Covariates selection assessment for field scale digital soil mapping in the context of precision fertilization management

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I. Context & Objectives

Prescription maps are a precision agriculture tool that allows to perform variable rate fertilizations: this means optimizing the dose of fertilizer, associating the most suitable quantity to each area of the field.

This is particularly important in the case of nitrogen fertilization: the lack of nitrogen, in fact, leads to a reduction in yield and quality, while an excess involves pollution risks and an unnecessary cost for farms.

In the present work, an assessment is carried out of what are the most useful **covariates** to include in the digital soil mapping of **field-scale** properties of agronomic in different farms of the **Umbria** Region in **Central Italy**, in particular **Bennicelli** and **Bertoldo** sites.

II. Methodology

The experimental sites involved in the research are located in the region of Umbria (Central Italy). The study were conducted during the experimental year 2018/2019.

The construction of prescription maps involves 3 phases:

1. Identification of the propriate covariates;
2. Identification of homogeneous areas of the field (MZ);
3. Identification of the fertilization strategy and the correct nitrogen dose to be administered.

In order to select the appropriate covariates, cross-validation was conducted to evaluate the estimation accuracy of the combination between the available covariates (three depth-level resistivity maps, Digital Elevation Model DEM data, and vegetation indices (VI) NDVI & MNDWI and bare soil indices BSI & DBSI.

Electrical Apparent Resistivity

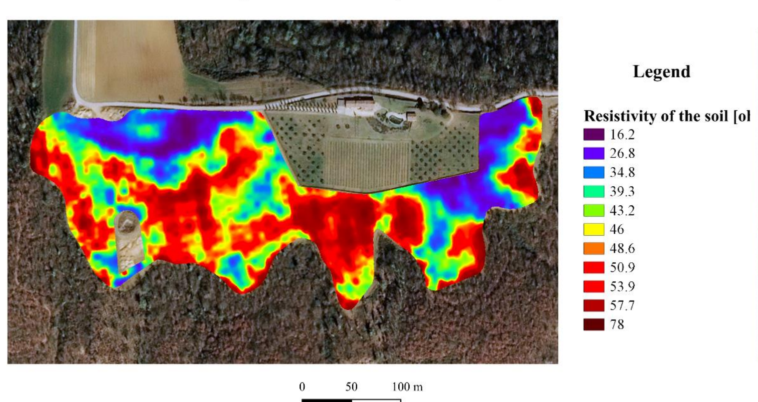
The mapping of the apparent electrical resistivity of the soil was acquired through a survey conducted in vertical mode via an EMAS system, at an effective measuring depth of 1.8 m.

Procedure: Acquisition of geophysical data continuously.

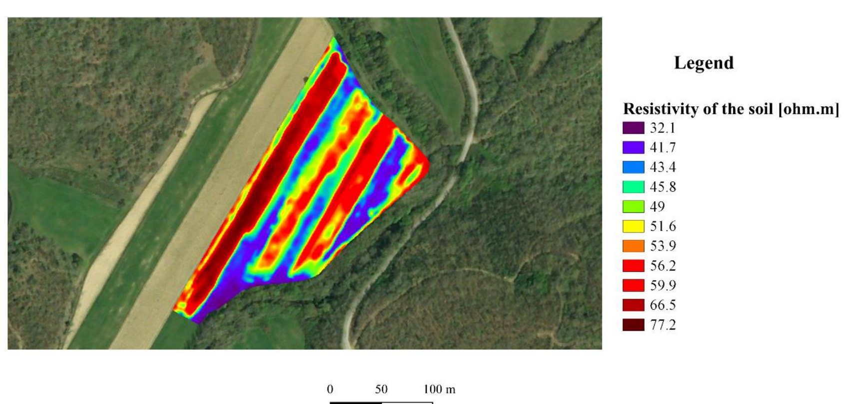
Soil depth:

- (0 – 50 cm)
- (0 – 100 cm)
- (0 – 180 cm)

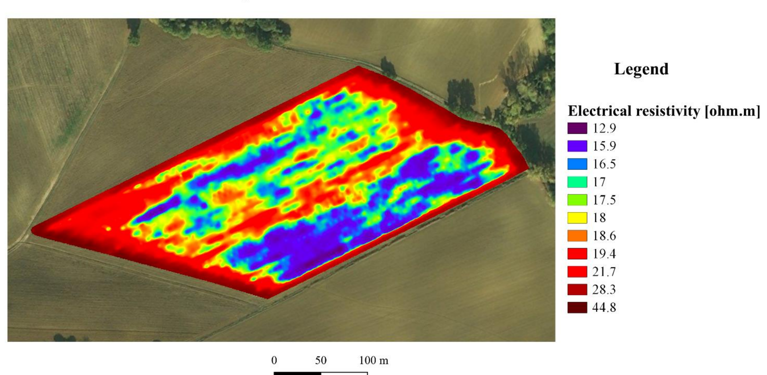
Electrical resistivity of the soil (0-50 cm) - Bertoldo site



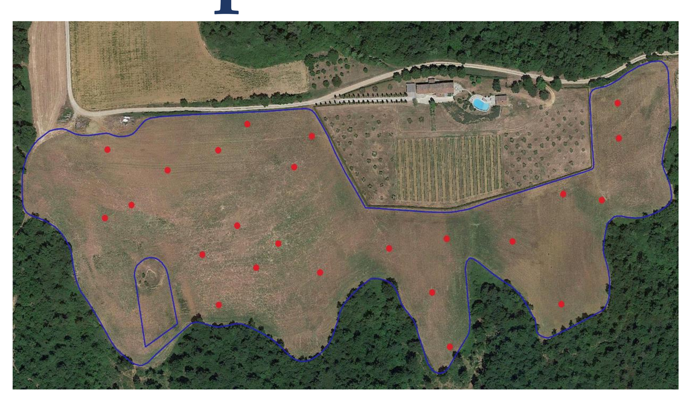
Electrical resistivity of the soil (0-50 cm) - Val di Rose site



Electrical resistivity of the soil (0-50 cm) - Bennicelli site



Top Soil Data

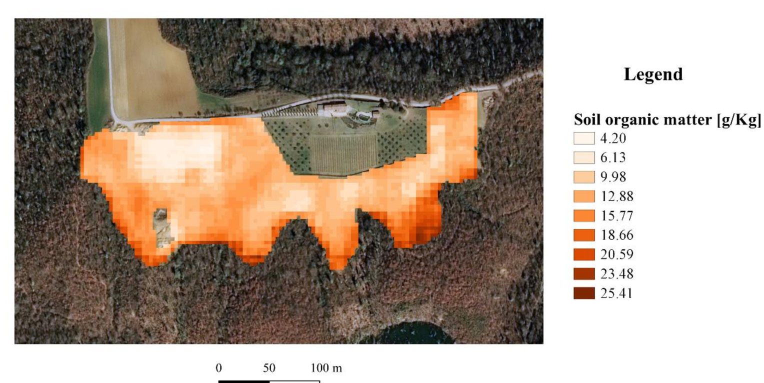


- 20 to 26 samples collected in November 2018.
- Stratified sampling according to soil conditions variability.

Lab analysis

- pH
- Cation Exchange Capacity
- Texture (sand, silt, clay)
- Nitrogen
- Organic carbon
- K & P
- Carbonates

Soil organic matter - Bertoldo site



DSM

Regression-Kriging based on a combination of different covariates, to select the appropriate variables.

Implementation of the fertilization algorithm

- The **fuzzy k-means** clustering algorithm, implemented using an R language script to identify the Management Zones analysis.
- To manage **fertilization** according to the **precision agriculture** approach, the methodology adopted is based on monitoring the **nutritional status** of the crop during the season through **remote sensors** and on the integration with information on the **MZ** and **NDVI** obtained from clustering. → **Variable rate fertilization algorithm:** Holland and Schepers (2010). The principle for the application of the treatment considers a **high nitrogen application** for the areas defined as **less soil productivity potential**.

III. Results

Bennicelli site

	Clay		Organic Matter		Carbon	
	ALL	Only VIs	ALL	Only VIs	ALL	Only VIs
Mean error	0.0008	0.0042	0.0007	0.0093	-0.0007	0.0095
Correlation Obs-Pred	0.2944	-0.7919	0.7702	0.6921	0.7812	0.7285
Correlation Pred-Res	-0.1591	-0.8475	-0.0936	-0.03143	-0.0585	0.0419
RMSE	0.1090	0.1296	0.1430	0.1614	0.1396	0.1533

Bertoldo site

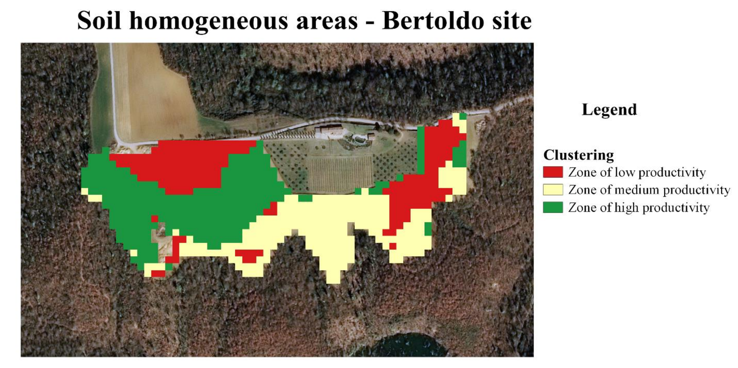
	Clay		Organic Matter		Carbon	
	ALL	Only VIs	ALL	Only VIs	ALL	Only VIs
Mean error	-0.0048	-0.0064	0.0030	-0.0071	0.0053	-0.0017
Correlation Obs-Pred	0.7037	0.6327	0.6095	0.5484	0.2446	0.2603
Correlation Pred-Res	-0.1899	-0.1525	-0.1718	-0.2457	0.1069	0.1235
RMSE	0.1965	0.2128	0.5511	0.5908	1.0920	1.2060

- ALL: refer to the covariates resistivity + DEM + spectral indices.
- Only VIs: refer to use of spectral indices as the only covariates.

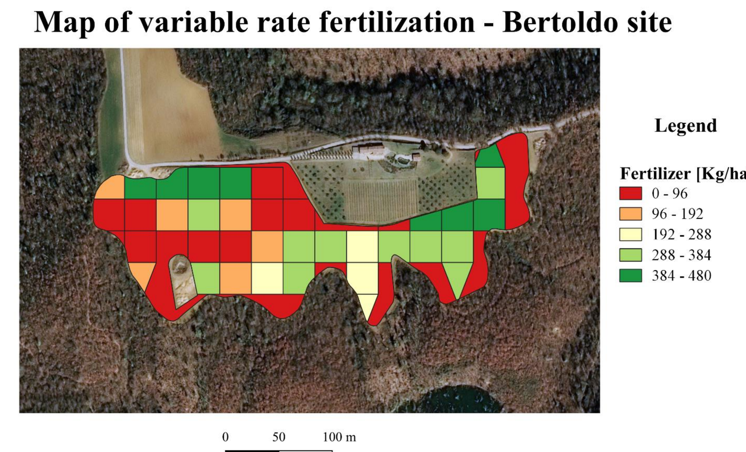
The **model** including **resistivity** and **DEM** variables developed for **DSM** estimation showed a **better accuracy** than the model without for each soil variable, in terms of **mean error, correlation between the observed and predicted values, correlation between the predicted and the residual values,** and **RMSE**.

Fertilization mapping

Soil homogeneous areas - Bertoldo site



Map of variable rate fertilization - Bertoldo site



IV. Conclusion & Outlook

- The results obtained in this study confirm that the use of the resistivity and the DEM data as covariates can significantly reduce the estimation error of DSM maps and increase the correlation between the observed and predicted data. The add of these covariates is of an added value potentially of interest for digital soil mapping. The estimation of soil variables maps (texture, organic matter and carbon) when adding the resistivity and DEM data to other covariates was, however, more accurate as compared to the use of only bare and vegetation indices as covariates.
- The prescription maps respond to the needs of customizing the doses of fertilization for each area of the field through the application strategy. In this way, the farmer can optimize his intervention in full respect of the environment and regulations with consequent economic savings.
- Another tool that can be beneficial is the redaction of the prescription maps for variable dose fertilization via **multi-temporal** analysis (Sentinel-2) to highlight areas with different persistent vegetative vigor, indicative of areas with different production potential.