Physikalisches Institut
Heidelberg University
Germany

NS Neutron Simulation

# Use of CRNS for scheduling irrigation

Water Management using Smart Radiation Sensors

18.07.2022

Markus Köhli[1], Cosimo Brogi[2], Martin Schrön[3] and Ulrich Schmidt[1]

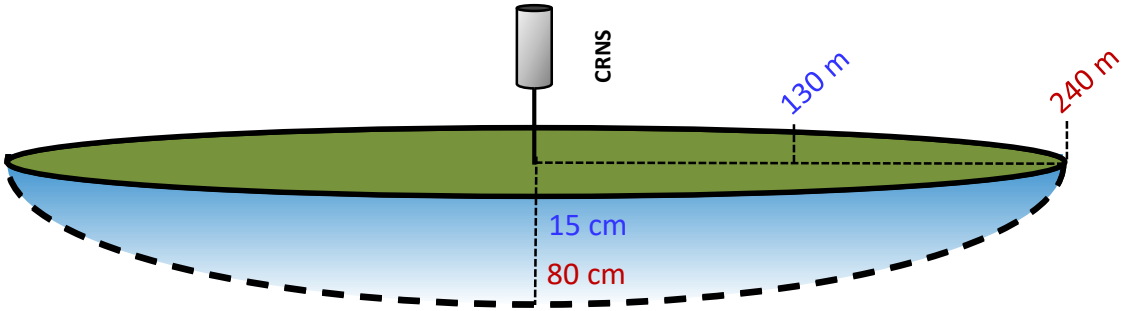
[1] Physikalisches Institut, Heidelberg University, Heidelberg, Germany
[2] Agrosphere Institute (IBG-3), Forschungszentrum Jülich, Jülich, Germany
[3] Helmholtz Centre for Environmental Research - UFZ, Leipzig, Germany

Cosmic Sense

DFG FOR 2394

# NS > Motivation

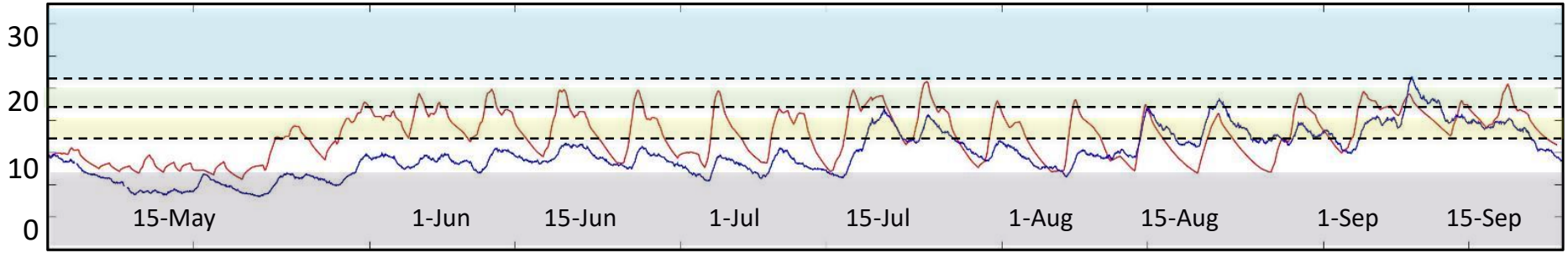
Integration of CRNS in Smart Agriculture

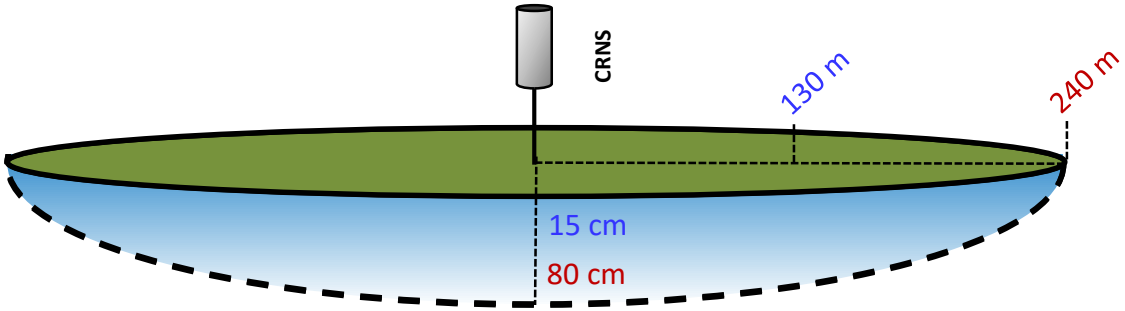



- ✓ One sensor per field
- ✓ Large measured volume
- ✓ No removal during management
- ✓ Low maintenance

# NS > Motivation

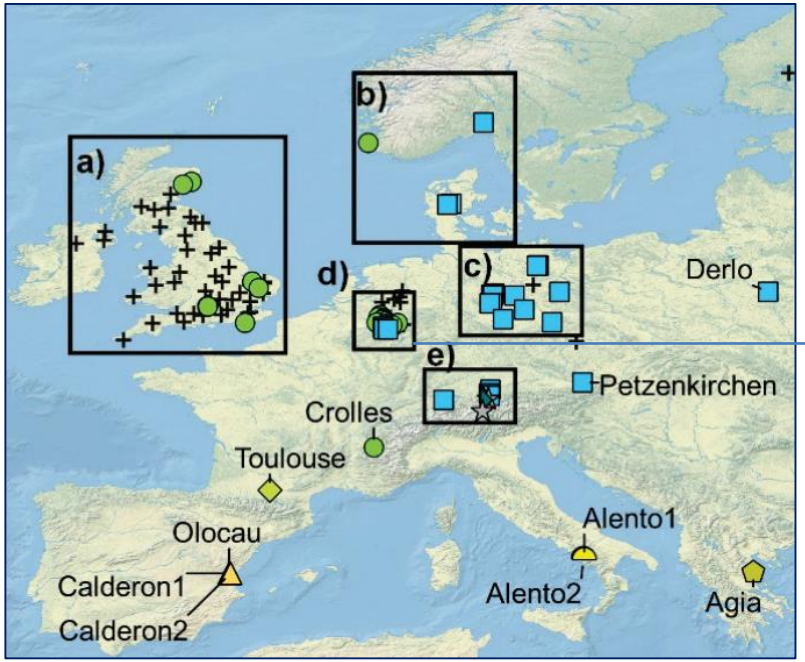
Integration of CRNS in Smart Agriculture



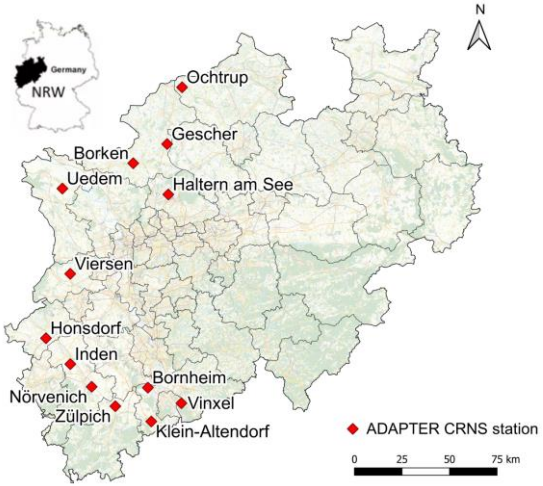




- ✓ One sensor per field
- ✓ Large measured volume
- ✓ No removal during management
- ✓ Low maintenance

# NS > CRNS Networks




COSMOS-Europe sites (Bogena 2021, ESSD)




ADAPTER sites (Ney 2021, MetroAgriFor)

# NS > ADAPTER - Climate Resilient Agriculture

Devices with NB-IoT modems

Cellular Network

IoT–Provider

Packed Gateway

VPN Gateway

Open VPN

Server
- Data processing
- Data storage
- Modelling

VPN Gateway

www.adapter-projekt.de

- transmission of the observation data via **N**arrow **B**and **I**nternet **o**f **T**hings (**NB-IoT**) in near real-time

In collaboration with
Patrizia Ney
FZ Jülich

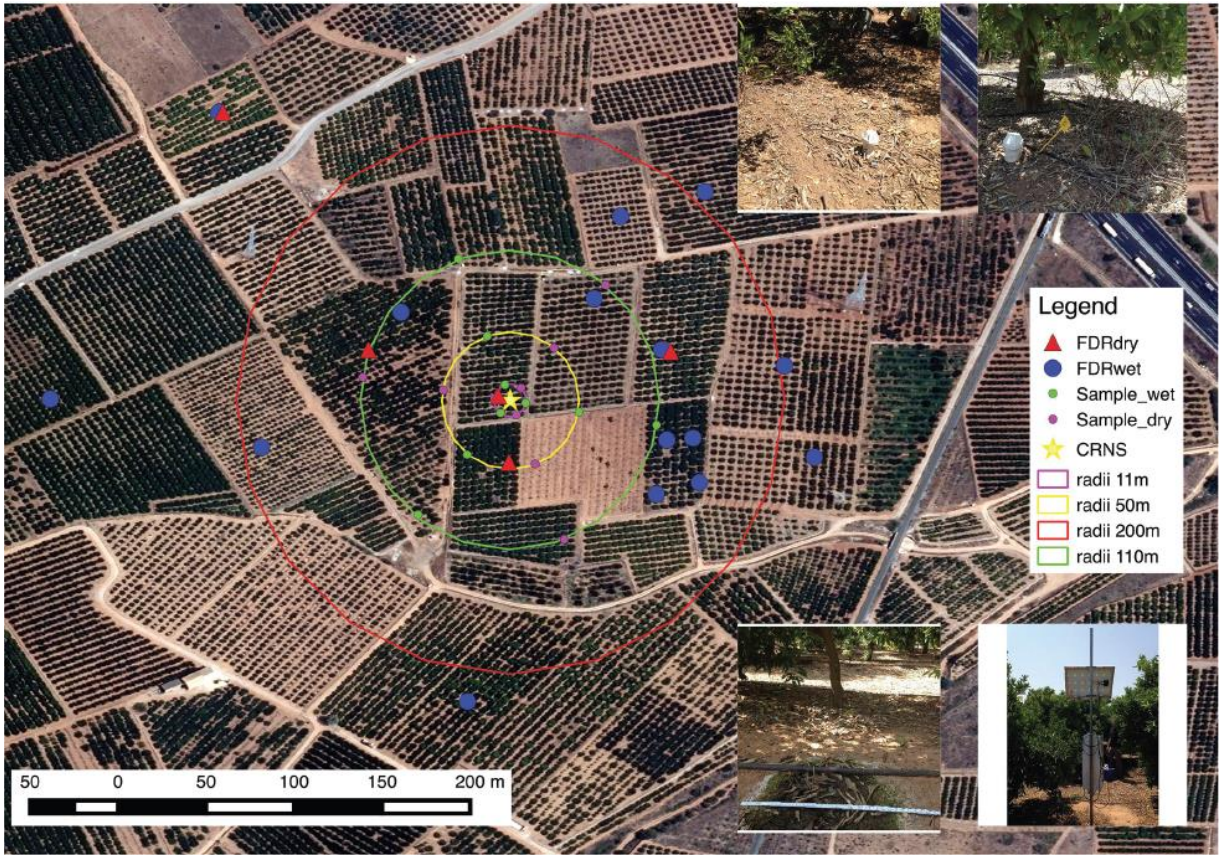
# Valencia Citrus Tree Fields

https://www.mapsland.com/europe/portugal/elevation-map-of-portugal-and-spain

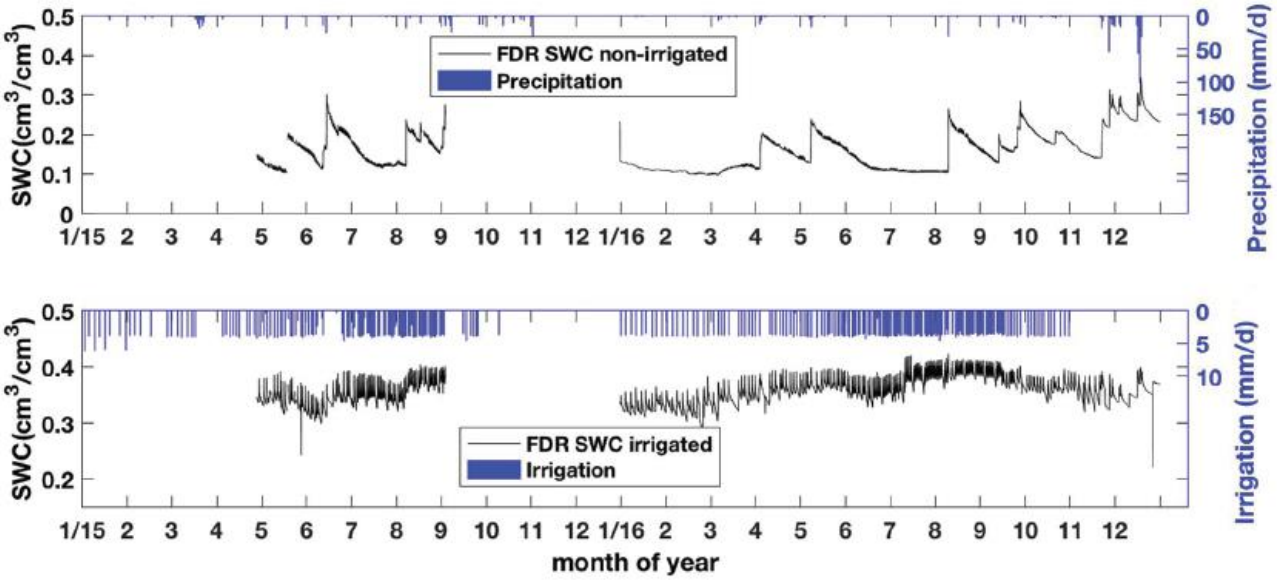
In collaboration with
Dazhi Li
FZ Jülich

# Picassent Site Overview

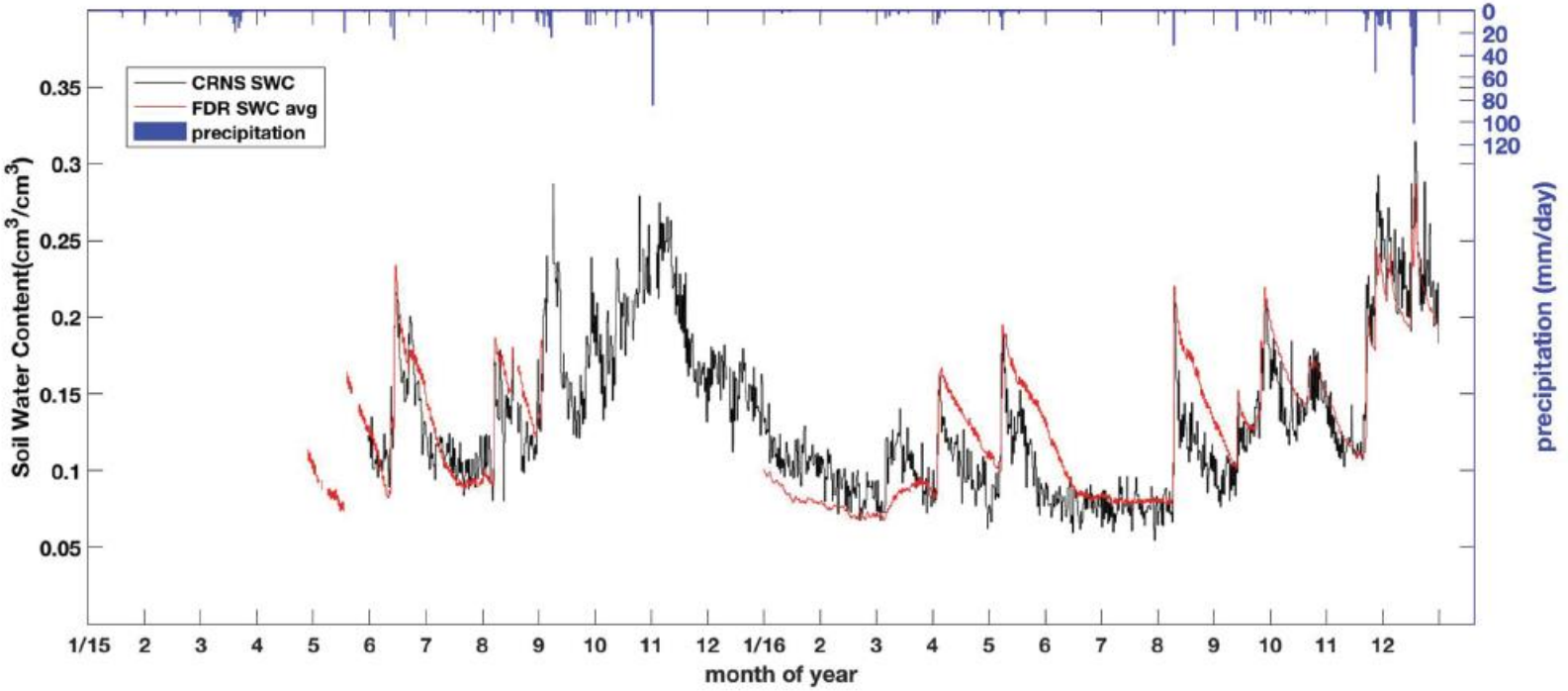
* D. Li et al. (2019) Can Drip Irrigation be Scheduled with Cosmic-Ray Neutrons?



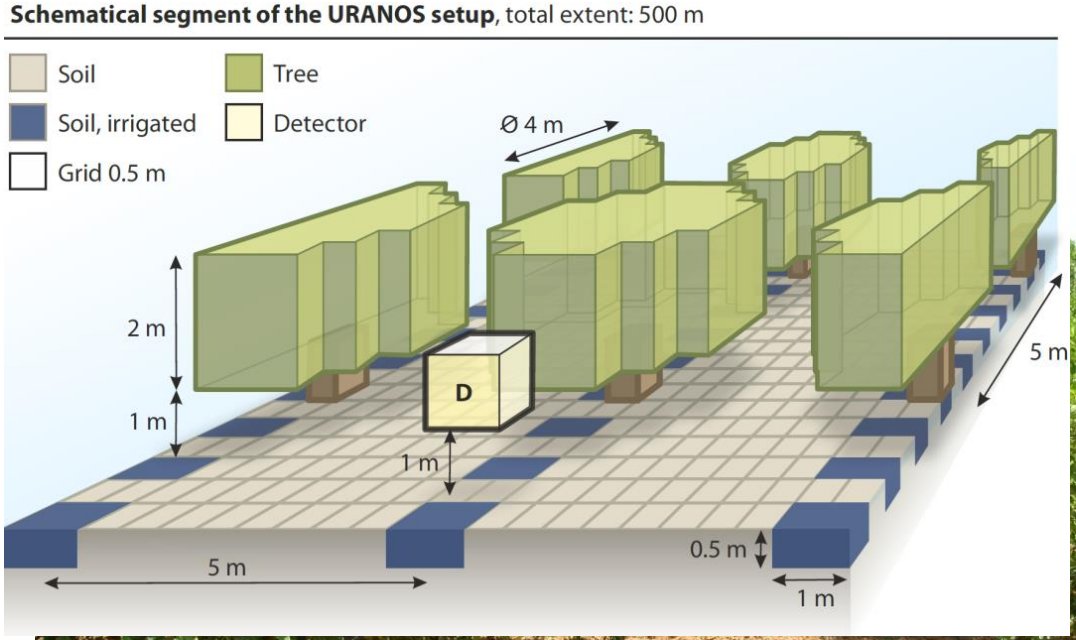
# Picassent SWC timeseries



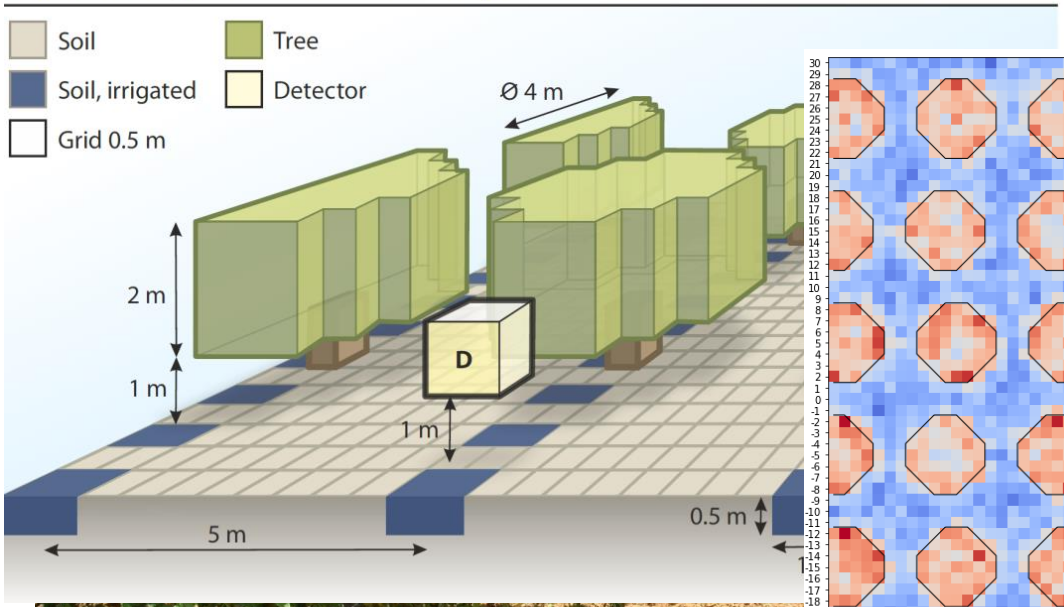
# NS > Picassent SWC timeseries

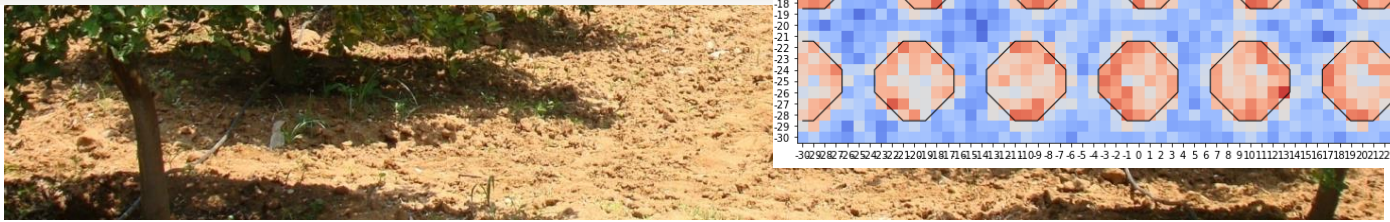


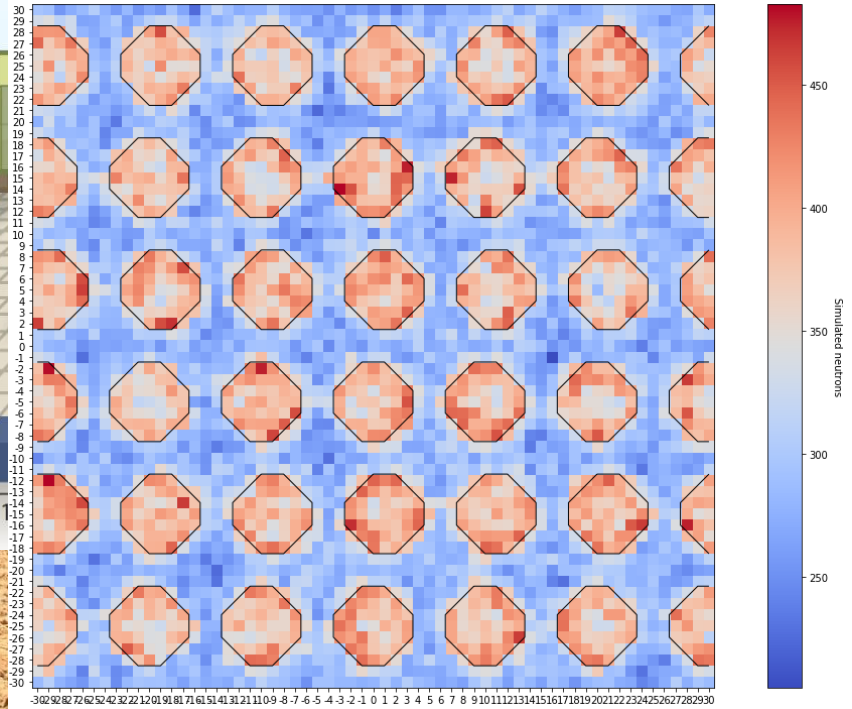
# Picassent URANOS simulation



# Picassent URANOS simulation

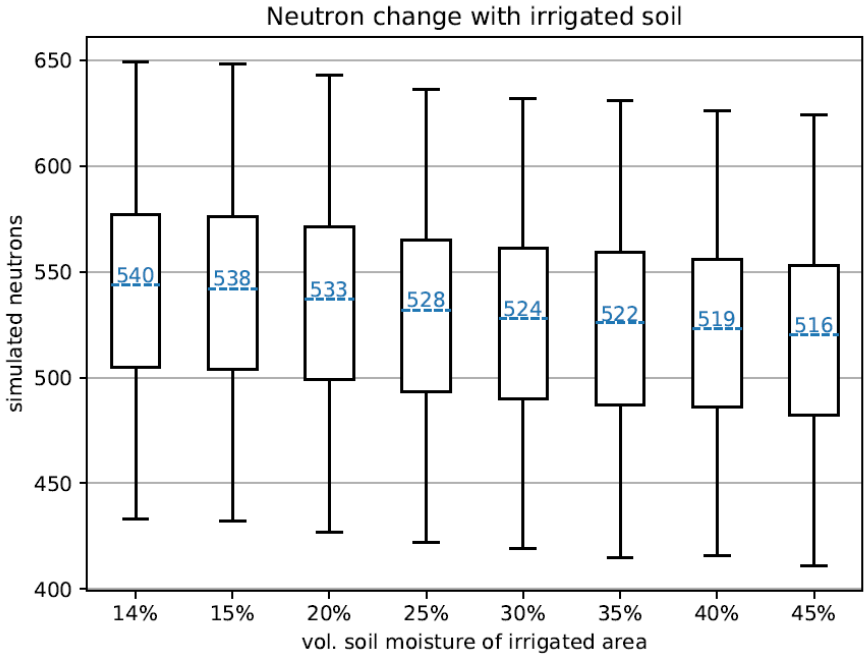


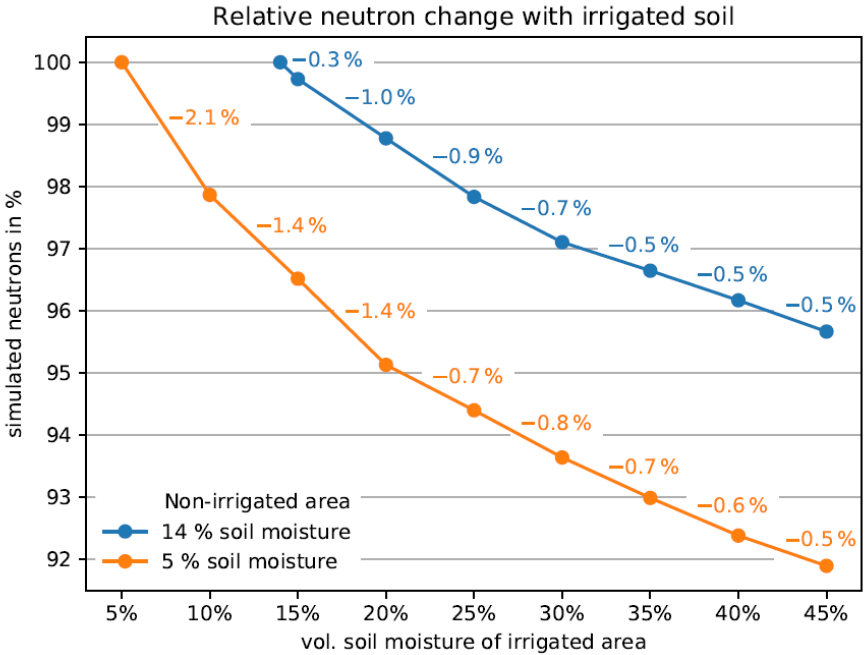


# Drip Irrigation – Simulation Results

Lemon trees: 3 kg/m³ biomass
8 % of soil irrigated



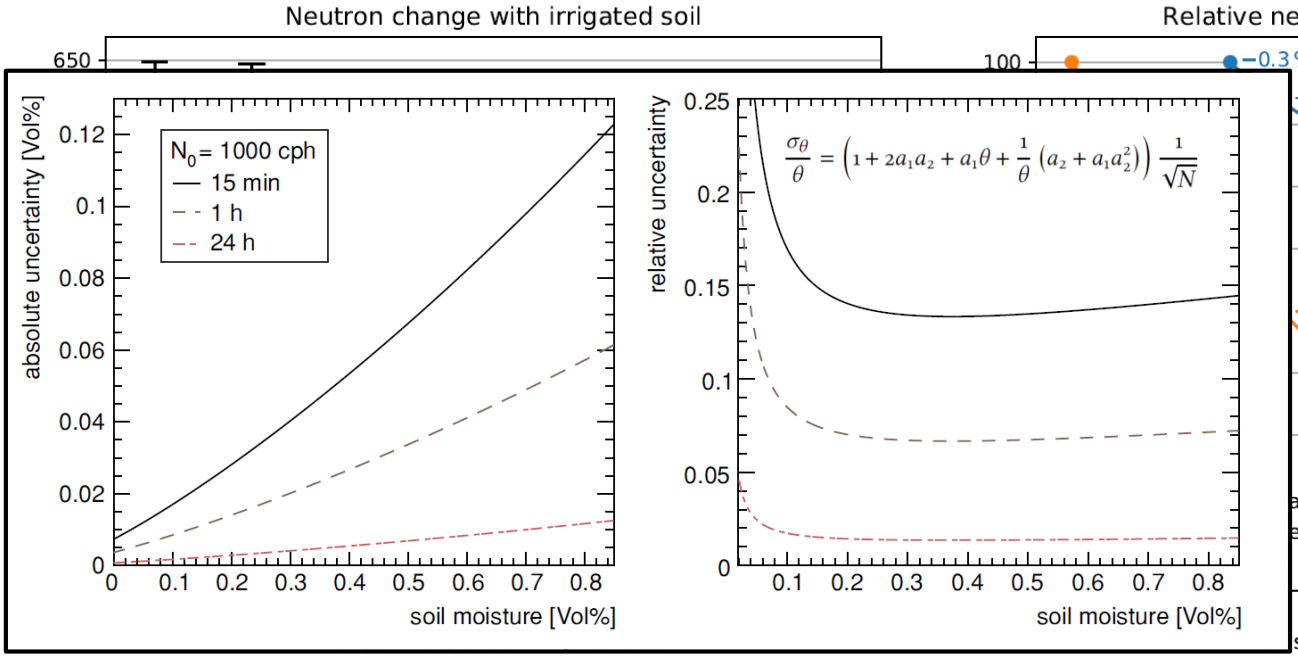

Only a few percent change -> needs large sensor

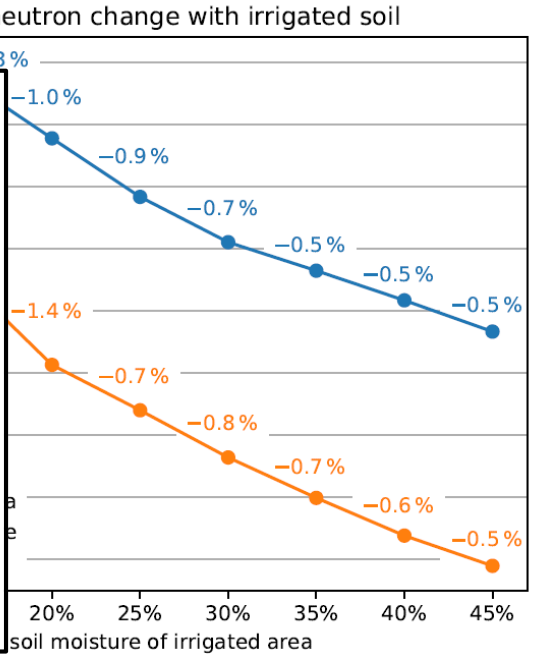


# Drip Irrigation – Simulation Results

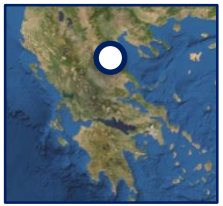
Lemon trees: 3 kg/m³ biomass
8 % of soil irrigated

Only a few percent change -> needs large sensor



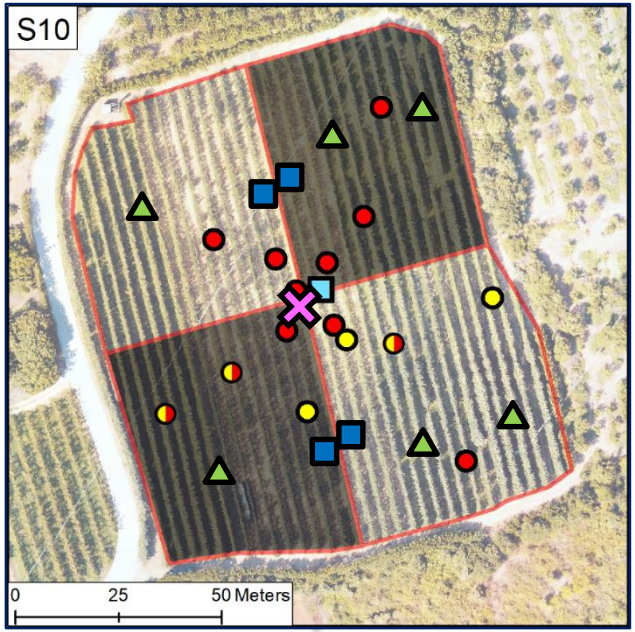
# NS > Greece – Sprinkler irrigation

In collaboration with
C. Brogi
FZ Jülich

ATLAS
AGRICULTURAL INTEROPERABILITY AND ANALYSIS SYSTEM

# NS > Greece – Agia experimental site




- Cosmic Ray Neutron Sensor
- Atmos41 (climate station)
- SoilNet (soil moisture, *h*, and temperature)
- Water Meters (irrigation in $m^3$)
- Sap-Flow
- Monitoring Camera
- Irrigation plots

- 1.21 ha apple orchard equipped with sprinkler irrigation
- 30 nodes with 204 instruments. Near-real time transmission with NB-IoT, LoRaWAN, and 4G

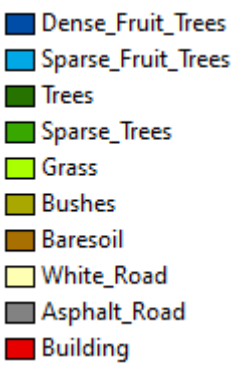
In collaboration with
C. Brogi
FZ Jülich

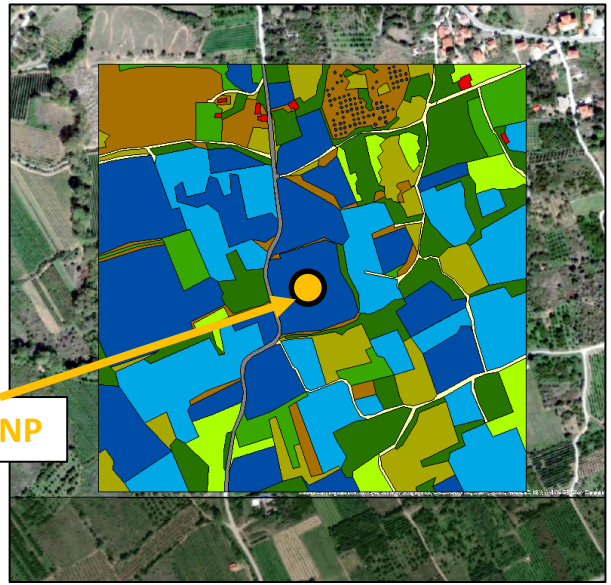
ATLAS
AGRICULTURAL INTEROPERABILITY AND ANALYSIS SYSTEM

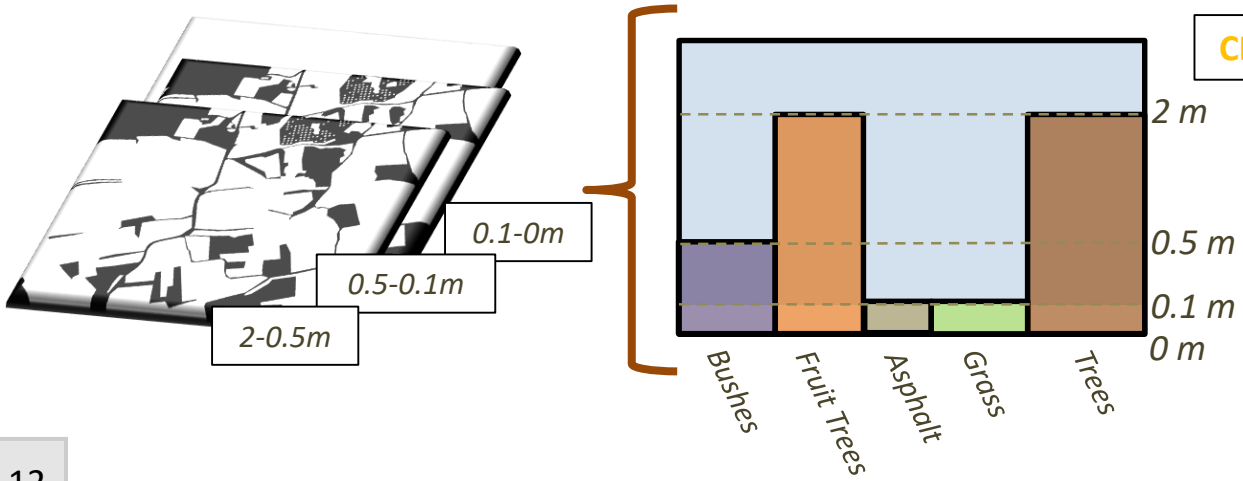
# URANOS Agia simulation

Setup of the actual scenario simulations:

- 600x600 meters domain (center CRNP)
- Irrigation area coincident with field S10
- 8 layers covering 1000 meters of air and 1.6 meters of soil.
  - 4 layers of air (with source/detector)
  - 3 layers of vegetation/air
  - 3 layers of soil (0-0.125, 0.125-0.35, 0.35-1.6)



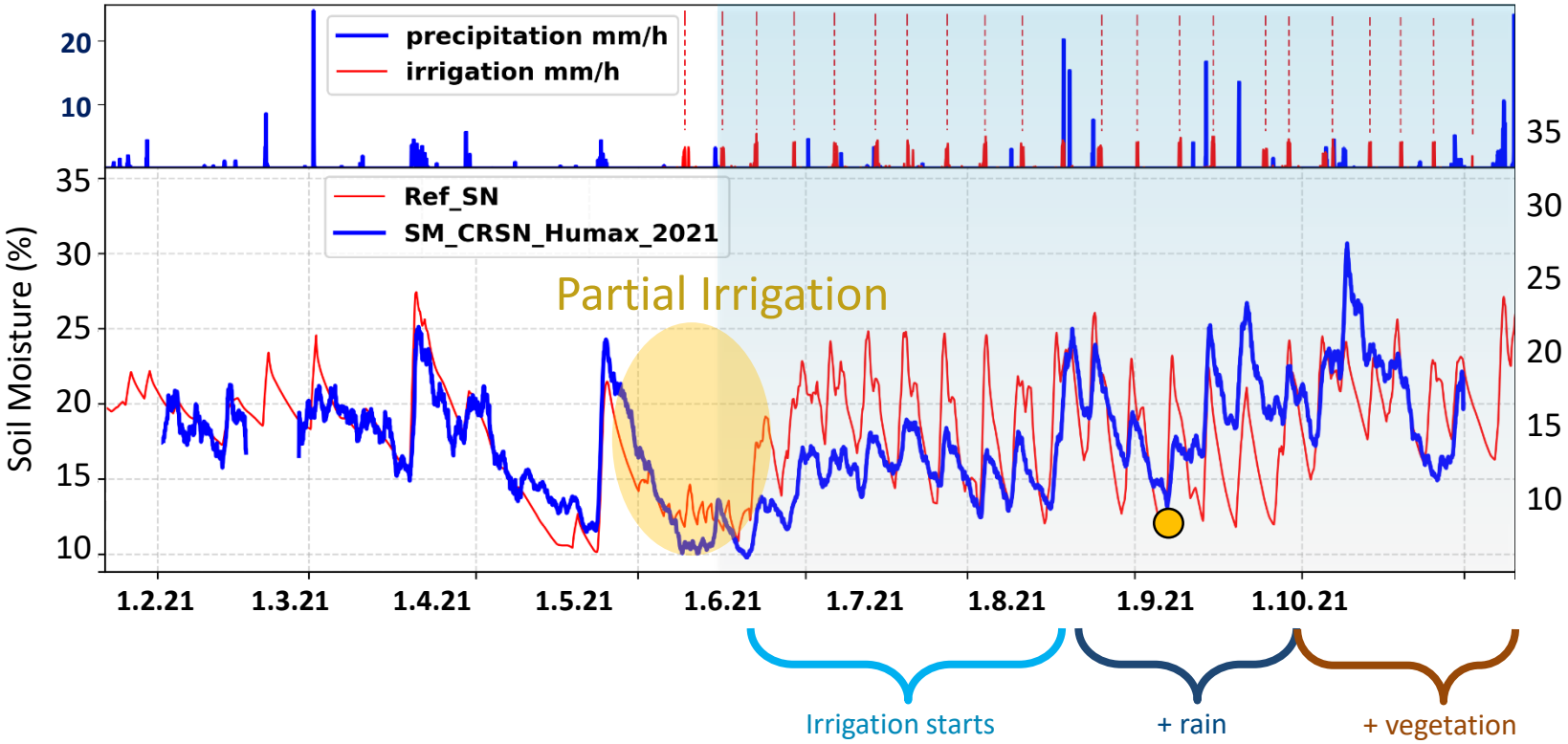



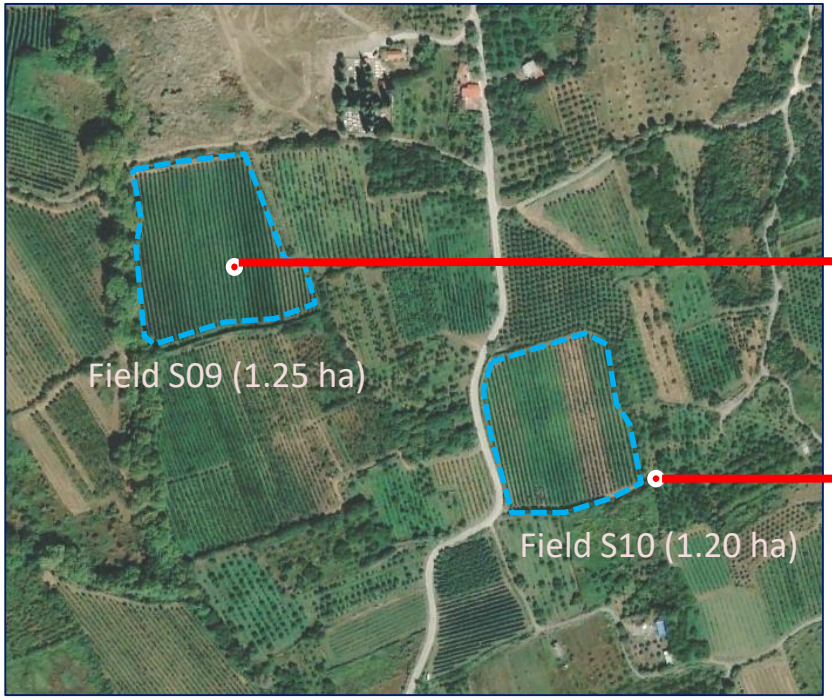
# NS > Agia CRN timeseries

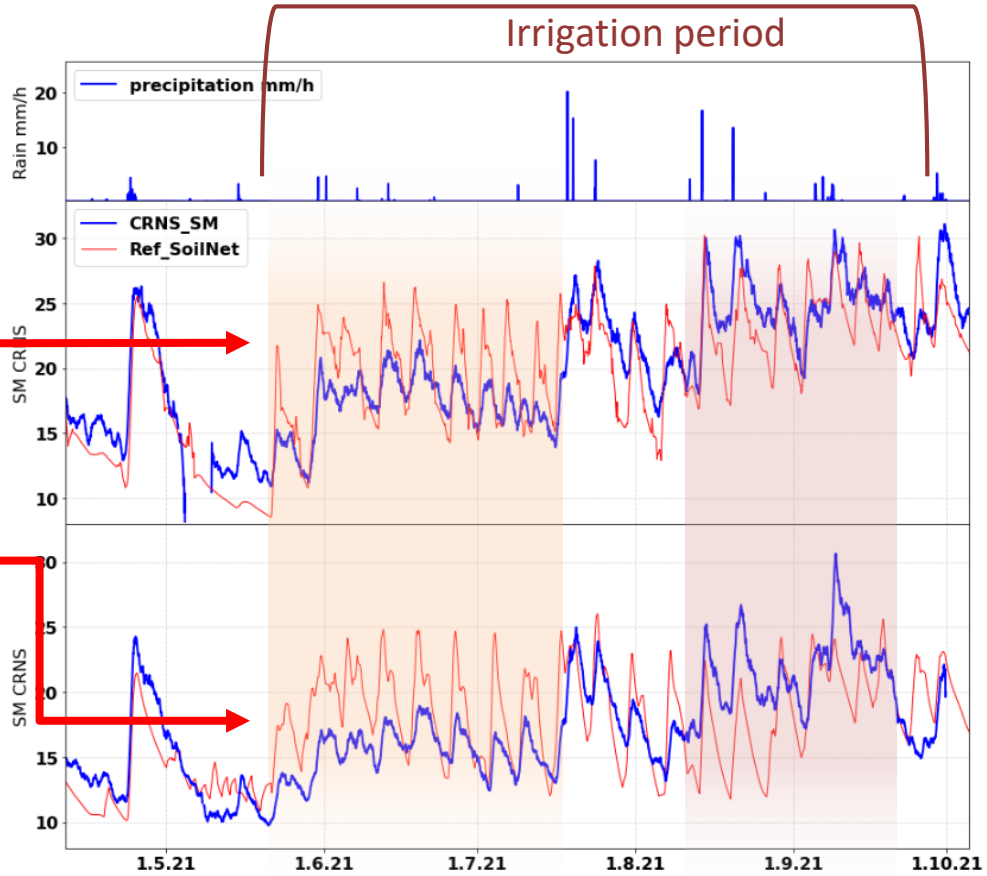
Before irrigation, the soil moisture obtained with the CRNS well match the reference data.

With irrigation, only the temporal dynamics are partially represented.

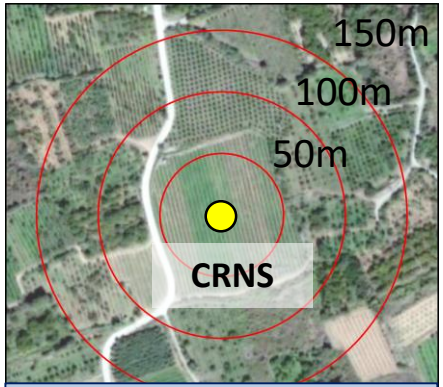


# Agia CRN timeseries

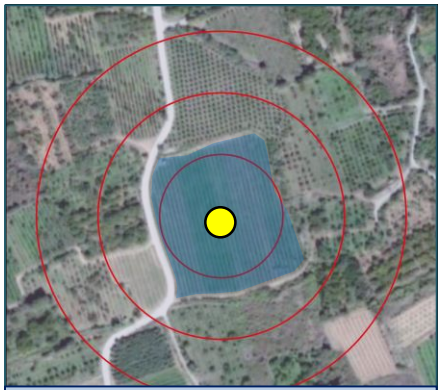


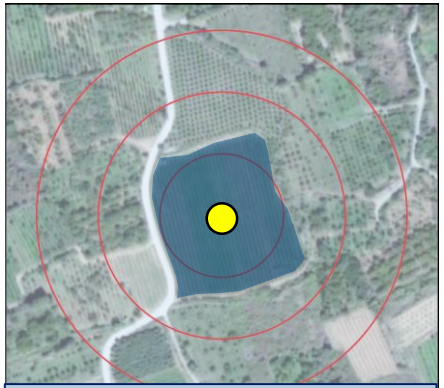
# Agia – irrigation scenarios



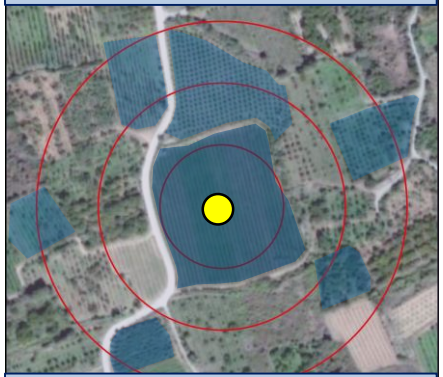

Standard conditions



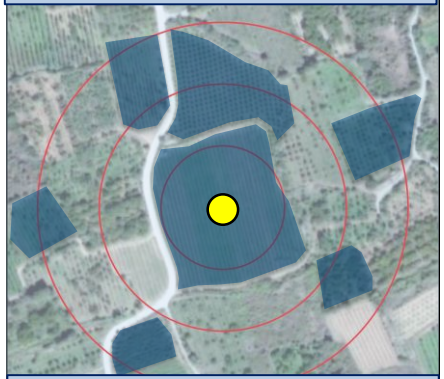
Irrigated field



Irrigation + rain

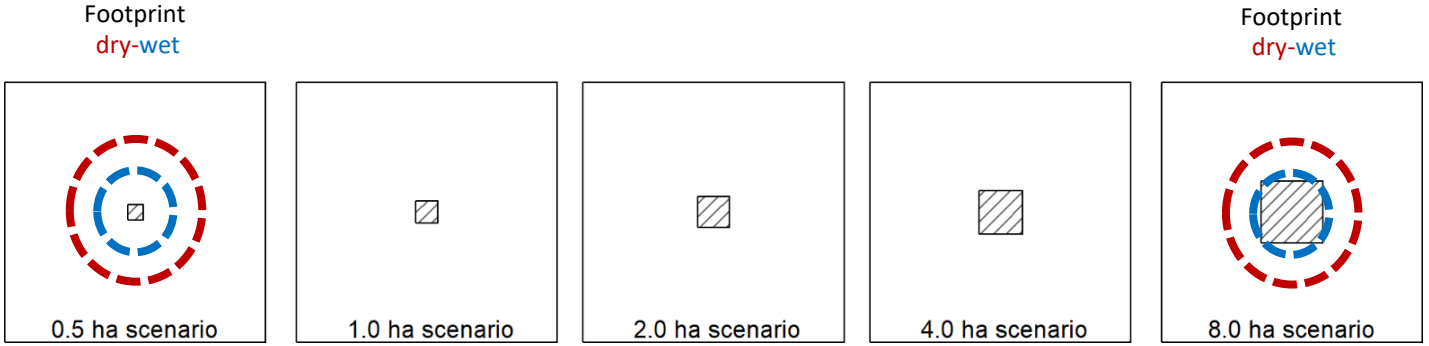


Multiple irrigations

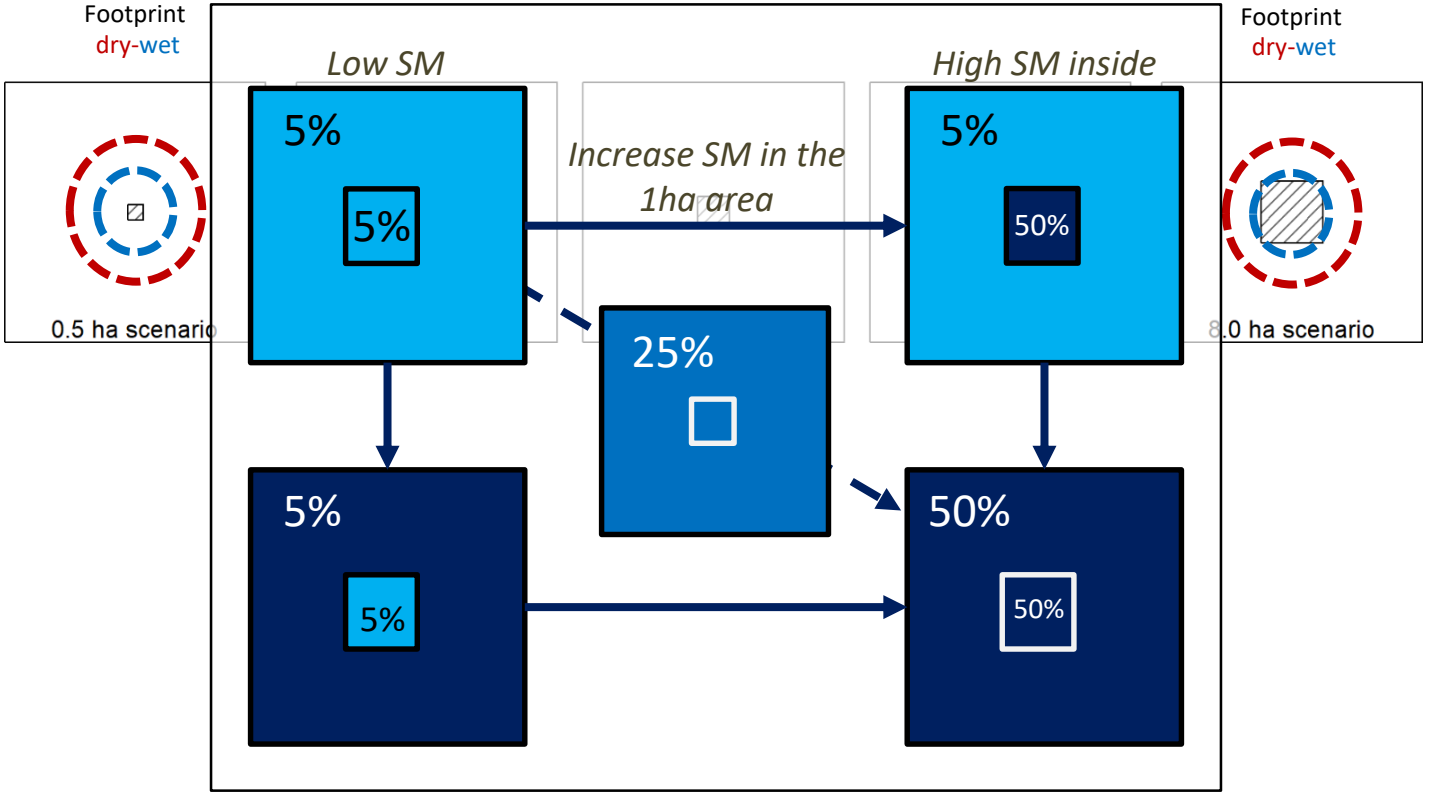


Nightmare!

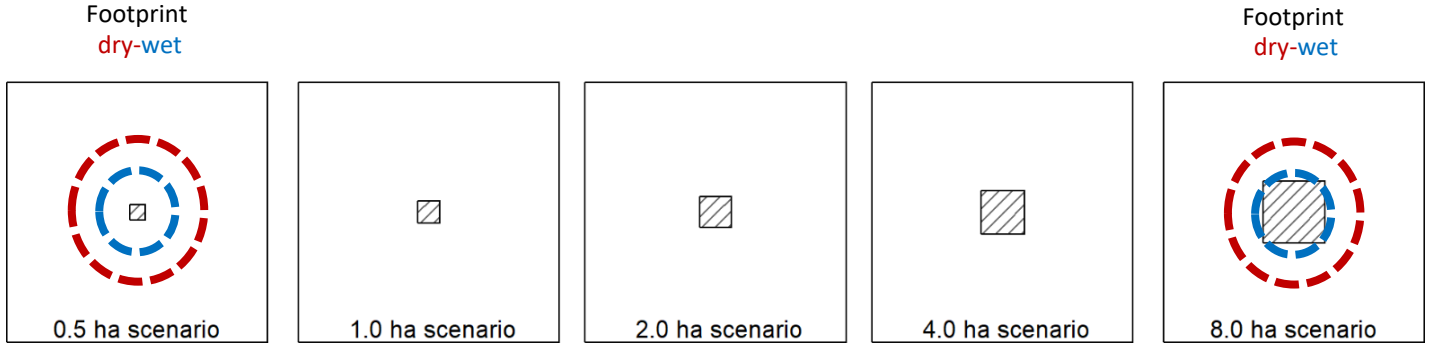
# NS > URANOS sprinkler irrigation scenarios

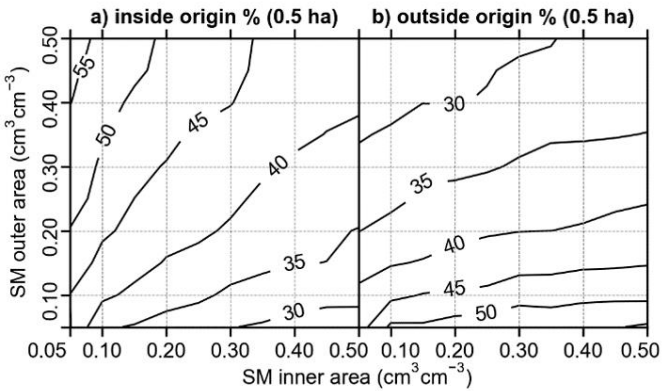


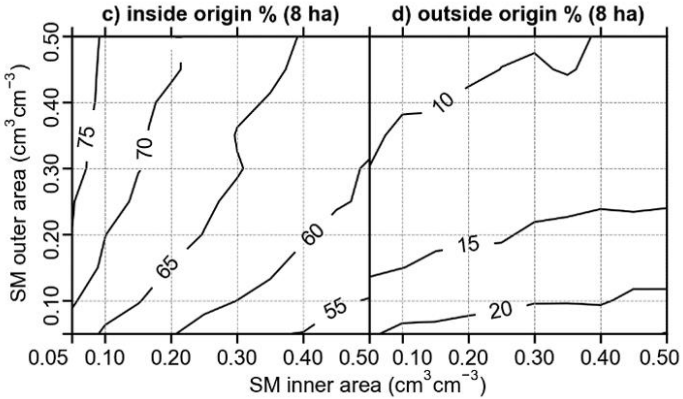
# URANOS sprinkler irrigation scenarios



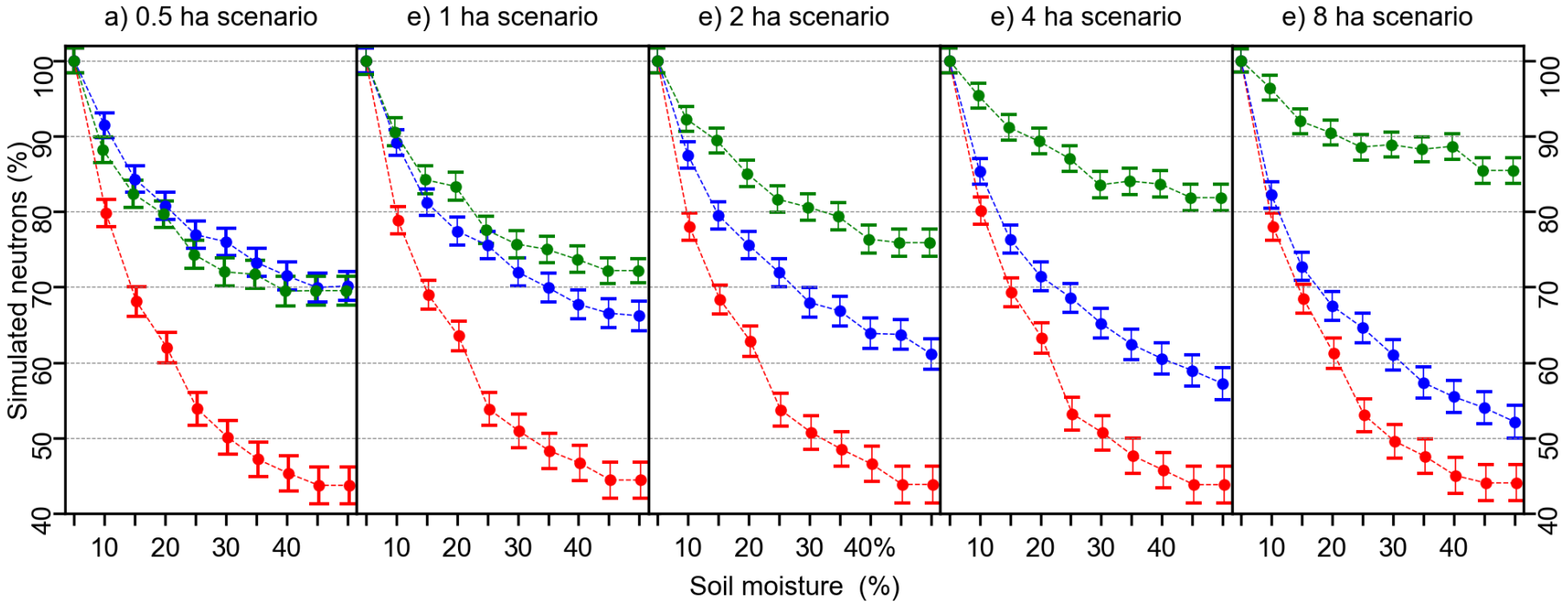
# URANOS sprinkler irrigation scenarios



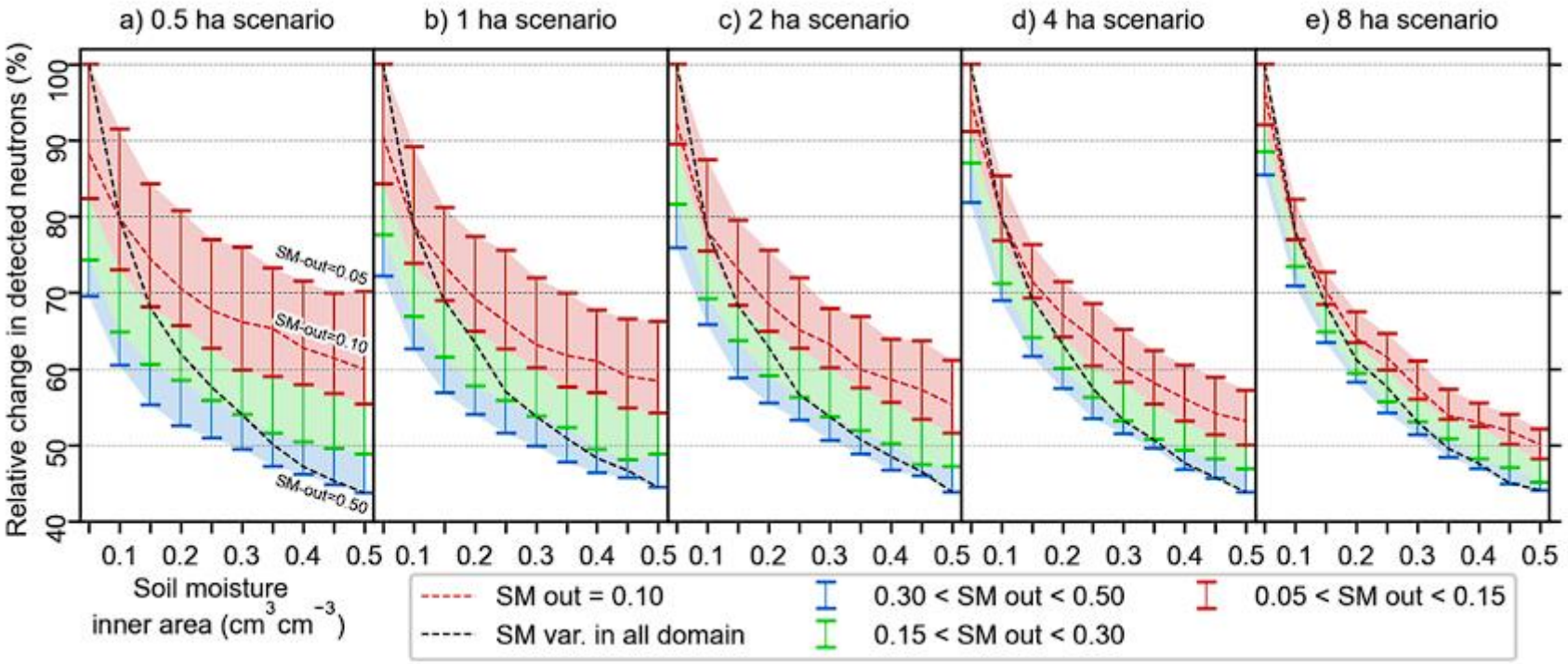
# NS > Sub-Footprint CRN intensity changes






Physikalisches Institut, Universität Heidelberg

# Sub-Footprint CRN intensity changes



# NS > Summary

- **Site-specific intensity functions** can describe sub-footprint heterogeneity
- Drip irrigated SWC changes can only be resolved by a large sensor
- Sprinkler irrigation > 1 ha can be resolved if outside SM can be estimated
- Sub-Footprint heterogeneity in CRNS for irrigation quantitatively understood

Our partners are Cosimo Brogi, Heye Bogena, Harrie-Jan Hendricks-Franssen, Sander Huismann, Olga Dombrowski from FZJ.
From SWRI Thessaloniki, Vasilios Pisinaras, Andreas Panagopoulos, Ioannis Tsakmakis, Kostantinos Babakos and Anna Chatzi.

# NS > Summary

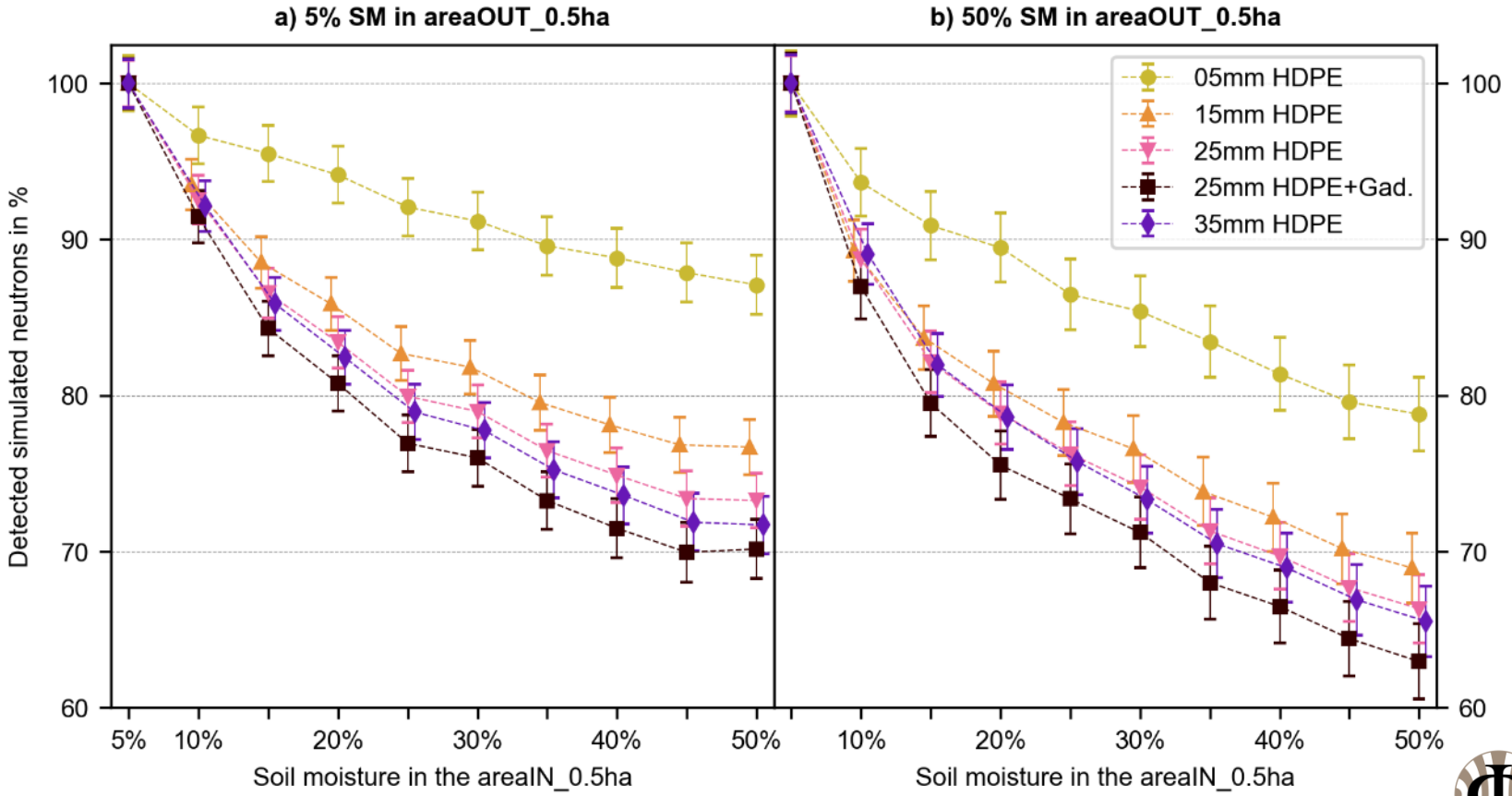
- **Site-specific intensity functions** can describe sub-footprint heterogeneity
- Drip irrigated SWC changes can only be resolved by a large sensor
- Sprinkler irrigation > 1 ha can be resolved if outside SM can be estimated
- Sub-Footprint heterogeneity in CRNS for irrigation quantitatively understood

Outlook:

- Analytical expressions for field scenarios: size, target SWC delta, outside conditions

Our partners are Cosimo Brogi, Heye Bogena, Harrie-Jan Hendricks-Franssen, Sander Huismann, Olga Dombrowski from FZJ.
From SWRI Thessaloniki, Vasilios Pisinaras, Andreas Panagopoulos, Ioannis Tsakmakis, Kostantinos Babakos and Anna Chatzi.

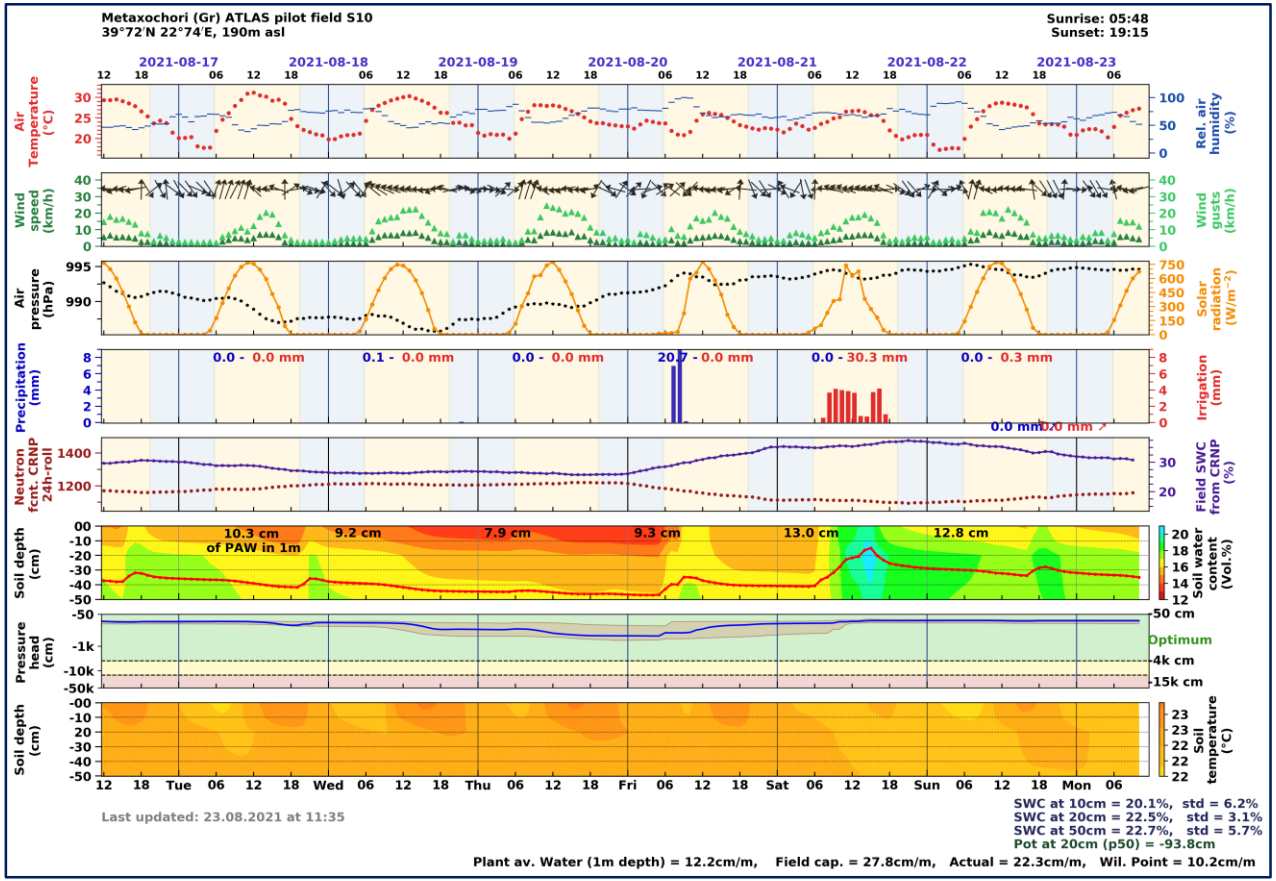
# Influence of moderator thickness



# Cosmic Sense NS > Agia frontend example

*Data recorded in the instrumented field between 17th and 24th Aug 2021*

- Air temperature
- Wind speed
- Air pressure
- Precipitation
- CRNS soil moisture
- SoilNet soil moisture
- SoilNet pressure head
- SoilNet temperature




- Air humidity
- Wind gusts
- Solar radiation
- Irrigation
- Neutron count
- Plant av. water