Leveraging Earth Observation for Accurate Early Forecasting of Irrigation Needs

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Context

- According to FAO, irrigation is a critical component of global agriculture, supporting 40% of food production on 22% of cultivated land.
- Globally, agriculture uses about 70% of all water withdrawals for human use.
- As climate change intensifies, the demand for irrigation water is expected to rise, particularly in vulnerable regions like the Mediterranean basin.

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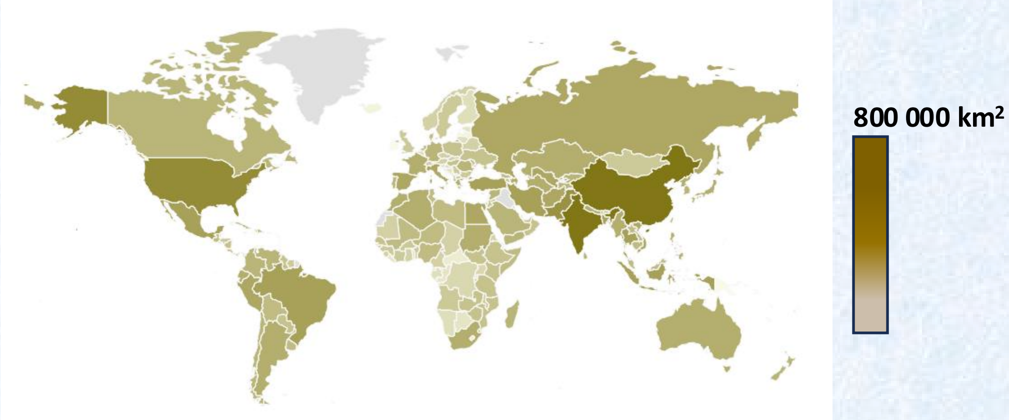
To maintain a sustainable balance between water supply and water availability, tools that can provide early forecasts of irrigation needs at basin/regional scale are essential.



https://worldostats.com/agriculture-food/irrigated-land-by-country/

EarTH Observation for the Early forecasT of Irrigation needS

Objective: To implement a Spatial Decision Support System for forecasting irrigation demand at the basin scale

Aim: To enhance irrigation resource planning and improve water use efficiency in agriculture

THETIS integrates:

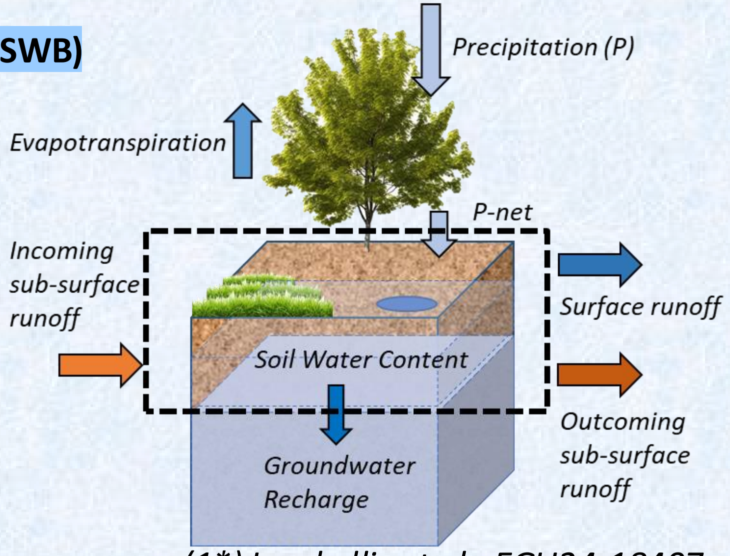
- Innovative thematic maps derived from **EO** (**SAR** and **Optical** data)
- **Hydrological** (SWB) and **crop** (CM) modelling
- AI models for the spatialization of weather and climate data
- WEBGIS interface

Expected result: Irrigation needs forecasts:

- I: at an early stage (before crop seeding)
- II: at the beginning of the crop season
- III: during the crop season

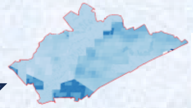
Soil water balance model (SWB)

- Application at the **basin** scale
- Integration between national-scale and monthly intervals models (**BIGBANG**) and **daily/sub-daily** scales models (**DREAM** and **SMAR** models)



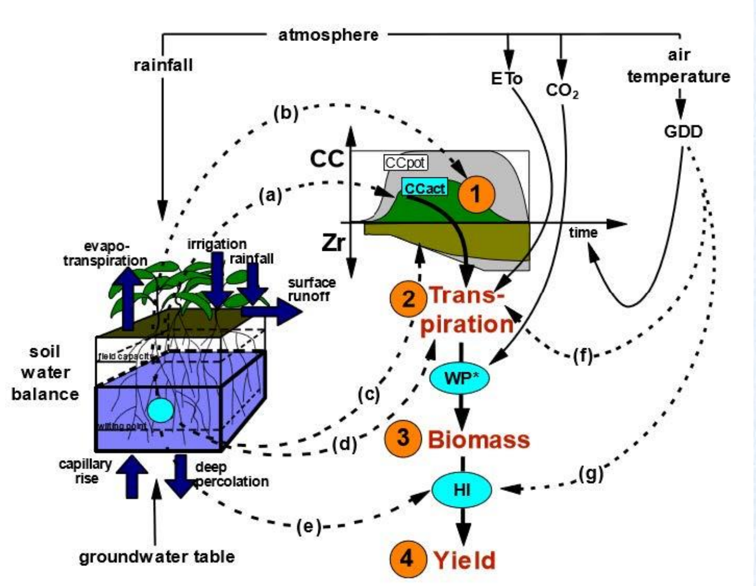
(1) Iacobellis et al., EGU24-18407*

Initialize



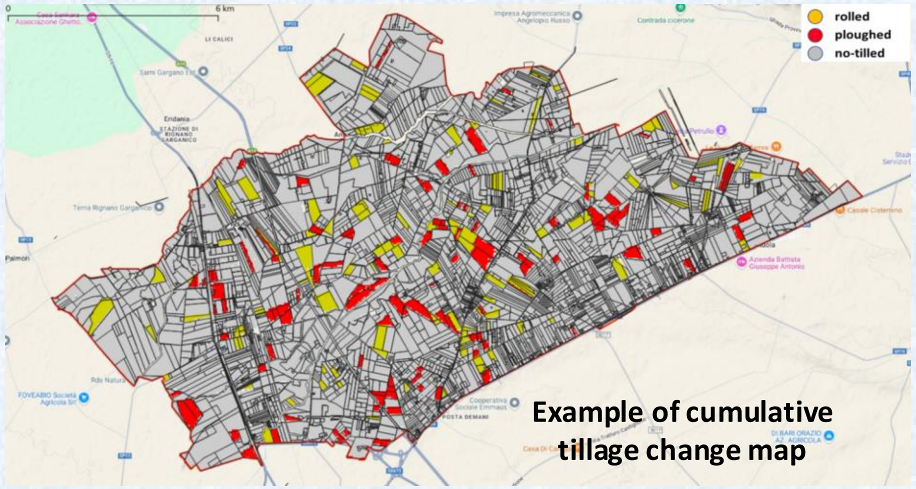
Crop model (CM)

- Based on the **AquaCrop** model
- Simulation of three interconnected levels: **Leaf development**, **Crop growth** and **Water productivity**

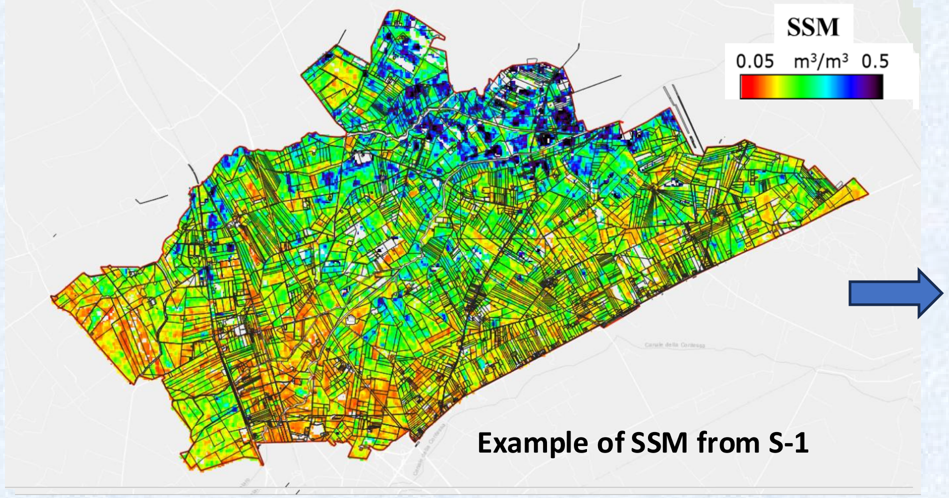


Maps of products derived from EO data

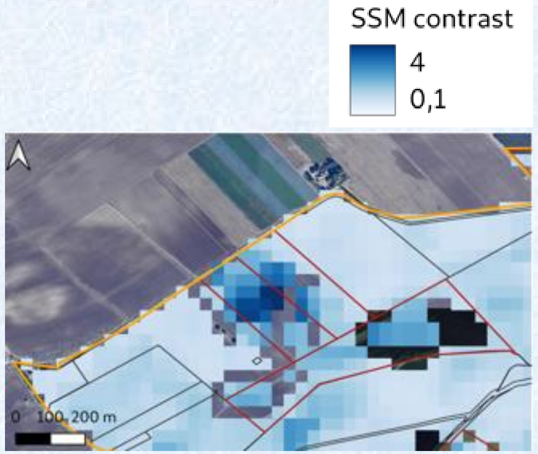
- **Crop rotations** from optical data
- **Cumulative tillage change** (ploughed or rolled) from SAR and optical data (e.g., Sentinel-1 and Sentinel-2) and LPIS (@~0.1 km)
- **Soil surface moisture (SSM)** from SAR Sentinel-1 / SAOCOM data (@~0.1 km)
- **Irrigated area** from high-resolution SSM SAR (@~0.1 km)
- **NDVI** from multi- or hyper-spectral optical data (Sentinel-2, PRISMA)
- **LAI** from optical data: Copernicus Land Monitoring Service (CLMS) product



Example of cumulative tillage change map



Example of SSM from S-1



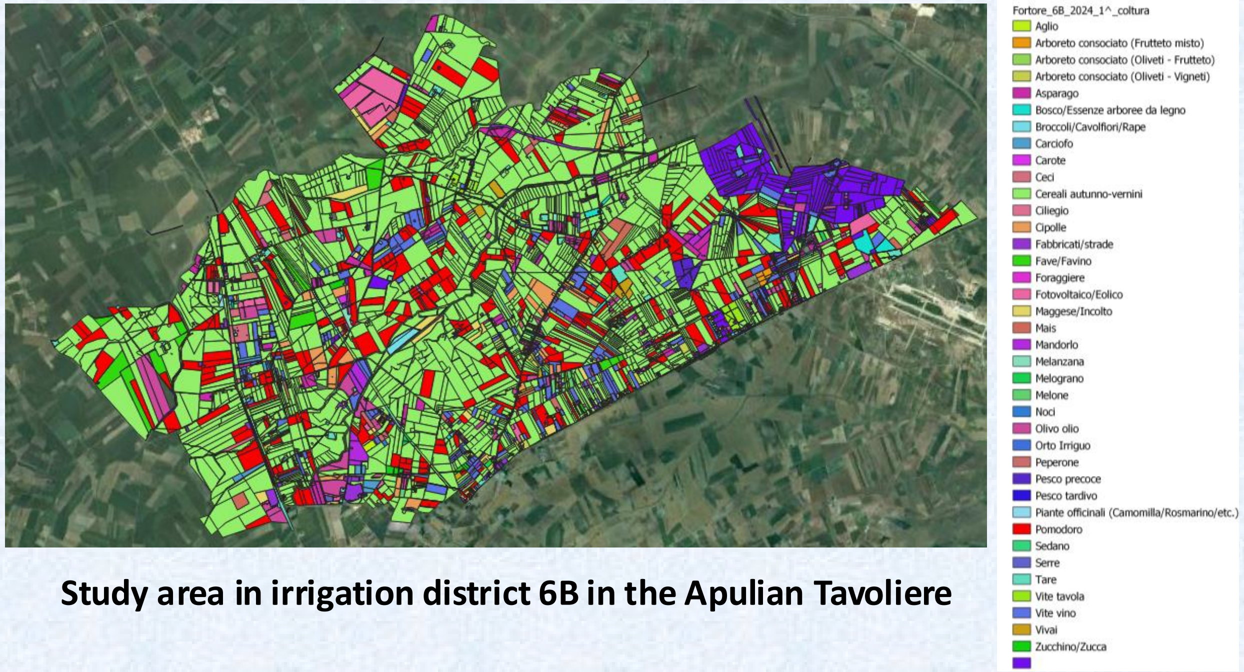
Example of SSM contrast from S-1

Study area: Apulian Tavoliere

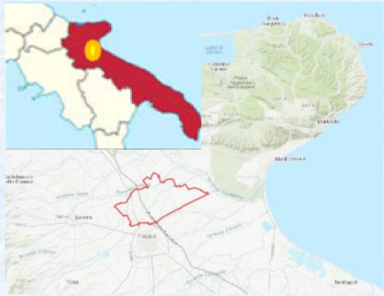
- Irrigation district managed by CBC (141 km^2)

CONSORZIO PER LA BONIFICA DELLA CAPITANATA

- Data (2021-2024)
  - 16 agrometeorological stations
  - Irrigation consumption
  - Crop surveys

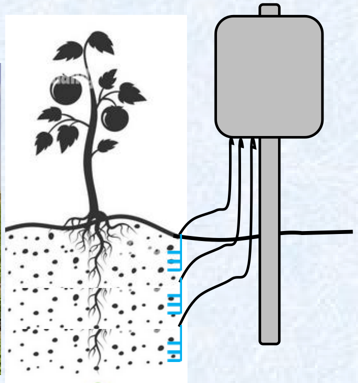


Study area in irrigation district 6B in the Apulian Tavoliere

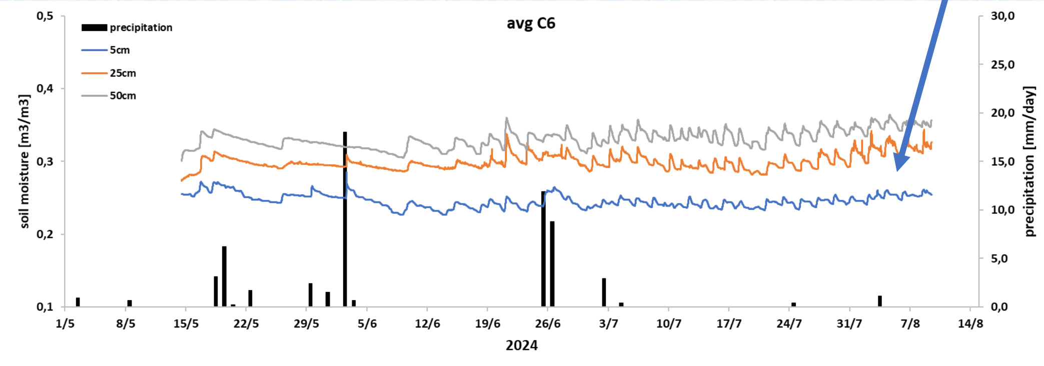


Drip irrigation. Irrigation regime becomes daily!

11 soil moisture measurement stations installed in 2024 in 4 fields (C6&7, C8B, C9, C10)



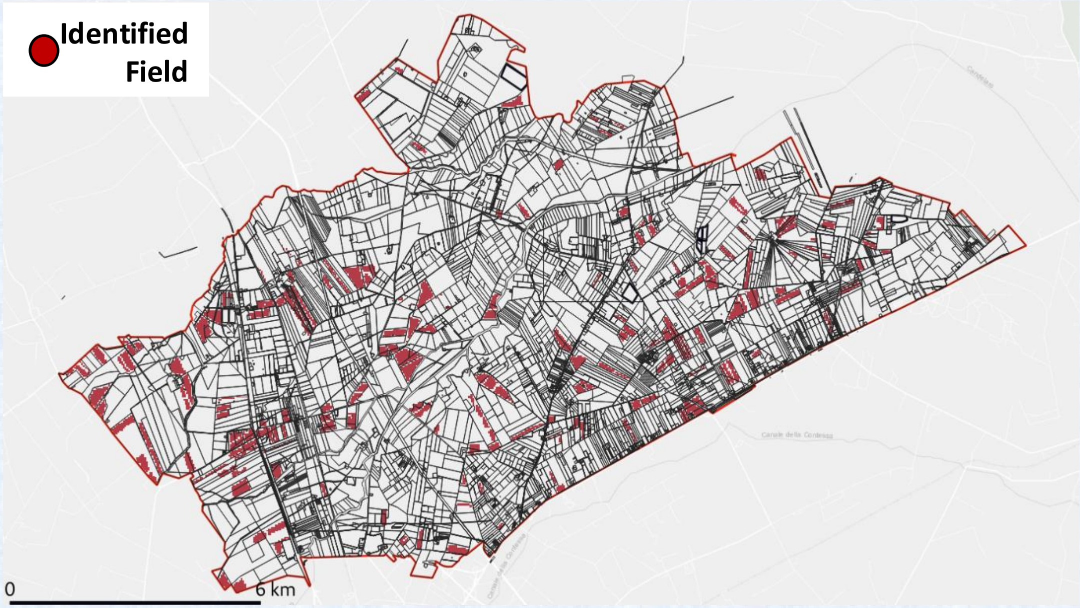
Focus: Tomato crop



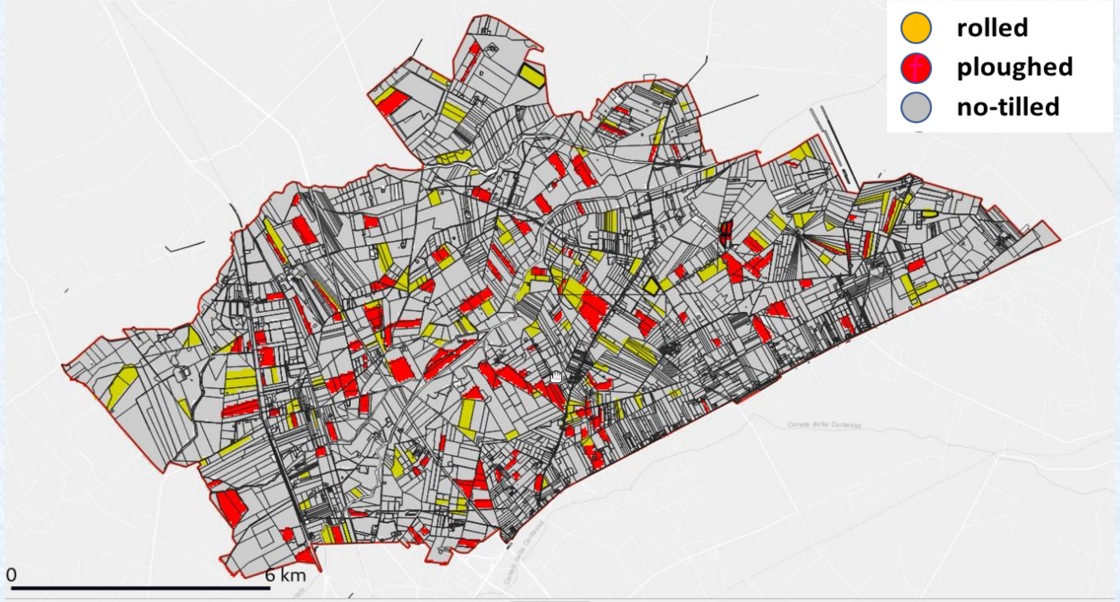
Example of (calibrated) soil moisture measurements, field C6

Rotation and tillage change maps

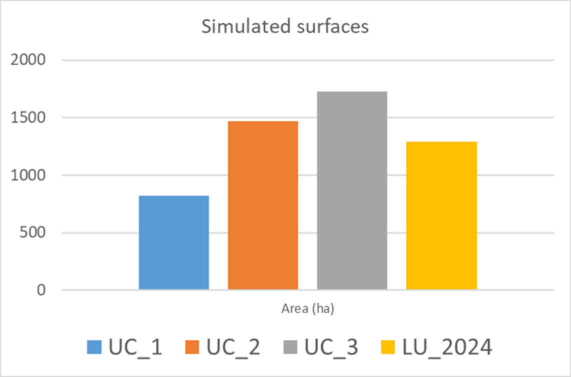
They allow the **early classification** of cultivated areas with irrigated crops, **before** vegetative development, through the identification of **tilled** and subsequently **irrigated** areas.



Example of crop rotation (2*) map available e.g., in March 2024, before the cultivation of the summer crops



Example of cumulative tillage change map (3*) available on March-May 2024, i.e., before the seeding of (irrigated) summer crops

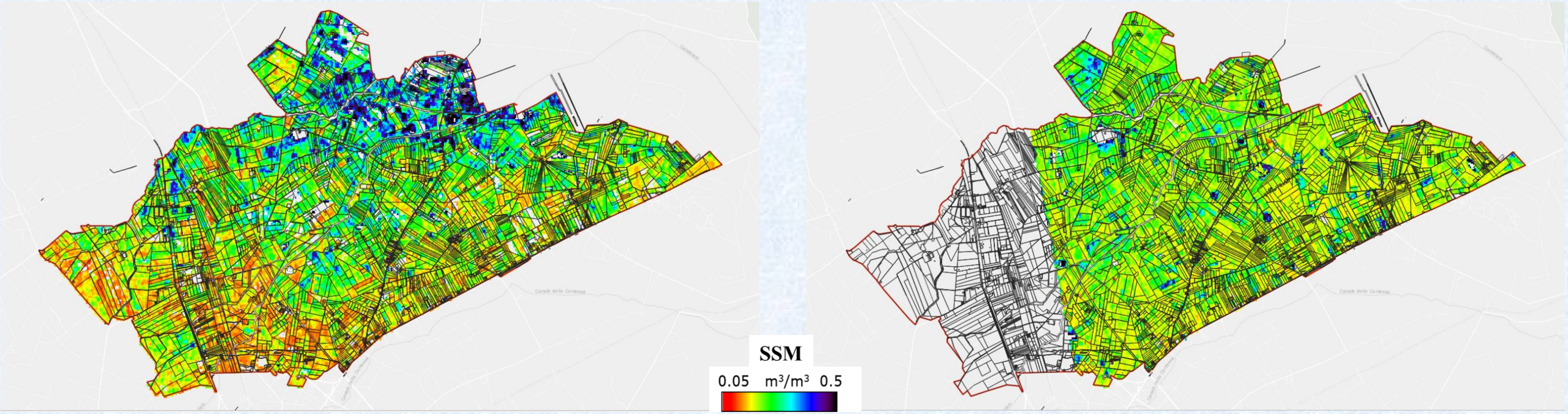


- Use Case 1: - 36%
- Use Case 2: + 14%
- Use Case 3: + 34% (compared to tomato area)

(2) Rinaldi et al., poster EGU25-11983*
(3) Satalino et al, IGARSS 2024*

Retrieval of Surface Soil Moisture (SSM)

- SSM estimated with Short Term Change Detection algorithm @~100 m spatial resolution applied to C- and L-band SAR data.
- SSM retrieval accuracy from C-band @~1 km estimated on historical data acquired by hydrological network stations: RMSE=~0.06 m^3/m^3 (4*)
- High-resolution SSM from C-band data corrected by 'masking' disturbances resulting from rapid changes in the soil or vegetation (e.g., due to agricultural tillage or to the rapid vegetation growth)
- C-band vs L-band: C-band is less sensitive to SSM compared to L-band under crops with branched structures, e.g., tomato or maize



SSM from C-band Sentinel-1 on 20240531

SSM from L-band SAOCOM on 20240525

(4) Balenzano et al., RSE 263 (2021) 112554*

Identification of irrigated areas from SSM maps

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SAOCOM on 10/06/2024

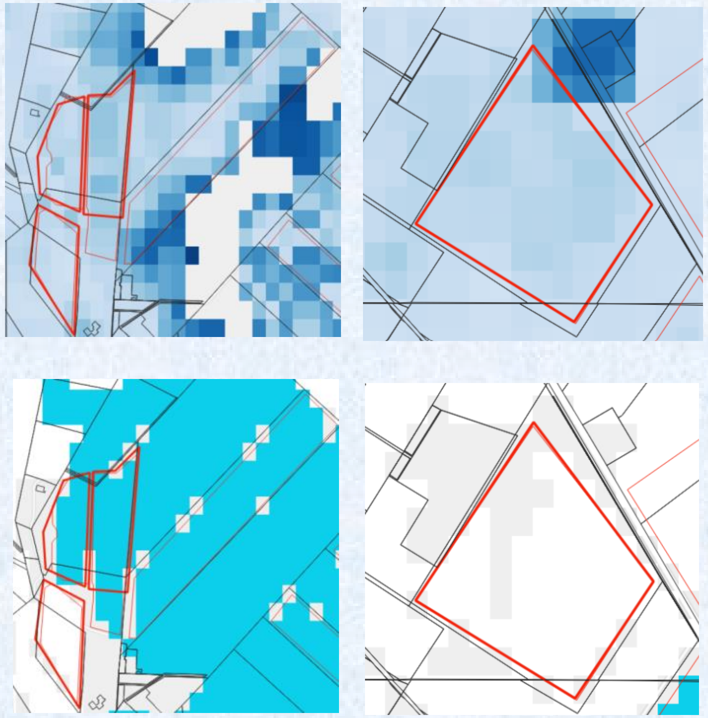
Sentinel-1 on 12/06/2024

2 days difference

Irrigation between the SAOCOM and S-1 acquisition

SSM contrast:

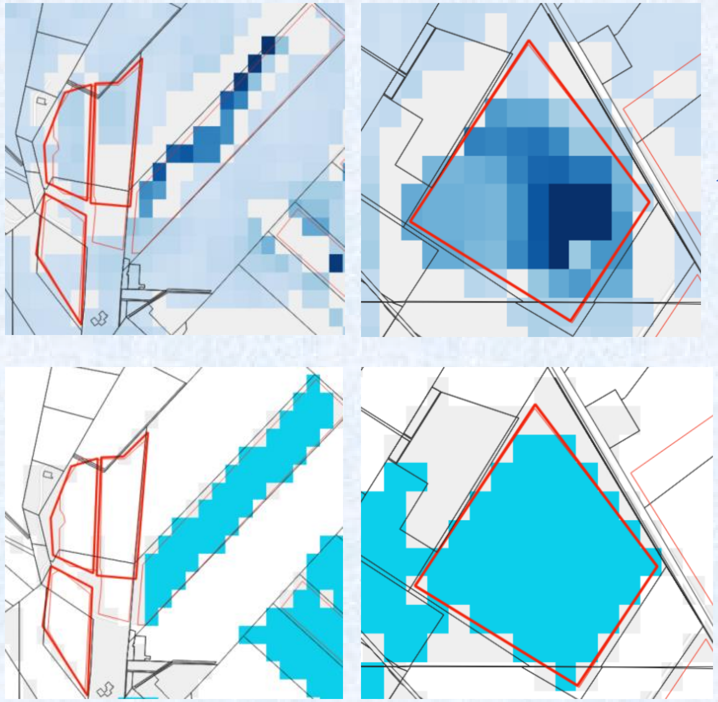
$$C = \frac{SSM_{1x1}}{< SSM_{50Q} >_{NxN}}$$



Red polygons: monitored tomato fields

SSM contrast
4
0,1

Classified Irrigated field



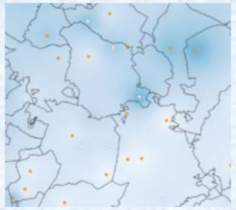
Thresholding SSM contrast and aggregation

Irrigation identification

Irrigation identification: L-band is complementary to C-band

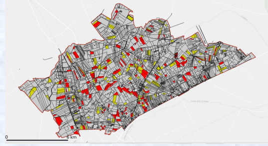
THETIS Output Map of irrigation needs

Main CM outputs: seasonal irrigation volumes, taking into account a climate models (ECMWF Copernicus), fixed and optimal irrigation strategy, for each Use Case (1, 2 and 3)




Spatialized Copernicus weather data

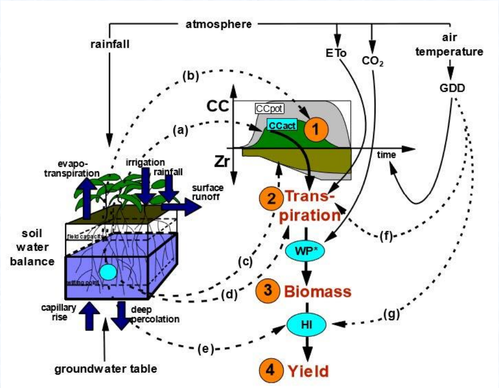
Soil data



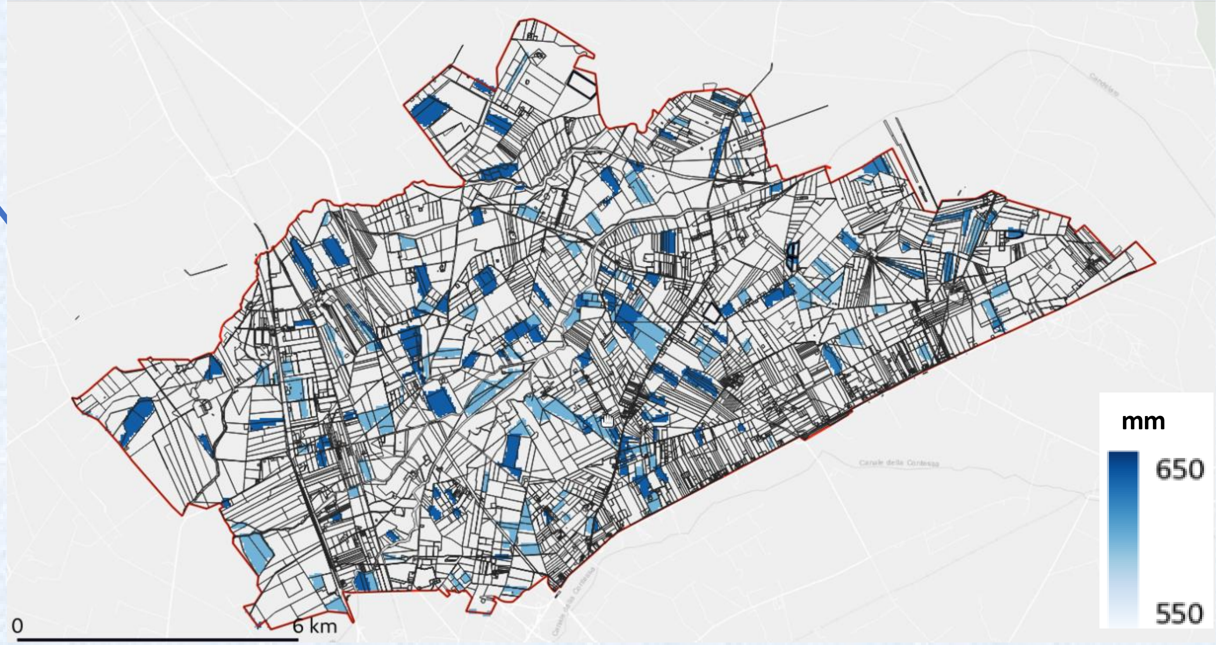
Field localization from EO data and provisional transplanting dates

Relative saturation from SWB

Crop Model



Example of output for Use case II
(at the begin of the season)

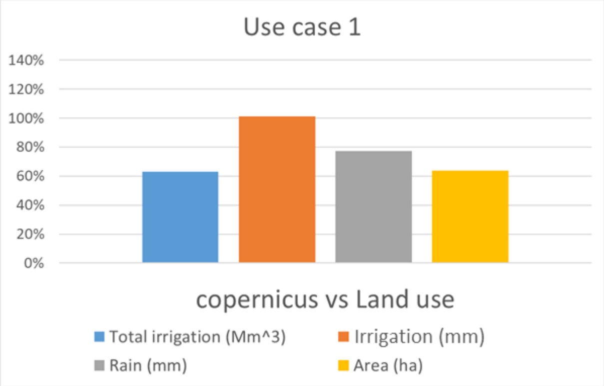


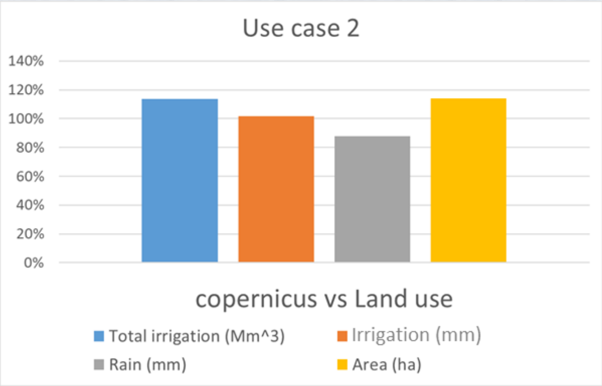
Irrigation needs forecast (Fixed irrigation strategy)

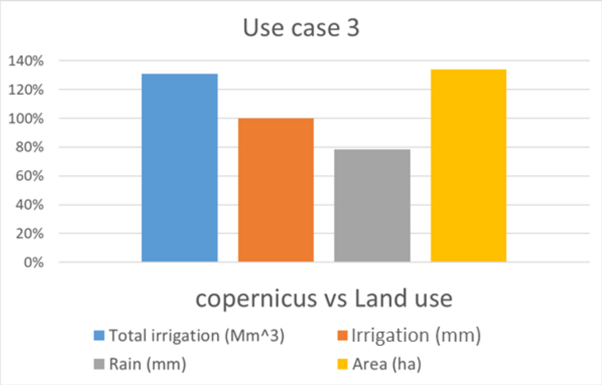
Irrigation needs forecast at district and field scale

Comparison at district scale of model simulations results using forecast and observed data, i.e.,: meteo, crop surfaces - transplanting dates

Fixed irrigation regime



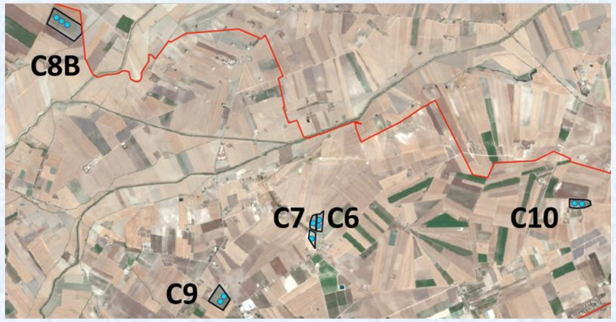




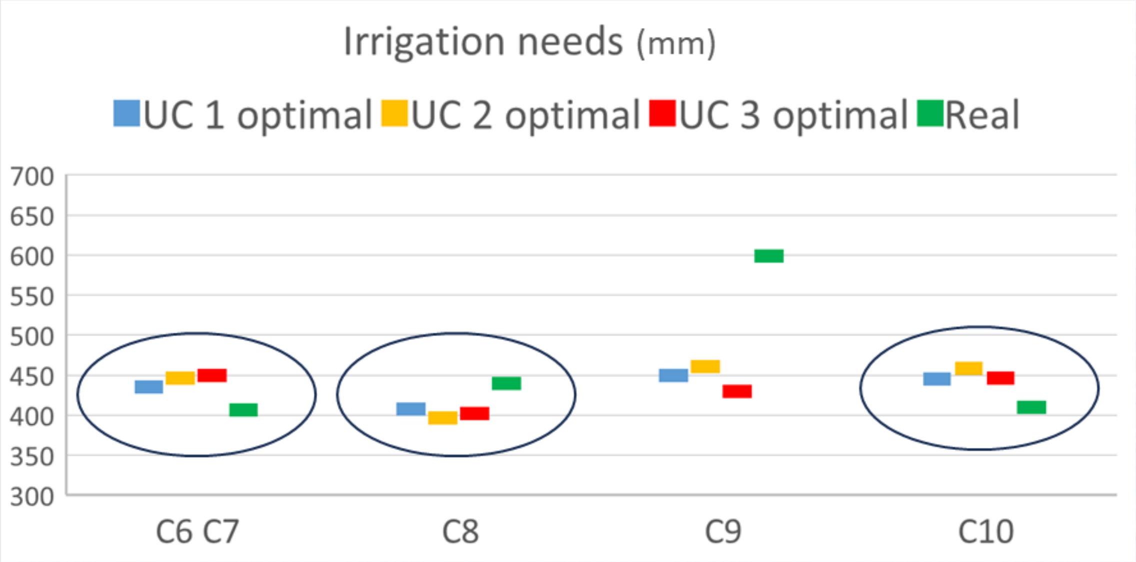
Total Irrigation (with respect to about 8 Mm^3 obtained from observed data):

- Use Case 1: - 37%
- Use Case 2: + 14%
- Use Case 3: + 31%

Comparisons at field scale of model simulations results using forecast data with water consumption measurements:

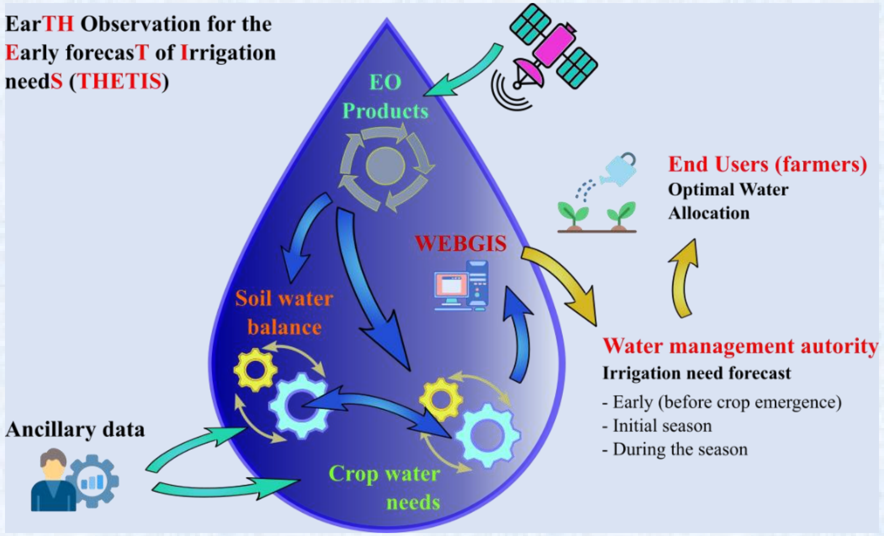


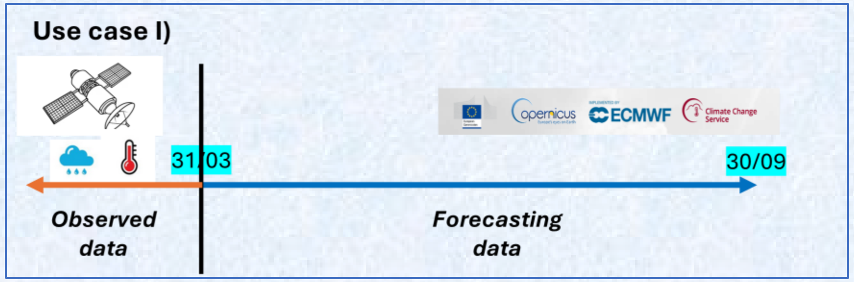
- C6/C7, C8, C10: close to measurements if simulated under the optimal irrigation regime (< 12% difference)



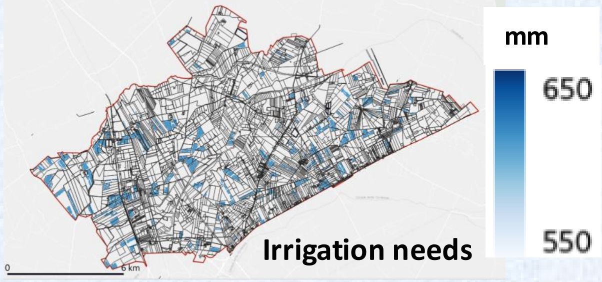
Conclusions

- The THETIS architecture for the early forecast of irrigation needs has been presented
- Main characteristics of THETIS is to integrate:
  - Innovative thematic maps derived from **EO** (**SAR** and **Optical** data)
  - **Hydrological** (SWB) and **crop** (CM) modelling
  - WEBGIS interface



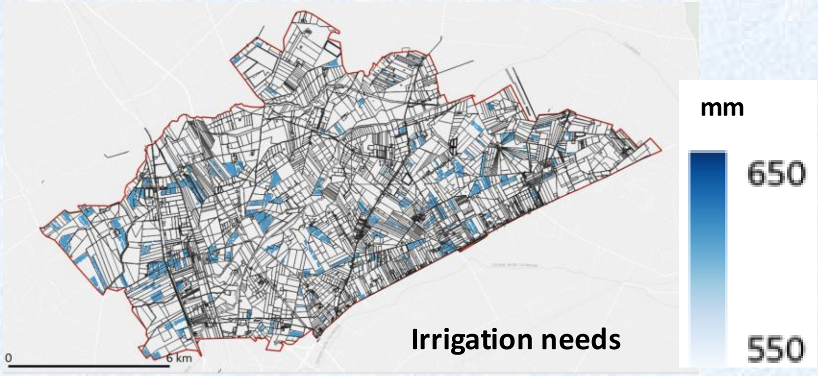


- **Results**: Irrigation needs forecasts:
  - I: at an early stage (before crop seeding)
  - II: at the beginning of the crop season
  - III: during the crop season



Conclusions (2)

- **Lesson learnt** on Irrigation needs forecasts:
  - at **district scale,** total irrigation volumes mainly depend on the early forecast of the cultivated area
  - at **field scale** they are quite close to measurements (simulations carried out under the optimal irrigation regime, about < 12% difference)



- **Activity extension:**

Multi-Year advanced Geospatial Earth Observation products over agricultural areas (MyGEO)

- continuously monitor over a longer period the use EO derived products and their robustness and accuracy in agriculture, across various climatic conditions and agronomic practices
- use of C-band and L-band SAR data (e.g., Sentinel-1/SAOCOM)
- systematically produce and assess Level-2 products (e.g., surface soil moisture)

HOMEPAGE • EVENTI •

WORKSHOP "TECNOLOGIE SATELLITARI E ANALISI MULTI-RISCHIO: L'ESPERIENZA DEI PROGETTI I4DP_SCIENCE E PROSPETTIVE FUTURE"

Thanks for your attention!

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