SensRes : Sensor data for downscaling digital soil maps to higher resolutions

Use of soil spectroscopy to support the mapping of Soil Organic Carbon (SOC) with remote sensing data

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Soil maps for large areas often fail to take into account local variations in soil properties due to their coarse resolution.

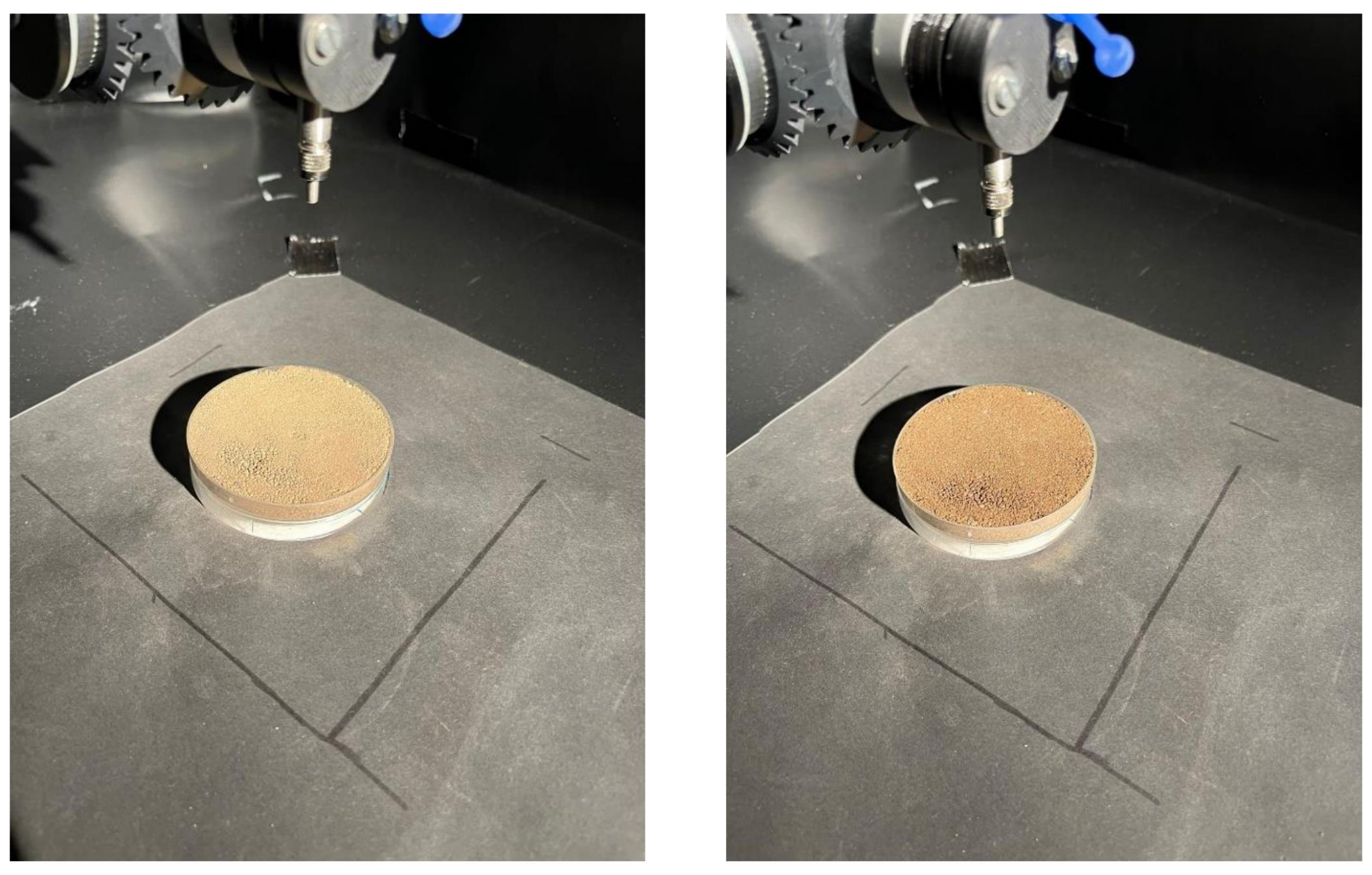
SensRes, a project within the European Joint Programme EJP SOIL, tested the potential of remote and proximal sensors that measure reflectance in the visible and infrared spectral domain to provide detailed soil information at the local scale.

This poster focuses only on the laboratory measurements, modelling and numerical experiments. The activities can be divided into three main parts.

Part 1 Laboratory measurements of the soil spectral reflectance were carried out at BOKU. Additional datasets were also gathered and unified into one database for SOC modelling. The chemical measurements were performed by different groups in Austria (AT), Denmark (DK) and United Kingdom (UK).

Highlight: Spectral measurements in the range 350-2500 nm of dry and wet soils were collected from multiple viewing angles using the DORNA 2 robotic arm allowing the spectral-directional characterization of the soil reflectance properties.

Four main datasets were compiled, and they are summarized in Table 1. Each measurement is labeled with a consecutive number from 1 to 56 corresponding to a different viewing angle. At each measurement, a standard sample of sand was measured at first. The raw spectral measurements were assembled in summary files in *csv* formats, including the chemical measurements and viewing angle information. An example of prepared soil sample and measurement is presented in Figure 1. An example of the corresponding spectral measurements are presented in Figure 2 for the nadir viewing angle only.



Dry sample

Wet sample

Figure 1 Soil sample prepared for spectral-directional measurements with the DORNA robotic arm with mounted a PSR-3500 spectrometer operating in the range 350-2500 nm.

Table 1 Soil datasets available on Zenodo (see references)

Country code	Laboratory measurements	Soil samples	Viewing angles	Responsible person	Filename in repository
AT	H2020 Landsupport + BOKU own data	75	56	Theresa Strobl & Franz Zehetner	AT_T.csv
AT	EJP SOIL BOKU	16	56	Matthias Lampert & Erich Inselsbacher	AT_M.csv
DK	EJP SOIL AARHUS	24	56	Matthias Lampert & Lucas Gomes	DK.csv
UK	Guildford	51	56	Ben Cutting	UK.csv

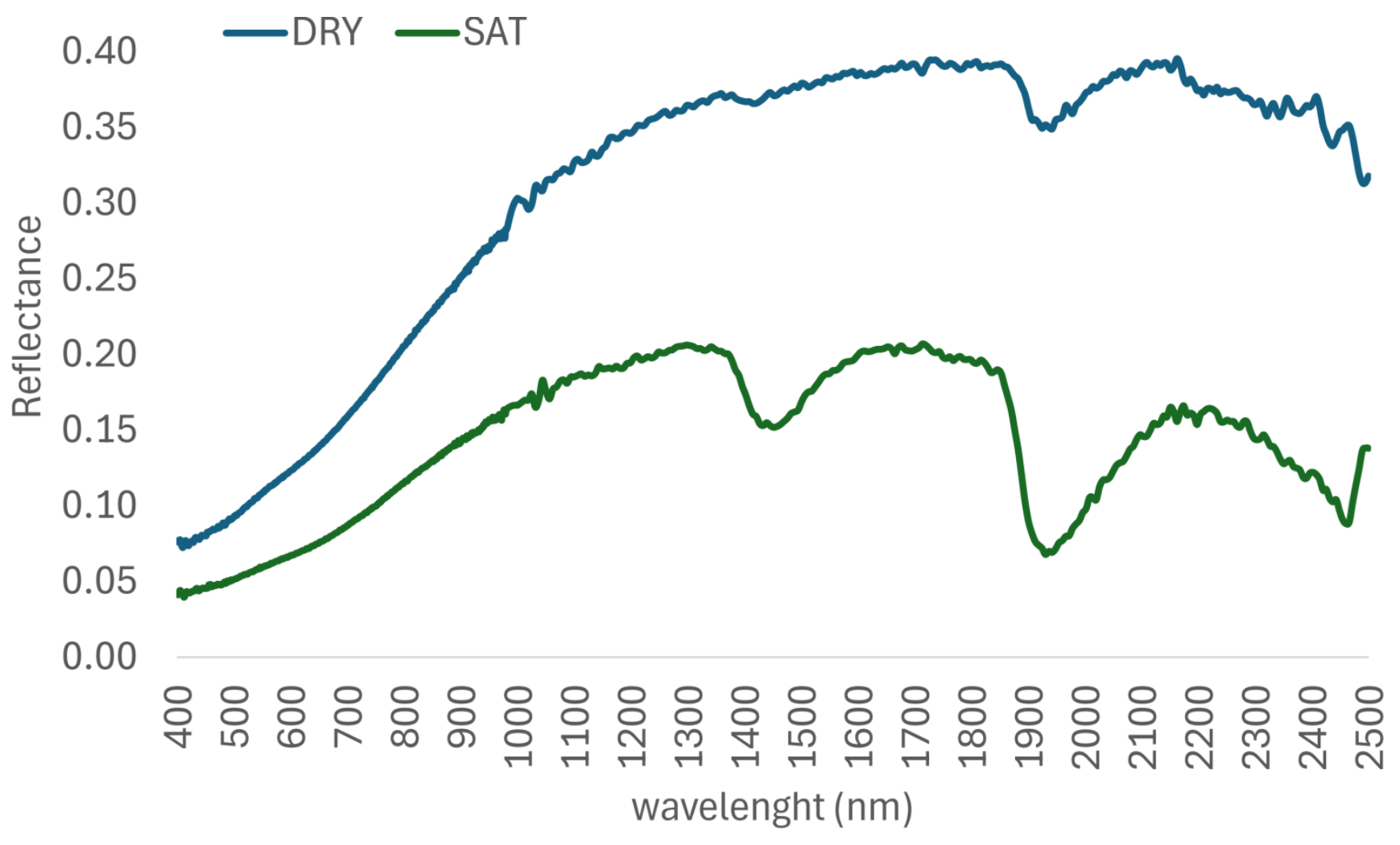


Figure 2 Example of spectral reflectance measurements for a soil sample under saturation and dry conditions (nadir view, SOC = 2.2%)

Part 2 Calibration of a model to estimate SOC. We tested statical approaches based on Partial Least Squares Regression (PLSR), Principal Components Regression (PCR) and Random Forest (RF).

All models were trained (on 70% of the data) and tested (on 30% of the data) using the same data partition. In this phase, a pool of the different datasets consisting only of nadir observations (n = 350) was considered, including all soil moisture conditions. Several variants of data reduction and transformation were tested, including spectral band averaging, derivative and logarithmic.

Highlight: The best model (RF, based on second derivative “d2”, log transformed “log” data using a total of 205 features) was further considered in the calibration and validation exercise with additional data. The results of the training and testing are shown in Figure 3.

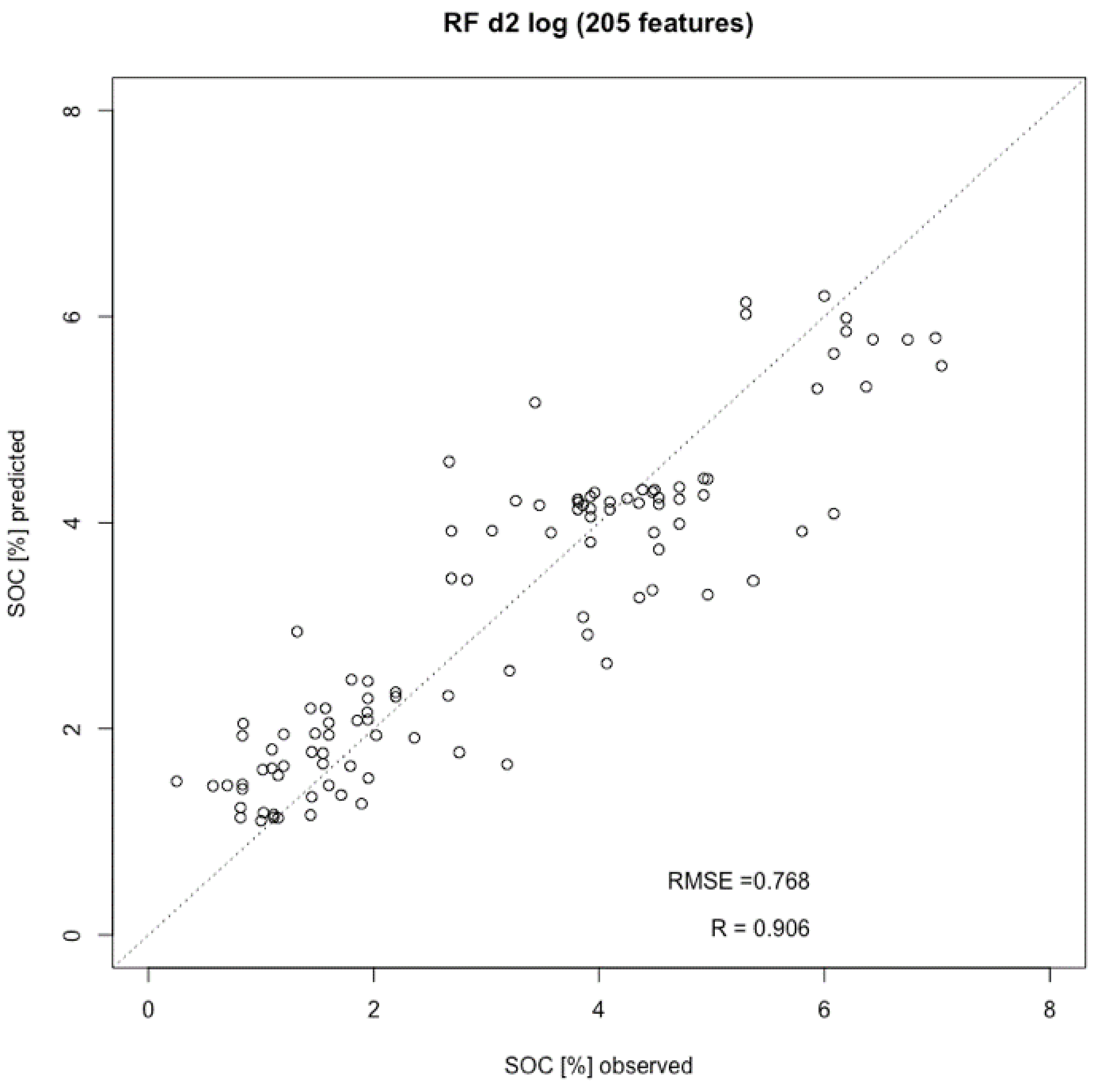


Figure 3 Scatterplots of the observed vs the predicted Soil Organic Carbon (SOC) for the testing (No. = 106) data.

Part 3 The best model (RF d2 log) was re-calibrated on all viewing angles using a total of 13953 observations for training and 5984 for testing to generate results presented in Figure 4 (based on 205 features) and Figure 5 (based on 8 spectral bands of Copernicus Sentinel-2). We can notice that the quality of estimation deteriorates when applied with limited spectral information compared to the 205 features.

Key conclusions: **Calibration Across Viewing Angles:** Accuracy improves with calibration across all viewing angles. **Data Type:** Hyperspectral data outperforms Sentinel-2, highlighting high spectral resolution's importance in SOC estimation. **Spectral Resolution:** Averaged 10 nm spectral data perform better than 1 nm data, reducing noise and overfitting. **Model Performance:** RF models excel over PLSR and PCR using log-transformed, 2nd derivative spectral data. **Outlook:** More experiments are needed to improve applicability with Sentinel-2 data and to better exploit the direction information.

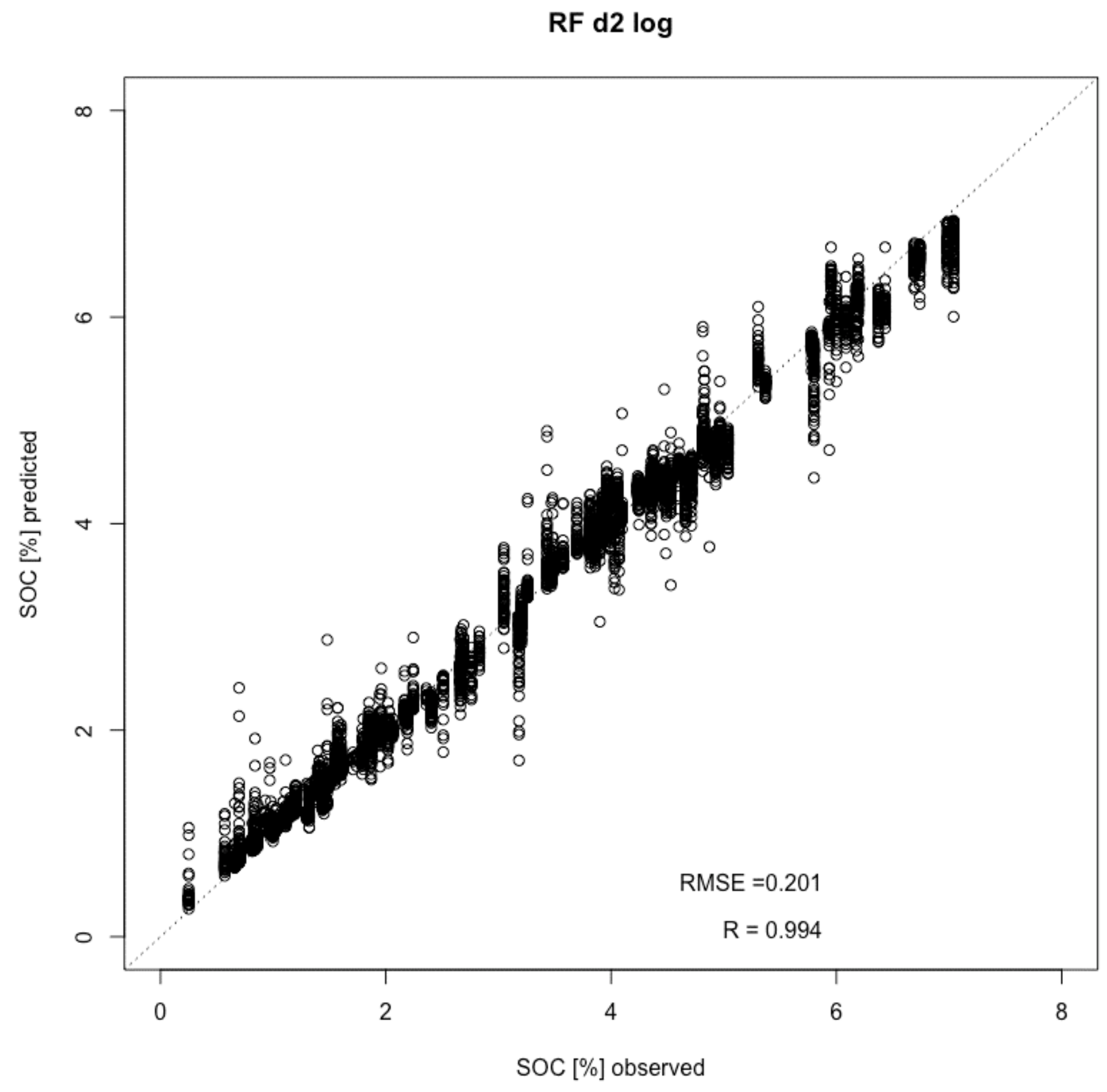


Figure 4 RF model (trained on d2_log transformed data) applied to the testing data for AT_T, AT_M and UK for all angles.

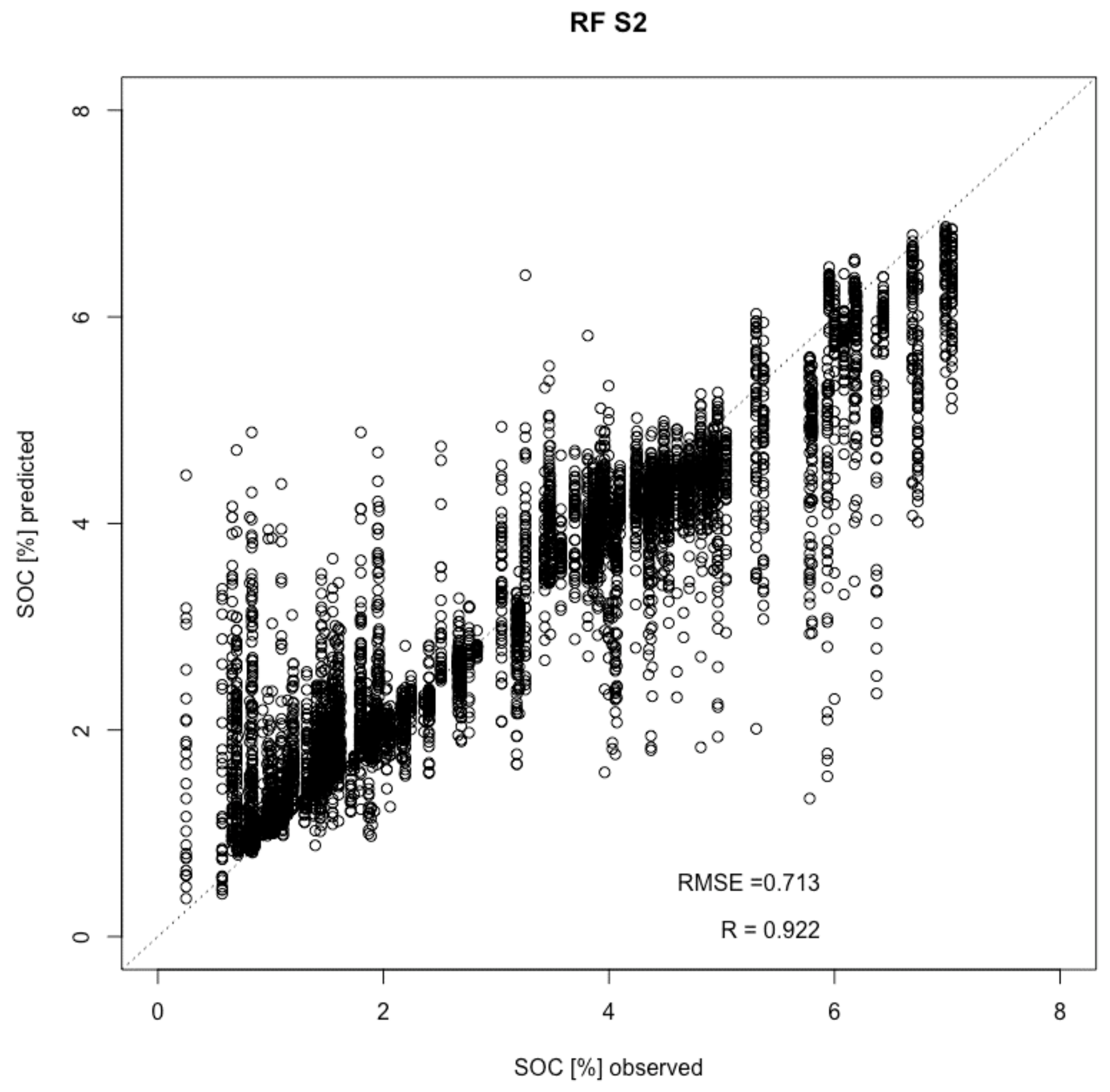


Figure 5 RF model (trained on Copernicus Sentinel-2-like spectral bands) applied to the testing data for AT_T, AT_M and UK for all angles using S2-like data.

SensRes project website: https://ejpsoil.eu/soil-research/sensres

Spectral data repository: https://zenodo.org/records/12771391

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