Phenotyping From Space: Evaluating Very High-Resolution Satellite-Based Trait Estimation in Winter Wheat Microplot Trials

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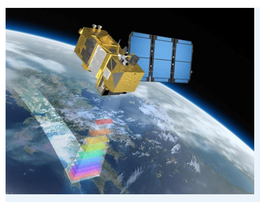
Context

- **Remote sensing** provides non-destructive, **high-throughput monitoring of plant traits** and has become central to field phenotyping.
- **Proximal** and **UAV** platforms have advanced trait measurement but **remain limited** by cost, logistics, and weather sensitivity.
- **Multi-environment trials** require strict protocols and standardized equipment, making **large-scale deployment challenging.**

Objective

Evaluate the potential of **Very High-Resolution (VHR)** satellite imagery for **microplot-level phenotyping** by addressing three key questions :

- **Spatial relevance**: Does the signal reliably represent individual microplots without strong interference from neighbours?
- **Temporal consistency**: Are VHR data stable enough to track plant trait dynamics over time?
- **Trait sensitivity**: Can VHR data capture treatment-induced differences and estimate ground-based phenotyping traits?

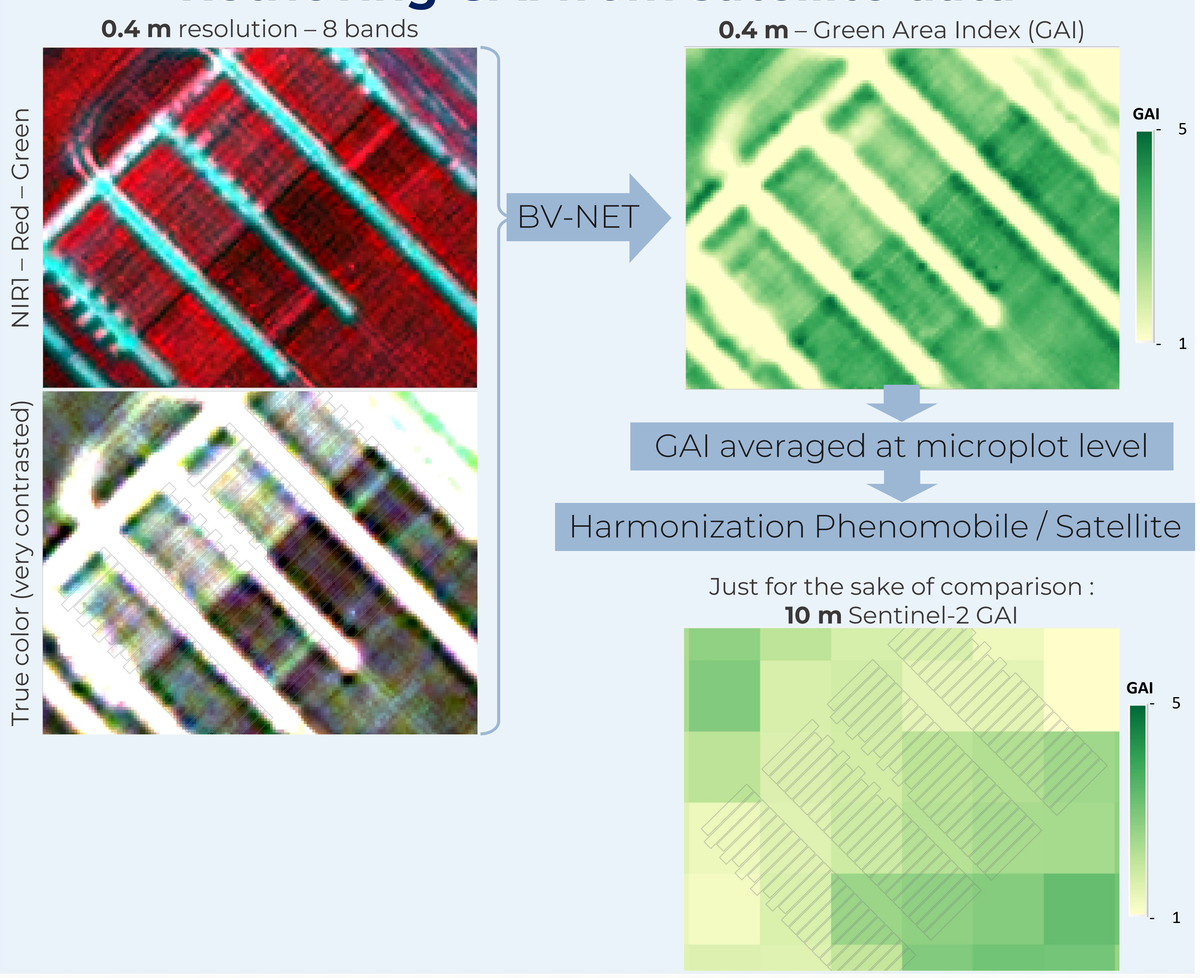




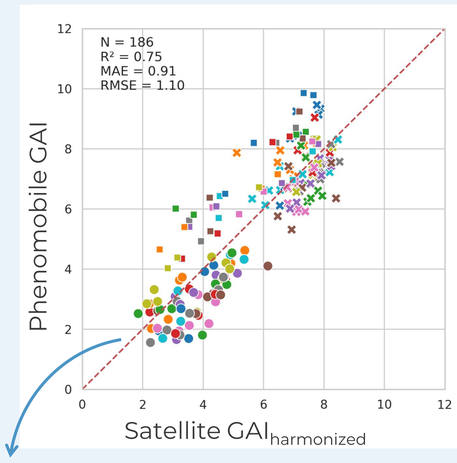
Experimental setup

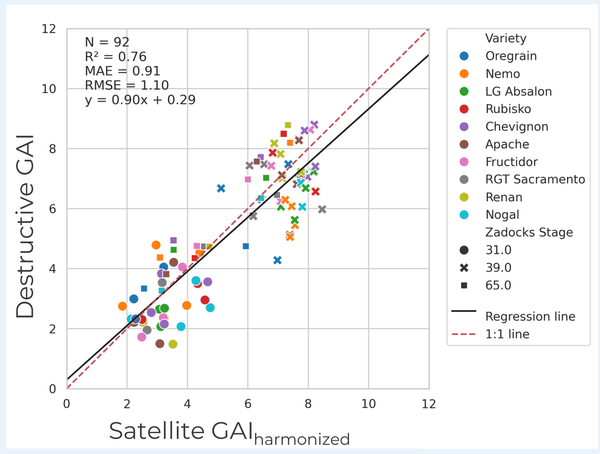
- **Treatments**: 10 winter wheat **varieties** X 2 **watering** regimes X 2 **sowing** dates.
- **Microplots** size: **1.4 x 8 m.**
- **Satellite data**: 3 cloud-free **WorldView-2** multispectral images (8 bands[2]), acquired within 3 days of ground sampling, pansharpened[3] to **0.4 m resolution.**
- **Ground data** : 200 **Green Area Index (GAI)**[1] measurements with **Phenomobile,** April–May 2022 & 2023 (Montpellier, France).

Retrieving GAI from satellite data



40cm satellite GAI aligns with ground data

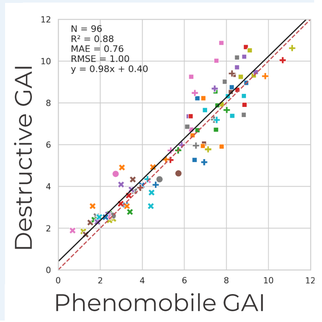




5-folds cross validation (Test-set)

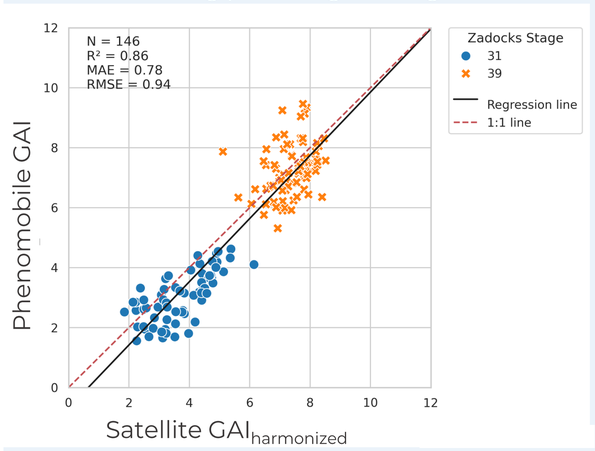
R^2	0.75	(± 0.03)
MAE	0.91	(± 0.08)
RMSE	1.11	(± 0.07)

Good correlation relative to destructive vs. phenomobile relationship.

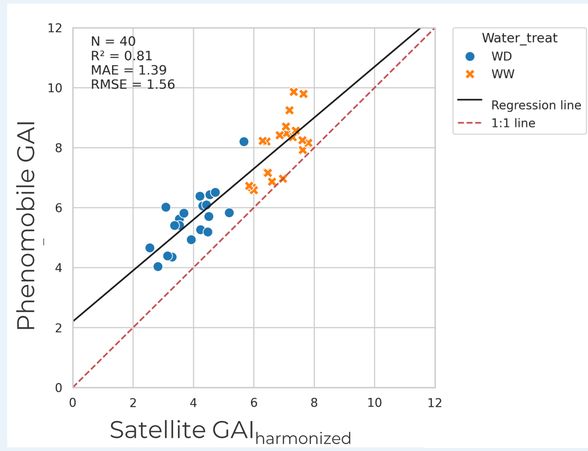


40cm satellite GAI captures differences among treatments

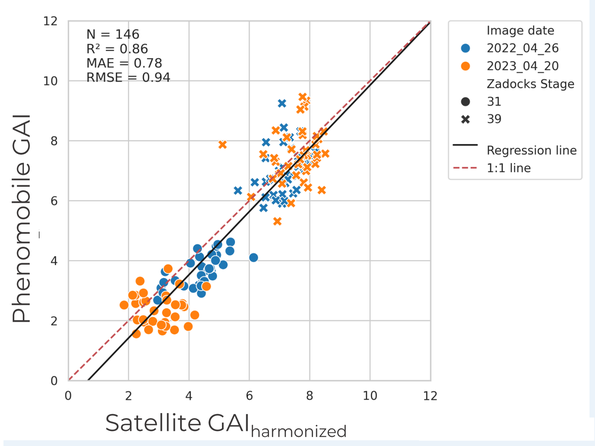
Among phenological stages



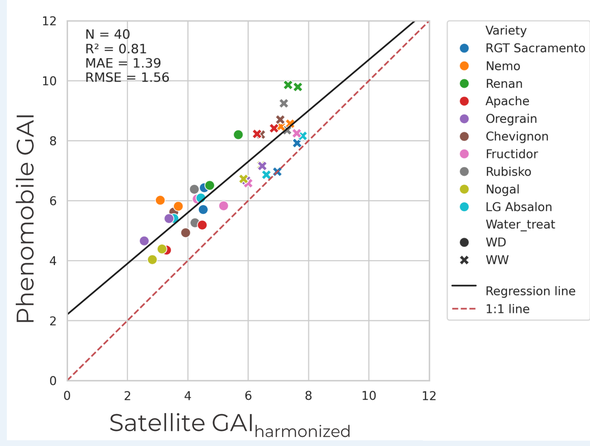
Among watering scenario (at Zadock 65)



Consistency among satellite image date



The ranking of varieties is preserved



Conclusions

- WorldView-2 images at 0.4 m effectively **captured treatment-induced variability** among microplots.
- Satellite data were **spatially and temporally consistent**, estimating ground-based GAI with relatively good accuracy (MAE = 0.91 ± 0.08).
- 0.4m satellite imagery shows strong potential as a scalable and reliable tool for **field phenotyping in multi-environment trials.**

[1] The Phenomobile measures the so called « True Plant Area Index » but here we call it GAI here as we can consider that all the plant is still green in April and May.
[2] The 8 bands : Coastal blue, B, G, Y, R, RE, NIR1, NIR2
[3] Native resolution of the images is 1.6m.

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