

Mapping soil organic carbon using UAV hyperspectral imagery and laboratory reflectance spectroscopy in Po valley region, Italy.

Angela Righi¹, Angelica DeRos^{1,2}, Luigi Sartori^{1,2}, Francesco Morari¹

¹Department of Agronomy, Food, Natural resources, Animals and Environment – DAFNAE, School of Agricultural Sciences and Veterinary Medicine, University of Padua, Viale dell'Università 16, 35020 Legnaro, Padova, Italy (angela.righi@unipd.it)

²Department of Land, Environment, Agriculture and Forestry TESAFA, School of Agricultural Sciences and Veterinary Medicine, University of Padua, Viale dell'Università 16, 35020 Legnaro, Padova, Italy

Introduction

The EU's Carbon Removal Certification Framework (**CRCF**) requires that carbon removals demonstrate both **additionality** and **persistence**, setting new standards for Monitoring, Reporting, and Verification (**MRV**).

To meet these requirements, we are testing a cost-effective and scalable approach that combines

- **field spectrometry,**
- **UAV-based hyperspectral imaging.**

In order to distinguish different fractions of Soil Organic Carbon and their persistence.

Materials and Methods

Hyperspectral Images:

- UAV model DJI Matrice 600 Pro;
- NanoHyperspec camera (Headwall Photonics) → 400-900 nm
- MicroHyperspec camera (Headwall Photonics) → 900-2500 nm



The ground spatial resolution of the combined image was 0.053 m that was then resampled to 0.1 m.

Materials and Methods

200 Ground Sampling Points

In field

In lab

- Recorded GPS position
- Spectra capture with portable ASD spectrometer (400-2500 nm) at a proximal distance of 5 cm

- Textural analysis with laser diffraction;
- Carbon analysis through different combustion temperatures:

Total Organic Carbon
(TOC400): 25-400°C

Recalcitrant Organic Carbon
(ROC): 400-600°C

Total Inorganic
Carbon: 600-900°C

Materials and Methods

Why differentiate SOC on its combustion temperature

SOC200: The Ultra-Labile Pool

Volatile, easily mineralizable compounds with rapid turnover. It indicates recent microbial activity but not persistent storage.

SOC300 & SOC400: The Responsive Labile Pools

Hot-water extractable carbon, carbohydrates, proteins; They respond quickly (1-5 years) to management practices (e.g., manure application, cover crops). The **best indicator** that links management to SOC change.

SOC500: The Transitional & Stable Pool

More recalcitrant material; overlaps with the stable carbon pool; Increases in this fraction signal that carbon is being stabilized. It is the Indicator of Medium-to-Long Term Sequestration.

Materials and Methods

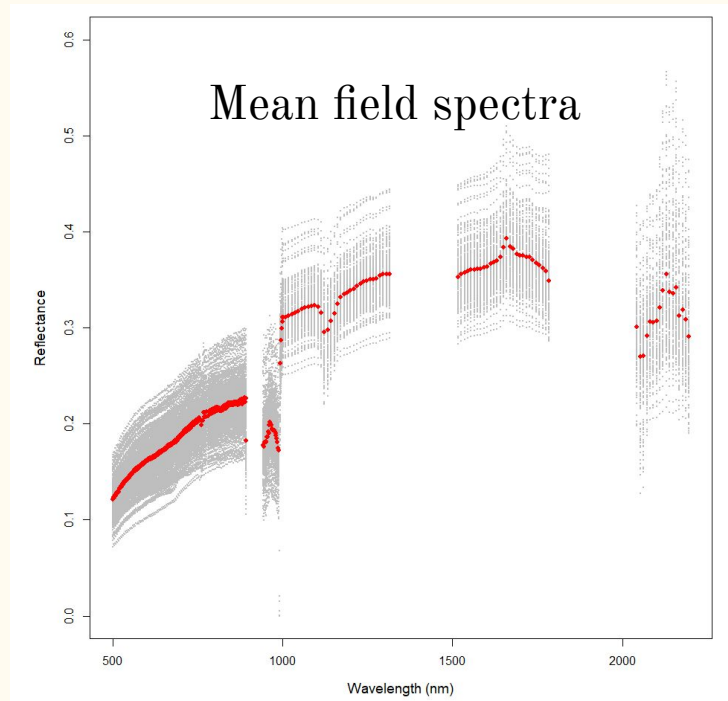
Modeling (identical procedure both on remote and proximal spectra)

1. Preprocessing

Trimming of the most water sensitive bands;

Splice correction to joint the different sensors;

Different combinations of Multiplicative Scatter Correction, Standard Normal Variate and Savitzky Golay filter applied.



Materials and Methods

2. **Band reduction** through Competitive Adaptive Reweighted Sampling and Successive Projection Algorithms.

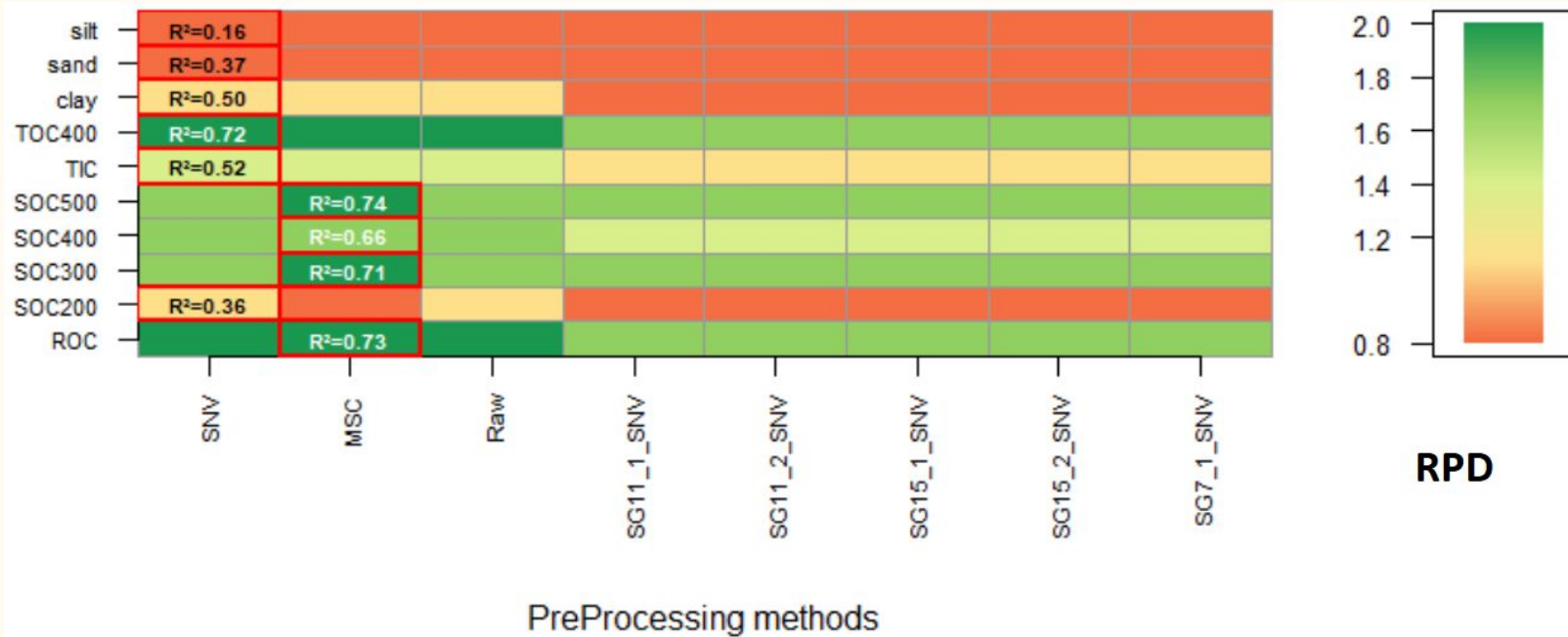
3. PLSR, Cubist and Random Forest tested with a 10 fold Cross Validation for:

- The complete spectra;
- The selected wavelengths;
- All different combinations of preprocessing.

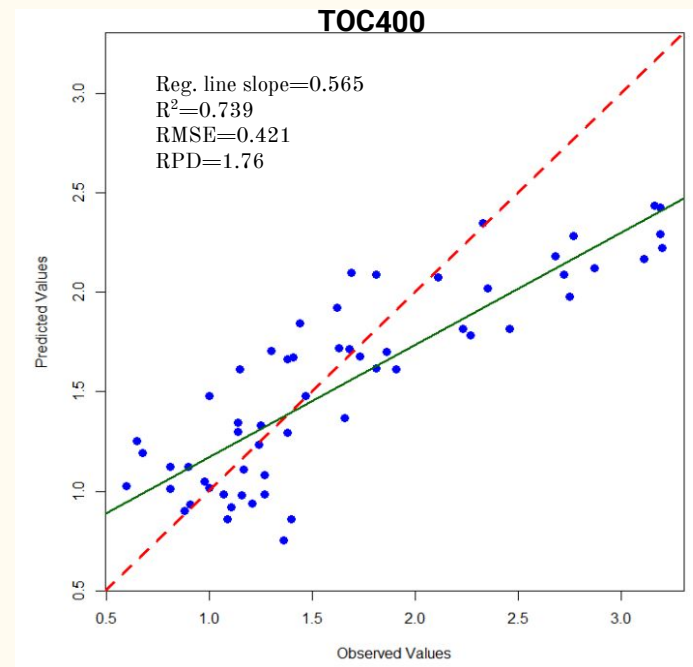
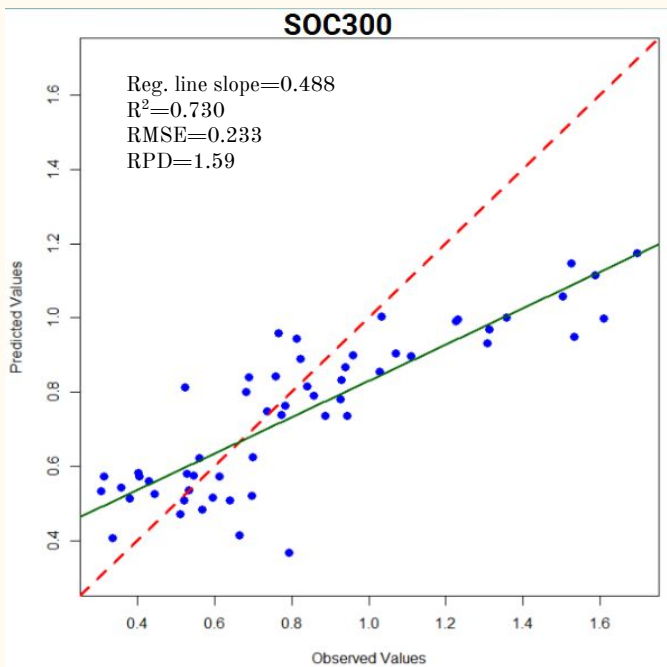
4. Selection of the best predictive model for each variable based on:

- R² (Determination Coefficient);
- RMSE (Root Mean Squared Error);
- RPD (Ratio of Performance to Deviation)
- BIAS

Results

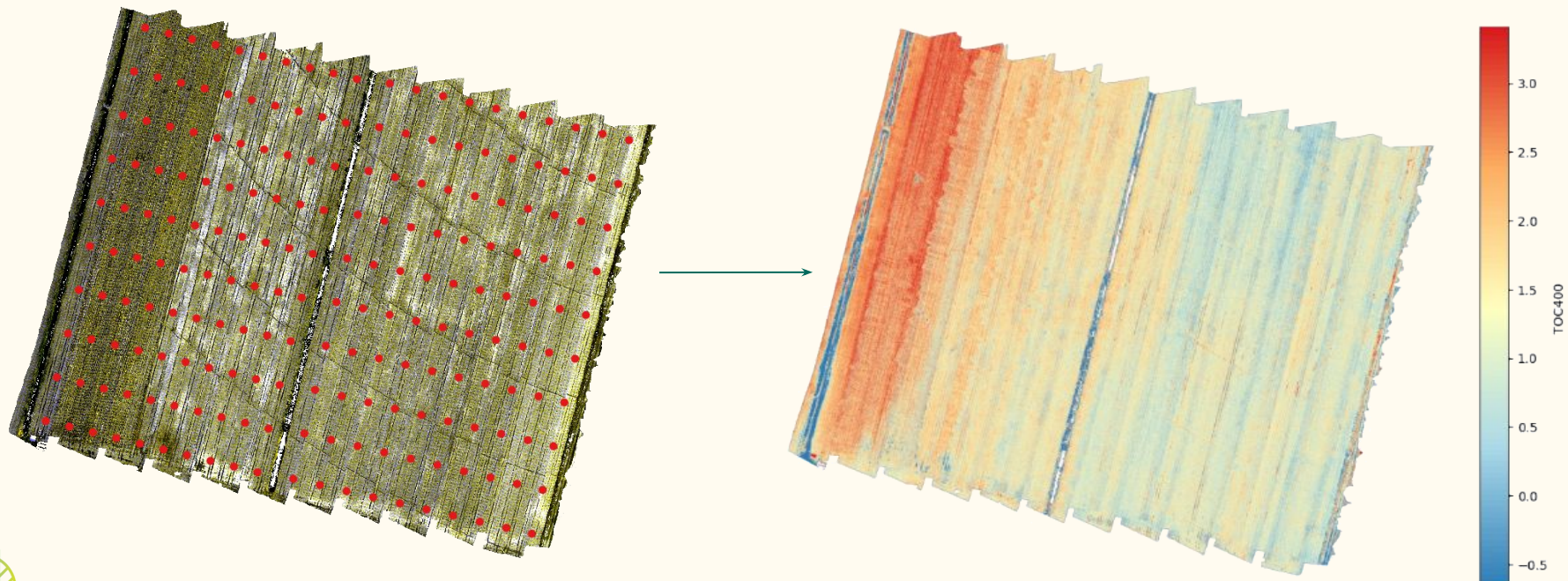


Results



Results

RGB composite (HS) and TOC400 prediction map



Future steps

Integration of data collected by Smartfirmer [Precision Planting] at the planting time (almost one point every meter) with the UAV ones.

Organic matter is estimated from the VNIR bands: 468, 592, 858, 1198 e 1468 nm.

Integration of our **Regional Soil Spectral Library** with samples scanned at different soil moisture levels. Five distinct humidity classes have been already characterized, broadening this range is essential. Calibrating UAV imagery with ASD measurements will allow to effectively overcome the confounding effect of variable water content on SOC estimates.

Thanks for your attention

Angela Righi
angela.righi@unipd.it