Light in the Field:
Portable Photonic Sensors
Redefining On-Site Adulteration Detection

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THEROS

The growing challenge of food adulteration & non-compliance

Increasing risk of fraud, non-compliance, and quality loss:

Supply Chain Complexity

Food chains are becoming longer and more complex – global → more vulnerability points

Economic Fraud

Economically motivated adulteration continues to rise in food products

Hidden quality loss

Quality degradation occurs during storage, transport, and processing and often goes undetected until it's too late

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Photonics beyond traditional testing

Need for rapid, low-cost, and non-destructive verification

Traditional laboratory methods

- accurate but slow, expensive
- requires sample preparation and specialized personnel
- impractical for routine checks in farms, cooperatives, and inspection agencies

VS

Photonic sensors

- on-site results are valueable
- Effective decision-making should be at the point of activity
- portable approaches make quality control continuous, rather than occasional

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Our sensors

NeoSpectra Scanner (Si-Ware Systems)

1350 - 2500 nm

MEMS-based spectral sensors (Spectral Engines)

1100 - 2450 nm

Cubert FireflEYE VNIR S185 **Hyperspectral Camera**

450 - 950nm

Reference instrument

PSR+ 3500 Spectroradiometer (Spectral Evolution)

350 - 2500 nm

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Applications

Detection of food adulteration – powder matrices
- Whole wheat flour adulteration
- Ground turmeric adulteration with non-authorised dyes

Detection of adulteration in liquid foods
- Apple juice dilution

Beverage analysis (alcoholic & non-alcoholic)
- Prediction of key quality parameters
- Quantification of preservatives or other nutrients (e.g. Vitamin C)
- Compliance assessment against maximum permitted limits

Differentiation of organic vs. conventional foods
- Discrimination of organic and conventional oranges

Estimation of bioactive compounds
- Assessment of phenolic content in various types of flours

Soil quality assessment
- Prediction of key soil indicators
- Discrimination of organic and conventional fields

Benefits of our portable sensors

NeoSpectra Scanner
(Si-Ware Systems)

1350 - 2500 nm

MEMS-based spectral sensors
(Spectral Engines)

1100 - 2450 nm

Cubert FireflEYE VNIR S185 **Hyperspectral Camera**

450 - 950nm

(Vis-NIR)

- Typically NIR spectral range (1100–2500 nm)
- Cost-effective analysis
- On-site, non-destructive measurements
- Rapid analysis (sample acquisition within seconds)
- Easy to use (no specialized training required)

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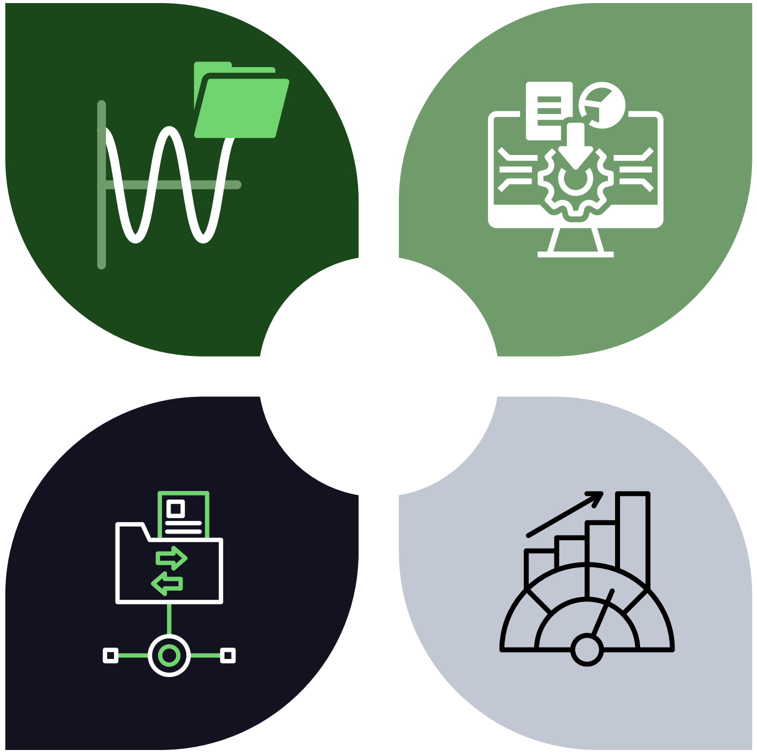
The THEROS approach: Combining photonics and AI

Building robust spectral libraries

Systematic collection of high-quality NIR spectra across multiple matrices (wheat flour, apple juice, oranges, soil) to capture natural variability, adulteration scenarios, and compositional differences.

Developing standardized measurement protocols

Harmonized procedures for sample handling, calibration, device operation, and spectral acquisition to ensure comparability, reproducibility, and compatibility with reference datasets.



Linking photonic signals with ML workflows

Preprocessing, standardization, feature extraction and modeling pipelines that transform raw reflectance data into reliable predictive information.

Converting raw spectra into decision-ready indicators

AI-driven tools that deliver:

i. Product Purity Index

ii. Organic Farming Compliance Marker

iii. Soil Quality Assessment Report

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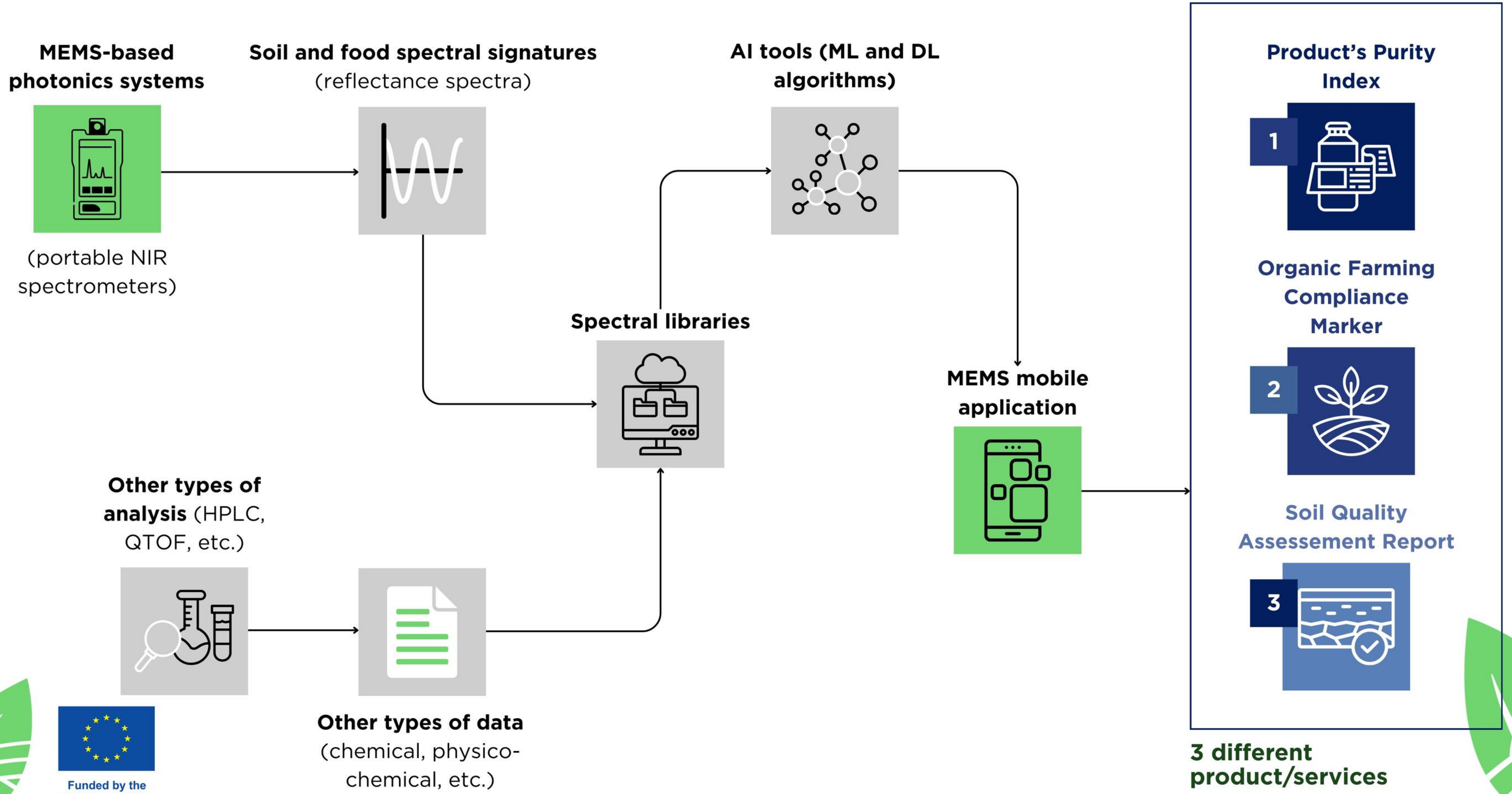
System Architecture



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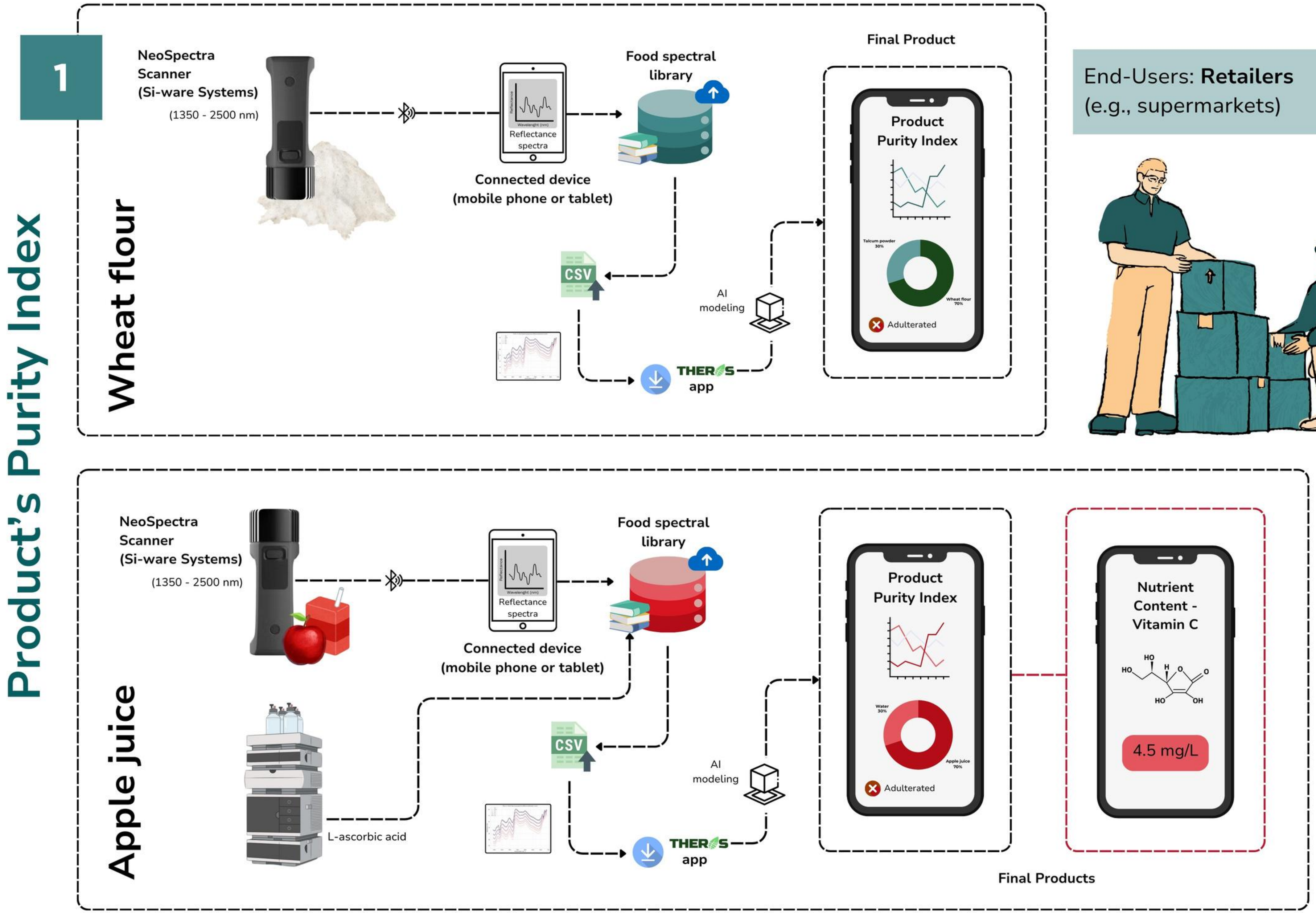

End-Users: **Retailers**
(e.g., supermarkets)

Flowchart of the methodololy developed for food adulteration and quantification of nutrient contents deviations from the labelled asset

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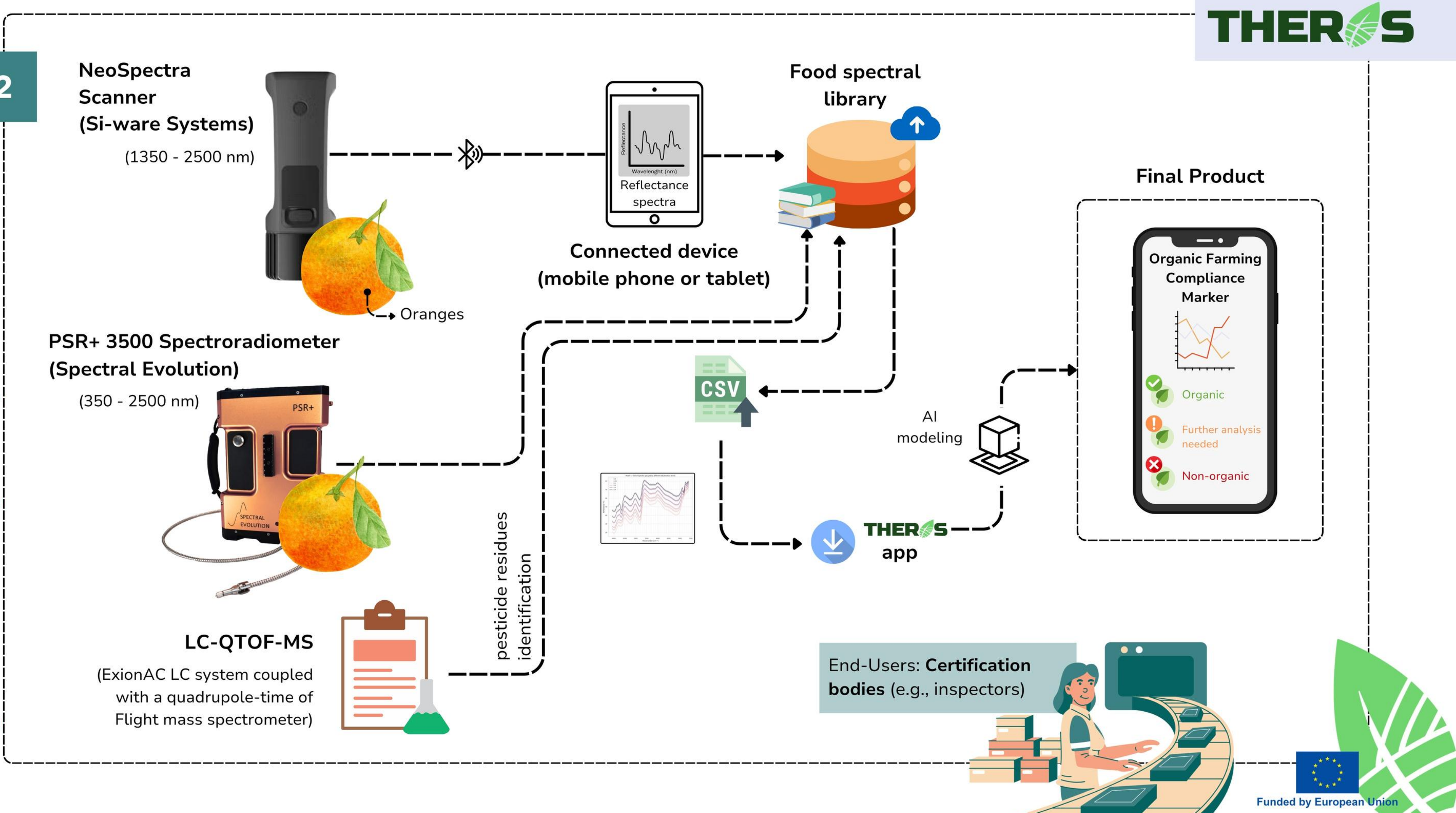
2 Organic Farming Compliance Marker

THEROS



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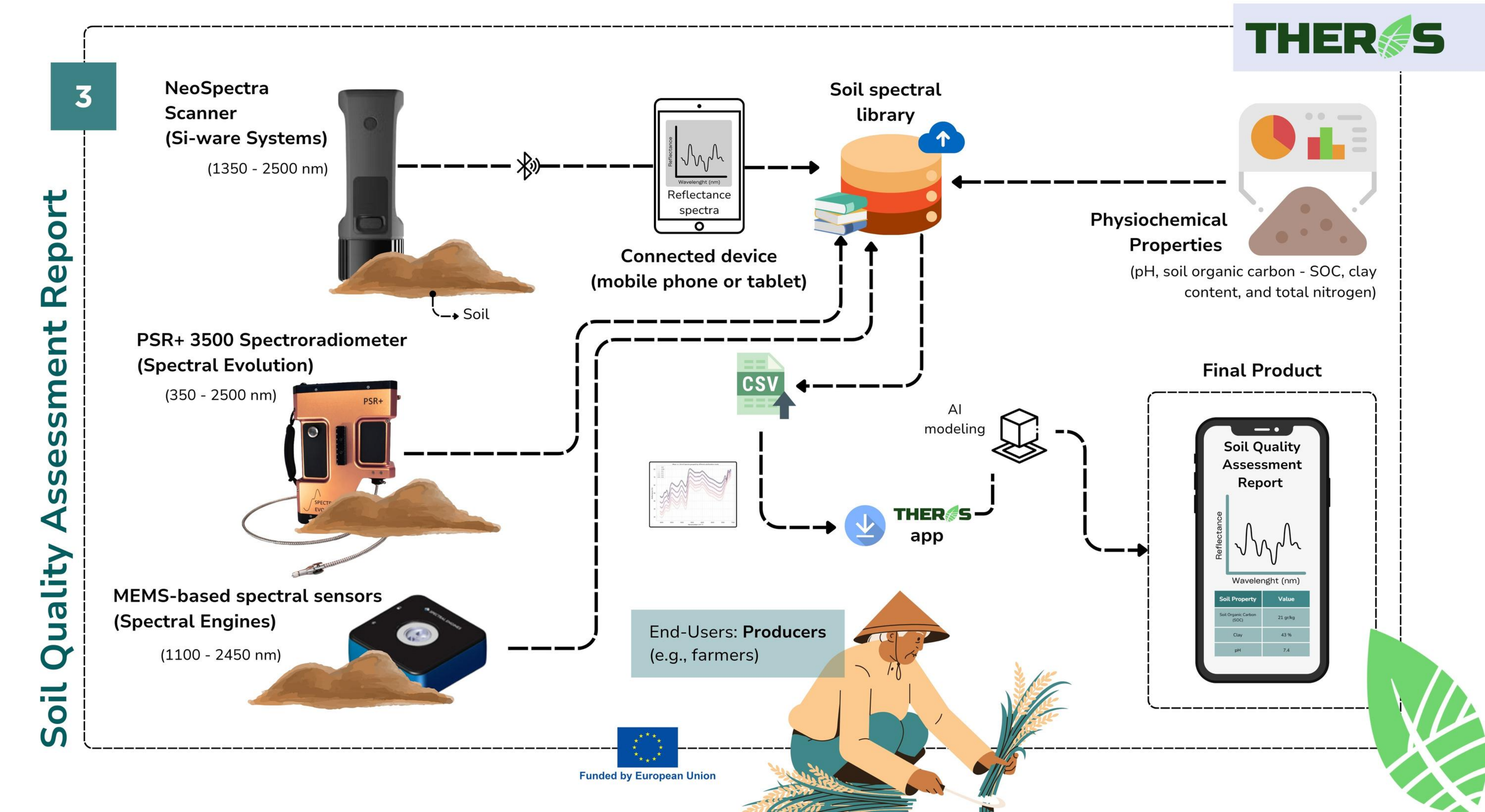
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Soil Quality Assessment Report
THEROS
NeoSpectra Scanner (Si-ware Systems)
(1350 - 2500 nm)
Soil
Reflectance
Wavelenght (nm)
Reflectance spectra
Connected device (mobile phone or tablet)
Soil spectral library
Physiochemical Properties
(pH, soil organic carbon - SOC, clay content, and total nitrogen)
PSR+ 3500 Spectroradiometer (Spectral Evolution)
(350 - 2500 nm)
PSR+
CSV
AI modeling
THEROS app
Final Product
Soil Quality Assessment Report
Reflectance
Wavelenght (nm)
Soil Property | Value
Soil Organic Carbon (SOC) | 21 gr/kg
Clay | 43 %
pH | 7.4
MEMS-based spectral sensors (Spectral Engines)
(1100 - 2450 nm)
End-Users: Producers (e.g., farmers)
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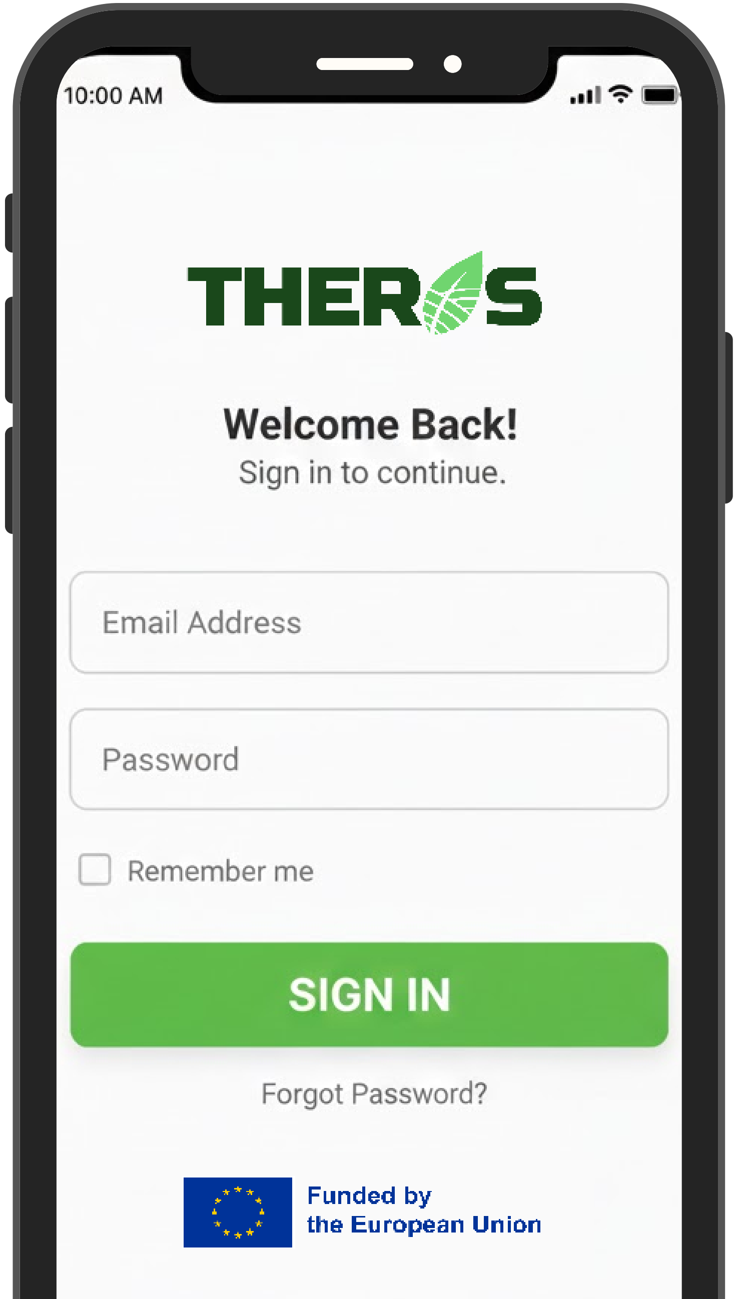
MEMS app

THEROS

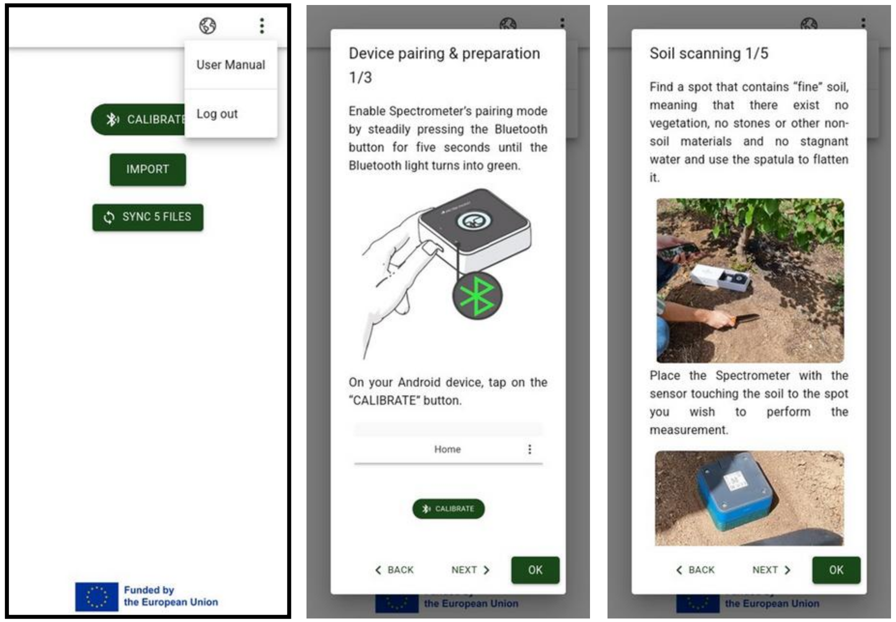
Select Device

Results Screen

Screens indicating the results of the ‘Calibration’ or ‘Take Sample measurement’ action



Help menu and step by step guide



Globalization: Localized translations have been added for all screens and text throughout the application, with support for English, Greek, and Serbian.

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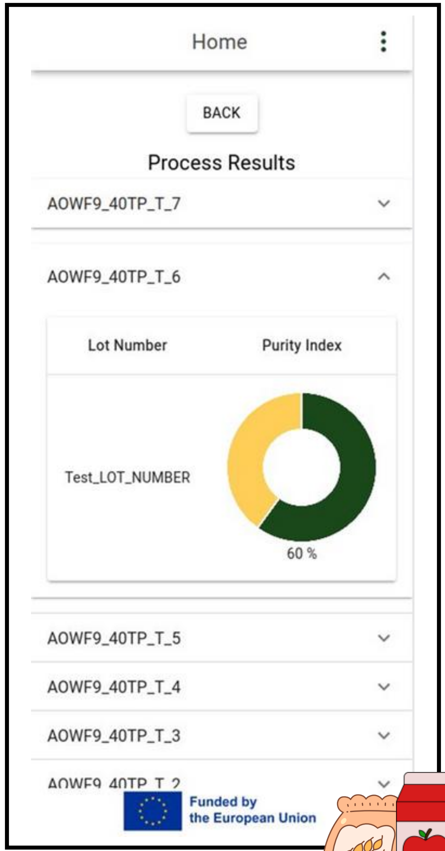
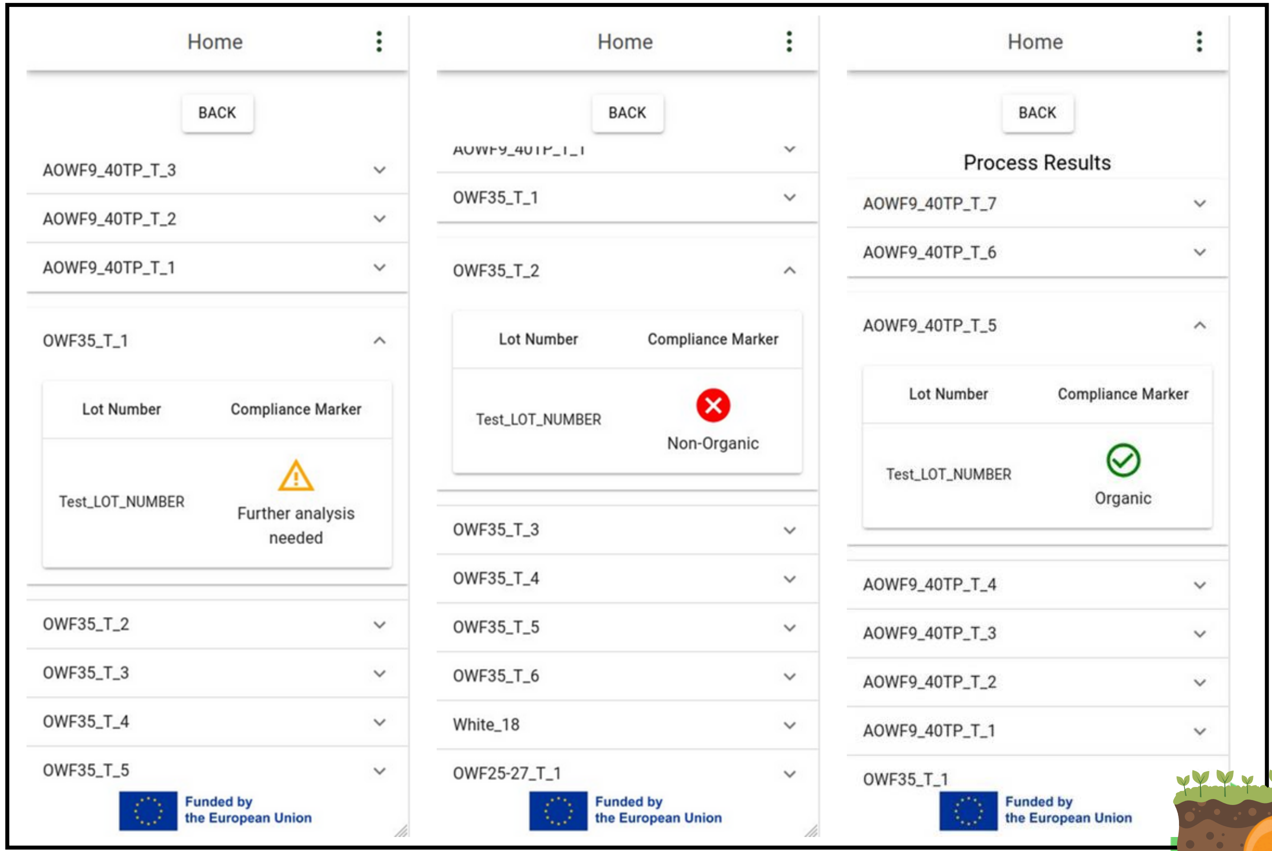
Application Outputs

Soil Quality Assessment Report

Product Purity Index



Organic Farming Compliance Marker



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MEMS Results at a Glance

Wheat Flour

- Regression (adulteration quantification):
 Random Forest (RF) → **R^2 = 0.93**, RMSE = 0.12%

→ **MEMS sensors accurately detect and quantify talc adulteration**

Apple Juice

- Dilution quantification:
 R^2 = 0.86, RMSE = 0.04% (ensemble method of Gradient Boosting, RF, PLSR, and SVM)
- Vitamin C prediction:
Gradient Boosting → **R^2 = 0.89**, RMSE = 0.35 mg/L, and RPIQ of 4.14

→ **Real-time quality and nutrient assessment directly from spectra**

Oranges

Total Accuracy: 0.87

- <u>Non-organic:</u> **Precision 0.83**, Recall 0.90, F1-score 0.87
- <u>Organic:</u> **Precision 0.87**, Recall 0.79, F1-score 0.83

→ **Spectral signatures alone enable strong discrimination between organic and non-organic oranges**

Soil

Soil Properties

- Soil Organic Carbon (SOC):
Best model: Ensemble → **R^2 = 0.77**, RMSE = 0.81
- Clay Content:
Best model: Ensemble → **R^2 = 0.83**, RMSE = 0.07
- Total Nitrogen:
Best model: RF → **R^2 = 0.45**, RMSE = 1.50
- pH:
Best model: RF → **R^2 = 0.89**, RMSE = 0.05

Organic vs Conventional Classification

Best model: Ensemble → **Accuracy = 0.76**, F-score = 0.78

→ **MEMS sensors enable reliable prediction of core soil quality indicators and support organic vs. conventional classification**

High-impact outcomes from MEMS-based photonics + AI (all pilots)

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Pilot demos: user acceptance & usefulness of the spectral systems

Three pilot demonstrations (online and in-person)

Key highlights from end-user feedback:

88.9% found the NeoSpectra handheld sensor very easy to operate.

77.8% rated the tools as very relevant for their daily work.

100% agreed the system can help producers check compliance before inspection.

88.9% rated the mobile app interface as very clear and intuitive.

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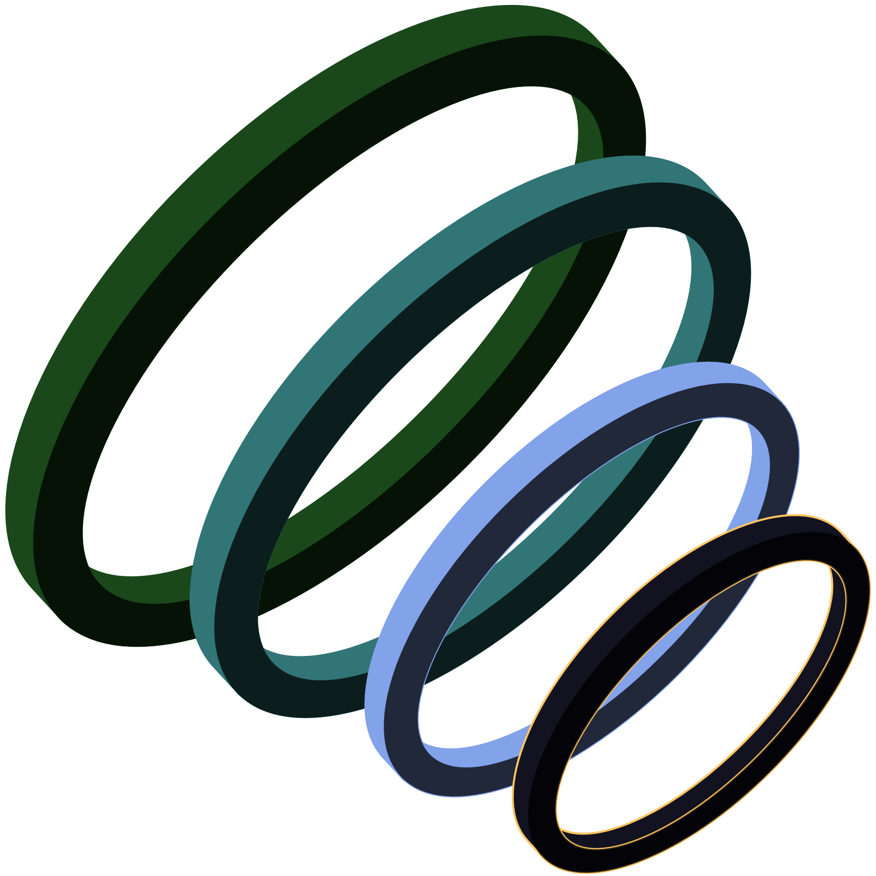
From Project Results to Real-World Impact

What this means for the agri-food sector — today and the day after the project:



Faster, more transparent supply chains

A continuously expanding data ecosystem

Reduced cost & inspection time for farmers, cooperatives, inspectors, certification bodies

Scalable to multiple products — we are already exploring new matrices

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Food Traceability & Transparency

THEROS establishes the verifiable traceability and transparency required by the EU **Farm to Fork Strategy**, accelerating the goals of the **Green Deal**.

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Thank you for your attention!

SPECTRA LAB

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