Sentinel-2 exposed soil composite for soil organic carbon prediction

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Introduction

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

- Factors mainly affecting the SOC prediction models performance are
  - Vegetation
  - Humidity
  - Crop residues
  - Roughness

Spectra differently affected in each sensing image → unstable spectra over time

Take the average over time of each pixel to stabilize the spectra

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Multitemporal image mosaicking (COMPOSITING)

What to include in a composite image?

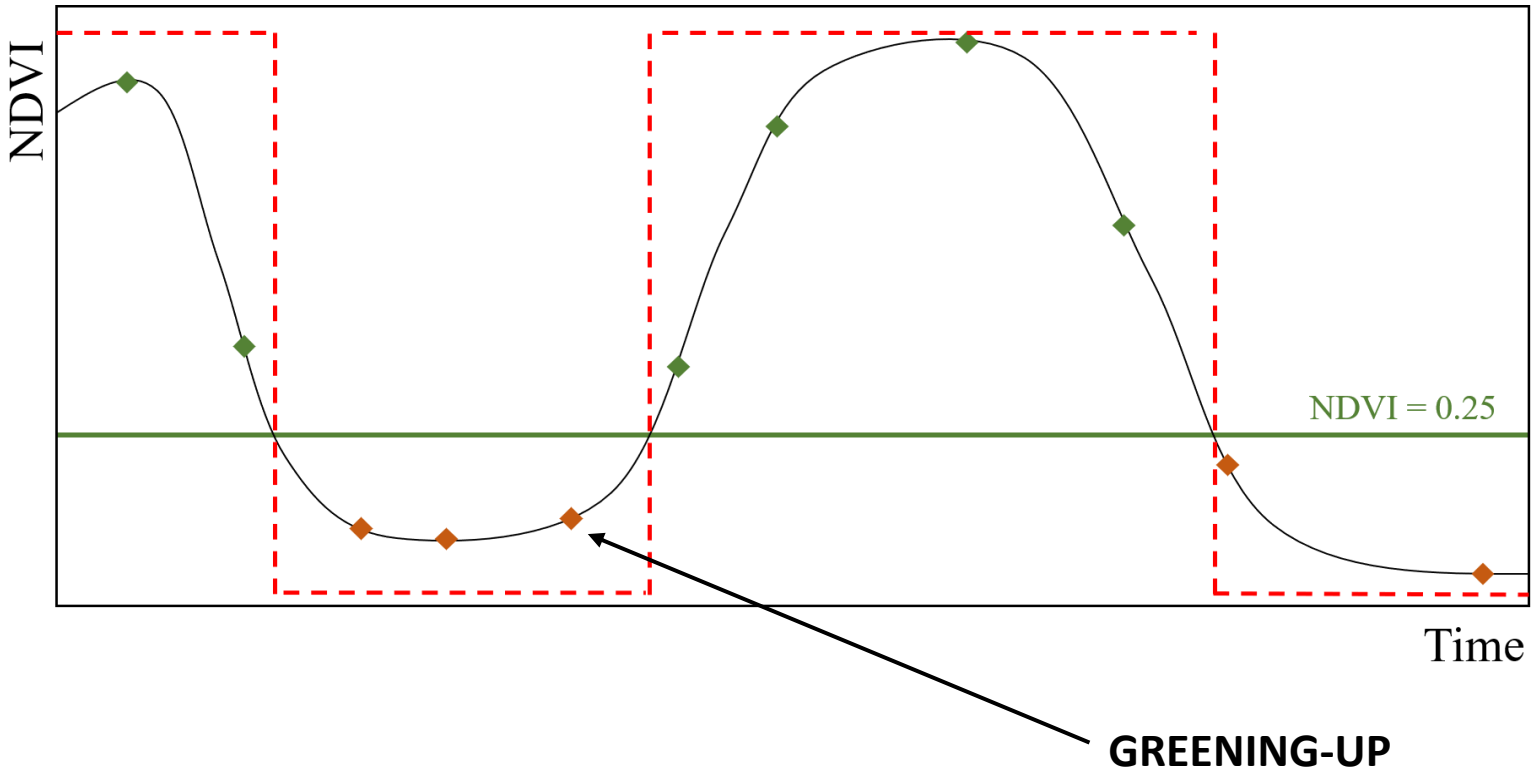
- High variability of soil spectra over time due to disturbing effects
- There is a need to filter out the most disturbed spectra in order to not affect the final composite
- The common approach: Application of index thresholds
  - NDVI < 0,25 ; NBR2 < X
- Our approach : ***Greening up moment*** combined with NBR2 index

Greening- up moment

- We propose a selection of appropriate image acquisition dates based on the crop phenology: the so-called ‘greening-up’ method.

- We hypothesize that a window exists in the cropping calendar, during which the surface conditions reflect the spectral signature of the soil. This occurs when soils are dry and in seedbed condition, and therefore are harrowed and without any green vegetation or crop residues. The highest likelihood for the occurrence of seedbed conditions is considered to be the last moment in the NDVI sequence, during which vegetation is on the verge of starting to grow

Greening-up moment



- Illustration of the recognition of the greening-up moment based on an NDVI time series
- The points indicate an imaginary satellite image acquisition
- The black curve is the shape of an ideal NDVI evolution of a cropland
- The red dashed line is binary representation of NDVI: NDVI =< 0.25 becomes phase 0 (red points), NDVI > 0.25 becomes phase 1 (green points).

Aims of the study

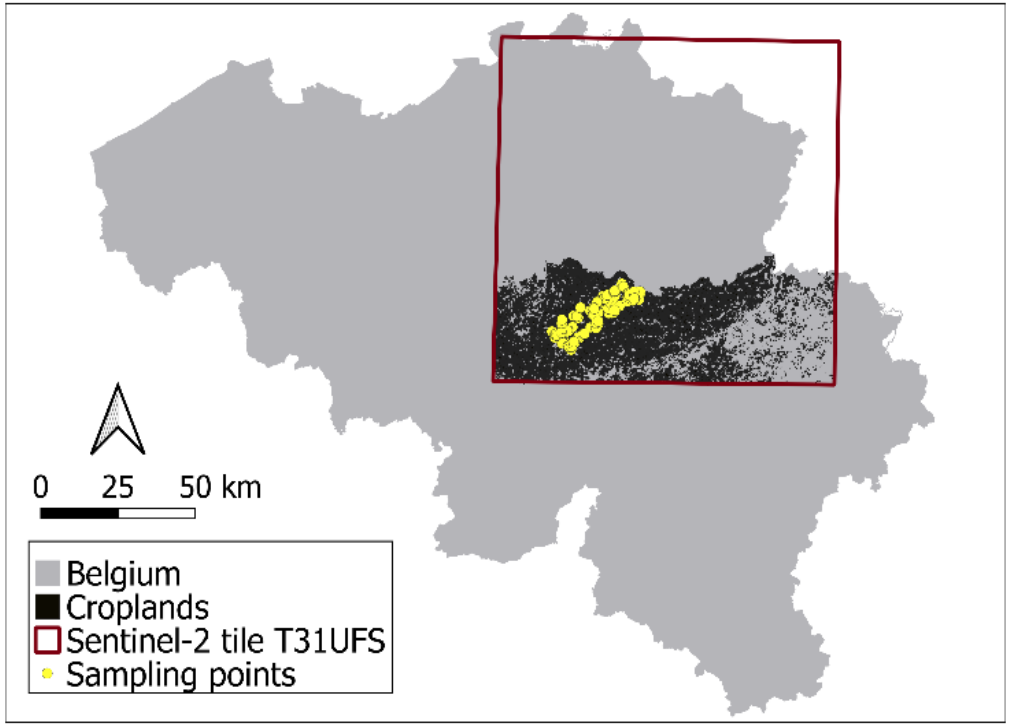
We aim to develop a robust method that allows selecting Sentinel-2 pixels with minimal influence of the following disturbing factors: crop residues, surface roughness and soil moisture.

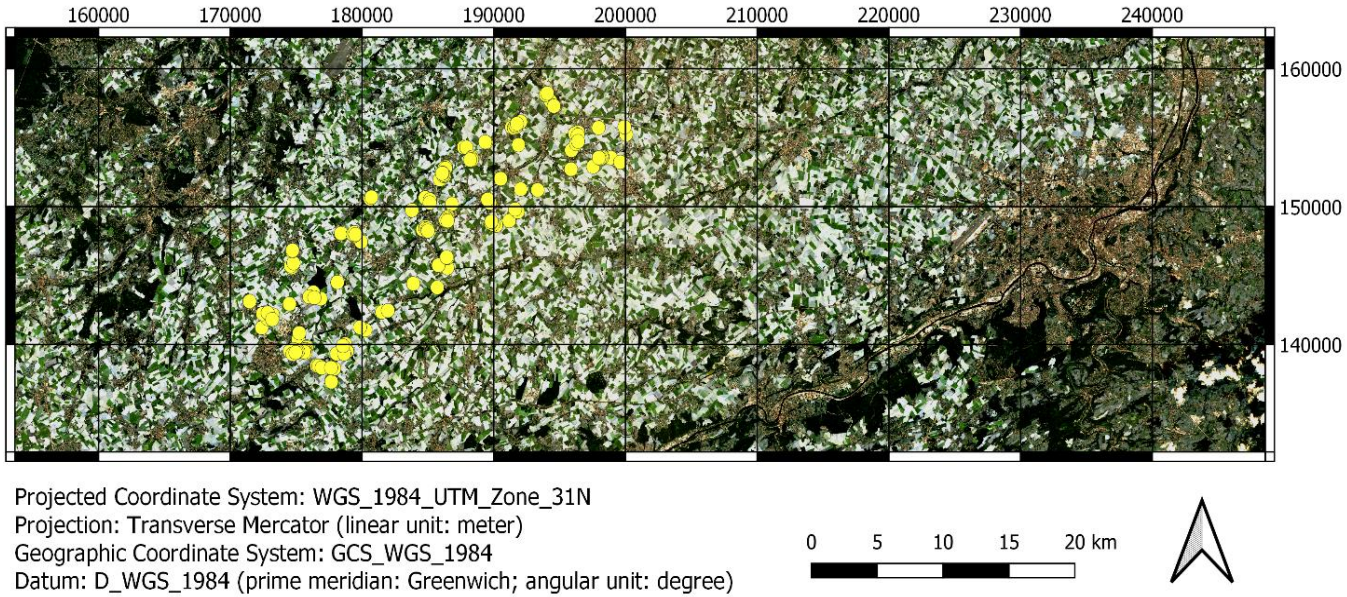
We build several composites based on different sets of criteria (combining NDVI, NBR2 and greening up) and use them to predict SOC in Belgian croplands.

Materials and methods

Study area in central Belgium

- Temperate oceanic climate (mean annual precipitation 790 mm)
- Loam belt region with well drained soils





Materials

- 36 cloud free Sentinel 2 multispectral images (tile T31UFS) from January 2019 to December 2020
- 137 surface soil samples with measured SOC (yellow points)

Methods

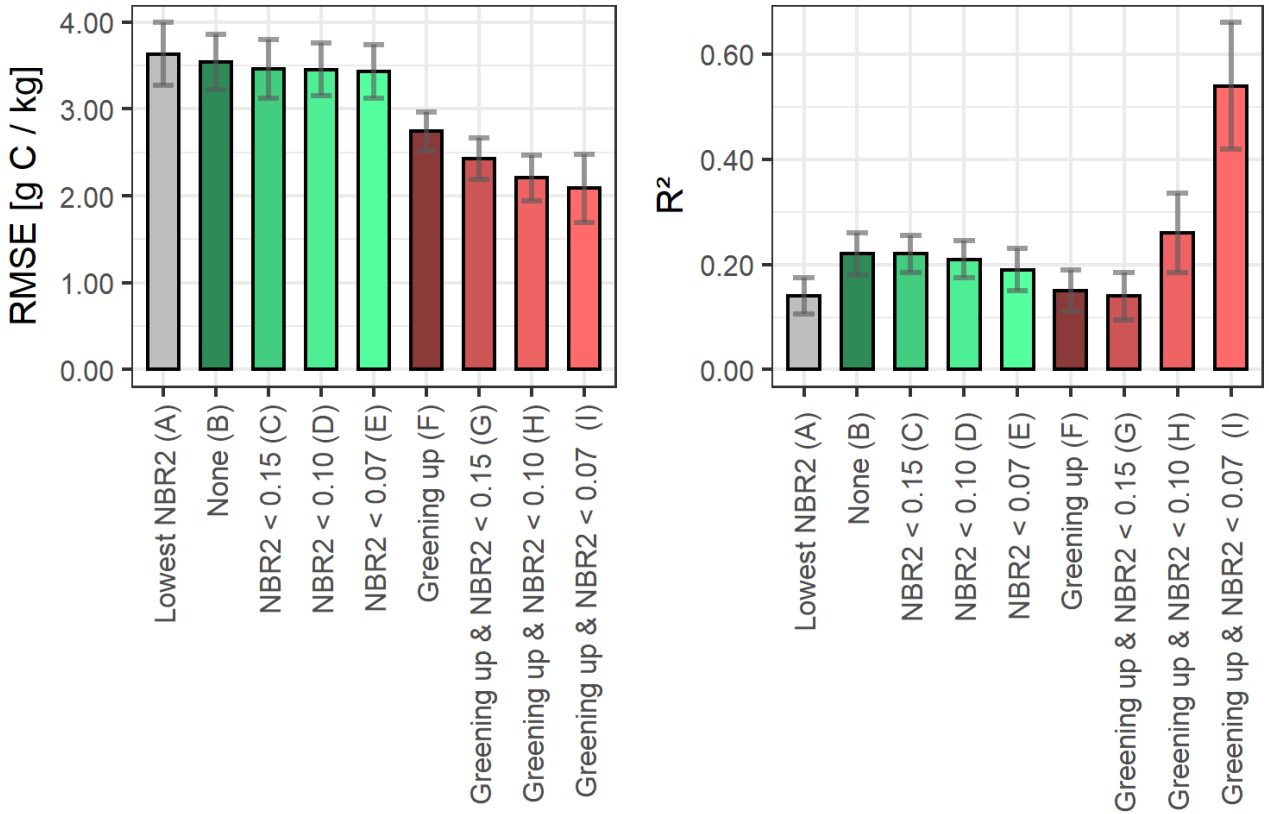
- Partial least squares regression (PLSR)

We build 9 types of composites

			NBR2			
Composite	NDVI < 0,25	Greening-up	lowest	< 0,15	< 0,10	< 0,07
A	✓		✓			
B	✓					
C	✓					✓
D	✓				✓	
E	✓			✓		
F	✓	✓				
G	✓	✓				✓
H	✓	✓			✓	
I	✓	✓		✓		

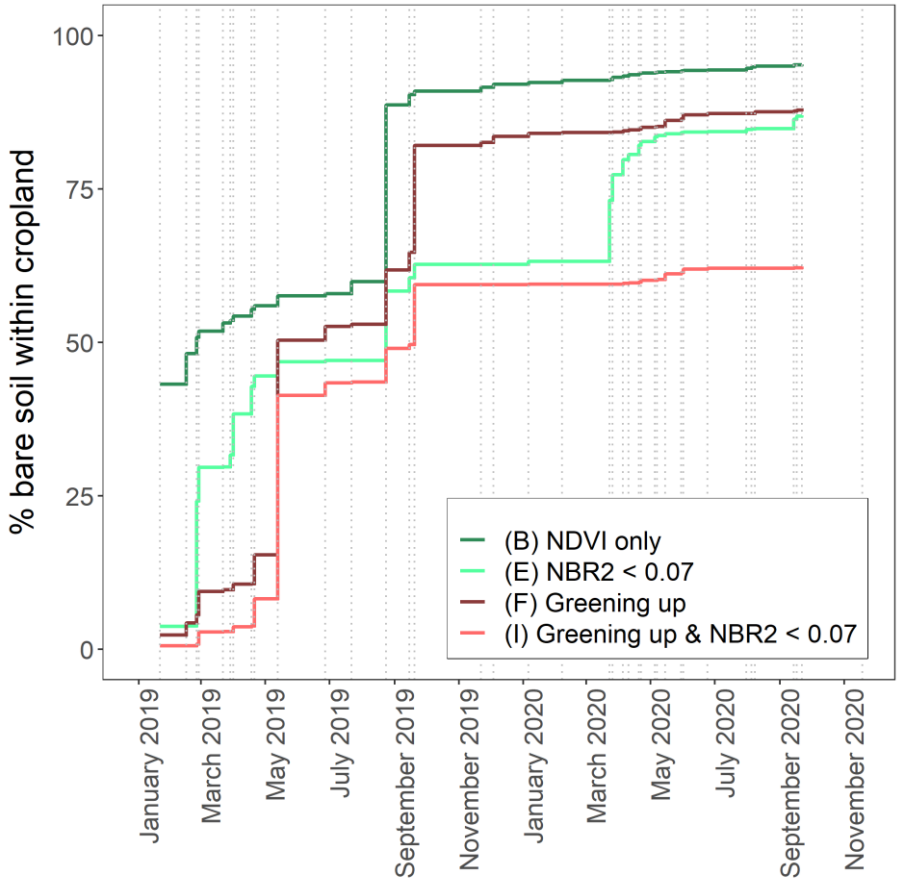
Results and discussion

The best SOC prediction model is obtained from composite built on the combination of greening-up with strict NBR2 threshold



Coefficient of determination (R^2) and Root Mean Square Error (RMSE) of the Partial Least Squares Regression (PLSR) models applied to Sentinel-2-derived composites based on various criteria.

62% of croplands is exposed during the 2019-2020 period on composite which combines greening-up with a strict NBR2 threshold



Cumulative percentage of exposed croplands extracted from all cloud free Sentinel-2 (S-2) images between January 2019 and December 2020, depending on the composite selection criteria (B, E, F or I). The vertical dashed lines are the S-2 acquisition dates.

Conclusion

- The composite built on the synergy of greening-up and NBR2 threshold allows for a good SOC prediction

  - The greening-up approach allows to select pixels which are in seed-bed conditions, hence no crop residues are present, and an eventual crust has been plowed -in

  - The NBR2 index then removes pixels affected by water

- We believe that the selection of acquisition date based on development of the cropping calendar provides a more reliable index and is easier to accomplish than empirically defining thresholds for multiple spectral indexes used in combination.