



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

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

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THEROS 

Introduction



- 🌿 In Europe's journey towards climate neutrality by 2050, sustainable food systems play a crucial role. Organic farming stands out for its promotion of eco-friendly practices and support for post-COVID recovery.
- 🌿 The Farm to Fork and Biodiversity Strategies aim to boost organic agriculture and aquaculture by 25% by 2030. However, challenges like fraud and adulteration threaten the integrity of organic products.
- 🌿 To address this, the European Commission is leveraging digital technologies such as blockchain to enhance traceability and transparency, fostering consumer trust.
- 🌿 THEROS project explores the significance of sustainable food systems, the role of organic farming, set targets, challenges posed by fraud, and ongoing efforts to ensure integrity in European food systems.



The Growing Demand for Organic and GI Products



Growing Demand for Organic and Geographical Indication (GI) Products

Consumer Interest: Rising consumer awareness about health, sustainability, and product authenticity drives demand for organic and GI products, with consumers seeking options that promise minimal chemicals and origin authenticity.



Market Expansion: The organic and GI markets are expanding globally, with GI products (e.g., wines, cheeses, olive oils) holding unique economic and cultural value, commanding premium prices for their quality and regional heritage.



Supply Chain Complexity: Meeting demand requires complex supply chains with multiple stakeholders, where each stage must be carefully managed to preserve product integrity from origin to consumer.



Need for Transparency, Traceability, and Authenticity



Transparency: Transparent supply chains allow consumers and stakeholders to track a product's journey, building trust in its organic or GI status.



Traceability: Essential for maintaining quality and compliance, traceability systems track each supply chain step to uphold standards.



Authenticity: Authenticity safeguards consumer trust and preserves the economic and cultural value of organic and GI products, preventing fraud and protecting regional identity.



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The Challenges for Organic and GI Products



THEROS Key Facts



- 🌿 **Project Title:** An integrated toolbox for improved verification and prevention of adulterations and non-compliances in organic and geographical indications food supply chain
- 🌿 **Call identifier:** HORIZON-CL6-2022-FARM2FORK-01-04
- 🌿 **Topic:** “Innovative solutions to prevent adulteration of food bearing quality labels: focus on organic food and geographical indications”
- 🌿 **Duration:** 01.01.2023 - 31.12.2025 (36 months)
- 🌿 **Funding scheme:** IA – Innovation Action
- 🌿 **EU contribution:** EUR 3,999,961.00
- 🌿 **Coordinated by:** Institute of Communication and Computer Systems (ICCS), Greece



THEROS Consortium

- **4 Research Institutes & Technology Organizations** (ICCS, AUTH, JSI, CERTH)
- **4 Control and Certification Bodies / Authorities** (ELGO, OCS, KIWA, BIO-HELLAS)
- **5 Large Enterprises & SMEs** (NTT DATA, SINERGISE, EBOS, SEABILITY, WRLS)
- **1 Regulatory Council for a DPO** (MEXILLON)
- **2 Retailers / Wholesalers** (UNIVER, SUMAVA)
- **1 Cooperative and Producer Association** (BIO-NET)



6 Participating Countries



17 Partners



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Motivation



SUSTAINABILITY

Promote sustainable farming to create resilient food systems that protect the integrity of organic products and benefit local farmers.

COMBATING FOOD FRAUD

Prevent adulteration and fraud in high-value organic and GI foods to protect consumer trust and product integrity.

TECHNOLOGICAL ADVANCEMENTS

Use digital technologies like blockchain and digital passports to improve traceability, integrity, and security in the food supply chain.

CLIMATE GOALS

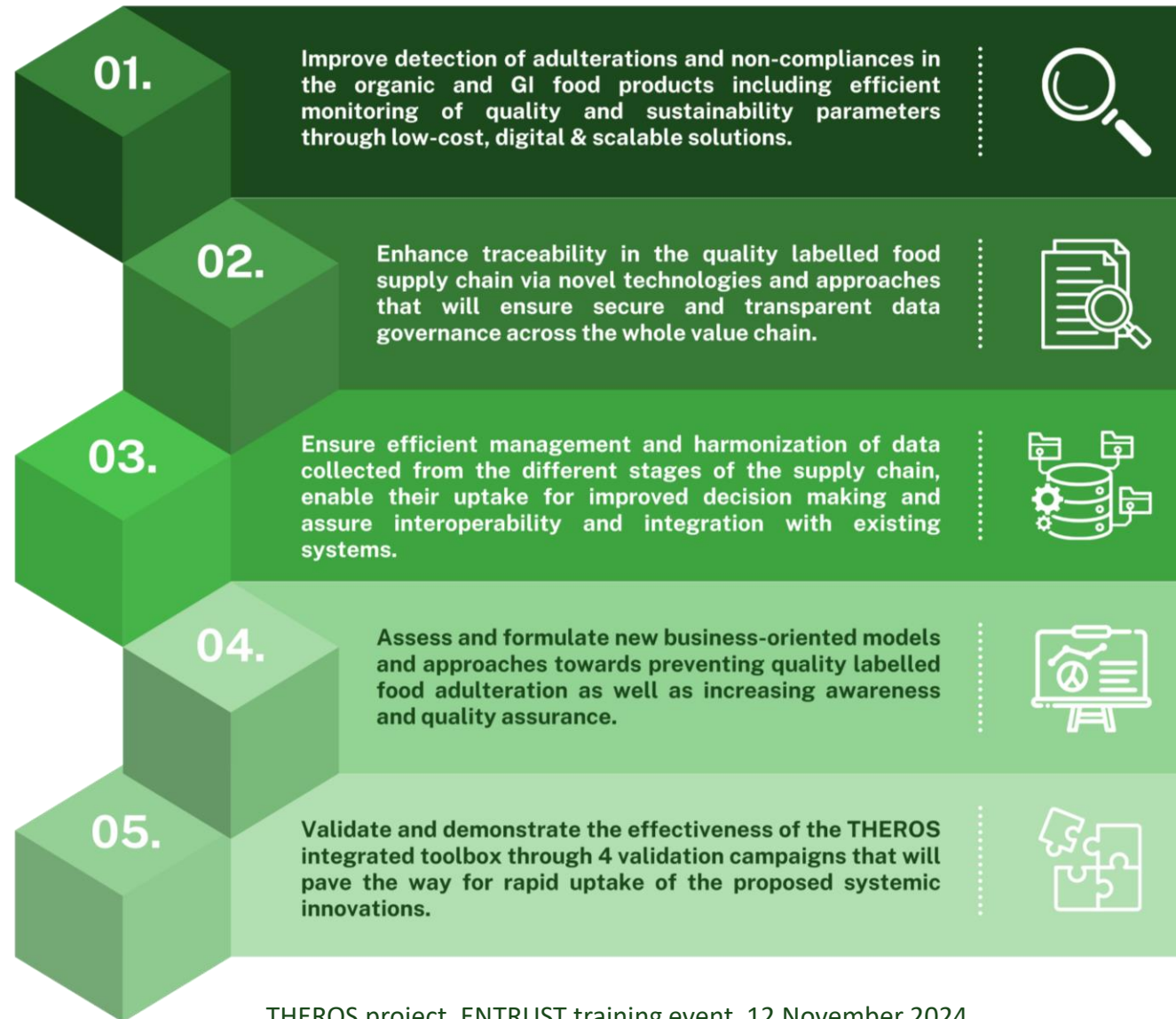
Aim for a climate-neutral Europe by 2050 through sustainable food systems and eco-friendly farming.

ECONOMIC AND SOCIAL BENEFITS

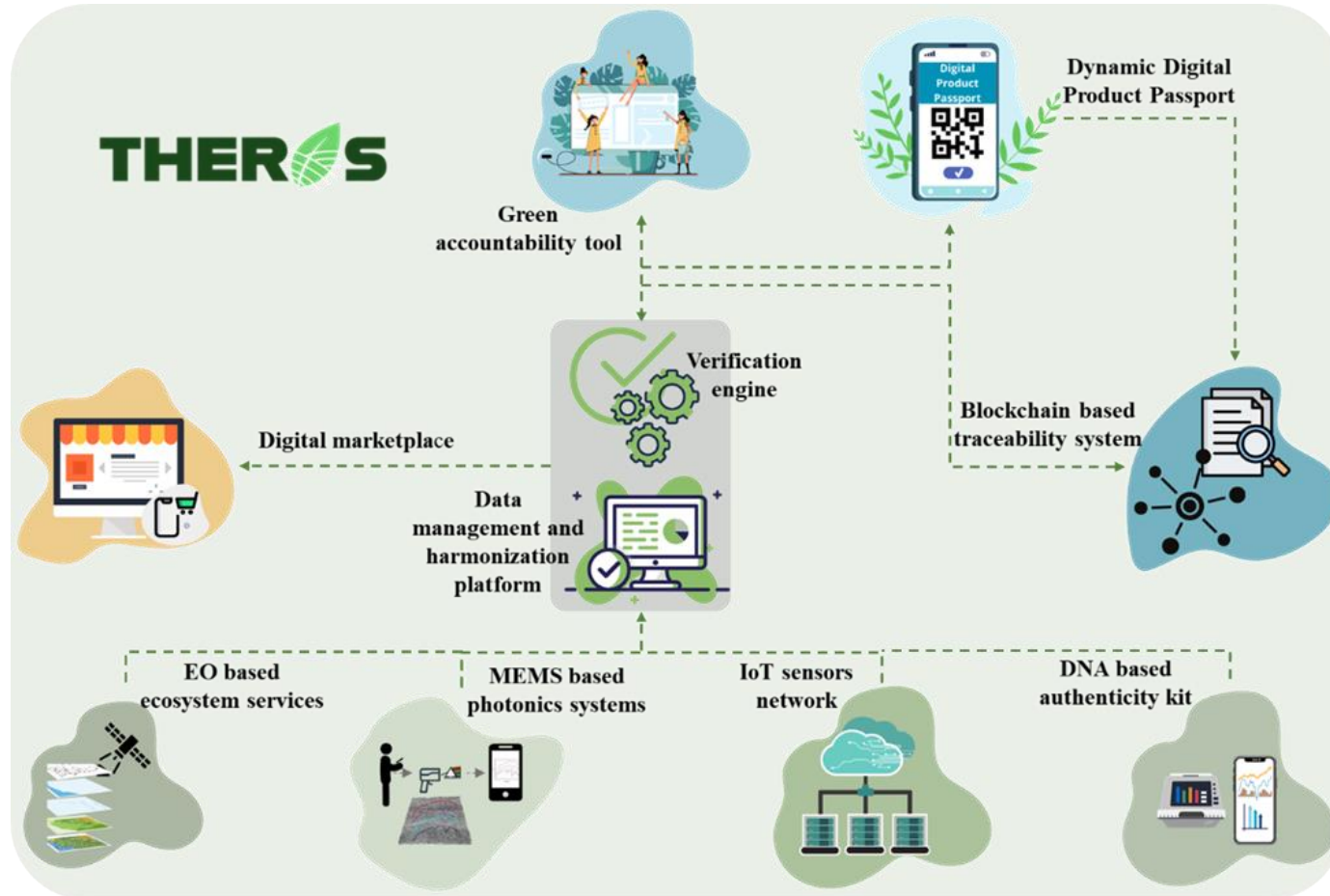
Support fair economic returns for local farmers, contribute to economic growth, and ensure safe, healthy, high-quality food for consumers.

POLICY SUPPORT

Align with European Commission initiatives to enhance transparency and restore consumer confidence in organic trade.



THEROS Vision & Concept



THEROS aims to implement an integrated toolbox being capable to modernize the process of verifying organic and geographical indications food products and preventing adulterations and non-compliances, while demonstrating enhanced traceability, security and transparency in the supply chain, through the use of various technologies and innovations

that leverage *Earth Observation, photonics, internet of things (IoT), DNA metabarcoding, blockchain, digital interfaces and product passport, advance analytics, machine learning, artificial intelligence and business models.*

At the same time, efficient mechanisms will be employed in order to ensure interoperability with existing control systems, as well as improved accessibility and sharing of data through harmonized and standardized means, whilst also demonstrating their uptake by relevant stakeholders for improved decision-making.



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THEROS main envisions



Low-cost, digital and scalable solutions.



Blockchain enhanced traceability system.



Platforms and algorithms allowing management and harmonization.



Interfaces to facilitate monitoring and inspections.



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THEROS Pilot Demonstrations



Pilot 1: Serbia



The pilot demonstration will focus on the employment of THEROS toolbox components in order to facilitate efficient large-scale monitoring of organic food assets.

Pilot 2: Greece



The pilot demonstration will focus on the verification of organic production practices.

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.

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.

Pilot Scope

Use of THEROS innovations

EO based ecosystem services, MEMS based photonics systems, Green accountability tool, Dynamic Digital Product Passport, Blockchain based traceability system, Verification engine, and Data management and harmonization platform

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

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



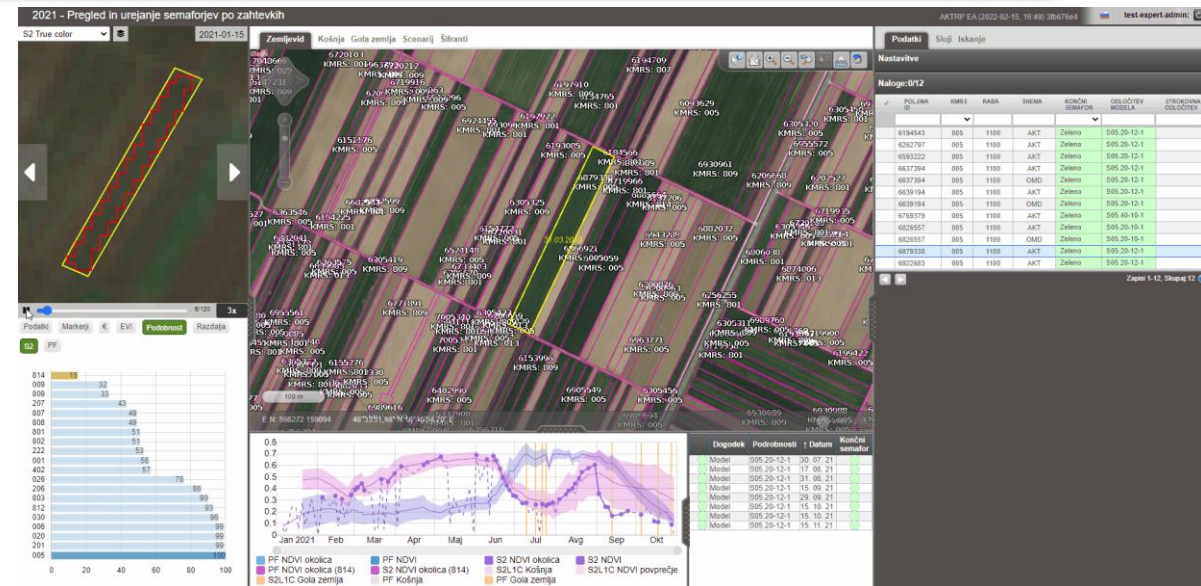
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Earth Observation (EO) Services

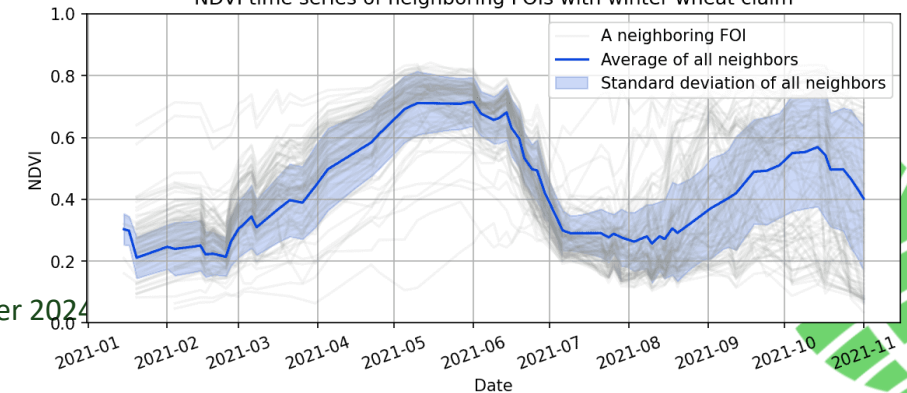


01. Establish sustainable supply chains for innovative Earth observation value added products and services, focusing on monitoring the compliance with organic standard using satellite imagery from Sentinel-2, including a model to distinguish between organic and conventional parcels.

- Use satellite imagery for monitoring parcels remotely
- Compute “markers” (machine learning) on satellite imagery to monitor agricultural activity
- Combing these markers to help agencies with risk assessment and monitoring of organic farming regulations compliance



NDVI time series of neighboring FOIs with winter wheat claim

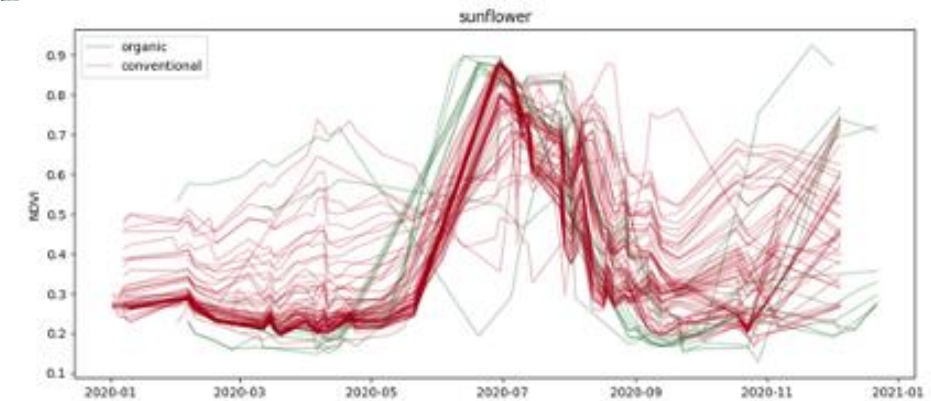
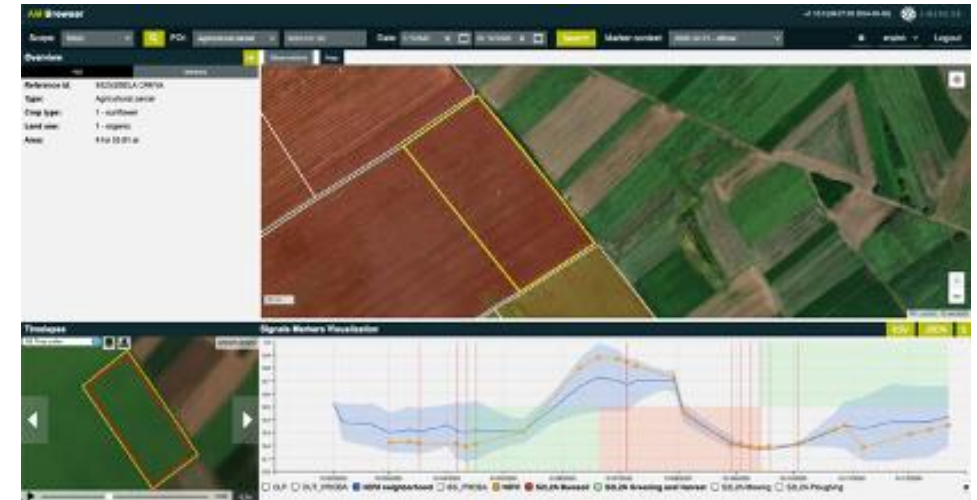


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Earth Observation (EO) Services

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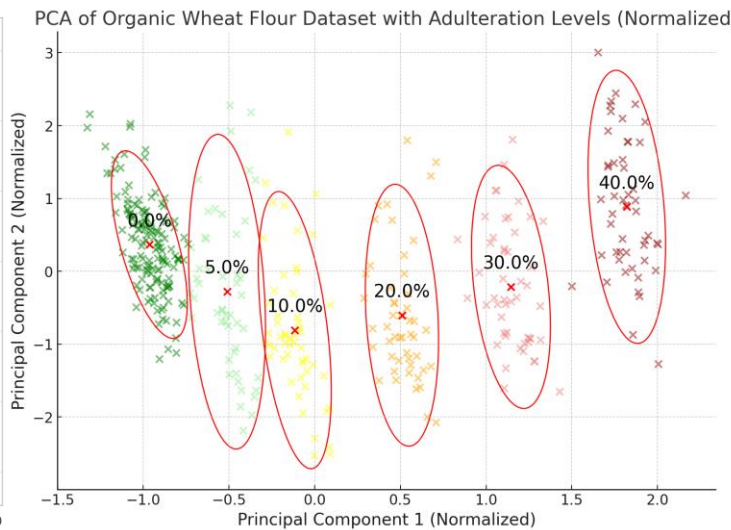
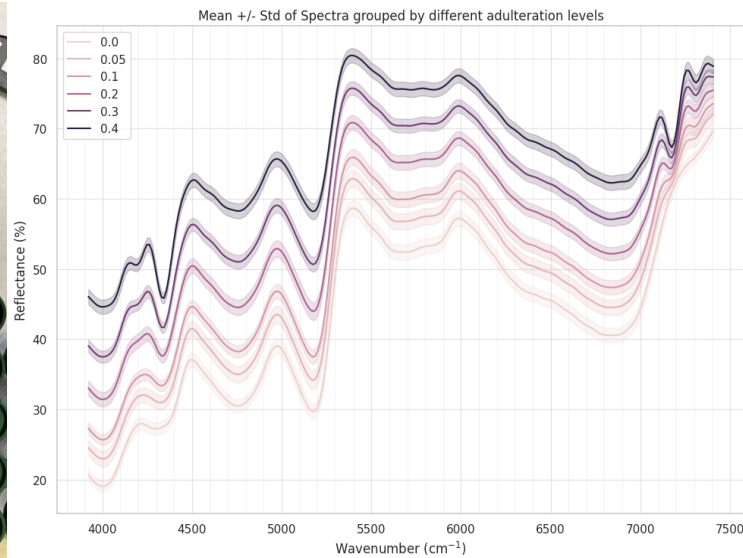
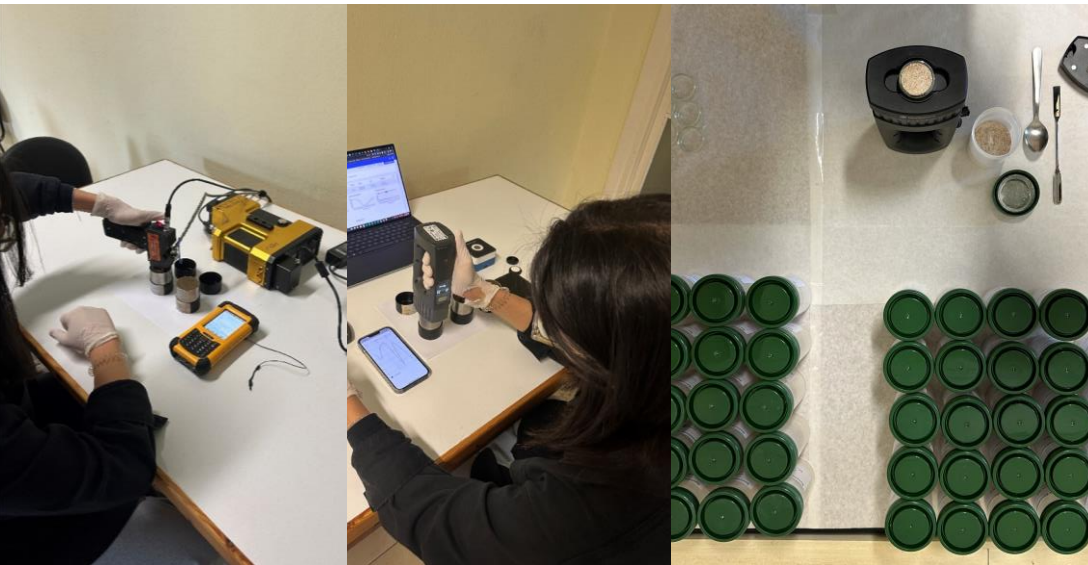
- The project developed and validated several Earth Observation (EO) **markers** to monitor *compliance* with organic farming practices, including:
 - Homogeneity,
 - Greening and harvest marker,
 - Baresoil marker,
 - Similarity and Euclidian Distance Marker,
 - Crop marker, and
 - Organic/non-organic 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.



MEMS-Based Photonics System

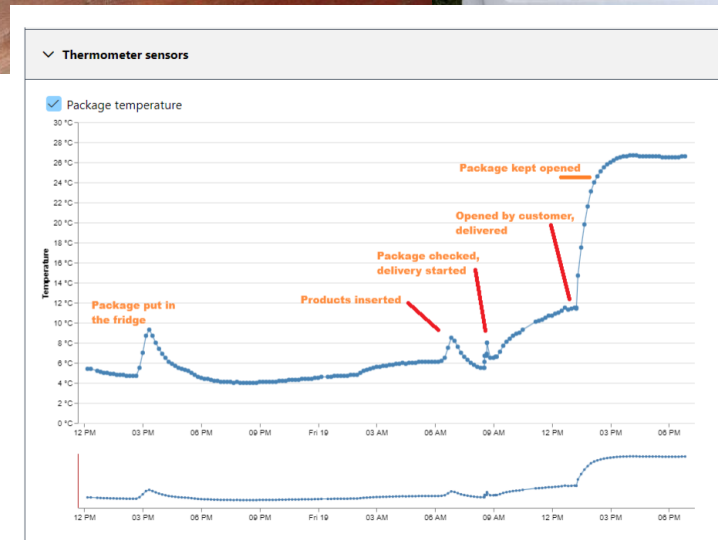
02. The MEMS system in THEROS advances food adulteration detection by providing quick, non-destructive analysis of organic products with high accuracy using low-cost, portable spectrometers.

- 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.



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.



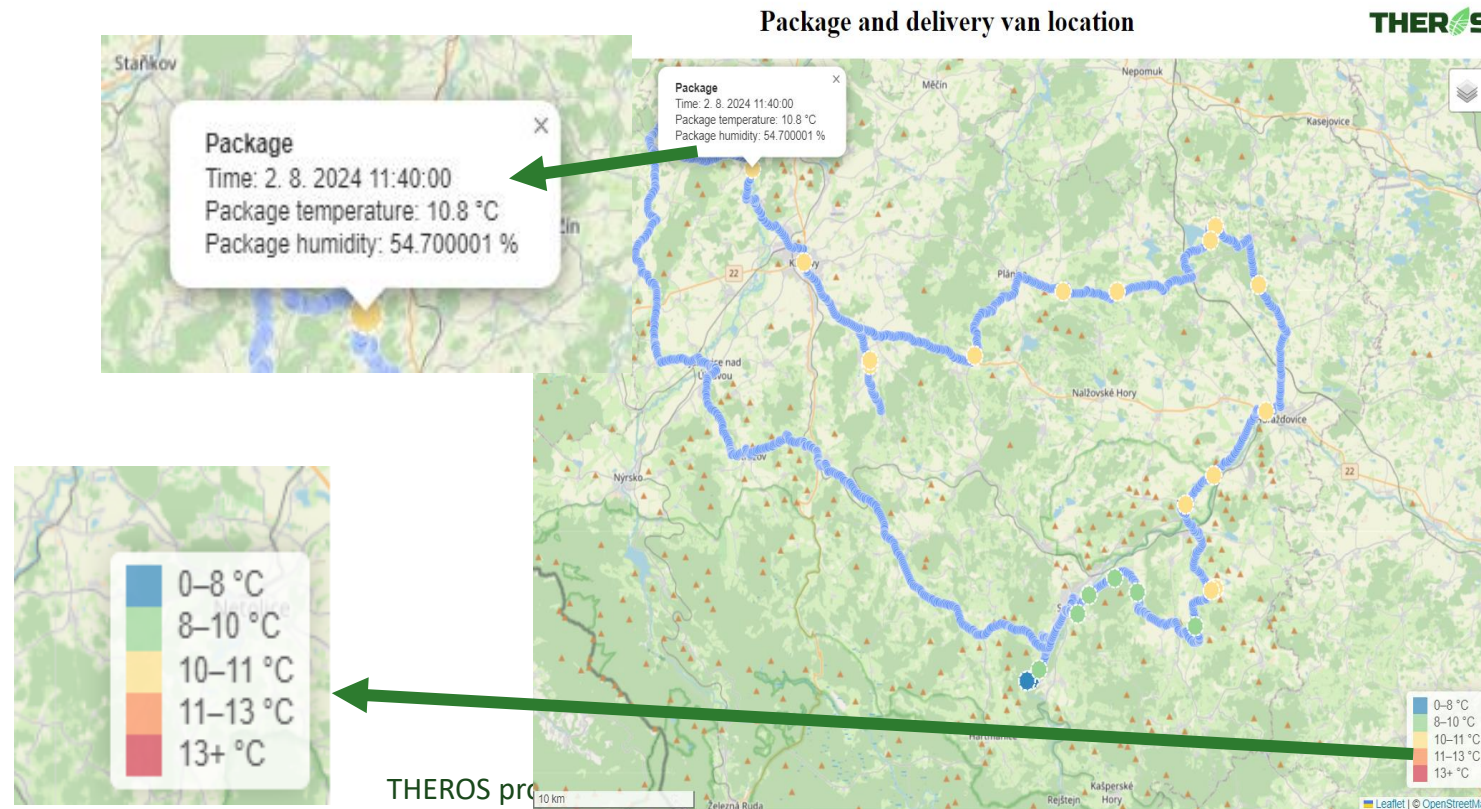
- Designed and deployed an IoT network to **monitor quality and climate parameters** during the *transport* of organic/GI foods, addressing both intentional and unintentional adulterations.
- Monitored air temperature, humidity, and package integrity, with real-time data transmission to the THEROS platform.
- 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.
- Conducted successful initial tests in the Czech Republic, demonstrating the system's effectiveness in ensuring product integrity.



IoT Sensors Network

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

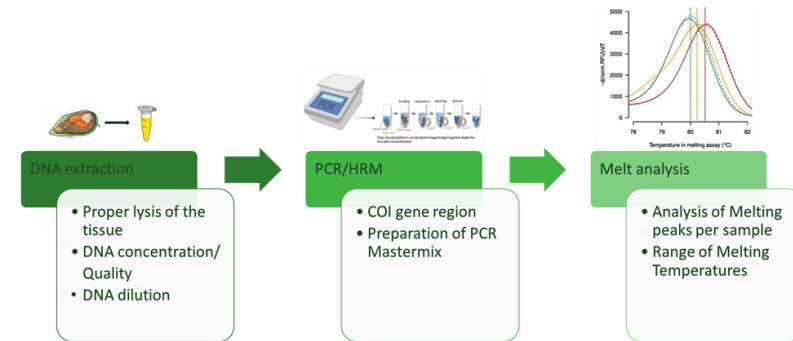


DNA-Based Authenticity Kit



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, significantly enhancing the detection of mislabeling and adulteration.
- The kit significantly enhances the detection of mislabeling and adulteration, providing a robust tool for stakeholders in the food sector, including certification authorities.



DNA Authenticity Kit | Data Ingestion App

| Submission form | | Manage pending records | | | | Stored records | | |
|-----------------|----------------|------------------------|---------------------------|----------------------|---------------|---------------------|----------------------------|---------|
| Labelled origin | Lot number | Sample code | Organism result | Melting temperatures | Query cover % | Sequence identity % | Submission timestamp (UTC) | Actions |
| Galicia, Spain | 20230000012704 | ES40 | Mytilus galloprovincialis | [84.78] | 100 | 90.52 | 2024-07-11 13:11:24.574Z | 🔒 |
| Galicia, Spain | 20230000012704 | ES39 | Mytilus galloprovincialis | [84.17] | 95 | 90 | 2024-07-11 13:10:57.807Z | 🔒 |
| Galicia, Spain | 20230000012704 | ES38 | Mytilus galloprovincialis | [82.98] | 100 | 100 | 2024-07-11 13:10:33.781Z | 🔒 |
| Galicia, Spain | 20230000012704 | ES37 | Mytilus galloprovincialis | [83.75] | 97 | 93.61 | 2024-07-11 13:10:12.761Z | 🔒 |
| Galicia, Spain | 20230000012704 | ES36 | Mytilus galloprovincialis | [82.07] | 100 | 100 | 2024-07-11 13:09:34.884Z | 🔒 |
| Galicia, Spain | 20230000012670 | ES34 | Mytilus galloprovincialis | [83.78] | 100 | 86.51 | 2024-07-11 13:08:09.914Z | 🔒 |
| Galicia, Spain | 20230000012670 | ES33 | Mytilus galloprovincialis | [81.69] | 100 | 100 | 2024-07-11 13:07:36.047Z | 🔒 |



Blockchain-Based Traceability System



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

Organization Name: Theros - Consortium Name Language User

Production Event

Trace Information:

| | | |
|-------------------------|---------------------------|--------------------------------|
| Purchase Order: | • Producer GLN: | • Producer Name: |
| <input type="text"/> | <input type="text"/> | <input type="text"/> |
| • Lot Number: | • Product Type: | • Product Variety Type: |
| <input type="text"/> | <input type="text"/> | <input type="text"/> |
| • Product Form: | Description: | • Production Date: |
| <input type="text"/> | <input type="text"/> | <input type="text"/> |
| • Quantity: | • Unit Of Measure: | Fertilizer Use: |
| <input type="text"/> | <input type="text"/> | <input type="text"/> |
| Best Before: | Expiry Date: | • Country Of Origin: |
| <input type="text"/> | <input type="text"/> | <input type="text"/> |
| Preservation Technique: | Product Ownership Source: | Product Ownership Destination: |
| <input type="text"/> | <input type="text"/> | <input type="text"/> |
| Product Custody: | Parcel ID: | Coordinates: |
| <input type="text"/> | <input type="text"/> | <input type="text"/> |

Certificates: +

Doc Name:

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- 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.



Mobile application for MEMS

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

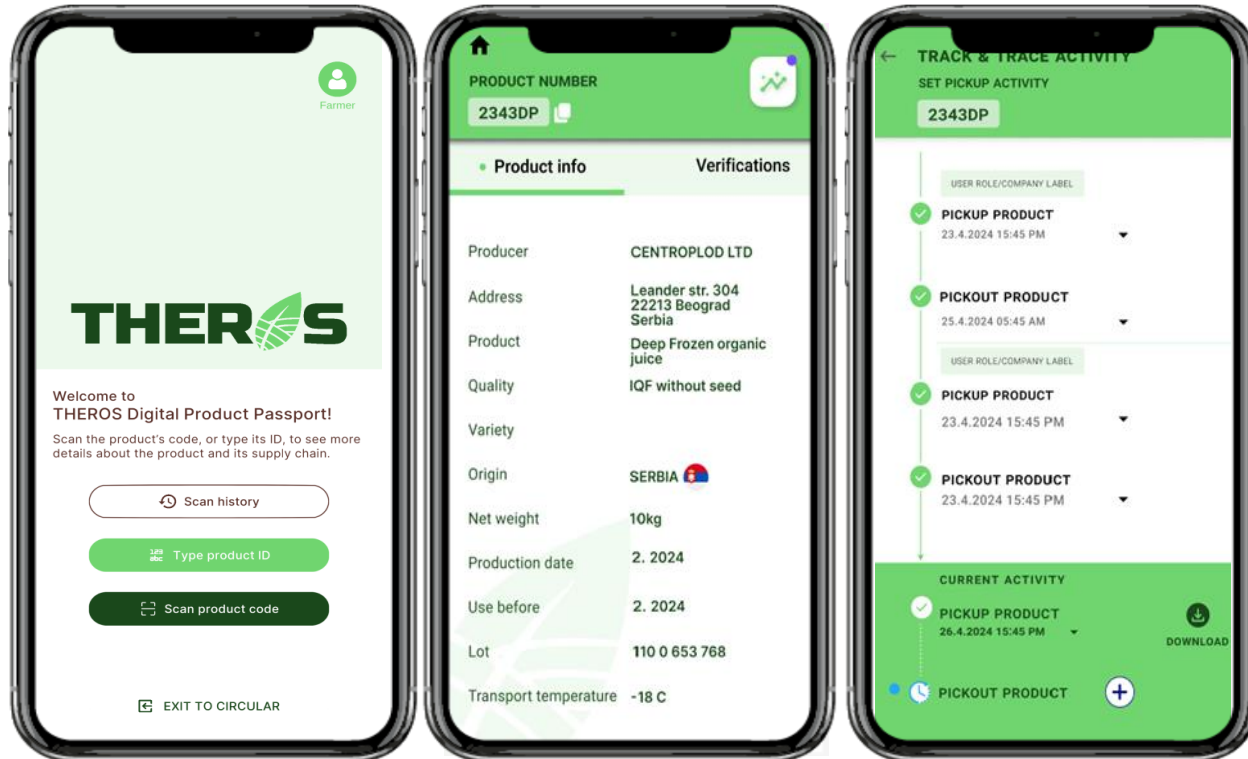
- This application was designed to facilitate **data acquisition from spectrometers**, with seamless integration via Bluetooth connectivity.
- The app supports offline operation, ensuring that data is stored locally and synchronized once an internet connection is available.
- Key functionalities include user login, device selection, data acquisition, and secure data transmission via a REST API, which integrates TLS encryption to protect data during transmission.
- 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.



Dynamic Digital Product Passport (dDPP)



07. 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.

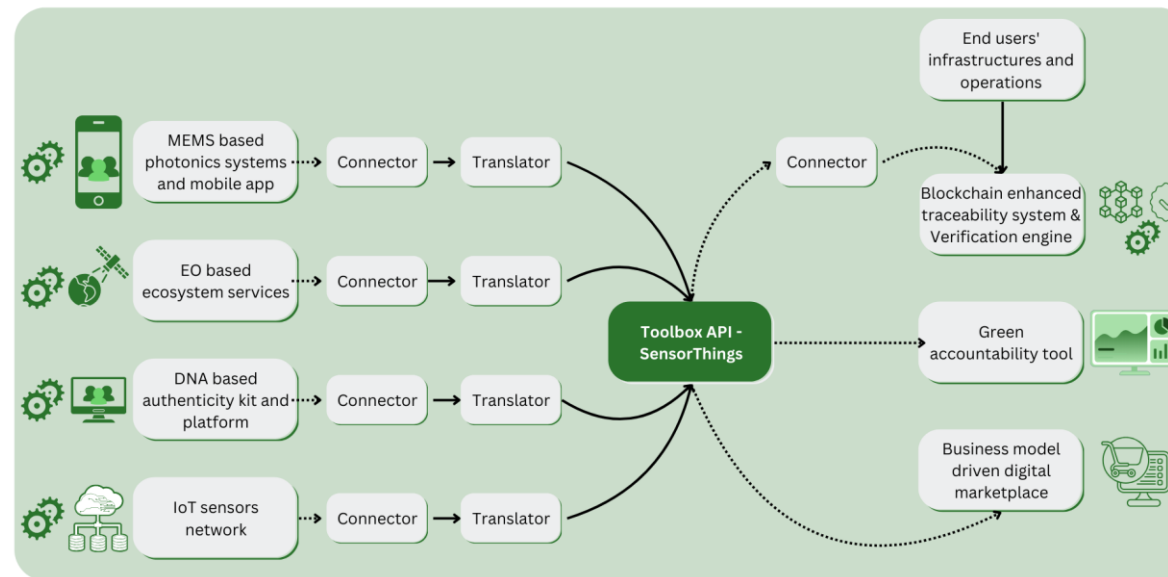


- By scanning a product's code or entering an identification number, users such as farmers, transporters, certification bodies, and consumers can access **detailed data on the product's status**.
- The app was designed with a user-friendly interface and tailored features for different user groups, ensuring 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.



08. 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.

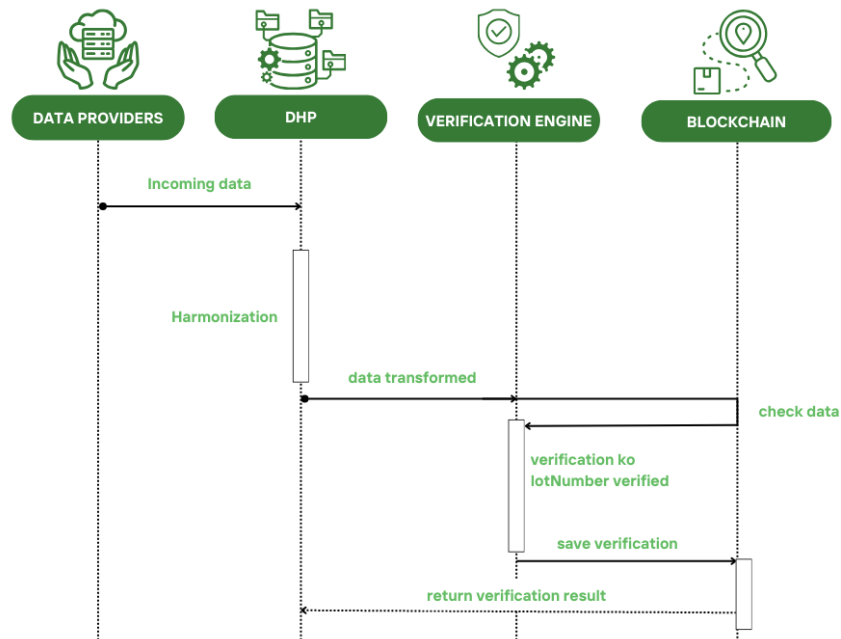
- Implemented a **robust data management platform** integrating diverse data sources from all THEROS components.
- Facilitated seamless communication and data exchange via a single interface (Toolbox API) using open standards (SensorThings OGC).
- Supported secure user access and interoperability with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



THEROS verification engine



09. 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.



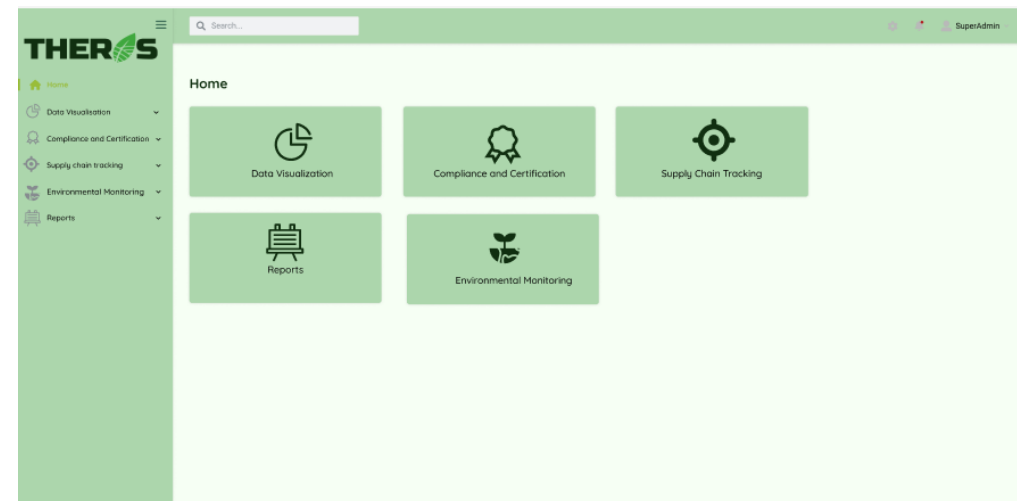
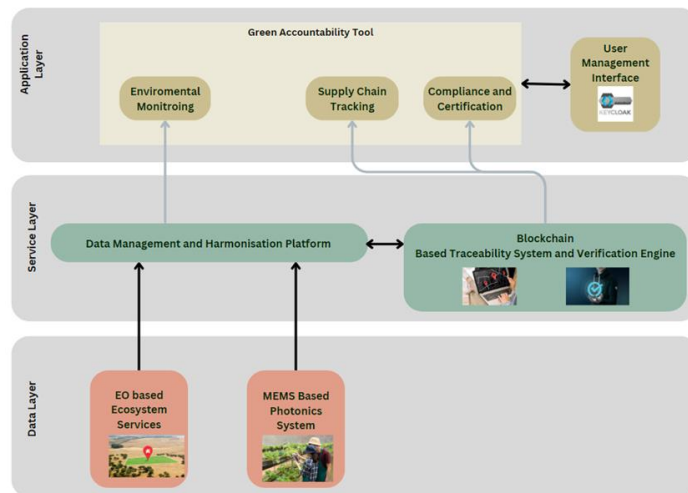
- This engine processes data from various sources, applying **business rules** defined by data providers to ensure that products **meet specific standards**.
- The engine then issues *verification events*, which are recorded in the system and can be consulted later for traceability purposes. This automated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



Green Accountability Tool

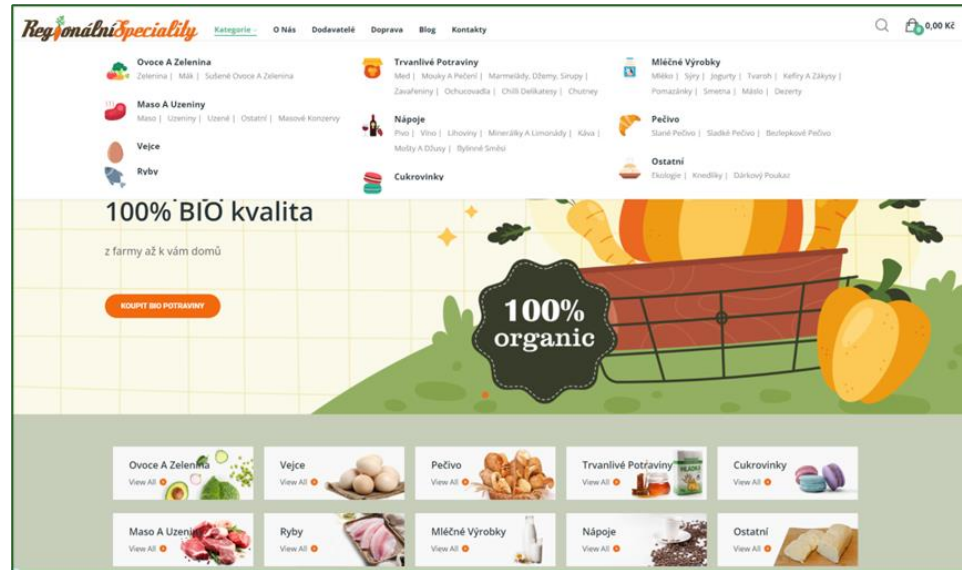
10. The Green Accountability Tool (GAT) was developed to help stakeholders assess and monitor the environmental impact of their activities across the supply chain.

- 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.



Business model driven digital marketplace

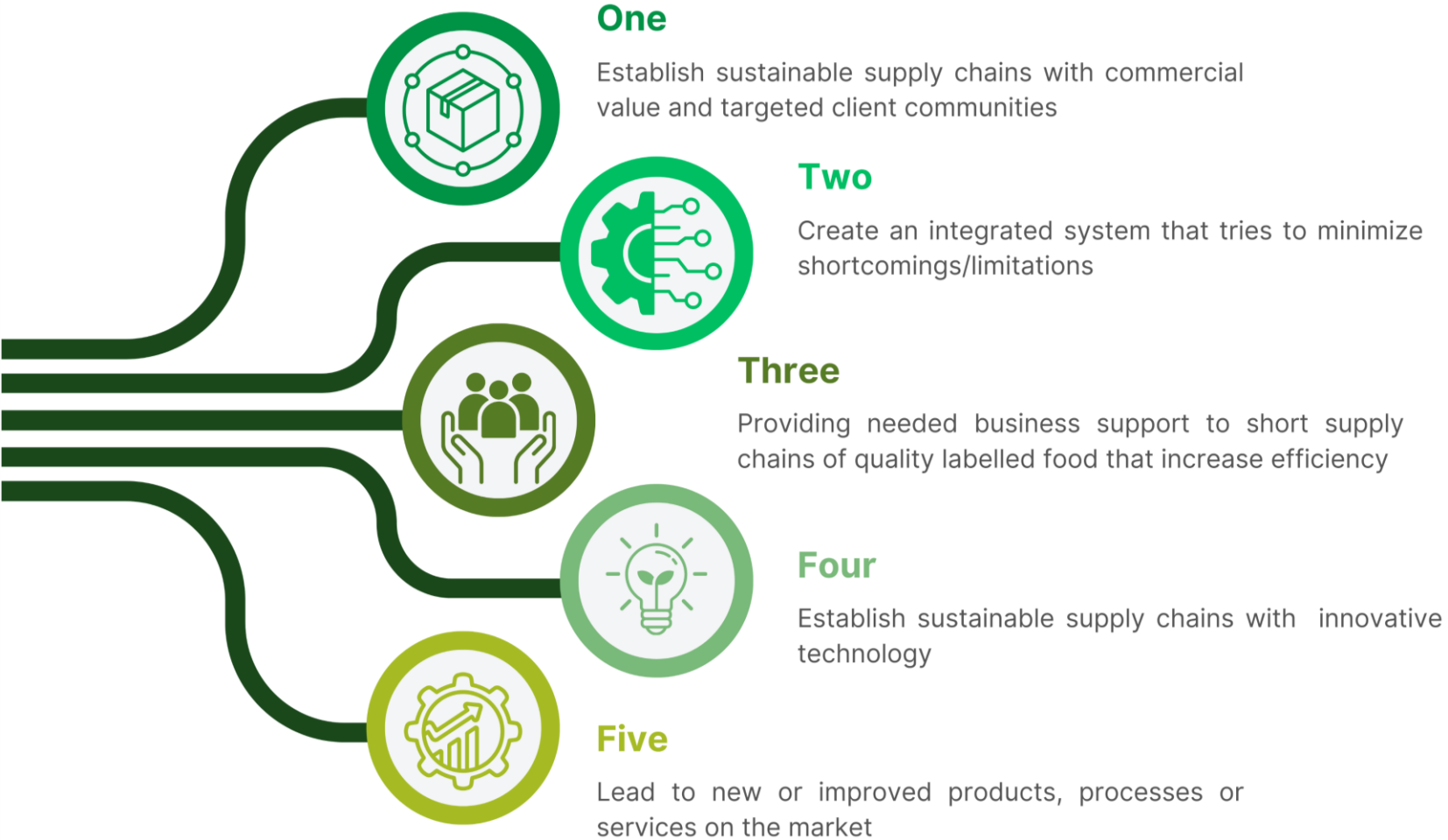
11. The Digital Marketplace was developed as an online platform that connects organic and GI food producers with consumers and other supply chain actors.



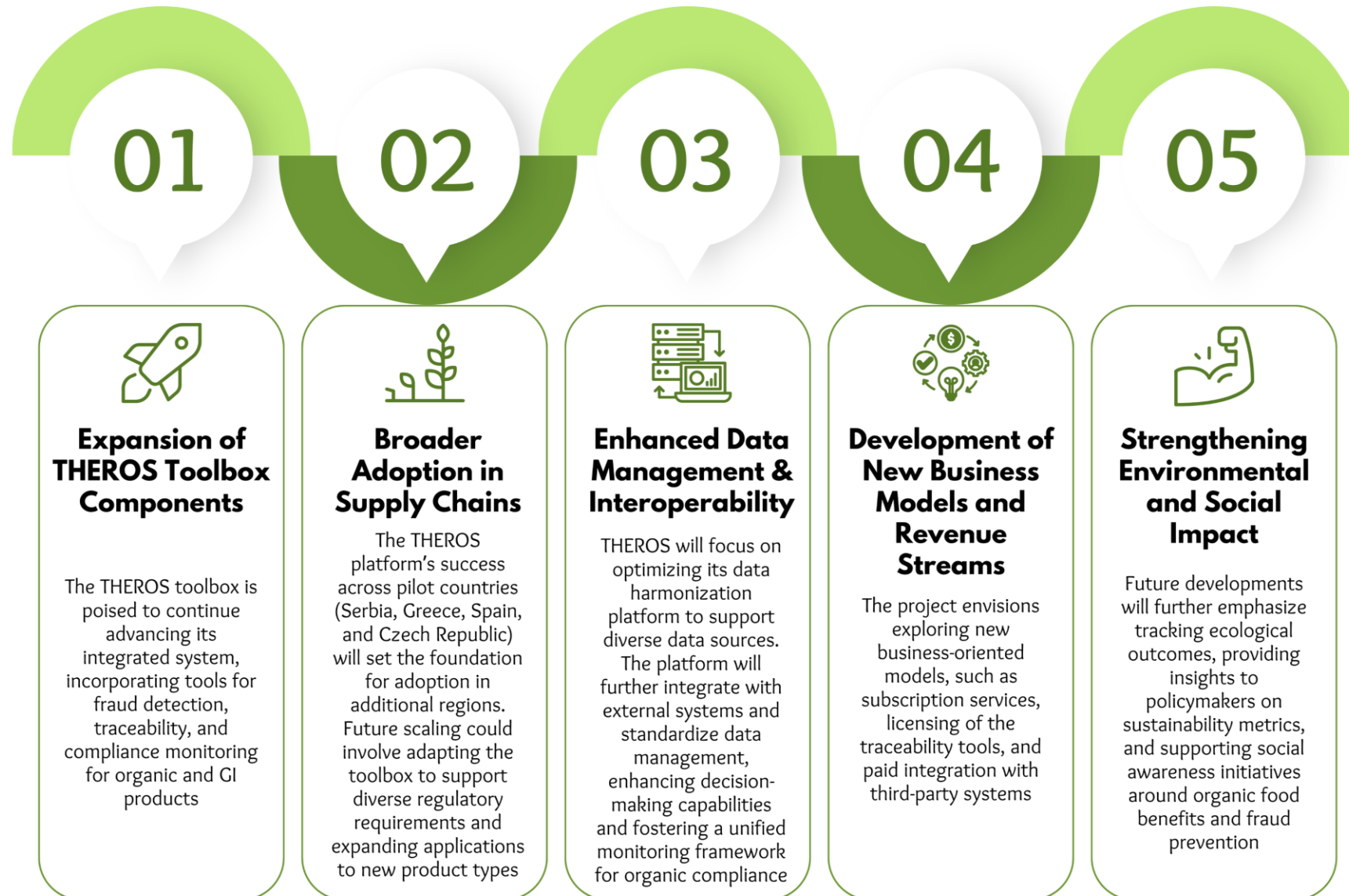
- This marketplace **leverages IoT and blockchain technologies** to ensure real-time monitoring of product conditions during transportation and storage, enhancing traceability and transparency.
- The marketplace allows producers to showcase their products, ensuring that consumers have access to verified 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.
- The first version of the Digital Marketplace has been launched, with 15 suppliers and 80 products already involved, and the platform is expected to expand as more stakeholders join.



Expected Impacts of THEROS



Future Prospects and Expansion





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Thank you for your attention!

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