Politecnico di Bari

Dams & Reservoirs DAY 2025

Water and Energy security for Europe

OPEN DAY ON DAMS



Impianti e Modelli per la Gestione delle Risorse Idriche

BARI , 30 maggio 2025

LA MODELLISTICA COLTURALE PER LA STIMA DEI FABBISOGNI IRRIGUI

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ITCOLD – II Concorso Fotografico

The Application of Crop Module (CM) in the THESIS Platform

Objectives of CM:

✓Formalize the growth and development of irrigated crops (tomato in open field);

✓Estimate water consumption by the cropping system (transpiration, evaporation, drainage);

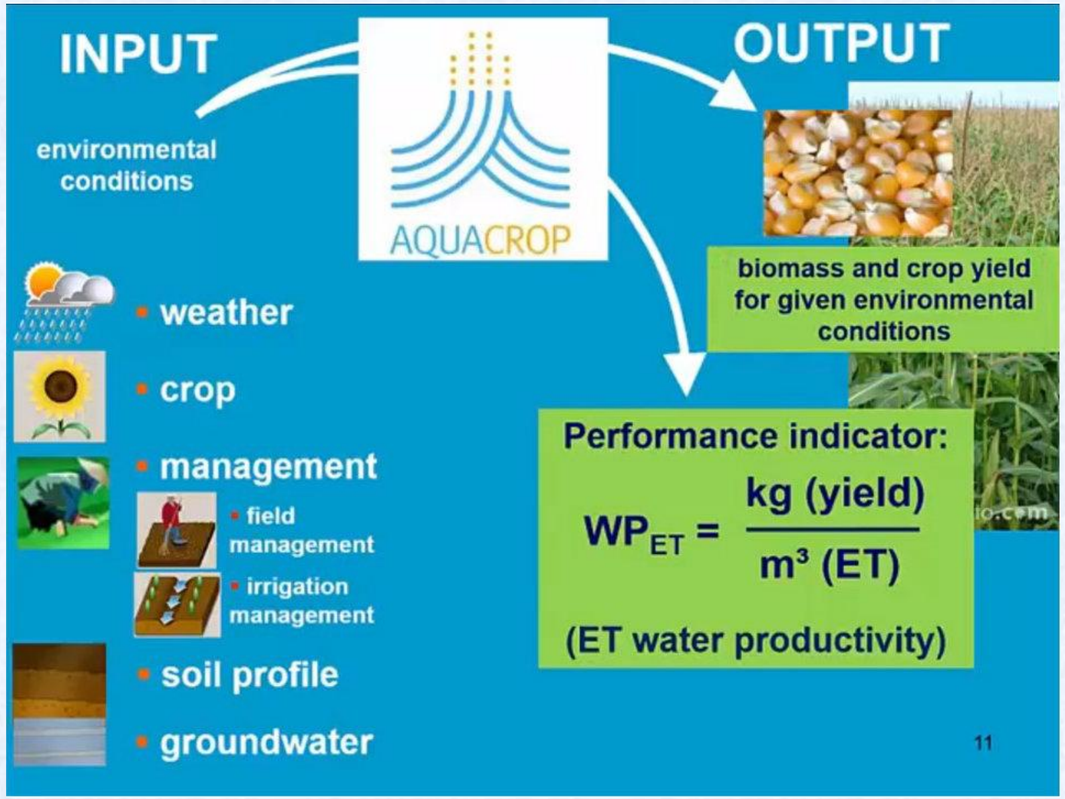
✓Identify and quantify the irrigation needs necessary to satisfy the crop's water requirements.

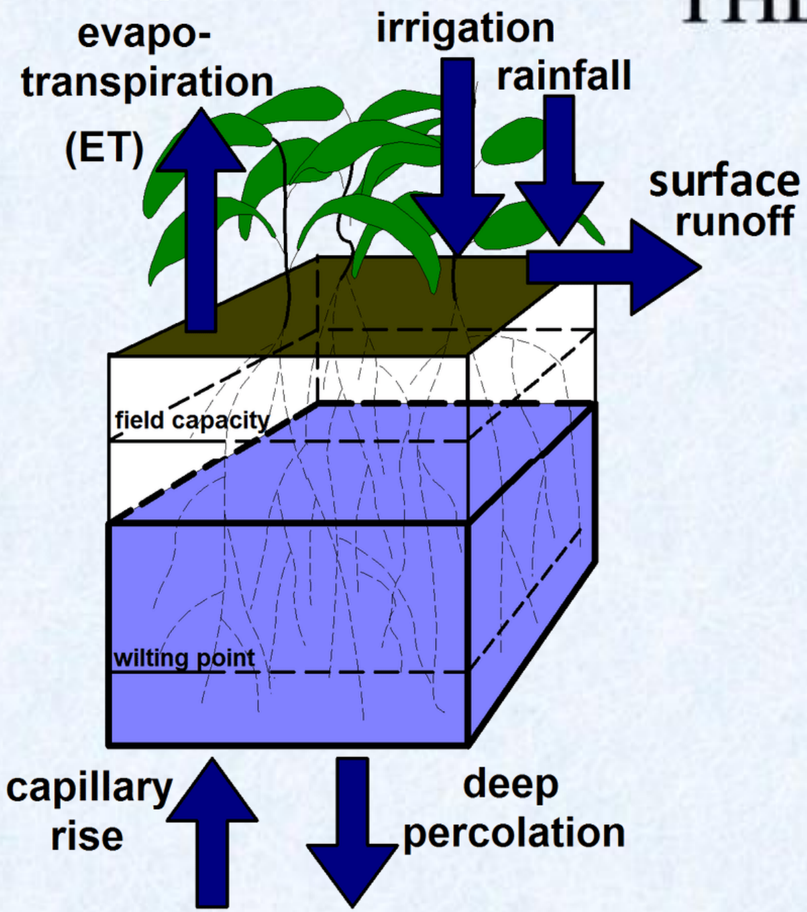
Results obtained from the Teti platform

❖ Create predictive maps of irrigation needs and required water quantities during the upcoming growing season at:

- Early stage (April 1st): for planning irrigation demands managed by the Capitanata reclamation consortium;
- beginning phase (May 1st): Estimation of water demand and irrigation for the transplanted crop (hypothetically) occurring in the second half of May.
- beginning phase (June 1st): Estimation of water demand and irrigation for the transplanted crop (hypothetically) occurring in the second half of May.

Soil Crop Water model: AquaCrop





The crop model employed in this study is AquaCrop, developed by the Land and Water Division of the FAO (Food and Agriculture Organization).

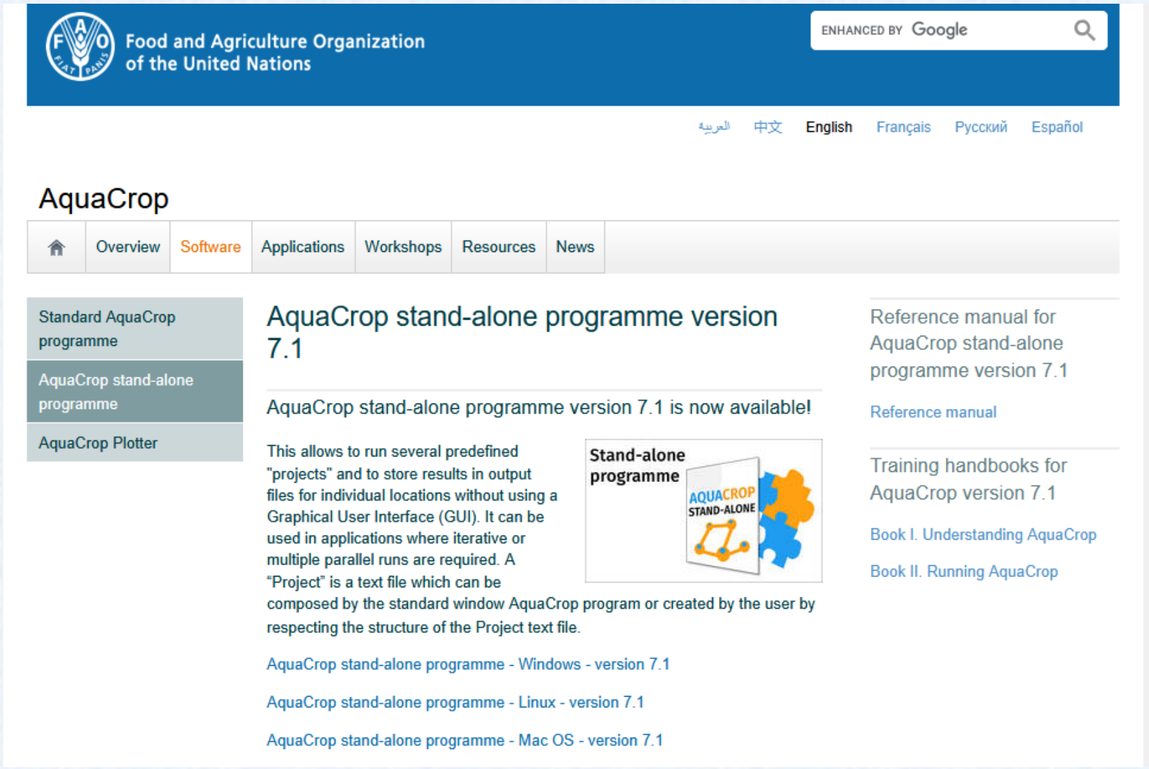
AquaCrop-OS

The crop model (CM) used in this study was AquaCrop, developed by the FAO to simulate crop yield as a function of water availability.
AquaCrop accounts for key variables such as evapotranspiration, water use efficiency, and soil water balance.

AquaCrop is available in two versions:

- The application, compatible with Windows, Linux, and Mac OS, can be downloaded free of charge from the FAO AquaCrop website.

- Python version available at GitHub.

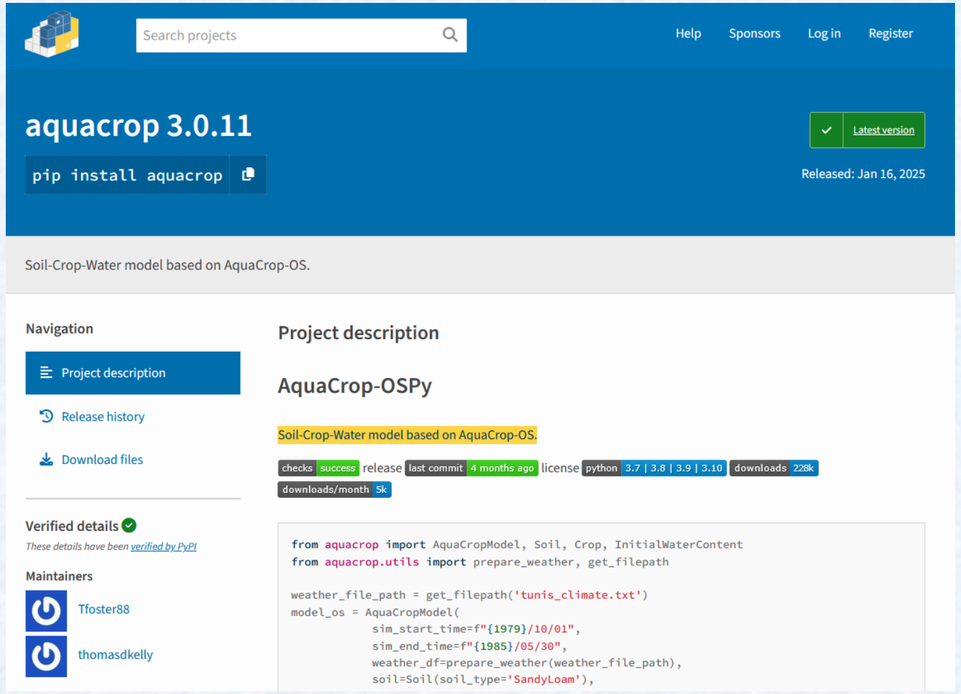


AquaCrop-OS

The Python version was chosen for integration into the TETI platform due to its greater flexibility in data processing and compatibility with other analytical tools. It enabled automated simulations across multiple fields simultaneously, allowing variations in soil configurations, initial water content, and irrigation strategies. In contrast, other versions only support simulations of one field at a time.

It is important to emphasize that the two versions exhibit slight differences in their outputs, as the Python version was developed by a different team than the Windows version.

However, a comparison of the results revealed that these differences are negligible.



AquaCrop-OS

Running an AquaCrop simulation requires several input parameters, including:

- Crop characteristics
- Soil properties
- Meteorological data
- Irrigation strategy
- Initial soil water content conditions
- Simulation start

At the end of the simulation, AquaCrop generates four output files:

- Daily soil water content
- Daily crop water status
- Daily crop production statistics
- Overall seasonal crop performance statistics

CM design: Calibration and Validation

First step

- Adapting the Cropping Model to the soil and climatic conditions of processing tomato cultivation in the Capitanata region.
    - Experimental data from CREA trials on processing tomatoes grown under optimal (2021, calibration) and water-stressed (2022, validation) conditions were used.
- Adaptation to the environmental conditions of the study area was achieved by adjusting the coefficients and algorithms of the predictive models underlying the simulation of crop growth and development dynamics. A trial-and-error calibration procedure was applied to minimise the discrepancy between observed and simulated data.
- Finally, the robustness and reliability of the Cropping Model (CM) were assessed through validation using appropriate statistical indices, which confirmed the model's performance under conditions differing from those of the calibration phase.

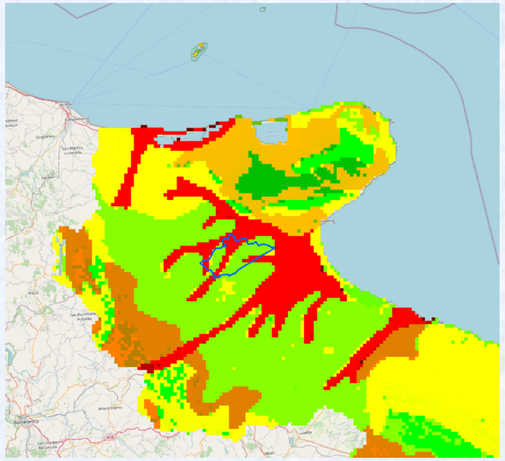
AquaCrop Py

The crop model (CM), after calibration, can be used with the following inputs:

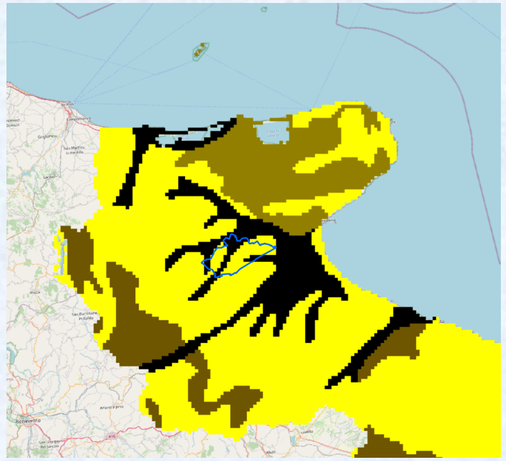
- Soil characteristics were obtained from the European Soil Data Centre (ESDAC) (https://esdac.jrc.ec.europa.eu/content/maps-indicators-soil-hydraulic-properties-europe).
- Weather data were sourced from the Copernicus Climate Change Service (C3S), spatialized by UniBA.
- Irrigation strategies included two options:
  - Fixed irrigation (12 mm every two days)
  - Optimal irrigation.
- Soil water content was derived from Relative Saturation maps (rTHS), generated by Poliba.
- Transplanting dates were also considered as input.

Soil data

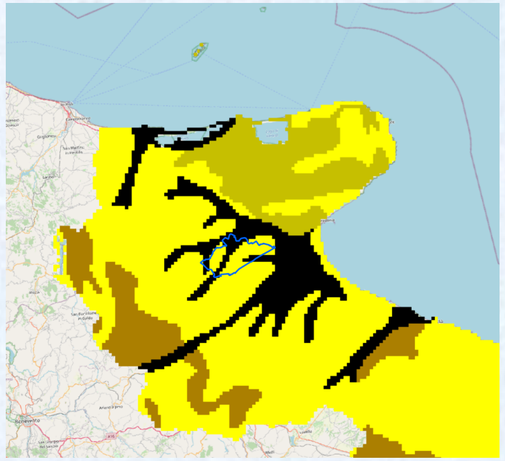
JOINT RESEARCH CENTRE
EUROPEAN SOIL DATA CENTRE
(ESDAC)



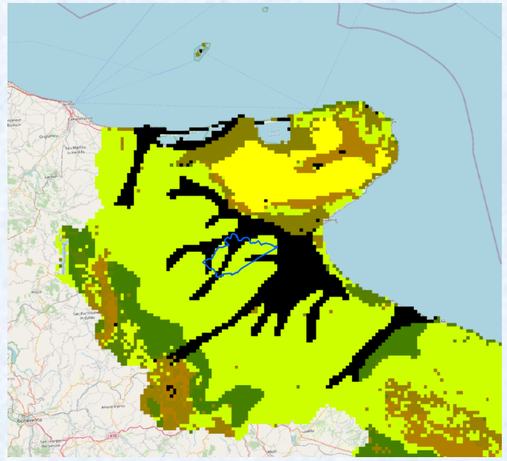
ks: saturated hydraulic conductivity (cm/day)



wp: water content at wilting point (cm3/cm3)

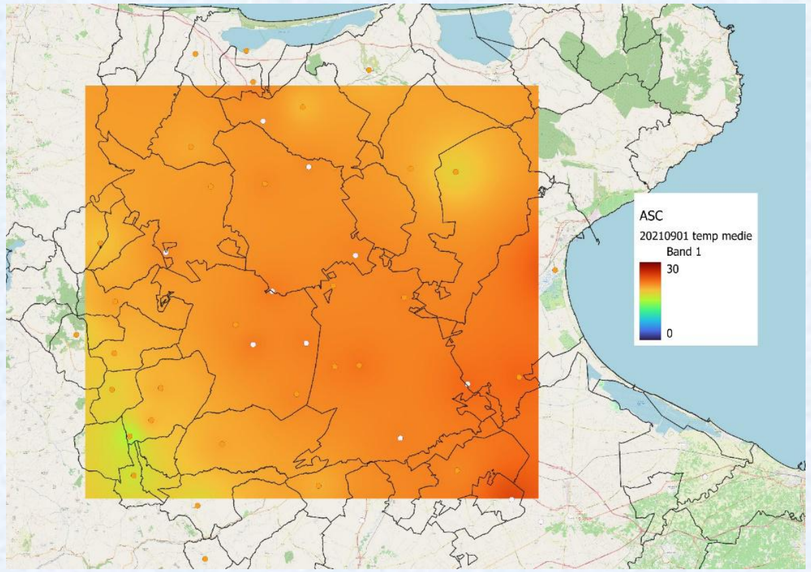


fc: water content at field capacity (cm3/cm3)

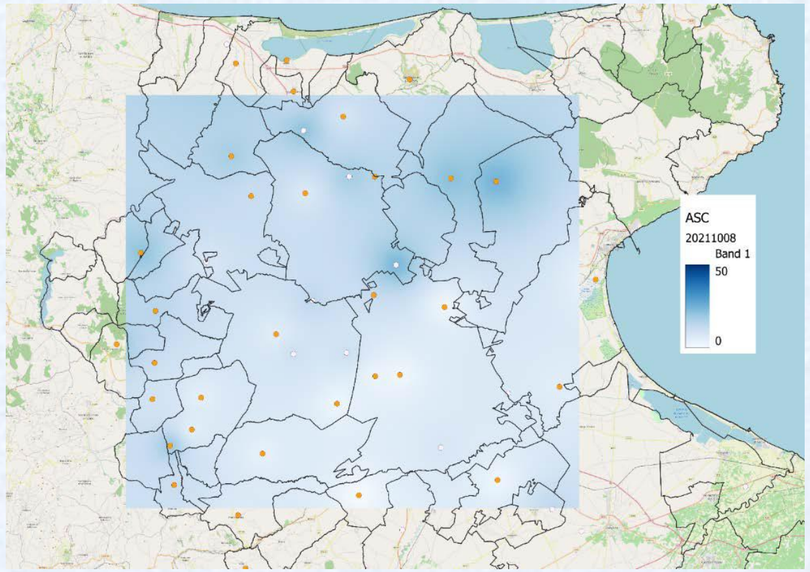


ths: saturated water content (cm3/cm3)

Spatialized weather data of temperature and precipitation



The Blaney-Criddle equation is a simpler method used to estimate reference crop evapotranspiration (ET_0)



$$ET_0 = -1.55 + 0.96 \times p(0.457 \times T_{ave} + 8.128)$$

Schrodter – Hinweise 1985

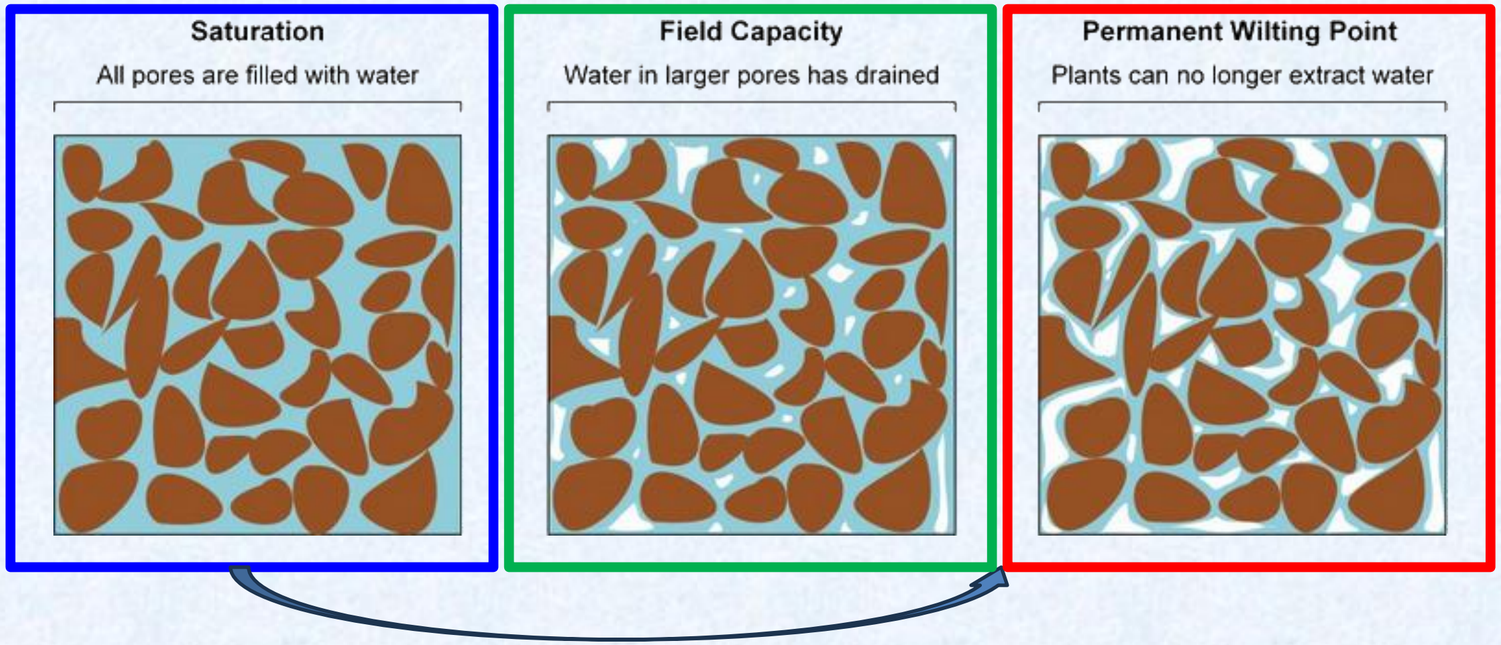
ET_0 = Reference evapotranspiration (in mm/day)

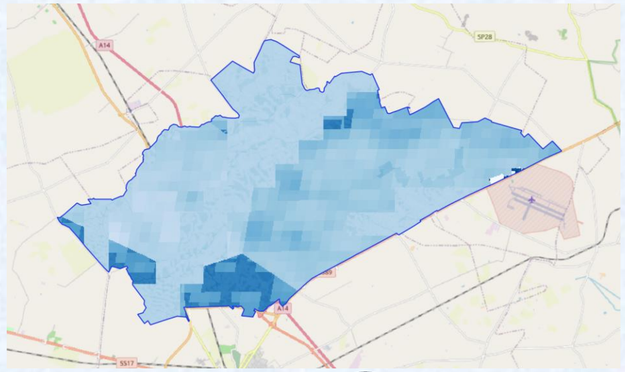
p = The mean percentage of annual daytime hours during the month of interest (based on latitude and time of year)

T = Mean daily temperature (°C)

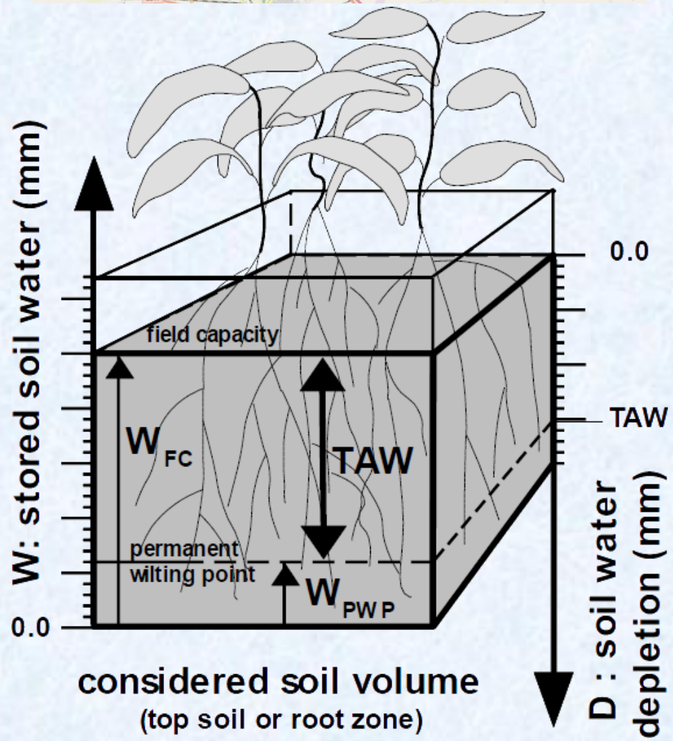
0.457, 8.128, 0.96 = constant used to adjust the relationship between temperature and evapotranspiration (ET_0)

Relative saturation (RS) vs Total Available soil Water (TAW)





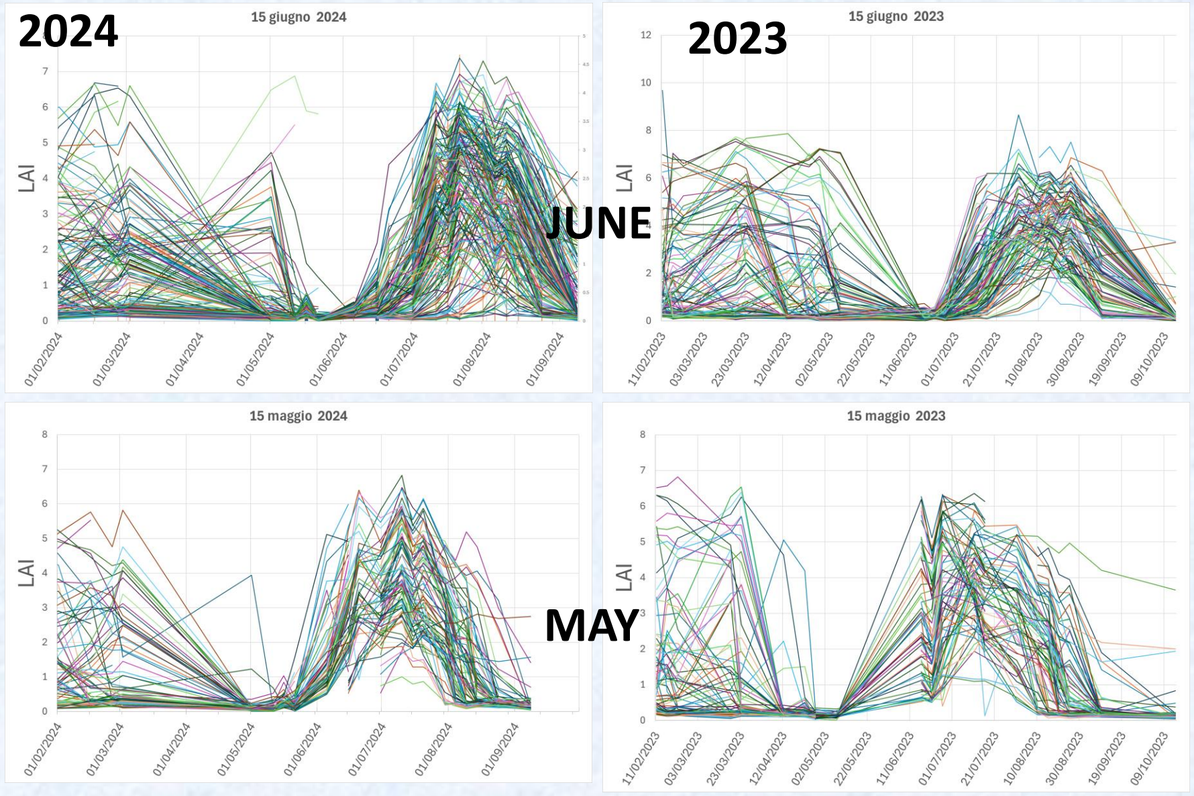
$$TAW = \frac{RS \times ths - wp}{fc - wp} \times 100$$

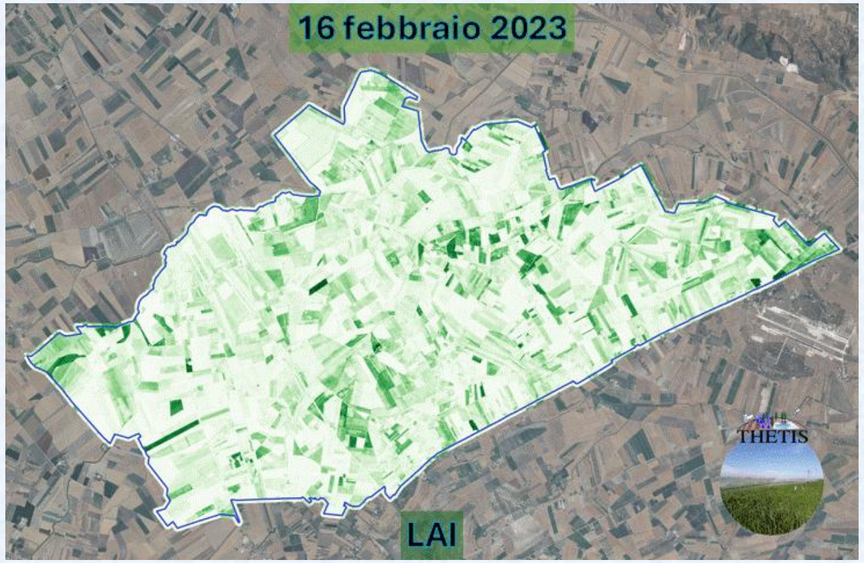


Total Available soil Water (TAW):

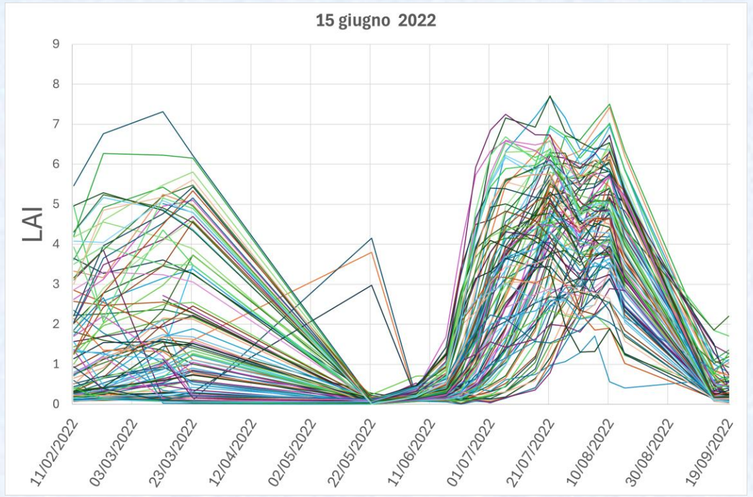
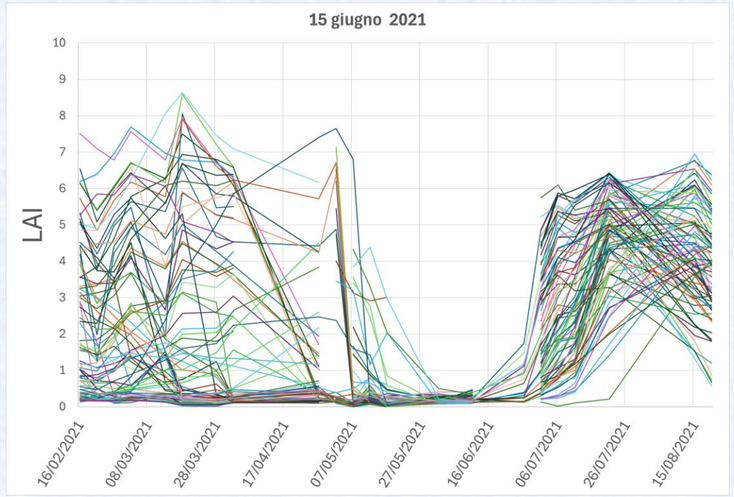
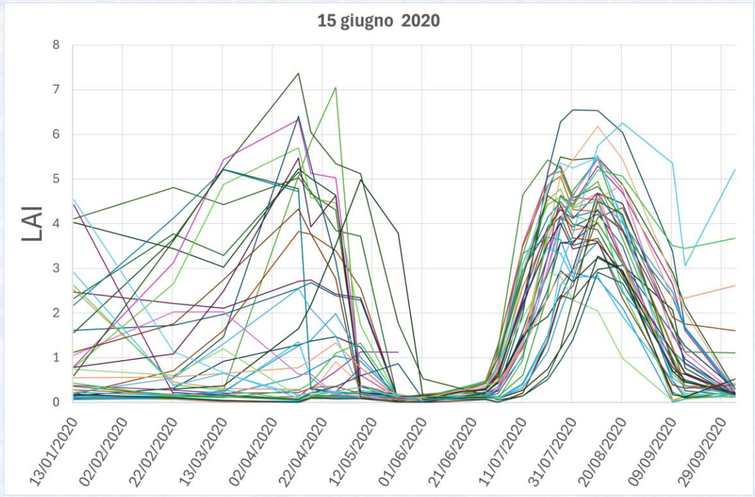
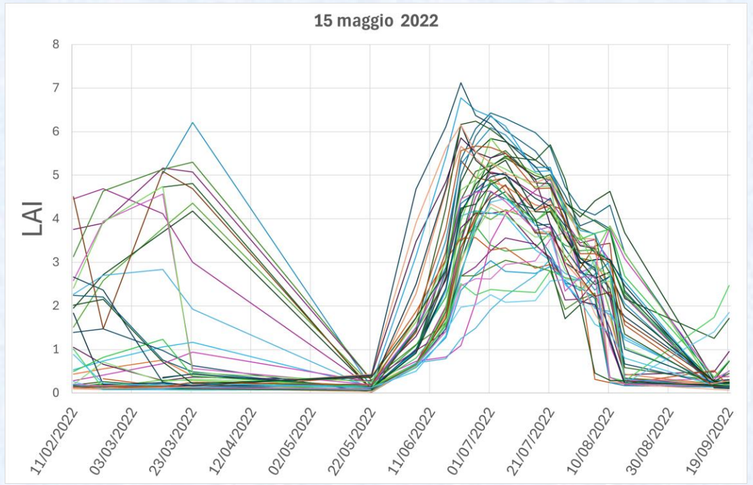
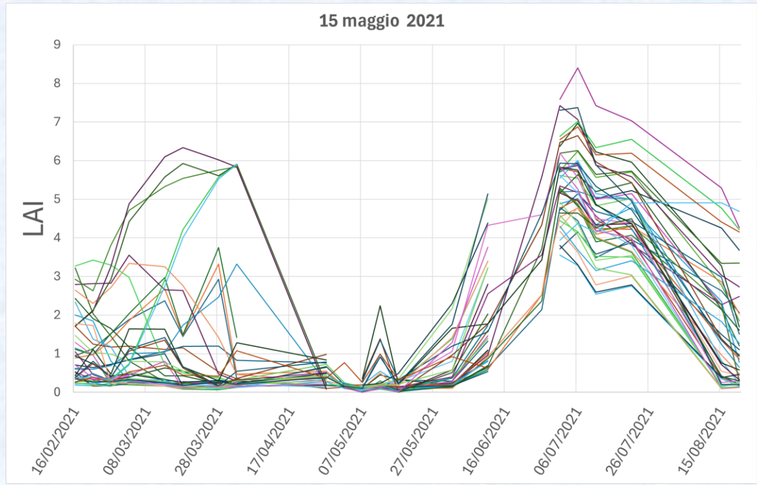
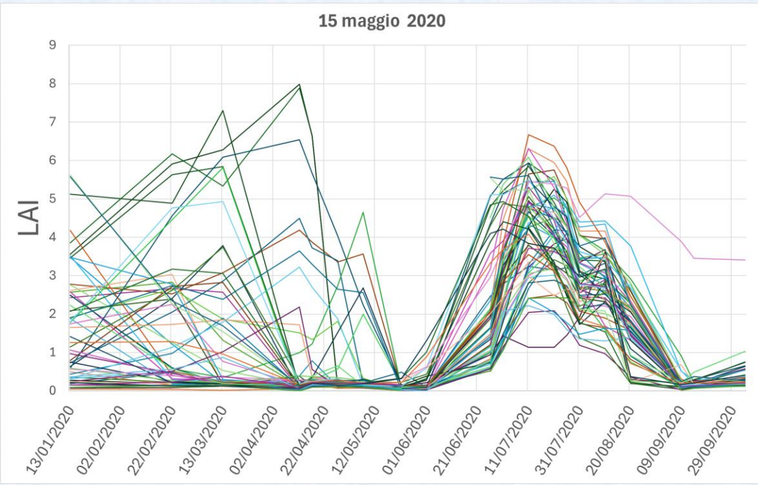
In AquaCrop, the total water available in the soil is the water that a crop can theoretically extract from the fine fraction of the soil volume considered, between the wilting point and the field capacity.

Transplanting date

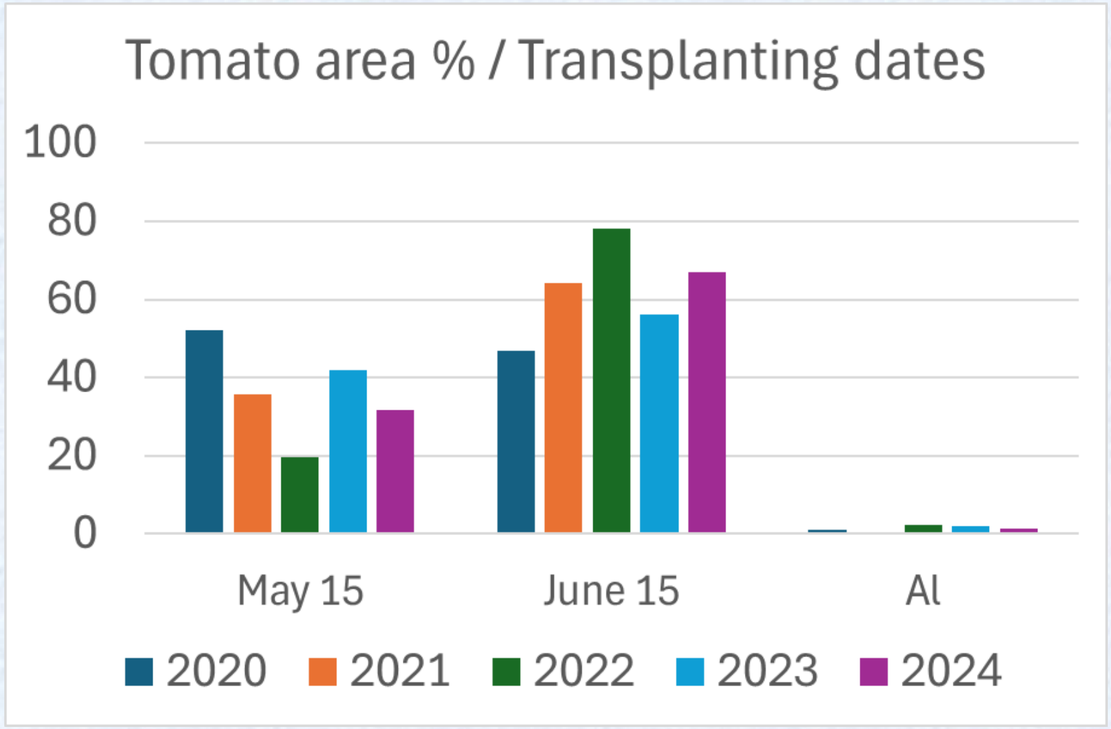


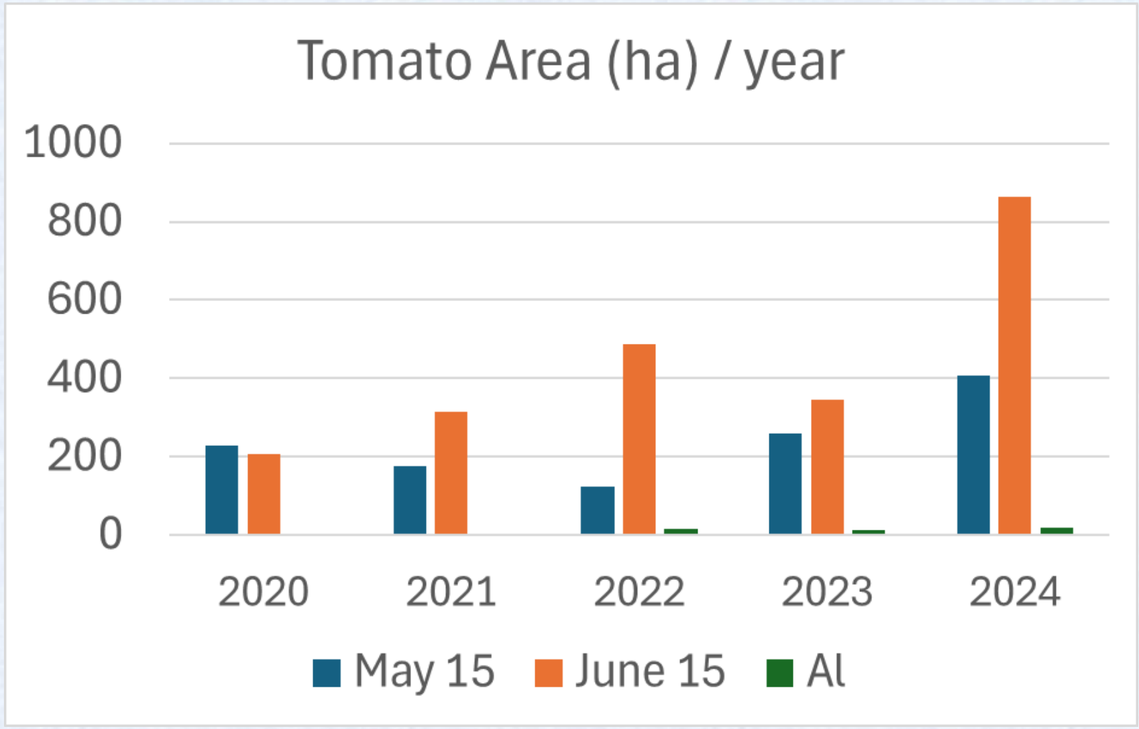


Transplanting dates

	2022	2021	2020
JUNE			
MAY			

Soil data

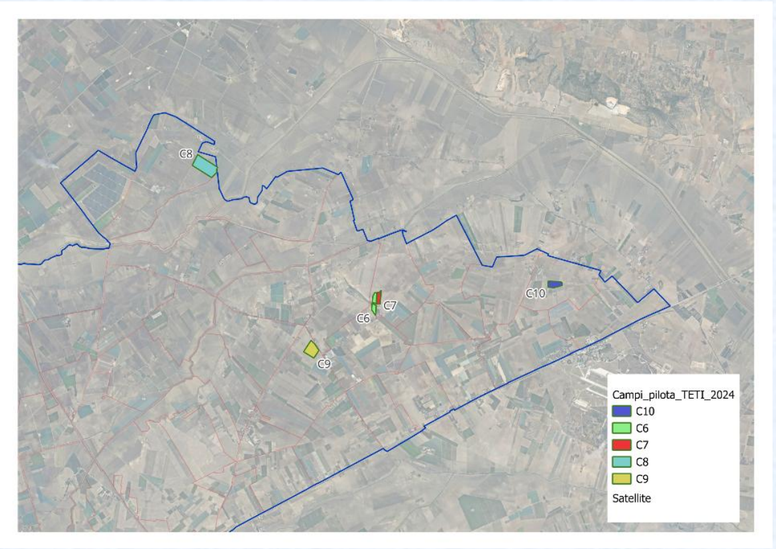

Tomato area % / Transplanting dates
100
80
60
40
20
0
May 15
June 15
Al
2020
2021
2022
2023
2024


Tomato Area (ha) / year
1000
800
600
400
200
0
2020
2021
2022
2023
2024
May 15
June 15
Al

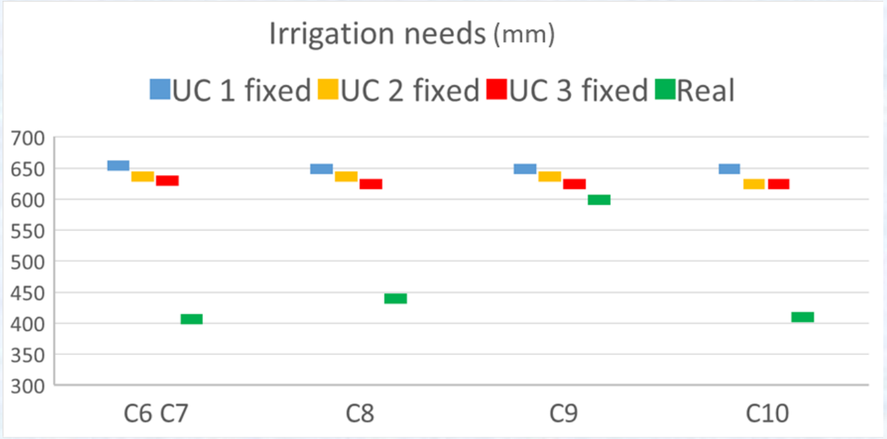
Irrigation Consumption of Tomatoes in District 6/B

Four tomato fields were observed throughout 2024.

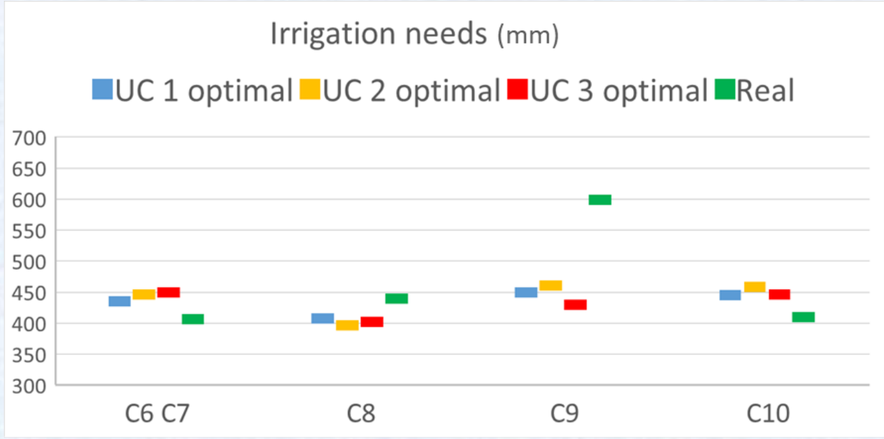
Fields C6/C7, C8, and C10 exhibited values in 2024 that were closely aligned with the estimates obtained from the CM simulations using the optimal irrigation regime, with a deviation of +/- 12%.
Field C9, on the other hand, displayed values similar to the simulated consumption levels under a fixed irrigation program.



fixed irrigation



optimal irrigation



Irrigation Consumption of Tomatoes in District 6/B

In 2024, we conducted direct land-use surveys in District 6/B from June to August.

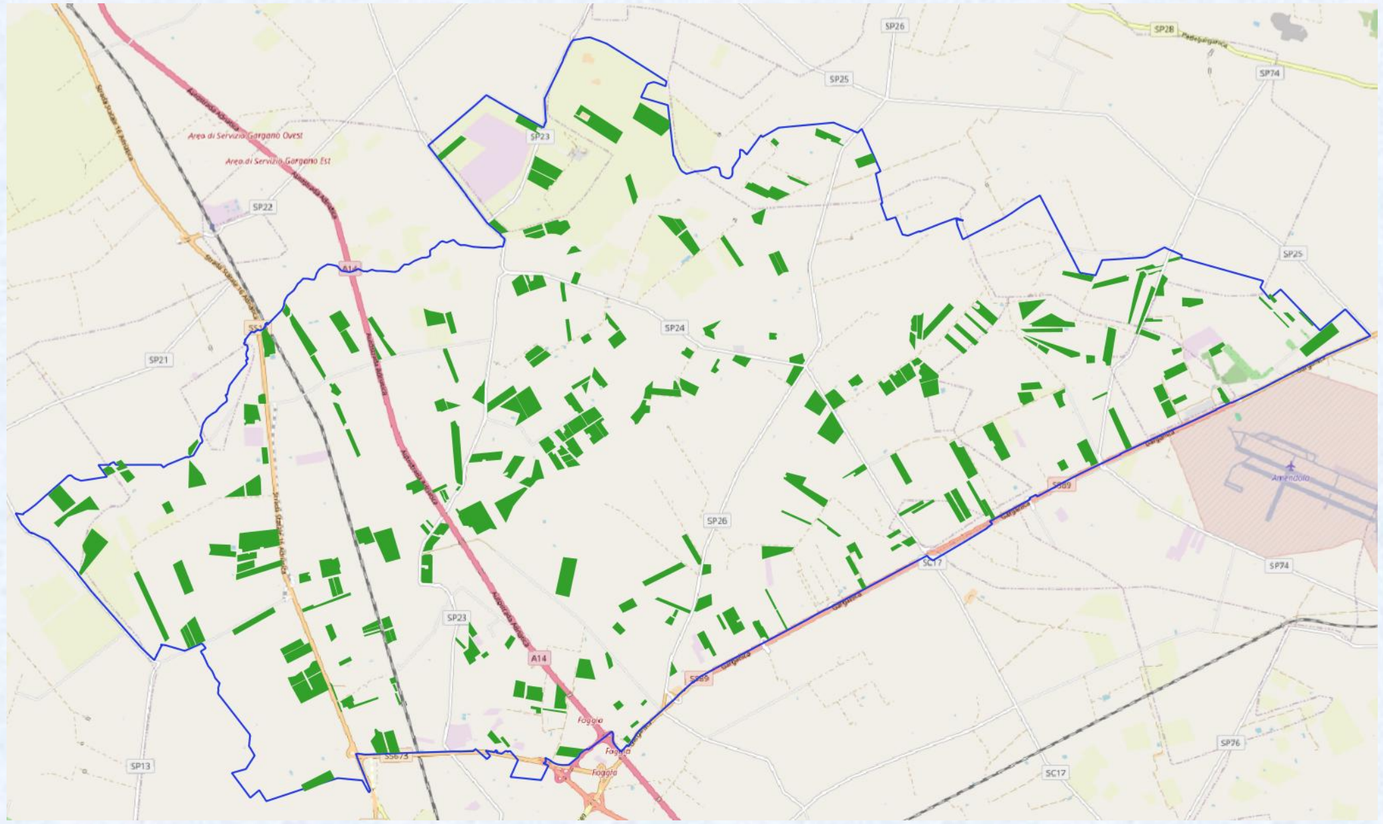
A total of 273 tomato fields, covering an area of 1,264 hectares, were identified.

Each of these fields was simulated using actual weather data from the two CBC stations, with transplantation taking place on May 31, 2024.

Two irrigation regimes were applied:

- 12 mm every other day;
- optimal irrigation.

The average results from the simulations were used to compare the outcomes across the three use cases.

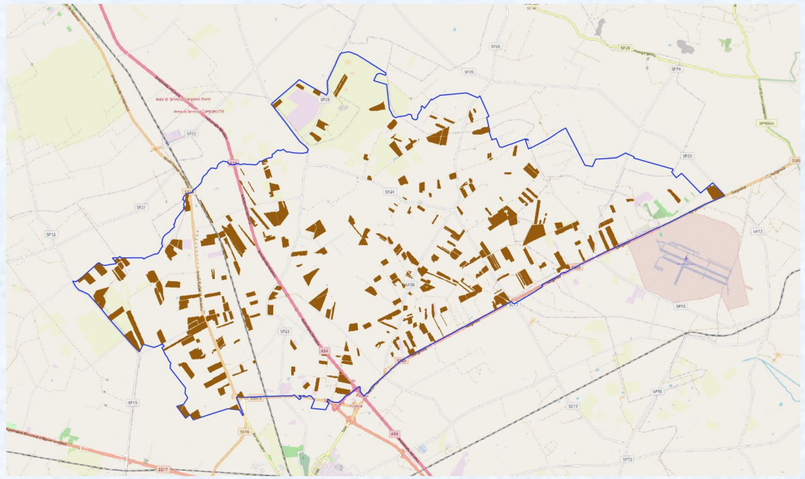


Irrigation Consumption of Tomatoes in District 6/B

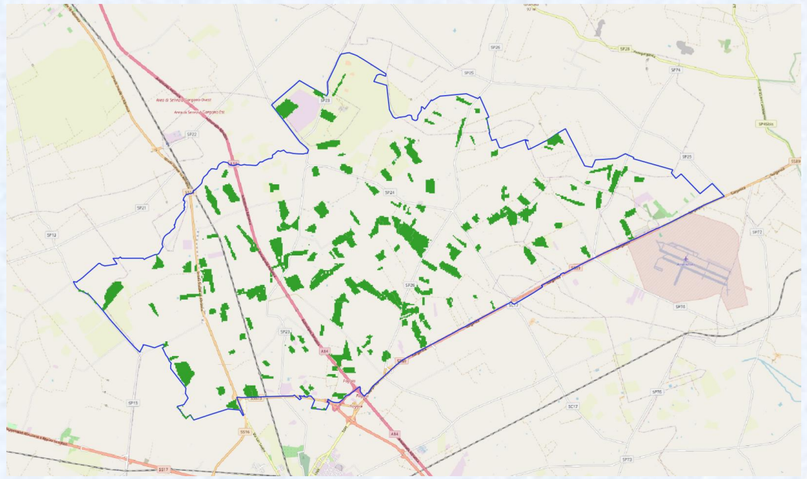
Simulations were conducted for the three use cases.

For Use Case 1, the transplantation date was set to May 31, while for Use Cases 2 and 3, it was set to May 15 and June 15, respectively.

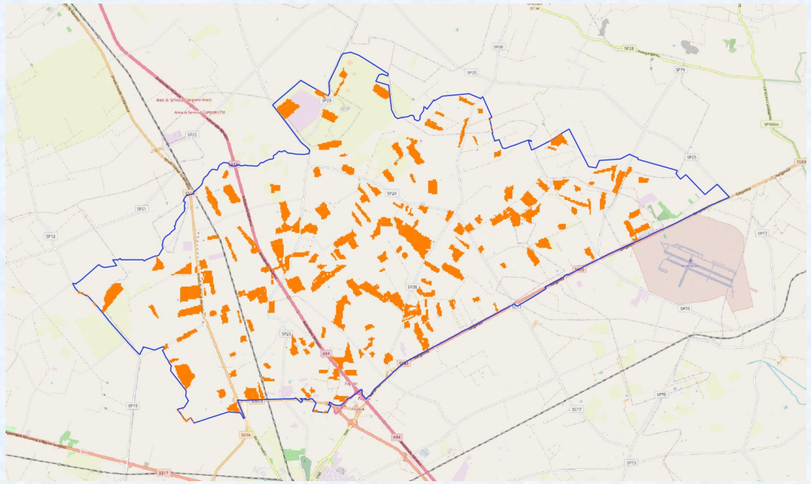
Use Case 1:
262 fields covering a total area of 1611 hectares.



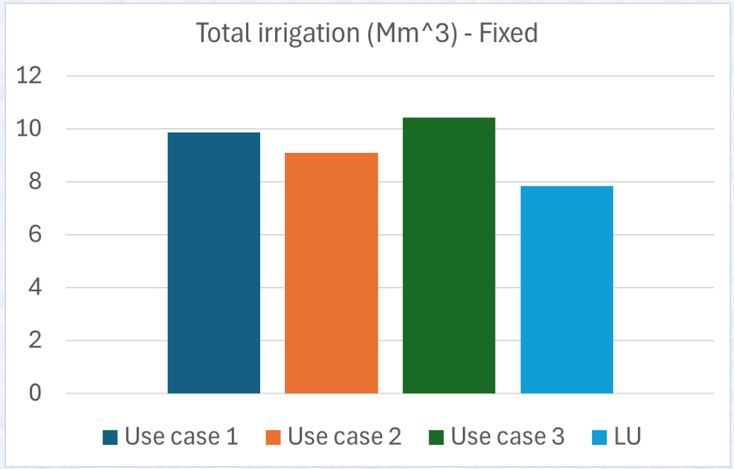
Use Case 2:
228 fields covering a total area of 1471 hectares.



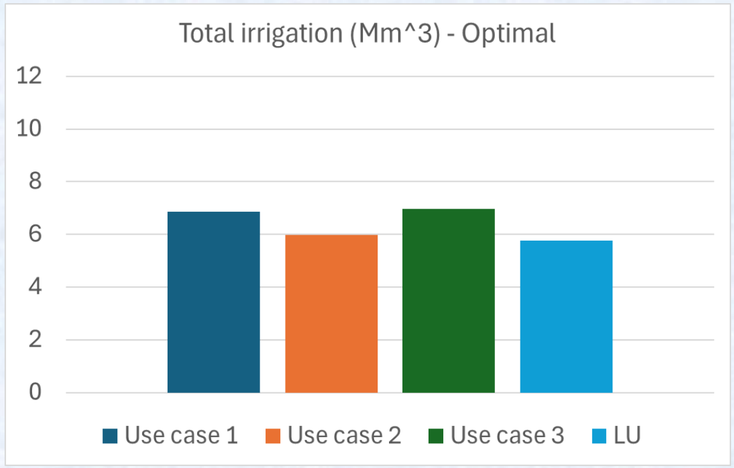
Use Case 3:
255 fields covering a total area of 1727 hectares.



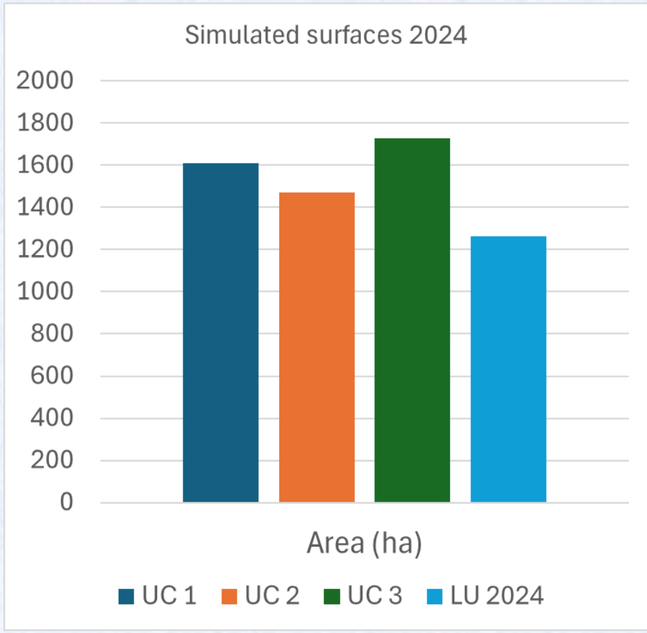
Irrigation Consumption of Tomatoes in District 6/B



+ 25%



vs LU	fixed	optimal
Use case 1	+ 25.94%	+ 18.89%
Use case 2	+ 16.07%	+ 3.62%
Use case 3	+ 33.26%	+ 20.93%

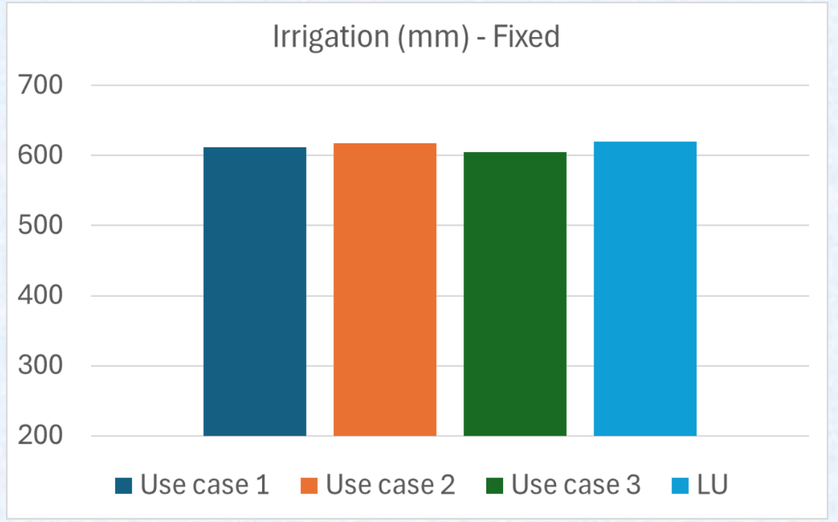


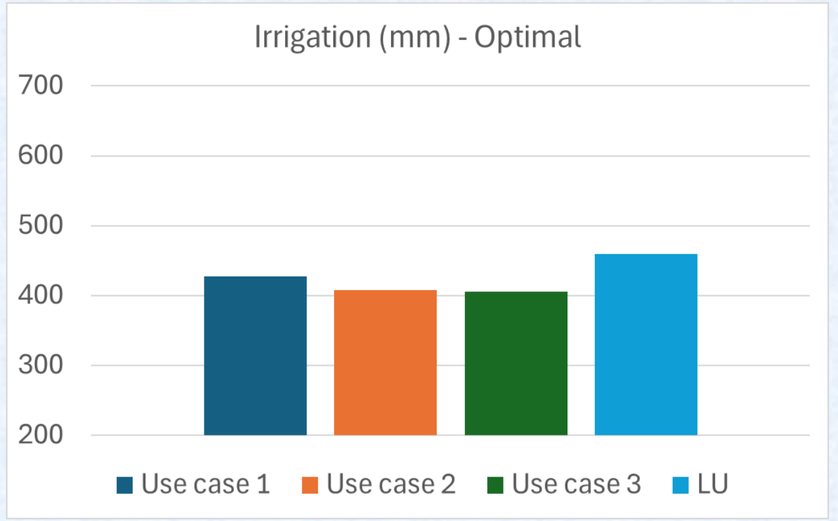
Irrigation Consumption of Tomatoes in District 6/B

The comparison of irrigation consumption per hectare between fixed and optimal irrigation across the three use cases shows very similar water requirements.

	fixed	optimal
Use case 1	-1.25%	-6.89%
Use case 2	0.87%	-11.15%
Use case 3	-0.10%	-11.72%

The difference is more pronounced with optimal irrigation.

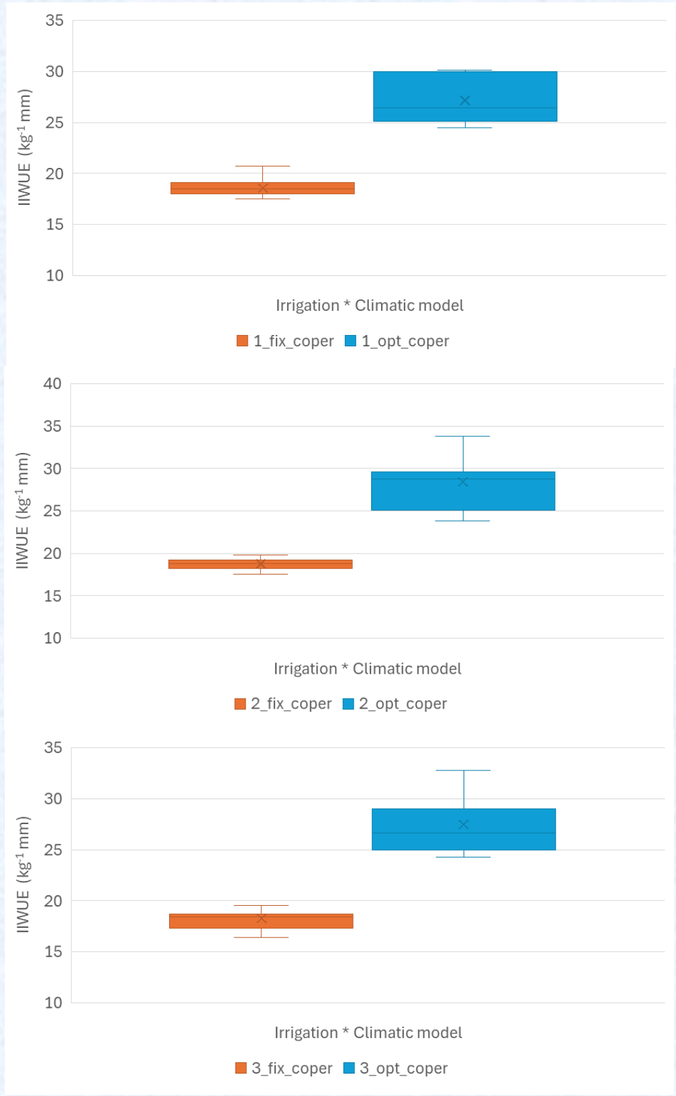


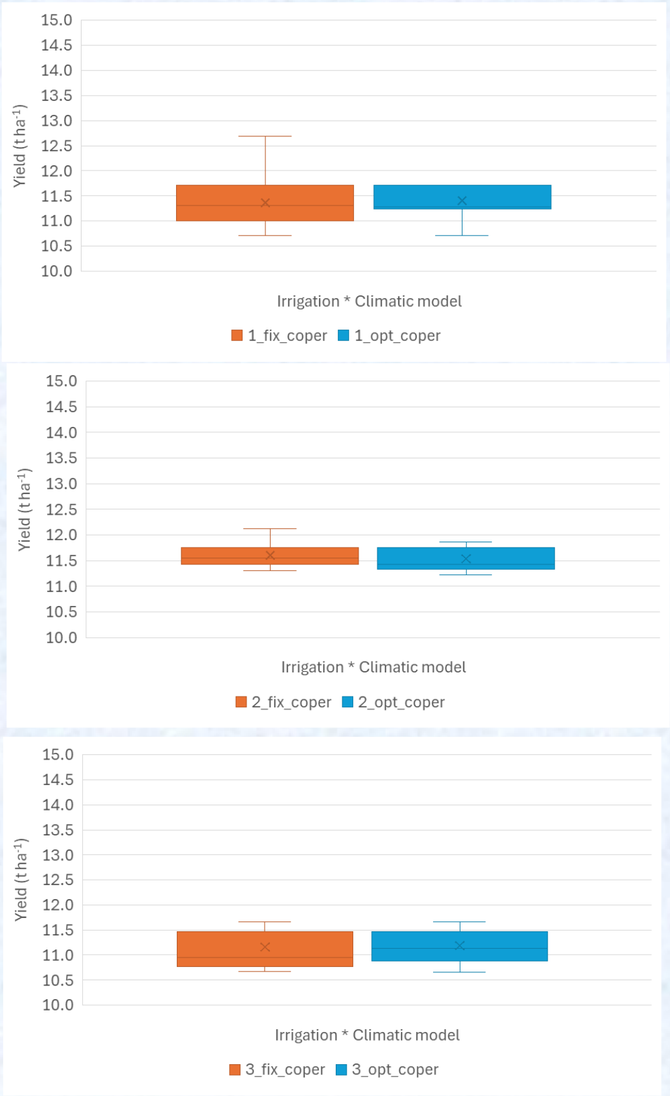


Irrigation Consumption of Tomatoes in District 6/B

Irrigation Water Use Efficiency (IWUE) measures how efficiently water is used relative to crop production. It is defined as the ratio of yield to the amount of water consumed by the plant.

For the same yield of approximately 11.5 t/ha, the IWUE demonstrates that fixed irrigation results in water wastage.





Conclusions

- ✓ The AquaCrop Crop Model (CM), integrated into the TETI platform, has been demonstrated to accurately predict the irrigation requirements of tomato crops.
- ✓ In particular, the pilot fields revealed a strong correlation between the farmers' fixed and optimal irrigation practices and the AquaCrop simulation results.
- ✓ Accurate estimation of the cultivated areas is crucial for predicting seasonal irrigation demands.
- ✓ Applying CM in optimal mode could result in irrigation water savings of up to 25%.

OPEN DAY ON DAMS

Impianti e Modelli per la Gestione delle Risorse Idriche

Grazie per l'attenzione

Sergio Ruggieri

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