THEME 1

Field scale mapping of soil carbon stock with limited sampling by the use of proximal sensors

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INTRODUCTION

Mapping soil features at high detail usually has high cost, is time-consuming for high number of sampling, and the results are often questionable. The use of proximal sensors allows a quick and cheap recording of data with a very high spatial density.

OBJECTIVES

The present work wants to test the combined use of two proximal sensors, namely visible-near infrared Diffuse Reflectance Spectroscopy (Vis-NIR DRS) and passive γ-ray spectrometers, to obtain high detailed maps of soil C stocks at a depth of 0 to 30 cm (CS30) using a limited number of sampling sites per field (1 sample per hectare).

Vis-NIR DRS was used to increase the number of data-points at low cost, whereas gamma-ray maps were used as covariates in the prediction model.

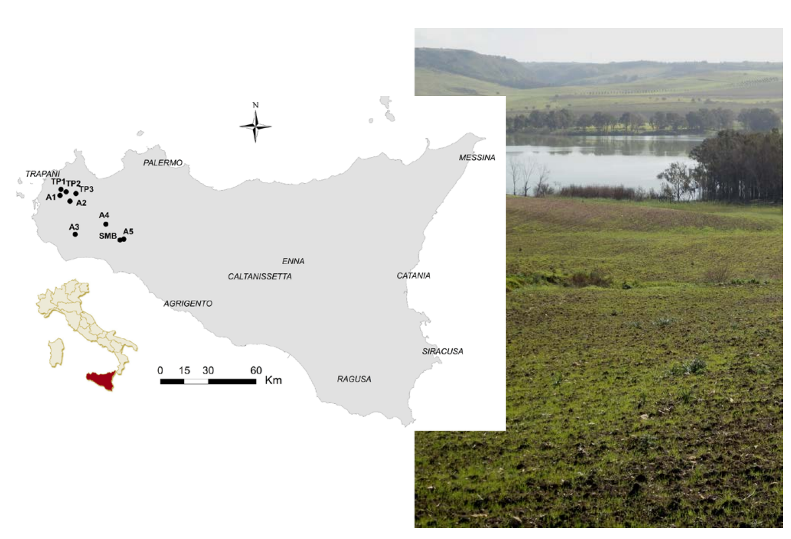


Fig. 1: Study field

The surveyed fields span between 2 and 6 ha, and they were dislocated into nine areas, cultivated with extensive row-croplands. The parent materials included marls, clays and silty-clays deposits of marine origin (Miocene-Pliocene), as well as clayey-calcareous flysches and calcarenites of Cretaceous-Paleogene.

METHODOLOGY

Field proximal soil survey was made by γ-spectroradiometer (“The Mole”, Soil Company) carried out in a backpack and connected to GPS. “The Mole” can measure total gamma-rays emitted from the soils (TC) and the radionuclides contribution (^{40}K, ^{232}Th, ^{238}U).

Simultaneously with the γ-radiometric surveying, 208 soil samples (0-30 cm deep) were collected with a frequency of 8 samples per hectare.

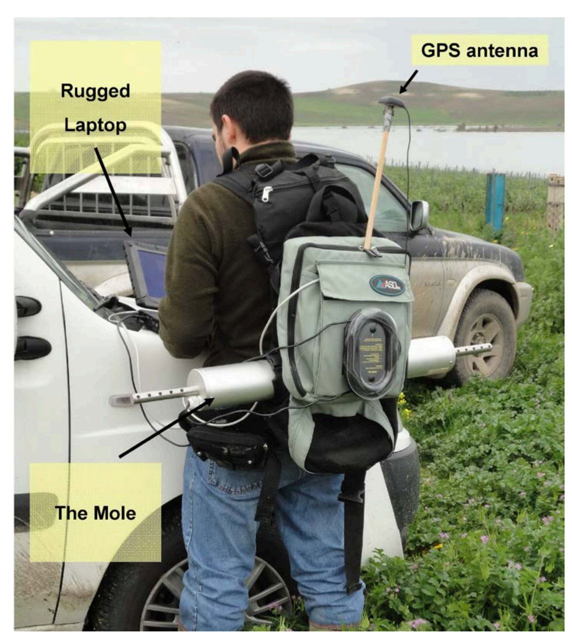


Fig. 2: Use of γ-spectroradiometer in the field

The samples, previously dried and 2-mm sieved, were scanned by (Vis-NIR DRS), using a Fieldspec 3 Hi-Res, which has bands ranging between 350 and 2500 nm.

Fig. 3: Sample scanning with field

32 representative samples were selected, by the means of k-means clustering, for calibration. Other 36 samples were randomly selected for final validation of the maps.

CS30*f* : Carbon stock (0-30 cm) on the fine earth (< 2 mm) predicted by Vis-NIR spectroscopy.

CS30: Carbon stock (0-30 cm) corrected for gravel content and interpolated within experimental field by Geographical Weighted Multiple Regression (GWMR), using γ-ray maps (total counts & radionuclides concentration) as covariates.

RESULTS

The soils showed similar texture, gravel content, SOC, and then CS_{30}. A1, TP1 and TP3 areas showed the highest mean values of TC (> 470 Bq·kg^{-1}), whereas A2 and A5 showed the lowest TC. A3 and A5 were spatially homogeneous, whereas the highest spatial variance was clearly observable in the sites A2, TP2 and A4. This was mainly due to the presence of strongly eroded areas characterized by thin soils, high stoniness, and scarce soil organic matter.

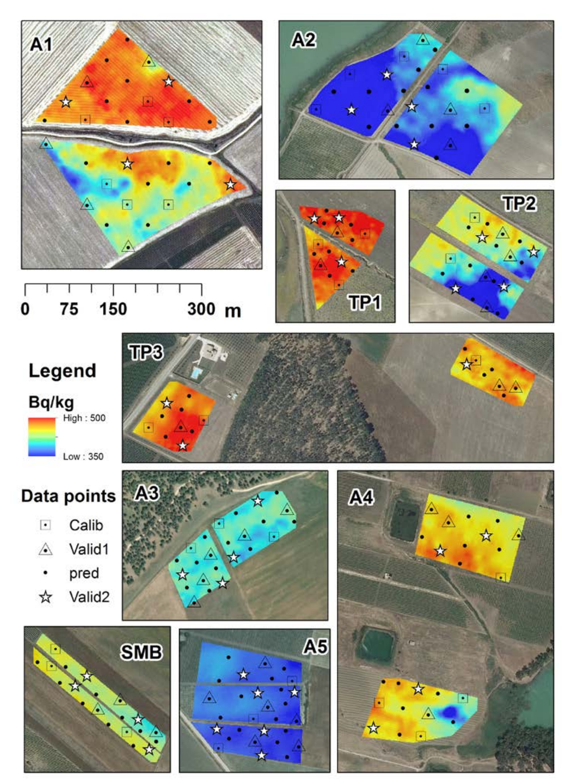
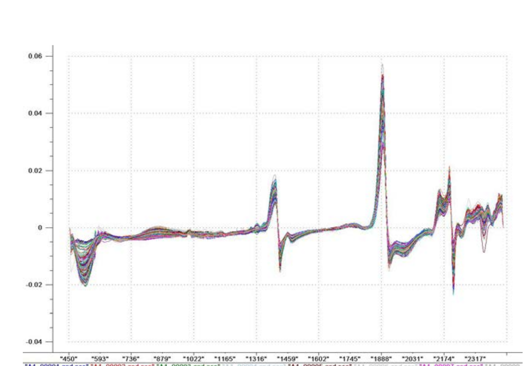


Fig. 4: Maps of gamma-rays total counts and soil features of each field

Tab. 1: Sample characteristics

Site	SOC		Clay		CaCO3		Gravel m3·m3		CS30 (kg·m-2)	
	Mean	Stand. dev.	Mean	Stand. dev.	Mean	Stand. dev.	Mean	Stand. dev.	Mean	Stand. dev.
A1	0.95	0.08	72.8	3.1	1.5	1.5	0.05	0.05	3.58	0.56
A2	1.54	0.30	59.2	7.0	15.1	9.2	0.14	0.09	4.47	0.99
A3	1.46	0.19	63.3	2.3	22.2	1.6	0.10	0.00	4.61	0.50
A4	0.82	0.15	59.8	9.2	5.8	1.9	0.06	0.05	3.10	0.59
A5	1.10	0.33	50.0	7.4	26.0	9.2	0.05	0.03	4.22	1.30
TP1	0.73	0.20	51.8	2.8	7.0	1.2	0.03	0.02	2.96	0.66
TP2	0.69	0.28	50.5	3.1	18.5	12.8	0.13	0.10	2.43	0.83
TP3	1.16	0.14	50.4	6.4	2.3	1.3	0.03	0.01	4.58	0.47
SMB	1.11	0.16	53.5	1.6	19.0	3.0	0.06	0.04	4.04	0.54

Vis-NIR DRS predictive model of CS30*f* was performed by Partial Least Square Regression (PLSR). The calibration of the PLSR predictive models of CS30*f* showed good accuracy and no outliers. The coefficient R^2 of the model was 0.86 and the RMSE was 0.43 kg·m^{-2}. The external validation set of 36 samples (*Valid1*) showed mean value and standard deviation of 4.42 and 1.39 kg·m^{-2}, respectively. The validation showed a coefficient R^2 of 0.77, RMSE of 0.67 kg·m^{-2}, and RPD of 2.06.



Graph 1: Vis-NIR spectra of the soil samples

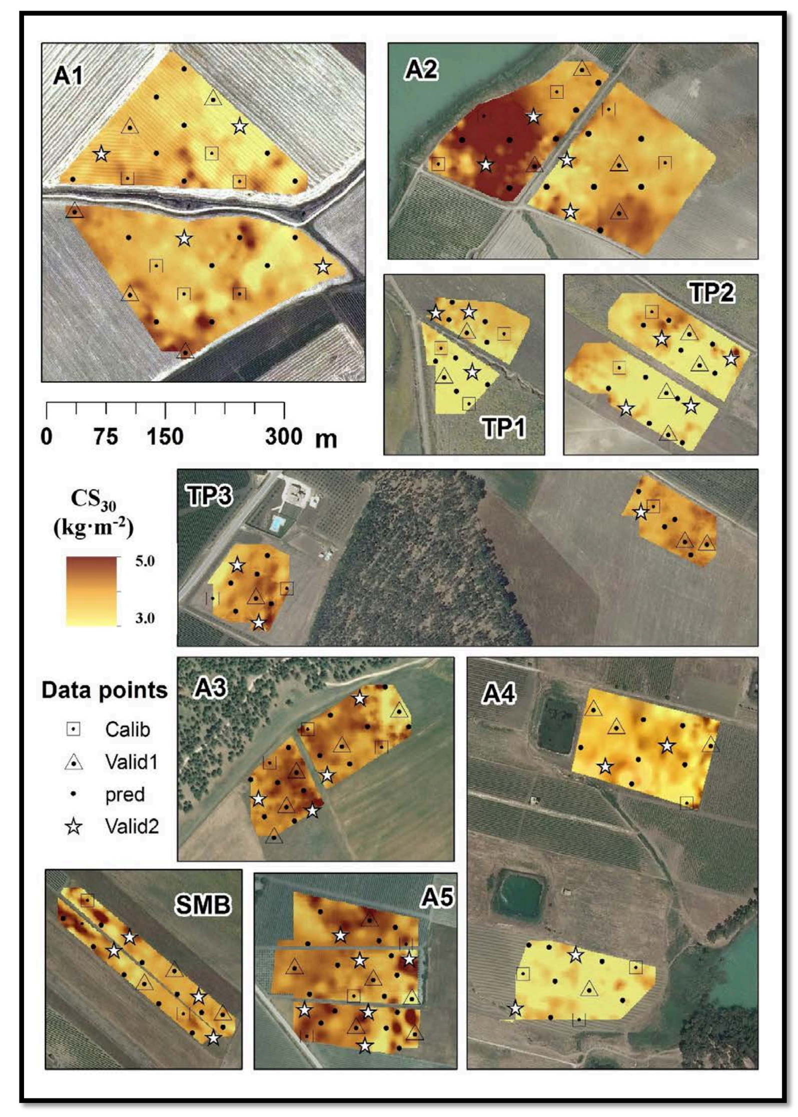
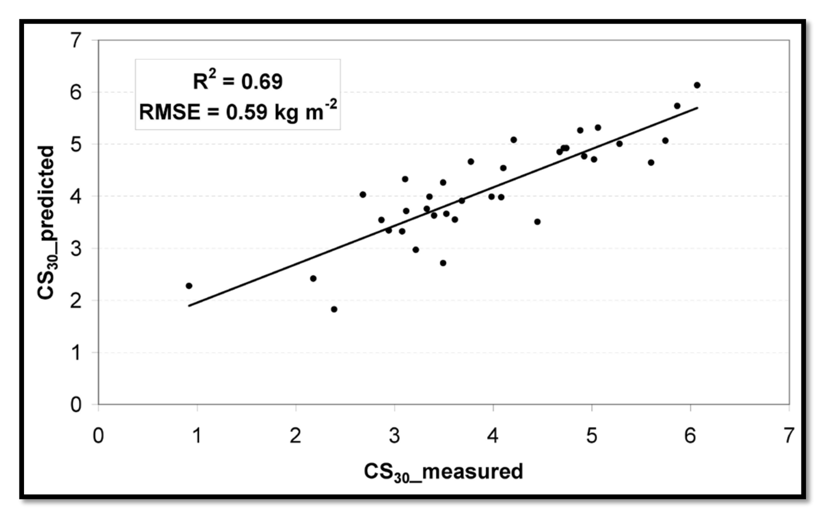


Fig. 5: Maps of carbon stock (0-30 cm) predicted by GWMR using γ-ray maps as covariates



Graph 2: Relative (Fig. 5) validation graph (Valid2 sites)

The interpolation of CS30, carried out within each area through GWMR, provided maps with acceptable accuracy (R^2 between 0.76 and 0.93). The validation of the CS30 maps, performed with the external set (*Valid2*) of the 36 samples analyzed by traditional methods, showed R^2 of 0.69, and RPD of 1.93.

CONCLUSION

This method allows predicting soil carbon stock on fine earth (CS30*f*) by Vis-NIR spectroscopy with acceptable errors, saving a considerable amount of money and time for conventional laboratory analysis. Using gamma-ray spectroscopy maps as covariates to interpolate CS30 within fields is accurate, although site-specific models are needed. The accuracy of CS30 maps allows their use for several purposes, like comparing the effects of different soil management strategies in agriculture and monitoring the effects of soil erosion on soil carbon pool.