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

Klara Dvorakova ¹,* , Pu Shi ¹, Quentin Limbourg ², and Bas van Wesemael ¹

¹ Georges Lemaître Centre for Earth and Climate Research, Earth and Life Institute, Université Catholique de Louvain, 1348 Louvain-la-Neuve, Belgium
² Walloon Agricultural Research Centre (CRA-W), Farming systems, territories and information technology unit, 5030 Gembloux, Belgium
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

<table>
<thead>
<tr>
<th></th>
<th>Sentinel 2</th>
<th>APEX</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Altitude (km)</strong></td>
<td>786</td>
<td>3.6</td>
</tr>
<tr>
<td><strong>Sensor type</strong></td>
<td>multispectral</td>
<td>hyperspectral</td>
</tr>
<tr>
<td><strong>Spectral range (nm)</strong></td>
<td>443 – 2190</td>
<td>413 – 2431</td>
</tr>
<tr>
<td><strong>Spectral bands</strong></td>
<td>13</td>
<td>285</td>
</tr>
<tr>
<td><strong>Resolution</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spatial (m)</td>
<td>10 – 20 – 60</td>
<td>2</td>
</tr>
<tr>
<td>Temporal (day)</td>
<td>5</td>
<td>2 – 13</td>
</tr>
<tr>
<td><strong>Noisy bands (nm)</strong></td>
<td>—</td>
<td>413 – 440, 1310 – 1555, 1750 – 2000</td>
</tr>
<tr>
<td><strong>Signal to noise (SNR)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VNIR</td>
<td>89:1 to 168:1</td>
<td>50:1 to 700:1</td>
</tr>
<tr>
<td>SWIR</td>
<td>50:1 to 100:1</td>
<td>40:1 to 600:1</td>
</tr>
</tbody>
</table>
How to estimate crop residue cover with remote sensing products?

We tried

<table>
<thead>
<tr>
<th>Sentinel 2</th>
<th>APEX</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Normalized Burn Ratio</strong> (<em>NBR2</em>)</td>
<td><strong>Cellulose Absorption Index</strong> (<em>CAI</em>)</td>
</tr>
<tr>
<td>$NBR2 = \frac{R_{SWIR1} - R_{SWIR2}}{R_{SWIR1} + R_{SWIR2}}$</td>
<td>$CAI = 0.5 (R_{2.0} + R_{2.2}) - R_{2.1}$</td>
</tr>
<tr>
<td>$R_{SWIR1}$: 1610 nm (B11)</td>
<td>$R_{2.0}$: 2026 nm</td>
</tr>
<tr>
<td>$R_{SWIR2}$: 2190 nm (B12)</td>
<td>$R_{2.1}$: 2100 nm</td>
</tr>
<tr>
<td></td>
<td>$R_{2.2}$: 2214 nm</td>
</tr>
</tbody>
</table>
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
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.
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
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.