Estimation of soil organic carbon from spectral data in a Mediterranean agricultural mountain landscape

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EGU General Assembly 2019

Soil System Science SSS10.3

Remote sensing techniques for soil and crop monitoring

Introduction

- Soil organic carbon (SOC) is a useful indicator of soil fertility that plays an important role in improving soil quality, increasing agronomic productivity and maintaining sustainability of agricultural systems.
- The use of hyperspectral data for SOC estimation offers a fast, cost-effective, and non-destructive alternative to conventional soil analyses. Spectral data analysis with multivariate statistical methods has been already successfully used to transfer soil reflectance data on quantitative estimation of SOC content.
- The employment of field-based or UAV-portable spectral sensors could be a solution to obtain more data also in the spatial domain. However, type of sensor and conditions of data acquisition are determinants of the quality and accuracy of the output spectral data.

Objective: this study aims to test the possibility of employing the vis-NIR spectral information of a small portable multispectral camera for the quantitative prediction of organic carbon content in Mediterranean soils. This is done by comparing Partial Least Squared Regression (PLSR) model performances on traditional laboratory-based spectra and spectral data acquired in outdoor conditions. It also test the stability of model performances from repeated measures under different sky conditions.

Materials and methods

The study area: a rain-fed agroforestry system in the central part of the Ebro Basin, NE Spain.

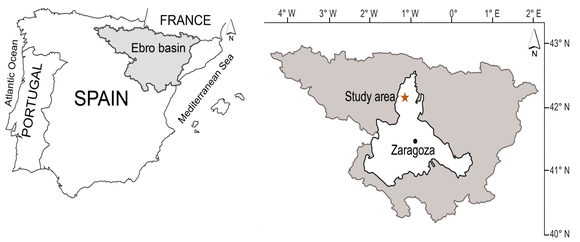


Figure 1. Location of the sampling area

Soil samples: 73 soil samples were collected from 3 land-use types: cropland, forest and pine afforestation.

Figure 2. Land use types considered for sample collection

Chemical analysis: SOC content (g*kg^{-1}) of all soil samples was measured at 550° C by dry combustion using a LECO RC-612 multiphase carbon analyser.

Reflectance (+ irradiance) data:

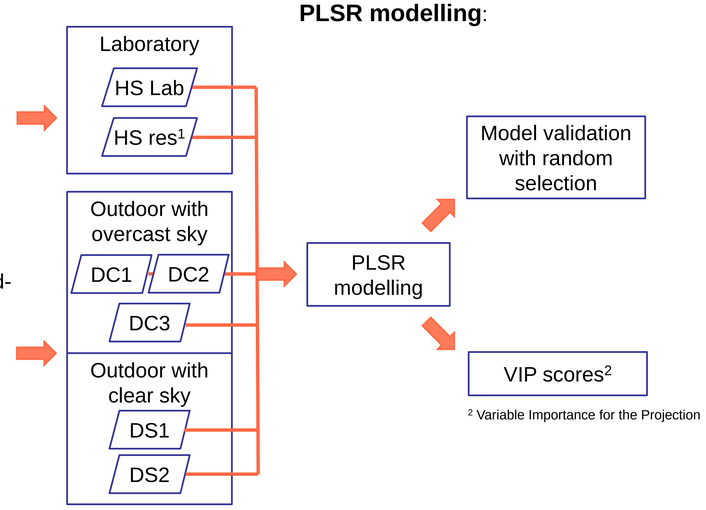
ASD FieldSpec 3 FR

- 350-2500 nm spectral range
- 1 nm output resolution

Micasense Rededge-M + Downwelling Light Sensor

- Spectral broad-bands at:
  475±10 nm
  560±10 nm
  668±5 nm
  717±5 nm
  840±20 nm

PLSR modelling:



[2] Variable Importance for the Projection

[1] Resampled to Rededge-M resolution

References & Acknowledgements: This research was supported by the "MOVE-IN Louvain" Incoming Post-doctoral Fellowship (L.Quijano as a beneficiary), co-funded by the Marie Curie Actions of the European Commission (MSCACOFUND).

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- Quijano L., Gaspar L., Navas A. 2016.Spatial patterns of SOC, SON, ^{137}Cs and soil properties as affected by redistribution processes in a Mediterranean cultivated field (Central Ebro Basin). Soil and Tillage Research, 155, 318-328.

Results and Discussion

Soils: were classified as Calcisols, pH ranged between 6.8 and 8.93 and most of the soil samples had silt loam texture. Selected soil samples had a wide range of SOC content from 2 to 71 g kg-1. Soil organic carbon (SOC %) was significantly lower in cultivated soils ($p<0.05$) than in forest and abandoned soils.

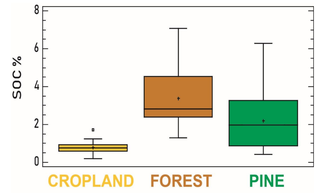

Figure 3. Samples SOC content from laboratory chemical analysis

Irradiance: Irradiance values measured by the Downwelling Light Sensor (DLS) were stable across repeated measures during the overcast day, slightly less stable during the clear sky conditions.

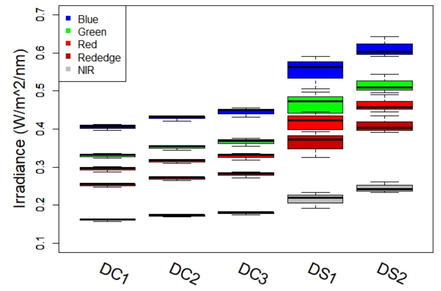

Figure 4. Irradiance values measured by the DLS during the different picture acquisitions

PLSR: Results of PLSR modelling show that the tested multispectral narrow-bands were useful for SOC prediction with a level of accuracy comparable to the one obtained with hyperspectral data in the full vis-NIR-SWIR range. Also, performances were stable across the repetitions in different sky conditions.

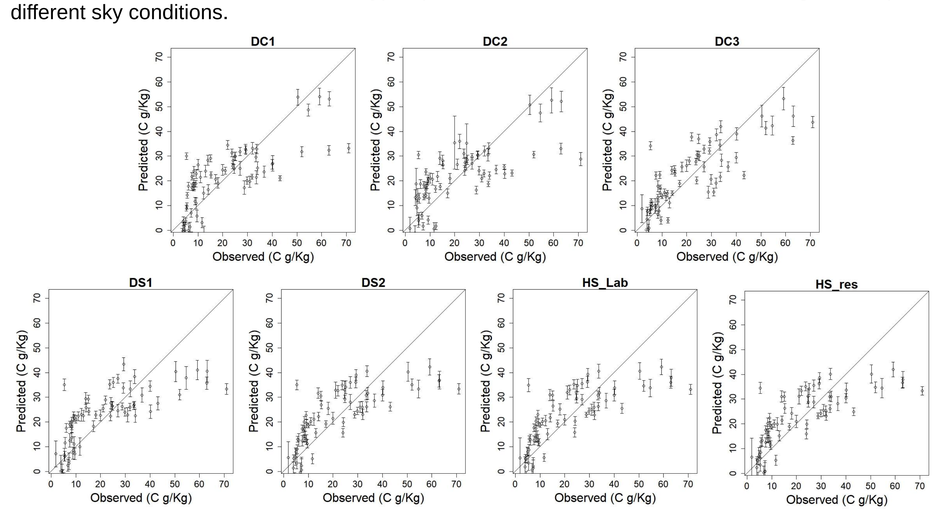

Figure 5. Observed vs predicted SOC values for all of the considered datasets.

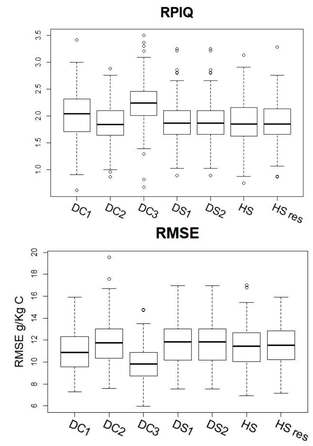

Figure 6. Summary of model performances in terms of Ratio of Performance to Interquartile Range (RPIQ) and Root Mean Squared Error (RMSE)

VIP scores: the Variable Importance for the Projection (VIP) score shows that:

- In the full vis-NIR-SWIR spectrum, the region containing more information for PLSR modelling of SOC is in the 400-800 nm range, with a peak around 550 nm, followed by the 2000-2400 range;
- When using the multispectral data, PLSR finds more informative the broad-bands at 668, 717 and 840 nm.

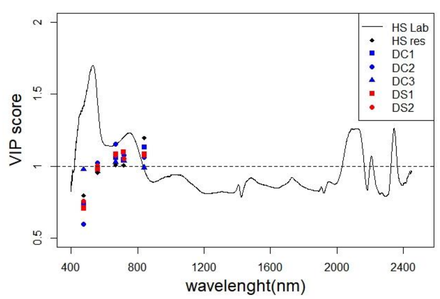

Figure 7. Variable Importance for the Projection (VIP) scores for all the considered datasets.

Conclusions

The spectral data provided by the tested multispectral camera can be successfully employed for SOC prediction in outdoor conditions on Mediterranean soils, both in terms of accuracy and stability, providing an efficient method for fast acquisition of data also in the spatial domain, especially in the perspective of UAV applications.