Soil organic carbon mapping from remote sensing: The effect of crop residues

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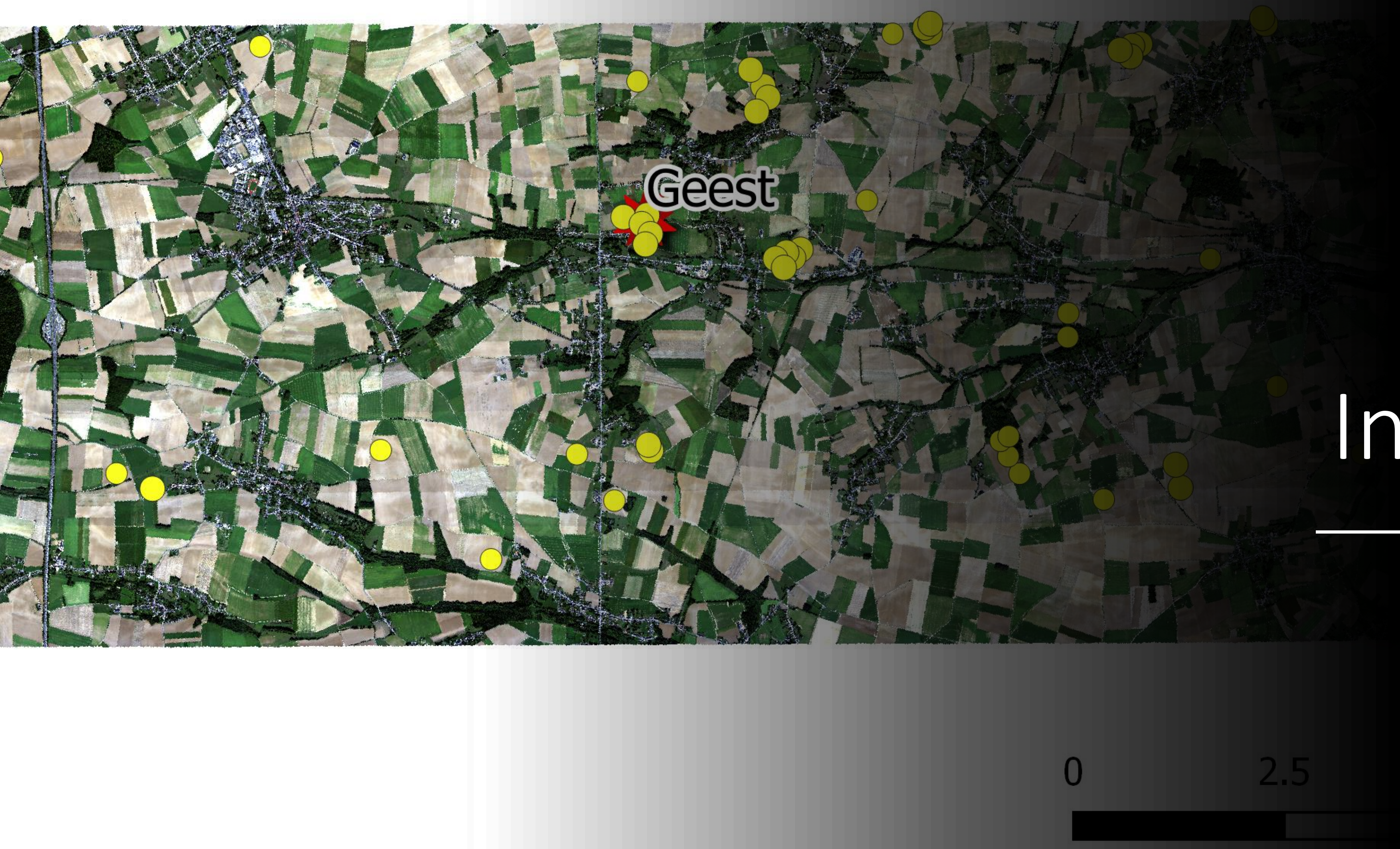


Introduction

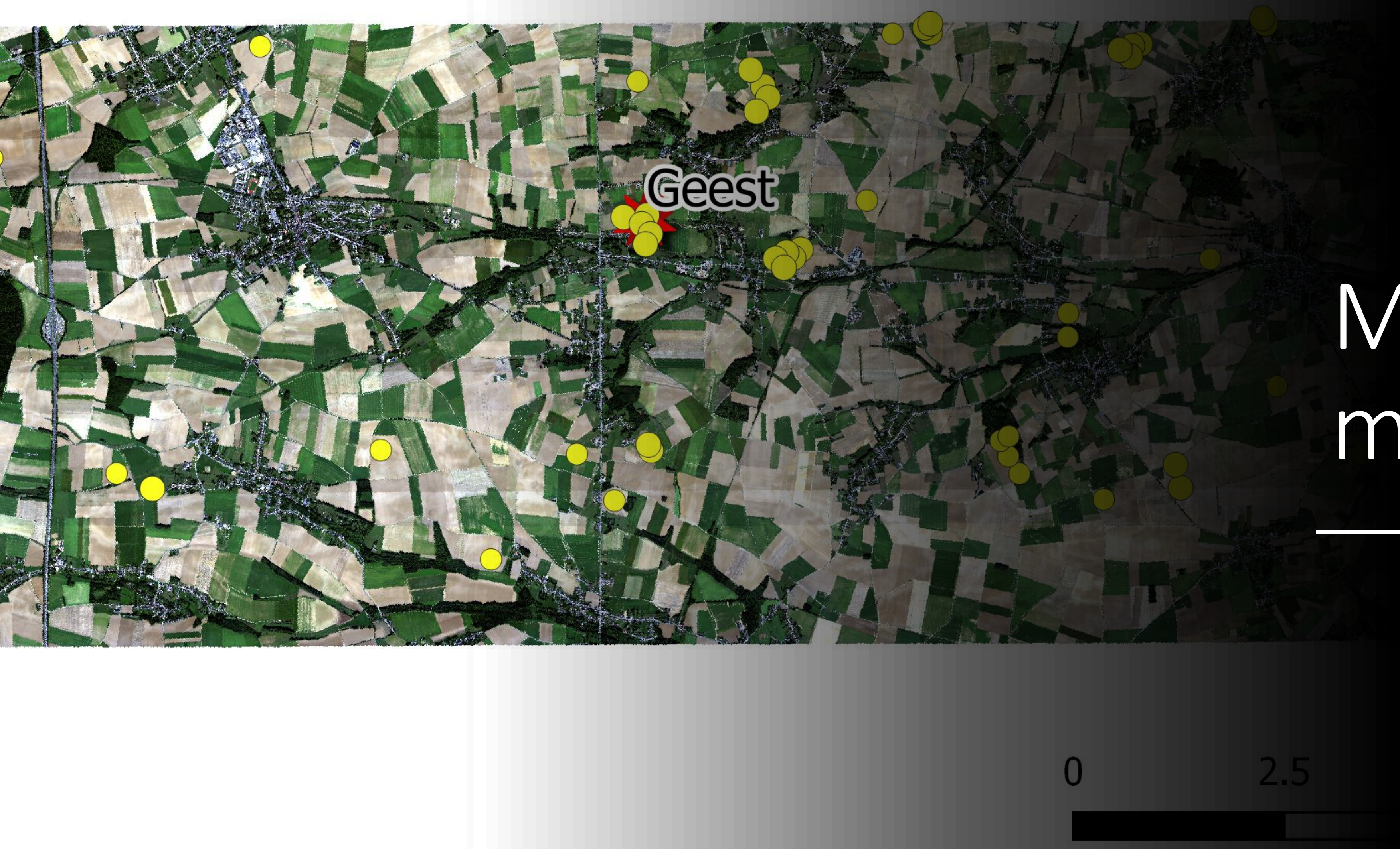
Soil organic carbon (SOC) prediction from remote sensing is hampered by soil surface conditions

- Strong demand for mapping and monitoring SOC because :
  - SOC has a direct control on soil fertility, soil structure stabilization, water holding and cation exchange capacity
  - Soils have been losing SOC since the onset of agriculture → soil functions of many croplands are threatened
- Factors mainly affecting the SOC prediction models performance are
  - Vegetation
  - Humidity
  - **Crop residues** ⟵ **Subject of this study**
  - Roughness

Aims of the study

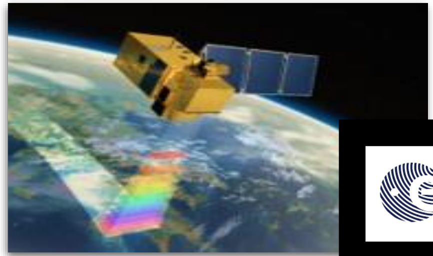
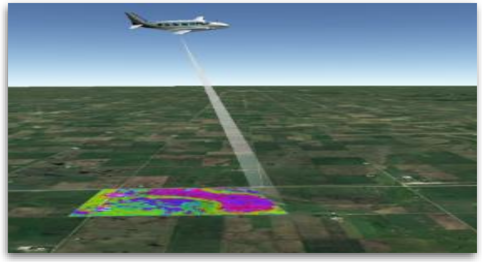
1. Test the effects of crop residue (quantified by a hyperspectral index from an airborne image) on the performance of SOC prediction models

2. Establish whether a multispectral index calculated from Sentinel-2 imagery can be used as a proxy for crop residue quantification



Materials and methods

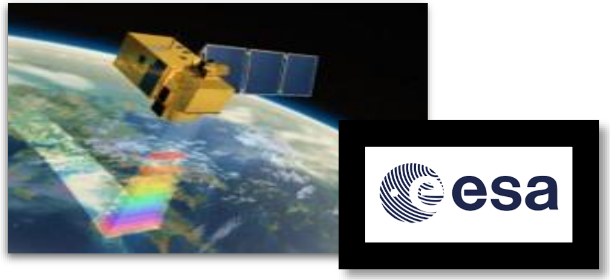
Airborne and spaceborne remote sensors characteristics

Satellite multispectral	Airborne hyperspectral
	

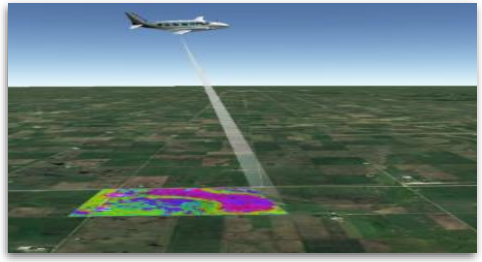
	Sentinel 2	APEX
Altitude (km)	786	3.6
Sensor type	multispectral	hyperspectral
Spectral range (nm)	443 – 2190	413 – 2431
Spectral bands	13	285
Resolution **Spatial (m)** **Temporal (day)** **Spectral (nm)**	 10 – 20 – 60 5 15 – 180	 2 — 2 – 13
Noisy bands (nm)	—	413 – 440, 1310 – 1555, 1750 – 2000
Signal to noise (SNR) **VNIR** **SWIR**	 89:1 to 168:1 50:1 to 100:1	 50:1 to 700:1 40:1 to 600:1

How to estimate crop residue cover with remote sensing products?

Satellite multispectral



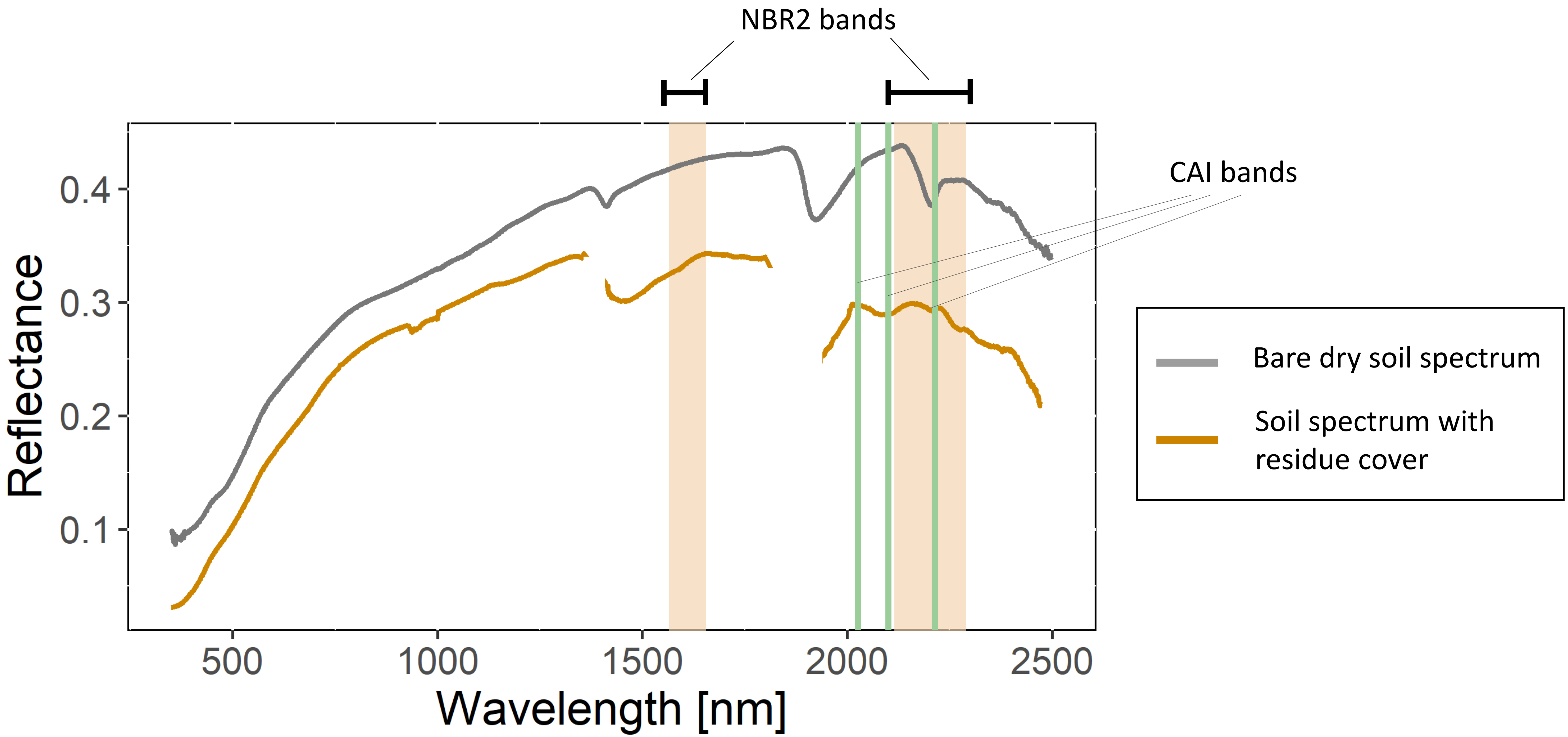
Airborne hyperspectral



We tried

Sentinel 2	**APEX**
Normalized Burn Ratio **(NBR2)**	Cellulose Absorption Index **(CAI)**
$NBR2 = \frac{R_{SWIR1} - R_{SWIR2}}{R_{SWIR1} + R_{SWIR2}}$	$CAI = 0.5\,(R_{2.0} + R_{2.2}) - R_{2.1}$
R_{SWIR1}: 1610 nm (B11) R_{SWIR2}: 2190 nm (B12)	$R_{2.0}$: 2026 nm $R_{2.1}$: 2100 nm $R_{2.2}$: 2214 nm

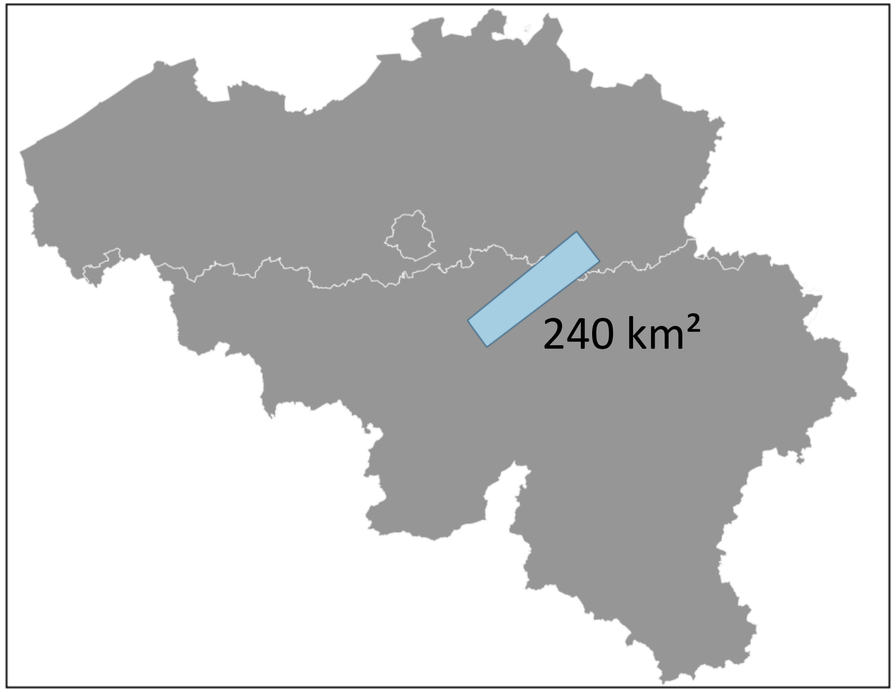
How to estimate crop residue cover with remote sensing products?

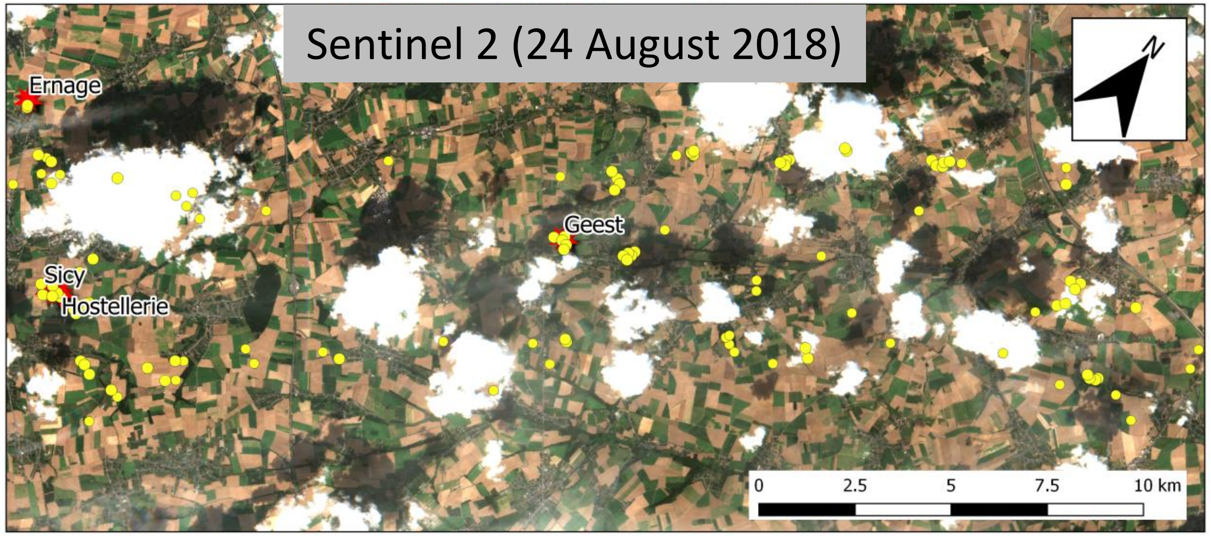


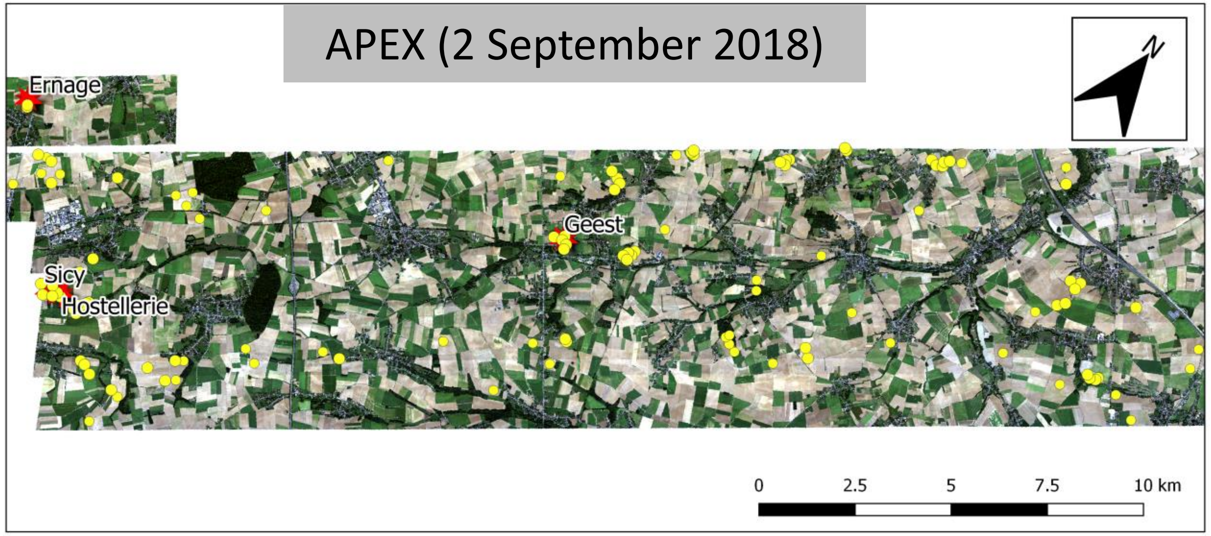
Study area in central Belgium

- Temperate oceanic climate (mean annual precipitation 790 mm)

- Loam belt region with well drained soils







Materials

- Sentinel 2 multispectral image
- APEX hyperspectral image
- 104 surface soil samples with measured SOC (yellow points)
- 276 surface soil samples covering three field trials (obtained from the Walloon Agricultural Research Center (CRA-W) database; red stars)

Methods

- Partial least squares regression (PLSR)

Results and discussion

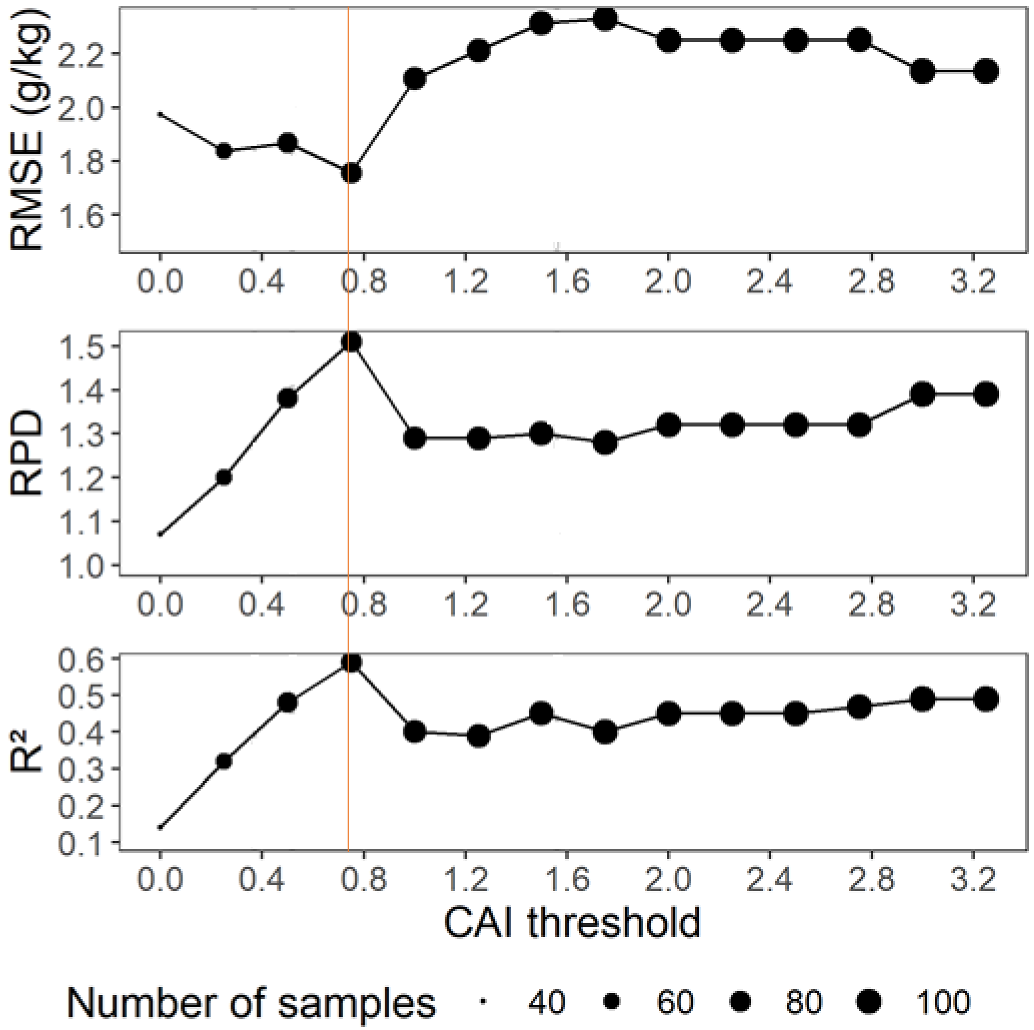
For reminder

Aims of the study

1. **Test the effects of crop residue (quantified by a hyperspectral index from an airborne image) on the performance of SOC prediction models**

2. Establish whether a multispectral index calculated from the Sentinel-2 imagery can be used as a proxy for crop residue quantification

SOC prediction model improves if we calibrate on samples with lower CAI (i.e. lower residue cover)

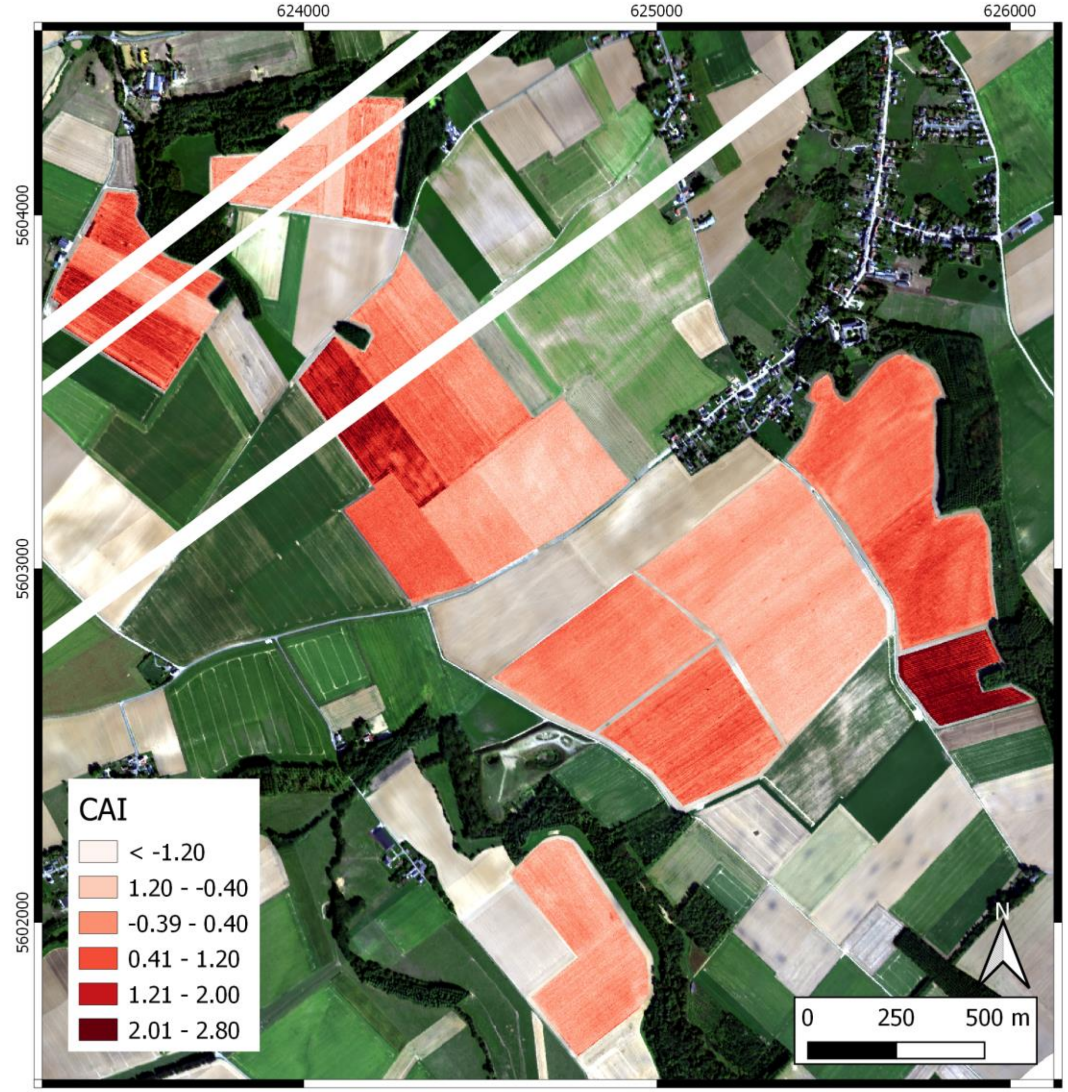


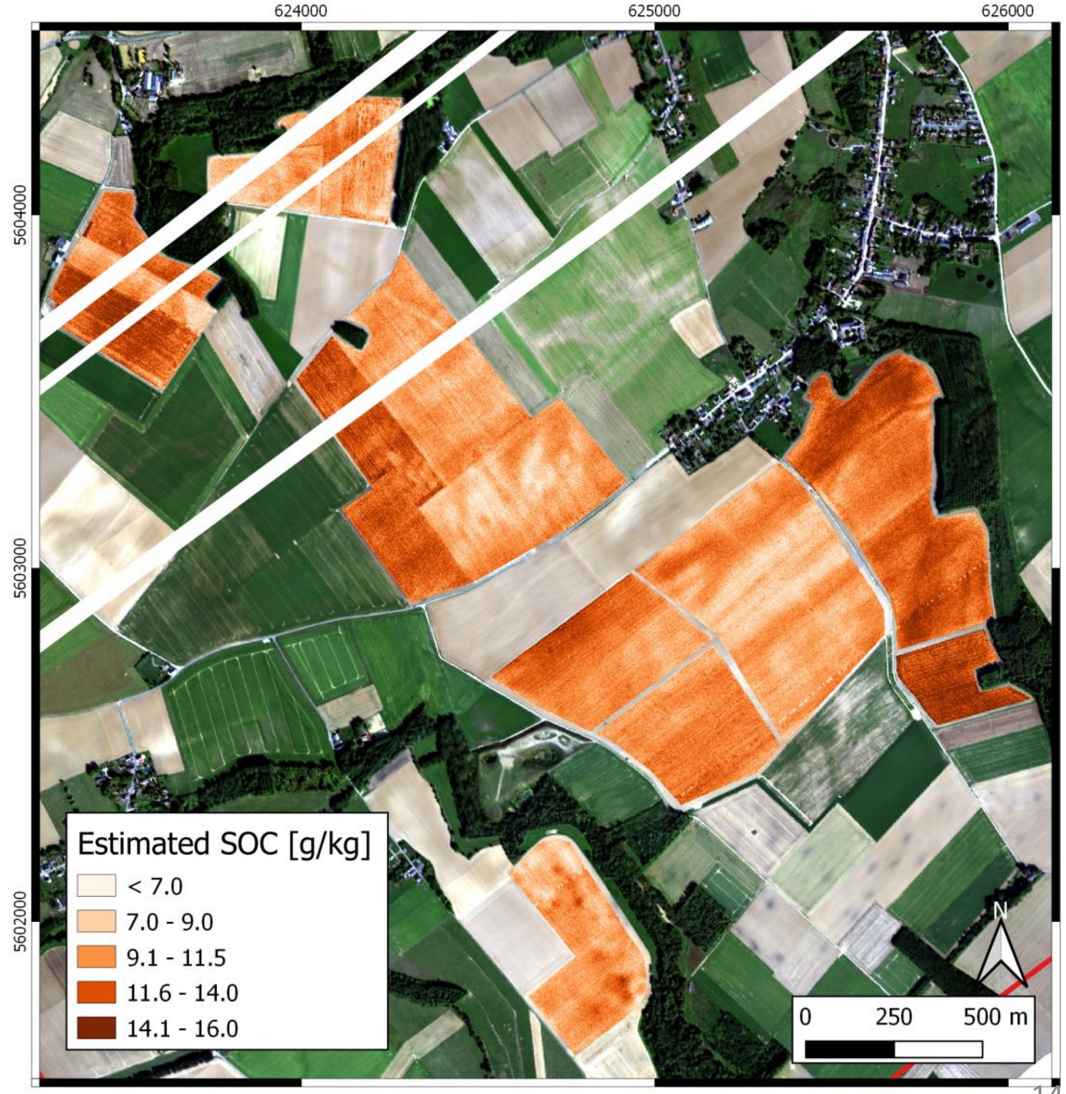
- CAI calculated on an airborne hyperspectral image from 2 September 2019

- High CAI = high crop residue cover
- Low CAI = low crop residue cover

- The best SOC prediction model is found when samples with CAI < 0.75 are used to calibrate the model (orange vertical line)

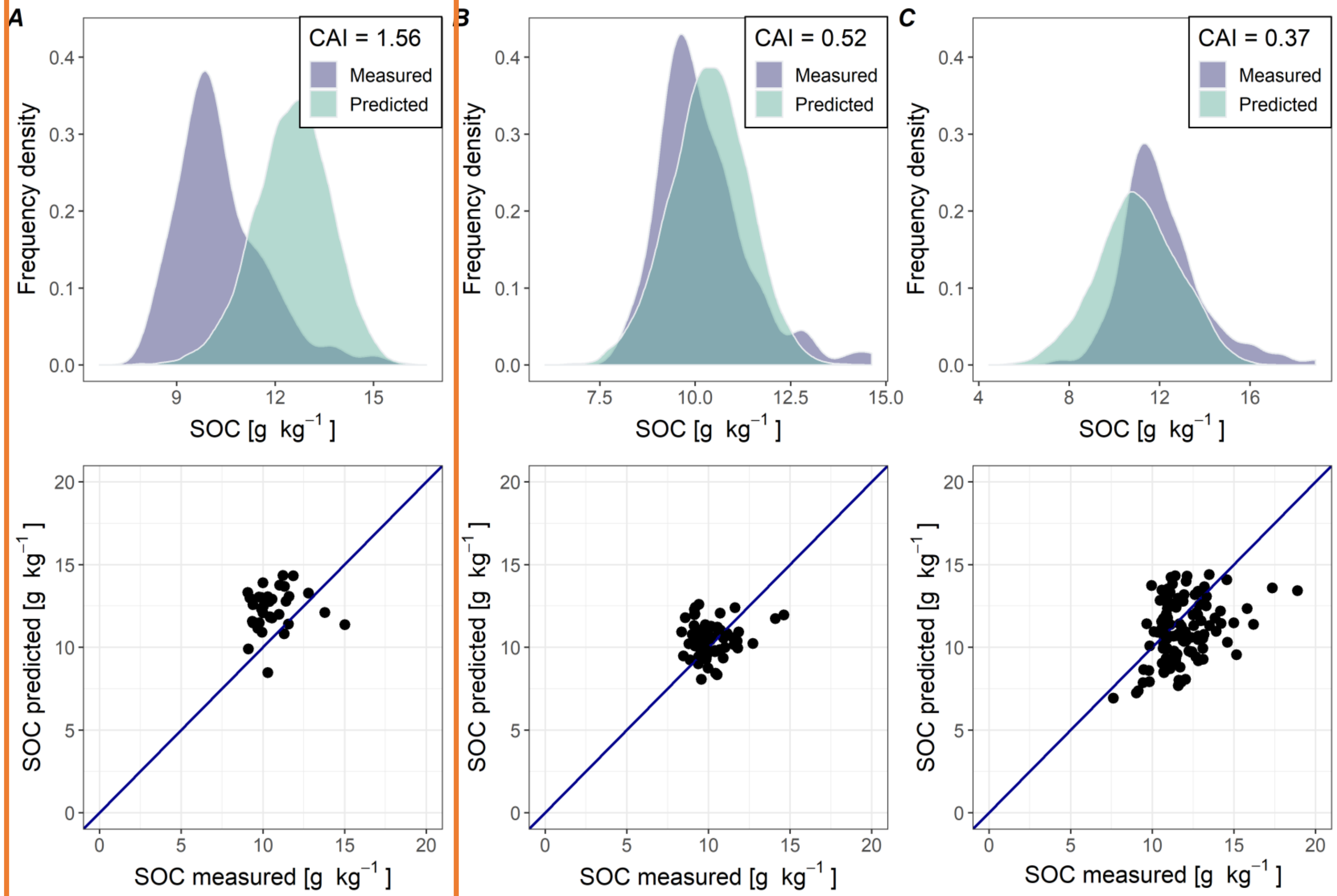
Areas with higher CAI have a higher SOC predicted





Comparison of the predicted SOC obtained from PLSR model and the measured SOC values in the three fields: SOC is overestimated for field with high CAI (i.e. high residue cover)

This field showed a crop residue cover of 24% at the moment of APEX overflight



For reminder

Aims of the study

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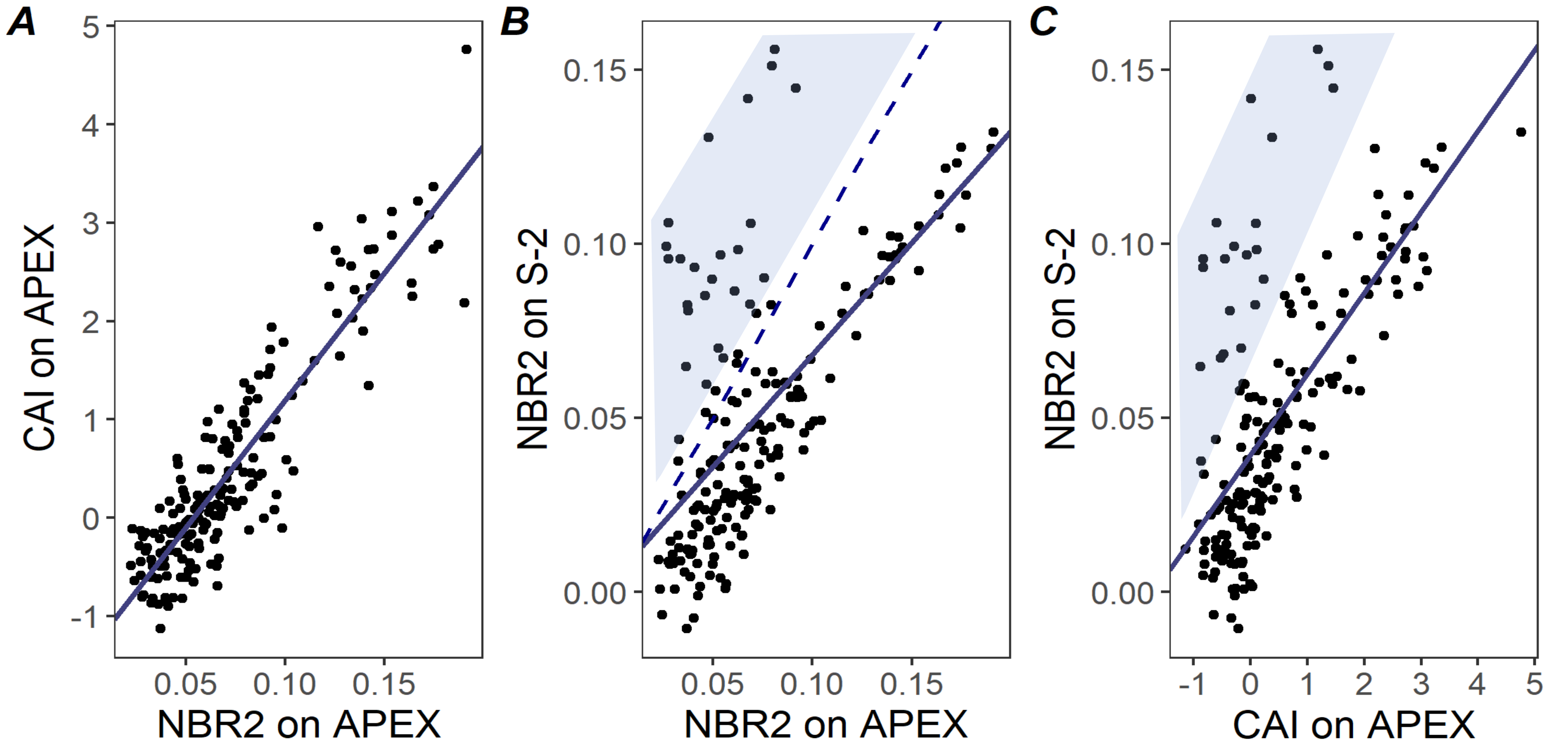
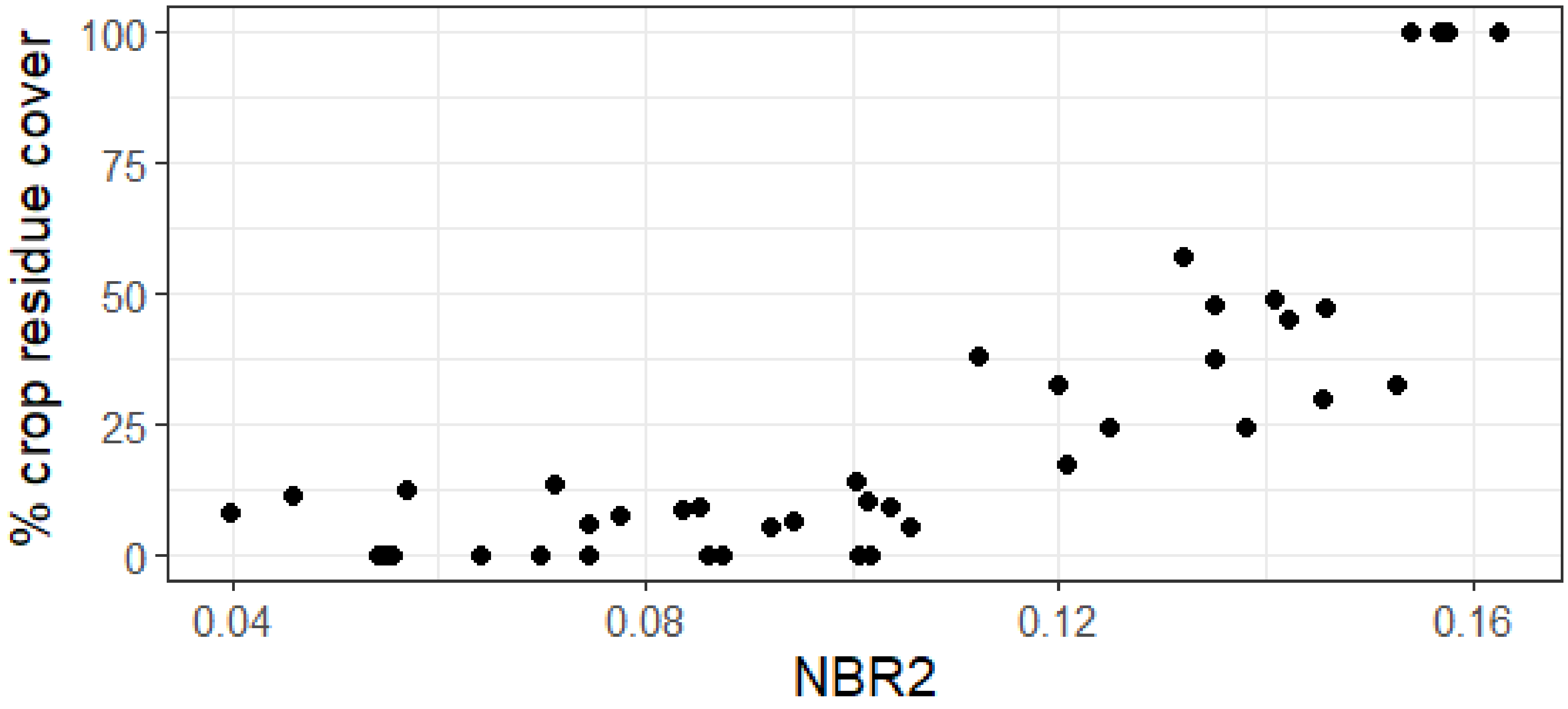
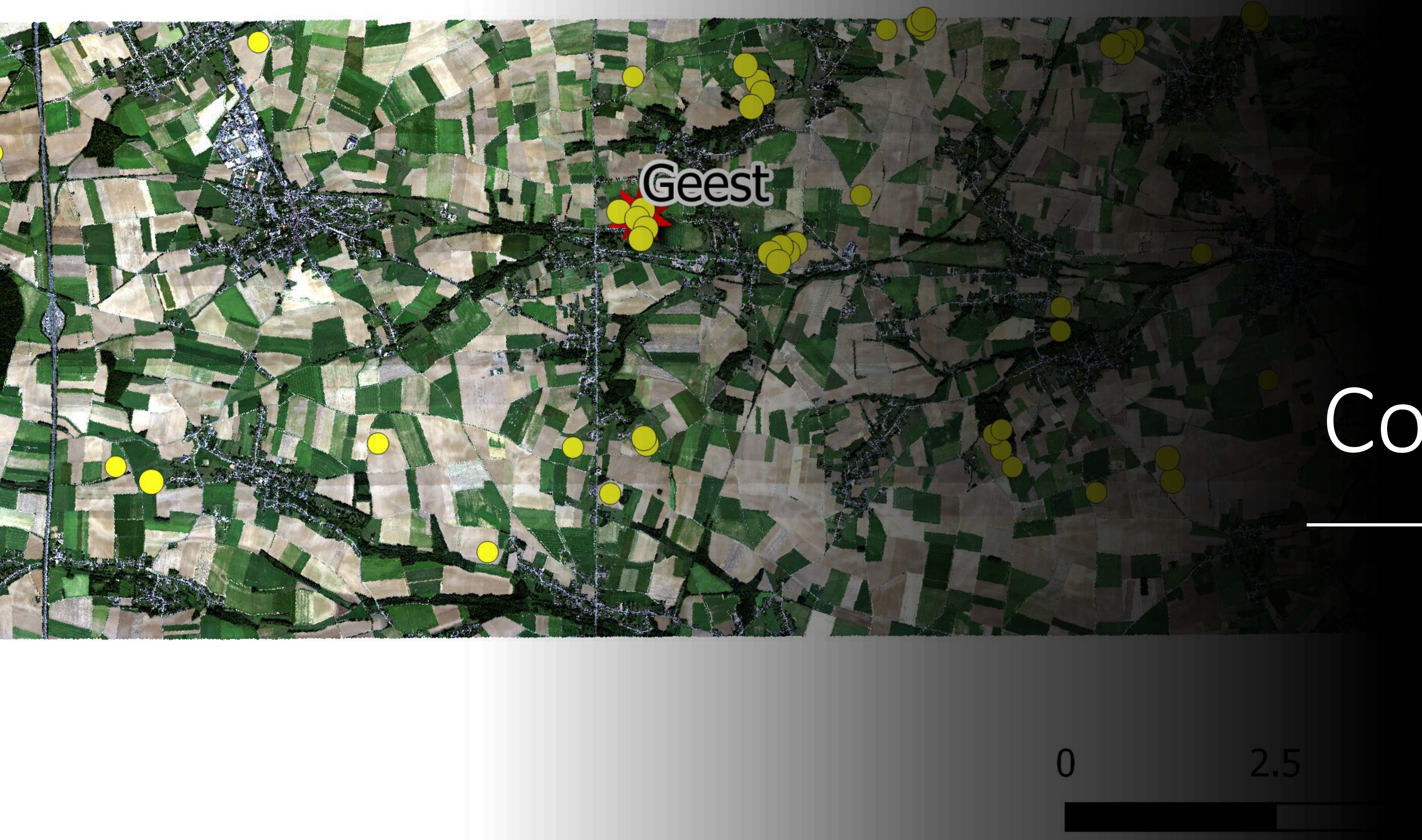
During **dry conditions** at the acquisition dates, CAI and NBR2 show a linear relationship



- The shaded blue areas represent the fields which have been ploughed between the acquisition dates of the two images : 24 August (Sentinel 2) vs. 2 September (APEX)
- The blue lines are the linear regression models

However, **when soils are wet** (October 2019), **the relationship** between crop residue cover and NBR2 **is poor**





Conclusion

- The disturbing effects of crop residues influence the SOC prediction accuracy.
  - SOC overestimation for fields with extensive residue cover.
  - For dry soils in seedbed condition, the pure pixel selection based on CAI thresholds improves the SOC prediction accuracy.
  - A CAI threshold of 0.75 allowed for the best SOC prediction model.
- When soils are dry and in seedbed condition, CAI and NBR2 indexes based on both hyperspectral airborne and multispectral satellite sensors show a linear relationship. By extrapolation, a linear relationship exists between crop residue cover and both CAI and NBR2.
- The linear relationship between NBR2 and crop residue cover does not hold when soils are wet.