Regional soil characterization through the integration of remote sensing, geophysics, and field data

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**Objective**

Determination of **clay content** in soils of different parent materials in Germany by gamma-ray spectrometry and hyperspectral imaging.

**Motivation**

- **Clay content in soils** influences nutrient storage, pollutant retention, soil fertility and erosion.
- **Spatial information on clay content** provides important information on soil functions and soil degradation.
Results (1): Handheld gamma-ray spectrometry

Clay content in soils of different parent materials was derived from measurements of radioactive isotopes of potassium ($^{40}$K) and thorium ($^{232}$Th) using handheld gamma-ray spectrometry.

Training data set (70%: n=139)

Clay$_{predicted} = c_1 \cdot \text{factor}_{pm} + c_2 \cdot K + c_3 \cdot \text{Th}/K + c_4 \cdot \text{Th}$

Factor$_{pm}$: Soil parent material specific factor
K: Potassium
Th: Thorium

1000 iterations
Mean RMSE: 8.37 %
Mean MAE: 6.04 %

Validation data set (30%: n=56)

Ground truthing:
Soil sampling
- n=195
- Depth: 0-4 cm

Laboratory analyses
- Clay content: particle-size fractionation
- K content: X-ray fluorescence analysis (XRD)
- Th content: Inductively Coupled Plasma - Mass Spectrometry (ICP-MS)
Results (2): Helicopter gamma-ray spectrometry

• Helicopter gamma ray spectrometry was validated successfully by handheld gamma-ray spectrometry

• Clay content in soils was measured successfully by helicopter gamma-ray spectrometry

• Boundary effects close to forests have to be considered
Results (3): Hyperspectral imaging

Hyperspectral imaging was successfully applied to predict clay content in soils from laboratory data, airborne data and satellite data.

### laboratory data

<table>
<thead>
<tr>
<th></th>
<th>$R^2$ training</th>
<th>$R^2$ validation</th>
<th>RMSE training</th>
<th>RMSE validation</th>
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</thead>
<tbody>
<tr>
<td>Laboratory</td>
<td>0.98</td>
<td>0.97</td>
<td>0.94</td>
<td>1.52</td>
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<tr>
<td>Airborne</td>
<td>0.84</td>
<td>0.53</td>
<td>2.73</td>
<td>4.30</td>
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<tr>
<td>Satellite</td>
<td>0.85</td>
<td>0.88</td>
<td>2.57</td>
<td>2.01</td>
</tr>
</tbody>
</table>

Laboratory: working range about 4 cm

Airborne: pixel 2.5 m

Satellite (Prisma): pixel 30 m
Usability of results

- **Gamma-ray spectrometry** and **hyperspectral imaging** are promising for **mapping soil properties** as **clay content**

- Gamma-ray spectrometry completes hyperspectral imaging **in the top soil down to 30 cm depth**

- Combination of both methods can provide continuously updated **spatial soil data at local and regional scales**

- In particular, **satellite hyperspectral imaging** can support land use planning and soil protection at **inaccessible areas** impacted by ongoing conflicts or munition residues