Topsoil calcium carbonate mapping combining local SSL and PRISMA hyperspectral imagery

Najmeh Rasooli [1] , Saham Mirzaei [2], Stefano Pignatti [2],
(1) Ph.D. Graduate, Department of Soil Science, Faculty of Agriculture, Shahid Bahonar University of Kerman;
(2) Institute of Methodologies for Environmental Analysis (IMAA)- Italian National Research Council (CNR), C. da S.Loja, 85050 Tito Scalo, Italy
email: sahammirzaei@cnr.it

ABSTRACT

Particular consideration of the factors affecting crop yield is required for sustainable and reliable management. Pistachio (Pistacia vera L., 1753) is one of the most important agricultural products of Iran, which accounts for more than 50% of the world pistachio market. Calcareous soils with pH levels above 7.5 would accelerate the stabilization of P, Fe, and Cu nutrients and lead to their deficiency in plants.

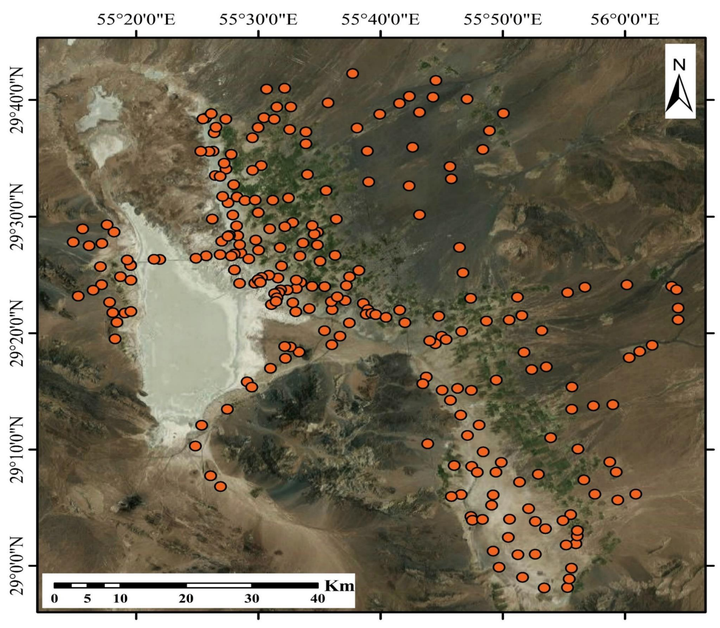
Point spectroscopy data is confirmed to have the functionality and suitable results to estimate soil variables, but this method evaluates soil properties just at the sampling points. Image spectroscopy ensures a way to obtain soil spatiotemporal variation over large areas. Given that both spectroscopy (proximal and remote) rely on lab-measurement of the soil variables for calibration this research aims to fusion between Soil Spectral Library (SSL) and hyperspectral PRISMA imagery, to obtain accurate soil calcium carbonate equivalent (CCE) assessment minimizing the lab-measurement.

PRISMA imagery and soil spectroscopy laboratory

When moving from the laboratory to the spaceborne scale new challenges arise for soil property quantification, e.g., weather conditions and atmospheric attenuation, soil conditions, internal pixel variations of the soil property, or even fractions of other land cover types within the pixel. Generally, the prediction accuracy decreases from laboratory spectral data to spaceborne satellite observations with decreasing spectral resolution. Recently, considerable efforts have been allocated to the use of an innovative approach for the fusion of laboratory spectra with remote sensing data, which could improves the accuracy of predicting soil properties in large areas using satellite data.

Study Area & data

The study area is located in Srijan area (4000 Km²), in the southwest of Iran (latitude 55°32′E, longitude 29°23′N, altitude. 1760 m) with an aridic-thermic soil moisture-temperature regime. A total of twelve PRISMA L2D (prisma.asi.it) geocoded reflectance images, acquired from June/2020 to December/2023; co-registered with the closest Sentinel-2 image (of about 0.5 pixel of RMS) and smoothed by Savitzky-Golay filter (frame-size of 7 and 3rd degree polynomial) were used. This approach started with predicting the CCE values at sampling points based on the general SSL of the entire Iranian soil, then these values were linked to the spaceborne spectra, building a GPR model, and finally mapping the soil variables using remote-sensing data.



Methods

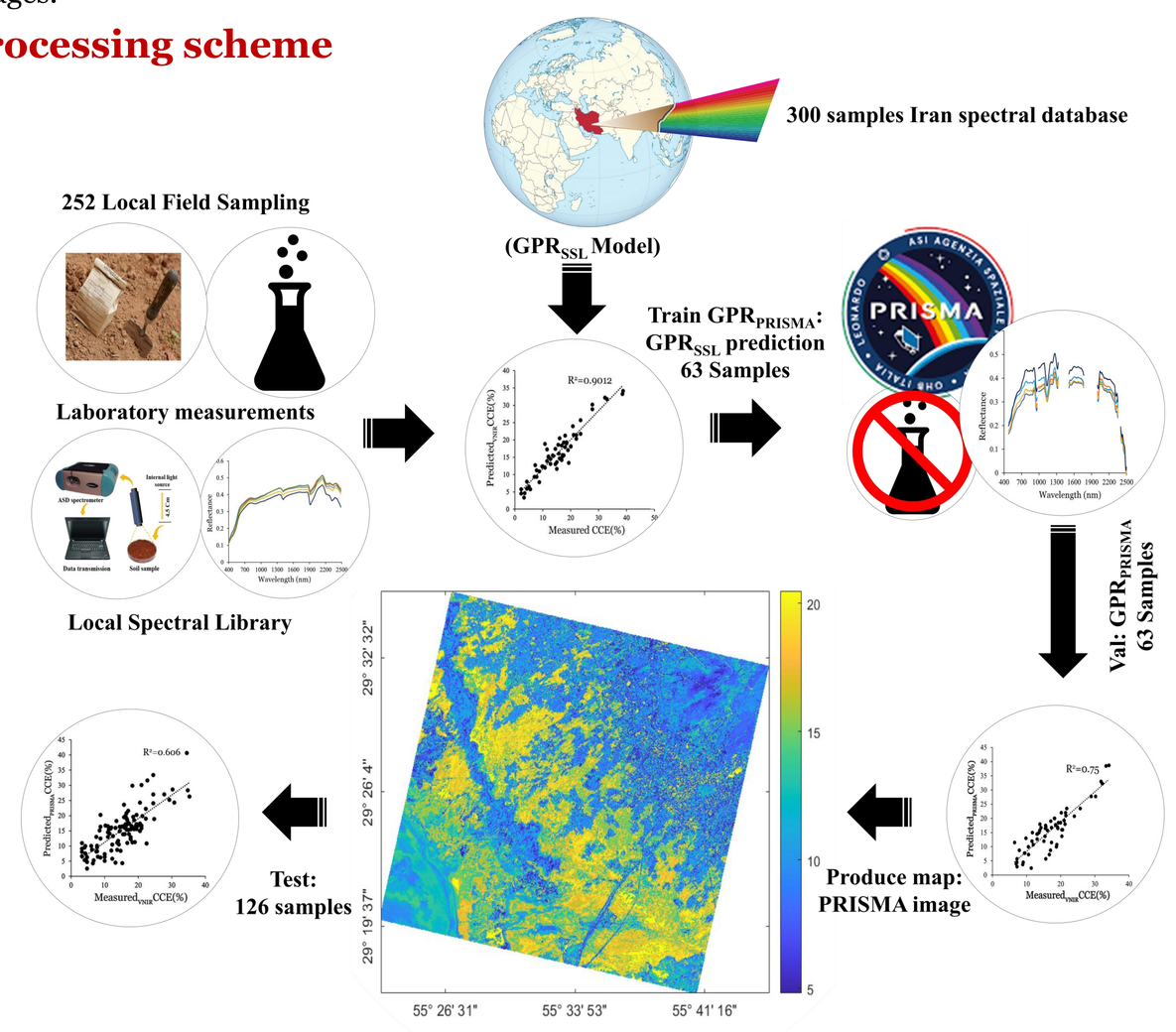
A general SSL of entire Iran soil, composed of 300 samples (CCE min=1.25%, max=51.3%, std=8.33%), has been used to train the Gaussian Process Regression (GPR - MATLAB) algorithm. This GPR model (named GPR_{SSL}) was validated by K-fold cross-validation approach (k=10).

GPR_{SSL} was used to estimate the CCE values on a subset of 63 samples, ¼ of the local collected SSL, composed of 252 samples (CCE min=2.25%, max=44.75%, std=8.64%).

GPR_{SSL} CCE prediction showed, with respect to wet analysis, R^2=90%, RPIQ=3.4, and RMSE=2.29%.

On PRISMA pre-treated data set, 63 spectra, ¼ of the entire (252 samples) local sample, different from the ones collected for the GPR_{SSL}, and the relative CCE values predicted by GPR_{SSL} were used on a new GPR_{PRISMA} algorithm to build a model applicable to PRISMA images.

Processing scheme



Results

Validation and test were performed on different data sets composed of another ¼ and ½ of the local SSL, respectively.

CCE values applied for val/test derived from: GPR_{SSL} and Wet Analysis

Both validations show very similar results in terms of the selected statistical metrics:

Validation: The RMSE for GPR_{SSL} and wet analysis were 4.06% and 3.67, respectively;

Test: The RMSE for, GPR_{SSL} and wet analysis were 4.00% and 4.10%, respectively.

For all cases the RPIQ are between 2-2.5 which means the model are very good.

Accuracy assessment	GPR_{PRISMA} (n. 63)	R^2	RMSE	RPIQ
Validation	GPR_{SSL}	0.75	4.06	2.23
	Wet Analysis	0.79	3.67	2.46
Test	GPR_{SSL}	0.606	4.00	2.27
	Wet Analysis	0.600	4.10	2.15

CONCLUSIONS

The results endorse the importance and relevance of SSL spectral libraries for CCE soil evaluation in support of their quantification, and, consequently, can become an important alternative to bypass laboratory analysis.

Furthermore, the combination of SSL and remotely sensed images like PRISMA, ENMAP, EMITS, CHIME, PRISMA2 and SBG images, within a GPR algorithms procedure can overcome the issue of local sampling in remote countries or in not fully accessible areas.

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