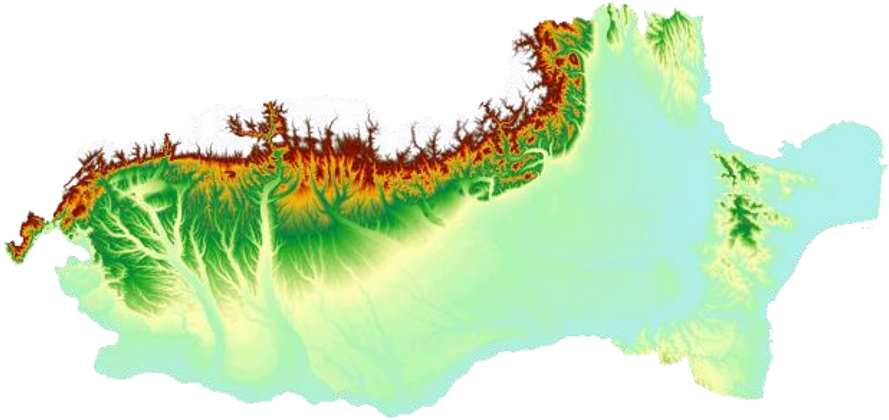
Virtual Water Values (ViWA)

ViWA

Multiscale Monitoring of Global Water Resources and
Options for their Efficient and Sustainable Use

The Romanian Plain – Coupling Agro-Ecological Modeling and Sentinel-2 Observations to Measure the Water Use Efficiency of Crop Production



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Romanian Plain in the scope of ViWA

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- The scope of ViWA: development of a global high-resolution monitoring system for observing agricultural management and for assessing the sustainability of agricultural water use
- Agricultural yield and water use efficiency (WUE) is the product of natural boundary conditions (climate, topography, soil, …) and farmers' management
  - natural boundary conditions can be determined by models
  - agricultural management can be observed by satellite data

$$\mathrm{WUE} = \frac{\mathrm{Crop\ Yield\ [kg]}}{\mathrm{Evapotranspiration\ [m^3]}}$$

→ ViWA Core: coupling of PROMET crop simulations with Sentinel-2 EO data

→ derivation of **actual management**, **yield** and **WUE**

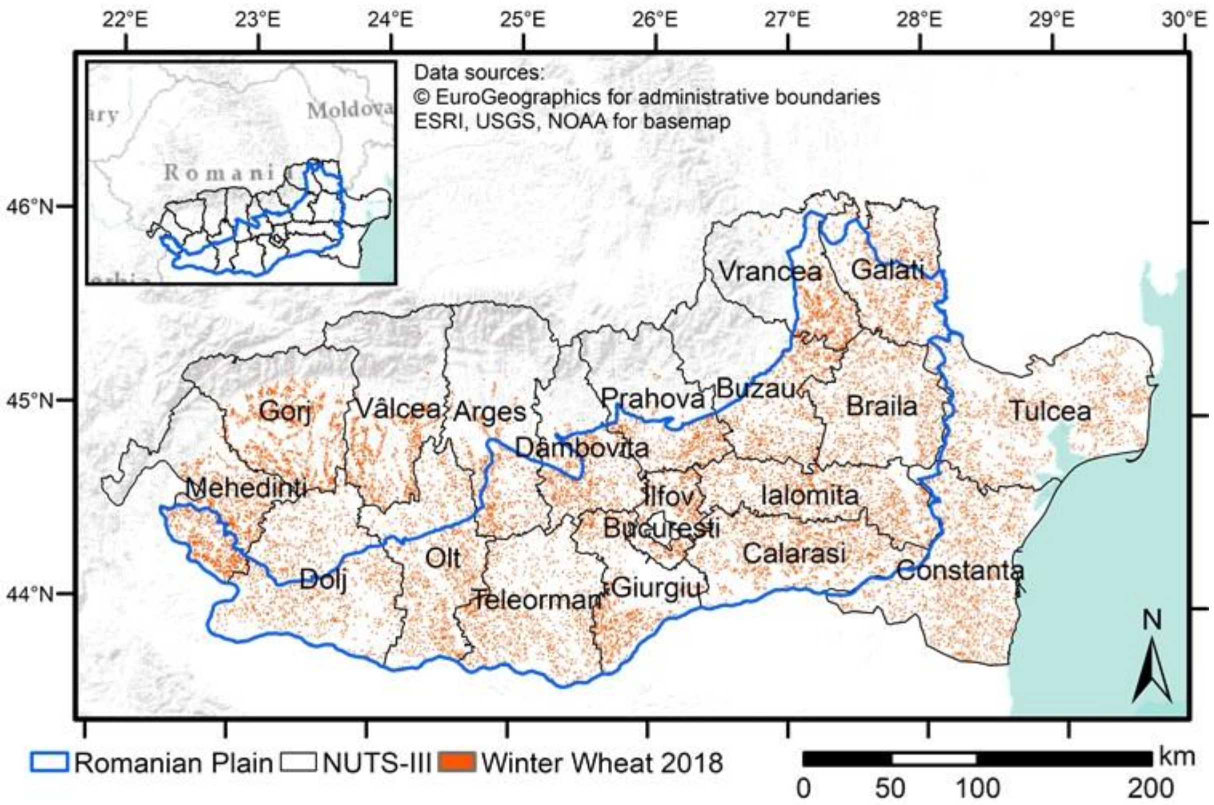
→ Romanian Plain serves as a test region for ViWA's global monitoring system

The Romanian Plain

- Extensively used, fertile cropland with large agricultural potentials, but recurrent droughts
- Low crop yields and WUE due to poor fertilization, low degree of mechanization, inefficient irrigation
- Improving WUE is key for sustainable agricultural management

Major question:

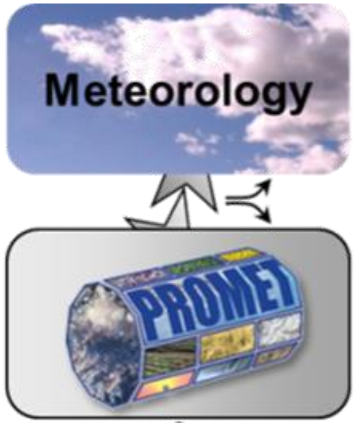
How can we derive yield & WUE through the coupling of PROMET crop simulations with Sentinel-2 EO data?



Methods (I): the PROMET agro-ecological model

Global reanalysis (ERA5)

Near real-time Input:
S2 data streams (LAI)



Input:

Tables and GIS-layers

Output:

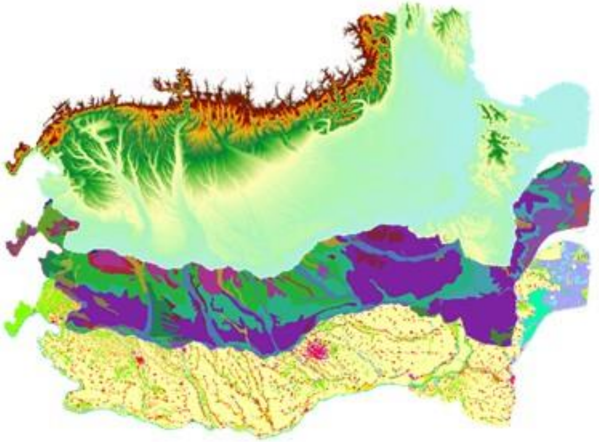
Raster data and tables

Validation
Yield statistics

SRTM

HWSD

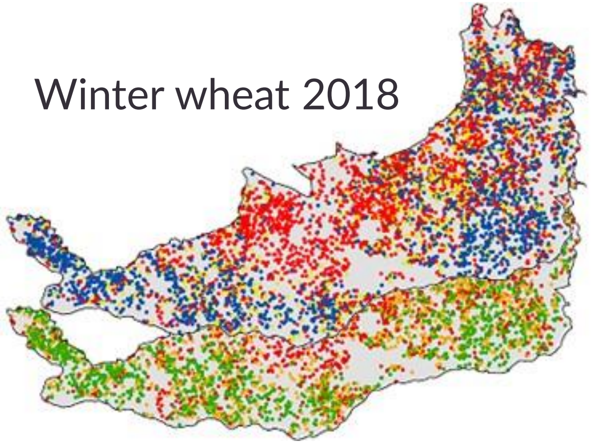
CORINE 2018



Agro-ecological model:
(Mauser & Bach 2009; Hank et al. 2015)

- Biophysically based crop growth modeling
- Spatially explicit (1 km²)
- Hourly time steps
- Allows assimilation of EO data

Winter wheat 2018



WUE

Yield

Parametrizations

Management parameters ?

Methods (II): LAI derivation from Sentinel-2

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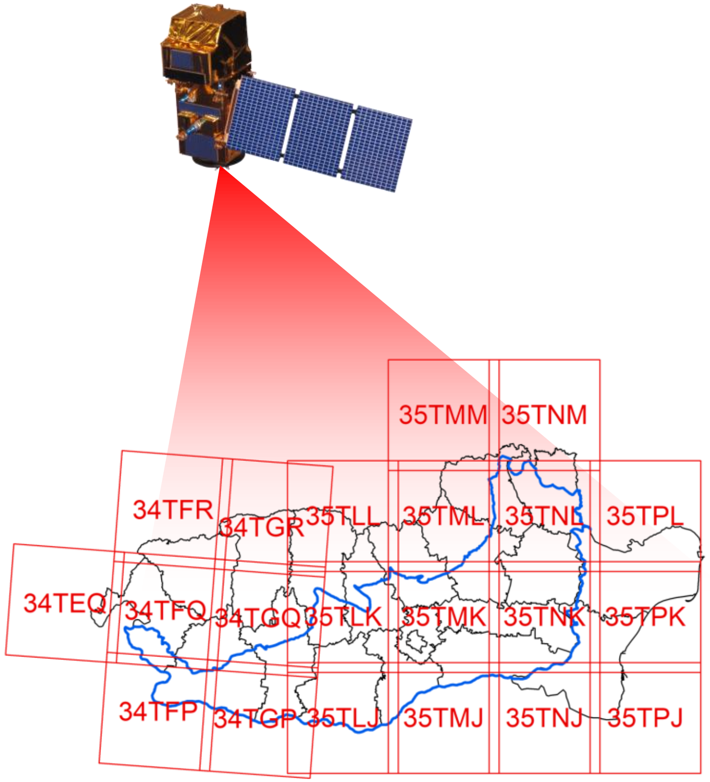
Input:

Optical EO data: Sentinel-2

food security tep

Output:

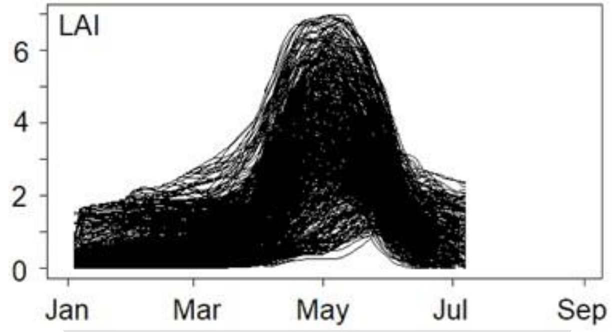
Continuous LAI courses

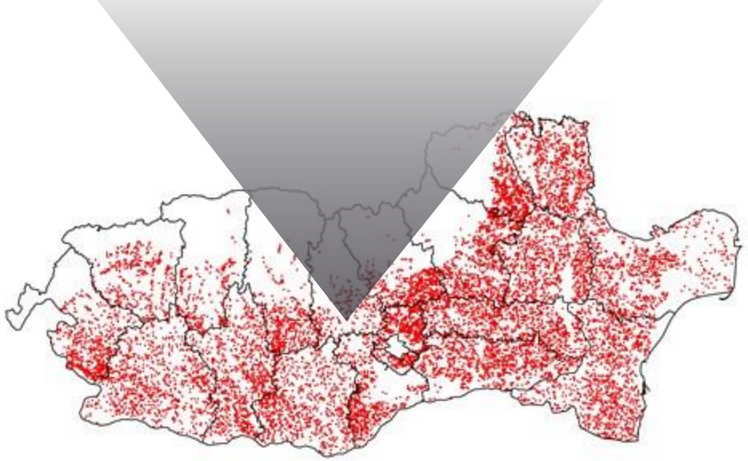


Sentinel-2 processing chain:

- Preprocessing (atmospheric correction, crop type classification)
- Plant parameter retrieval (SLC inversion) (Verhoef & Bach 2003, 2007, 2012) → green LAI
- Sampling & temporal interpolation

Vista





Coverage: 21 tiles, full growing season 2018
Repetition rate: ~3 days

Sample of >10,000 pixels identified as winter wheat in 2018

Methods (III): Informing PROMET with Sentinel-2

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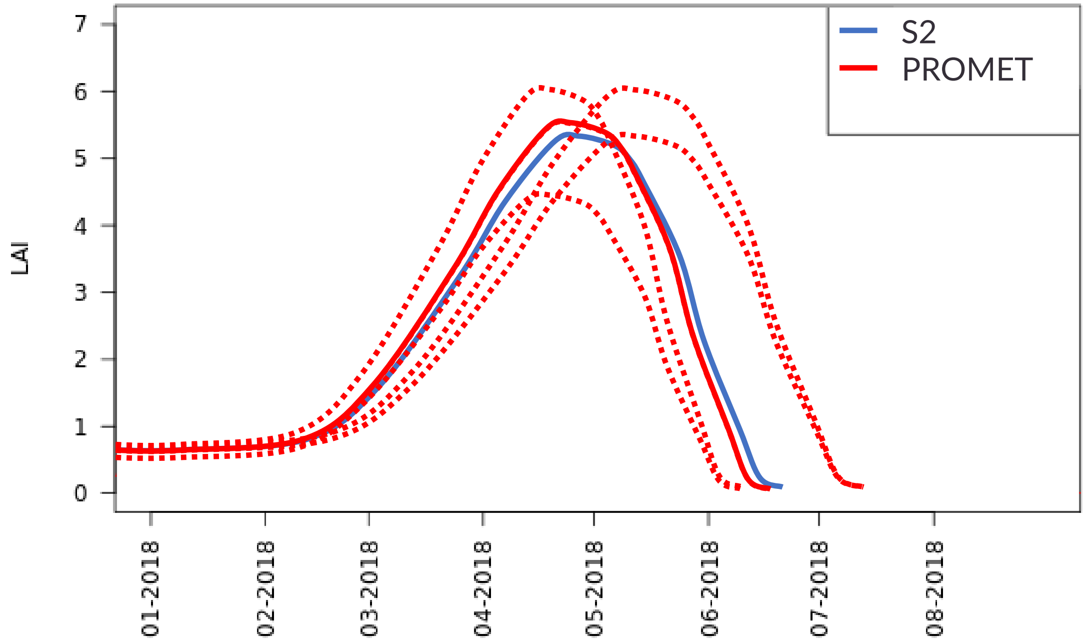
- Ensemble of PROMET simulations with large variation in management
  - **Seeding date** (early–late)
  - **Fertilization level** (poor–high)
  - **Cultivar selection** (early ripening–late ripening)

PROMET ensemble with >2,000 members



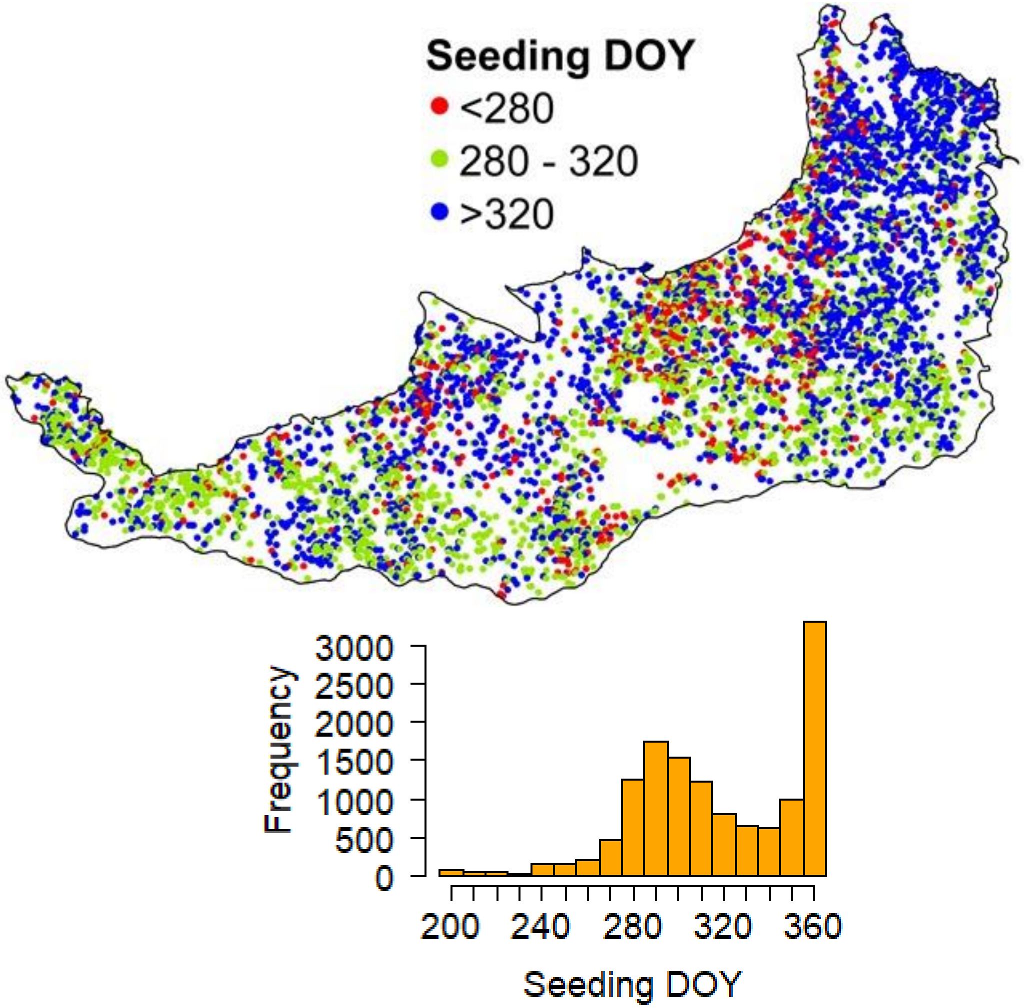
Selection of best-fitting PROMET ensemble member on each winter wheat pixel:

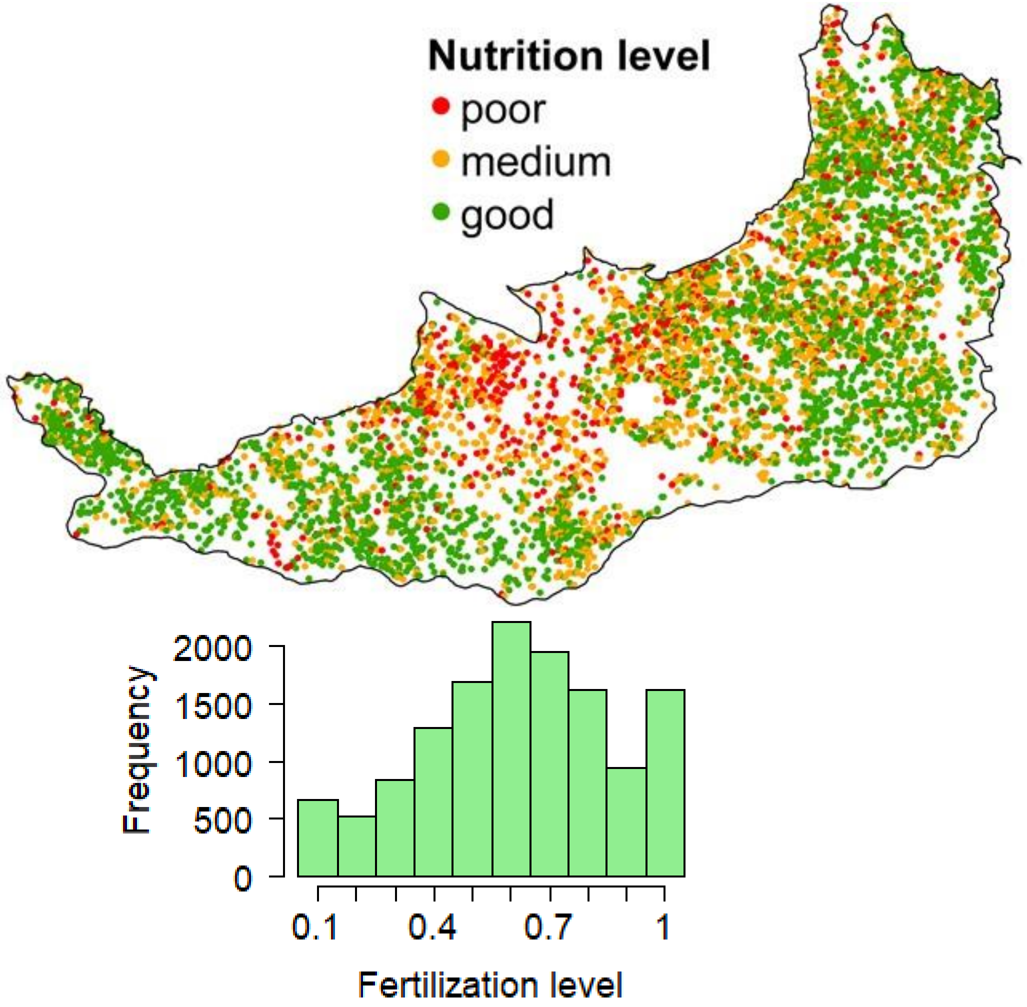
✓ Lowest RMSE between S2-LAI and PROMET-LAI

→ **actual management** identified per pixel from best-fitting ensemble member

Results (I): Actual management distribution 2018

- What do we learn from the PROMET ensemble comparison with Sentinel-2?





Methods (IV): Assimilating Sentinel-2 in PROMET

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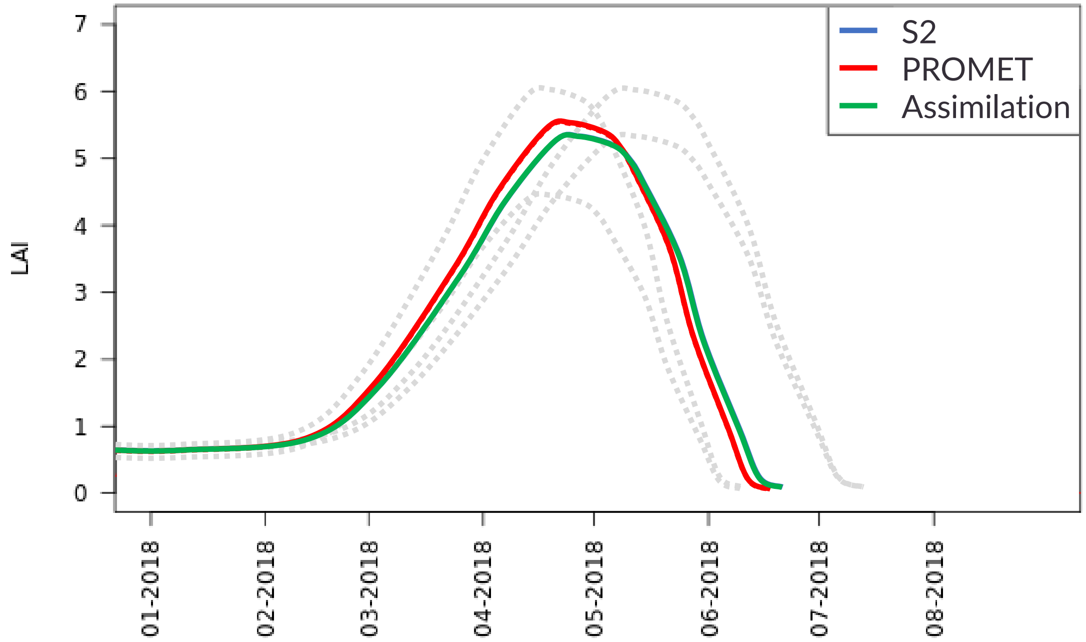
- Results of PROMET ensemble simulations
  - **Seeding date** (early–late)
  - **Fertilization level** (poor–high)
  - **Cultivar selection** (early ripening–late ripening)

Best-fitting ensemble member selected per pixel



Direct assimilation of measured S2-LAI courses in PROMET simulations driven with best-fitting (=actual) management per pixel

→ **actual yield** and **WUE** determined per pixel from assimilation

Results (II): Actual yield & WUE 2018

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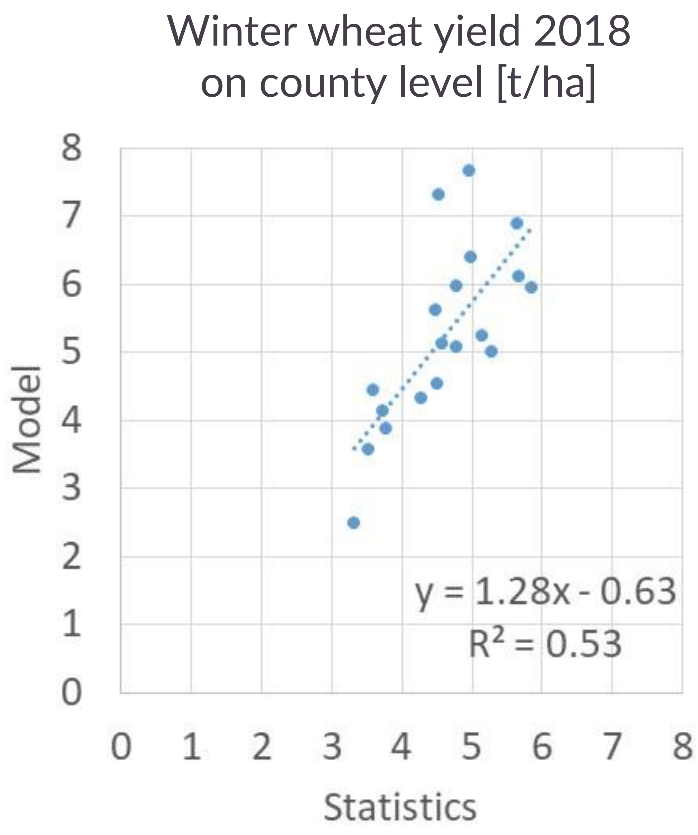
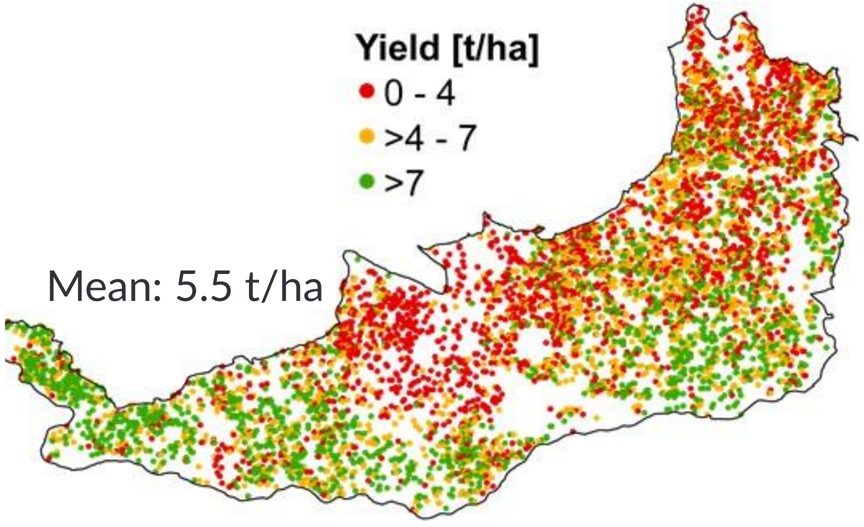
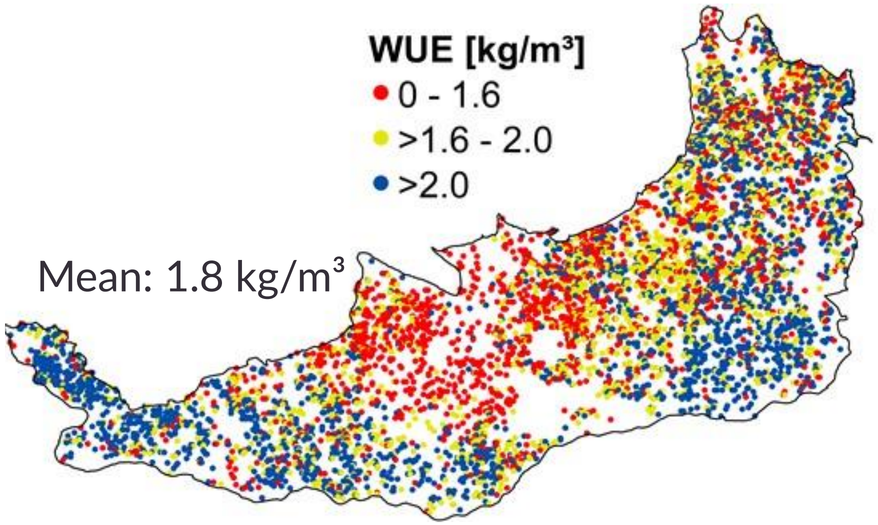
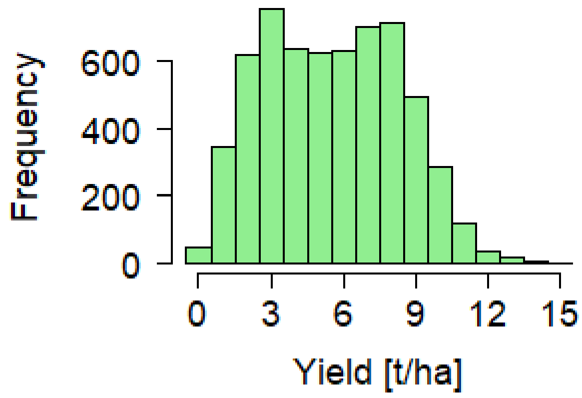
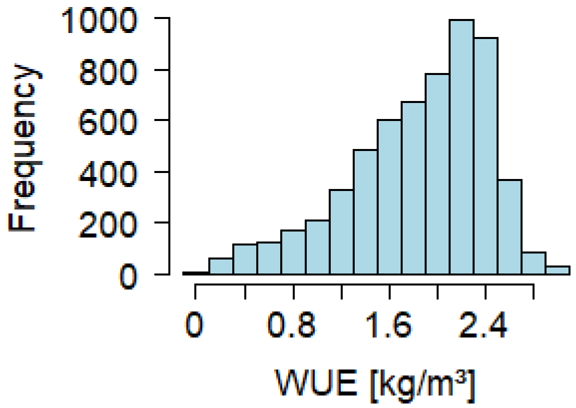
- What do we learn from the assimilation of S2-LAI in PROMET?











Conclusions

- Coupling data streams of high-resolution EO satellites (Sentinel-2) with mechanistic crop models (PROMET) results in a deeper understanding of actual agriculture and its water uses
  - Derivation of **actual management** (e.g. seeding, crop variety, harvest)
  - Determination of **actual yield, evapotraspiration** and **WUE**

  → Basis for global yield & WUE monitoring system

Further Research Questions

- What are regional potentials to **minimize yield gaps** and to **maximize WUE?**
- In the context of "sustainable intensification" how to close yield gaps within the limits of sustainability (minimization of ecological footprint)
  - How much land could be given back to nature at saved?
  - How much water could be saved?
- What are regionally tailored management recommendations for a more efficient and sustainable use of scarce agricultural water resources in the context of "sustainable intensification"?

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