An integrated toolbox for improved verification and prevention of adulterations and non-compliances in organic and geographical indications food supply chain

THEROS project:
Harnessing Advanced Agri-Data Tools - Transforming Organic & GI Supply Chains

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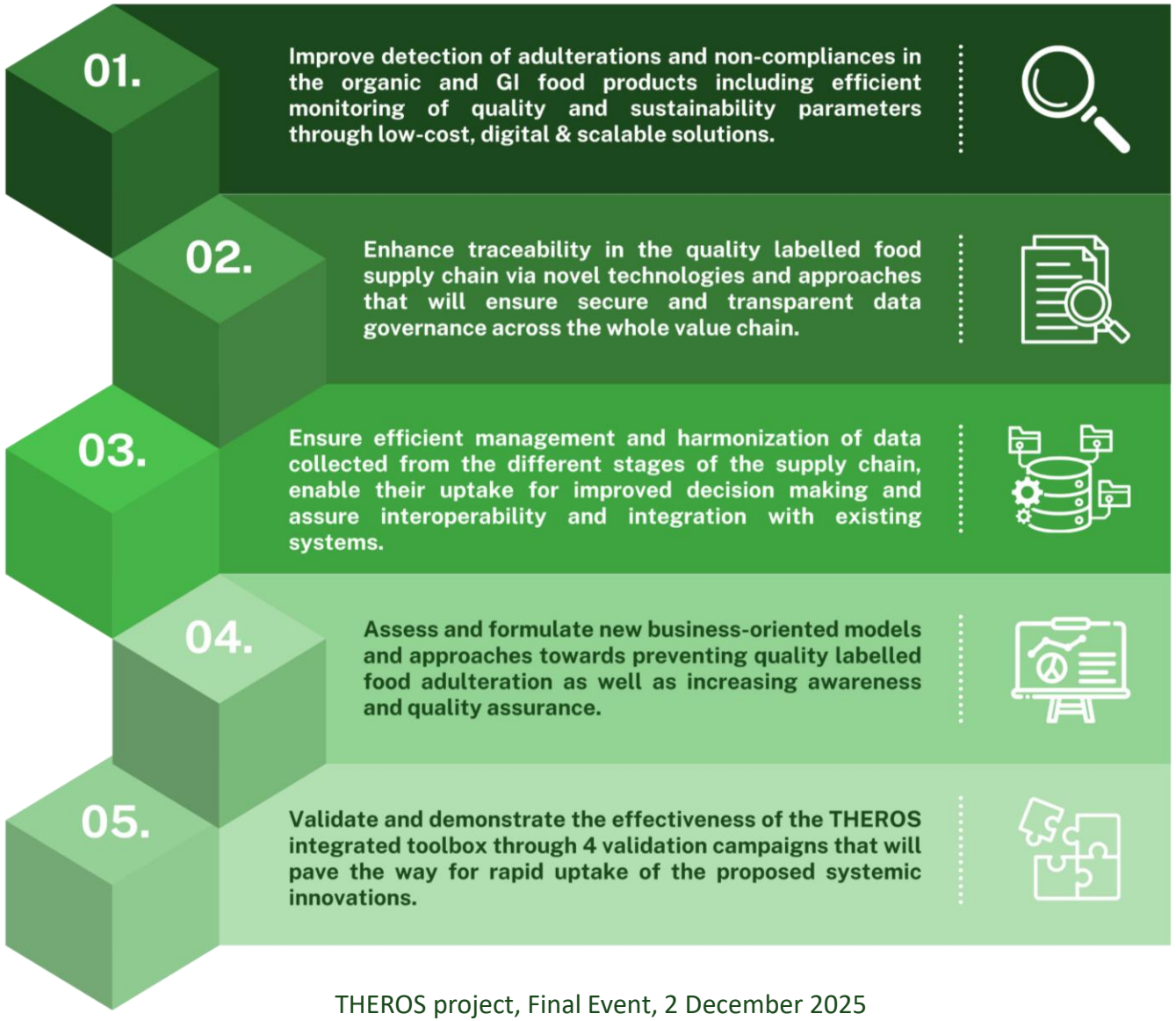
THEROS

THEROS Objectives



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THEROS Vision & Concept

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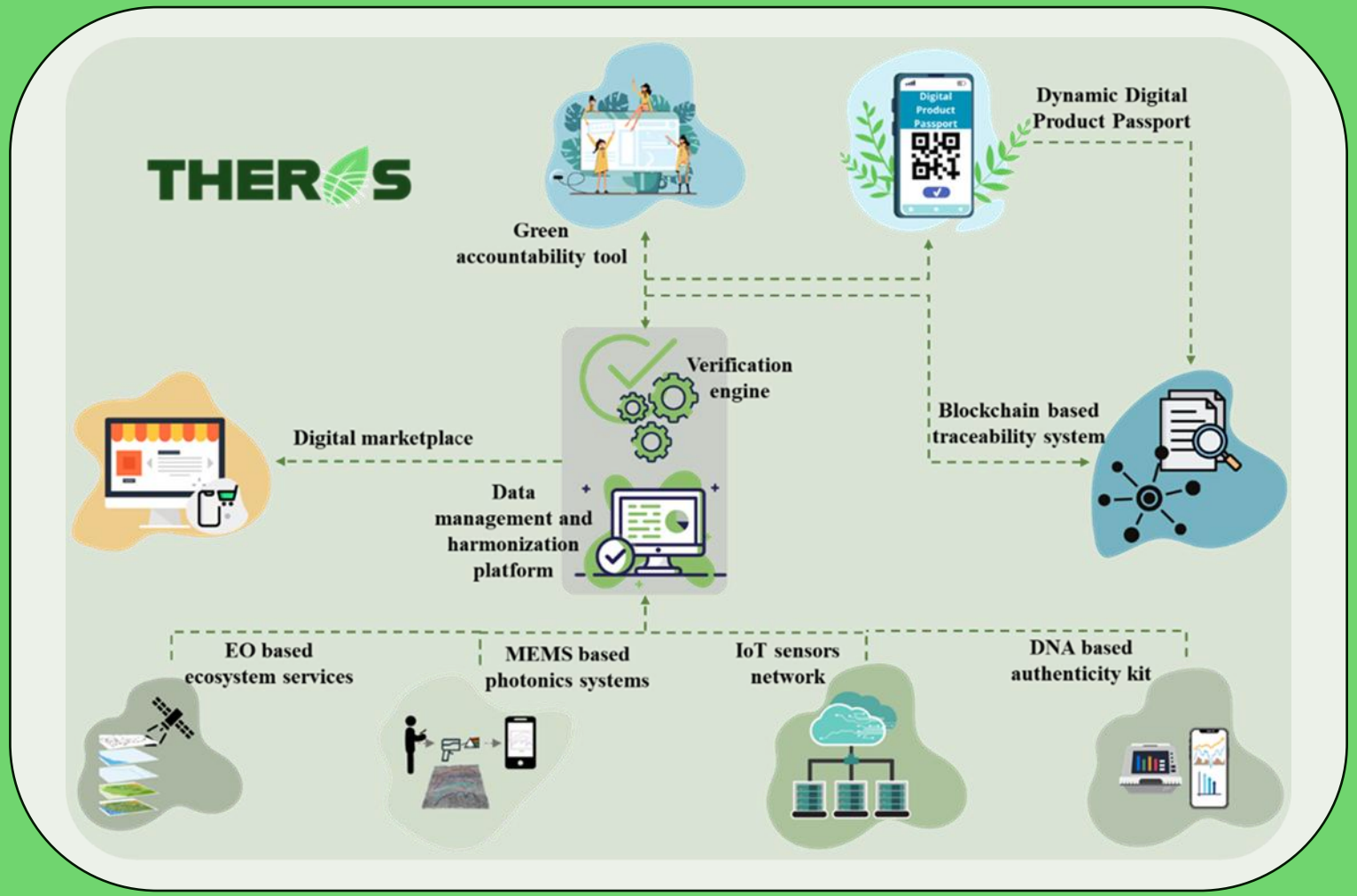
Low-cost, digital and scalable solutions.

Blockchain enhanced traceability system.

Platforms and algorithms allowing management and harmonization.

Interfaces to facilitate monitoring and inspections.



Pilot 1: Serbia

Pilot 2: Greece

Pilot 3: Czech Republic

Pilot 4: Spain

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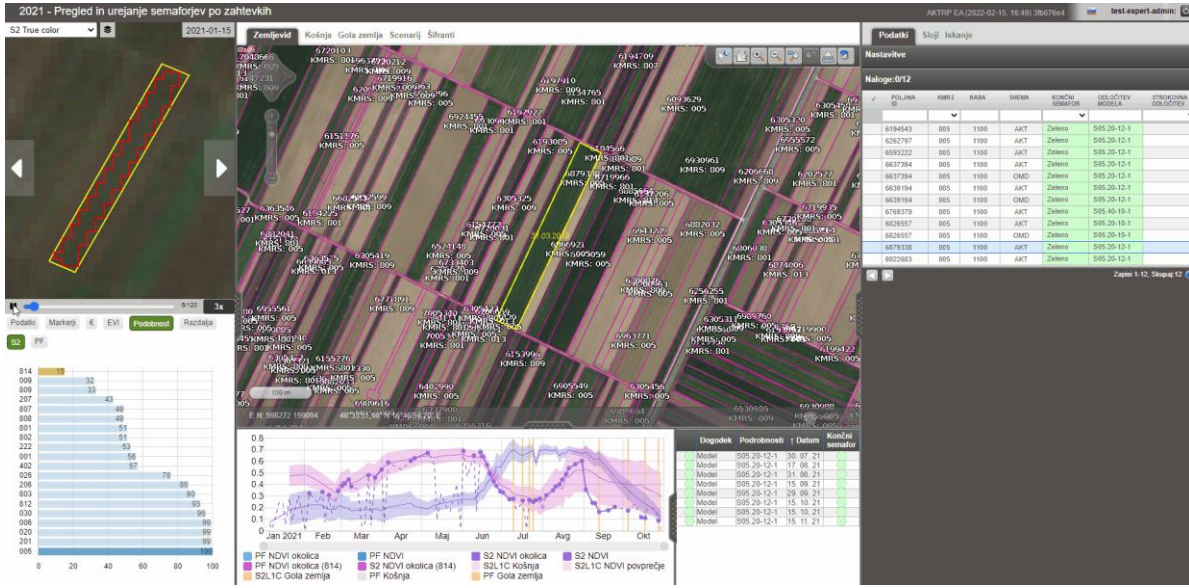
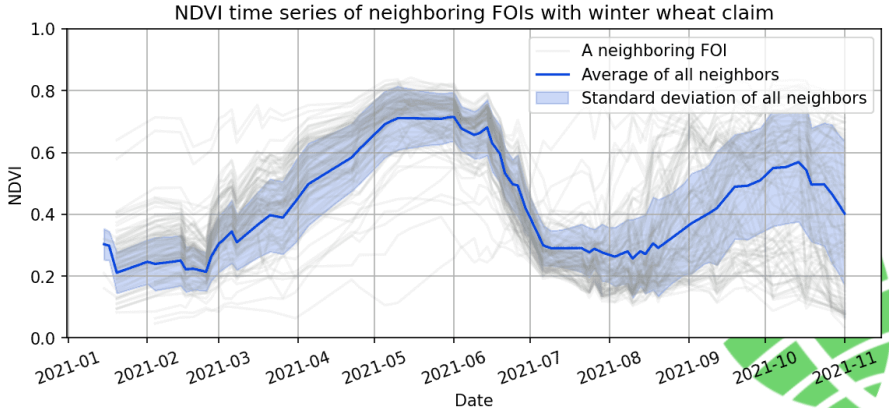
Earth Observation (EO) Services

01. Establish sustainable supply chains for innovative Earth observation value added products and services, focusing on monitoring the compliance with organic standard using satellite imagery, including a model to distinguish between organic and conventional parcels.

- Compute "**markers**" (machine learning) on satellite imagery to monitor agricultural activity.
- Novel machine learning techniques to address challenges related to the complexity of carbon footprint and sequestration study and its impact.
- Combining these markers to help agencies with risk assessment and monitoring large areas of organic farming regulations compliance.





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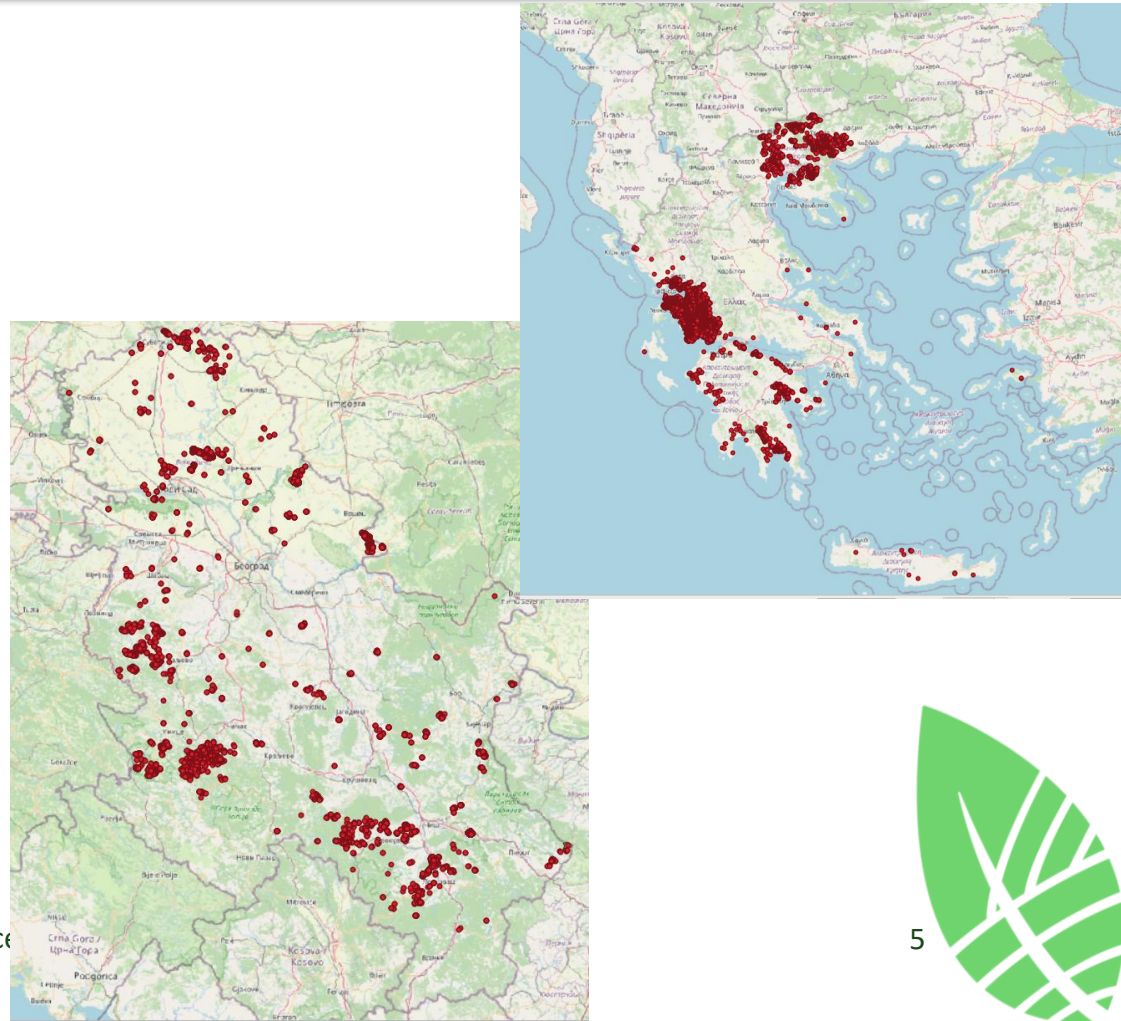
Earth Observation (EO) Services

01. Establish sustainable supply chains for innovative Earth observation value added products and services, focusing on monitoring the compliance with organic standard using satellite imagery from Sentinel-2, including a model to distinguish between organic and conventional parcels.

- The project developed and validated several Earth Observation (EO) **markers** to monitor *compliance* with organic farming practices, including:
  - Homogeneity,
  - Greening and harvest marker,
  - Baresoil marker,
  - Similarity and Euclidian Distance Marker,
  - Crop marker, and
  - Organic/non-organic markers.
- These markers were tested in pilot areas in Serbia and Greece, and their results are integrated into the THEROS toolbox via a RESTful API.
- These tools significantly enhance the ability of certification agencies to monitor large areas and identify non-compliance efficiently.



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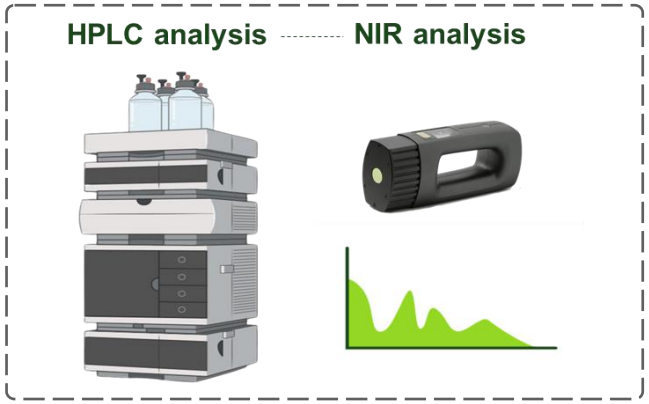
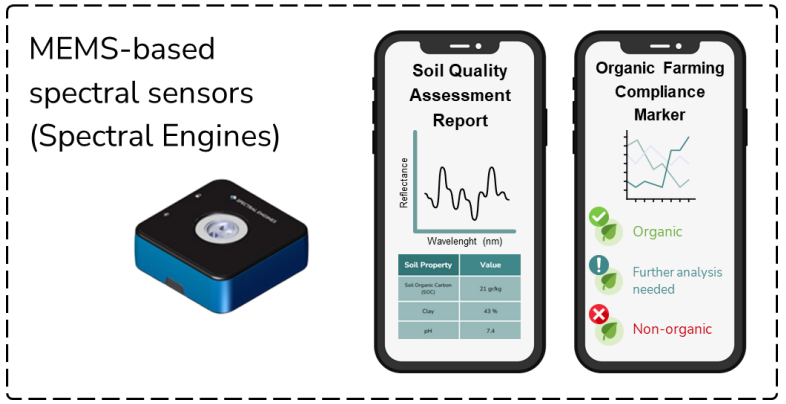
MEMS-Based Photonics System

02. The MEMS system in THEROS advances food adulteration detection by providing quick, non-destructive analysis of organic products with high accuracy using low-cost, portable spectrometers.

- Deployed low-cost MEMS sensors for **non-destructive analysis** of organic products, like wheat flour and apple juice.
- Achieved high accuracy (R^2=0.93 for wheat flour).
- Developed **AI models** to differentiate between organic and non-organic oranges and *analyze soil properties*.
- Created a comprehensive spectral library supporting fraud detection and environmental impact assessments.





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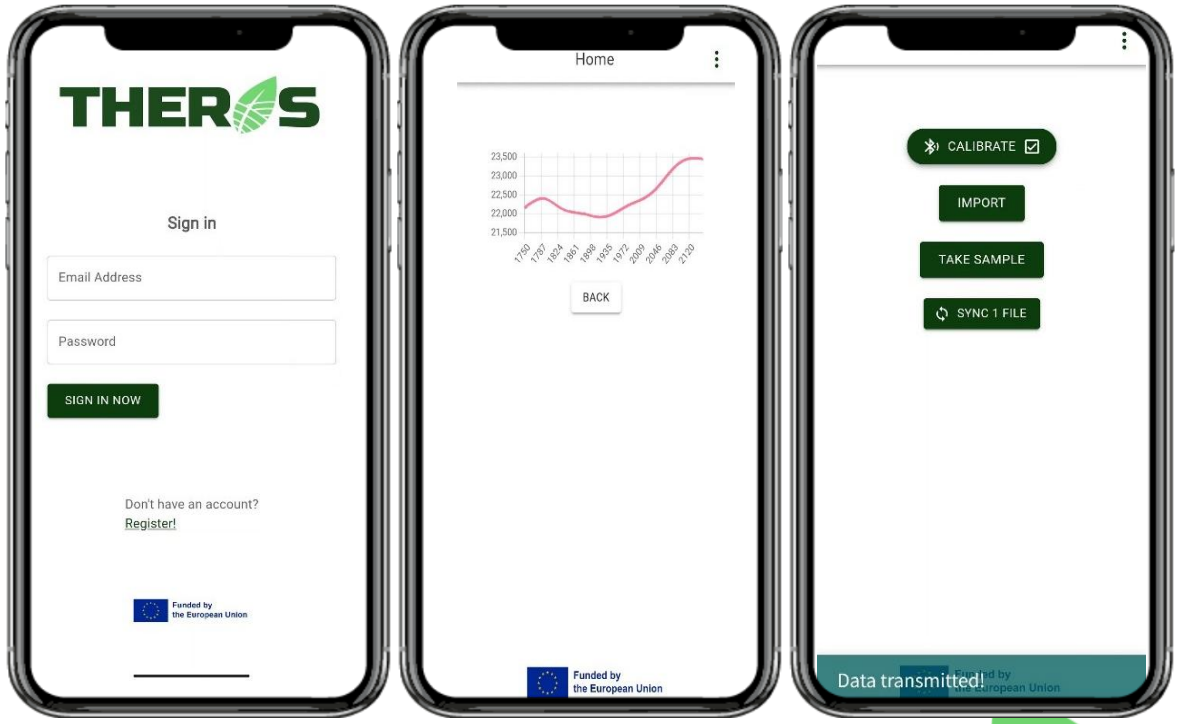
Mobile application for MEMS

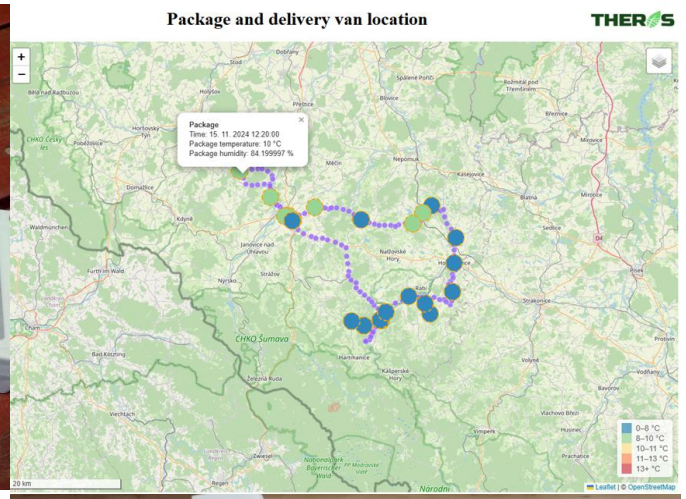
02. The project achieved significant progress in developing the mobile application that controls MEMS-based photonic systems.

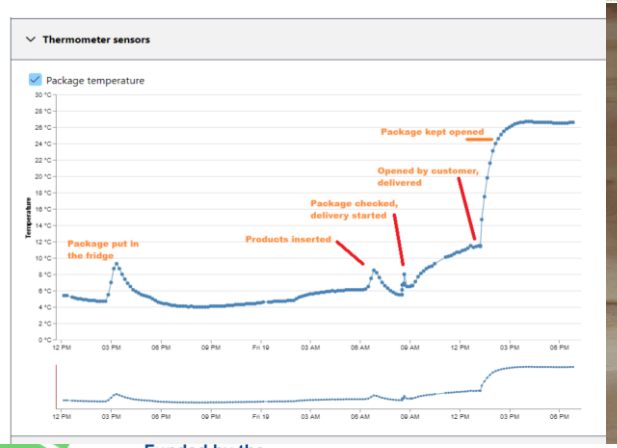
- This application was designed to facilitate **data acquisition from spectrometers**, with seamless integration via Bluetooth connectivity.
- The app supports offline operation, ensuring that data is stored locally and synchronized once an internet connection is available.
- The application also allows manual data ingestion for non-compatible devices, making it versatile for various user needs.
- This app plays a critical role in enabling **on-the-spot verification of food authenticity**, particularly in detecting adulterations in organic food products.



IoT Sensors Network

03. IoT sensors enable the monitoring of quality/climate parameters related to the transport of organic/GI foods, including the effective recording of all key tracking events and thus preventing potential misuse of the trademark.





- Designed and deployed an IoT network to **monitor quality and climate parameters** during the *transport* of organic/GI foods, addressing both intentional and unintentional adulterations.
- Monitored air temperature, humidity, and package integrity, with real-time data transmission to the THEROS platform.
- The integrity status of the package represents the opening or closing of the package by connection or disconnection of a magnetic button in the cover of the box.

IoT Sensors Network

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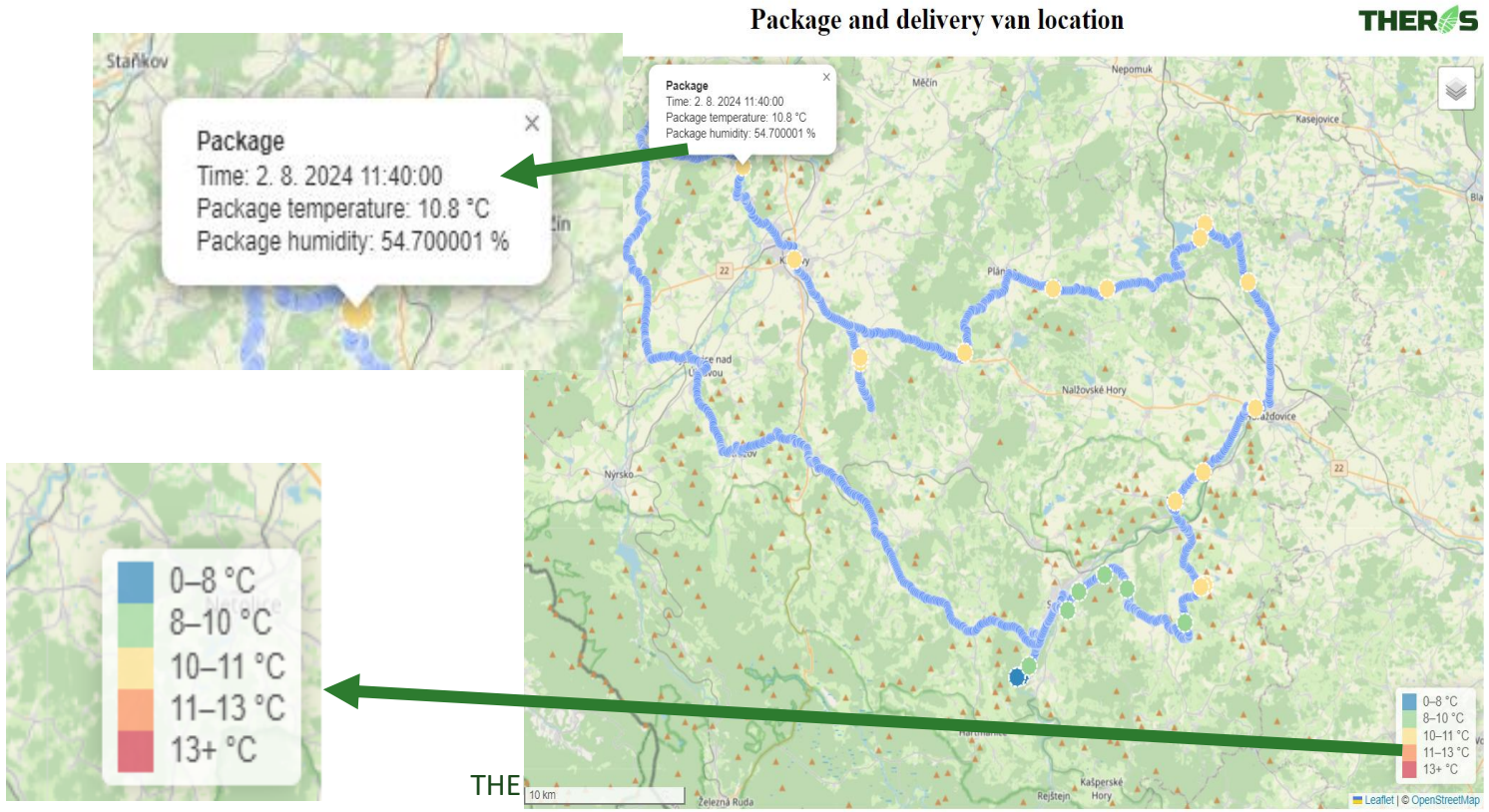
- Developed web map application to visualise positions and measurements by points with colours scale depending on temperature



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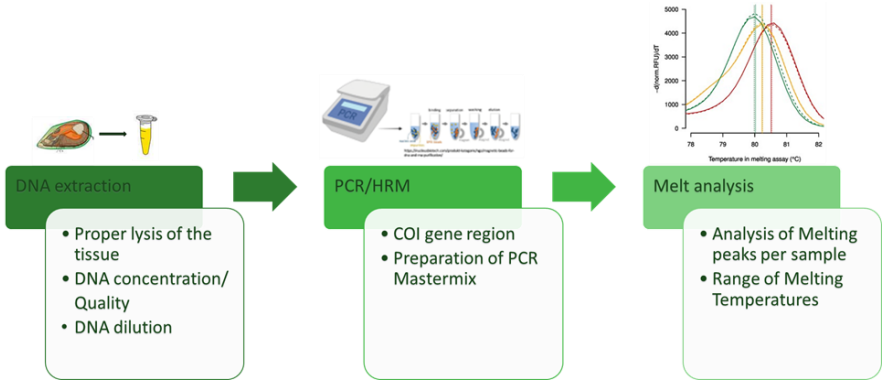
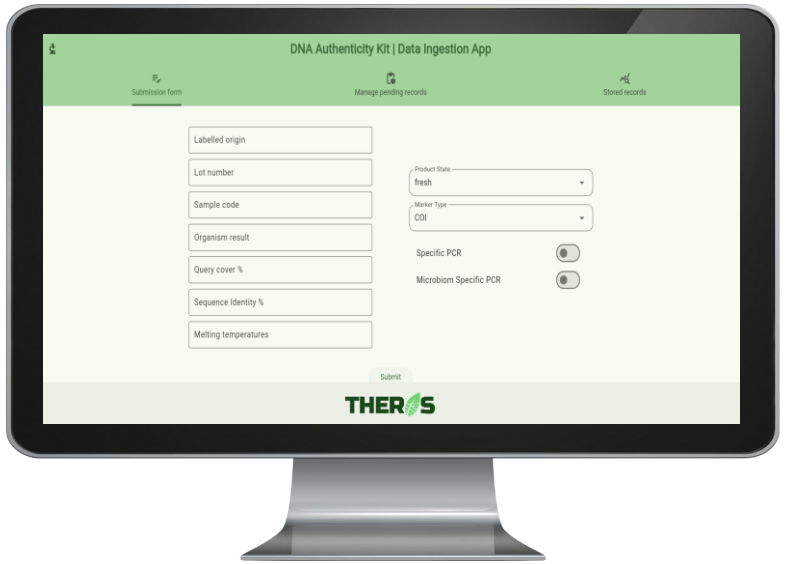
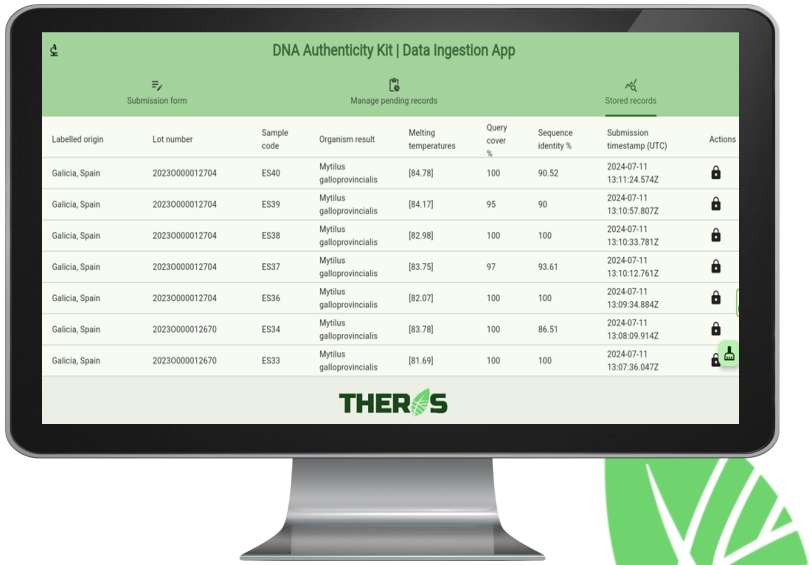
DNA-Based Authenticity Kit

04. THEROS developed portable DNA analysis kit to verify the species origin and authenticity of food products, particularly focusing on organic and GI-labelled products, with high-resolution melting profiles and DNA sequences providing accurate identification of species and product origin.

- In the Spanish pilot the kit was used to analyze mussels, using **DNA barcoding regions** such as COI and 16S to ensure the authenticity of the products.
- **Machine learning models** were created to *predict the origin* of mussels based on DNA sequences and melting temperatures.
- The kit significantly enhances the detection of mislabeling and adulteration, providing a robust tool for stakeholders in the food sector, including certification authorities.







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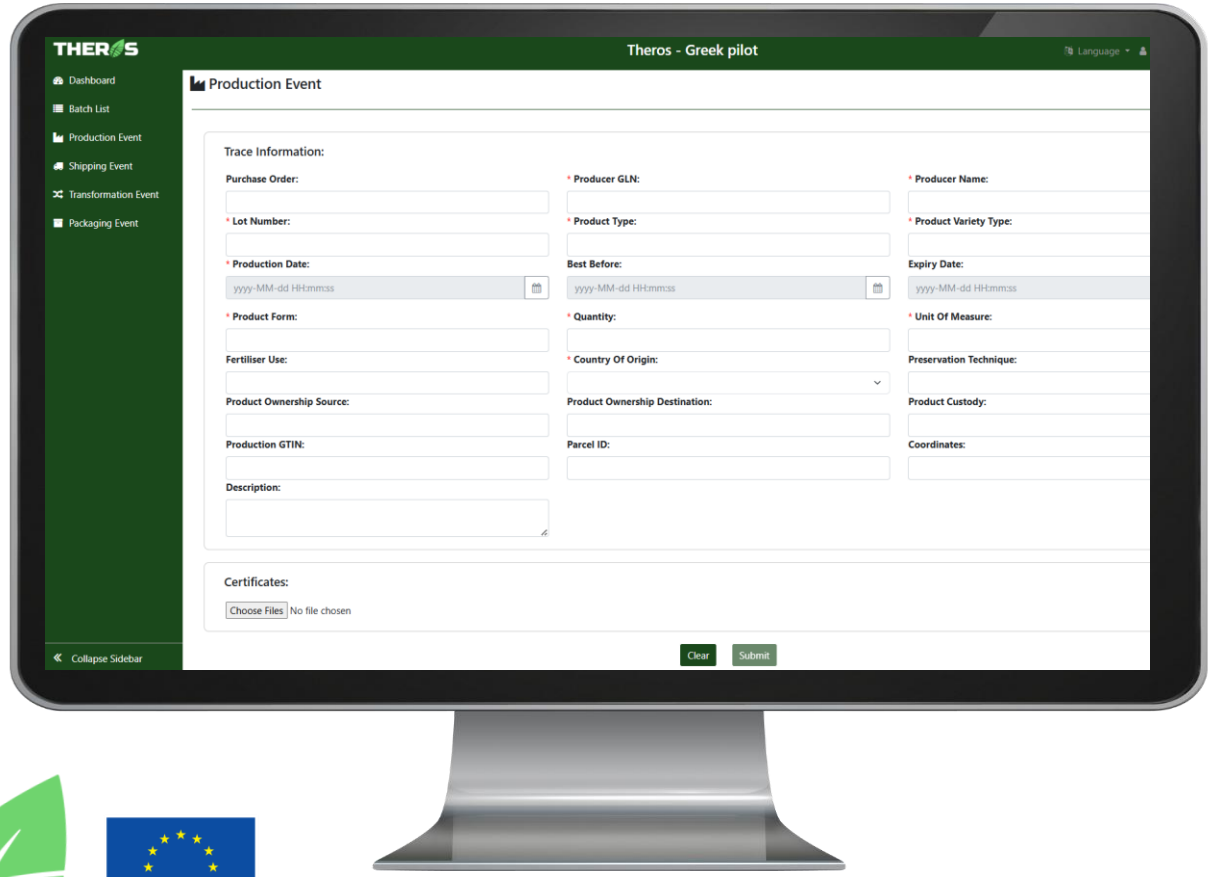
Blockchain-Based Traceability System

05. THEROS developed a blockchain platform to ensure secure and transparent tracking of food products across the supply chain.



- Developed a blockchain platform to secure and transparently **track food products across the supply chain**.
- Recorded every transaction and movement from farm to consumer, facilitating the *detection and tracing of discrepancies*.
- Integrated the blockchain system with existing ERP systems in pilot cases, with additional manual data entry screens for unexpected situations.

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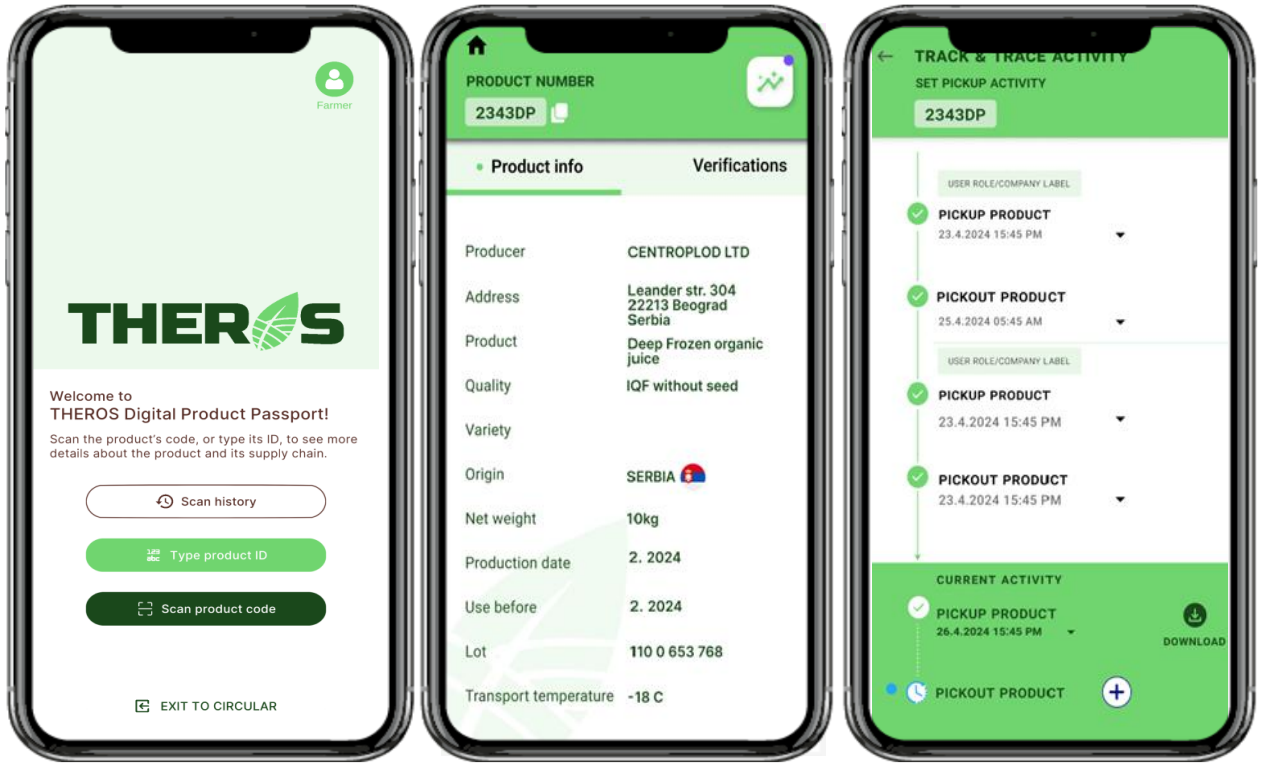
Dynamic Digital Product Passport (dDPP)

06. The Dynamic Digital Product Passport (dDPP) offers real-time traceability and verification of organic and GI food products, integrating seamlessly with other THEROS tools for a unified interface.



- By scanning a product's code or entering an identification number, users such as farmers, transporters, certification bodies, and consumers can access **detailed data on the product's status**.
- The app was designed with a user-friendly interface and tailored features for different user groups, ensuring that relevant data is accessible and actionable.
- The backend system of the dDPP fuses data from the traceability and verification modules, presenting it in a structured format that supports *decision-making across the supply chain*.
- The app's architecture is flexible, allowing for the inclusion of various data types, including product verification, compliance, sustainability, and traceability.

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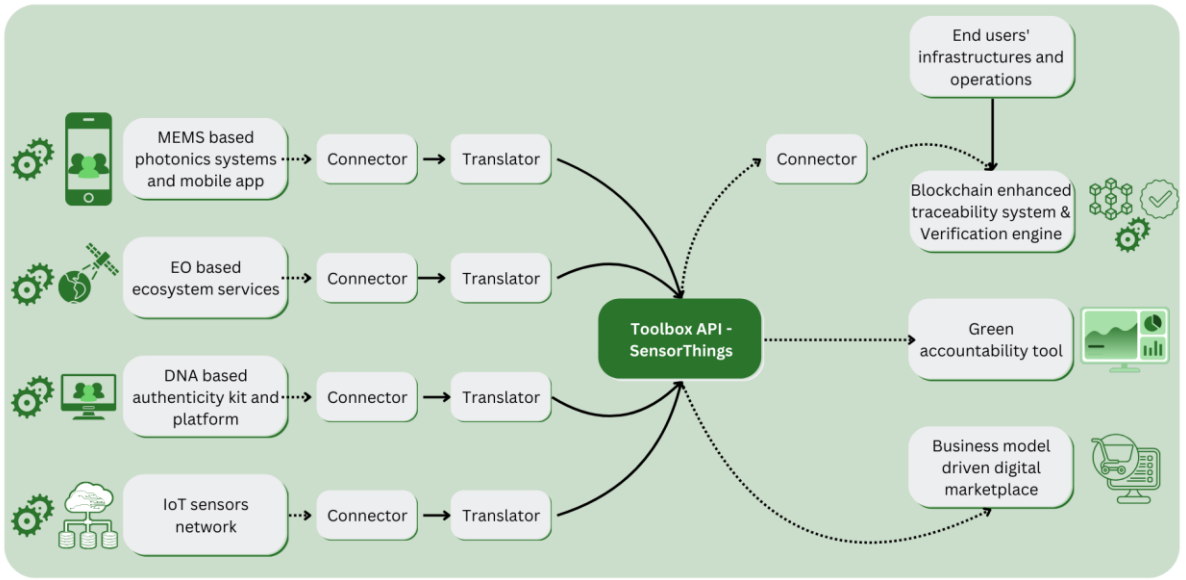
Data management, harmonisation and interoperability

07. The project implemented a robust data management and harmonization platform that integrates diverse data sources from all THEROS toolbox components. This platform acts as a broker between components, facilitating seamless communication and data exchange.

- Implemented a **robust data management platform** integrating diverse data sources from all THEROS components.
- Facilitated seamless communication and data exchange via a single interface (Toolbox API) using open standards (SensorThings OGC).
- Supported secure user access and interoperability with existing systems, essential for widespread adoption of the THEROS toolbox.



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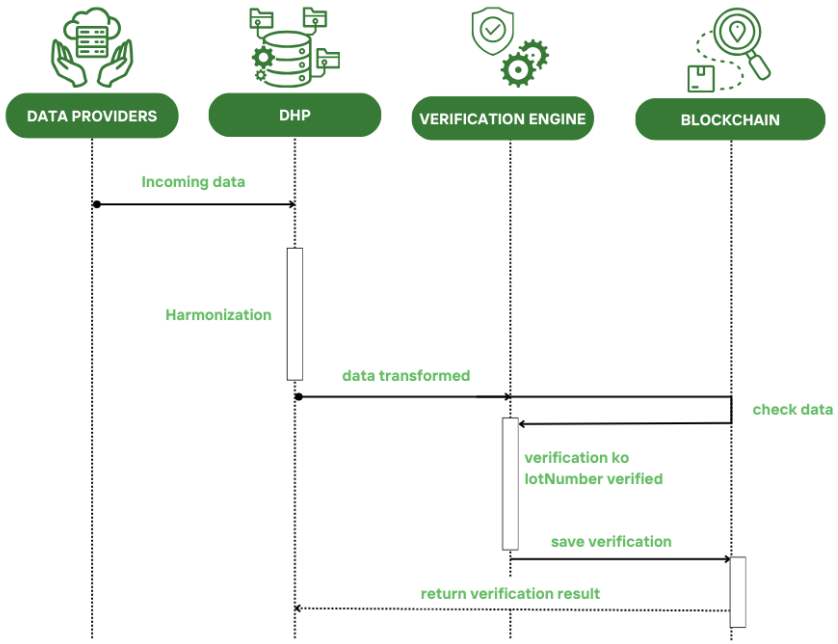
THEROS verification engine

08. A critical component of the THEROS toolbox, the verification engine was developed to automate the process of validating the integrity and authenticity of organic and GI food products.



- This engine processes data from various sources, applying **business rules** defined by data providers to ensure that products **meet specific standards**.
- The engine then issues *verification events*, which are recorded in the system and can be consulted later for traceability purposes. This automated system enhances transparency and trust in the supply chain by providing a reliable mechanism for verifying the organic origin and compliance of products.

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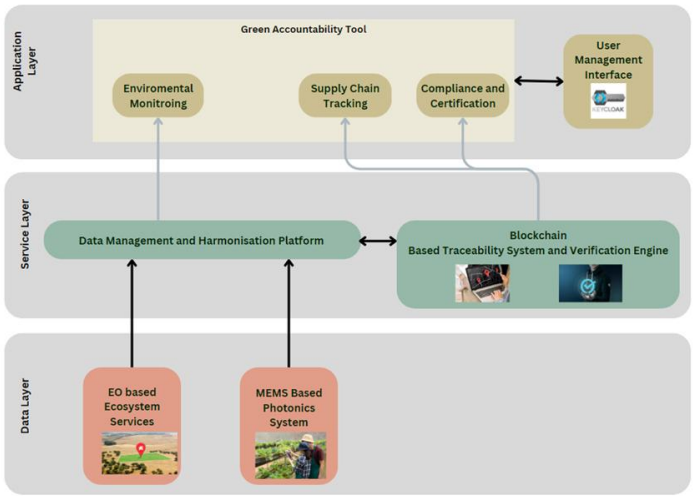
Green Accountability Tool

09. The Green Accountability Tool (GAT) was developed to help stakeholders assess and monitor the environmental impact of their activities across the supply chain.

- This tool integrates data from various sources, including EO-based monitoring and MEMS photonic systems, to provide insights into the **sustainability of farming practices**.
- The GAT offers a user-friendly interface that allows users to track key environmental metrics, such as *carbon footprint and compliance with green certifications*.
- The tool also supports decision-making by offering **recommendations** for improving environmental performance.
- The initial version of the GAT has been completed, and it is integrated into the THEROS platform to ensure that environmental accountability is a core aspect of the supply chain management process.



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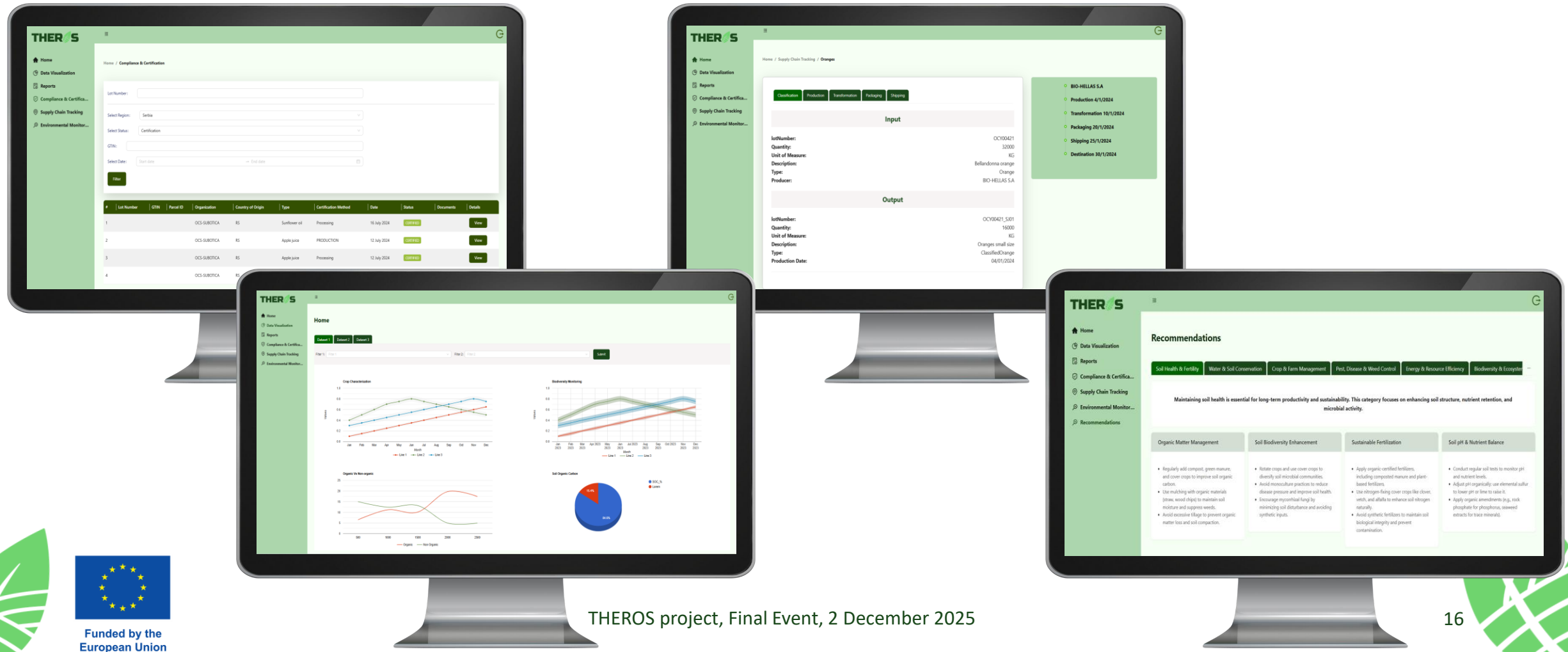

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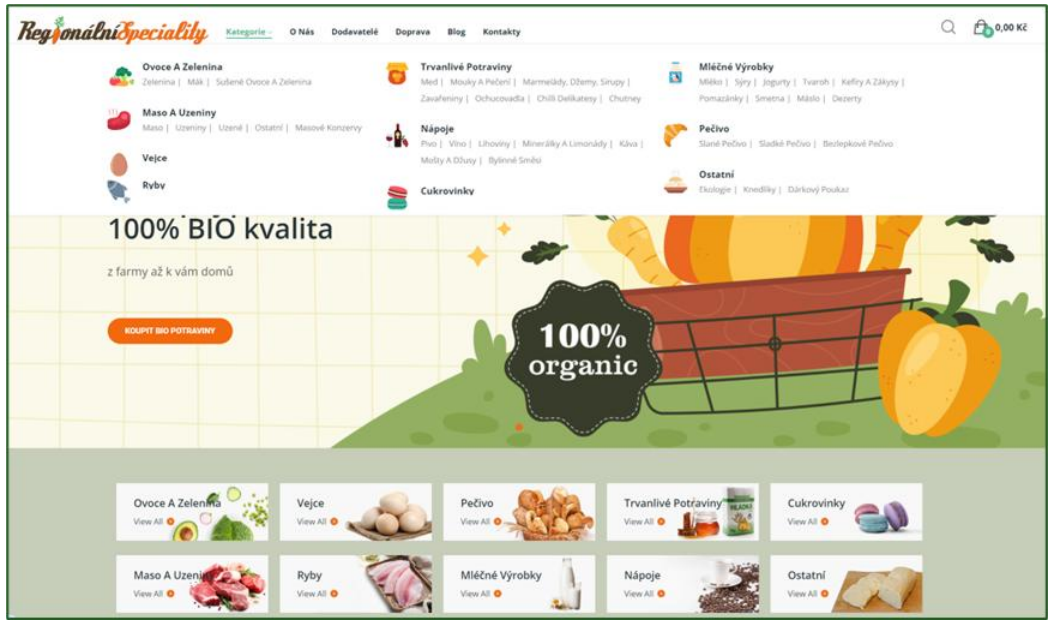
Business model driven digital marketplace

10. The Digital Marketplace was developed as an online platform that connects organic and GI food producers with consumers and other supply chain actors.



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- This marketplace **leverages IoT and blockchain technologies** to ensure real-time monitoring of product conditions during transportation and storage, enhancing traceability and transparency.
- The marketplace allows producers to showcase their products, ensuring that consumers have access to verified and authentic quality-labelled food items.
- The platform also **supports transactions and interactions** between various stakeholders, providing a secure environment for the exchange of goods and information.

Lessons Learned & Replication Potential

Lessons Learned (Five Key Takeaways)

Co-creation is essential for real-world relevance

Working closely with farmers, control bodies, SMEs, and certifiers ensured that tools were practical, accepted, and aligned with actual supply-chain needs. Multi-actor feedback loops significantly improved usability and performance.

Data integration is the biggest barrier — and the biggest enabler

Bringing EO, MEMS, DNA, IoT, and blockchain into a single ecosystem was challenging, but once achieved, it unlocked new traceability, authenticity, and compliance capabilities that individual tools alone could not deliver.

Standardisation and interoperability are non-negotiable

The need for harmonised data models, interoperable APIs, and compliance with EU frameworks (Data Act, CAP, Organic Regulation) became evident early on. Standardisation is the foundation for scaling THEROS beyond the pilots.

Scalability depends on flexibility, not uniformity

A modular architecture and configurable tools allowed THEROS to adapt to different regions, product types, and regulatory contexts. This flexibility is key to replicating THEROS in new value chains and territories.

Simplicity drives adoption

Users preferred straightforward dashboards, clear workflows, and automated indicators. The simpler the interface, the faster the uptake — especially for farmers and SMEs with limited digital maturity.

This opens clear pathways for THEROS technologies to be embedded into regulatory and market-driven systems.

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Future Prospects and The Road Ahead

01

Scaling Real-World Uptake

THEROS tools are ready for adoption across supply chains, enabling producers, certifiers, and control bodies to enhance trust and transparency.

02

Expansion to New Regions & Sectors

The modular toolbox can be easily adapted to additional countries, GI/organic sectors, and diverse product categories.

03

Interoperability & Policy Alignment

THEROS integrates with EU priorities - Organic Regulation, GI reform, Digital Product Passports, and the EU Data Strategy - supporting compliance and data-driven governance.

04

New Business & Service Models

Future pathways include subscription-based traceability services, licensing of tools, and paid integrations with existing platforms and certification systems.

05

Strengthening Environmental & Social Impact

Future developments will enhance tracking of ecological outcomes, better sustainability insights for policymakers, and stronger consumer awareness on organic products and fraud prevention.

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Thank you for your attention!

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