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Enhancing large-scale winter wheat LAI retrieval from Sentinel-2: a soil-informed radiative transfer-based approach

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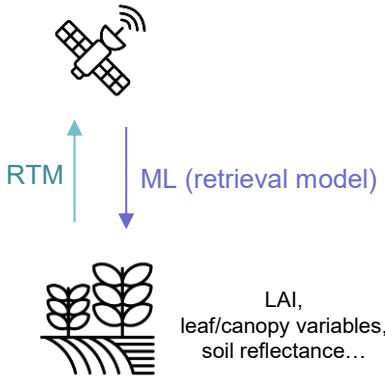
How can we monitor fields across Switzerland?

Leaf Area Index (LAI) as a indicator for biomass, crop cover, soil erosion...

- Radiative transfer models (RTM) simulate remotely sensed vegetation/soil reflectances
- Machine learning models invert the task to get LAI from reflectance
- Local soil can play important role at low LAI



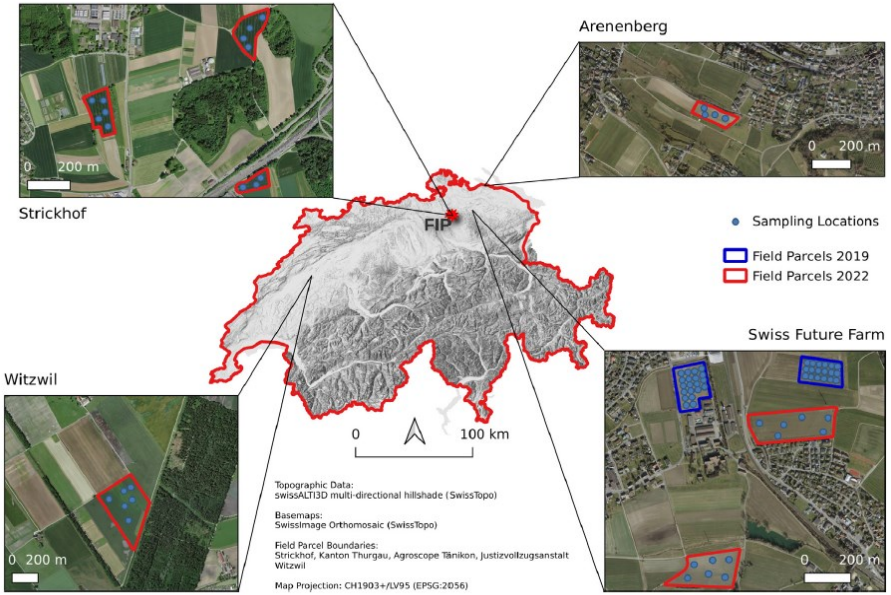
Low LAI

Seen from Sentinel-2

Data

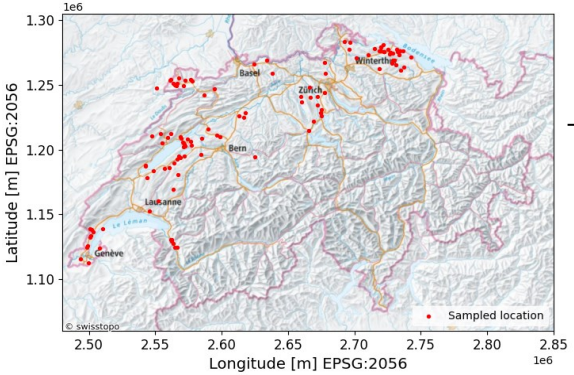
Case study for winter wheat in Switzerland

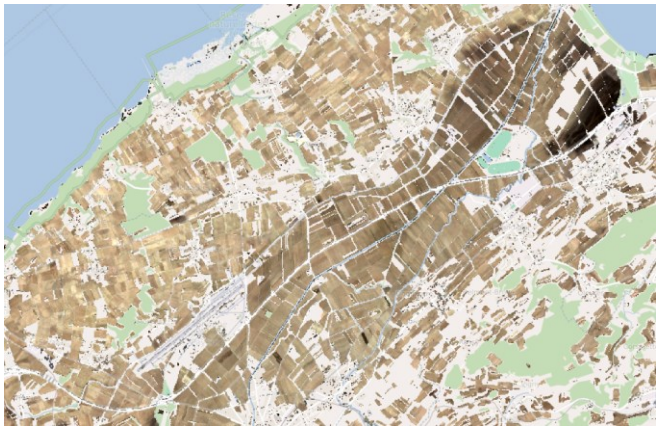
- Sentinel-2: 10m resolution, 13 bands, 2017 to 2023
- In situ LAI measurements across Switzerland (224 observations)



Graf et al. (2023) Insights from field phenotyping improve satellite remote sensing based in-season estimation of winter wheat growth and phenology, Remote Sensing of Environment 299, 113860. https://doi.org/10.1016/j.rse.2023.113860.

Collecting bare soil reflectances





DLR SoilSuite – Sentinel-2

Filter agricultural land → Remove clouds, snow, shadows → Remove vegetation and crop residue → Yearly mean bare soil composites → Sample representative spectra

Using S2 Scene Classification Layer

NDVI < 0.25
NBR2 < 0.075

- *K-means clustering into 5 groups.*
- *Sample from each cluster (total 125 spectra)*

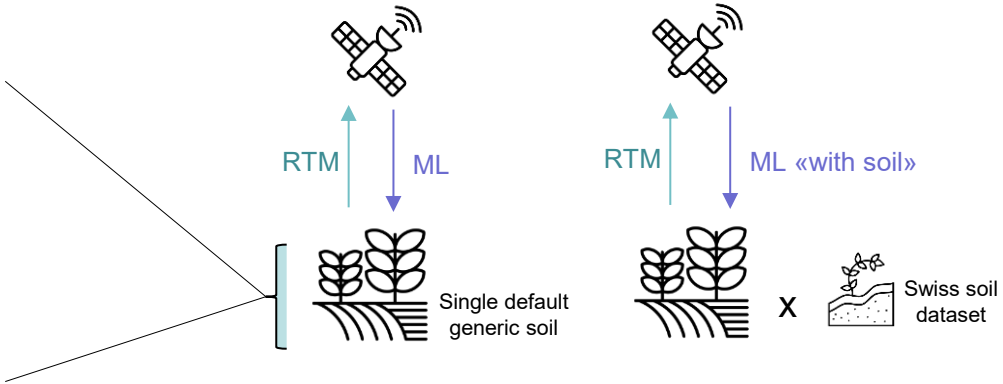
Train retrieval models

1. *Parametrise RTM for winter wheat*

LAI	Other leaf variable…	Other canopy variable…	…
1	50	13	35
…	…	…	…
2.4	67	8	49
…	…	…	…
4.8	80	4	52

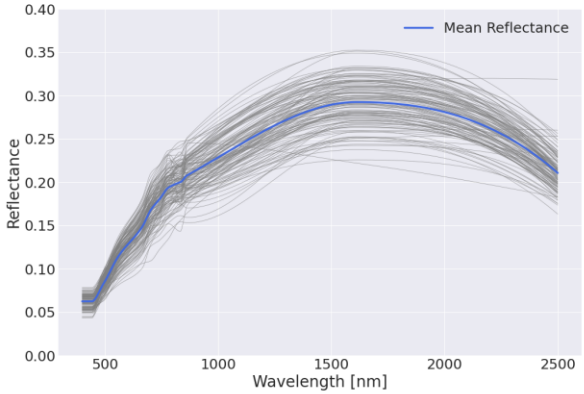
~50k combinations
Using values for winter wheat *(Danner et al., 2019)*

2. *Train 2 retrieval models*



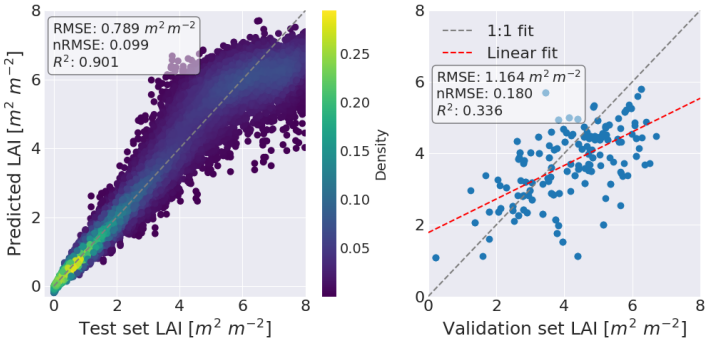
Results: addition of soil

- Variety of background soil conditions collected



- Adding the soil dataset to the methodology improved LAI retrieval

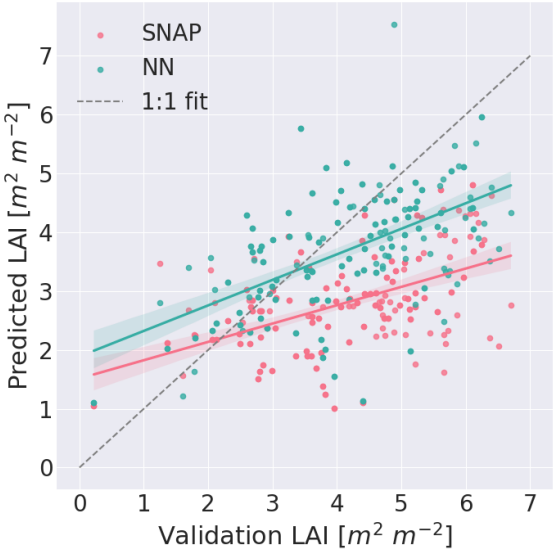
	Default	With soil
Validation RMSE [m^2/m^2]	1.303	1.164
Validation nRMSE	0.201	0.180

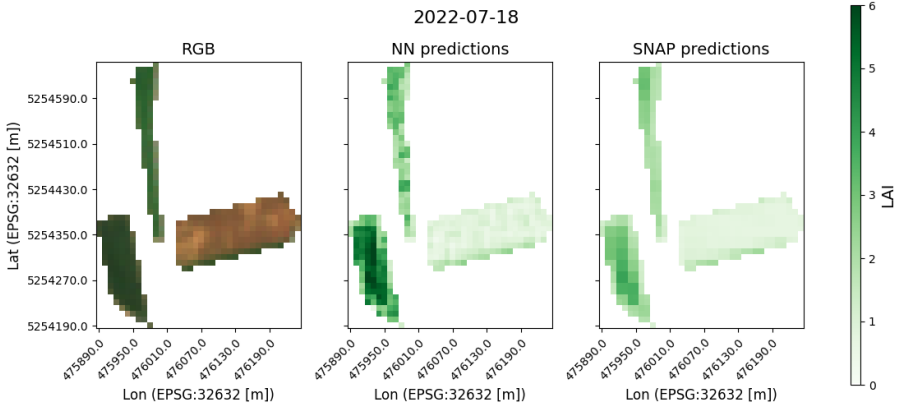


Results: comparison to SNAP

Global LAI baseline: ESA's Sentinel Application Platform ***(SNAP)*** LAI

- ML retrieval model for Sentinel-2
- Uses 7 soil signatures for a global representation





Key takeaways

- Bridging local and global: context-specific information can be collected across large scales and simply incorporated
- Our Swiss winter wheat LAI model outperforms SNAP LAI
- Pipeline for crop- and biome-specific LAI retrieval models

Thank you for listening!

In review:
"*Enhancing large-scale winter wheat LAI retrieval from Sentinel-2: a soil-informed radiative transfer-based approach*", Ledain et al., Computers and Electronics in Agriculture, 2025.

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