodology supported by in-situ soil moisture observations allows us to provide accurate information for the farmers, but it is spatially limited.

The role of remote sensing
- Remote sensing is allowing us to spatialize the drought indicator.

Next steps
- Exploit the RZSM product that we helped to develop (Stefan et al., 2021).
- Check if NDVI based Kc are better than the ones we are using.
- Explore the possibility to use state of the art ETa remote sensing products.

The final objective is to be able to calculate drought indices and irrigation recommendations anywhere based on remote sensing data.

This work was possible thanks to the collaboration of :