ESTIMATION OF SURFACE SOIL ORGANIC MATTER BY MEANS OF HYPERSPECTRAL DATA ANALYSIS

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Objectives

• Determine Soil Organic Matter by Means of Hyperspectral Images

• Compare CASI-2 & SASI Capabilities

• Detect Factors Disturbing the signal

• Perform a Model of Prediction
STUDY SITE: LORRAINE BELGE

- Area: 50 km²
- 14 agricultural parcels
- 135 soil samples
- Sandy to clayey soils

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STUDY SITE: LORRAINE BELGE

Area: 50 km²
14 agricultural parcels
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Sandy to clayey soils
Methodology: Forward Stepwise Multiple regression

1) Statistical Study of Soil Organic Matter
2) Spectral Signature Analysis
3) Multiple Regression by a Stepwise Procedure:
   - find the Best Correlated Bands
   - SOM\(p = A_0 + A_1R_1 + A_2R_2 + \ldots + A_nR_n\)
   SOM\(p\) = predicted soil organic matter
4) Validation
   - 20 Samples for validation
   - Accuracy via PRMSE

\[ PRMSE = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (V_{ri} - V_{pi})^2} \]
Results: Soil Organic Matter

- large range of SOM
- Mean of SOM = 2.2%
- Soil Moisture variability
- Positive relationship between SOM and moisture ($R^2 = 0.61$)
Results : Visual Analysis

(a) Vegetation (3)
(b) Bare Soil (2) Soil with plant debris (1) Soil with manure (4)

Profiling Spectral

- Vegetation (3)
- Bare Soil (2)
- Soil with plant debris (1)
- Soil with manure (4)

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Results: Spectral Analysis

- Three hyperspectral measurements of the same soil surface.
- Good overlapping of the ASD and the CASI/SASI but in some expected regions of the spectrum
- Large shift of the NIR spectrometry measurements in the laboratory (\(^?\) Soil moisture)
Results: Disturbing Factors

<table>
<thead>
<tr>
<th>Samples</th>
<th>SOM (%)</th>
<th>Moisture (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L3</td>
<td>3.20</td>
<td>14.4</td>
</tr>
<tr>
<td>L4</td>
<td>3.16</td>
<td>19.4</td>
</tr>
<tr>
<td>L9</td>
<td>3.16</td>
<td>20.0</td>
</tr>
<tr>
<td>L2</td>
<td>3.22</td>
<td>25.1</td>
</tr>
</tbody>
</table>
Results: Disturbing Factors

Cleaned Pixels

Soil with plant debris

Cleaned pixels

Soil with plant debris
Results : Models analysis

Calibration phase

\[ V_p = A_0 + A_1 R_{\lambda 1} + A_2 R_{\lambda 2} + \ldots + A_n R_{\lambda n} \]

<table>
<thead>
<tr>
<th>Model numbers</th>
<th>R² Change</th>
<th>Cumulated R²</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>-0.25</td>
<td>-0.25</td>
</tr>
<tr>
<td>3</td>
<td>-0.05</td>
<td>-0.10</td>
</tr>
<tr>
<td>5</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>7</td>
<td>0.35</td>
<td>0.50</td>
</tr>
<tr>
<td>9</td>
<td>0.55</td>
<td>0.75</td>
</tr>
<tr>
<td>11</td>
<td>0.75</td>
<td>0.95</td>
</tr>
<tr>
<td>13</td>
<td>0.95</td>
<td>0.95</td>
</tr>
<tr>
<td>15</td>
<td>0.95</td>
<td>0.95</td>
</tr>
<tr>
<td>17</td>
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<td>0.95</td>
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<tr>
<td>19</td>
<td>0.95</td>
<td>0.95</td>
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<tr>
<td>21</td>
<td>0.95</td>
<td>0.95</td>
</tr>
<tr>
<td>23</td>
<td>0.95</td>
<td>0.95</td>
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</tbody>
</table>
Results: SOM Models (CASI-2 + SASI)

Calibration phase

<table>
<thead>
<tr>
<th>SOM (%)</th>
<th>Measured</th>
<th>Predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samples and predicted SOM</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Results: SOM Models (CASI-2 + SASI)

Validation Phase

PRMSE values

Models numbers

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Results: SOM Models (CASI-2 + SASI)

Validation Phase
CASI + SASI

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Results: SOM Models (CASI-2)

Validation Phase

CASI-2

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Results: SOM Models (SASI)

(a) SOM (%)

(b) R² = 0.5429
### Results: Selected Bands

<table>
<thead>
<tr>
<th>Order</th>
<th>$\lambda$ (nm)</th>
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<tbody>
<tr>
<td>1</td>
<td>2010</td>
</tr>
<tr>
<td>2</td>
<td>690</td>
</tr>
<tr>
<td>3</td>
<td>520</td>
</tr>
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<td>4</td>
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<td>5</td>
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<tr>
<td>6</td>
<td>488</td>
</tr>
<tr>
<td>7</td>
<td>526</td>
</tr>
<tr>
<td>8</td>
<td>2104</td>
</tr>
<tr>
<td>9</td>
<td>1970</td>
</tr>
<tr>
<td>10</td>
<td>652</td>
</tr>
<tr>
<td>11</td>
<td>1433</td>
</tr>
</tbody>
</table>

In agreement with Palacios-Orueta et al., 1996, RSE and with Ben-Dor et al., 2002, Int.J.R.S.
Conclusions

- High correlation ($R^2 = 0.88$) between the surface soil organic matter and the selected bands of the two sensors;
- Selected bands are comparable to those found by other authors;
- Both sensors contribute to the model of SOM prediction but among the studied models, the 3 more sensible bands are often given by the SASI sensor;
- Disturbing factors (soil moisture, plant residues, roughness) affect dramatically the relationship between SOM and the selected bands.
Perspectives

- APEX 2002: preliminary results
- High potential of the hyperspectral methodology for the study purpose
- Pursue the study with the APEX 2003 campaign
  - Extension to a new site for a better validation
  - Use of PCA as an alternative to the present approach
  - Quantify the impact of the disturbing factors