

EO for Agriculture Under Pressure

Workshop 2024

13-16 May 2024 | ESA-ESRIN | Frascati (Rome), Italy

Estimation of winter cereals yield exploiting remotely derived phenometrics from LAI time-series.

CONTEXT, ISSUES AND MITIGATION

- Predicting crop yield** was a key issue since the first farming systems were set.
 - It's even more compelling now because of climate change and a growing population.
- Earth Observation (EO) programs give the opportunities to **monitor crop growing over large areas** at field scale.
 - used in **data-driven approaches** to estimate yield employing a variety of approaches.

GOAL

Estimate yield of winter cereals at field level exploiting a **multi-year dataset of ground data** and satellite derived **time series of Leaf Area Index (LAI)** with a non-parametric regressive approach.

Scientific questions:

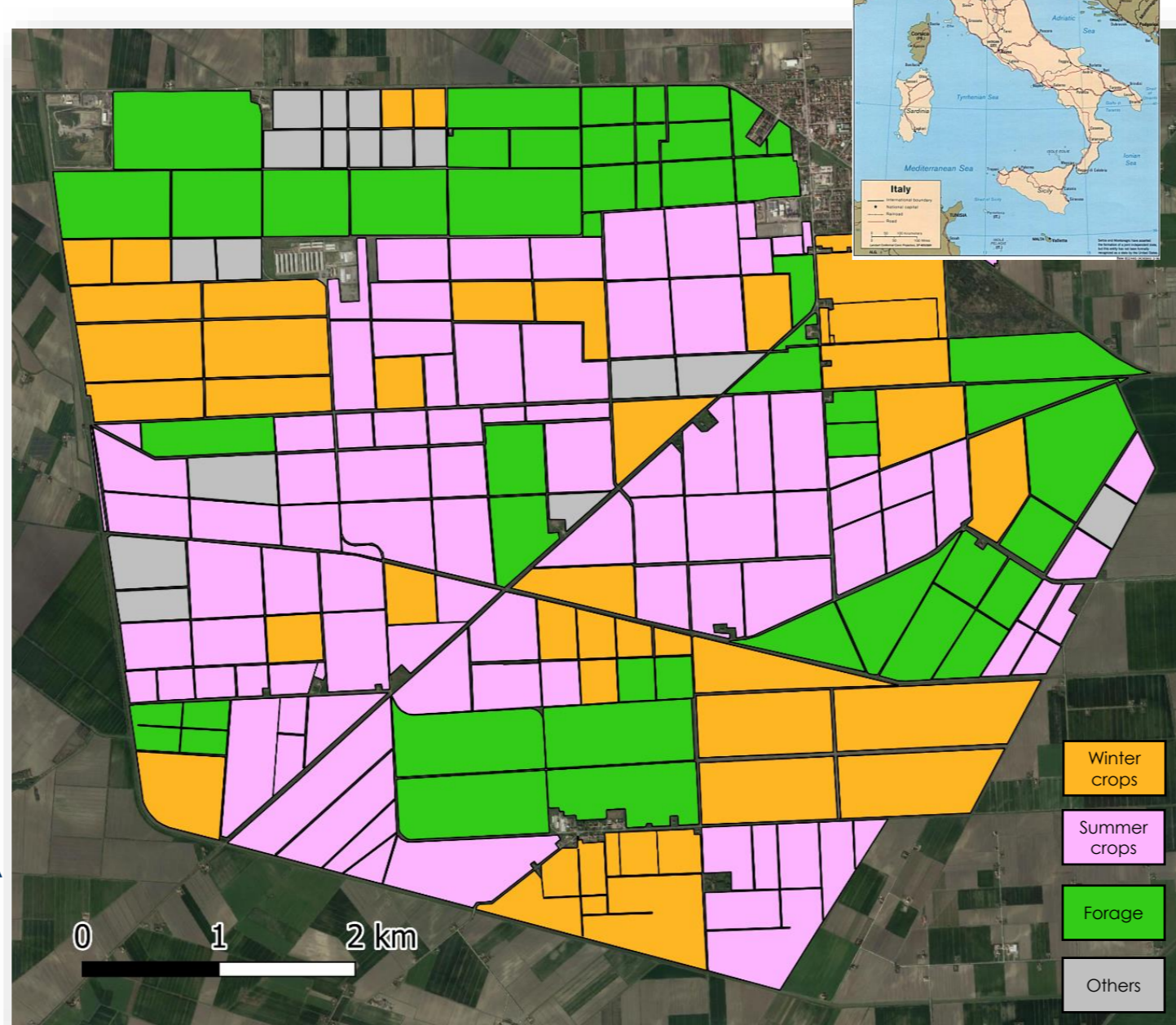
- which phenology metrics is more promising to explain yield variability?
- how far can we go without exploring other variables (e.g. rainfall, temperature, biotic and abiotic stresses)?

STUDY AREA AND MATERIALS

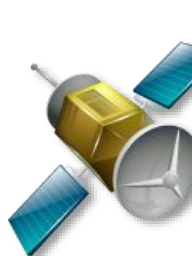


Field data

- #183 grain yield of winter cereals.
 - Collected on 20*20 m elementary sampling units (ESU).
 - Acquired for 4 cropping seasons (2020-2023).



Location: Jolanda di Savoia (ITA)
Farm size: 3850 ha



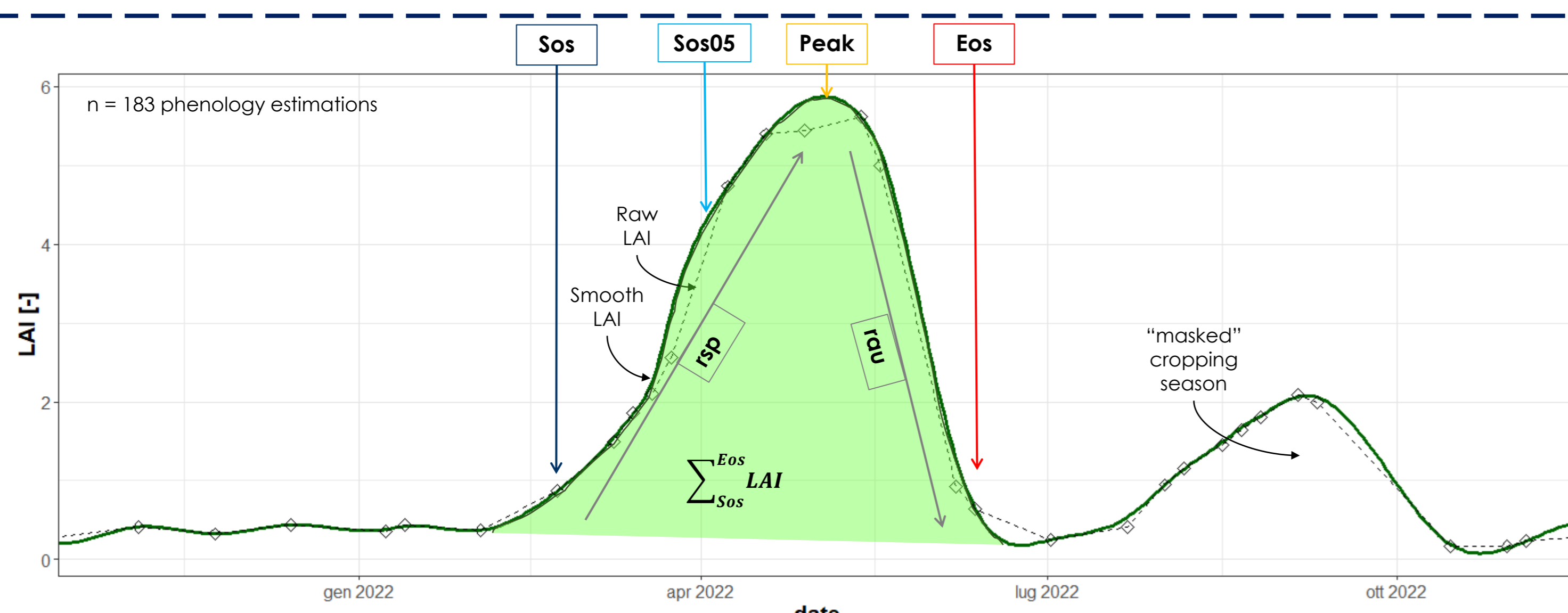
EO imagery

- Sentinel-2: automatic processing procedure to compute LAI with biophysical processor (Weiss et al., 2016) from THEIA Sentinel-2 archive (atmospherically corrected with MAJA).
 - spatially co-registered using AROSICS algorithm,
 - Covering all cropping seasons (Oct-Jul).

METHODOLOGICAL STEPS

- LAI time-series** extraction in correspondence of ESUs (#183 samples).
- raw data gap filling & interpolation** exploiting time series analysis of R package {sen2rts} <https://ranghetti.github.io/sen2rts>.
 - Based on two iterations of Savitzky-Golay filter.
- Phenological metric extraction** with method inherited from R package {phenpix} – Filippa et al., (2016.)
 - About **30 phenometrics** are computed to fully describe the crop growth (i.e. LAI curves).
- Regression analysis (#126 train; #31 test):**
 - Single variable importance investigate with linear regression
 - Multivariate tests conducted with **random forest (RF)** algorithm.

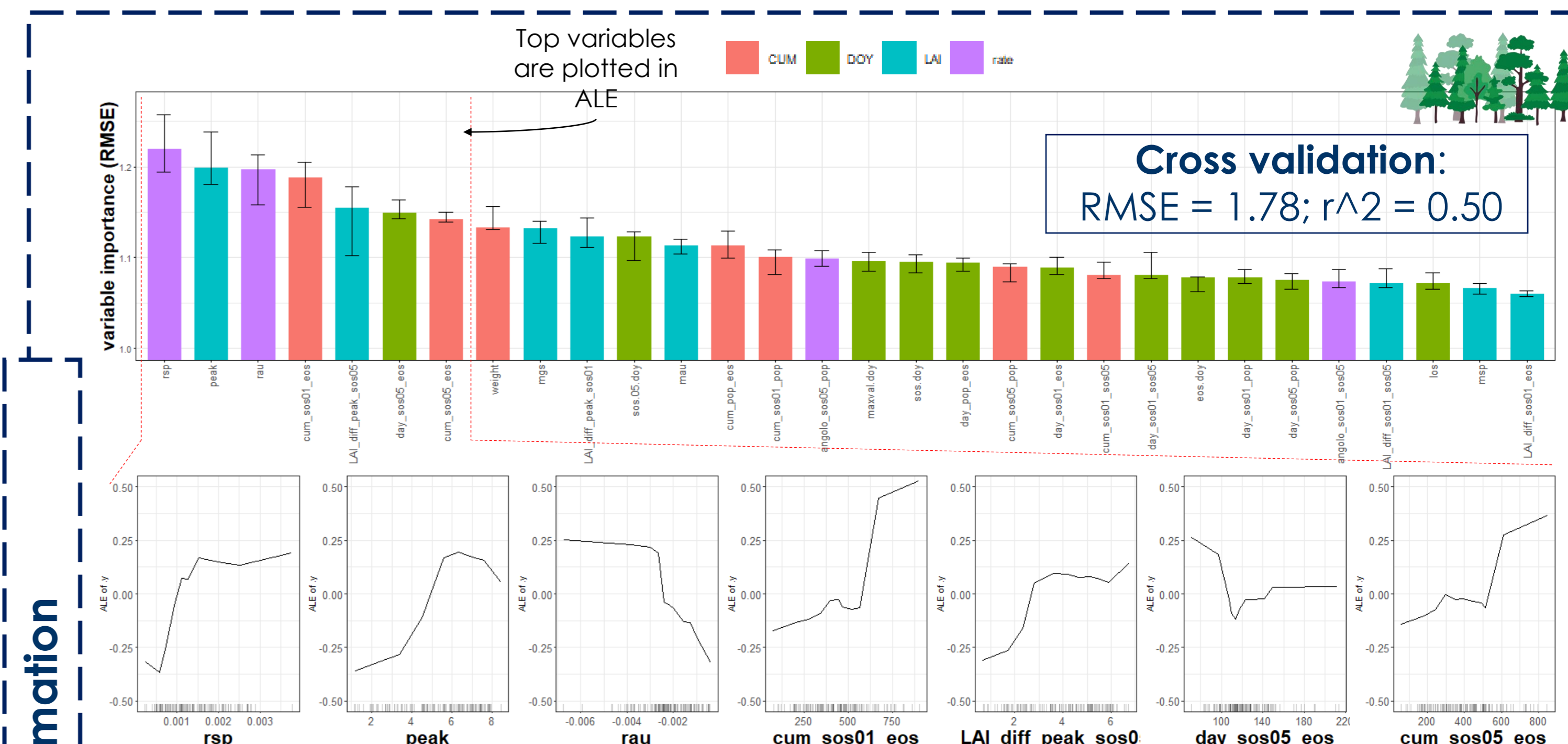
RESULTS and DISCUSSION



Four phenological metrics (Sos, Sos05, Peak, Eos) were computed getting key dates of vegetation cycle.

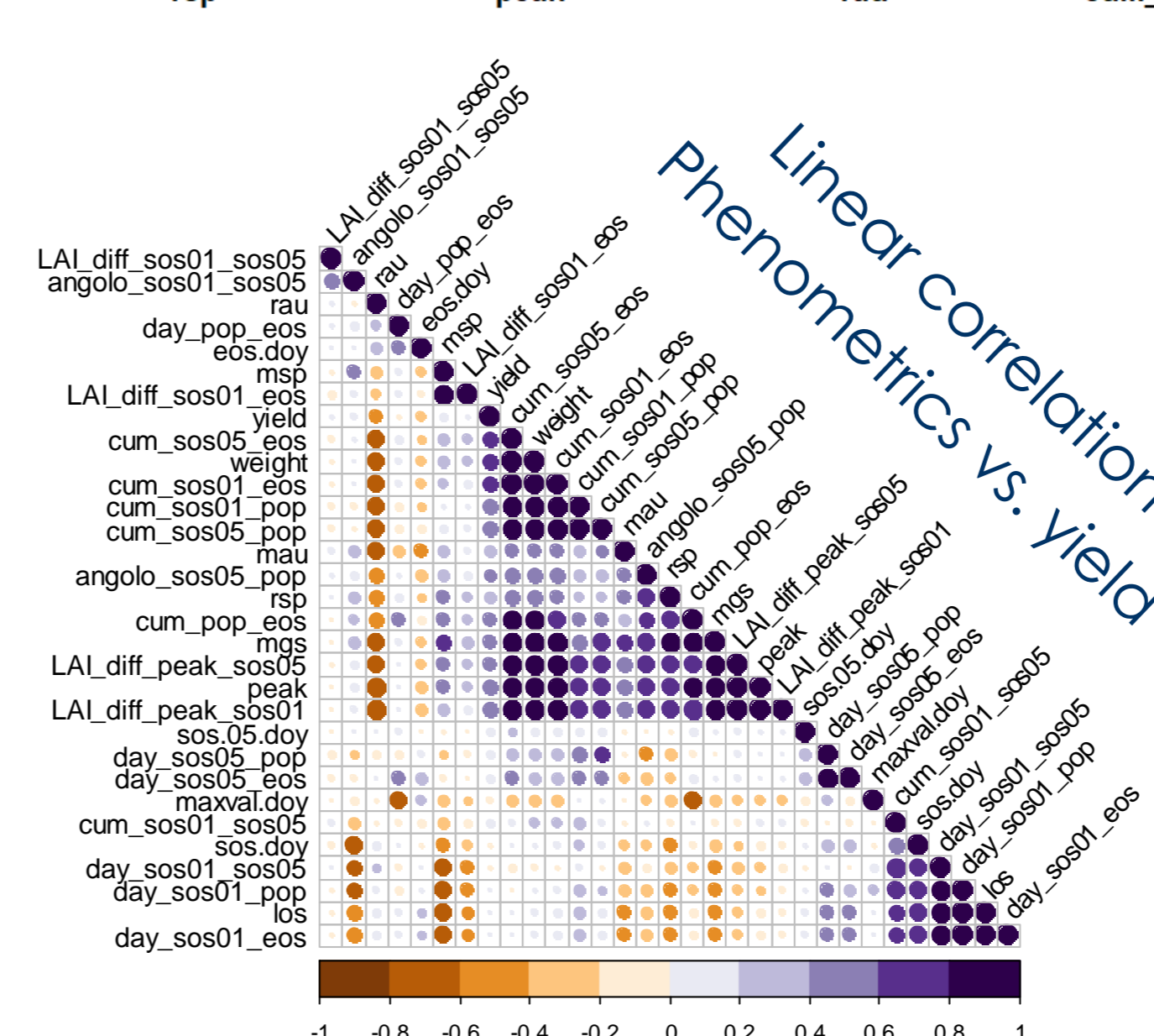
About 30 regressors were derived, summarized in 4 classes:

- 7 CUMULATES,
- 11 DATES and distance between phenometrics,
- 4 RATES of growing season and angle,
- LAI VALUE @ phenometrics occurrence and differences.

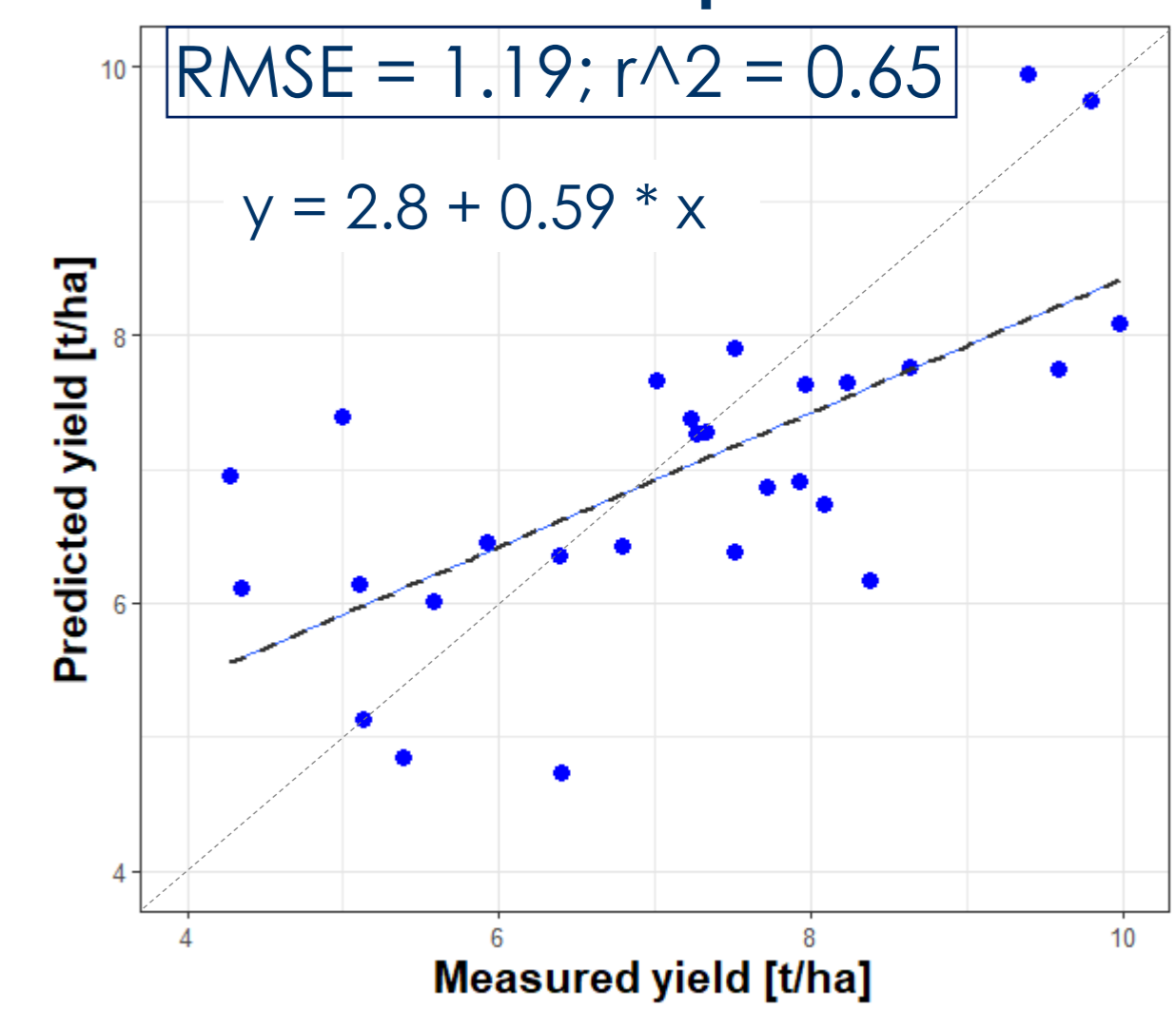


Cross validation:
RMSE = 1.78; $r^2 = 0.50$

Yield estimation



Validation With Independent Dataset



Validation of random forest trials show an average correlation with yield ($r^2 = 0.65$) and moderate estimation errors (RMSE = 1.20 and MAE = 0.94).

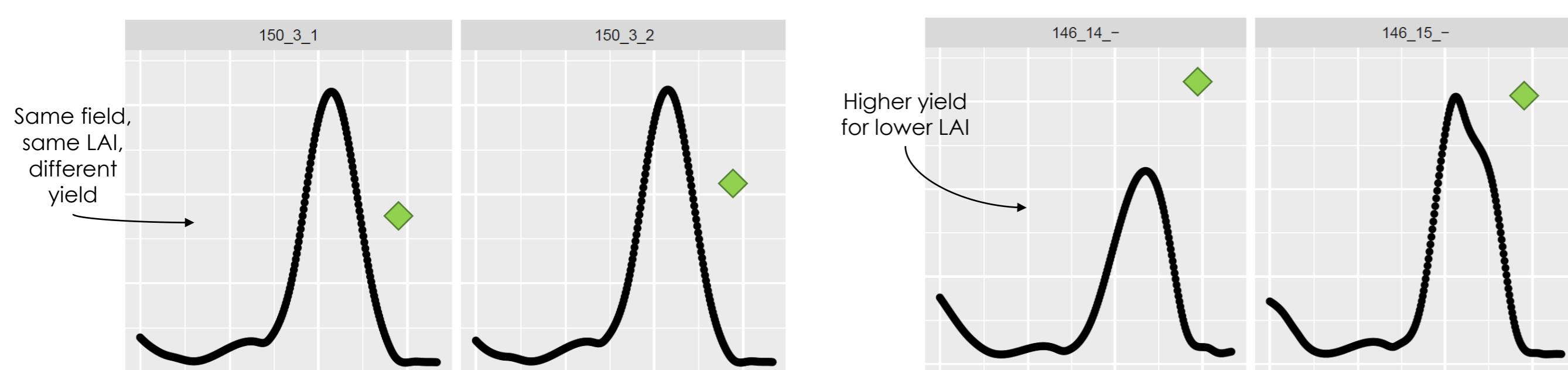
Classes of key predictors are:

- RATES** = of vegetative (rsp) and senescence (rau),
- LAI VALUE** = at peak,
- CUMULATES** = of the whole LAI curve,
- DATE** = of mid-vegetative phase (sos05),

Accumulated Local Effects (ALE) Plot display how these proxy influence yield. → e.g. rsp matters only for very low value; value of LAI at peak don't influence yield when above 6.

PRO & CONS

- (PRO) Semi-automatic processing chain:** smoothly computation of LAI and phenometrics from S2 time-series.
 - Metrics extracted are coherent with phenological stages in the AOI.
- (PRO) RF trials** allow us in understanding which LAI features reflects in a yield loss (or gain) at the end of the season.
- (CONS)** The **explained variance of yield is generally low**.
 - Peculiar cases and potential causes: Flower sterility, a lot of weed (unlikely), plant lodging (very common), field sample not representative.



Open questions for the community

- Agrometeorological expert:** Which metric derived from meteorological variable is more promising to be considered in impacting hence estimating **winter cereals yield changes**?
- Digital farming expert:** Expand yield dataset using yield maps from combines.
- Crop modeling expert:** Replace estimated LAI with crop model simulation, to expand the cases of LAI per yield → hybrid framework