Aristotle University
of Thessaloniki

IN SITU SOIL SPECTROSCOPY FOR ENVIRONMENTAL MONITORING: CASE STUDY IN WESTERN GREECE ORANGE ORCHARDS

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SPECTRA LAB

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RSCy2024

'Tenth International Conference on Remote Sensing and Geoinformation of Environment' 08-09 April, 2024 - Cyprus

8 April 2024

Paphos, Cyprus

A few words about our laboratory

Laboratory of Remote Sensing, Spectroscopy and GIS

Research Topics, Know-how and Domain Applications

Earth Observation

- Advanced analytics algorithms
- Open-source geospatial data management and analysis software

Infrared spectroscopy

Soil data sharing and analytics

Food ingredient analytics

Development of integrated sensing systems

- Industry 4.0 and Agri-food sector tools

Ecological modelling

Monitoring applications in agricultural resource management

Monitoring and reporting applications in environmental management (e.g., carbon cycle)

15 ongoing projects EU and national research and innovation

H2020 BACCHUS: Develop a smart robotic system for automated harvesting in agriculture with specific emphasis in optimal harvesting of grapes based on XAI techniques and hyperspectral imagery data in real field conditions

H2020 Soil4Africa: provide an open-access soil information system with a set of key indicators and underpinning data, accompanied by a methodology for soil monitoring across the African continent.

H2020 DIONE: An integrated EO-based toolbox for modernising CAP area-based compliance checks and assessing respective environmental impact, focusing on fusion of in situ and spaceborne sensing systems for soil

H2020 e-shape: cloud-based contributions to Earth Observation in support of GEOGLAM, and CAP farming advisors with soil-crop related services.

ESA WORLDSOILS: Develop an operational Soil Monitoring System to provide spatial explicit soil indicators at global scale, exploiting space-based EO data leveraging XAI techniques

H2020EIFFEL: Revealing the role of GEOSS as the default digital portal for building climate change adaptation & mitigation applications

Horizon Europe AI4SoilHealth: co-design and maintain an open access European-wide digital infrastructure, compiled using state-of-the-art AI methods combined

Research team

20 researchers with multidisciplinary background

Open Vacancies

Publications

50 journal scientific publications (2017-2024)

Funding

3.5M received (2017-2024)

~50% in size during the pandemic

Network

Regional champion laboratory in **FAO**

R&D facilities

State of the art research facilities in spectral collection and analysis

THEROS

Transparency and trust in organic food supply chain & GI products.

6 countries

17 partners

THEROS overarching objective is to develop a digital toolkit for the modernization of the **certification process** of **organic and PGI products** as well as for the detection of fraud in food products.

THEROS will assess the environmental impact through the direct monitoring of key soil variables and through carbon sequestration models with the synergistic use of in-situ and Remote Sensing.

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Funded by the European Union

THEROS pilot activities

Pilot 1: Serbia

Pilot application using THEROS digital toolbox to detect adulteration and protect authenticity in food

Pilot 2: Greece

Pilot Scope

Pilot demonstration for organic farming certification

Use of THEROS innovations

Earth observation services, MEMS photonic systems, Green accountability tool, Dynamic Digital Product Passport, Blockchain traceability tool, Verification engine, Data management and harmonisation platform

Pilot 3: Czech Republic

The pilot demonstration will focus on the design and validation of an extended innovative business model aimed primarily at supporting the availability of organic food.

IoT sensors network, Blockchain based traceability system, Verification engine, Digital marketplace, and Data management and harmonization platform

Pilot 4: Spain

This pilot demonstration will define and engage a group of supply chain participants, aiming to cover 100% of the value chain, including initial harvesting, aggregation, transformation, shipping, packaging and selling events.

DNA based authenticity kit, Dynamic Digital Product Passport, Blockchain based traceability system, Verification engine, and Data management and harmonization platform

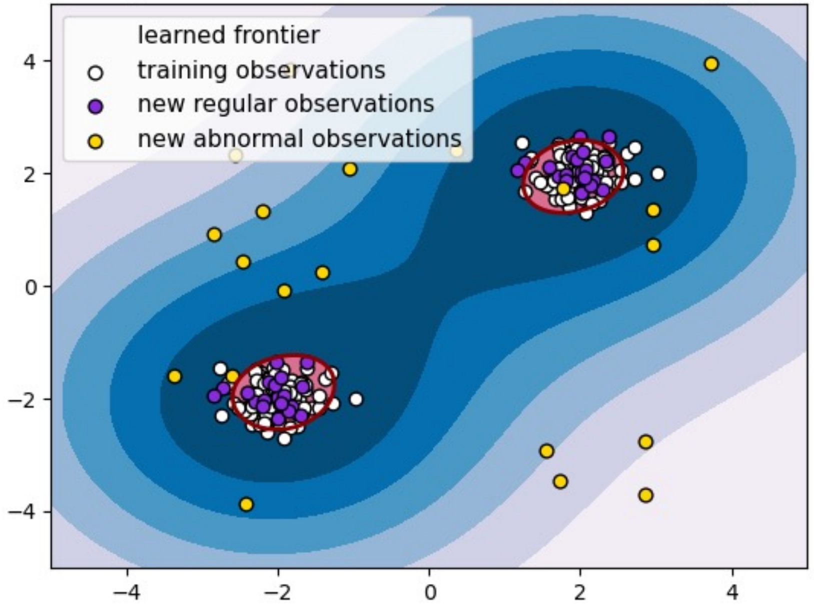
Farming practices monitoring

Chemometrics (1st phase)

Development of an analytical library with soil chemical analysis

Standard classification method (2nd phase)

Creation of a database of reference data (spectral library) using Vis-Nir spectroscopy on organic and non-organic soils



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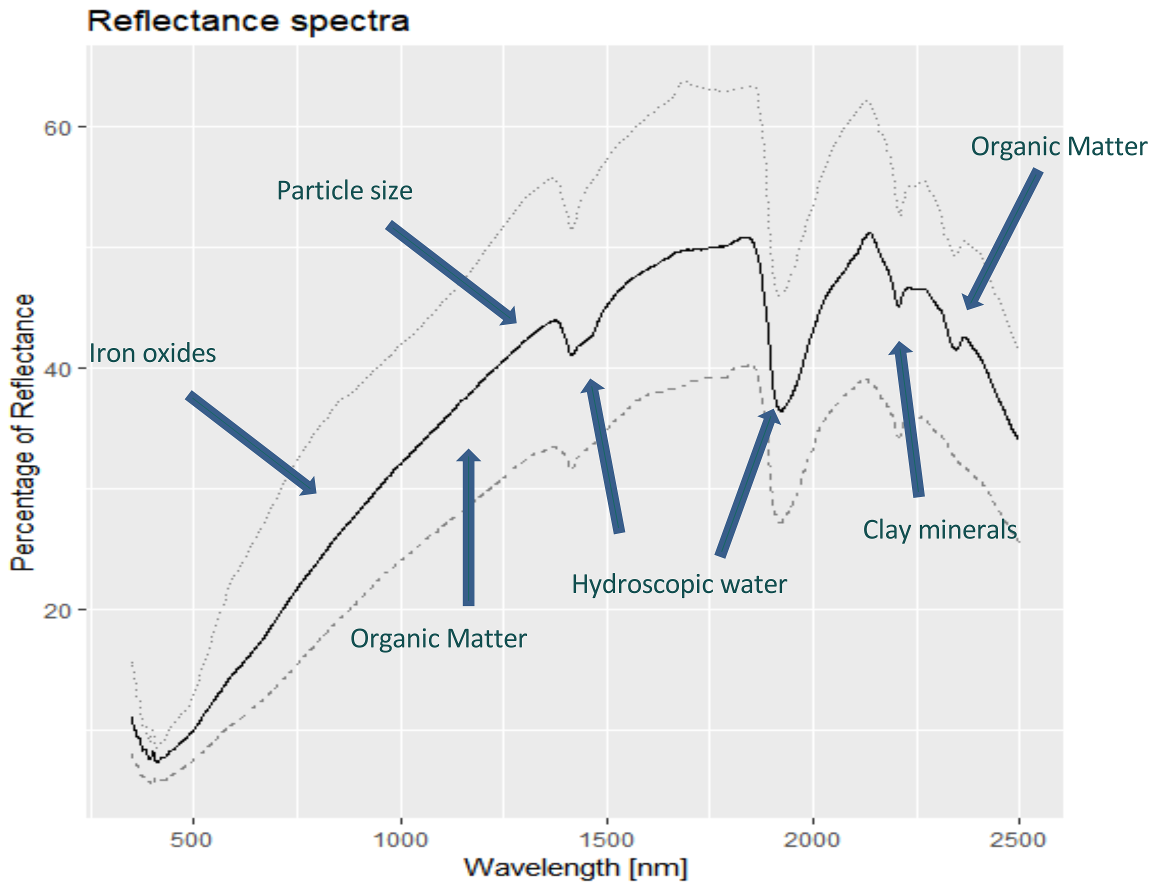
Why soil spectroscopy?

- Reliable, fast and non-destructive method for quantifying various soil characteristics
- Different parts of the electromagnetic spectrum provide information about different soil properties
- in-situ spectra are affected by ambient factors (shadows, roughness, soil moisture or vegetation)
- Instrumentation can be expensive and must be used by experienced operators → advent of MEMS reduced costs and simplified procedures



Methodology

Field visit

- Sampling methodology – dense distribution of randomly selected sampling locations
- Soil preparation for spectral measurement (Removal of stones, vegetation, crust or other materials)
- Direct spectral measurement of topsoil
- Soil sample collection for chemical analysis

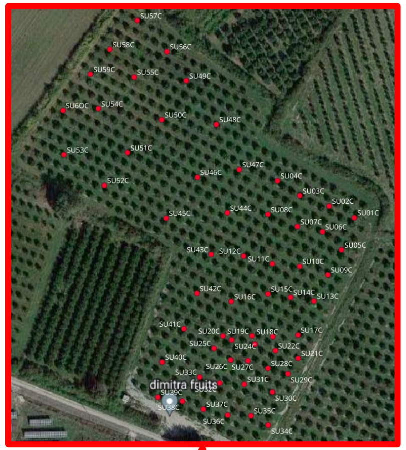
Analysis

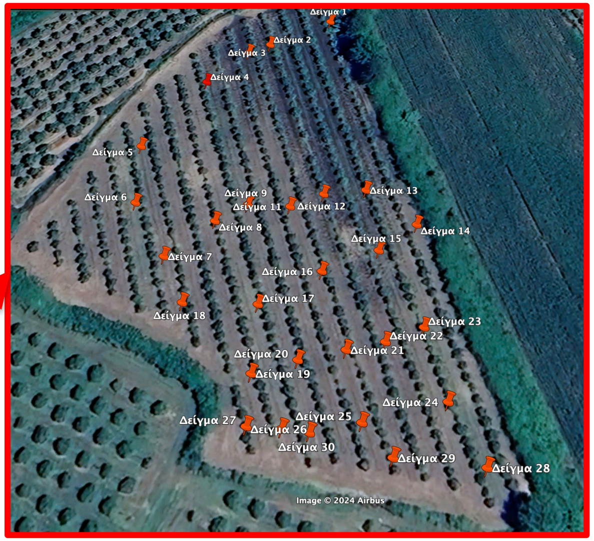
- Determination of Soil Organic Carbon content (Dry Combustion) and Clay content (Hydrometer method)
- Development of Soil Spectral Library (Sample ID, reflectance, SOC %, Clay %, Organic/Non-Organic labeling
- Modeling
  - Spectra preprocessing (Smoothening, SG filtering, Normalization)
  - Train-Test split (random split)
  - Modeling (ensemble method for classification)
  - Modeling assessment (Accuracy, F-score)

Pilot area

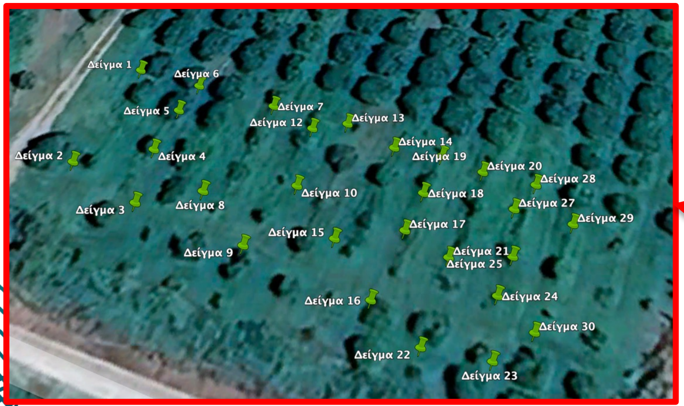
- One organic and two conventional farming orchards located to Agrinio, Region of Western Greece
- Total area 40 hectares (23 conventional, 12+5 organic)
- Collected 120 soil samples and spectral measurements

Conventional orange orchards (12 hectares)

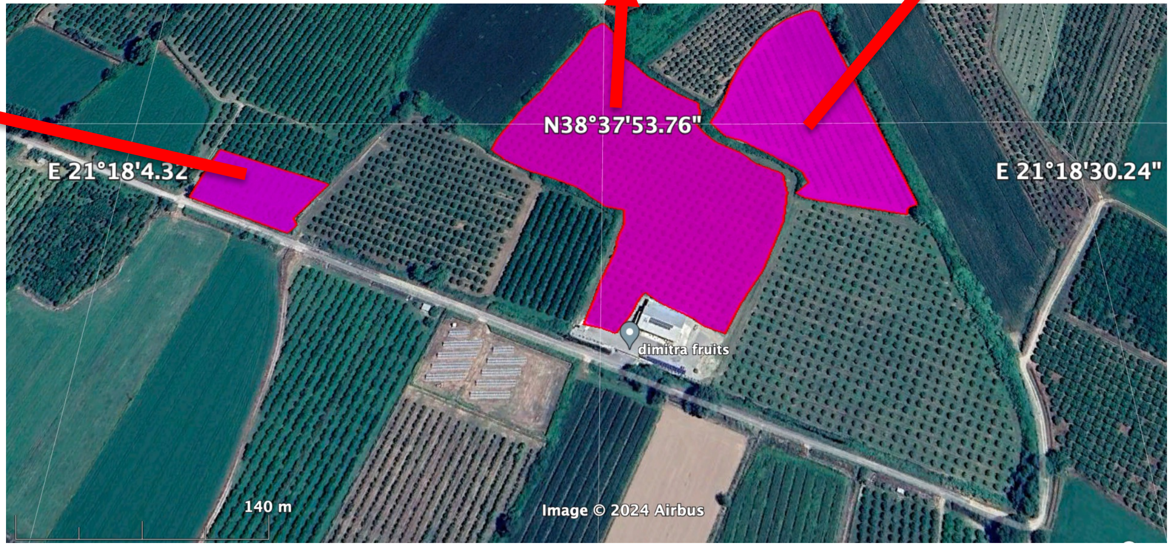




Organic orange orchards (12 hectares)



Organic orange orchards (5 hectares)



The portable spectrometer

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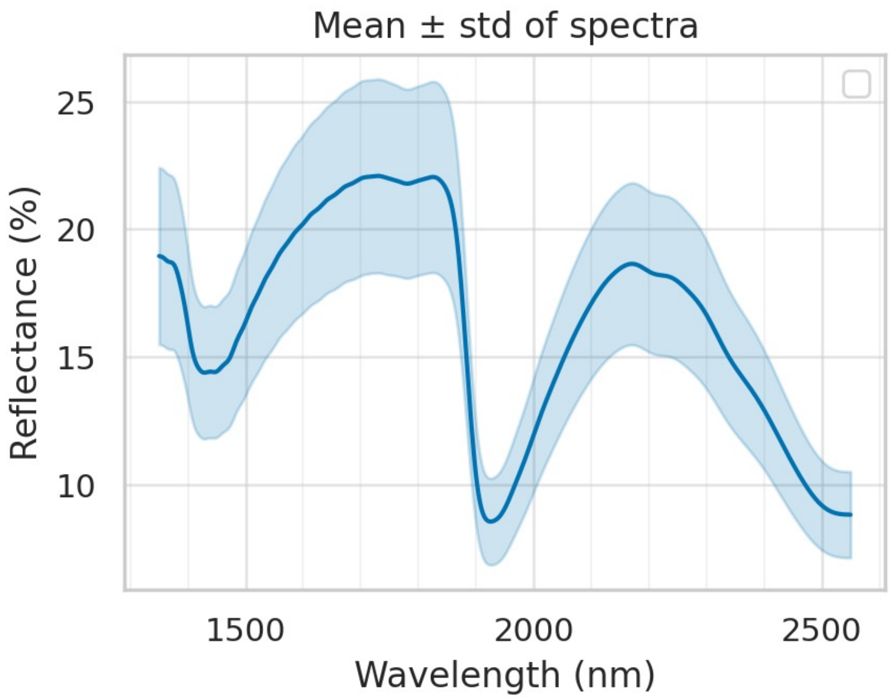
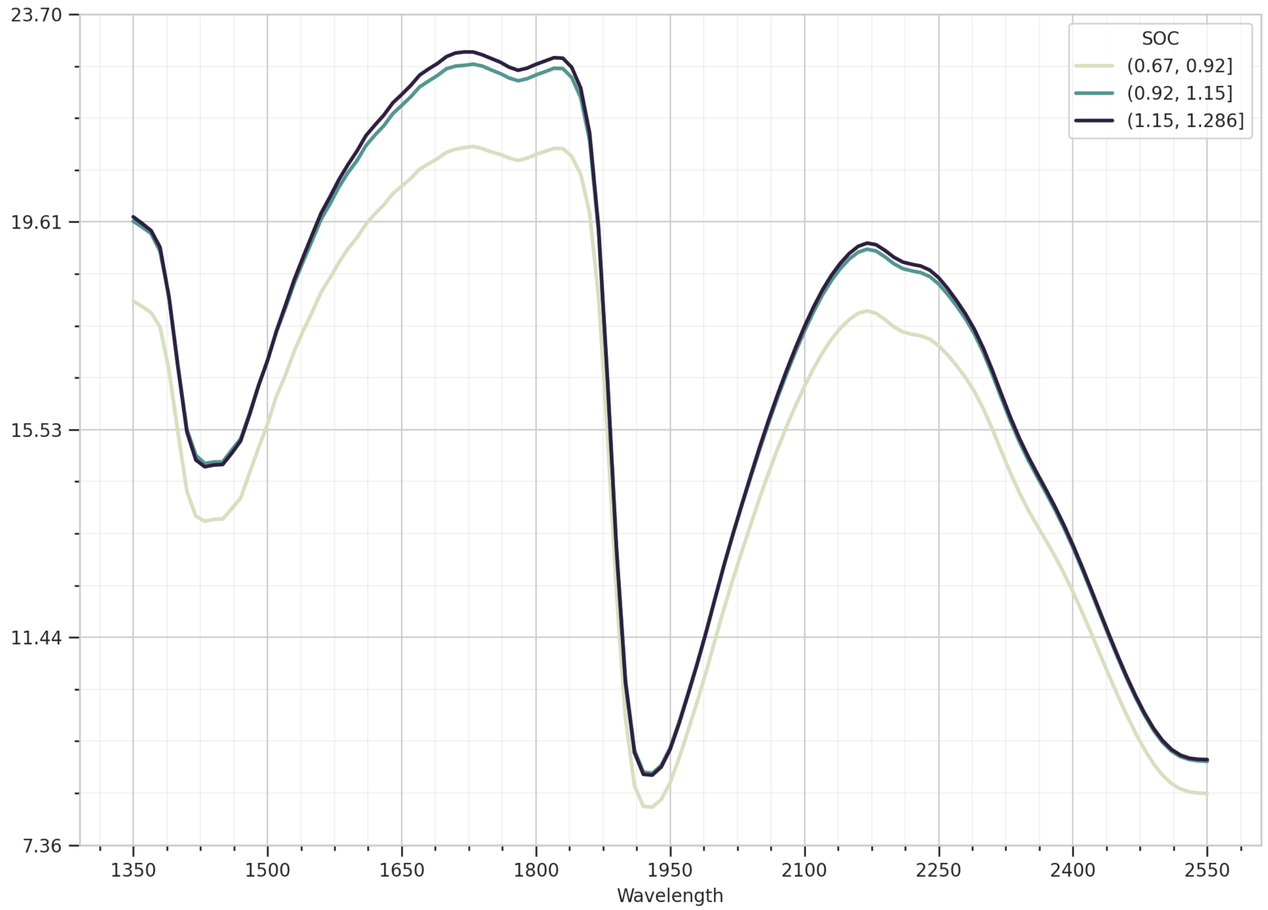
- NeoSpectra-Scanner portable NIR handheld spectrometer
- 6mmdiameter of collected light
- Wavelength range 1250 - 2500 nm
- 16nm resolution
- Wireless connectivity
- IP65 ingress protection
- 178 X 91 X 62 mm
- 1kg weight

Spectral analysis

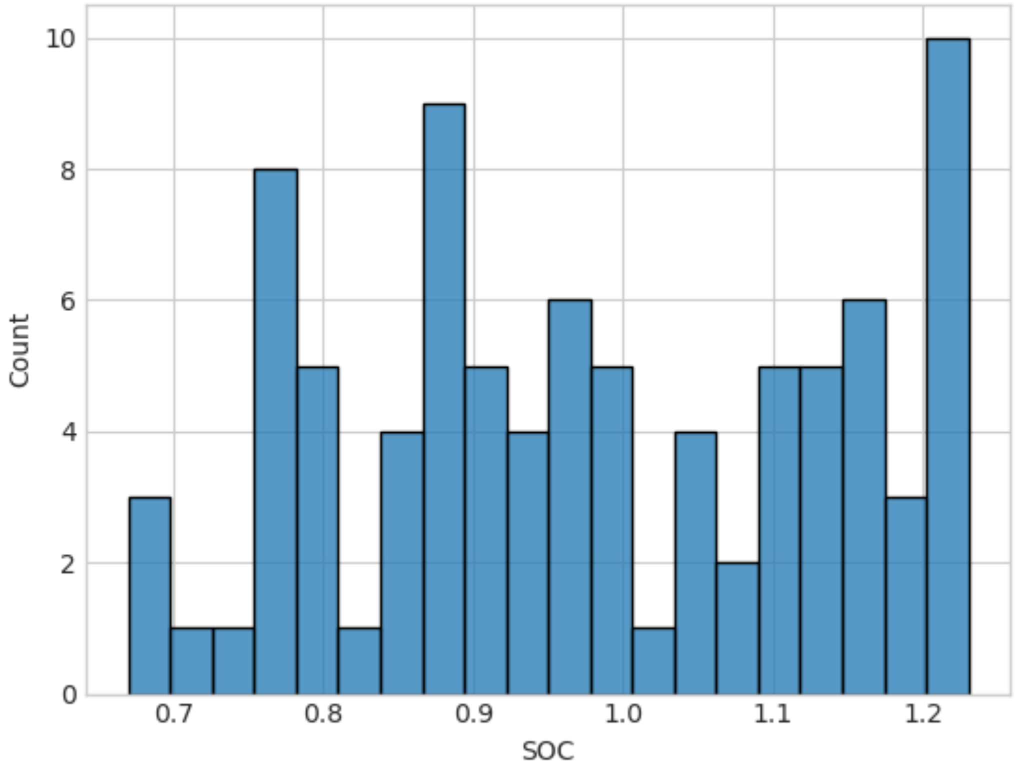


- Captured the reflectance from 120 spectral signatures
- Small variability in reflectance
- We will further explore distinctive differences between groups of spectral signatures from:
  - Different SOC content
  - Different Clay content
  - Soils from Organic and non-organic farms

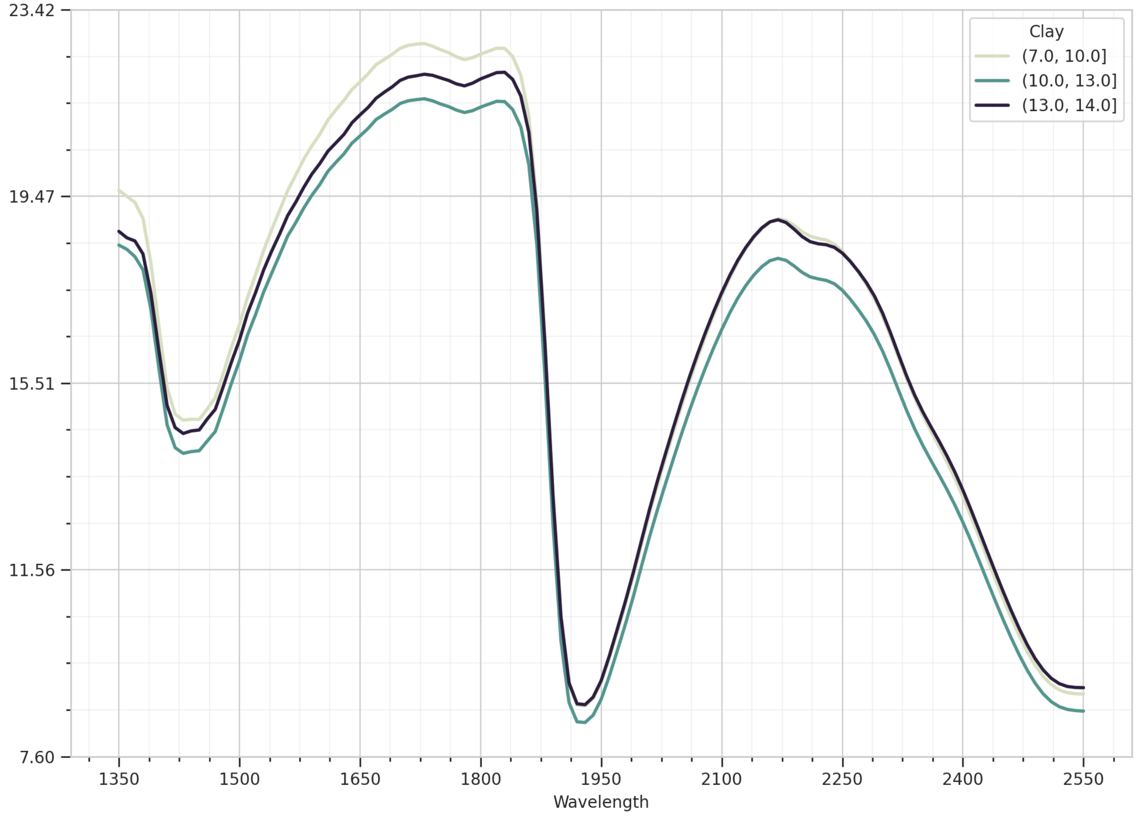
Spectral reflectance for different SOC levels



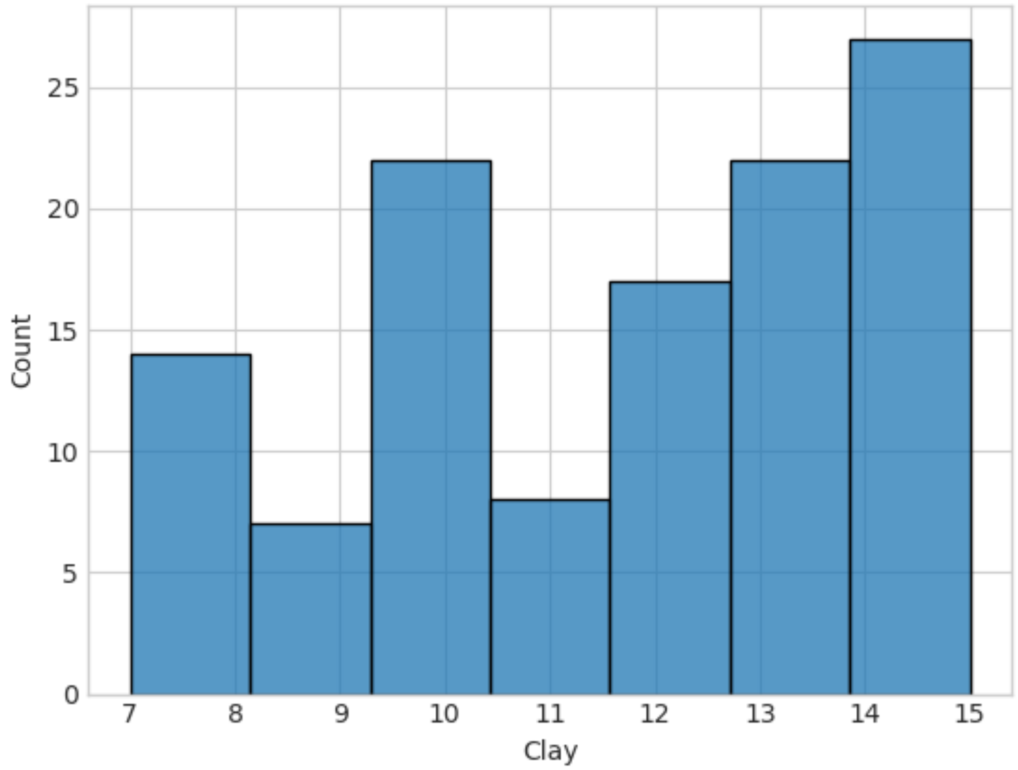
- Classified soil samples in three classes with “low”, ”medium”, ”high” SOC content – (based on tertiles separation)
- Slight differences in albedo at the median spectral reflectance of each group



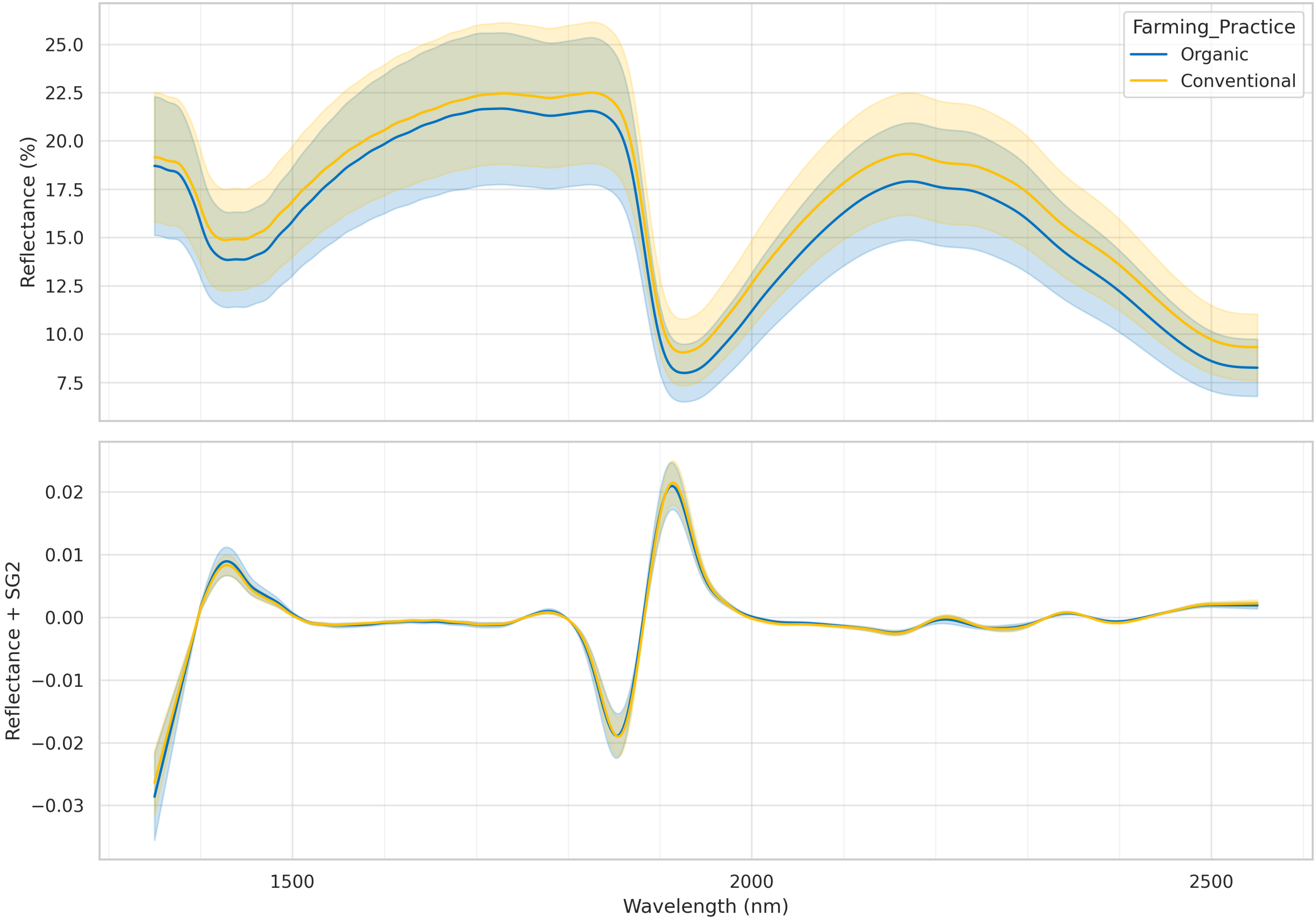
Spectral reflectance for different Clay levels



- Classified soil samples in three classes with “low”, ”medium”, ”high” Clay content – (based on tertiles separation)
- Not clear differences in albedo, but mostly in specific spectral regions



Spectral reflectance based on Organic or Conventional practices



- Classified soil samples in two classes “organic”, ”conventional”
- Slight differences in albedo, evidence that conventional are brighter than organic
- No differences in spectral regions, meaning that it is hard to identify compounds that are prohibited by organic farming (e.g. herbicides, pesticides) – thus we will try to classify based on the effect of their usage to the Soil, and cross-correlations of them

Classification Results

Class	Accuracy	F-Score
SOC (low/medium/high)	0.75	0.71
Clay (low/medium/high)	0.79	0.76
Organic/Conventional	0.76	0.78

We used the ensemble method:

- Trained different classifiers
- Each voted for the class each data point belongs
- The final classification was assigned by majority voting
- Model assessment was performed over an independent test set (20%)

Classifers used

- Random Forest
- K-Nearest Neighbour
- Decision Tree
- Support Vector Machines
- Gradient Boost
- Logistic Regression
- Naïve Bayes
- Multi-layer Perceptron classifier

Remarks and future work

- Low-cost MEMS sensors can provide information for SOC and Clay content with NIR spectra
- It is not sensor-restricted – there are plenty of market ready solutions
- More soil properties except SOC or Clay can be assessed (i.e. Nutrient Content)
- Difficult to estimated within-field variability when the range of SOC and Clay contents are small
- It is useful for identifying ”hot” and “cold” regions within a single parcel, i.e. regions with lower SOC content and suggest different treatment
- Classification can provide insights for discriminating organic and conventional farms – Way larger database needed

A unified protocol for soil spectroscopy (in-situ or laboratory) needs to be developed - IEEE P4005 standards and protocols for soil spectroscopy works towards this direction

IEEE SA STANDARDS ASSOCIATION

Next steps

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- Expand the library with more measurements from the same and different field
- Compare with laboratory spectra
- Automate the procedure of analyzing soil spectra
  - Develop a mobile app that operates the spectrometer and transmits the data to a database
  - Perform server-side modelling for real-time analysis
- Simplify the measuring pipeline
- Transit to crowdsourcing era – Many spectrometers used by many farmers to substitute (to some extend) chemical analysis

https://spectralab.gr/

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Thank you for your attention!

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