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

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Executive Summary

THEROS Knowledge Base is designed to serve as a repository of user-friendly materials customized to meet the diverse needs of stakeholders, acting as a central hub of outcomes and results essential for the success of the ambitious and visionary THEROS project. Funded under the European Union's Horizon Europe Framework Programme, THEROS aims to implement an integrated toolbox capable of modernizing the process of verifying organic and geographical indications food products. THEROS aims to prevent adulteration and non-compliance through various technological innovations and data sources while demonstrating enhanced security, transparency and interoperability in the quality labelled food supply chain.

This report is the final version of the THEROS knowledge base, based on the initial version outlined in D6.4. While deliverable D6.4 focused on methodologies for creating end-user materials and drafted respective templates, D6.5 presents the final products systematically collected based on knowledge and experience gained within WP3, WP4, and WP5. Final set of end-user materials featured in the THEROS knowledge base comprise various Cookbooks, Policy Briefs and Practice Abstracts resulting from experience in developing respective tools and their implementation in THEROS pilots, as well as alignment with existing third-party resources and liaison with EU bodies and other relevant research activities & projects within EU.

Finally, the report presents the completed online interactive version of the THEROS knowledge base, featuring fully implemented wireframes and map views at various levels. The THEROS knowledge base now functions as a dynamic and adaptable platform that consolidates the project's findings and facilitates effective dissemination of its results. Designed for long-term relevance and usability, it will continue to support the project's objectives beyond its completion.

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Abbreviations & Acronyms

Abbreviation / acronym	Description
API	Application Programming Interface
AUTH	Aristotelio Panepistimio Thessalonikis
AWS	Amazon Web Services
BIO	Biological
BIOH	Inspection institute for organic products sa
BIONET	Agrotikos Synetairismos Bioparagogon Dytikis Elladas
CAP	Common Agricultural Policy
CBS	Certification Bodies
CCA	Circa is Latin for "around" or "about". It is often shortened to c., ca., ca or cca
CDSE	Copernicus Data Space Ecosystem
CERTH	Ethniko Kentro Erevnas kai Technologikis Anaptixis
COI	Cytochrome C Oxidase I
CPU	Central Processing Unit
CRUD	Create, Read, Update, and Delete
CTE	Critical Tracking Events
DC	Distribution Center
DDPP	Dynamic digital product passport
DIAS	Data Information Access Service
DL	Deep Learning
DNA	Deoxyribonucleic Acid
DPO	Protective Designation of Origin
Dxy	Deliverable xy
EBOS	EBOS technologies limited
EC	European Commission
EFA	Ecological Focus Area
EIP-AGRI	EIP-AGRI Operational Group projects

ELGO	Ellinikos georgikos organismos
EO	Earth Observation
ERP	Enterprise Resource Planning
EU	European Union
EVERIS	Everis ingenieria slu
FDIs	Final Draft International Standard
FOI	Feature of Interest
GAT	Green Accountability Tool
GDPR	General Data Protection Regulation
GI	Geographic indications
GIS	Geographic Information System
GMOs	Genetically Modified Organisms
GPRS	General Packet Radio Service
GR	Greek
GS1	Standard GS1
GUI	Graphical User Interface
HRM	High resolution melt analysis
ICCS	Institute of communication and computer systems
INAB	Institute of Applied Biosciences
IoT	Internet of Things
ISO	International Organization for Standardization
IT	Information Technology
JSI	Jožef Stefan institute
JSON	JavaScript Object Notation
KIWA	Kiwa españa slu
LSP	Logistic Service Provider
MEMS	Micro-electromechanical systems
MEXILLON	Consello regulador mexillon de galicia
ML	Machine learning
MQTT	Message Queuing Telemetry Transport
Mx	Month x

NDVI	Normalized difference vegetation index
OCS	Doo organic control system Subotica
OGC	Open Geospatial Consortium
PA	Practice Abstract
PCA	Principal Component Analysis
PCR	Polymerase chain reaction
PO	Project Officer
PU	Public
QR	Quick Response
QR Code	Quick Response code
RF	Retail Facility
REST API	Representational State Transfer Application Programming Interface
RFID	Radio Frequency Identification
SEAB	SEAbility Ltd.
SEF	Serbian name for their national e-invoicing system is Sistem E-Faktura, generally shortened to SEF
SINERGISE	Sinergise laboratory for geographical information systems, Ltd.
SSCC	Serial Shipping Container Code
SSO	Single Sign-On
SUMAVA	Sumavaprodukt s.r.o.
UI	User Interface
UNIVER	Univerexport export-import d.o.o., Novi Sad
URL	Uniform Resource Locator
VIS-NIR	Visible (vis) and Near Infra-Red (nir) radiation
WMS	Web Map Service
WP	Work Package
WRLS	Wirelessinfo

1. Introduction

1.1 Purpose of the document

Deliverable 6.5 outlines the steps involved in developing and finalizing the dynamic version of the THEROS knowledge base. This version translates the results from the project's implementation and piloting activities (Work Packages 2–5) into actionable knowledge. The aim is to provide relevant stakeholders and practitioners with practical tools and insights to prevent adulteration of organic and Geographical Indication (GI) products.

Complementary to the initial version of Deliverable D6.4, which focused on methods for collecting relevant data and information, as well as templates prepared for that purpose, Deliverable D6.5 is dedicated to a structured presentation of compiled materials tailored to specific end users, including a web-based version. Consequently, the core of this deliverable consists of various appendices containing detailed examples of the respective materials.

1.2 Intended readership

Deliverable 6.5 is a public deliverable that addresses consortium members and any interested reader (i.e., the Public (PU) dissemination level).

It is primarily written for the European Commission (EC), the Project Officer (PO) and the consortium members of the THEROS project as an overview of materials included in the THEROS Knowledge base. On the other hand, this report also serves as a stand-alone comprehensible document for the public.

1.3 Document structure

The introductory chapter provides background information on the purpose of the document, the intended readership and the document structure. The second chapter summarizes the data collection methodology presented in detail in D6.4. The third chapter provides an overview of the individual materials included in the online THEROS Knowledge Base, while the main part of this report consists of numerous annexes with detailed content.

2. Methodological framework

2.1 Sources of information

For the development of the final version of the Knowledge base, the following three main sources of information were exploited and are detailed in D6.4[1]:

- Components for monitoring, adulteration detection, and traceability in THEROS (developed within WP3).
- User-centric tools and models in THEROS for enhanced transparency, verification, interoperability, and green accountability traceability (developed within WP4).
- Lessons learned, including feedback from various stakeholders involved in demonstrations across the four THEROS pilots (WP5).

2.2 End-user materials

Materials resulting from the project and included in the online version of THEROS Knowledge base comprise the following:

- *THEROS Toolbox*, a comprehensive collection where individual THEROS solutions are presented and discussed in detail (Annex 5).
- *THEROS pilot dossiers*, detailed documentation outlining the implementation of THEROS solutions across the four pilot sites (Annex 6).
- *THEROS "Network of Networks"* with integration with respective third-party resources and initiatives.
- *Practice abstracts:* The standard EIP-AGRI common format [1] is used and altogether nine practice abstracts were prepared (Annex 1).
- *Cookbooks:* A dedicated "cookbook" was developed for each of the nine individual THEROS tools and solutions (Annex 2). Each cookbook contains a comprehensive list of all necessary components and resources required for the application, along with clear, step-by-step instructions to ensure easy implementation and replication. It places strong emphasis on practical demonstrations, offering helpful tips, tricks, and troubleshooting guidance. Additionally, each cookbook includes graphical and pictorial elements to support understanding and usability.

[1] Del 6.4: THEROS knowledge base (initial version), available at: https://theros-project.eu/wp-content/uploads/2024/11/6.4.pdf

- *Policy briefs* with recommendations aimed at encouraging the adoption of THEROS tools and methodologies by relevant control and certification bodies, authorities, and policymakers (Annex 3).

3. THEROS Knowledge base materials

In this section, a general overview of the materials included in the knowledge base, as discussed in Section 2.1, is provided, with the full version of the content to be included in the Annexes, due to the extensive length of these materials.

3.1 THEROS knowledge base: online version

Online version of the THEROS Knowledge base is available via https://theros-project.eu/theros-knowledge-base/. The six main pillars indicated in Figure 1 are (I) THEROS Toolbox; (ii) THEROS Pilot Dossiers, and (iii) "Network of Networks" (iv) Practice Abstracts (v) Cookbooks (vi) Policy Briefs, with integration with respective third-party resources and initiatives.

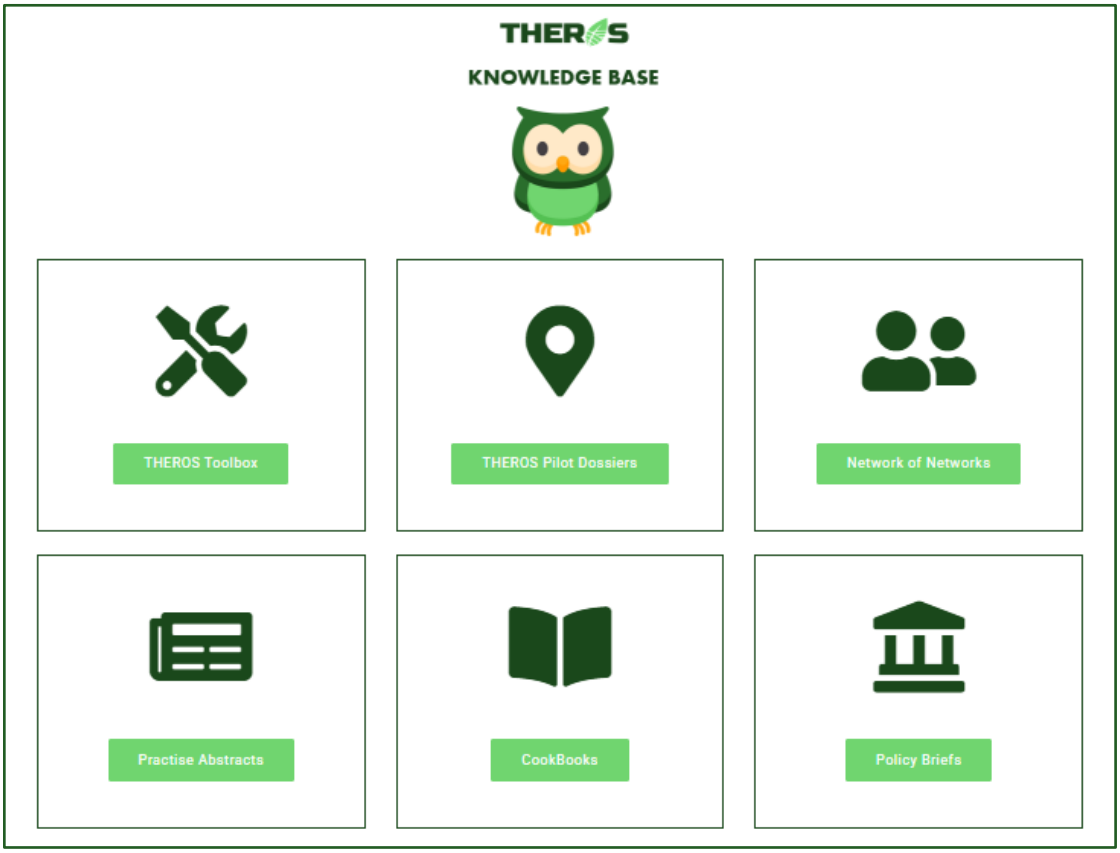

Figure 1: Mock-up of the online version of the THEROS knowledge base

3.1.1 THEROS Toolbox

This section contains access to details regarding all 9 THEROS tools and solutions. For each, information originally gathered using respective templates and provided within this report in Annex 5, is structured according to five main elements (Figure 2):

- **General info:** A concise summary that introduces the system, solution, or concept. It outlines the purpose, goals, and general approach, giving readers a high-level understanding of what the solution does and why it exists.

- **Key Components:** The fundamental building blocks or modules that make up the solution. Each component typically has a defined role or function, and this section explains how they interact or contribute to the overall functionality.
- **Interfaces & services:** The points of interaction between different components or between the solution and external users or systems. This includes APIs, data formats, protocols, and methods of communication that allow components to exchange data or trigger operations.
- **Usage & applications:** The practical implementation and real-world relevance of the system. This section explains who the system is for, how it can be used, and the problems it helps to solve, often highlighting use cases, benefits, and target users.
- **Materials:** Resources used

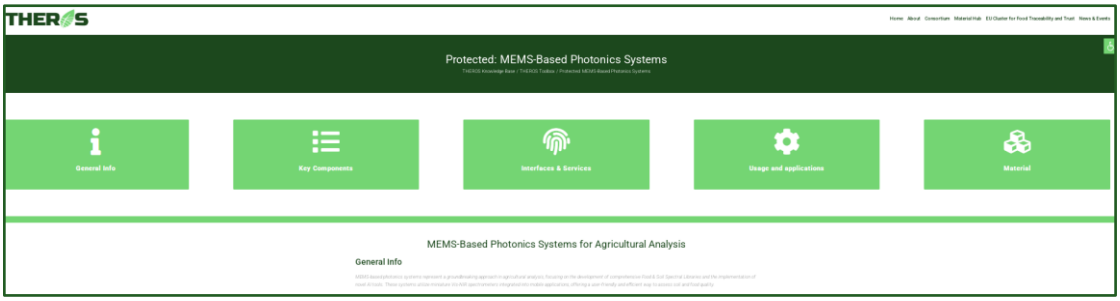

Figure 2: Example of online content depicting THEROS MEMS solution

3.1.2 THEROS Pilot Dossiers

This section contains access to details regarding four THEROS pilots. For each, information originally gathered using respective templates and provided within this report in Annex 6, is structured according to three main elements (Figure 3):

- **General Information**, which focuses on the national context of organic production and control, followed by a general description of the pilot project, including its location, climate, targeted food products, and other relevant details.
- **Implementation Reference Framework**, which outlines which THEROS tools are tested and how, the protocols for data collection and available infrastructure, the approach to analyse the collected data, and the involvement of stakeholders and their roles.
- **Impact Assessment & Evaluation**, which addresses lessons learned, with one part focusing on positive drivers and success stories and another on barriers faced and mitigation strategies.

Figure 3: Example of online content for Czech pilot

3.1.3 Network of Networks

This section covers two aspects related to networking activities and alignment with existing related activities (Figure 4):

- **Food Fraud Databases** sub-section contains description and access to various (i) public/institutional online databases dealing with the food fraud and safety aspects; (ii) respective databases developed within various research projects, and (iii) THEROS tools/solutions specific databases used or created for the purpose of the project.
- **Projects & Institutions** sub-section provides (i) access to related sister projects and (ii) collection of key EU bodies, strategies, networks, regulations, and certification systems related to organic agriculture, food quality, and fraud prevention.

Figure 4: Network of Networks section in the online version of the Knowledge base

3.1.4 Practice Abstracts

This section presents a total of nine Practice Abstracts (PAs). In addition to the three examples initially provided in Deliverable D6.4, six new abstracts have been developed to address the needs of various THEROS stakeholder groups—namely, farmers/producers, retailers/wholesalers, and control and certification bodies. All nine Practice Abstracts have been prepared in the standard EIP-AGRI common format [1]. They are available online (Figure 1Figure 5) and are also included in full in Annex 1.

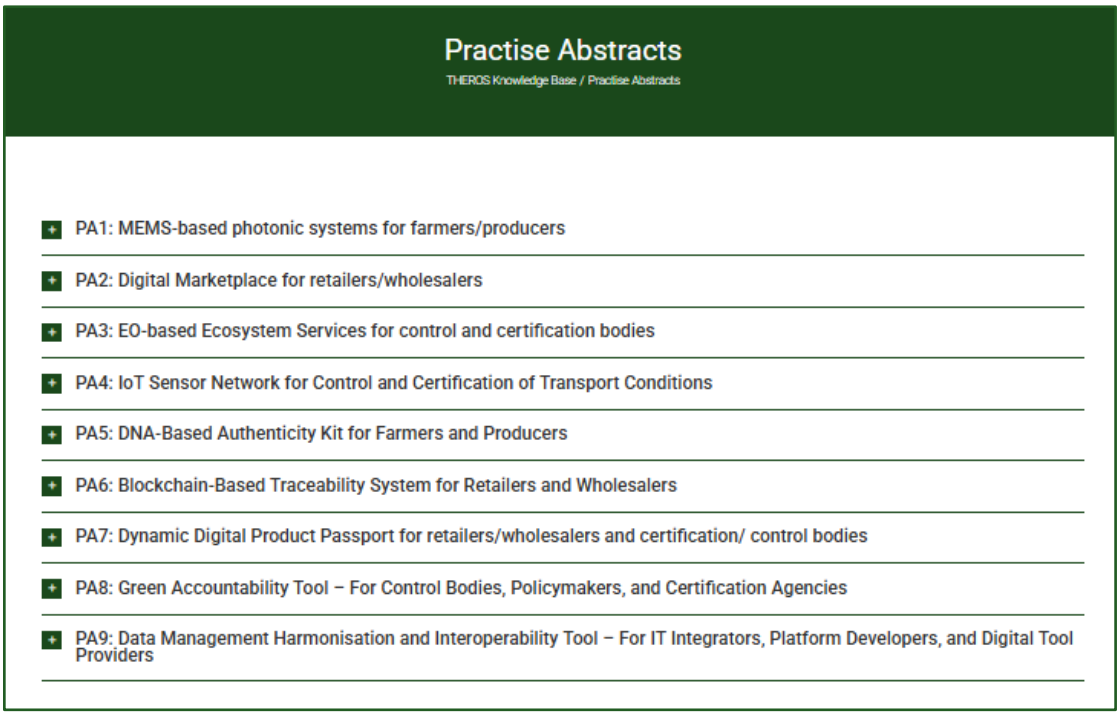

Figure 5 Practise Abstracts section in the online version of the Knowledge base

3.1.5 Cookbooks

The cookbooks for individual THEROS solutions vary in length and content, reflecting the unique characteristics and requirements of each tool. Nevertheless, they all follow a common structural framework designed to guide users through the entire application process. Each cookbook begins with a general introduction that provides context and outlines the tool's overall purpose. This is followed by detailed, step-by-step instructions that break down the workflow into clear, actionable phases—from initial setup and data access to processing, analysis, and interpretation. Additionally, each cookbook includes a "Possible Applications" section, highlighting practical use cases tailored to different stakeholder needs. All nine developed cookbooks are available online (Figure 6) and are also provided in full in Annex 2.

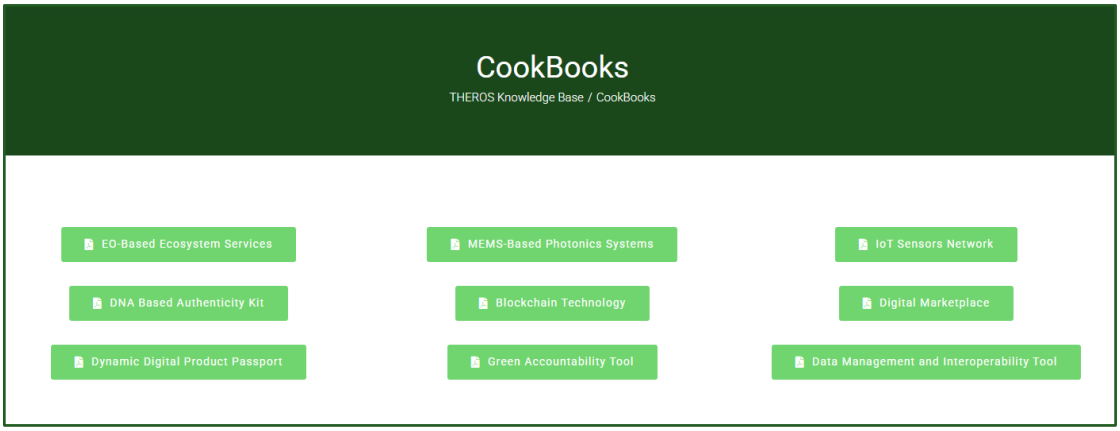

Figure 6 Cookbooks section in the online version of the Knowledge base

3.1.6 Policy briefs

Within the THEROS framework, policy briefs (Figure 7) function as strategic instruments to foster the uptake of THEROS technologies and methodologies by certification bodies, control authorities, and policymakers. These briefs distil the project's technical innovations into clear, actionable policy recommendations that support more transparent, secure, and sustainable agri-food systems. The five policy briefs developed under THEROS are:

- *From Farm to Fork: Advancing Food Traceability Through THEROS Innovations*
- *Toward a Connected Food Chain: Enabling Interoperability for Smarter Governance*
- *Digital by Default: Modernising Agri-Food Compliance Across the EU*
- *Protecting What Matters: A Policy Agenda to Tackle Food Fraud in Organic and GI Markets*
- *Empowering the Informed Consumer: Closing the Knowledge Gap in EU Quality Labels*

The complete set of policy briefs is provided in Annex 3.

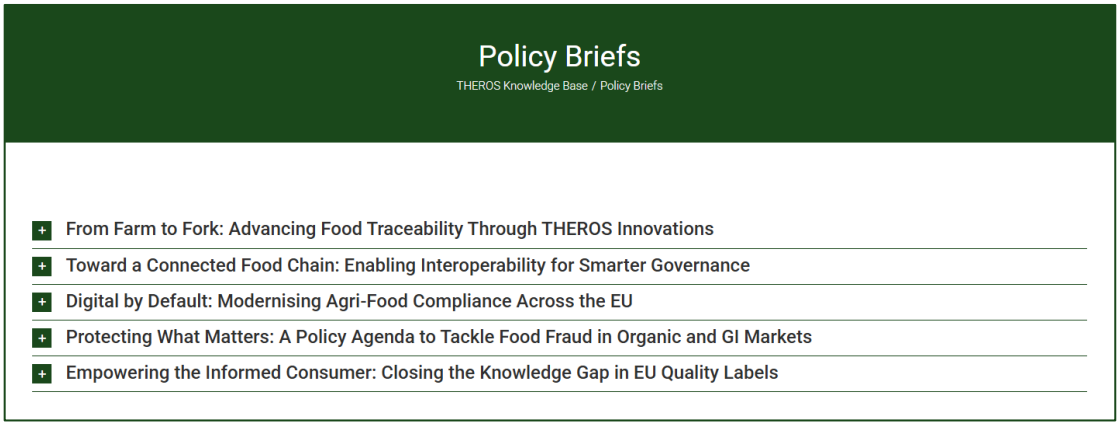

Figure 7 Policy Briefs in the online version of the Knowledge base

3.2 Cluster activities

THEROS knowledge base is actively disseminated and communicated to relevant EU projects and bodies, serving as conduits for exchanging information and collaboration. In particular, this is the case within the "EU Cluster for Food Traceability and Trust" (Figure 8) that THEROS is actively participating.

This ever-growing cluster of sister projects currently comprising thirteen projects aiming to explore synergies and opportunities for collaboration and cross-fertilisation in the development of new solutions to tackle food fraud (Figure 1). These projects share a common goal: to build a more transparent, trustworthy, and sustainable food system in Europe. Despite differing in focus areas, they are united by key themes. Most

projects aim to improve traceability and authenticity of food products using digital technologies such as blockchain, AI, IoT, and sensors (e.g., THEROS, ALLIANCE, WATSON, SEA2SEE, TITAN). Others focus on empowering consumers through better food labelling, digital tools, and combating misinformation, while working to revolutionise the combat against food fraud (e.g., TealHelix, INFOODMATION, DRG4FOOD, EFF-CoP). Several initiatives work to reduce food waste, enhance sustainability, and promote responsible consumption (e.g., CUES, FOODGUARD, ROSETTA). Many projects include real-world pilots and co-creation with stakeholders to ensure practical impact. Together, they form a comprehensive effort to reshape Europe's food systems through innovation, collaboration, and policy support.

Annex 4 provides an updated list and description of projects in the cluster, supporting cross-referencing, collaboration, and links to relevant EU bodies and initiatives. This ensures the THEROS knowledge base is widely shared and integrated into a broader "network of networks," promoting synergies and stakeholder collaboration.

Figure 8: Overview of projects participating in the EU Cluster for Food Traceability and Trust

4. Conclusions

This report summarises efforts in the creation of the THEROS knowledge base throughout the lifetime of the project, and complement D6.4, the initial version that was more focused on the methodological aspects.

To this end, various materials (Practice Abstracts, Cookbooks, Policy Briefs etc.) and tailored for specific stakeholder group involved, are provided in both online (https://theros-project.eu/theros-knowledge-base/) and offline format (see Annexes of this report). This approach enables continuous refinement of the project's knowledge dissemination approach and ensures the effective communication of results throughout the project's lifecycle and beyond.

Disclaimer of Warranties

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Declaration of generative AI and AI-assisted technologies in the writing process: During the preparation of this work, the authors used ChatGPT 4o to shorten and summarise texts and perform language editing. After using this tool, the authors reviewed the content, edited it as necessary, and take full responsibility for the content.

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Annex 1: Practice abstracts

PA1: MEMS-based photonic systems for farmers/producers

MEMS-based photonics system is a simple portable low-cost spectrometer operating at Vis-NIR integrated into mobile applications, offering a user-friendly and efficient way to assess soil and food quality.

This tool comprises three essential components. A mobile application to capture spectral signatures of food or soil, automatically transmitting data to a harmonization platform while ensuring security and data integrity. Second, food and soil spectral libraries, which contain various reference spectral signatures and measurements, enable the calibration and validation of AI models for signatures interpretation. Lastly, AI tools transform these spectral signatures into meaningful indicators for soil and food assessment.

Three main services are then provided: (i) Product Purity Index that estimates product purity by analysing possible adulteration of food products. (ii) Organic Food Labelling Detection that develops deep learning classifiers to differentiate between organic and non-organic products, and (iii) Soil Quality Assessment service that provides quantified information on soil properties such as organic carbon, clay content, acidity/alkalinity, calcium carbonates, and salinity.

The tool is suited for the use of farmers, due to its ease of use, featuring "point-and-shoot" method. Moreover, the mobile application can function offline by capturing and storing data for later transmission when connectivity is available, enabling its use also in remote or internet-limited locations.

PA2: Digital Marketplace for retailers/wholesalers

The digital marketplace is a platform bringing together regional producers, enabling the promotion of their organic food and products and making it easier for interested parties to purchase goods. The platform will allow customers to purchase organic food from the involved producers or small retailers. New services will be implemented in the system to verify the marked products and to monitor the conditions affecting the quality of the transported goods.

This marketplace includes essential functions like authorisation, authentication, and administrative tools, and integrates with external platforms like the Atlas Regional Attractions promotional website to promote organic products. Additionally, it features a transport-condition verification component that monitors the conditions of goods during transit, ensuring quality from producer to customer.

The Digital Marketplace provides a fully managed PrestaShop platform customized for sellers, offering a comprehensive suite of features designed to support all aspects of

running a successful online business. Sellers have access to user-friendly tools for efficiently listing and managing products. They can also maintain a customer database, manage orders, and create promotional pricing. Additionally, the automated order fulfilment system simplifies the management of orders, shipping processes, and auto-email notifications, thereby streamlining operations and improving overall efficiency.

PA3: EO-based Ecosystem Services for control and certification bodies

Earth Observation-based ecosystem services is a tool developed to distinguish between organic and conventional farming practices. It leverages satellite imagery and derived markers to monitor organic farming compliance and assess general parcel conditions, monitoring and verification of maintenance of ecological focus areas and, of multiannual crop rotation plans, including intra-field analysis. The tool integrates with cloud-based data repositories and services, and uses novel machine learning and data fusion techniques, towards large-scale monitoring and verification of organic farming practices.

The following markers are currently computed and made available: The Homogeneity Marker identifies fields growing multiple crops when only one should be present, aiding in verifying compliance with organic certifications. The Greening and Harvest Marker tracks the lifecycle phases of crops, useful for monitoring practices and crop rotation schedules. The Bare Soil Marker detects exposed soil, helping verify the timing of agricultural activities. The Similarity and Euclidian Distance marker belong to the group of crop classification markers, and they determine the crop growing on a FOI by comparing the FOI to its neighbourhood. The Crop Marker assesses the consistency of declared crops with actual vegetation, while the Organic/Non-Organic Marker determines if the growth patterns of a parcel align with organic farming practices.

This tool's capability to retrieve and process satellite imagery on the cloud, coupled with advanced data fusion and analytics, empowers control bodies with precise, real-time data to certify organic farms more effectively. In this way, they can require accurate and up-to-date information over large areas quickly and efficiently, which helps with flagging suspicious activity and allows targeted spot visits to the parcels identified as suspicious. Advanced machine learning techniques are also employed to tackle the complexities associated with studying carbon footprints, sequestration, and their impacts. These techniques include transfer learning, multi-scale learning, and integration with physical process models (e.g., EPIC) to support the regional-scale mapping of relevant parameters.

PA4: IoT Sensor Network for Control and Certification of Transport Conditions

The IoT Sensor Network enables real-time and offline monitoring of temperature and humidity during the transport of perishable goods, with a focus on supporting control

and certification bodies. Sensors placed inside packaging or containers track environmental conditions critical for maintaining organic product integrity and certification compliance. Data is collected and processed via the SensLog platform, offering analytics, threshold alerts, and visualisation tools tailored for verification tasks.

Battery-powered sensors log data every 5–15 minutes and transmit it via cellular networks or store it for later retrieval. The SensLog platform integrates this data using REST APIs, storing it with time and location metadata. It performs statistical analysis, detects threshold violations or sustained deviations, and generates automatic alerts. The system provides a web-based interface for visualising spatial-temporal trends and generating transport condition certificates post-delivery.

This tool is ideal for control and certification bodies that require reliable, transparent, and up-to-date information to ensure compliance in the transport of organic or perishable products, enabling more targeted inspections and efficient certification workflows.

PA5: DNA-Based Authenticity Kit for Farmers/ Producers

The DNA-Based Authenticity Kit empowers farmers/ producers to verify the species origin of their products, ensuring transparency, traceability, and compliance from the first stage of production. It enables rapid, on-site DNA testing to detect mislabelling, substitution, or adulteration, supporting the integrity of certified and high-value food products like mussels.

The portable kit includes tools for DNA extraction, PCR amplification, and melt curve analysis, all operable in field or facility settings. After a simple sampling and preparation process, results are generated and provided in CSV/PDF format through user-friendly software. The Verification Engine automatically validates the results, offering reliable documentation for traceability, reporting, and certification.

Farmers / producers can use this tool at multiple points in the supply chain—from harvesting and processing to packaging and shipment—to demonstrate product authenticity. By integrating this testing early in the value chain, producers improve their ability to meet regulatory requirements, maintain market trust, and protect their brand from fraud or contamination issues.

PA6: Blockchain-Based Traceability System for Retailers /Wholesalers

The blockchain-based traceability system offers retailers/ wholesalers a secure, transparent way to track product origin, handling, and quality across the supply chain. Using blockchain's inherent immutability, this tool ensures that data—from harvest to delivery—is tamper-proof, auditable, and accessible to verified stakeholders.

The system supports the standardized GS1 data model and critical tracking events (CTEs), allowing each supply chain actor to upload, view, and share traceability data. Retailers can access this information through a user-friendly web interface or API, enabling seamless integration with existing ERP systems. Data can include production dates, certifications, transport information, and transformation processes.

A built-in Verification Engine validates data integrity and allows certification bodies to check if quality standards and documentation are met. Retailers and wholesalers benefit from improved supply chain visibility, easier compliance checks, and stronger customer trust through proof-backed claims on product origin and authenticity.

By participating in this system, retailers gain real-time access to verified traceability records, helping them reduce fraud risk, manage recalls efficiently, and offer high-quality, certified products with confidence.

PA7: Dynamic Digital Product Passport for retailers/wholesalers and certification/ control bodies and consumers

The Dynamic Digital Product Passport (dDPP) is a tool designed to enhance transparency, traceability, and trust across the food supply chain. By scanning or entering a product's identification number, users instantly access verified information on product origin, certification, environmental impact, and movement across the supply chain stages.

Accessible through a user-friendly mobile app, the dDPP integrates real-time data from blockchain, sensor networks, EO data and MEMS systems via a harmonized backend infrastructure. It supports role-specific user interfaces—enabling producers, wholesalers, retailers, and certification bodies to view verification status and logistics data directly from their interface.

The dDPP helps verify product authenticity, supports fraud detection, and enhances consumer confidence by enabling transparent product histories. Certification bodies can rely on time-stamped, location-tagged data to confirm compliance, while retailers gain a powerful tool for offering verified organic and GI products to customers.

By delivering reliable, dynamic product data at the point of sale or inspection, the dDPP improves supply chain coordination and strengthens accountability from farm to fork. Ultimately, the dDPP fosters greater consumer trust by providing transparent, verifiable product information that empowers informed purchasing decisions and reinforces confidence in product quality and certification.

PA8: Green Accountability Tool – For Control Bodies, Policymakers, and Certification Agencies

The Green Accountability Tool (GAT) is a digital platform designed to support certification bodies, policymakers, and food supply chain actors in tracking, verifying, and improving organic and GI-certified food systems. Through intuitive dashboards and visualisation tools, GAT offers real-time insights into compliance, traceability, environmental monitoring, and supply chain operations.

GAT enables users to track certification status via a traffic light system, monitor environmental data from Earth Observation and MEMS photonic systems, and view complete product histories, including transformation and transport. It also provides tailored sustainability recommendations for farmers based on soil and environmental metrics.

Integrated with the THEROS Verification Engine and Data Management Harmonisation and Interoperability Tool, GAT facilitates decision-making, reporting, and transparency across stakeholders. Certification bodies gain immediate access to up-to-date compliance information, while policymakers benefit from actionable insights to guide sustainable food policy.

PA9: Data Management Harmonisation and Interoperability Tool – For IT Integrators, Platform Developers, and Digital Tool Providers

The Data Management Harmonisation and Interoperability Tool is the backbone of the THEROS ecosystem, enabling integration of heterogeneous data from Earth Observation, IoT sensors, MEMS photonics, and DNA kits into a unified, standardised digital format. It ensures interoperability across tools and traceability services by applying custom data translators and centralising access through a cloud-based API (THEROS Toolbox).

Using the OGC-compliant SensorThings API, the platform supports seamless data exchange between components such as the Verification Engine, blockchain ledger, dDPP, Digital Marketplace and Green Accountability Tool. Role-based access is securely managed through the integrated Keycloak identity provider.

Ideal for IT integrators, platform developers, and digital service providers, this tool simplifies the integration and consumption of diverse datasets, enhancing reliability, scalability, and compliance across the food supply chain. It enables smart services to access harmonised data for verification, certification, analytics, and real-time monitoring—building a fully interoperable traceability system.

Annex 2: Cookbooks

EO Based Ecosystem Services (Earth Observation Satellite Monitoring)

General Introduction

The EO Based Ecosystem Services tool leverages satellite remote sensing technologies to monitor agricultural land, focusing primarily on organic farming compliance and environmental status of parcels. Using multi-spectral satellite imagery (primarily Sentinel-2) and advanced cloud computing, it generates temporal and spatial vegetation markers to analyse crop types, growth stages, and soil exposure. The purpose is to enable large-scale, timely, and objective monitoring of agricultural activities that traditionally required labour-intensive field inspections.

This tool addresses the challenge of verifying organic certification compliance and identifying suspicious agricultural practices remotely, enabling certification bodies and policymakers to efficiently target resources and interventions.

Details with demonstrations can be found at https://area-monitoring.sinergise.com/docs/

Detailed Step-by-Step Instructions

Step 1: Define the Geographic Area and Time Window

- Use geographic coordinates or parcel IDs to specify the exact polygons representing agricultural fields.
- Select a time period corresponding to the growing season or any timeframe relevant for compliance monitoring (e.g., April to October).
- Ensure the spatial resolution and revisit frequency of the satellite data matches the monitoring needs.

Step 2: Access Satellite Imagery

- Connect to Sentinel Hub using its API or OGC (Open Geospatial Consortium) standard services (WMS, WMTS).
- Request specific spectral bands relevant for vegetation analysis, typically red (R), near-infrared (NIR), and short-wave infrared (SWIR).
- Retrieve multi-temporal imagery, ensuring cloud cover filtering to maximize data quality.

Step 3: Cloud-based Image Processing

- Use Sentinel Hub Processing API to perform on-the-fly calculations:
  - Calculate vegetation indices such as NDVI (Normalized Difference Vegetation Index), which correlates strongly with plant biomass and health.
  - Compute time series statistics: averages, percentiles, maxima, minima over the selected period.

These steps reduce data volume and processing complexity on the client side.

Step 4: Marker Provider Module Request

- Using the parcel identifiers and time window, query the Marker Provider REST API for specific marker types:
  - Homogeneity marker: Detects multiple crop types within a single parcel by analyzing spectral uniformity.
  - Greening and Harvest marker: Identifies the start and end of crop growth periods using NDVI seasonal patterns.
  - Bare Soil marker: Detects exposed soil surfaces which indicate ploughing or harvested fields.
  - Crop marker: Validates the declared crop type based on spectral time series comparison.
  - Similarity and Euclidian Distance marker: Determines the crop growing on a FOI by comparing the FOI to its neighbourhood.
  - Organic/Non-Organic marker: Classifies parcels as organic or conventional farming based on temporal vegetation signatures.
  - Specify the desired output format (usually JSON).

Step 5: Data Interpretation and Visualization

- Visualize temporal NDVI curves and marker outputs using GIS software or custom dashboards.
- Use homogeneity markers to flag parcels with unexpected crop mixtures.
- Analyze greening markers to verify sowing and harvesting dates.
- Cross-check bare soil markers with farmer declarations to detect discrepancies.
- Integrate organic/non-organic classification results for compliance verification.

Step 6: Reporting and Decision Making

- Compile marker data into compliance reports.
- Use insights to prioritize in-field inspections, focusing on flagged parcels.

- Support policy design by analyzing trends in organic farming compliance at regional or national scales.

Possible Applications

- **Certification agencies:** Remote monitoring reduces field visits and fraud risk.
- **Farmers and advisors:** Crop growth tracking enables optimized input management.
- **Environmental agencies:** Monitoring land-use changes and ecological impact.

MEMS Based Photonic Systems (Mobile Miniature Vis-NIR Spectrometers)

General Introduction

MEMS-based photonic systems are compact, low-cost visible and near-infrared (Vis-NIR) spectrometers integrated with mobile devices to analyse food and soil samples rapidly. Unlike traditional laboratory spectrometers, these handheld devices enable field-based spectral measurements with high portability. Coupled with AI models and spectral libraries, they translate raw spectral data into actionable insights on organic certification, adulteration, and soil properties.

The core value is democratizing access to sophisticated spectral analysis, allowing farmers, certifiers, and retailers to perform rapid, on-site quality assessments without specialized lab infrastructure.

Detailed Step-by-Step Instructions

Step 1: Device and App Setup

- Power on the MEMS spectrometer and pair it with the mobile device via Bluetooth or USB.
- Open the THEROS harmonized mobile app designed for spectrometer control and data management.

Step 2: Calibration Procedure

- Perform a white reference calibration by scanning a certified reference tile or white surface as instructed by the app.
- Confirm calibration quality by scanning a known sample.

Step 3: Sample Measurement

- For food items: position the spectrometer probe in direct contact or close proximity to the sample surface (e.g., fruit skin, powder surface).
- For soil: place the probe on a flat soil surface or soil-filled container.
- Use the app's step-by-step guidance to initiate a scan.
- Maintain stable positioning until the app confirms measurement completion.

Step 4: Data Upload and Storage

- Measurements are automatically encrypted and transmitted to the THEROS harmonization platform if internet is available.
- If offline, data are stored locally and uploaded later when connection is re-established.
- Each spectral record is tagged with metadata: GPS location, timestamp, operator ID, sample type.

Step 5: AI-Powered Data Processing

- Spectral signatures are compared against large, curated spectral libraries containing labeled reference data (both for food purity and soil properties).
- Machine Learning models predict:
- Product purity (detecting adulteration or mixing)
- Organic vs. conventional classification
- Soil parameters such as organic carbon content, texture, pH, salinity.

Step 6: Results Visualization and Reporting

- The app displays user-friendly reports with color-coded purity scores, organic likelihood, and soil quality indices.
- Export options allow sharing data with certification bodies or farmers.

Possible Applications

- On-farm quality control and certification verification.
- Rapid adulteration screening in markets and supply chains.
- Soil health monitoring to inform fertilization and land management decisions.

DNA Based Authenticity Kit

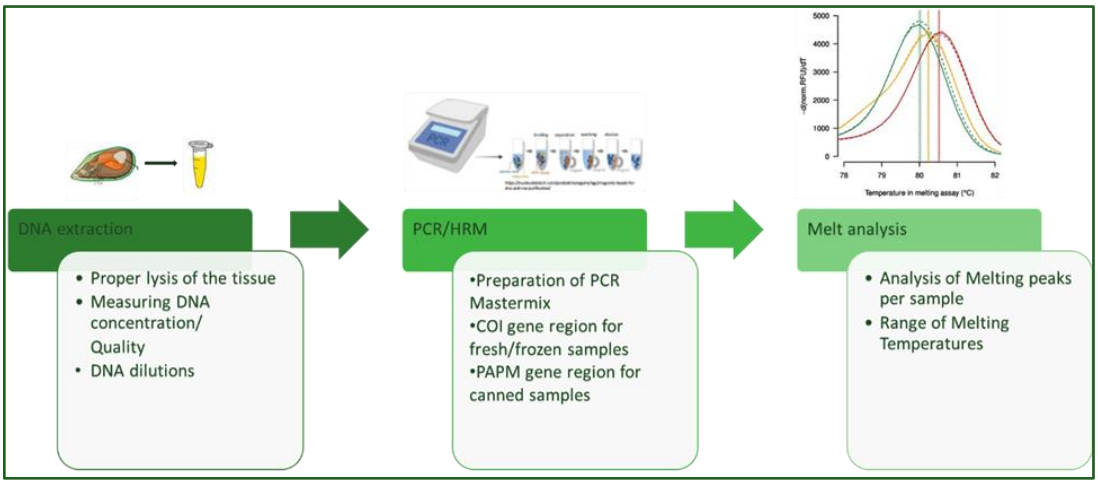
General Introduction

The objective of the DNA-based authenticity kit aligns with the goal of improving traceability, compliance and transparency across the supply chain of mussels'

production, by identifying mislabeling and substitution cases. Specifically, the DNA based authenticity kit module comprises of portable DNA based molecular methods, allowing rapid extraction of DNA profiles and their automated transformation on meaningful information regarding the verification of species origin, provenance of the food product and protecting the final consumers from adulteration issues. More specifically, the kit 1) allows for the complete transparency of the supply chain, from the production phase until the product reaches the consumers, detailing all the information related to the product identity, 2) allows participants to extract the results in CSV/PDF format through the analysis software of the portable device, and 3) validates information through the Verification Engine. The DNA based authenticity kit is designed for stakeholders needing real-time authentication during production, packaging, transport, and retail stages.

The DNA based authenticity kit will be implemented in the Spanish pilot, for the identification of the Galician mussels. The checkpoints where the DNA test will be applied are 3. The first point will be at the landing port where the mussel is offloaded by the producers (Verification point 1). The other DNA samples will be done in the transformation stages at the 2 processing companies. One of the products tested will be fresh product (Verification point 2) and the other cooked canned product (Verification point 3).

The main experimental procedure consists of 3 steps as shown in the image:



Short step-by-step instructions

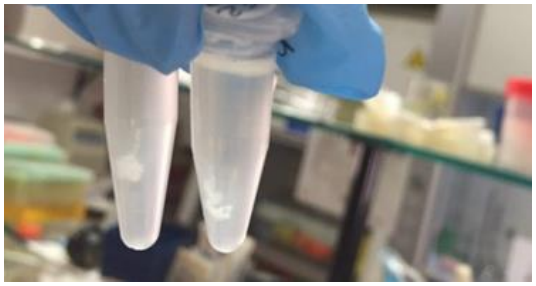
Step 1: Sampling and DNA extraction

- Sampling procedures are performed according to the standard procedures that are applied for GMO detection (based on ISO/FDIS 6498:2011). Four subsampling operations are implemented to reduce the subsampling errors, (Esbensen and Paasch-Mortensen, 2010): 1.

Composite subsampling (or incrementing), 2. Comminution (particle size reduction), 3. Mixing/blending, 4. Representative mass reduction.

- DNA is extracted from multiple samples of the product under investigation through the application of specific molecular methods to obtain genetic material (DNA).
- The molecular methods of DNA extraction will be applied on cultivation sites and through different preparation stages (packaging, transportation, etc.) of the final product, all the way to the selling points of the products, in order to prevent any adulteration issues.

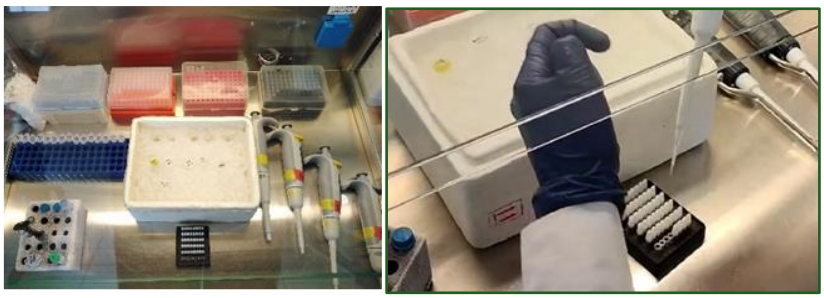
Sample preparation for DNA extraction



Extracted DNA

Step 2: PCR & HRM Analysis

- PCR analysis is performed on a portable device that is connected to a laptop powered by a portable battery.
- PCR analysis is based on a specific molecular method that allows the amplification of a specific gene of interest, in our case, the PAPM gene region for fresh and canned samples that will allow the rapid identification of the species origin, based on the nucleotide differences of the DNA sequences translated into Melt curves and Melting Temperatures.
- After the PCR analysis, melt analysis is performed on the amplified DNA sequences based on their melting temperatures.

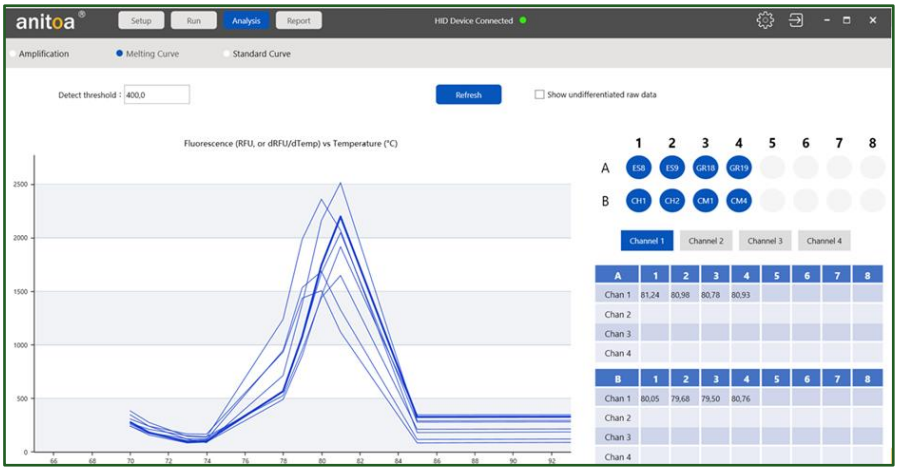


Preparation of PCR components and reaction

Maverick qPCR device

Step 3: Analysis of Melting profiles

- Melting profiles are generated, providing numerical data corresponding to melting temperatures.
- Melting temperatures are specifically based on the amplified DNA sequences and can detect any DNA alterations specific to each organism.
- Specific melting temperatures from each sample correspond to a specific species' origin.
- The software provides results in a csv/pdf file.



Melt profiles for analysed samples corresponding to different melting temperatures corresponding to the identified species

Step 4: Reporting and Verification

- Identify discrepancies between labeled and detected species.
- Generate authenticity and adulteration reports for certification or regulatory compliance.
- Archive results for traceability.

Detailed Step-by-Step Protocols

Basic Skills You Should Know Before Starting with DNA extraction

1. Basic Laboratory Safety Practices:

- **Understanding and Following Protocols:** You should be comfortable reading and following written procedures. DNA extraction protocols often have precise steps and timing that need to be adhered to for optimal results and safety.
- **Personal Protective Equipment (PPE):** Knowing when and how to use essential PPE like gloves, lab coats, and eye protection is non-negotiable. This protects you from the chemicals used and prevents contamination of your samples.
- **Handling Chemicals Safely:** Familiarity with basic chemical handling, including knowing the potential hazards of reagents like lysis buffers, alcohols, and elution buffers, and how to dispose of them properly, is crucial.
- **Waste Disposal:** Understanding the correct procedures for disposing of different types of lab waste (e.g., biological waste, chemical waste, sharps) is essential for safety and environmental responsibility.

2. Accurate Pipetting Techniques:

- **Using Micropipettes:** You should be proficient in using various sizes of micropipettes (P20, P200, P1000, etc.) to accurately measure and dispense small volumes of liquids. This includes setting the correct volume, using the correct tips, aspirating and dispensing liquids without introducing air bubbles, and understanding forward and reverse pipetting techniques. Inaccurate pipetting can lead to incorrect reagent concentrations and failed extractions. Tutorial available on https://youtu.be/QGX490kuKjg?si=9M31VhC-2uhudmEz

3. Basic Centrifugation:

- **Operating a Centrifuge:** You'll need to know how to load a centrifuge correctly to ensure balance, set the appropriate speed (RPM or RCF) and time, and safely retrieve your samples. Centrifugation is a common step in separating cellular components and precipitating DNA.

4. Understanding Solution Preparation (Basic):

- **Making Dilutions:** You might need to prepare working solutions from stock solutions. Knowing how to calculate and perform basic dilutions (e.g., serial dilutions) will be beneficial.

- **Understanding Molarity and Percentage Solutions (Optional but Helpful):** While many extraction kits provide ready-made buffers, a basic understanding of these concepts can be useful for troubleshooting or if you ever need to adapt protocols.

5. A General Understanding of DNA and its Properties:

- **Basic DNA Structure:** Knowing that DNA is a double-stranded molecule and carries genetic information will provide context to the extraction process.
- **DNA Solubility:** Understanding that DNA is soluble in aqueous solutions but can be precipitated out of solution using alcohols (like ethanol or isopropanol) and salts is key to the precipitation step in many extraction methods.
- **Sensitivity of DNA:** Recognizing that DNA is susceptible to degradation by enzymes (nucleases) and physical shearing will emphasize the importance of gentle handling and using nuclease-free reagents.

6. Maintaining a Clean and Organized Workspace:

- **Preventing Contamination:** DNA is everywhere! Knowing how to keep your workspace clean and organized minimizes the risk of contaminating your samples with foreign DNA (which can lead to false positives in downstream applications like PCR). This includes wiping down surfaces, using fresh consumables, and working in a designated clean area if possible.

DNA extraction Protocol (Preparation time: 30-40 minutes)

- Kit contents of NucleoType DirectLyse Reagent (up to 500 extractions)
  - Extraction Buffer XLR (60 mL)
  - Liquid Proteinase K (250 µL)
- Consumables, and equipment to be supplied by user
  - Consumables
    - Sterilized knife/blade for cutting the tissue
    - Disposable pipette tips (aerosol barrier pipette tips are recommended to avoid cross contamination)
    - Microcentrifuge tubes (1.5 or 2.0 mL)
    - Equipment
    - Manual pipettors
    - Heat incubator
    - Vortex mixer
    - Centrifuge for microcentrifuge tubes (1.5 or 2 mL)
    - Personal protection equipment (lab coat, gloves, goggles)
    - PCR cycler for follow-up analysis
- Extraction protocol steps
  1. Transfer sample material (recommended sample amount: e.g. 1 mm diameter of tissue) into a 1.5 mL or 2 mL tube.

2. Add 200 µL Extraction Buffer XLR.
3. Add 1 µL Liquid Proteinase K.

Note: Typically, a volume of 0.5 µL Liquid Proteinase K is sufficient. In some cases, it might be beneficial to use up to 2.5 µL Liquid Proteinase K.

Note: If several samples are processed, a premix may be prepared, e.g. for 10 samples: 1 mL Extraction buffer XLR and 5 µL Liquid Proteinase K. The mixture is stable at room temperature for up to 1 h. Store the mixture aliquoted at -20 °C for later use.

4. Mix by pipetting.
5. Incubate at room temperature (15-25 °C) for 2 min.

Note: DNA is released in this step.

Note: Typically, this short incubation is sufficient for adequate DNA release. It is not necessary to completely dissolve / lyse the sample. For some applications, a longer incubation might be beneficial.

6. Optional: Centrifuge for 3 s at 8,000xg if solution contacted the upper part of the tube or lid.

Note: It is important, that all the solution / material is subjected to the following heat incubation. Ideally, use an incubator which heats the lid or make sure that all solution / material is in the lower part of the tube if using a heating block which does not heat the lid of the tube.

7. Incubate for 5 min at 99 °C.
8. Centrifuge for 2 min at 12,000 x g to sediment any debris and to obtain a clear supernatant.

Note: Heat incubation and centrifugation eliminates / reduces PCR inhibitors from the solution.

Note: Typically, cleared lysates are stable for at least one day at room temperature (15-25 °C), several days at 4 °C, and two years at -20 °C.

9. Transfer clear lysate/supernatant to a new 1.5 mL or 2 mL tube.
10. Extracted DNA may be used as a template for PCR or qPCR without further cleanup steps. We recommend using 1-2 µL of the clear supernatant as template for a 20 µL PCR.

Note: Given the variability in DNA concentration and PCR efficiency, users can perform a series of dilutions (1:10 or 1:100) to ascertain the optimal concentration for their PCR. The input DNA may be increased or further diluted.

PCR preparation (Preparation and run time: 40-50 minutes)

Basic Skills You Should Know Before Starting with PCR

1. Mastery of Basic Laboratory Safety Practices:

- **Protocol Adherence:** Just like with DNA extraction, following PCR protocols is paramount. Small deviations can significantly impact the outcome.

- **Personal Protective Equipment (PPE):** Consistently using gloves, lab coats, and eye protection is essential to protect yourself and prevent contamination of your PCR reactions.
- **Safe Handling of Reagents:** Understanding the properties and safe handling of PCR reagents like primers, dNTPs, buffers, and especially DNA polymerase is important.
- **Proper Waste Disposal:** Knowing how to dispose of PCR waste, including potentially contaminated tubes and tips, is crucial for lab safety.

2. Precision in Pipetting:

- **Micropipette Proficiency:** Accurate pipetting is absolutely critical for PCR. You need to be confident in using various micropipettes to dispense nanolitre to microliter volumes precisely. Incorrect volumes of even one reagent can lead to failed or unreliable PCR. Practice proper aspiration and dispensing techniques to avoid air bubbles and ensure accuracy. Tutorial available on https://youtu.be/QGX490kuKjg?si=9M31VhC-2uhudmEz

3. Understanding the PCR Process (at a high level):

- **The Three Steps:** Knowing the basic principles of denaturation, annealing, and extension, and what happens at each temperature, will help you understand why the cycling parameters are important. More information on https://youtu.be/wBrNbbAIAFo?si=E6GOQ7LK565I48GB
- **The Role of Each Component:** Understanding the function of each reagent in the PCR mix (template DNA, primers, DNA polymerase, dNTPs, buffer, magnesium chloride) is key to troubleshooting if things go wrong.

4. Primer Handling and Storage:

- **Resuspension and Dilution:** You'll likely receive primers in lyophilized form and need to resuspend them to a stock concentration and then dilute them to a working concentration. Knowing how to perform these calculations and steps accurately is important.
- **Proper Storage:** Understanding the importance of storing primers correctly (usually at -20°C and minimizing freeze-thaw cycles) to prevent degradation is crucial for their effectiveness.

5. Maintaining a Sterile and Contamination-Free Environment:

- **Aseptic Technique:** PCR is incredibly sensitive to DNA contamination. You need to practice good aseptic technique, including using sterile filter tips, working in a clean area (ideally a PCR hood if available), and using fresh reagents.

- **One-Way Workflow:** Establishing a workflow where you handle pre-PCR reagents in one area and post-PCR products in a separate area can help prevent contamination of your future reactions with amplified DNA.

➢ Kit Contents

Mastermix is a 2x concentrated, ready-to-use real-time PCR reagent optimized for specificity and post-PCR high resolution melt (HRM) analysis. It contains hot start DNA polymerase, dNTPs, $MgCl_2$, EvaGreen dye, enhancers and stabilizers in a proprietary formulation optimized for HRM applications (SNP genotyping, mutation scanning, and methylation detection).

➢ Reagents, consumables, and equipment to be supplied by user

- PCR / qPCR Reagents
- Consumables

- Disposable pipette tips (aerosol barrier pipette tips are recommended to avoid cross contamination)
- Microcentrifuge tubes (1.5 or 2.0 mL)
- Equipment
- Manual pipettors
- Vortex mixer
- Centrifuge for microcentrifuge tubes (1.5 or 2 mL)
- Personal protection equipment (lab coat, gloves, goggles)
- PCR cycler

➢ Protocol steps for PCR/HRM

- Thaw precision melt super mix and other reaction components. Mix each component thoroughly and centrifuge briefly to collect at the bottom of the tube.
- Prepare an adequate volume of assay master mix by adding all required components except the sample template according to the table below.

Table 1 Reaction setup

Component	Volume per10 µl Reaction, µl
2x Mastermix	5
Forward primer	0.5
Reverse primer	0.5
DNase-free water	3
Genomic DNA (add in step 4)	1
Total reaction mix volume	**10**

- Mix the assay master mix thoroughly and dispense equal aliquots into each PCR tube.
- Add equal amounts of sample DNA (1 to 50 ng genomic DNA, in the same volume) to each PCR tube, seal, and vortex for 20 to 30 sec to ensure thorough mixing of reactions. Centrifuge the tubes to remove air bubbles.
- Follow the PCR and HRM guidelines in the following Table.

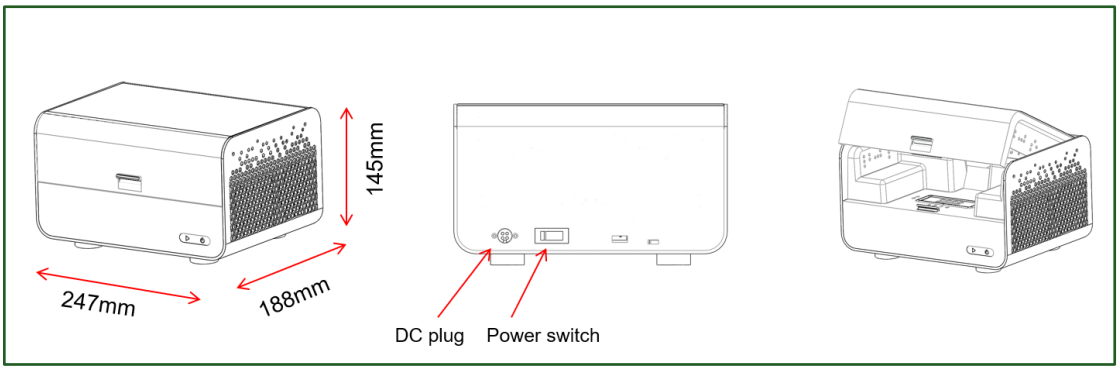
Table 2 PCR and HRM guidelines

Cycling Step	Temperature	Time	# Cycles
Initial DNA denaturation	95°C	2 min	1
2-step PCR Cycling			
Denaturation	95°C	3 sec	40–45
Annealing/extension (+read)	60°C (= primer Tm)	30 sec	
Melting Analysis			
Melting (+read)	65–90°C (in 0.2°C increments)	10 sec/step	1

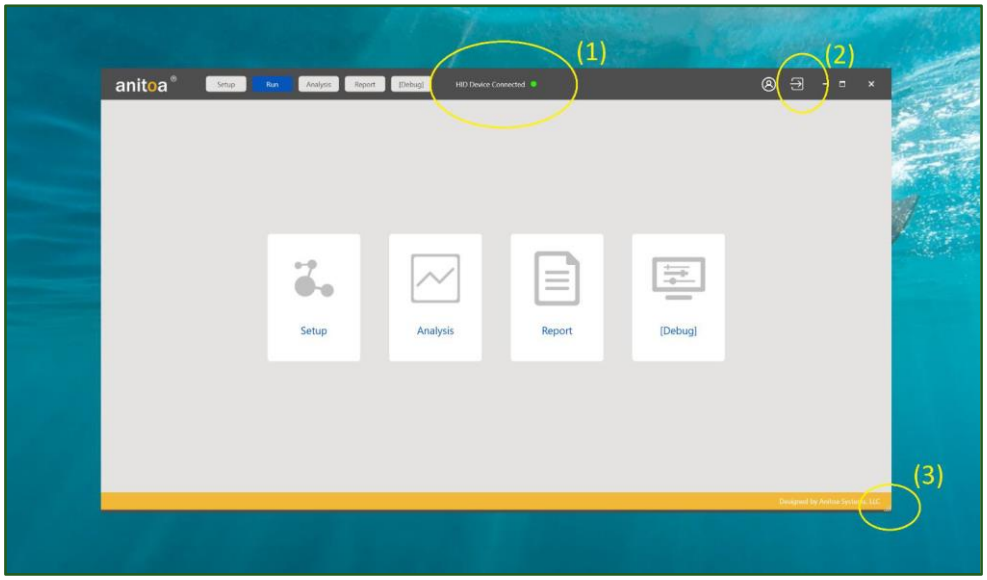
- Load PCR tubes into the real-time PCR instrument and start the PCR/Melt run.
- Perform PCR and Melt data analysis according to the instrument and software guidelines.

Preparing and setting the device (Time: 10 minutes)

- Device (Maverick qPCR-MQ1084 -4 channels-8 wells)

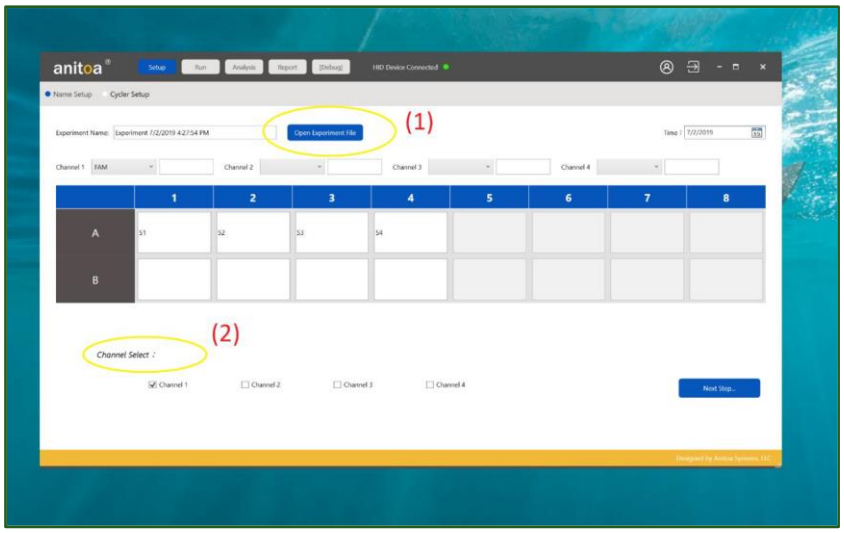


- Power up the instrument
  - The instrument is powered through an external AC/DC power adapter. The power adapter accepts AC input ranging 110V to 240V and produces DC output of 15V.
  - The DC power input connector port is located at the back of the instrument.
- Connect to a PC via USB
  - The instrument is equipped with an USB port at the back, we can connect the instrument to a Windows® based PC via the supplied USB cable.
- qPCR tube/plasticware requirement
  - Maverick qPCR requires the use of full transparent qPCR tubes with flat caps.
- System Requirement
  - The Maverick software Windows version required Microsoft Windows 10 or later (Including Windows 11).
- Launching the software
  - When the Maverick PC software is launched, after a brief delay for device initialization, the front page will display as shown in the following Figure.

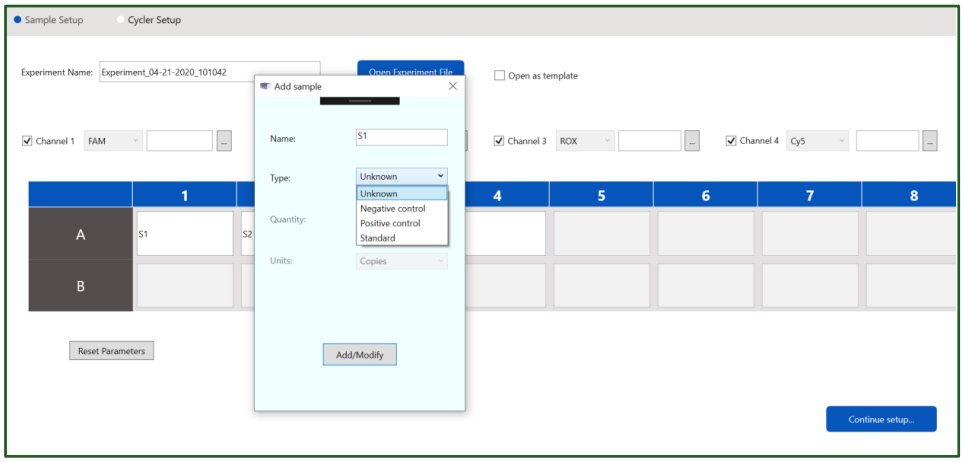


Marker (1) is an indicator of whether the Maverick USB device is found. If found, a message “HID Device Connected” is shown along with a green dot. Marker (2) is the home button. At any time of running this software, click this button to return to this front page. Marker (3) is the place to drag to resize the Maverick software windows.

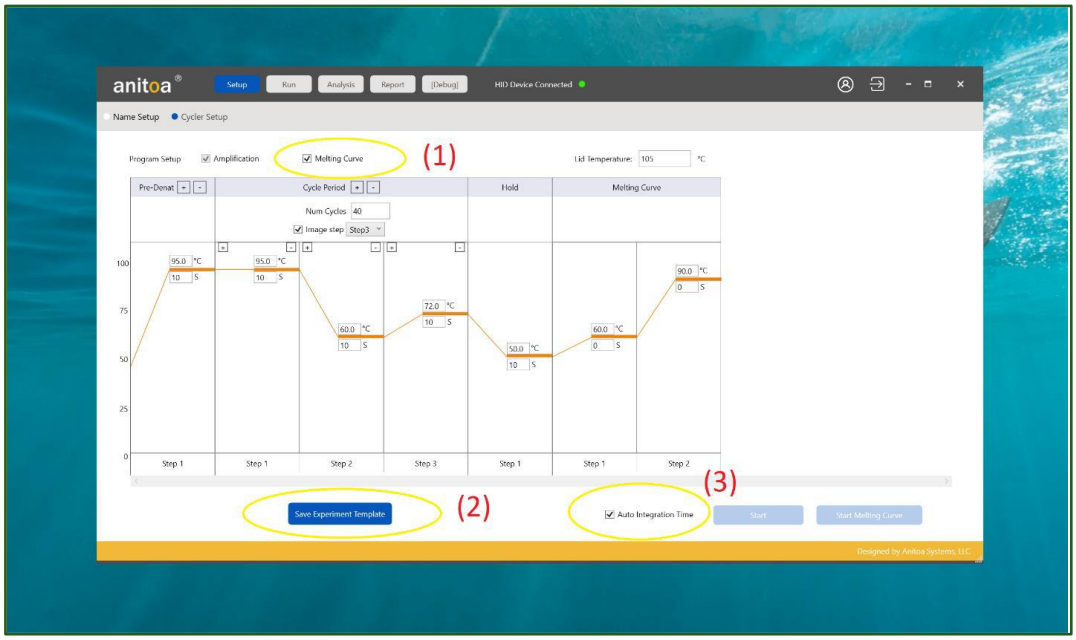
- Samples and fluorescence channels set up
  - The software automatically detects the number of reaction wells the connected instrument can support. Each reaction well can be associated with a sample. In this page, the user can enter a name for each sample.
  - It is important to select the fluorescence channels (Marker (2)) we need to use for the experiment. The selection of the channels depends on the type of fluorescence dyes used in the assay design.



- Additional sample property setup
  - By double clicking the sample grid in the Sample setup window, the user can set up additional information about the sample by entering values in a pop-up window shown below. Additional property includes type of sample as well as standard quantities.



- The setup page – Cycler setup
  - Here we can setup the thermal cycler program. We could choose the type and number of thermal periods and steps, assign time period and temperatures. We could have up to two Pre-Denature periods. The main thermal cycling period can have 2, 3, or 4 steps. We can also define at which step the fluorescence capture is done. Lastly, we have a hold period whose temperature and time period are configurable.

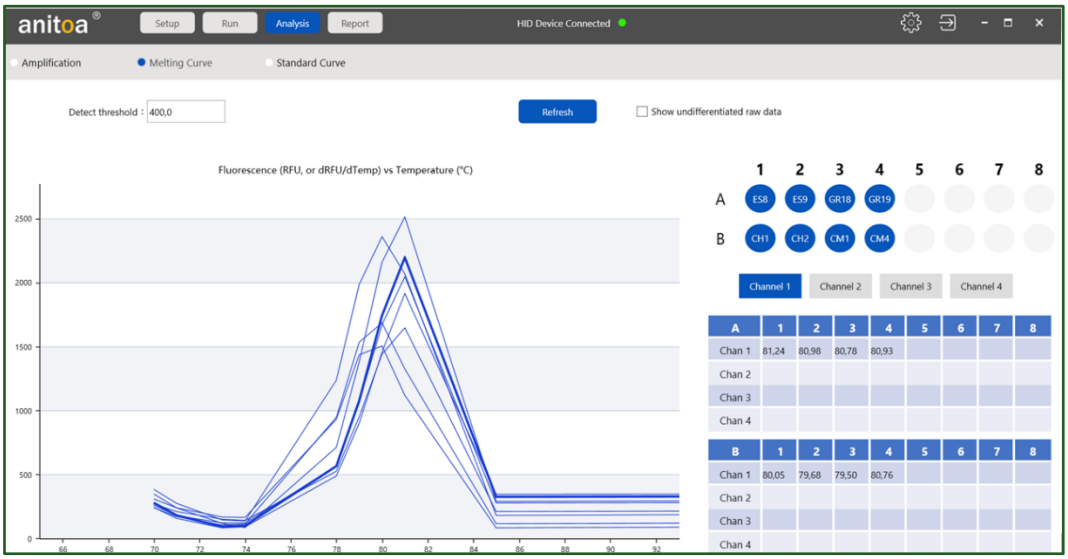


- Melting curve analysis period
  - We can also add a Melt Curve (Marker (1)) analysis period at the end of the main thermal cycling program. The Melt curve analysis can be triggered either manually by clicking the start melt analysis button, or automatically by checking the check box.
- qPCR amplification thermal cycling program starts when the user clicks on the "Start" button
- When the qPCR cycler starts to run, the software will automatically switch to Run pages. The first Run page will allow us to monitor hot lid and reaction well temperature. We can easily see if the temperature is going through the cycling programs or not.
- Running amplification program
  - When running normal qPCR amplification program, the amplification window will real time monitor the fluorescence signal from the samples. In addition, the Run-Amplification Curve page will also show the current run status and estimated remaining run time.
- Running melt analysis

- When running Melt analysis, the "Run-Melt curve" will show the fluorescence change rate as function of temperature.

Analysis/Interpretation of results (Time: 10 minutes)

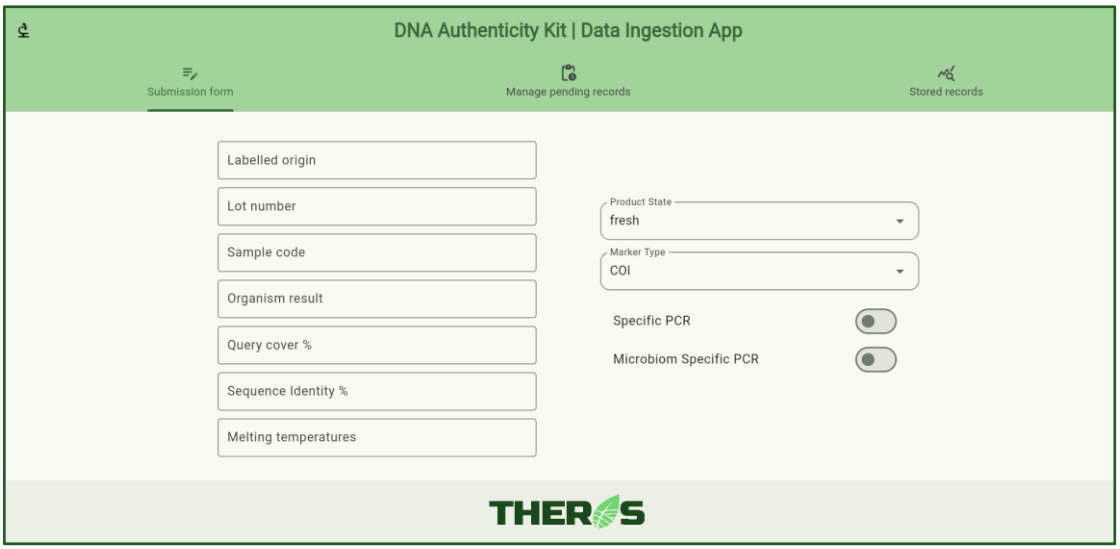
- Amplification analysis: This will show the amplification curves for all samples. We can select the samples and study, setting several parameters to this analysis.
  - According to the amplification results from bacteria pcr the Galician mussels show to amplify earlier in terms of cycles (at the 20th cycle) compared to the ones from Greece or Chile.
- HRM analysis is performed and melting temperatures per sample are analysed.
  - Melting temperatures for PAPM ranging around 80-81 identify the species as *M. galloprovincialis*. If not, species is different (around 79 is *M. chilensis*)



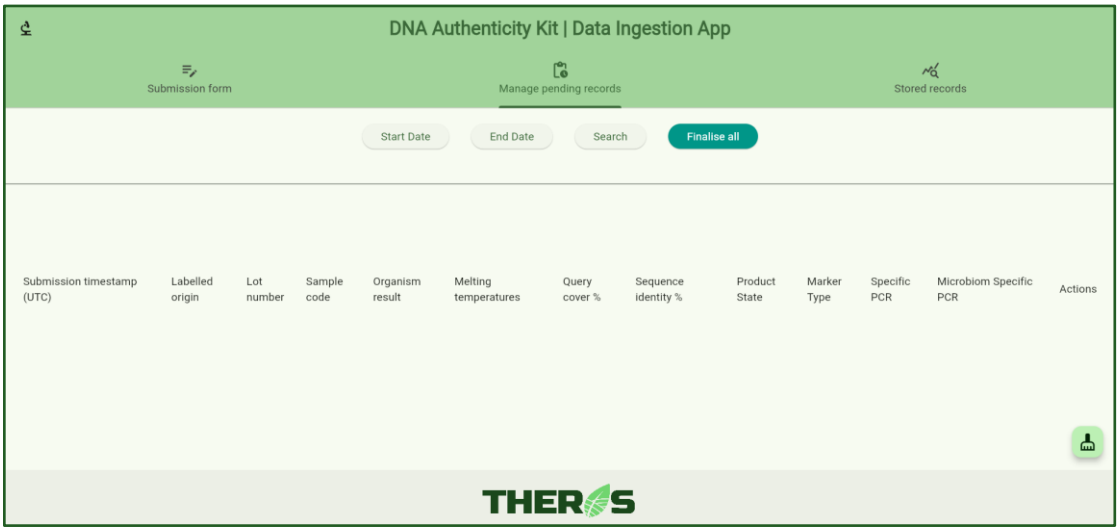
- Save experiment and Print Report
  - Open report page to print report and save experiment.
  - The experiment file will contain all the settings and experiment results.
  - Two report formats will be used for report generation. The excel file report is hand editable. The PDF report is easier to store and use on different platforms.

Insertion of the results into the Data Ingestion App (Time: 10 minutes)

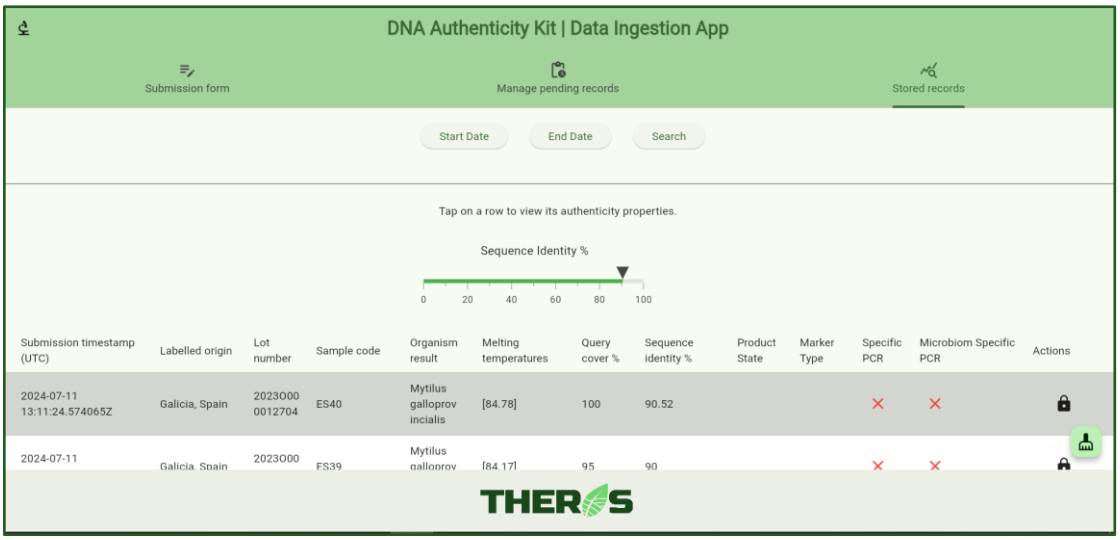
- Open the app through the link https://dna-auth-kit-theros.iccs.gr/home



- Insert all information about the tested products, regarding “Labelled origin”, “Lot number”, “Product state”
- Insert information about the analysis: “Sample code”, “Marker Type” “Specific PCR”, “Microbiome Specific PCR”
- Insert results from PCR and HRM analysis: “Organism Result”, “Melting temperatures”, “Sequence Identity”
- Submit your results
- Check your submission details



- If correct, finalise your submission.
- Final results will be shown as shown in the following figure



Possible Applications

- Verification of fish, meat, herbal products authenticity.
- Detection of substitution and adulteration in food supply chains.
- Support for certification authorities and customs inspections.
- Increased traceability and transparency for the producing and supply chain of the mussels' products, providing the consumers with validated information regarding the species identity and the geographic origin of the products.
- This module significantly enhances monitoring capabilities for adulteration issues and mislabelling of the food products. The application of specialized and robust molecular methods will be applied to fresh and canned products throughout the whole process of cultivation, packaging, transportation and selling points, ensuring that the final consumers are protected from adulteration events.
- The module is suitable for stakeholders in the food sector who acquire accurate information on the origin of the food products. Also, it is suitable for certifications authorities as it facilitates a more accurate identification method of possible adulteration events based on specialized molecular techniques.

Troubleshooting

➢ DNA Extraction

1.**Low DNA Yield**

- **Problem**: You don't get enough DNA after the extraction process.
- **Possible Causes & Solutions**:

- **Insufficient starting material**: Make sure you're using an adequate amount of your sample. If the expected yield is very low, consider pooling samples if possible.
- **Incomplete lysis**: The cells or tissue might not have been broken down effectively to release the DNA. Ensure thorough homogenization or lysis according to your protocol. For tough samples like some bacteria or tissues, consider using a combination of mechanical (e.g., bead beating) and chemical methods. Verify that your lysis buffer and any enzymes (like Proteinase K) are fresh and active. Ensure proper incubation time and temperature for lysis.
- **Incomplete DNA precipitation**: DNA might not have fully precipitated out of the solution. Ensure you're using the correct type and volume of alcohol (usually ethanol or isopropanol) and that the incubation time and temperature for precipitation are adequate. Sometimes, adding a carrier like glycogen or tRNA can help precipitate very small amounts of DNA.
- **Poor DNA solubilization**: The final DNA pellet might not have dissolved properly. Allow sufficient time for resuspension, sometimes up to several hours or even overnight at room temperature or 37°C with occasional gentle mixing (vortexing or pipetting). Make sure the resuspension buffer is appropriate (e.g., TE buffer). Avoid overdrying the DNA pellet, as this can make it very difficult to dissolve. Drying for no more than 5 minutes is generally recommended.
- **DNA degradation**: Nucleases (enzymes that break down DNA) might have been present and degraded your sample. Process samples quickly after collection or freeze them immediately. Store DNA samples properly at -20°C or -80°C in an appropriate buffer like TE buffer (which contains EDTA, a nuclease inhibitor). Avoid storing DNA in water for long periods.

2. **Poor DNA Quality/Purity**

- **Problem**: The extracted DNA is contaminated with other molecules.
- **Possible Causes & Solutions**:
  - **Protein contamination** (low A260/A280 ratio): Proteins can co-purify with DNA. Ensure that protease digestion steps (like using Proteinase K) are effective and that wash steps in column-based kits are performed thoroughly to remove proteins. Phenol-chloroform extraction followed by ethanol precipitation can also help remove proteins. Avoid overloading purification columns.
  - **RNA contamination** (high A260/A280 ratio): RNA can be co-extracted with DNA. If RNA is a concern for your downstream applications, include an RNase digestion step in your protocol after DNA extraction.

- **Salt or other chemical contamination**: Residual salts or chemicals from the extraction buffers can remain in the final DNA sample, interfering with downstream applications. Ensure you perform all wash steps thoroughly as described in your protocol. For column-based methods, ensure the final elution buffer is compatible with your downstream use.
- **Carryover of cellular debris** (cloudy DNA solution): Some cellular debris might have been transferred during the separation steps. Re-centrifuge the sample and carefully transfer the supernatant containing the DNA to a new tube, avoiding the pellet. Increasing the centrifugation speed or time might help separate debris more effectively.

3. **DNA Degradation**

- **Problem**: The extracted DNA is fragmented or damaged.
- **Possible Causes & Solutions**:
  - **Harsh handling**: Vigorous vortexing or pipetting, especially of high molecular weight DNA, can cause shearing. Handle DNA solutions gently.
  - **Enzymatic degradation**: As mentioned earlier, nucleases can degrade DNA. Follow proper sample collection, processing, and storage guidelines, and use nuclease-free reagents.
  - **Improper storage**: Avoid storing DNA at room temperature for extended periods or in water without a buffering agent.

4. **Difficult Sample Types**

- **Problem**: Certain sample types can be challenging to lyse and may contain PCR inhibitors.
- **Possible Causes & Solutions**:
  - **Ineffective lysis**: Optimize the lysis method for your specific sample type. This might involve mechanical disruption (bead beating, sonication), enzymatic digestion (lysozyme for bacteria, cellulase for plants), or a combination of methods.
  - **Presence of inhibitors**: These samples often contain substances that can inhibit downstream enzymatic reactions like PCR. Use specialized extraction kits designed for these sample types, which often include steps to remove inhibitors. Techniques like column purification or precipitation can help.

➢ **General Tips for successful DNA extraction**:

- **Follow the protocol carefully**: Pay close attention to all steps, reagent volumes, and incubation times.
- **Use high-quality reagents**: Ensure your buffers and enzymes are fresh and have not expired. Use nuclease-free water and plastics.

- **Avoid contamination**: Wear gloves and use sterile techniques to prevent introducing DNases or other contaminants.
- **Work gently**: Avoid harsh mixing, especially after DNA has been released.
- **Optimize for your sample type**: Different samples require different extraction methods. Choose a protocol that is known to work well for your specific material.
- **Assess DNA quality and quantity**: After extraction, it's crucial to quantify your DNA (e.g., using a spectrophotometer like NanoDrop or a fluorometer) and assess its quality (e.g., by checking the A260/A280 ratio and running a gel to check for degradation).

➢ **PCR Preparation and Run**

1. No PCR Product or Very Low Yield

- **Problem:** You don't see amplification curves or very low amplification curves.
- **Possible Causes & Solutions:**
  - **Missing or Incorrect Reagents:** Double-check that you've added all the necessary components (template DNA, primers, polymerase, dNTPs, buffer, $MgCl_2$) at the correct concentrations. Prepare a fresh master mix to rule out reagent degradation.
  - **Template Issues:**
    - **Insufficient template:** Increase the amount of template DNA. However, be cautious not to overload, which can also cause problems.
    - **Degraded template:** Check the integrity of your template DNA using gel electrophoresis. If it's degraded, you'll need to prepare fresh DNA.
    - **Inhibitors present:** Many substances can inhibit PCR. Ensure your DNA extraction method removes inhibitors effectively. Consider diluting your template, using a DNA purification kit specifically designed to remove inhibitors, or trying a different DNA polymerase that is more resistant to inhibition.
    - **Target sequence not present:** Verify that your template DNA actually contains the target sequence.
  - **Primer Problems:**
    - **Incorrect primer concentration:** Optimize primer concentration (typically between 0.1-1 µM). Too little primer leads to low yield, while too much can cause non-specific amplification or primer dimers.
    - **Poor primer design:** Ensure your primers are specific to the target sequence, have appropriate melting temperatures (Tm) that are within 5°C of each other, avoid self-complementary

regions or complementarity between the primers (potential for primer dimers), and have a GC content between 40-60%. Use primer design software to check for these issues.
        - **Primer degradation:** If your primers have been stored improperly or through many freeze-thaw cycles, they might have degraded. Order fresh primers.
    - **Suboptimal Annealing Temperature:** The annealing temperature is critical for primers to bind specifically to the template. If it's too high, primers may not bind efficiently; if it's too low, they might bind non-specifically. Determine the optimal annealing temperature, which is typically 5°C below the lower Tm of your primer pair. Running a temperature gradient PCR can help you find the ideal annealing temperature.
    - **Insufficient Denaturation:** Incomplete denaturation of the double-stranded DNA template will prevent primer binding. Ensure the initial denaturation step is long enough (e.g., 2-5 minutes at 94-98°C) and that the denaturation step in each cycle is sufficient (e.g., 30 seconds at 94-98°C). For GC-rich templates, you might need higher temperatures or longer times.
    - **Polymerase Issues:**
        - **Inactive or insufficient polymerase:** Ensure your polymerase is stored correctly and hasn't expired. Try increasing the amount of polymerase.
        - **Incorrect polymerase:** Make sure you're using a polymerase suitable for your application (e.g., a high-fidelity polymerase if sequence accuracy is crucial).
    - **Insufficient Cycling:** Increase the number of PCR cycles (typically 25-35). However, be cautious as too many cycles can lead to non-specific products.
    - **Thermocycler Malfunction:** Verify that your thermocycler is functioning correctly and reaching the programmed temperatures.

2. <u>Non-Specific Melt curves</u>

- **Problem:** You see non-specific melt profiles.
- **Possible Causes & Solutions:**
    - **Incorrect Annealing Temperature:** As mentioned above, an annealing temperature that is too low can cause primers to bind to non-target sequences. Increase the annealing temperature in small increments (e.g., 1-2°C).
    - **Excessive Primer Concentration:** Reduce the concentration of your primers.
    - **Too Much Template DNA:** Decrease the amount of template DNA.

- **High Magnesium Concentration:** Optimize the $MgCl_2$ concentration. Too much magnesium can reduce PCR stringency, leading to non-specific amplification. Start with 1.5-2.0 mM and adjust in 0.5 mM increments.
- **Too Many PCR Cycles:** Reduce the number of cycles.
- **Primer Dimers:** These are small, non-specific products that occur when primers anneal to each other. Redesign your primers to avoid complementarity at the 3' ends. Increase the annealing temperature. Increase the primer concentration.
- **Degraded Template DNA:** Degraded DNA can lead to amplification of random fragments. Use fresh, high-quality template.
- **Hot-Start PCR Not Used:** If you're using a polymerase that doesn't have hot-start capabilities, premature polymerase activity at lower temperatures can lead to non-specific products. Use a hot-start polymerase or perform the PCR setup on ice and quickly transfer it to the pre-heated thermocycler.
- **Contamination:** Ensure your reagents and workspace are free of DNA contamination. Use fresh reagents, sterile techniques, and filter tips.

3. <u>Incorrect Product Size</u>

- **Problem:** The band on your gel is the wrong size.
- **Possible Causes & Solutions:**
  - **Mispriming:** Primers might be binding to a non-target sequence that is a different size. Review your primer design and increase the annealing temperature to improve specificity.
  - **Insertions or Deletions in Template:** If your template DNA has unexpected insertions or deletions, the PCR product size will be different.
  - **Polymerase Errors:** While less common, some polymerases can introduce errors that might affect the apparent size on a gel, especially over many cycles. Using a high-fidelity polymerase can help.
  - **Heteroduplex Formation:** If you have multiple slightly different PCR products, they can form heteroduplexes that migrate differently on the gel. This is more common in multiplex PCR or when amplifying related sequences. Denaturing the PCR product and running it again might resolve this.
  - **Incomplete Extension:** Ensure the extension time is sufficient for the expected product size (generally 1 minute per 1 kb).

➢ **<u>General Tips for successful PCR:</u>**

- **Careful Pipetting:** Ensure accurate pipetting of all reagents.
- **Proper Mixing:** Mix your PCR reaction thoroughly but gently.

- **Use Controls:** Always include a positive control (DNA known to amplify with your primers) and a negative control (no template DNA) to help troubleshoot.
- **Optimize One Parameter at a Time:** When troubleshooting, change only one variable at a time to understand its effect.
- **Consult Your Polymerase Manual:** Different polymerases have different optimal conditions and recommendations.
- **Keep Good Records:** Note all your reaction conditions and any modifications you make.

Glossary

DNA Extraction Glossary:

- **Lysis:** The process of breaking open cells and tissues to release their contents, including DNA.
- **Lysate:** The solution containing the cellular components after lysis.
- **Homogenization:** A mechanical method used to physically disrupt tissues or cells during lysis.
- **Proteinase K:** An enzyme used to digest proteins, which can interfere with DNA purification.
- **RNAse:** An enzyme used to degrade RNA, often used when pure DNA is desired.
- **Precipitation:** The process of making DNA insoluble in a solution, usually by adding alcohol (ethanol or isopropanol) and salt, causing it to clump together and separate from the liquid.
- **Pellet:** The solid form of precipitated DNA that collects at the bottom of a tube after centrifugation.
- **Supernatant:** The liquid portion of a sample remaining after centrifugation and pelleting.
- **Wash Buffer:** A solution used to remove residual contaminants (salts, proteins, etc.) from the DNA pellet or bound DNA on a column.
- **Elution Buffer:** A solution used to release the purified DNA from a solid matrix (like a spin column) into a liquid form.
- **Yield:** The amount of DNA obtained from an extraction procedure.
- **Purity:** A measure of how free the extracted DNA is from other contaminants like proteins, RNA, and salts, often assessed by spectrophotometry (e.g., A260/A280 ratio).
- **Integrity:** The quality of the extracted DNA, referring to whether it is intact (high molecular weight) or degraded (fragmented).

PCR Glossary:

- **PCR (Polymerase Chain Reaction):** A laboratory technique used to amplify a specific segment of DNA, creating many copies from a small starting amount.
- **Template DNA:** The original DNA sample that contains the target sequence to be amplified.
- **Primers:** Short, single-stranded DNA sequences that are complementary to the ends of the target DNA region and serve as starting points for DNA synthesis.
- **DNA Polymerase:** An enzyme that synthesizes new DNA strands by adding nucleotides complementary to the template strand, starting from the primers. A common example is *Taq* polymerase.
- **dNTPs (deoxyribonucleotide triphosphates):** The building blocks of DNA (adenine, guanine, cytosine, and thymine) that are added by the polymerase to create new DNA strands.
- **Buffer (PCR Buffer):** A solution that provides the optimal chemical environment (pH, salt concentration) for the DNA polymerase to function.
- **$MgCl_2$ (Magnesium Chloride):** A cofactor for the DNA polymerase and its concentration can affect primer annealing and enzyme activity.
- **Thermocycler:** A machine that precisely controls the temperature and time cycles of PCR.
- **Denaturation:** The first step of each PCR cycle, where the double-stranded DNA template is heated to a high temperature (e.g., 94-98°C) to separate it into single strands.
- **Annealing:** The second step, where the temperature is lowered (typically 50-65°C) to allow the primers to bind (anneal) to their complementary sequences on the single-stranded DNA template.
- **Extension/Elongation:** The third step, where the temperature is raised to the optimal temperature for the DNA polymerase (usually 72°C), and the polymerase extends the primers, synthesizing new DNA strands complementary to the template.
- **Cycle:** One complete round of denaturation, annealing, and extension. PCR typically involves 25-35 cycles. In some cases 40-45 cycles are recommended.
- **Amplicon:** The specific DNA fragment that is amplified during PCR.
- **Primer Dimers:** Small, non-specific DNA products formed when primers anneal to each other and are extended by the polymerase.
- **Non-Specific Bands:** PCR products of unexpected sizes that arise from primers binding to non-target sequences.
- **Hot-Start PCR:** A technique that prevents polymerase activity at lower temperatures to reduce non-specific amplification and primer dimer formation.
- **Melting Temperature (Tm):** The temperature at which 50% of a given DNA duplex (like a primer bound to its complement) is denatured into single

strands. Primer Tm is crucial for determining the optimal annealing temperature.

IoT Sensor Network

General Introduction

The IoT Sensor Network comprises distributed temperature and humidity sensors embedded inside product packaging or transport units. It enables real-time and offline monitoring of environmental conditions critical for maintaining product integrity during logistics. Data is centrally collected and processed using SensLog platform components, which perform analytics and threshold alerts.

This network is essential to ensure perishable goods, especially organic products, are transported under required conditions to maintain certification standards.

Detailed Step-by-Step Instructions

Step 1: Sensor Selection and Configuration

- Choose sensors capable of measuring temperature and relative humidity with suitable accuracy and battery life.
- Configure sampling intervals (e.g., every 5-15 minutes) depending on product sensitivity.

Monitoring units for deployment in package

Step 2: Sensor Deployment

- Place sensors securely inside packages or transport containers, ensuring good environmental exposure.
- Initialize sensors and synchronize clocks.

Step 3: Data Collection and Transmission

- Sensors log data locally and transmit via cellular IoT/GPRS network if coverage allows.
- If no network, data remains stored until sensors are retrieved for offline download.

Step 4: Data Integration into SensLog Platform

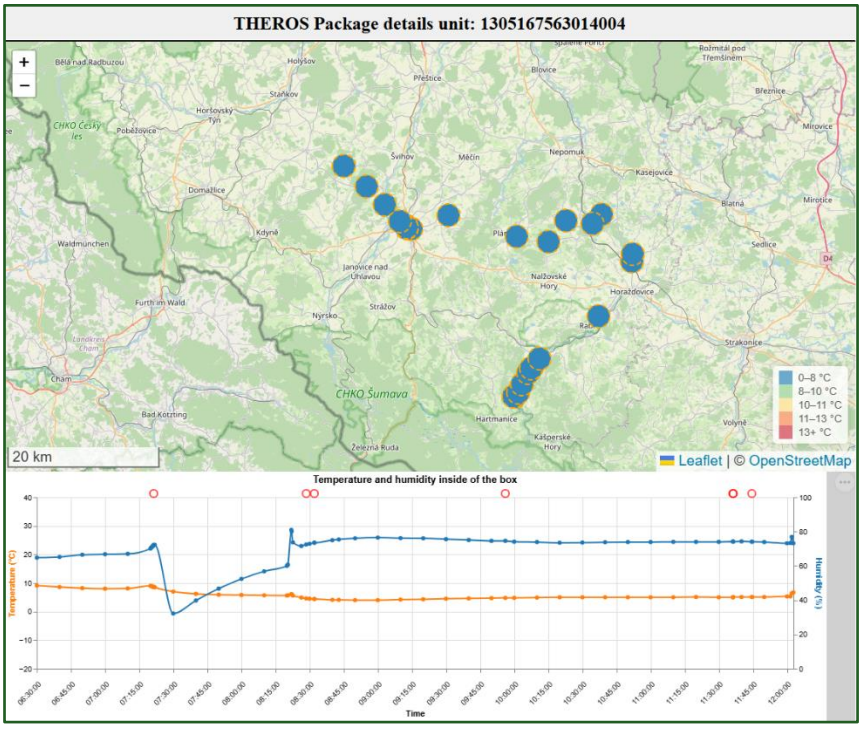
- Use SensLog Connector to receive sensor data streams through REST APIs.
- Store data in SensLog's data model with time and location metadata.

Step 5: Analytics and Alerting

- SensLog Analytics processes data streams for:
- Statistical summaries (min, max, average)
- Threshold violations (temperature or humidity outside preset ranges)
- Complex pattern detection (e.g., sustained deviations)
- Generate alerts or flags for out-of-compliance events.

Step 6: Visualization and Reporting

- Visualize data via SensLog Web Map Visualisation App, showing spatial-temporal trends.
- Generate transport condition certificates post-delivery, indicating if conditions were met.



Example of Web map visualisation app for selected package delivery

Possible Applications

- Cold chain monitoring for fresh fruits, vegetables, dairy, and meats.
- Verification of organic product transport compliance.
- Enhancing transparency and consumer confidence in product quality.

Blockchain Technology for Food Traceability

General Introduction

The blockchain traceability solution creates an immutable ledger recording all critical tracking events (CTEs) across the supply chain using GS1 standards. It ensures data integrity, transparency, and accountability, allowing all stakeholders to securely share product information and verify certifications. Smart contracts enforce business rules automating validation and compliance checks.

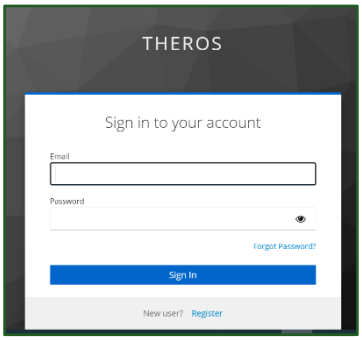
This technology combats food fraud, supports regulatory compliance, and builds consumer trust by providing tamper-proof provenance data.

Detailed Step-by-Step Instructions

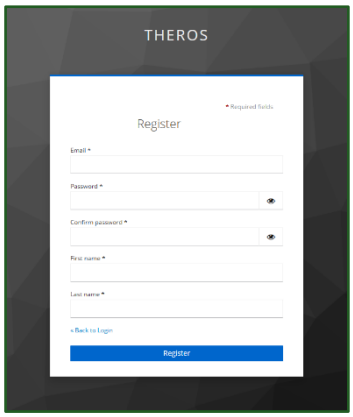
Step 1: Stakeholder register

- Access the Blockchain platform via the provided link. Choose any of the available options, and once redirected to the login screen, click the 'Register' button at the bottom.

Blockchain platform link



- Complete the requested information in the form and click the button at the bottom.



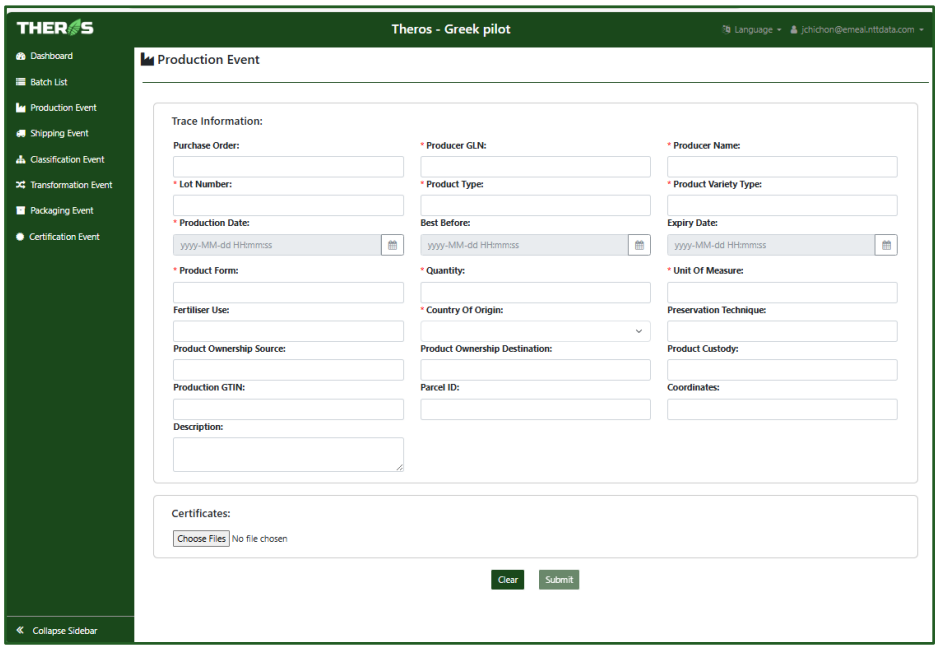
- Verify your account via the confirmation email received.
- Send an email indicating your role on the platform (e.g., “I am a processing company in the Serbian pilot,” “I am a Spanish certification body,” etc.). This email should be sent to any of the NTT DATA members involved in the project.
- Wait to receive confirmation that your user account has been successfully created and that access has been enabled.

Step 2: Register a Traceability Stage Using the FrontEnd

- Navigate to the Blockchain platform link (same link as in Step 1). Select your access type based on the email you received to access the main menu, where you will see different sections in the lefthand panel. These screens are tailored to your specific user permissions, so they may differ from those shown in the example.

- Select the event (traceability stage) for which you want to register information. As an example, we will use the Production event.

Note: Depending on the pilot you belong to, the expected sequence of events may vary. It is important to know the correct order for your specific case. These differences are detailed in later sections.



- After selecting the desired event, a screen will appear with key fields to define that specific stage. Complete the form with the information related to the traceability stage being recorded. Fields marked with a red asterisk are mandatory. The remaining fields are recommended but not required.

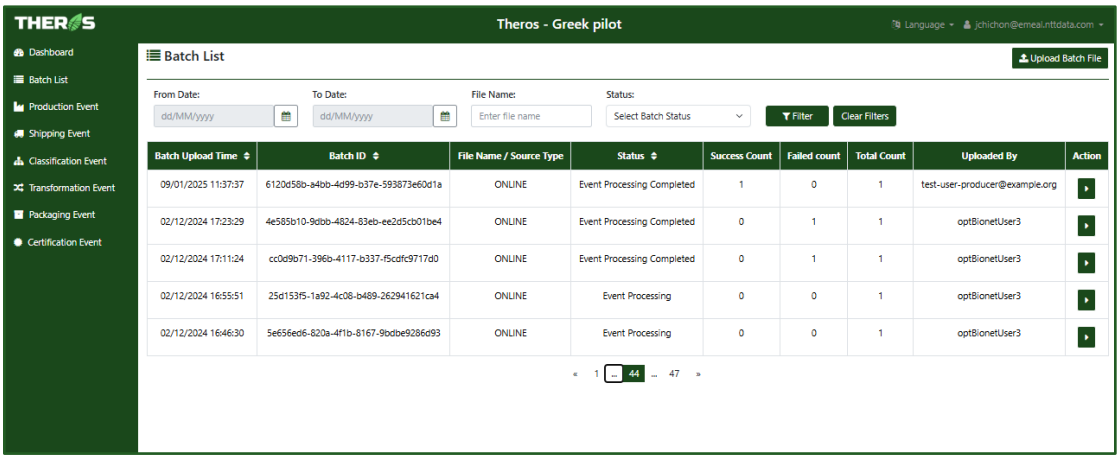
If you have any supporting documents, attach them by clicking the 'Choose Files' button.

Once all mandatory fields are completed, the 'Submit' button will become enabled. This button will send the provided information to the platform, where it will be validated before being permanently recorded on the blockchain network.

Note: After an event is submitted to the platform, it may not be registered if it contains errors or if it depends on prior events that have not yet been recorded. It is recommended to verify whether the submitted event was registered correctly by performing Step 3.

Step 3: Checking the Status of an Event

- Go to the Batch List section located in the lefthand panel.



This screen provides technical information designed to check the status of uploaded events. Each row represents an event or batch of information, displaying details such as upload time, submitting user, and additional metadata. To check the status of your event, focus on the 'Status', 'Success Count',' Failed Count', and 'Total Count' columns.

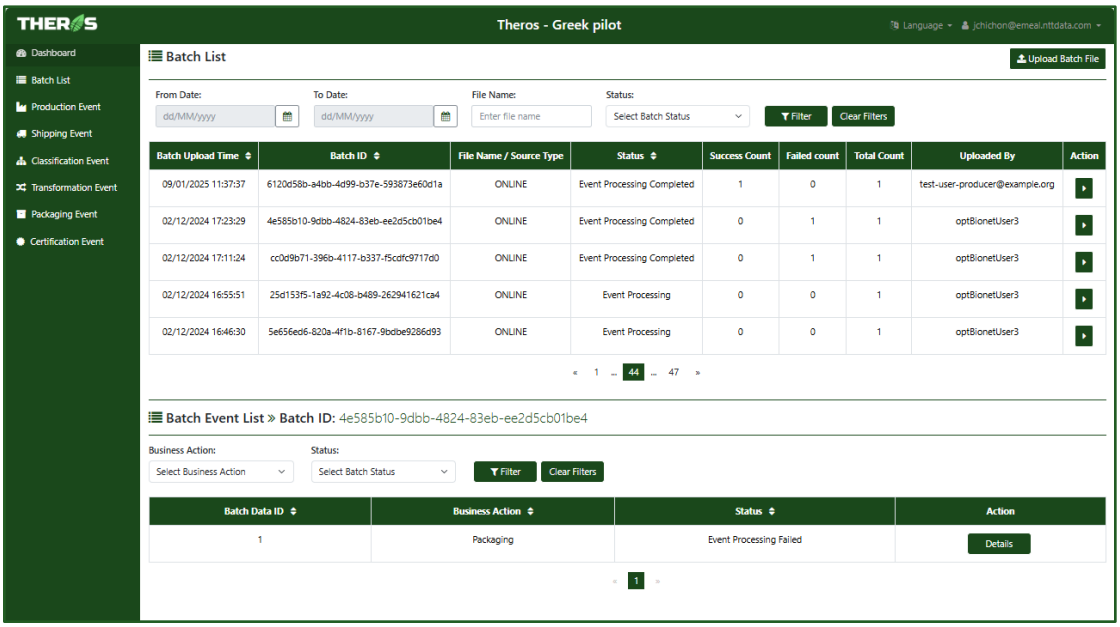
Note: Each time a new event is uploaded, it appears at the top of the list, so the entries are sorted from newest to oldest by default.

Status	Success Count	Failed count	Total Count
Event Processing Completed	1	0	1
Event Processing Completed	0	1	1
Event Processing Completed	0	1	1
Event Processing	0	0	1
Event Processing	0	0	1

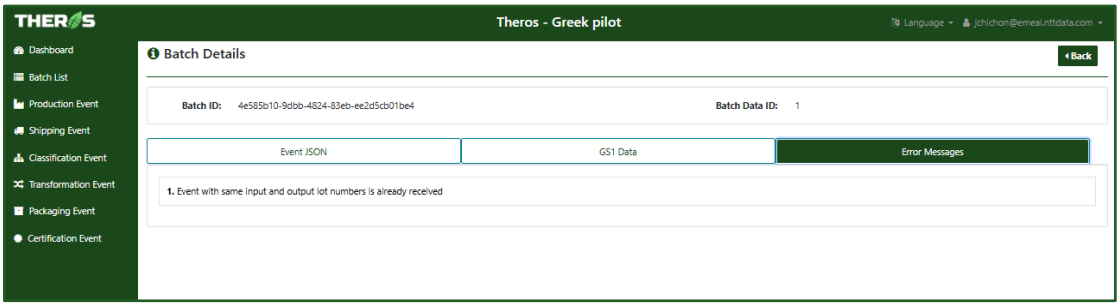
The 'Status' column shows a textual indication of whether the event has been processed or is pending. However, the 'Success Count', 'Failed Count,' and 'Total Count' columns indicate whether the event was actually registered:

- Total Count shows the number of events uploaded (when using the frontend, this will always be 1).
- If the event was registered successfully, Success Count will show a value of 1.
- If an error occurred, Failed Count will show a value of 1.
- If both Success Count and Failed Count are zero, the event is pending due to unmet conditions and has not been registered.

In the latter two cases (pending or failed), you can view further details to understand the issue. Select the row you wish to inspect, and a new section called Batch Event List will appear at the bottom of the screen.



Click the 'Details' button on the right side of this new section. This will open a new page containing additional sections. The section of interest is 'Error Messages' on the right, which explains why the event could not be registered correctly.

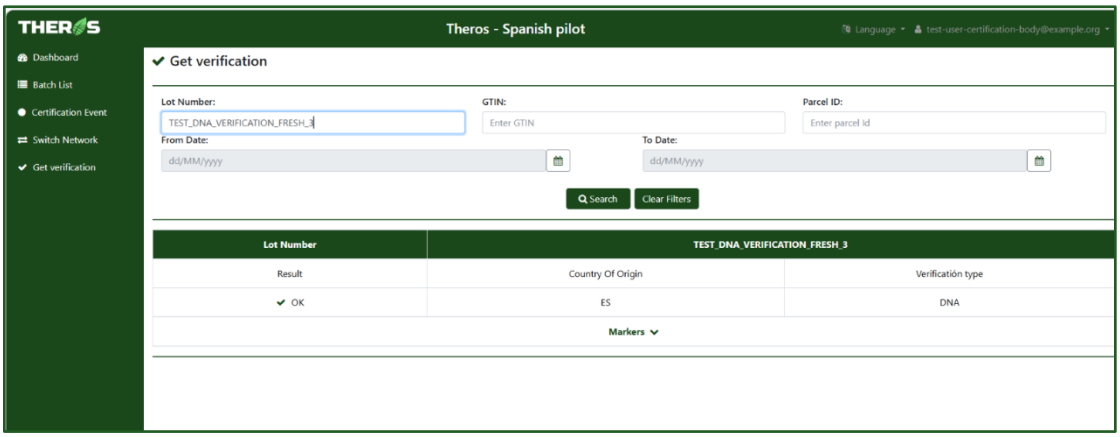


Note: Events with errors must be re-entered with the appropriate corrections to ensure proper registration.

Note: This functionality has been added to aid in debugging errors and may not cover all possible scenarios.

Additional screens are also available exclusively for certifiers, enabling them to verify whether the verification events associated with a given batch meet the thresholds established for each pilot.

By accessing the 'Get Verification' section and searching by the lot number identifier, the lower part of the screen displays the analyses performed on that batch. The result may be OK for batches that meet the requirements, or KO for those that do not.



Step 4: Querying Recorded Traceability Data

To query the information recorded on the platform, use the **Digital Product Passport (DPP)** tool. This tool displays the various traceability stages for registered products.

Additional Traceability Information

Sequence of events

It is important to consider the pilot you are part of when creating events, as each follows a specific workflow that must be adhered to.

Spanish Pilot

There are two possible sequences depending on the product type:

- Canned Product
  Production → Shipping → Transformation → Shipping
- Fresh Product
  Production → Shipping → Classification → Transformation → Shipping

Serbian Pilot
Production → Shipping → Transformation → Packaging → Shipping

Greek Pilot
Production → Shipping → Transformation → Packaging → Shipping

Czech Pilot

There are two possible sequences depending on whether the seller participates:

- Seller Participating
  Production → Packaging → Shipping → Packaging → Shipping
- Seller Not Participating
  Production → Packaging → Shipping

Other Considerations

- The field named lotNumber is the identifier for each batch being recorded and can only be reused in consecutive events. Using a previously registered lotNumber will result in an error.
- In events that include both input and output stages, identifiers must be distinct; otherwise, the system will generate an error. The identifier used for the output stage should be used in the next event to continue the flow.
- If an intermediate event is entered before previous events are registered, the batch will not be recorded until the prior events are correctly registered with the appropriate identifiers.
- Mandatory dates in each event must be coherent; an event at a later stage cannot have a date earlier than or equal to that of a previous event.

Possible Applications

- Full supply chain transparency for organic, geographical indication, and premium products.
- Automated regulatory compliance and audit trail generation.
- Enhanced anti-fraud measures through unalterable data records.

Digital Marketplace Platform

General Introduction

The Digital Marketplace is a web-based e-commerce platform designed to connect organic/regional producers with customers while integrating verification tools such as transport condition monitoring. Built on PrestaShop Marketplace Builder, it supports multi-vendor management, product listing, order processing, and GDPR-compliant customer data management.

Its objective is to foster market access for small producers, enhance consumer confidence, and support sustainable food systems.

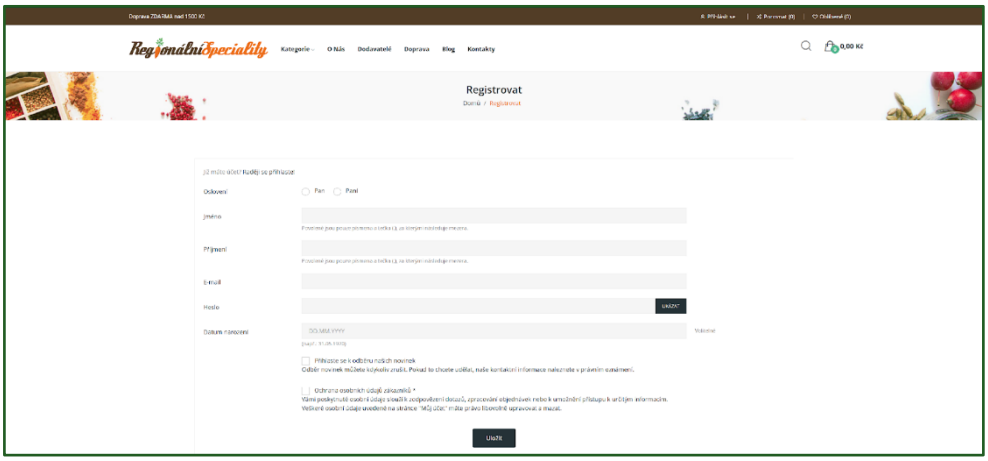
Detailed Step-by-Step Instructions

Registration and Login

As a customer, you can, but do not have to, register. If you want to sell on the Digital Marketplace, registration is mandatory.

1. **Registering a new user:**
    a. Visit **THEROS Digital Marketplace**.
    b. Click the "**Sign In**" button in the top right corner.

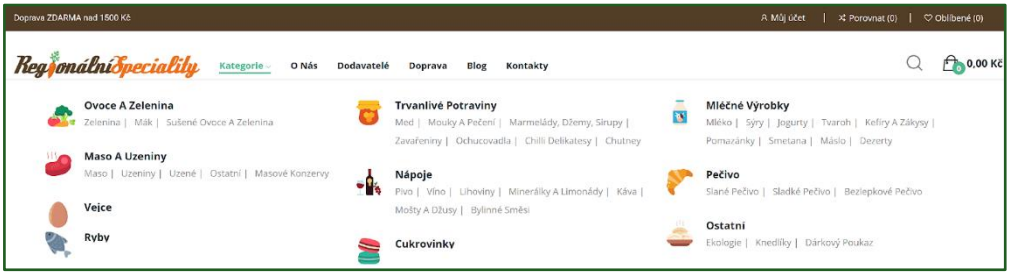
c. If this is your first visit, select "**Create an Account**" and fill in the required details, such as your name, email, and password.



- Confirm your registration via the email that will be sent to you.

2. **Logging in again:**
   a. Click "**Sign In**" and enter your email and password.
   b. If you have forgotten your password, use the "**Forgot Password**?" link and follow the instructions.

Searching and Filtering Products

1. **Searching for Products:**
   a. Use the search bar at the top of the page and enter the product name or a keyword.
2. **Filtering Products by Category:**
   a. 

   In the left menu, you will find a list of categories such as "**Fruits and Vegetables**", "**Meat and Sausages**", "**Dairy products**" etc.
   b. Click on a specific category to view products in that group.

Information on Organic Food and Protected Labels

1. **Understanding different organic and protected labels:**
   a. **National BIO Logo ("biozebra")**: This logo with the label "**Product of Organic Farming**" certifies organic food in the Czech Republic

b. **Regional Food:** A label awarded by the **Ministry of Agriculture** to the highest quality agricultural and food products that win regional competitions. The product must be made in the region where the award was given, using local ingredients.

c.

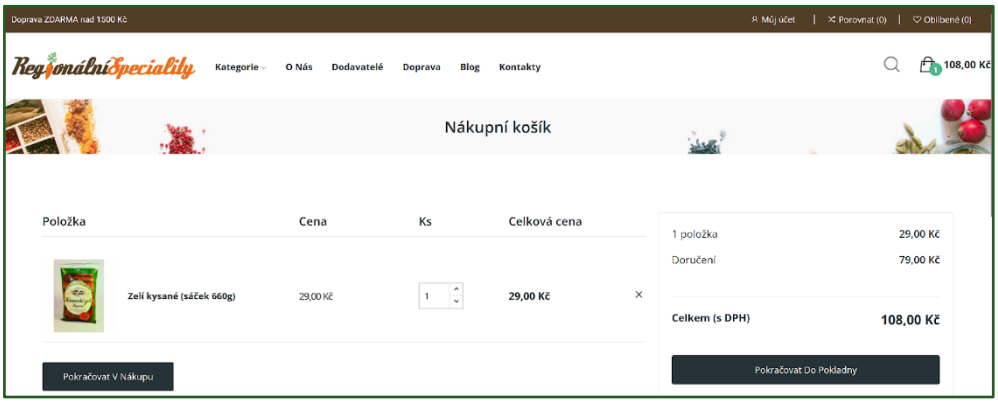
- **Klasa:** This label prioritizes offering high-quality food that has exceptional characteristics, increasing its added value and ensuring uniqueness compared to regular products available on the market.

- **ŠUMAVA Original Product**: This label is granted by the **Regional Development Agency of Šumava** to artisanal products, agricultural goods, and natural products. It guarantees the **local origin of the product**, its connection to the Šumava region, as well as its **quality and environmental friendliness**.

Shopping Process

1. **Adding a product to the cart:**
   a. On the product page, click "**Add to cart**".
2. **Viewing the cart:**
   a. Click on the cart icon in the top right corner to view the current contents.
3. **Editing quantity or removing a product from the cart:**
   a. In the cart, you can adjust the number of items or remove products using the appropriate buttons.
4. **Checkout process:**
   a. After reviewing the cart contents, click "**Proceed to Checkout**".
   b. Enter your delivery details and select your preferred shipping and payment method.

c. **Note:** For products with variable weight (e.g., meat), the exact weight is determined only after order preparation, so payment is only possible via cash on delivery.



Shipping

1. **Standard shipping:**
    a. You can choose standard shipping.

- Delivery time varies depending on the selected carrier and your location.

2. **Monitored Shipping:**
    a. You can also opt for monitored shipping, which allows real-time tracking of your package and shipping conditions throughout the entire delivery process.

- As part of the **THEROS Digital Marketplace development**, one of the key improvements was adding shipment monitoring functionality. This feature was implemented to enhance transparency, security, and the quality of transported products, especially those requiring strict storage and transportation conditions, such as fresh organic food. This system enables automated tracking of transportation conditions and the generation of certificates verifying compliance with transport parameters.

Delivery and Quality

3. **Quality of Delivered Goods:**
    a. Products are carefully packaged to maintain their freshness and quality.
- If you are dissatisfied, please contact customer support for assistance.

User Guide for Farmers and Sellers

Welcome to **trh.regionalnispeciality.cz**, an online marketplace where farmers and local producers can sell their products directly to customers. This guide provides you with step-by-step instructions on how to create a seller account, add farm products, and manage orders.

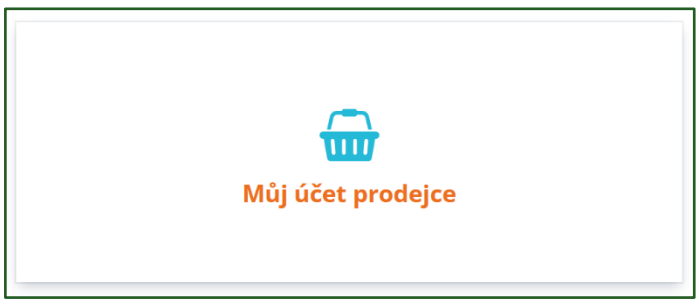
1. How to Start Selling

1.1 Registering as a Seller

1. Go to trh.regionalnispeciality.cz and click on **'Register as a Seller'**.
2. Fill in the **registration form** with information about your farm or business.
3. Accept the **terms and conditions** and submit the application.
4. Wait for **approval** from the marketplace administrator.

1.2 Setting Up Your Online Store

1. After approval, log in and go to **'My Seller Account'**.



2. Set up your store:

a. **Choose a store name** that reflects your farm or products.
b. **Upload a logo and banner** (recommended but not required).
c. **Enter your contact information** and store address.
d. **Set up shipping options** (personal pickup, mail, refrigerated transport, etc.).

1.3 **Membership and Fees**

- Some services may require **a small membership fee** (monthly, annual, or one-time).
- **A percentage fee** is deducted from each successful sale.
- Invoices can be found in the **membership settings**.

2. Adding Products

2.1 How to Add a New Product

1. Go to **'My Products' > 'Add New'**.
2. Fill in product details:
   a. **Product name** (e.g., Organic Apples, Fresh Goat Cheese).
   b. **Description** – highlight the quality, origin, and benefits of the product.
   c. **Upload high-quality product photos**.
   d. **Set the price and stock quantity**.
   e. **Choose delivery methods**.
3. Submit for **approval by the administrator**.

2.2 Editing and Updating Products

- You can edit your products at any time in the **'My Products'** section.
- Each change must be **approved by the administrator** before appearing online.

2.3 Choosing Product Categories

- Your products must be assigned to allowed categories.
- If you need a new category, contact the administrator.

3. Managing Orders

3.1 Processing Customer Orders

1. You will receive **a notification** when an order is placed.
2. Go to the **'Orders'** section to see order details.
3. Pack the product and change the status to **'Shipped'**.
4. If possible, add a tracking number.
5. Mark the order as **'Completed'** after delivery.

3.2 Returns and Complaints

- Customers may request a **refund or product exchange** according to marketplace rules.
- You can **approve or reject** the request depending on the situation.
- In case of a dispute, contact **marketplace support**.

4. Payouts and Receiving Money

4.1 How to Get Paid

- Once an order is completed, your **commission** is recorded.
- **A small fee** is deducted by the marketplace before payout.

4.2 Requesting a Payout

1. Go to the **'Withdrawals'** section in your seller account.
2. Choose your **preferred payment method** (bank transfer, PayPal, etc.).
3. Enter the amount and submit the **withdrawal request**.
4. Once approved, the money will be sent to you.

5. How to Increase Sales

5.1 Making Products More Visible

- Use **clear product titles** and detailed descriptions.
- Upload **high-quality photos** showing freshness and packaging.
- Offer **discounts or promotional bundles** to attract customers.

5.2 Communicating with Customers

- Enable the **contact form** so customers can ask questions about your products.
- If available, use **live chat** for quick responses.
- Respond to customer inquiries **as quickly as possible** to build trust.

5.3 Managing Reviews

- Customers can **leave ratings and reviews** on your products.
- You can reply to reviews in the **'My Seller Account'** section.
- More positive reviews = **more sales**!

6. Additional Features

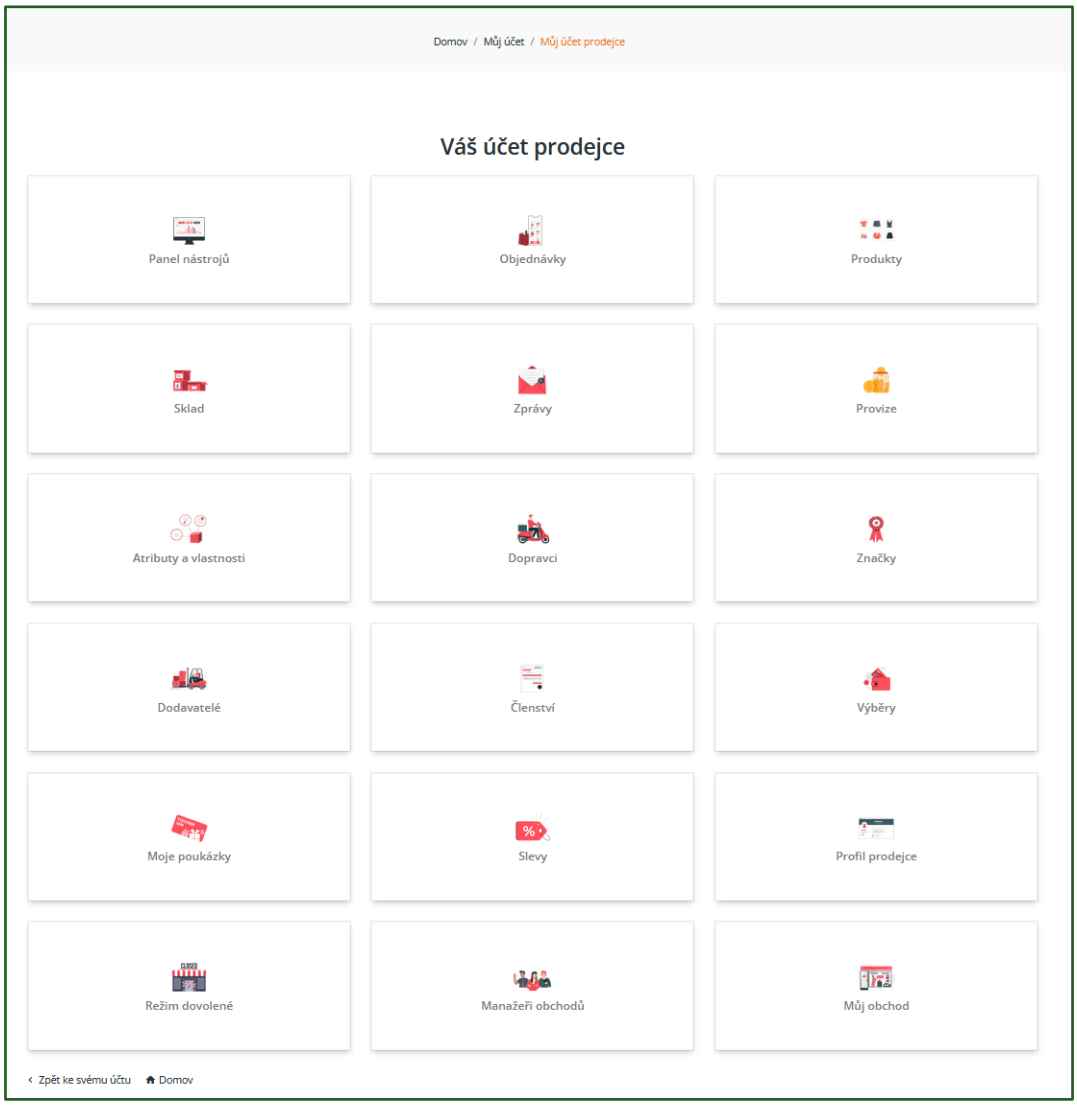
6.1 Vacation Mode

- If you need to **pause your store**, activate **vacation mode**.
- Options:

- Display a **message** for customers.
- Temporarily **disable purchases**.
- Hide **all products** until you return.

6.2 Reporting Issues

- If you encounter **a technical issue**, contact marketplace support.
- If you encounter **abuse or unfair practices**, report it to the administrator.



For more information, visit the "**About Us**" or "**Contacts**" section on the THEROS Digital Marketplace website.

We look forward to your visit!

trh.regionalnispeciality.cz

Possible Applications

The THEROS Digital Marketplace offers a versatile foundation that extends well beyond its initial implementation for organic and geographically indicated food products. Thanks to its modular architecture, advanced technology integration, and focus on trust and traceability, the platform has strong potential for application in various sectors and contexts.

In the agri-food sector, the marketplace model can be replicated for other specialized food categories, such as products with animal welfare certification, fair trade items, or allergen-free goods. Its IoT-enabled quality monitoring and blockchain-supported traceability are particularly suitable for high-value or sensitive product chains where transparency and authenticity are critical, such as fresh fish, meat, dairy, or functional foods.

The marketplace's infrastructure can also be adapted to support short supply chains in other industries, including artisan crafts, regional cosmetics, or natural textile products. These sectors similarly benefit from direct-to-consumer channels, storytelling, and certification-based trust building.

Beyond commerce, the THEROS platform can be used as an educational and awareness-raising tool. The ability to present the full journey of products—from origin to delivery—supports food literacy, sustainability education, and consumer engagement in regional development initiatives. This opens doors to cooperation with tourism, schools, and local authorities promoting local heritage and responsible consumption.

Moreover, with minor adaptations, the platform can serve as a backbone for public procurement systems focused on sourcing sustainable or locally certified goods for schools, hospitals, or municipalities.

In summary, the THEROS Digital Marketplace is a replicable and transferable model suitable for various domains requiring trust, traceability, and transparent value chains, offering scalable potential across Europe's circular, digital, and green economy initiatives.

Dynamic Digital Product Passport (dDPP)

General Introduction

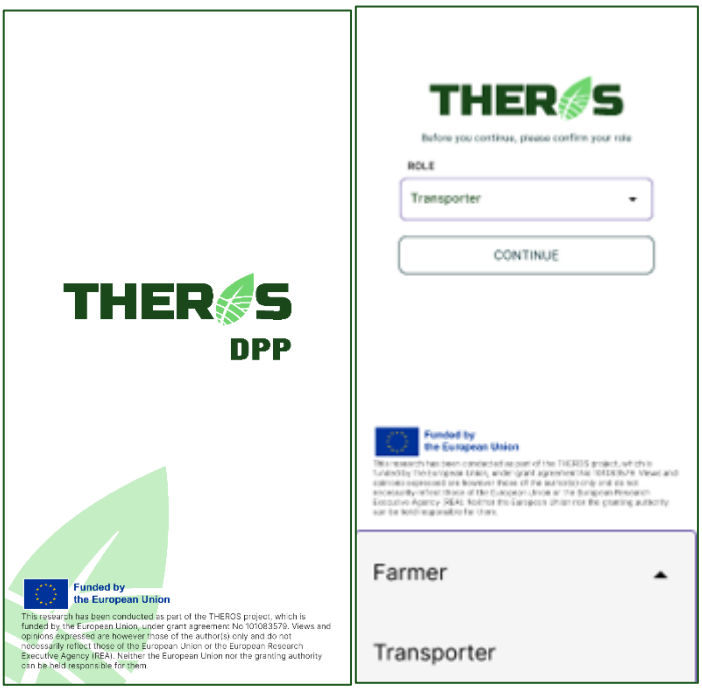
The dDPP system provides a mobile-first interface for stakeholders to access comprehensive product information across the supply chain via scanning or ID input. It consolidates traceability data, certification status, and sustainability metrics into a single "passport," enhancing transparency and enabling real-time updates.

The tool empowers consumers, producers, and regulators with trusted, easily accessible product histories.

Detailed Step-by-Step Instructions

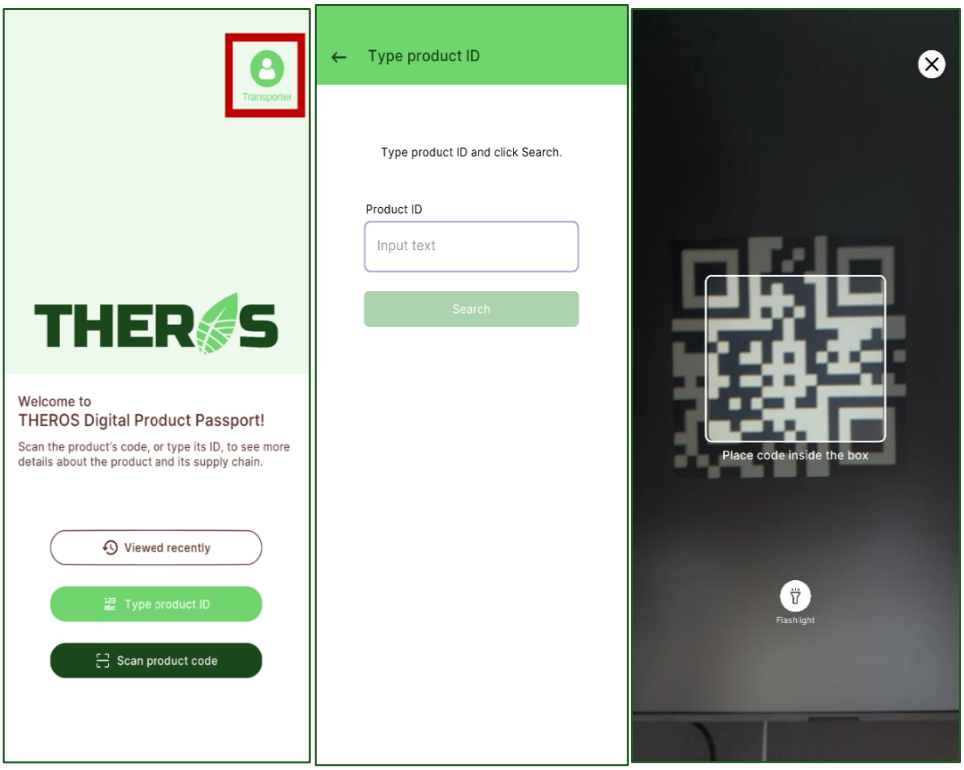
Step 1: Install and Launch Mobile dDPP App

- Available for smartphones/tablets on iOS or Android.



Step 2: Scan Product Barcode or Enter ID

- Use built-in camera to scan QR code or manually enter product serial number.

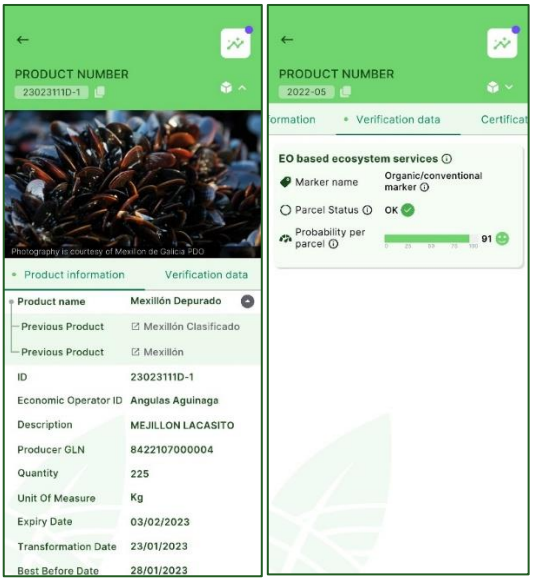


Step 3: Retrieve Product Data from Backend

- App requests dDPP data from backend server including traceability events, certification status, environmental info.

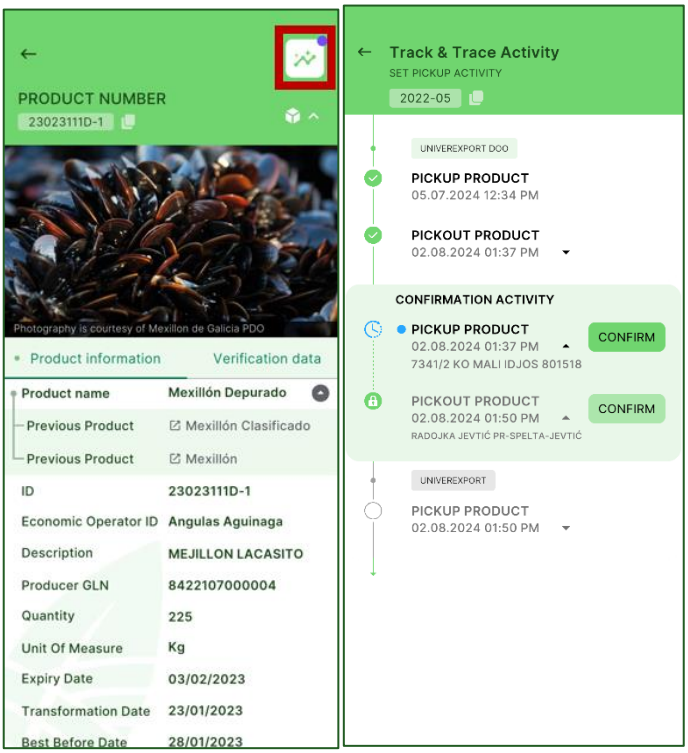
Step 4: Display Detailed Product Information

- Show timelines of supply chain events, verification checks, and compliance certificates.
- Provide user-friendly dashboards with sustainability indicators.



Step 5: Update Tracking and Verification Data

- Authorized supply chain actors update status as product moves through chain.
- Updates are securely transmitted and integrity checked.



Step 6: Data Integrity and Security

- Integrity framework ensures that timestamps and geolocations are genuine to prevent tampering.

Possible Applications

- Consumer verification of product origin and sustainability.
- Real-time supply chain management and fraud prevention.
- Support for certification agencies in ongoing monitoring.

Green Accountability Tool (GAT)

General Introduction

GAT is an integrated digital platform designed to aggregate, visualize, and analyse diverse datasets related to organic and geographic indication food product supply chains. It facilitates compliance monitoring, DNA authenticity verification, environmental impact assessment, and supply chain transparency. By consolidating complex datasets into intuitive dashboards, GAT supports decision-making for certifiers, policymakers, producers, and retailers.

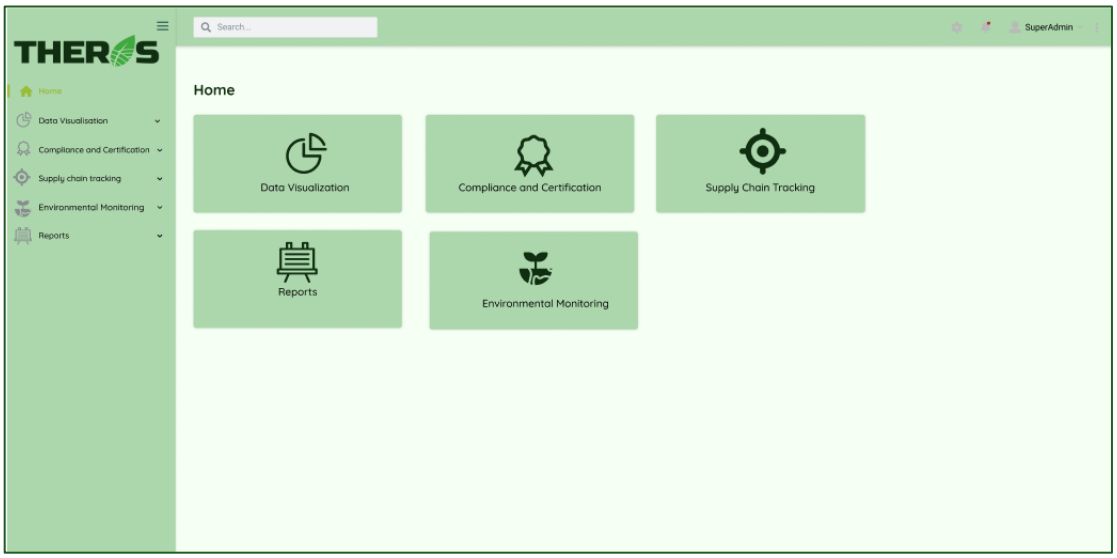
Detailed Step-by-Step Instructions

Step 1: User Authentication

- Login via secure Keycloak system with role-based permissions.

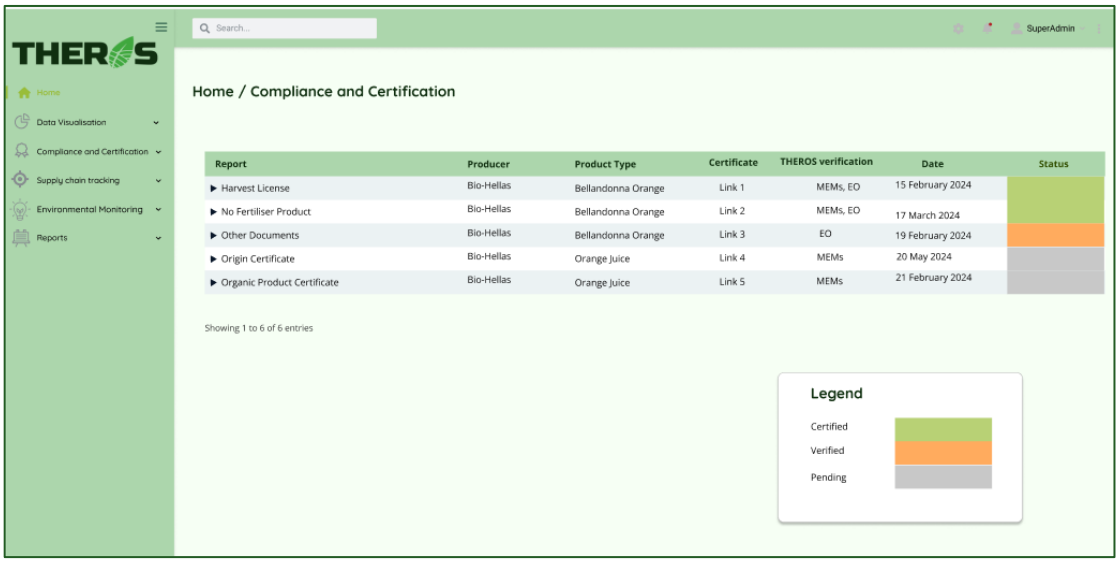
Step 2: Data Visualization Module

- Load data layers (EO markers, MEMS photonics, IoT sensors).
- Use interactive filters (product, region, time) to customize view.
- Compare multiple datasets side by side.



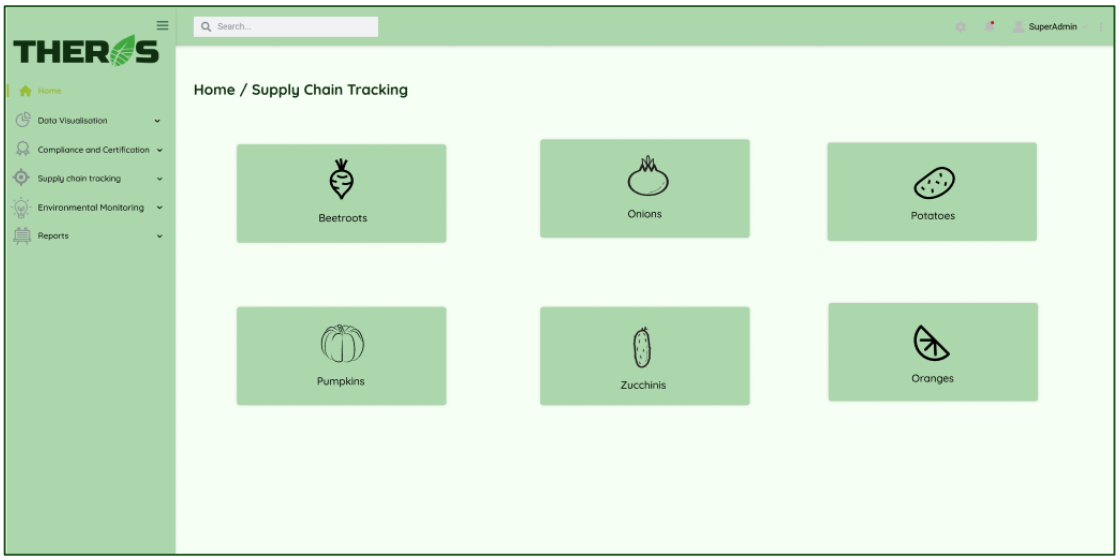
Step 3: Compliance and Certification Module

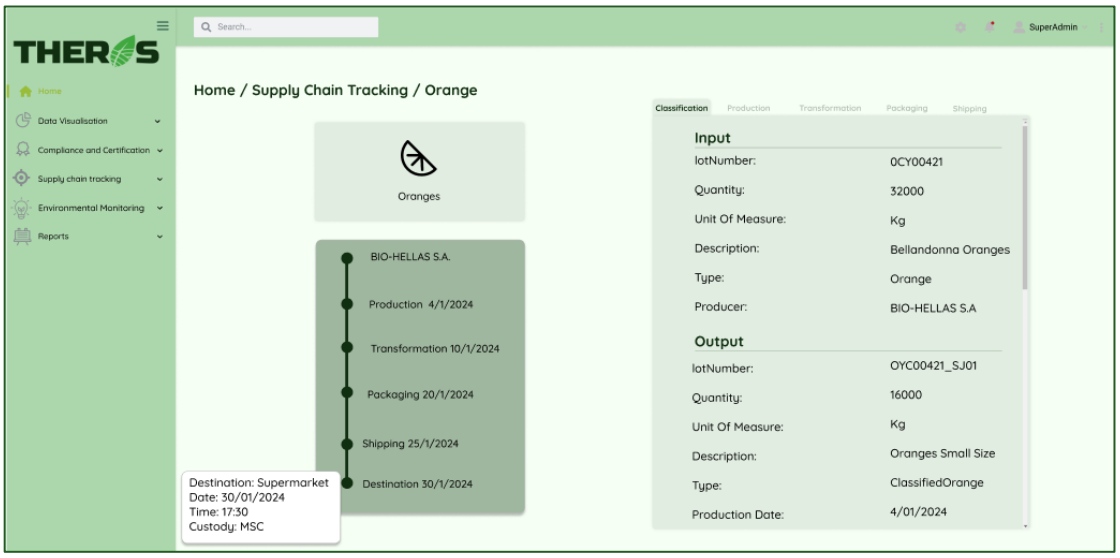
- Monitor certification statuses with color-coded traffic light system.
- View detailed verification outcomes from blockchain and DNA modules.



Step 4: Supply Chain Tracking Module

- Explore product event timelines with details on handlers, timestamps, and event descriptions.



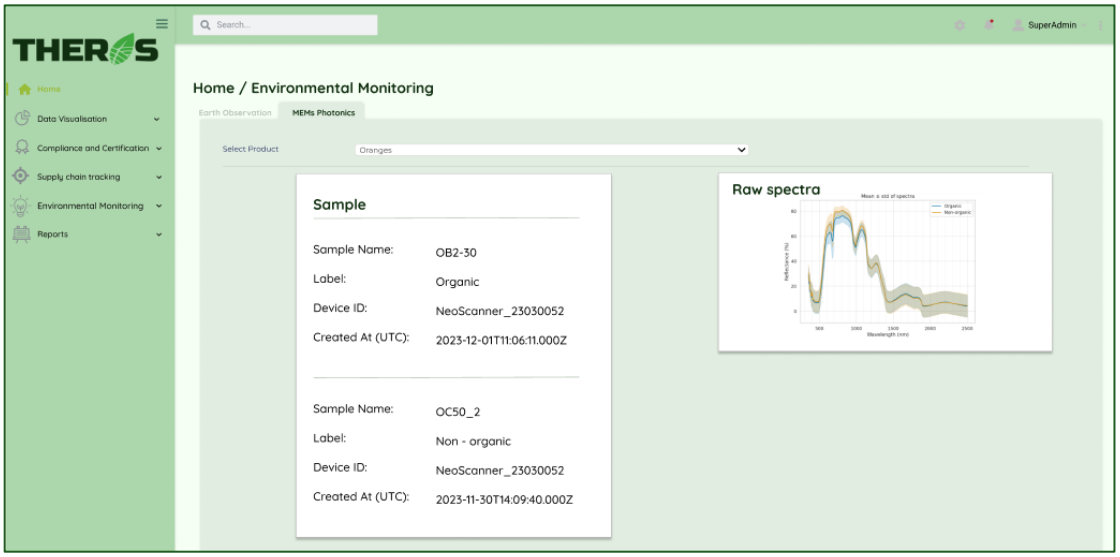


Step 5: Reporting Module

- Generate compliance reports combining multiple tool outputs.
- Export data for audits or external review.

Step 6: Environmental Monitoring Module

- Visualize Earth Observation data with compliance heatmaps.
- Analyse photonic spectral results for soil and product purity.



Step 7: Farmers' Recommendations Module

- Access actionable, sustainable farming practices tailored for organic systems.
- Receive general guidance on soil health, water use, pest control, and organic fertilisation.
- View lamp-signed recommendations triggered by specific metric readings (e.g., pH, nutrients).

Possible Applications

- Centralized compliance and authenticity monitoring.
- Informed policy decisions based on real-time data.
- Enhanced transparency and sustainability promotion.

Data Management, Harmonisation and Interoperability Tool

General Introduction

This cloud-native platform addresses the challenge of heterogeneous data sources by implementing standardized data connectors, translators, and unified APIs conforming to OGC SensorThings API standards. It acts as the backbone for data exchange across THEROS tools, ensuring interoperability, scalability, and security.

Keycloak identity provider secures user and service interactions, while Kubernetes ensures operational resilience.

Detailed Step-by-Step Instructions

Step 1: Connect Data Sources via Connectors

- Deploy connectors customized for each source (IoT sensors, Earth Observation, MEMS, DNA kits, blockchain).
- Establish secure connections and configure data polling or push mechanisms.

Step 2: Data Translation and Standardization

- Translators convert raw source data into harmonized JSON SensorThings API format.
- Data fields are normalized (units, timestamps, geo-coordinates).

Step 3: Centralized Data Access via Toolbox API

- Use RESTful endpoints to query integrated data streams.
- Apply filters for device, location, time, and data type.

Step 4: User and Service Authentication

- Use Keycloak to authenticate API requests and enforce role-based access control.
- Manage single sign-on (SSO) and token-based secure communication.

Step 5: System Monitoring and Scaling

- Monitor CPU, memory, and network metrics using Kubernetes dashboards.
- Auto-scale services to maintain performance under load.

Step 6: Data Provisioning to Consumer Applications

- Feed GAT, blockchain verification, and external clients with unified data.

Possible Applications

- Enabling seamless data integration for multi-tool analytics.
- Ensuring secure, scalable infrastructure for large-scale monitoring.
- Central authentication and authorization improving security across THEROS ecosystem.

Annex 3: Policy briefs

From Farm to Fork: Advancing Food Traceability Through THEROS Innovations

A Policy Brief

Executive Summary

Food fraud, non-compliance, and lack of transparency continue to undermine consumer trust and product integrity in organic and geographical indication (GI) food sectors. The THEROS project presents a technology-enabled approach to traceability, using tools such as IoT sensors, blockchain, and DNA authenticity kit. This brief presents the policy importance of traceability, using findings from THEROS, and recommends steps to support its uptake by control bodies, policymakers, and food industry stakeholders.

Introduction

As global food supply chains grow more complex, the risk of fraud, mislabelling, and non-compliance increases—especially in high-value segments like organic and GI-certified products. Traceability—the ability to track food products through all stages of production, processing, and distribution—is fundamental to ensuring food safety, authenticity, and sustainability. Traceability serves not only consumer protection but also regulatory compliance, brand value, and sustainability objectives. THEROS has developed a novel suite of tools and methodologies to support these goals through digital innovation.

Problem Description

Current traceability systems rely heavily on manual inspections and fragmented data sources, which are susceptible to errors, delays, and fraud. As seen in numerous food scandals, lack of traceability undermines consumer trust and exposes certification bodies to reputational risk. Organic and GI products are particularly vulnerable due to higher market premiums, making them frequent targets of mislabelling and adulteration. The absence of real-time, verifiable data limits the enforcement capabilities of regulatory authorities and hampers efforts toward sustainable, transparent food systems.

Policy Options: THEROS Toolbox Contributions

Option 1: Maintain the Status Quo – Fragmented and Paper-Based Systems

Most traceability practices in Europe still rely on a patchwork of paper records, stand-alone databases, and unverified certifications. While this option minimizes immediate disruption and costs:

- Risks remain high for fraud, mislabelling, and human error.
- Consumer trust deteriorates as inconsistencies arise in organic and GI labelling.
- Enforcement is reactive, slow, and resource intensive.
- Data verification is difficult, with limited cross-checking capability between actors.

This approach may satisfy minimal compliance but undermines long-term food integrity and competitiveness in premium food markets.

Option 2: Promote Sector-Specific Technology Upgrades Without Integration

In this option, authorities encourage or subsidize digital tools (e.g. blockchain for traders, IoT for logistics, or mobile apps for farmers) but leave integration and interoperability to market forces.

- Some process efficiencies are gained, especially within individual supply chain stages.
- However, lack of coordination results in data silos and repeated inputs.
- Verification remains limited, with gaps between certification, transport, and origin data.
- Trust is fragmented across actors using incompatible systems.

This option reflects a decentralized innovation strategy, but its benefits are uneven and often inaccessible to smaller producers and certifiers.

Option 3: Implement a Unified, Interoperable Traceability Framework Inspired by THEROS

This proactive approach involves establishing a harmonized digital ecosystem where all traceability components—from DNA testing and blockchain records to EO monitoring and environmental data, dDPP and mobile for MEMS—are interoperable. This is the model demonstrated by the THEROS project across multiple EU pilots.

- Blockchain-enhanced traceability ensures immutable product histories.
- IoT system tracks real-time product conditions.
- MEMS system detects adulterations.
- DNA-based authenticity kits verify species and origin.
- Digital Marketplace integrates verified producer data into consumer-facing platforms.
- Green Accountability Tool (GAT) links traceability to sustainability metrics.

- Verification methodology ensures effectiveness in diverse real-world contexts.

The benefits of this option include:

- End-to-end transparency across supply chains.
- Data integrity and faster fraud detection.
- Regulatory alignment with EU sustainability and digitalisation goals.
- Stronger consumer confidence and international market positioning.

Though this requires initial investment, capacity building, and coordination, it offers the most reliable path to modern, secure, and fair food systems.

Conclusion and Recommendations

Traceability is no longer optional. It is a policy imperative. THEROS proves that a holistic, scalable, and interoperable framework is achievable. Policymakers should:

1. **Mandate interoperability and digital traceability** as a core compliance requirement in organic and GI food supply chains.
2. **Support adoption of THEROS tools** by public authorities through funding incentives and training programs.
3. **Update certification schemes** to incorporate technology-based traceability standards (e.g. blockchain, sensor data).
4. **Promote public-private partnerships** to test and scale traceability innovations.
5. **Establish EU-wide guidance** on data harmonisation and traceability verification using platforms like THEROS.

Endnotes

Young & Quinn (2002). Writing Effective Policy Papers [2].
THEROS Project – Horizon Europe, GA No. 101083579.
European Commission Regulations on Organic and GI Products (EU 2018/848) [3].

Toward a Connected Food Chain: Enabling Interoperability for Smarter Governance

A Policy Brief

Executive Summary

Modern agri-food systems are awash with data—from satellites, sensors, DNA tests, and supply chain transactions. Yet without seamless interoperability across systems, this diversity remains underutilized, fragmented, or even contradictory. The EU-funded THEROS project demonstrates how harmonising data streams through a unified digital framework can empower certification bodies, improve compliance monitoring, and support more sustainable agriculture. This policy brief outlines the interoperability challenge and proposes actionable strategies for unlocking the full value of diverse data in food systems.

Introduction

The digitalisation of agriculture and food governance has brought a surge of new data sources, offering enormous potential to improve oversight, reduce fraud, and enhance sustainability. However, most systems—public or private—operate in isolation. This siloed structure creates inefficiencies, errors, and gaps in decision-making. THEROS, a Horizon Europe project, has developed a comprehensive platform architecture designed to enable data interoperability across critical functions: food authenticity verification, traceability, environmental performance, and certification support.

Problem Description

Despite the availability of rich datasets, control authorities and food system actors often struggle to connect and interpret them effectively. Key challenges include:

- Incompatible data formats across technologies (e.g. Earth Observation, IoT, lab results).
- Lack of shared standards for integrating public and private digital tools.
- Limited real-time interoperability, making compliance checks reactive instead of proactive.
- Data overload without actionable insights due to disconnected infrastructures.

In short, the value of data is being lost in translation—with critical consequences for food integrity, environmental accountability, and regulatory enforcement.

Policy Options

Option 1: Maintain Fragmented Digital Systems

- Low-cost in the short term but perpetuates inefficiencies and weakens systemic oversight.

Option 2: Promote Sector-Specific Digital Innovations

- Encourages development but increases integration burdens across different actors and contexts.

Option 3: Advance Interoperability-First Policy Frameworks

THEROS has demonstrated how to achieve system-wide harmonization:

- Data Harmonisation Platform: Integrates inputs from satellite imagery, mobile apps, DNA-based lab results, IoT monitoring, and certification systems.
- Verification Engine: Applies business logic to incoming data to verify authenticity, origin, and compliance.
- Operational Toolbox Architecture: Modular system enabling flexible integration with existing tools via open APIs and translators.
- Cross-Pilot Validation: Deployed across Greece, Spain, Serbia, and Czech Republic with confirmed cross-system functionality.
- Green Accountability Tool: Visualizes harmonized data to assess environmental impacts in real-time.

Conclusion and Recommendations

As food systems become more data-driven, interoperability must become a policy priority—not a technical afterthought. Policymakers can catalyse this shift by:

1. **Setting minimum interoperability standards** for food traceability and certification systems.
2. **Funding shared data infrastructure**, like harmonisation platforms and open-source APIs.
3. **Mandating compatibility across public procurement and certification platforms.**
4. **Establishing national or regional digital food observatories**, modelled on THEROS architecture.
5. **Incentivizing private sector compliance** with interoperable formats through certification benefits.

Endnotes

Young & Quinn (2002). Writing Effective Policy Papers [2].
THEROS Project – Horizon Europe, GA No. 101083579.
The Digitalisation of the European Agricultural sector [4].
Interoperability in data spaces: Building Europe's digital future [5].

Digital by Default: Modernising Agri-Food Compliance Across the EU

A Policy Brief

Executive Summary

The EU agri-food sector faces mounting challenges: climate change, food fraud, sustainability requirements, and increasingly complex compliance obligations. Traditional systems of inspection, traceability, and certification—largely paper-based and labour-intensive—are no longer sufficient to ensure transparency and integrity. Digital solutions offer a transformative opportunity to modernize compliance, improve traceability, and reduce the burden on both regulators and producers. This policy brief outlines the need for scalable, secure, and interoperable digital tools within the EU's Common Agricultural Policy (CAP) framework. Drawing on insights from the Horizon Europe THEROS project, it highlights how emerging technologies like blockchain, AI, Earth Observation (EO), and mobile sensors can be integrated to support compliance with organic, environmental, and food safety standards.

Introduction

The EU Green Deal, Farm to Fork Strategy, and CAP 2023–2027 call for a digital and sustainable transformation of agriculture. Central to this vision is the ability to verify claims—about sustainability, organic status, and food quality—through reliable, data-driven systems. Yet, many monitoring and verification processes are still manual, prone to error, and difficult to scale. Digital technologies are no longer optional—they are essential for ensuring the resilience, credibility, and efficiency of Europe's agri-food systems. Projects like THEROS demonstrate how digital tools can be effectively deployed for traceability, fraud prevention, environmental monitoring, and compliance verification.

Problem Description

The current regulatory and monitoring system suffers from key limitations:

- Manual inspections and declarations are time-consuming and susceptible to fraud or error.
- Data silos and paper-based systems hinder transparency, traceability, and coordination between actors.
- Small producers and authorities often lack access to cost-effective compliance tools.
- Lack of integration between systems (e.g., soil, crop, transport, certification) reduces the impact of isolated digital tools.

The EU is falling short in its capacity to monitor organic production, ecological practices, and sustainability claims at scale. Without a coordinated digital transformation, enforcement gaps will widen as regulations become more complex and data intensive.

Policy Options

Option 1: Continue with Analog and Fragmented Digital Systems

This option maintains the status quo: limited use of digital tools, often developed independently with no shared standards. While familiar and low risk in the short term, this approach cannot scale with the increasing demands for transparency, environmental data, and product authentication.

Option 2: Promote Digital Innovation at Sector Level

Member States or sectors (e.g. organic certification bodies) may adopt technologies independently. While this fosters experimentation, it risks fragmentation and redundancy. Without interoperability, trust and data utility are diminished.

Option 3: Advance an EU-Wide Digital Compliance Framework (THEROS Approach)

This strategic option involves coordinated investment and policy support for a unified, interoperable digital ecosystem. Drawing on the THEROS toolbox, the framework would include:

- Mobile-enabled MEMS spectrometers for field-level quality and soil analysis.
- EO-based monitoring services for organic farming and CAP compliance.
- Blockchain-enabled traceability systems to record and verify transactions along the supply chain.
- Green Accountability Tools for environmental performance monitoring.
- Digital marketplaces integrated with verified datasets to connect producers and consumers transparently.

These tools are interoperable, scalable, and validated through real-world pilots in Greece, Spain, Serbia, and the Czech Republic.

Conclusion and Recommendations

Digital transformation is not a matter of convenience—it is a requirement for a modern, credible, and sustainable food system. The EU must seize this opportunity to embed digital solutions into agri-food compliance structures.

Key Policy Recommendations:

- Mandate digital recordkeeping and traceability as part of CAP compliance and official inspections.
- Establish open standards and APIs for interoperability between national, EU, and private sector platforms.
- Invest in digital infrastructure and cloud-based compliance tools, especially for smallholder and organic producers.
- Incentivize innovation and adoption through CAP eco-schemes, digital vouchers, or certification fast-tracking.
- Support cross-border pilot projects to refine and harmonize digital solutions, building on projects like THEROS.

Endnotes

Young & Quinn (2002). Writing Effective Policy Papers [2].
THEROS Project – Horizon Europe, GA No. 101083579.
European Commission (2020). Farm to Fork Strategy [6].
Regulation (EU) 2021/2115 on CAP Strategic Plans [7].

Protecting What Matters: A Policy Agenda to Tackle Food Fraud in Organic and GI Markets

A Policy Brief

Executive Summary

Organic and Geographical Indication (GI) food products represent the highest standards of quality, tradition, and sustainability in the EU. However, their premium value also makes them frequent targets of fraud—ranging from false labelling and adulteration to unauthorized use of certification logos. Food fraud not only undermines consumer trust but also damages producers, distorts markets, and erodes the credibility of the EU's quality schemes. The THEROS project offers a new toolbox of digital and scientific solutions—such as blockchain traceability, DNA-based authentication, MEMS-based field testing, and satellite monitoring—to detect and prevent fraud in real-time. This policy brief calls for stronger enforcement, digital transformation, and harmonized approaches to protect the integrity of organic and GI products across the EU.

Introduction

EU quality labels—such as Organic, Protected Designation of Origin (PDO), and Protected Geographical Indication (PGI)—are essential for promoting rural development, preserving cultural heritage, and enabling consumers to make informed choices. Yet, their growing popularity and market value also expose them to fraudulent practices. According to the European Commission, food fraud costs the EU billions annually and is increasingly sophisticated. To remain credible, organic and GI certification systems must evolve with modern tools that can verify claims, detect anomalies, and support rapid enforcement. Projects like THEROS demonstrate that such tools are now viable, scalable, and field-ready.

Problem Description

Fraud in organic and GI products can take many forms, including:

- Mislabeling: Conventional products sold as organic or falsely bearing PDO/PGI labels.
- Adulteration: Dilution, substitution, or contamination of products (e.g. adding non-certified ingredients).
- False origin claims: Products marketed as coming from specific regions or using traditional methods without proper certification.
- Certification abuse: Forged or expired certificates, unverified logos, or unregulated supply chain actors.

Challenges in combating this fraud include:

- Manual inspection systems that are reactive and resource limited.
- Limited traceability between farm, processor, distributor, and retailer.
- Lack of harmonized data standards across Member States and certifying bodies.

Insufficient real-time tools to verify claims or detect fraud signals at scale.

Policy Options

Option 1: Strengthen Traditional Inspections and Documentation Requirements

This approach increases paperwork and manual audits. While it may catch some forms of fraud, it is expensive, time-consuming, and difficult to scale—particularly as organic and GI markets grow.

Option 2: Promote Voluntary Adoption of New Technologies

Encouraging industry-led innovation (e.g. QR code tracking or random product testing) can yield some success. However, without official validation and regulatory integration, these tools often lack legal weight and consistent use.

Option 3: Institutionalize a Multi-Layered Digital Anti-Fraud Framework (THEROS Model)

This proactive and systemic approach involves the coordinated adoption of smart tools developed and tested by the THEROS project:

- **Blockchain Traceability:** Secure, tamper-proof tracking of supply chain events.
- **MEMS Photonic Sensors:** Handheld field devices for in-situ testing of food composition and purity.

- **DNA Authenticity Kit:** Portable device for scientific validation of product origin or species.
- **EO Monitoring Tools:** Remote sensing of farming practices, land use, and crop cycles to verify organic claims.
- **Green Accountability Tool:** Assesses sustainability performance using traceable environmental data.
- **Digital Marketplace Integration:** Allows transparent consumer-facing verification of quality labels.

Together, these tools offer a resilient, real-time defence system against fraud in organic and GI food chains.

Conclusion and Recommendations

Protecting the credibility of organic and GI food systems is not only about consumer protection—it's about economic fairness, sustainability, and rural integrity. Food fraud undermines every one of these goals. Digital and scientific tools now offer a clear path to more effective, efficient, and trusted enforcement.

Key Policy Recommendations:

- Make digital traceability mandatory for organic and GI-certified supply chains.
- Recognize blockchain and scientific testing as official compliance and fraud-detection tools.
- Harmonize anti-fraud procedures across Member States, using interoperable platforms.
- Support certifying bodies with capacity-building and digital infrastructure funding.
- Incorporate THEROS-style technology pilots into CAP eco-schemes and organic policy frameworks.

Endnotes

Young & Quinn (2002). Writing Effective Policy Papers [2].
THEROS Project – Horizon Europe, GA No. 101083579.
2020 Annual Report: The EU Agri-Food Fraud Network [8].
EU Regulation 2018/848 on organic production [3].

Empowering the Informed Consumer: Closing the Knowledge Gap in EU Quality Labels

A Policy Brief

Executive Summary

While EU labels like Organic, Protected Designation of Origin (PDO), and Protected Geographical Indication (PGI) are designed to signal quality, tradition, and sustainability, many consumers still lack a clear understanding of what these labels mean, how certification works, or how to verify authenticity. This knowledge gap limits the impact of quality schemes, reduces consumer trust, and leaves room for fraud and greenwashing. Digital tools—such as QR-code-based traceability, blockchain verification, and mobile transparency apps—can play a vital role in making label information accessible, trustworthy, and easy to understand. This policy brief outlines the need for enhanced consumer education, digital transparency mechanisms, and EU-level strategies to empower shoppers and reinforce the credibility of quality labels.

Introduction

The EU has invested decades in building robust quality schemes to promote regional identity, biodiversity, animal welfare, and food authenticity. The Organic and GI labels are among the most recognized symbols in Europe's food system—but recognition does not equal understanding. In a 2020 Eurobarometer survey, while 96% of EU consumers recognized the organic label, only a fraction could correctly define what it means or distinguish it from similar, uncertified claims. With rising concerns over sustainability, health, and food fraud, empowering consumers with clear, credible information is more important than ever.

Problem Description

Despite wide label visibility, consumer knowledge remains shallow and inconsistent:

- Many consumers cannot distinguish certified organic/GI products from vague or misleading marketing claims.
- QR codes and certification numbers are often ignored due to poor interface design or lack of explanation.
- Younger and lower-income groups are especially vulnerable to misinformation or price-based deception.
- Limited feedback loops between certifiers, producers, and consumers reduce transparency and engagement.

As a result, well-intended EU quality labels are underutilized, and their market potential is not fully realized.

Policy Options

Option 1: Continue Awareness Campaigns Without Systemic Change

While basic promotional campaigns raise label visibility, they often fail to convey actionable knowledge or engage consumers in meaningful ways. This low-impact approach cannot keep pace with rising consumer demand for verified, transparent food information.

Option 2: Promote Decentralized Digital Transparency Tools

Mobile apps, QR-code tracing, and producer websites can offer more information—but without coordination or verification, these tools are fragmented and can be misused. Consumers are left to interpret inconsistent data on their own.

Option 3: Develop a Coordinated EU Consumer Transparency Strategy Using THEROS-Inspired Tools

This approach integrates public information campaigns with modern technology and participatory verification tools:

- QR-code integration with blockchain-based traceability platforms for verified supply chain data.
- User-friendly mobile MEMS that translate certification data into clear claims and visual scores (e.g., purity, organic compliance).
- Digital Dynamic Product Passport (dDPP) that consolidate all relevant product information—origin, certifications, compliance history etc. into a single, scannable interface.

- Interactive maps and storytelling tools that showcase regional value and environmental benefits of GI/organic practices.
- Digital Marketplace platforms with built-in fraud alerts, certification status, and product origin verification.

Conclusion and Recommendations

Consumers are key actors in enforcing food integrity—but only if they are well-informed and empowered. The EU must go beyond passive awareness and deliver actionable, verified, and easy-to-use digital transparency tools to bridge the knowledge gap.

Key Policy Recommendations:

- **Support interoperable digital transparency tools** that connect certification systems with consumers in real time.
- **Mandate the use of scannable, verifiable QR codes** on all organic and GI-labelled products.
- **Fund digital literacy and food label education campaigns**, especially targeting youth and urban consumers.
- **Integrate consumer feedback and fraud reporting systems** into digital platforms to close the accountability loop.
- **Include transparency and consumer engagement metrics** in CAP and Organic Action Plan evaluations.

Endnotes

Young & Quinn (2002). Writing Effective Policy Papers [2].
THEROS Project – Horizon Europe, GA No. 101083579.
Food labelling in the EU: Consumers can get lost in the maze of labels [9].
EU Organic Regulation 2018/848 [3].

Annex 4: EU Cluster for Food Traceability and Trust

Project Name	Description
ALLIANCE alliance-heu-project.eu	ALLIANCE aims to provide a holistic framework that safeguards data integrity and veracity, enhances traceability and transparency and reinforces interoperability in the quality labelled food supply chain through innovative technology solutions and validated approaches that fosters evidence-based decision making. The project leverages the power of emergent technologies to ensure capillar data collection, data veracity and integrity, and proactive risk management. ALLIANCE strengthens the geographical indication and organic food quality labels by ensuring the integrity and authenticity of these labels and by improving the traceability of the environmental impact and the sustainability of these products. Finally, it will equip food actors, farmers, public authorities, and policy makers with meaningful insights through 7 diverse use cases.
Watson watsonproject.eu	WATSON is developing a set of tools and systems that can detect and prevent fraudulent practices across the entire food supply chain. It will increase transparency through improved track-and-trace mechanisms containing accurate, time-relevant and untampered information on the food product throughout its whole journey. The project will also raise consumer awareness about food safety and value, leading to the adoption of healthier lifestyles and the development of sustainable food ecosystems. Moreover, it will demonstrate the solutions in six different use cases across a number of key food supply chains, covering important commodity groups in the European food system (e.g. wine, olive oil, honey, meat, fish, cereal and dairy).
FishEUTrust fisheutrust.org	FishEUTrust will establish five Co-creation Living Labs in the Mediterranean Basin, the North Sea and the Atlantic Sea. These will enable innovation and process validation and demonstrate the project's supply chain solutions. Examples of supply-chain innovation include creating sustainable business models, protecting cultural and culinary heritage, short food supply chains, exploiting underused fish species, and innovative engagement activities to stimulate positive consumer behaviour. The project will also develop tools to maximize trust by guaranteeing the quality, safety, and traceability of seafood products based on

Funded by the European Union

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Project Name	Description
	smart control systems (sensors), metagenomics, genetic biomarkers, isotopic techniques, and labelling/product passport/blockchain). These tools will be integrated into a single digital FishEUTrust data platform.
SEA2SEE sea2see.eu	SEA2SEE is an innovative European project which main goal is to make actors with sustainable seafood practices more visible to consumers thus giving them a competitive advantage. SEA2SEE project comes to fill in existing seafood traceability gaps through the development of an innovative end-to-end blockchain-based platform, along with professional and consumer applications to increase trust and social acceptance of sustainably fished and farmed seafood. The main objective of SEA2SEE is to significantly increase consumer trust and acceptance of sustainably fished or farmed seafood in Europe through the development and demonstration of an innovative end-to-end blockchain traceability model throughout the seafood value chain and the implementation of societal and sectoral strategies for co-creation, communication and awareness raising about the benefits of sustainably fished or farmed nutritious seafood. SEA2SEE holds significant potential to increase the consumption of sustainably fished or farmed seafood among European consumers by engaging them in providing trustworthy traceability information through participatory demonstrations of the use of web-based and digital tools.
CUES cuesproject.eu	CUES addresses the urgent need for a more sustainable food system that benefits the environment, society, and the economy. The project aims to foster a Triple Change in the food system concerning culture, food value chain, and policy. To this end, CUES will pilot nine food system interventions and policy dialogues, actively involving consumers, food value chain actors and policymakers. A learning community and toolkits for behavioural change and communication will be developed to motivate 3 million consumers to make sustainable food choices.
TEALHELIX https://www.tealhelix.eu/	The TealHelix project aims to improve how consumers make decisions about sustainable food by creating more personalised and inclusive labelling approaches. Using a method called motivational matching, we will develop new types of labels and digital tools to help people understand and choose more sustainable options. This personalised approach will also help overcome resistance to sustainability and meet the different needs of vulnerable consumers. We will combine knowledge from life cycle analysis, social and economic environments, and consumer behaviour to create a new way of aligning individual preferences with sustainability goals. Different types of labels, such as traditional, digital, and smart labels, will be tested in

Project Name	Description
	stores and online. To ensure lasting impact, we will also create industry standards for transparency and information on sustainability. The project will use advanced research methods, such as machine learning, surveys, and experiments, to study labelling approaches and gather evidence. In the end, these insights will be integrated into digital tools powered by AI to support better labelling solutions, helping consumers adopt sustainable practices while including those most in need.
TITAN https://titanproject.eu/	TITAN is a 4-year project that will provide an extensive platform for the development of a wide range of innovations that aid transparency and address societal and planetary health to make the food system fair, healthy, and environmentally friendly. The innovations will be supported by cross cutting Work Packages dedicated to stakeholder interests, implementation of digital technologies, policy recommendations, business support, management and communication and dissemination. TITAN will develop 15 innovative solutions including DNA-based detection methods, Blockchain, Artificial Intelligence (AI), and Internet of Things (IoT) to enhance transparency in agri-food businesses with a focus on SMEs, improve food choices by providing more transparent information to the consumer, enhance food safety and authenticity of products and provide improved information on the health and sustainability of food products.
FOODGUARD https://www.foodguard-project.eu/	FOODGUARD aims to develop and demonstrate co-created solutions that will support innovations & advances based on microbiome, microbial activities & technology hubs to address food, health, economic and environmental challenges. The envisioned approach consists of a framework of toolsets and methodologies to provide sustainable solutions in food processing, packaging, and across the food value chain to address food shelf-life increase and waste reduction in a holistic manner. FOODGUARD toolbox components will be extensively evaluated in real life settings through four pilot demonstrations in four different countries with the involvement of all relevant actors while covering diverse requirements and different food products.
ROSETTA	ROSETTA is an EU-funded project under the Horizon Europe Programme committed to exploring the relationship between food waste and marketing standards. The project aims to pioneer sustainable solutions and transform our approach to food resources as we comprehend and quantify the influence of marketing standards on food waste. Our primary objectives include

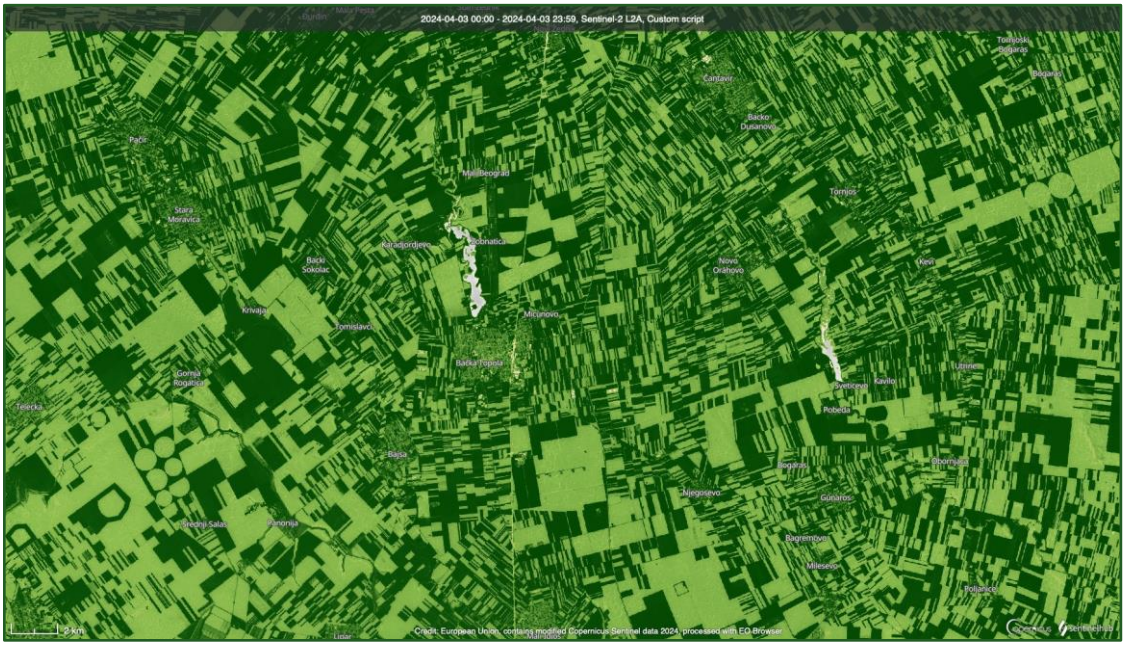
Project Name	Description
https://rosetta-project.eu/	the development of alternative marketing models, a mission we aim to achieve through 5 pilot cases (Ireland, Spain, Poland, Greece and Denmark). By leveraging these real-world scenarios, we aim to provide practical insights that will not only benefit businesses but also form recommendations for policy makers, marketing standards owners and regulators.
INFOODMENTION https://infoodmation.eu/	INFOODMATION aims to explore how mainstream media, social media, and marketing influence consumers' food choices.. The project will map communication strategies used by 3 key actors (governments, the private sector, and civil society) and assess their effects on dietary behaviors. This includes which channels, tools, and messages they use. It will also examine the effects of misinformation, the effectiveness of parental control and evaluate existing EU and national policies about food information to consumers. Through this analysis, INFOODMATION will identify best practices, develop responsible business strategies, and provide policy recommendations to foster healthier and more sustainable food choices among consumers., All project outputs, tools, and resources will be made available through the INFOODMATION Knowledge Hub, supporting food system actors in implementing responsible food communication strategies.
DRG4FOOD https://drg4food.eu/	DRG4FOOD paves the way for a trusted, data-driven food system that places consumer rights and digital responsibility at its core. Through a combination of pilot projects, open calls, and collaboration with innovators, the project explores how data can be used responsibly in areas like food traceability, targeted nutrition, and consumer empowerment. Building on these real-world experiences, DRG4FOOD is developing a European roadmap and a practical toolbox to guide policymakers, businesses, and civil society in designing food systems that respect privacy, enhance transparency, and empower citizens to make informed choices.
EFF-CoP http://www.eff-cop.eu/	EFF-CoP aim is to revolutionise the combat against food fraud and enhance transparency in our food supply chains. How? By establishing and mobilising The European Food Fraud Community of Practice (EFF-CoP), a sustainable Research and Innovation eco-system of food fraud researchers and end-users based on solid sociological principles. EFF-CoP has gathered a diverse group of stakeholders in our consortium and wider community, scientists, regulators, large and small-sized industry, certification scheme owners, the organic sector, fraud film festival organisers, the Food Authenticity Network and

Project Name	Description
	the Food Industry Intelligence Network, and many more to lay the groundwork. They are catalysers to start the conversations and reach out rapidly to a large number of prospective EFF-CoP members. That is only their beginning. They set out to understand the community's structure to discover the gaps and how they can start new conversations, they then will identify the needs of the various stakeholder groups and they have set up the EFF-Hub as their virtual headquarters. From now on, series of activities are rolled out – sharing existing research and innovation resources and educational materials, developing new ones – Good Practice Recommendations, factsheets, and case study materials, and they will host engaging virtual and live events to facilitate interactive collaboration. These events involve food fraud festivals, gamification-based training courses, living labs, 'authentic appetites' podcast series, the EFF-CoP on Tour program, webinars, virtual cafes, a food fraud incident preparedness workshop, and dedicated events for the future generation. EFF-CoP goal is to cultivate a vibrant community, a network of networks, at the end of the project, all dedicated to combating food fraud and learning from each other. To ensure our EFF-CoP stands the test of time, they are not only implementing the proven concept of 'CoP design for evolution' but also a comprehensive exploitation strategy and business plan. Together they will work towards a future with enhanced authenticity, traceability and transparency within our food supply chains.

Annex 5: THEROS Toolbox

EO based ecosystem services

The EO-Based Ecosystem Services module leverages satellite imagery and derived markers to monitor organic farming compliance and assess general parcel conditions. This module integrates with the DIAS/CDSE (Copernicus Data Space Ecosystem) and Amazon Web Services (AWS) Open Data storage, providing users with extensive satellite data archives and advanced machine learning models for area monitoring.



Example of satellite data input for EO based ecosystem service

Key Components:

i. *Image Provider*
   - Uses Sentinel Hub to efficiently retrieve Satellite Imagery.
   - Allows on-the-cloud processing of satellite imagery (i.e. computation of vegetation indices such as NDVI).
   - Enables access to custom data stored in cloud storage buckets.
   - Enables retrieval of temporal statistics over parcels to generate *signals* that are used as input for the markers.

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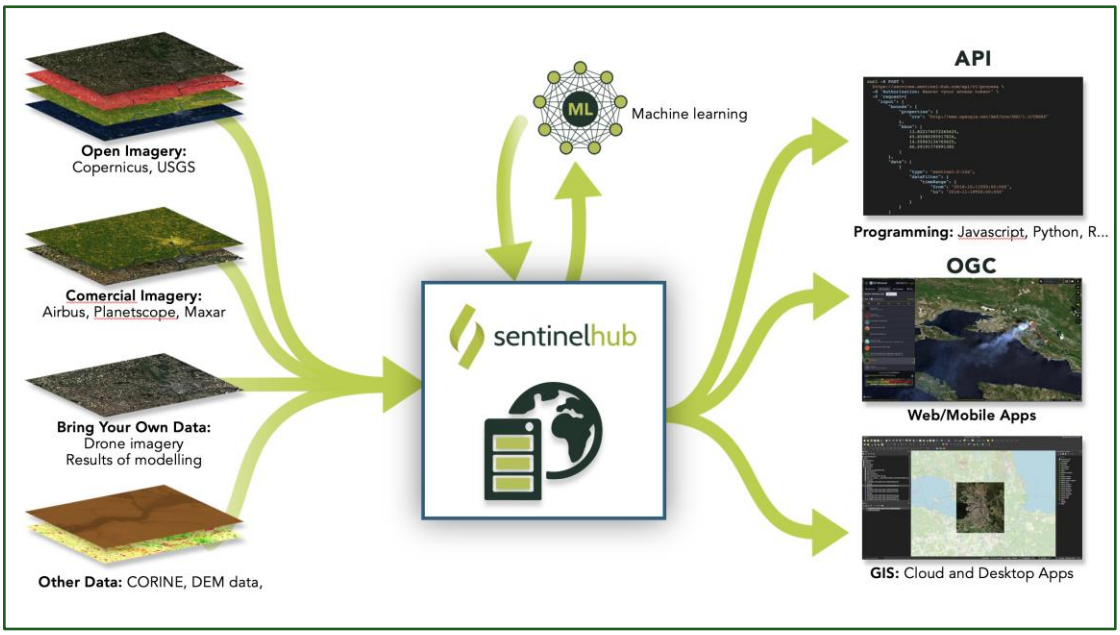


EO based ecosystem services and data flows

ii. *Marker Provider Module*

- Markers are insights about what is happening on the parcel derived from satellite (or other aerial) imagery.
- The module delivers computed markers for parcels within a specific area.
- Inputs include parcel identifiers, marker types, time range.
- Outputs are delivered in JSON format – they can either be classifications (i.e. the confidence of the model that the parcel is organic), events (i.e. the time period over which greening was detected on the parcel) or observation-based (i.e. the observations on which bare soil was detected).
- Utilizes the image provider module to source satellite imagery derived signals.

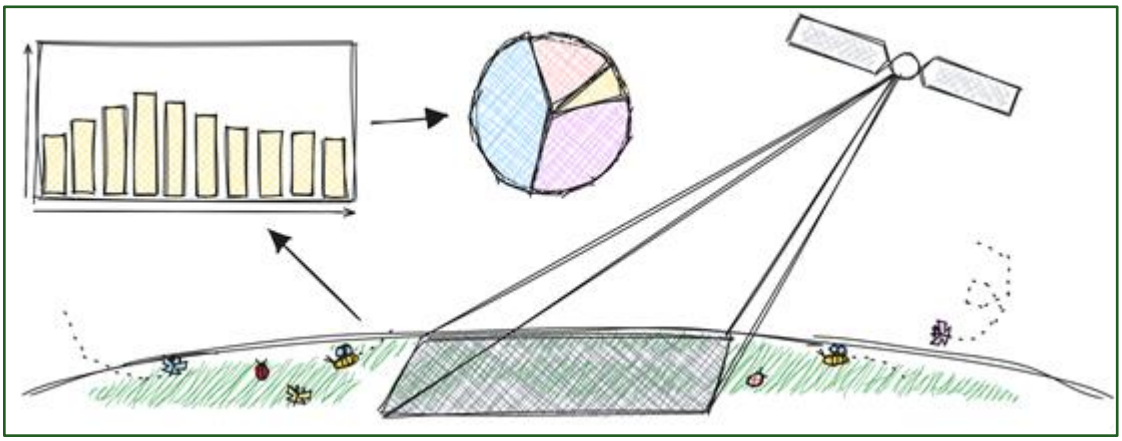


Image provider module for EO service

Interfaces

i. *Image provider*

- The image provider is based on Sentinel Hub, which allows retrieval of georeferenced raster data via it's API or through OGC compliant services
- The service offers various APIs (and more):
  - **OGC API**: Sentinel Hub allows retrieval of data seamlessly and effortlessly through the standard OGC services and enables access in standard GIS application with support for powerful WMS features.
  - **Processing API**: The Process API enables users to perform advanced processing tasks on satellite data. It supports the creation of custom image processing chains using a wide range of algorithms, including filtering, band math, index computation, and more.
  - **Statistical API**: Calculates statistics for a satellite image without downloading it. Calculate histograms, percentile calculations, and more.

ii. *Marker provider*

- Marker provider is connected to THEROS components through a Rest API.
- Marker information for a specific parcel can be retrieved by calling the service with the marker and scope identifier (where scope defines the area of interest and the time of interest).
- Marker provider returns results in JSON format.

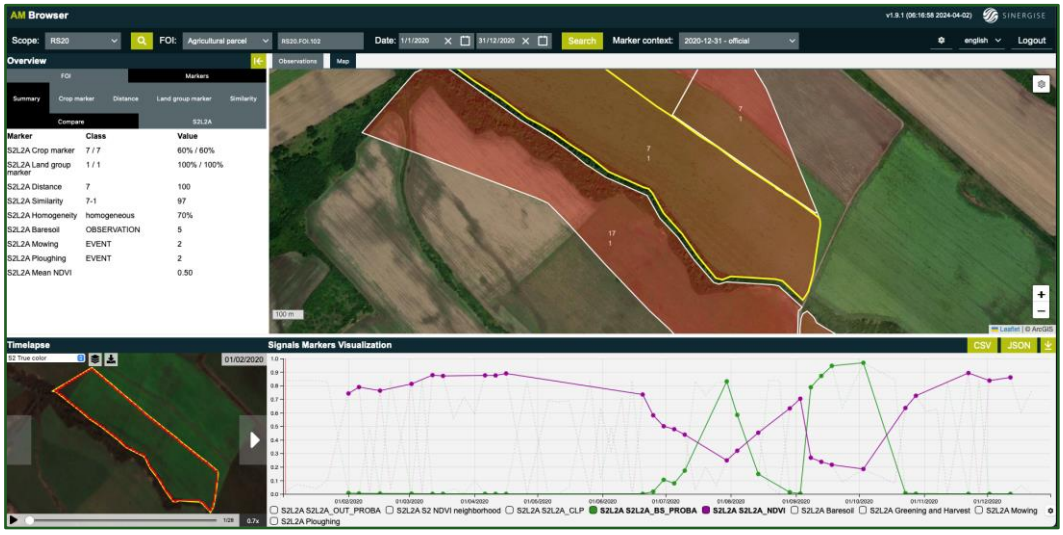
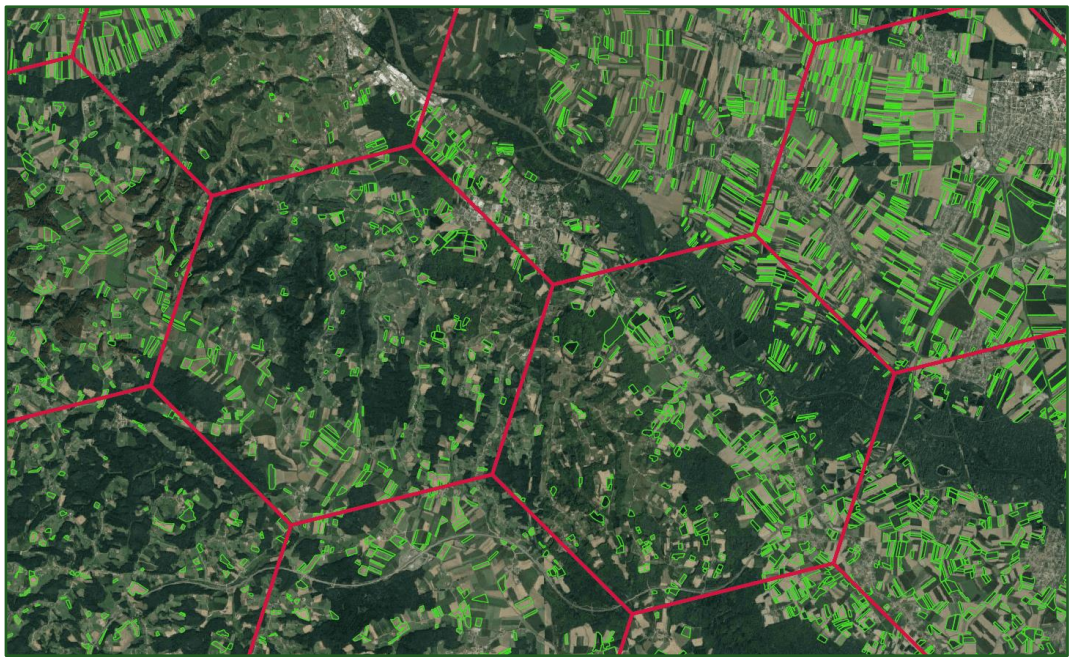


Image provider interface for EO based service

Services:

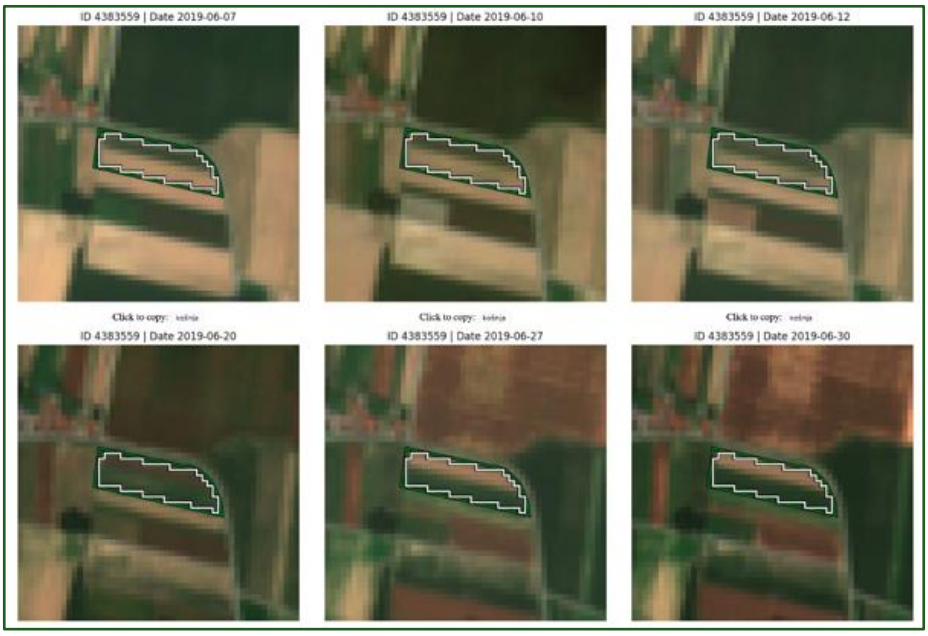
- **Imagery provider:** Given input parameters, return corresponding satellite / aerial / raster imagery for the given area.
- **Marker provider:** Retrieve marker information for a specific marker type and parcel.



Marker provider interface for EO based service

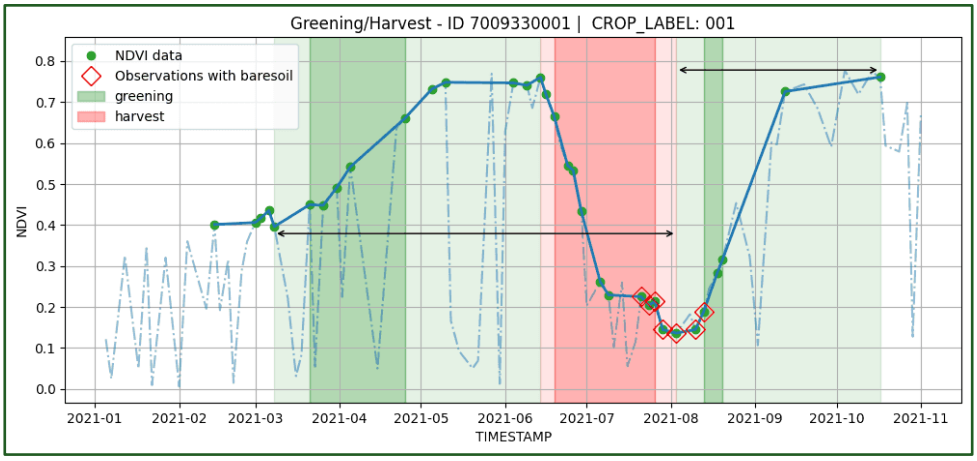
The following markers are currently computed and made available via the THEROS Marker provider:

- **Homogeneity marker:** The homogeneity marker serves to identify polygons on which several crops are being grown. The polygon for which the markers are computed should constitute only a single crop. This can help the certificate agency identify claims that are not consistent with the state on the ground.



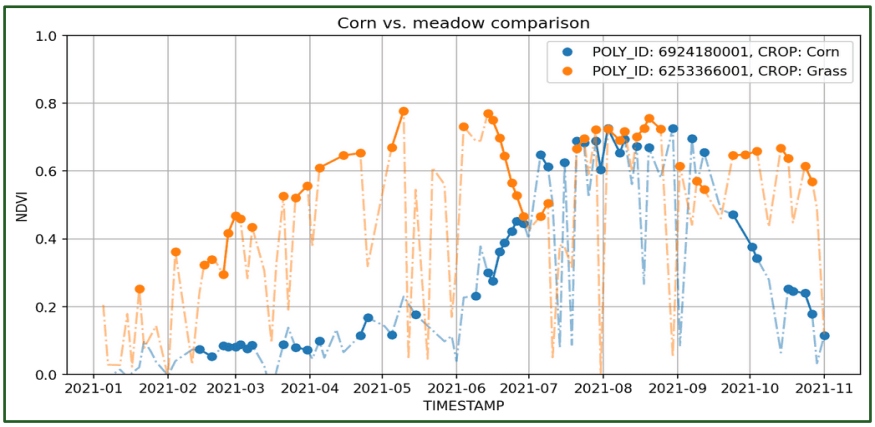
Homogeneity marker example

- **Greening and harvest marker:** The greening and harvest marker identifies greening and harvest phases in the FOI's NDVI time series and combines them into a single period that signifies the life cycle of a crop. It can be a very useful tool for detecting presence of catch crops or green cover and nitrogen-fixing crops, i.e. the management practices under the EFA obligation of which main objective it to safeguard and improve biodiversity on farms. The greening and harvest marker can give answers to the following questions: When was the main crop sown and when harvested? After the harvest of the main crop, when did the second crop start developing? Until when was the second crop present on the field, i.e. when was it harvested?



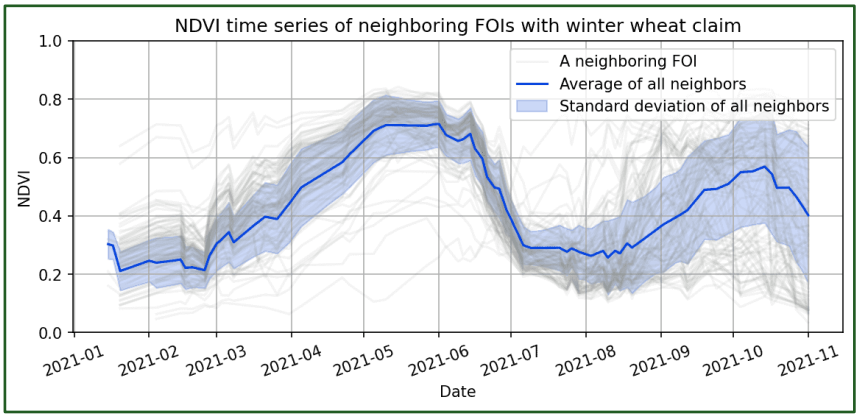
FOI's NDVI time series example

- **Bare soil marker:** The bare-soil marker identifies all observations with exposed bare soil due to field being recently ploughed, or due to non-photosynthetic vegetation cover. The latter can be a consequence of a harvest or vegetation drying up on the field. This can help identify periods where the field was bare and allow the agency to check whether this is consistent with what is being claimed.
- **Crop marker:** The crop marker can be used to determine consistency of an agricultural parcel (FOI) with its declared crop.
- **Organic / non-organic marker:** Similar methodology as is used for the crop marker is also used for the organic / non-organic marker. It checks whether a parcels temporal profile is consistent with a parcel that is grown as organic or not.



NDVI time series example for corn vs. meadow

- **Similarity and Euclidian Distance Marker:** Similarity and Euclidean distance markers belong to the group of crop classification markers. Output of both markers can be used to check validity of a FOI's claim. In their essence both markers compare signal time series of a FOI to signal time series of neighbouring FOIs. Similarity and Euclidean distance markers perform statistical comparison and don't require any model training, which is their biggest advantage.



NDVI time series example of neighboring FOIs

Usage and applications:

This module significantly enhances the monitoring capabilities for organic farming practices. It enables broad area monitoring of activities that are done on farms that are claimed to be organic. It aids in the precise identification of parcel conditions, using advanced statistical analysis and machine learning models that use satellite imagery as input.

Suitable for stakeholders in agricultural sectors who require accurate and up-to-date information on land use and compliance with organic farming standards over large areas quickly and efficiently. It helps with flagging suspicious activity and allows targeted spot visits to the parcels identified as suspicious.

MEMS based photonic systems

MEMS-based photonics systems represent a low-cost device for the rapid measurement of spectra, suitable for the accumulation of information related to agricultural products, either by directly scanning them or through soil scanning. These systems utilize miniature Vis-NIR spectrometers integrated into mobile applications, offering a user-friendly and efficient way to assess soil and food quality.

Key Components:

To retrieve the information contained in a single spectral signature, three key components are required:

i. *Mobile Application:*

It is a unified interface used for operating MEMS-based photonics devices and assisting the operator to capture the reflectance of the food or soil asset. Through intuitive graphical user interface, the user can follow an easy step by step procedure and capture the required spectral signature through the point and shoot method. As a minimum operational requirement, each application should enable the user to offload the captured data, while the THEROS application automatically transmits the obtained spectral signatures to the THEROS harmonization platform. This data transmission complies with security protocols that ensure that no data spoofing or loss will take place and facilitates data archiving and the production of analysis-ready data. Furthermore, the captured reflectance is visualized, while the extracted information is provided as a report containing specific information per use case (i.e. organic farming compliance marker, product purity score to address product adulteration, and key soil properties quantification).

ii. *Food & Soil Spectral Libraries:*

To convert each measurement obtained via the mobile application, a spectral library is required (Food or Soil accordingly). The library consists of a large number of different spectral signatures coupled with reference measurements (i.e. chemical analyses, or organic/conventional farming labels). These datasets a) will be enhanced with new measurements captured through the THEROS pilot demonstrations and b) will be used as calibration and validation sets for developing AI models for extracting the targeted information as modelling estimations.

iii. *AI Tools for Data Transformation:*

The AI component is used to transform a spectral signature to meaningful indicators of either soil or food assessment. To this end, state-of-the-art techniques are used to provide results with low uncertainty, end enhance organic farming certification, combat food adulteration and provide farmers with soil quality reports.

Interfaces:

- Spectral data collection via Vis-NIR scanning devices.
- ML & DL algorithms for data analysis.
  Mobile application UI for data visualization and report generation.

Services:

i. *Product Purity Index:*

Estimates product purity by analysing possible adulteration of food products.

ii. *Organic Food Labelling Detection:*

Develops deep learning classifiers to differentiate between organic and non-organic products.

iii. *Soil Quality Assessment:*

Provides quantified information on soil properties such as organic carbon, clay content, acidity/alkalinity, calcium carbonates, and salinity.

Usage and applications:

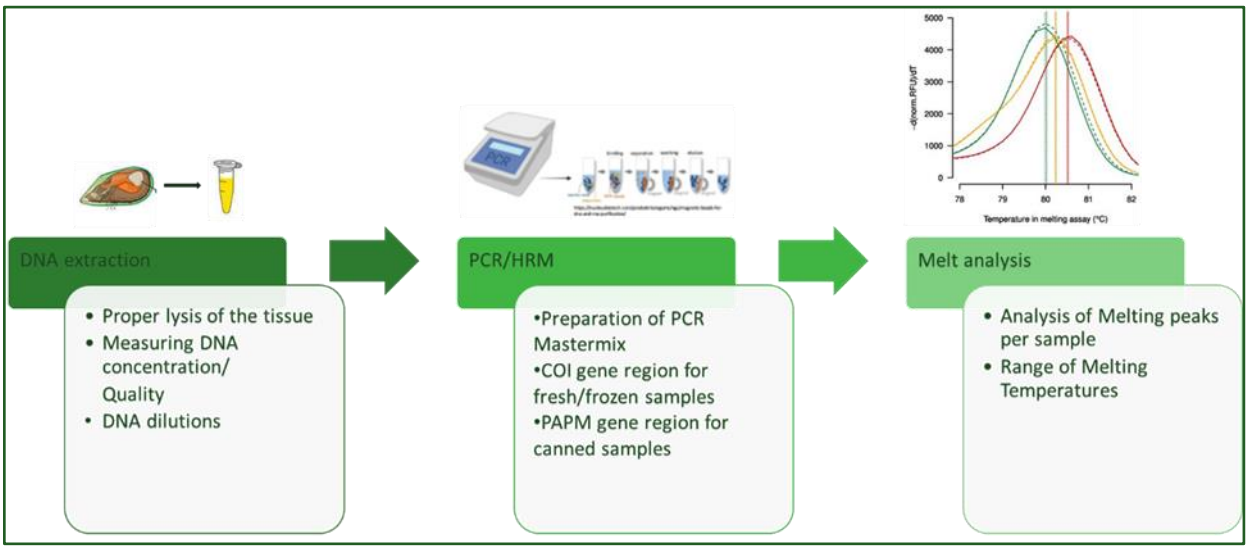
Designed for simplicity, the system employs a "point-and-shoot" method, enabling farmers, certification bodies, and retailers/wholesalers to easily assess soil and food quality. The mobile application could operate without an internet connection, storing data for later transmission. This technological advancement supports sustainable farming practices, compliance with organic standards, and enhances food safety monitoring.

DNA based authenticity kit

The DNA based authenticity kit module comprises of portable DNA based molecular methods, allowing rapid extraction of DNA profiles and their automated transformation on meaningful information regarding the verification of species origin, provenance of the food product and protecting the final consumers from adulteration issues. The DNA based authenticity kit consists of 2 parts: hardware and software. The hardware part is the main device for the HRM analysis process, that contains the Maverick MQx8 qPCR instrument and the laptop that is attached to the device. The software part is the Anitoa (Anitoa Systems, LLC), which is the main analysis tool that receives, processes and reports data and results. The output of the tool will be harmonized and properly aligned with the critical tracking events of the product through the THEROS data management and harmonisation platform, whilst allowing the information to be available through the blockchain based traceability network. All data collected and provided will feed the THEROS rule-based verification engine that will validate with respect to species and origin and enable the execution of transactions only if the genetic signature of the product has not been altered/manipulated. The checkpoints where the DNA test will be applied are 3. The first point will be at the landing port where the mussel is offloaded by the producers

(Verification point 1). The other DNA samples will be done in the transformation stages at the 2 processing companies. One of the products tested will be fresh product (Verification point 2) and the other cooked canned product (verification point 3).

Key Components:



Key Components of the DNA based authenticity kit

i. *DNA Extraction:*

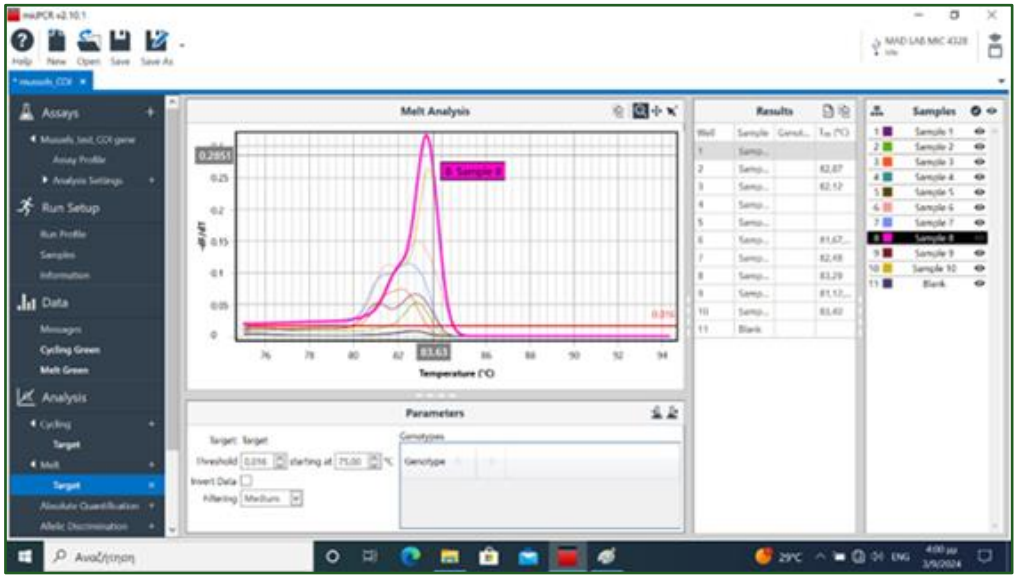
- Sampling procedures are performed according to the standard procedures that are applied for GMO detection (based on ISO/FDIS 6498:2011). Four subsampling operations are implemented to reduce the subsampling errors, (Esbensen and Paasch-Mortensen, 2010): 1. Composite subsampling (or incrementing), 2. Comminution (particle size reduction), 3. Mixing/blending, 4. Representative mass reduction.
- DNA is extracted from multiple samples of the product under investigation through the application of specific molecular methods to obtain genetic material (DNA).
- The molecular methods of DNA extraction will be applied on cultivation sites and through different preparation stages (packaging, transportation, etc.) of the final product, all the way to the selling points of the products, in order to prevent any adulteration issues.

ii. *PCR & HRM Analysis:*

- PCR analysis is performed on a portable device that is connected to a laptop powered by a portable battery.
- PCR analysis is based on a specific molecular method that allows the amplification of a specific gene of interest, in our case, the COI gene region for fresh/frozen samples and PAPM gene region for fresh/frozen and canned samples that will allow the rapid identification of the species origin, based on the nucleotide differences of the DNA sequences.
- After the PCR analysis, HRM analysis is performed on the amplified DNA sequences based on their melting temperatures.

iii. *<u>High Resolution Melting profiles& Melt temperatures:</u>*

- High-resolution melting (HRM) profiles are generated, providing numerical data corresponding to melting temperatures.
- Melting temperatures are specifically based on the amplified DNA sequences and can detect any DNA alterations specific to each organism.
- Specific melting temperatures from each sample correspond to a specific species' origin.
- The software provides results in a csv/pdf file regarding the confidence values of the results.



Melting curves and Melt temperatures from the PCR/HRM analysis

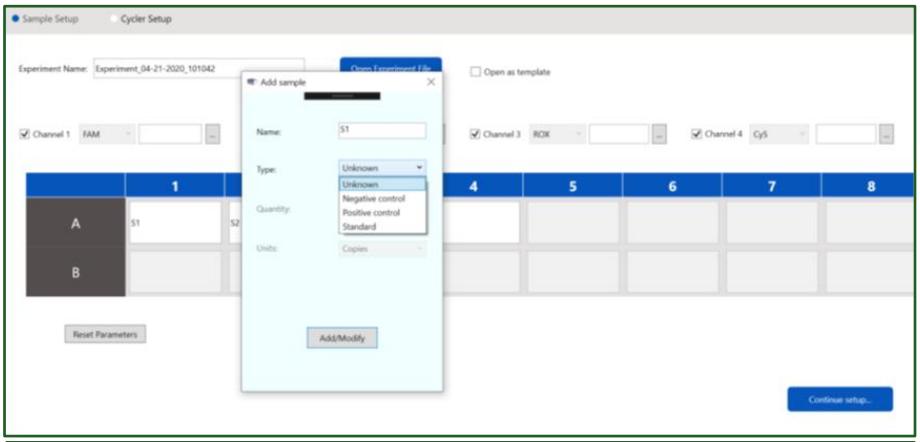
iv. *<u>Origin Verification provider</u>*

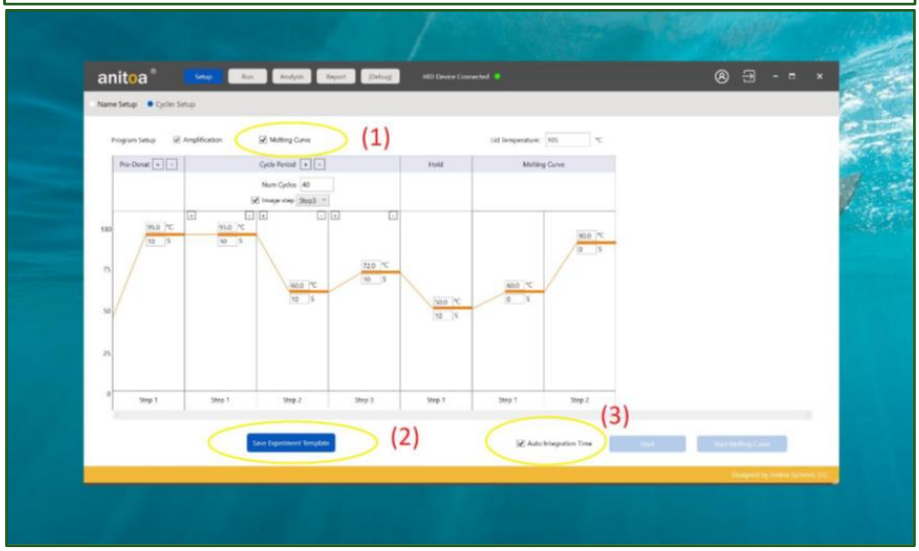
- Results are compared with a trusted source or database of species.

Interfaces:

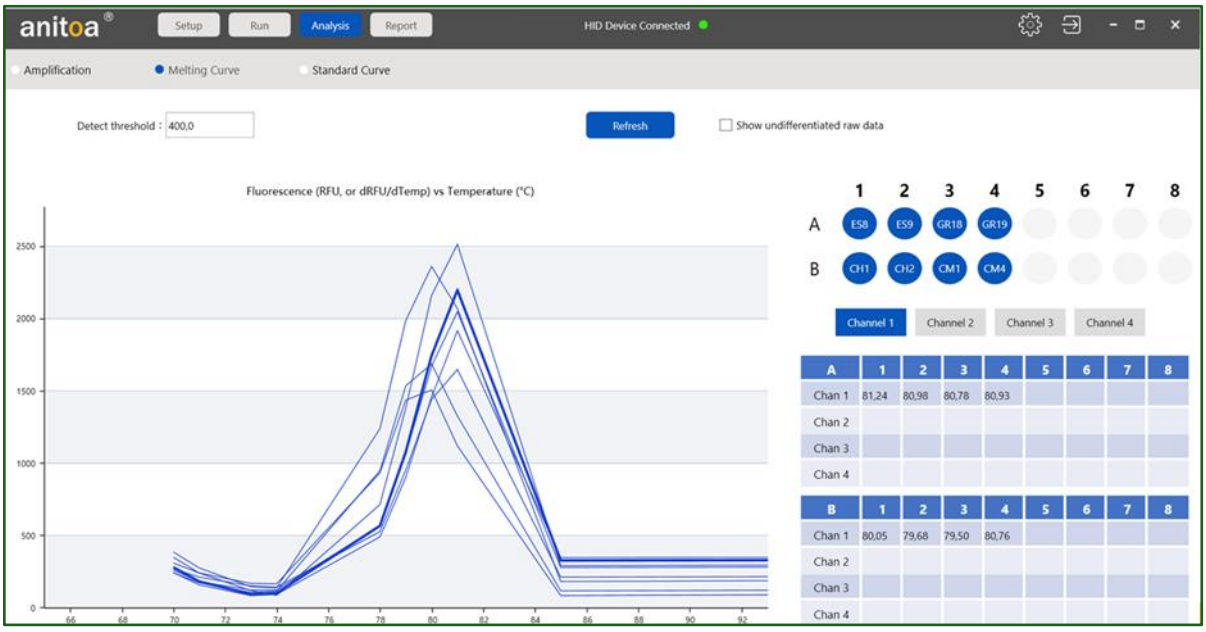
- HRM profiles and melting temperatures are provided through the analysis performed by specialized software that reports the data in real time on the connected laptop along with the PCR and HRM analysis, that is performed by the portable device.

PCR and HRM analysis performed by portable device





Interfaces of cycler set up



HRM profiles and melting temperatures

Services:

i. *Origin verification:*

- Based on the DNA analysis, the aim is to verify the origin of the species that is labelled on a specific product.
- The amplified DNA sequences that are produced through the PCR, are subjected to HRM analysis that produces the HRM profiles and melting temperatures that correspond to specific species.
- The data generated by HRM analysis are then analysed and compared to a database.
- Specific adulteration detection methods based on specific molecular techniques are applied to the food products, ensuring the correct labelling of the final product that reaches the consumers.

Usage and applications:

This module significantly enhances the monitoring capabilities for adulteration issues and mislabelling of the food products. The application of specialized and robust molecular methods will be applied to fresh products throughout the whole process of cultivation, packaging, transportation and selling points, ensuring that the final consumers are protected from adulteration events. The kit aims at increasing traceability and transparency for the producing and supply chain of the mussels' products, providing the consumers with validated information regarding the species identity and the geographic origin of the products.

This module significantly enhances monitoring capabilities for adulteration issues and mislabelling of the food products. The application of specialized and robust molecular

methods will be applied to fresh and canned products throughout the whole process of cultivation, packaging, transportation and selling points, ensuring that the final consumers are protected from adulteration events. The DNA based authenticity kit is suitable for stakeholders in the food sector who acquire accurate information on the origin of the food products. Also, it is suitable for certifications authorities as it facilitates a more accurate identification method of possible adulteration events based on specialized molecular techniques. The kit is suitable for stakeholders in the food sector who acquire accurate information on the origin of the food ingredients. Also, suitable for certifications authorities as it facilitates a more accurate identification method of possible adulterations based on specialized molecular techniques.

IoT sensor network

A network of IoT sensors is capable of monitoring quality parameters and verifying supply chain processes. The sensor network will enable combined monitoring of both climatic conditions during the transport of organic products and the registration of individual types of goods during loading and unloading.

Example of delivery package with installed monitoring unit

Key Components:

i. *Sensors:*

- Devices monitoring temperature and humidity inside of the package with products.

- Data are collected on internal memory and based on the version of the sensors – either sent by IoT network/GPRS to the SensLog data storage.

ii. *SensLog:*

- It provides receiving, storing, processing and publication of various sensor data.
- It contains the data model for the storage of observations and the main storage in the database.
- It has different REST APIs for data receiving and publication, proprietary or standardised.

iii. *SensLog Connector:*

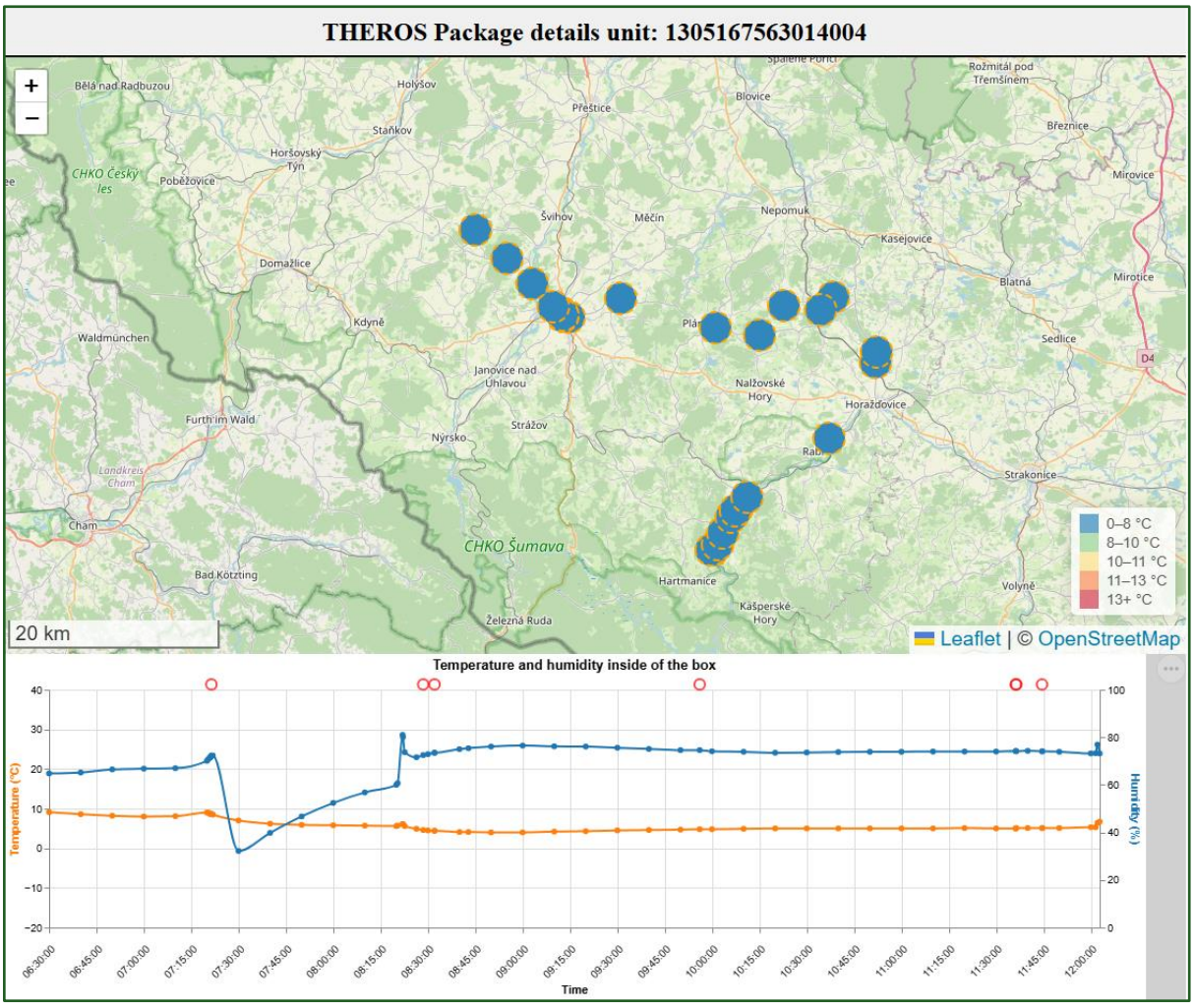
- The Connector is a component that implements the interface of the data provider or data consumer and translates it from or to the internal SensLog interface.
- It is a type of component which is implemented directly based on a specific use case.
- It can process interfaces in push or pull mode and provides SensLog REST API internally.

iv. *SensLog Analytics:*

- This component processes observations and provides other observations or alerts which can be stored in the main database or reported to other applications/channels.
- It can process data in three types:
  - Statistical processing
  - Threshold monitoring
  - Pattern value

Interfaces:

- **REST API** – main interface of the SensLog Platform; each component provides a set of services. Mainly proprietary interface with JSON data encoding. A standardised interface based on OGC SensorThingsAPI is provided for data receiving and publication.
- **Web Map Visualisation App** – A standalone application used for visualisation of observations in a mashup with different types of thematic maps. Observations can be visualised in the form of charts or geometry features with different symbology.



Example of visualisation app presenting location of package and chart with observed temperature and humidity

Services:

i. *Statistical processing*
- calculations of averages, min, max, aggregations etc.
- generating new observations

ii. *Threshold monitoring*
- compares observations with defined thresholds,
- if reaching from below or from above,
- monitors when the value is returning to a defined range.

iii. *Pattern values monitoring*
- Evaluate a combination of defined observations or compare observations with defined patterns in data.
- Generate an observation or report to other applications or channels.

Usage and applications:

The Czech pilot uses the IoT network to monitor conditions during package transport to ensure the correct delivery conditions for perishables. Sensors measure directly in the package and provide data online to the SensLog platform. Observations are paired with locations based on the selected method of delivery – direct monitoring of the delivery van or loading from the tracking log of the delivery company. SensLog Analytics processes observations to monitor defined thresholds, creating alerts when conditions are violated. The report is generated after a package is delivered to the customer. When the report does not contain any generated alerts, conditions were proper during the transport, and a certificate about the transport conditions can be provided.

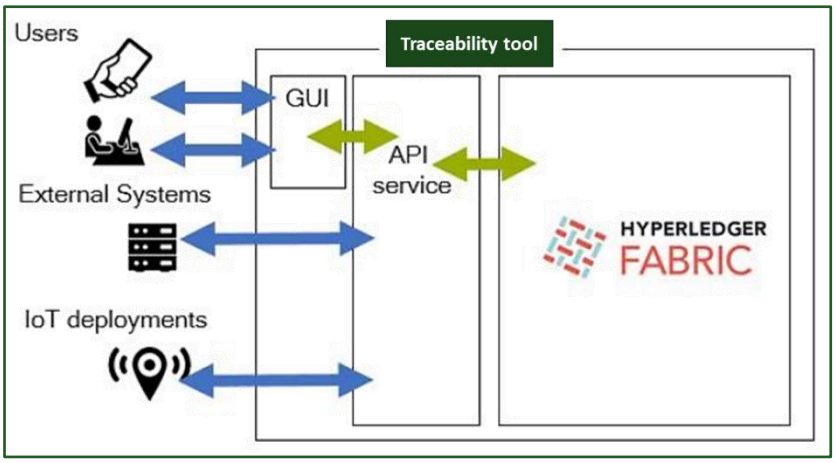
Blockchain technology

The food traceability tool that uses blockchain technology. Using its inherent properties of unchangeability and flexibility, all registered data are safely stored and available to be adopted according to specific end-users needs.

Key Components:

i. *Blockchain traceability system:*
- Standardised GS1 data model shared among the pilots.
- Management of virtual assets representing the traceable product and following the defined data model.
- Standardized (GS1) traceability events model reflecting all possible CTE (Critical Tracking Events) to be covered.
- Organizations and users representing the possible stakeholders (producers, LSPs, packagers, transformation companies, others).

ii. *Integrated Verification Engine:*
- GUI for certification and verification agency stakeholders and provision of associated users all secured using Keycloak.
- API services allowing the validation (or not) of assigned traceable units of product.
- API services allowing the upload of evidence documents acting as proof of previous validation decision.



Key components of blockchain

Interfaces:

- Traceability API.
- Verification API.
- GUI for input of traceability and verification data.

Services:

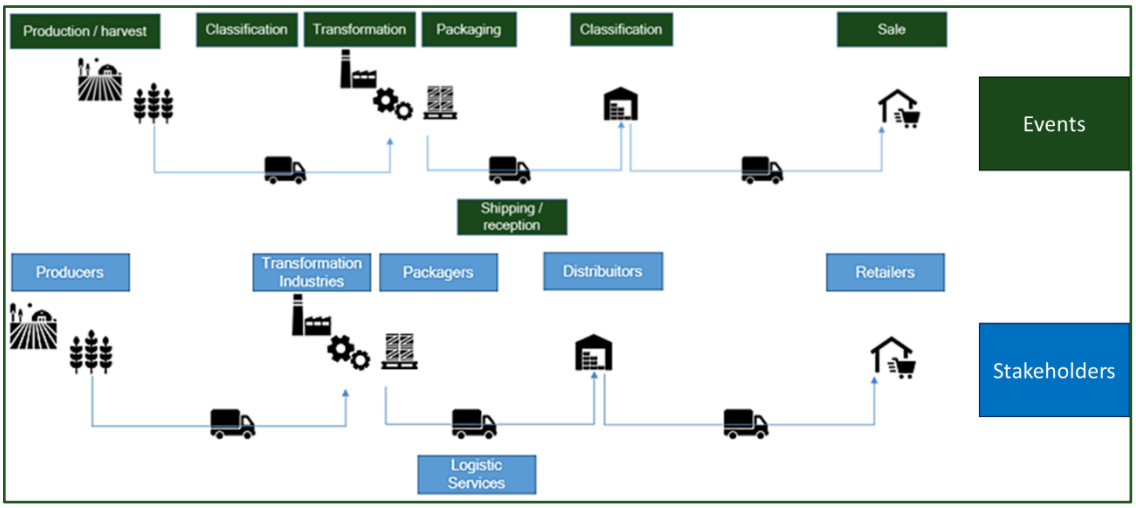
- **Traceability data upload:** Different stakeholders throughout the value chain will be able to upload their traceability data and certifications, through a dedicated GUI or an integration with their ERP systems, if possible.
- **Traceability data sharing:** Different stakeholders throughout the value chain will be able to query stored information that will be delivered in JSON format.
- **Traceability data visualisation:** All participants, depending on their role in the value chain, will be able to visualize either full or limited traceability information and upload the corresponding data depending on stakeholder role throughout the GUI provided by the Green Accountability Tool.
- **Verification engine:** The blockchain network will be able to automatically check the stored properties of a product to see if the desired quality is reached. Also, certification bodies will be able to check this information and determine whether there is a problem with the product or not.

Usage and applications:

The blockchain traceability system and verification engine will provide a blockchain-based system of record for product traceability during the execution of THEROS pilots.

The **traceability tool** will allow stakeholders involved in the pilots to upload the information describing their product at given Critical Traceability events (production/harvest, shipping, reception, transformation, …). Each stakeholder will be allowed to participate in the blockchain exactly at those events that apply to its role. Different stakeholders will be identified at the blockchain Certificate Authority including their digital identity as well as the organizations they belong to, making

digital identity both a way to identify participants and a method to define each participant´s role. The traceability blockchain will allow execution of those transaction types that represent the critical tracking events involved in the supply chain.

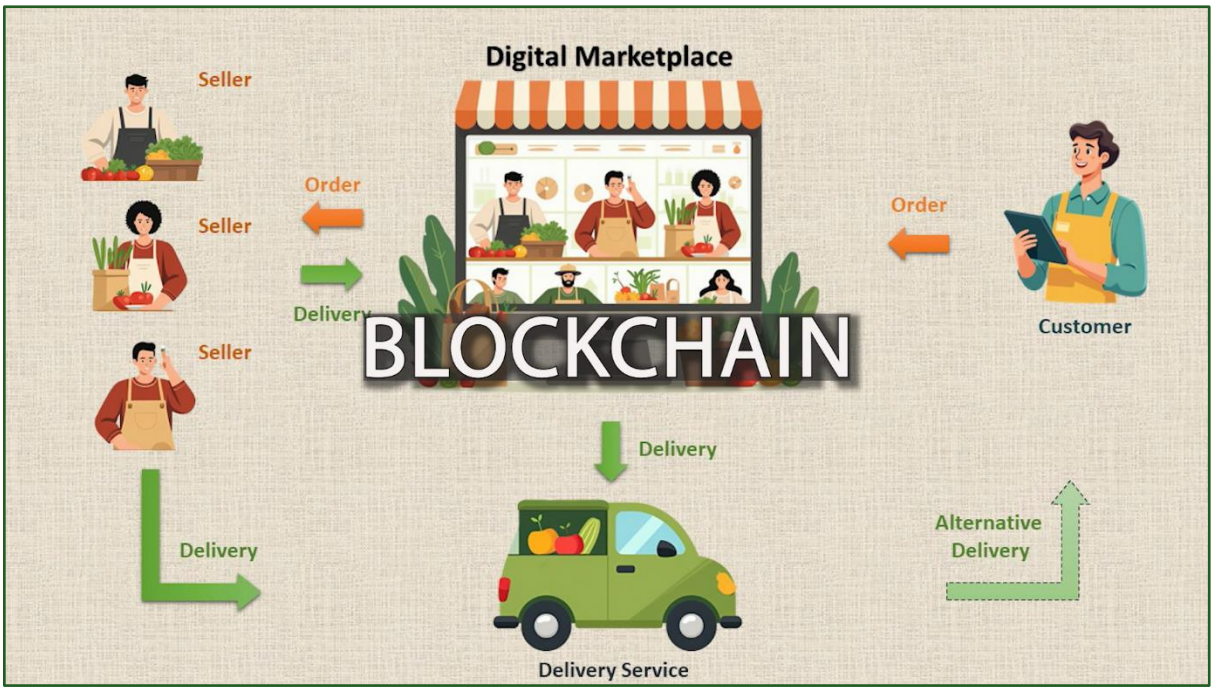


Overview of the blockchain-based system

Each pilot has a dedicated blockchain system structure with its own *business rules* (smart contracts) that define the sequence of CTEs that each pilot will have. These rules will integrate the data from other THEROS tools, in order to create the **verification engine** that will ensure that all the traceability data like environmental conditions during Shipping or origin will be correct.

Digital marketplace

The digital market platform bringing together regional producers, enabling the promotion of their organic or certified food and products and making easier for interested parties to purchase goods. The platform will enable customers to purchase organic or certified food from the involved producers or small retailers. New services will be implemented in the system to verify the marked products and to monitor the conditions affecting the quality of the transported goods.

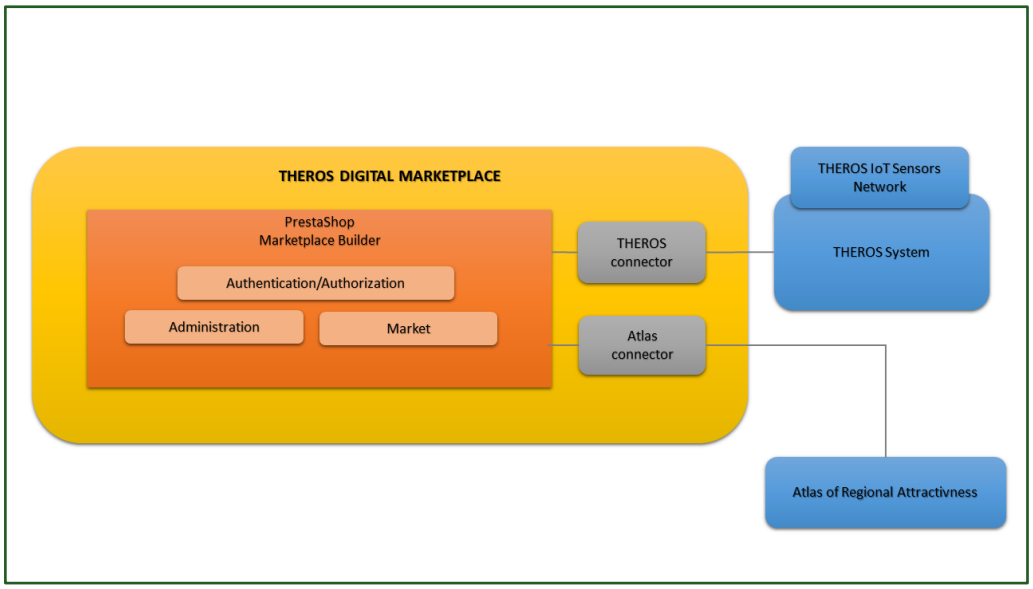


Overview of the digital marketplace

Key Components:

i. *Digital Market Place:*

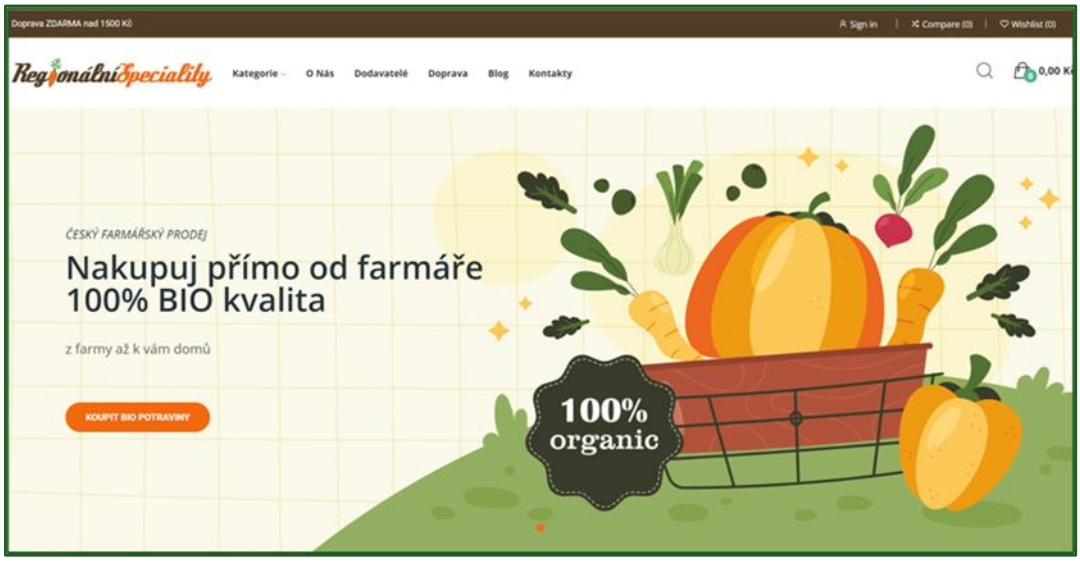
- Complex component with functionality enabling trading and user management i.e. to offer goods to the merchant and to buy the goods to the customer.
- It contains these basic components - the authorization and authentication component, the administration component and the business component itself.
- Connector to the verification engine utilizes data from IoT sensors and other sources to authenticate the integrity and origin of products listed in the marketplace. This component ensures, automated verification workflows, connection to blockchain-based THEROS traceability ledger.
- A unique component is the "Verification of transport conditions" component, which ensures the display of data obtained by the sensor network during the monitoring of conditions during the transport of goods from the producer to the customer.
- The solution also includes a connection with the Atlas Regional Attractions promotional website (external component), which enables the mutual sharing of information and the promotion of organic food and protected brands in the region and in the tourism sector.



Key components of the digital marketplace

ii. *Market App:*

- Basic business component providing the business activities themselves. The component is built on the technological solution PrestaShop Marketplace Builder and ensures the functionality of the central catalog with the support of multivendor options (that is, individual access of different sellers to the marketplace).

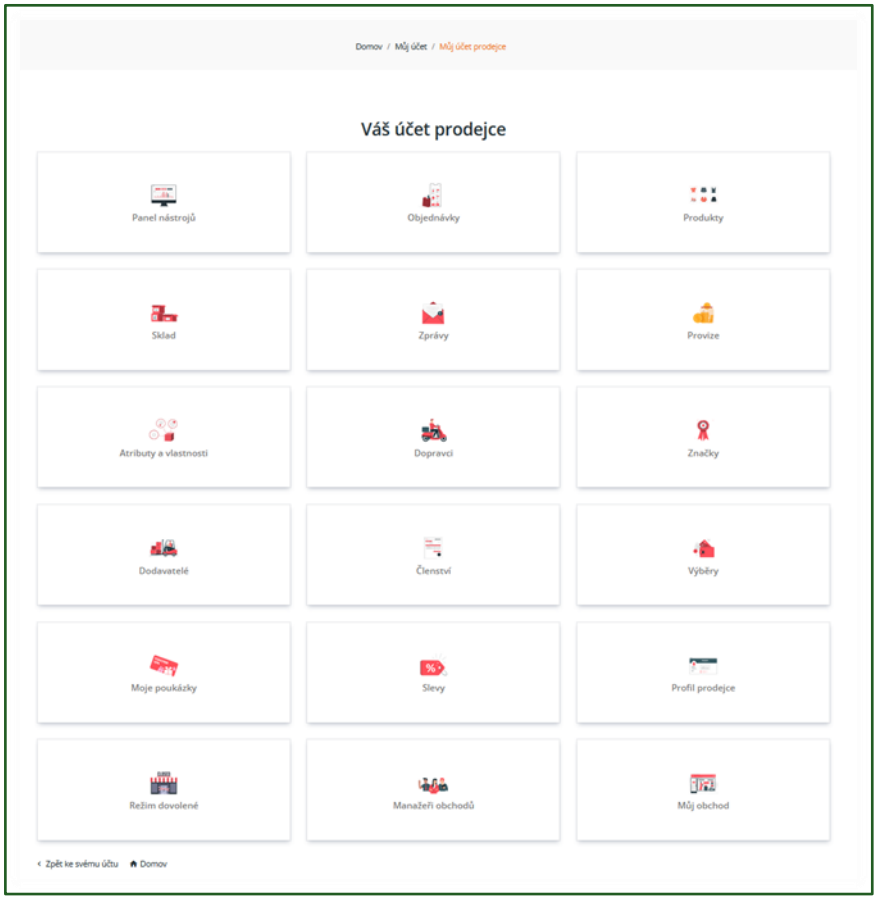


Market App

- This component also integrates other components for the basic functionality of the marketplace – payment system, dashboard, customer management, store management, sales and product actions, stock management, review and rating system.

iii. *Administration component:*

- Also based on the PrestaShop Marketplace Builder, the component provides the back-end interface for sellers to manage their goods, stocks, customers and conduct business activities within the marketplace.



Administration interface for sellers

iv. *Authentication/Authorization component:*

- Component responsible for verifying sellers and customers and granting them appropriate access to the marketplace's features

v. *Connector to the verification engine*

- The THEROS Verification Engine is a core component integrated into the digital marketplace to ensure the trustworthiness and authenticity of organic and geographically indicated food products. It operates as a middleware between the marketplace, the IoT sensor network, and the blockchain-based traceability ledger.
- The Verification Engine supports automated and semi-automated verification workflows that flag inconsistencies, anomalies, or gaps in the traceability data.

THEROS integration components

vi. *Transport-condition Verification component:*

- Interface for integration of IoT-Based Transport Condition Verification Component
- A unique innovation in the THEROS Digital Marketplace is the integration with the THEROS IoT Sensor Network (independent tool developed in the Task T3.3. This component visualizes environmental parameters (e.g., temperature, humidity) recorded during the transport of organic goods. Key features include:
- deployment of smart transport boxes with QR tags,
- real-time sensor data display per delivery,
- threshold-based alerts on temperature excursions,
- historical traceability of transport conditions,
- linkage of delivery data to each order and product batch.
- This data is presented in the user interface as part of the product or delivery information, strengthening transparency and compliance assurance.

Sensors in the box & data visualization

vii. *Atlas of the Regional Attractions component:*

- Expansion of mutual information sharing and promotion of organic food and protected brands in the region and in the tourism sector.

Interfaces:

- Main communication is solved via REST API with various encoding formats, direct communication using JSON. PrestaShop enables merchants to give third-party tools access to their shop's database through a CRUD API, otherwise called a web service.
- Market App communicate via REST API with external systems like SensLog Data Management and Atlas of Regional Attractions.

Services:

- Customers: The Digital Marketplace offers a comprehensive suite of services designed to optimize the shopping experience for customers:
  - *Wide Product Selection:* The marketplace provides a diverse array of products, ensuring customers can find nearly everything they need in one location.
  - *User-Friendly Interface:* Customers benefit from an intuitive interface that simplifies navigation and product discovery, making the shopping process seamless and straightforward.
  - *Efficient Order Fulfilment:* An automated system handles orders from purchase through to delivery, including precise shipment tracking and regular updates, which enhance the convenience of the buying process.
  - *Order history:* This section provides a comprehensive overview of all past transactions made by a customer. This section includes detailed information such as order references, dates, statuses, payment methods, and total amounts. Customers can easily track the progress of their orders, view invoice details, and re-order previously purchased items.
  - *Direct Contact with Sellers:* An integrated messaging system allows easy communication with sellers for inquiries or assistance, enhancing customer service and support. Customers can also use additional producer's services, if available.
  - *Address management:* Functionality that allows both customers and administrators to efficiently manage multiple addresses associated with user accounts. Customers can easily add, update, and delete their shipping and billing addresses through their personal account interface, ensuring accurate delivery and invoicing.
- Sellers (Producers/Retailers): The Digital Marketplace offers a fully managed PrestaShop platform tailored for sellers, providing a comprehensive suite of features designed to support every aspect of running a successful online business. Sellers are equipped with user-friendly tools for quickly and easily listing and managing products. Sellers are able to manage a database of their

customers, their orders and create price promotions. The automated order fulfilment system streamlines the management of orders, shipping, and auto-email notifications, simplifying operations and enhancing efficiency.

- All: Displaying the result and verification protocol of the monitoring of transport conditions provides all interested parties with information about the progress of transport and the risk of quality changes due to transport conditions.
  All: GDPR compliance: Managing GDPR compliance is streamlined through comprehensive features that allow users to handle their personal data with ease. The platform provides tools to facilitate data access, modification, and deletion requests from users, ensuring that all personal data is managed in accordance with GDPR regulations. Administrators can generate detailed data reports, track consent, and manage data portability.

Usage and applications:

THEROS digital marketplace is developed to enhance the resilience of the organic food industry against adulteration and non-compliance while promoting sustainability and ethical farming practices. It aims to authenticate organic products and strengthen the connection between producers and consumers, thereby increasing the availability of organic products. This initiative is part of a broader effort to establish a transparent, secure, and efficient supply chain that benefits all stakeholders involved.

The platform integrates various functions including producer presentations, product offerings, demand records, interconnectivity, delivery options, and payment systems, enhancing its operational efficiency.

Organic and regional product labels

A significant advantage of this marketplace is its integration with a sensor network within the transportation system, which monitors the conditions of goods in route. This feature ensures the integrity and authenticity of organic products by providing real-time data on transportation conditions, thereby boosting consumer confidence and accountability among producers.

Dynamic digital product passport

Dynamic digital product passport (dDPP) for organic/GI food assets is available through a mobile application with user-friendly interface allowing supply chain actors rapid access to information about quality labelled food asset (i.e. movement of the product at the different stages of the supply chain, its verification status, and other added value information regarding the product) via scanning or introducing the product's identification number and triggering other THEROS tools.

Key Components:

i. *DDPP Mobile app:*
- The mobile app providing user interface, that shows information included in the dDPP to end users.

ii. *DDPP Backend:*
- The backend integrating data sources and business logic required for the mobile app to provide its functionality.
- It integrates information related to traceability from the respective component.
- It integrates information related to the dDPP from other components through the harmonization platform.
- It integrates with the keycloak infrastructure in order to provide authorization information to the dDPP mobile app.

Interfaces:

- User interfaces based on the needs of different user groups, depending on the role in the supply chain.

Services:

- The end user can scan or input product's identification number and get relevant information included in the dDDP.
- DDPP details such as general information, environmental information and labels will be shown to the user. Moreover, the dDPP visualizations required in order to view tracking and certification information will be available through the UI of the app.
- The relevant stakeholders can update the status of a dDDPP related to tracking verification through the corresponding user interface of the mobile app.
- The integrity framework is a component that ensures high quality location and time data is transmitted within DPPs when required.
- The product scanner component receives a product identifier and retrieves the DDPP of a given product, if available.
- The dDPP mobile updater receives updated dDPP information from the mobile app and updates the dDPP (tracking verification) related information.

Usage and applications:

- Application in the food supply chain to
  - improve traceability
  - informed decision making
  - increase trust
  - assessment of fraud possibility

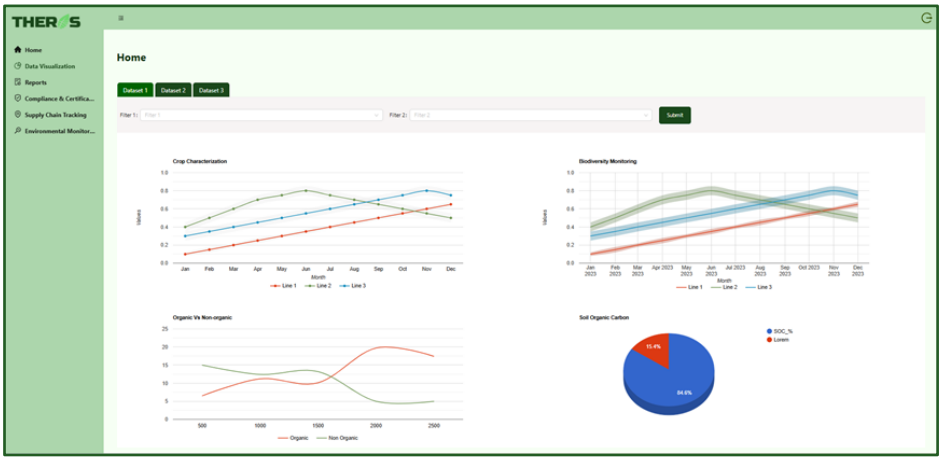
Green accountability tool

The Green Accountability Tool (GAT) is an intuitive digital platform designed to enhance transparency and efficiency in organic and geographic indication (GI) supply chains. It offers a user-friendly interface for monitoring various supply chain activities and facilitating interactions during certification and inspection processes. By presenting data and insights, GAT aids policymakers and supply chain participants in making informed decisions, ensuring compliance, and promoting sustainable practices.

Key Components:

i. *User Authentication*
- Provides login via secure Keycloak system with role-based permissions.

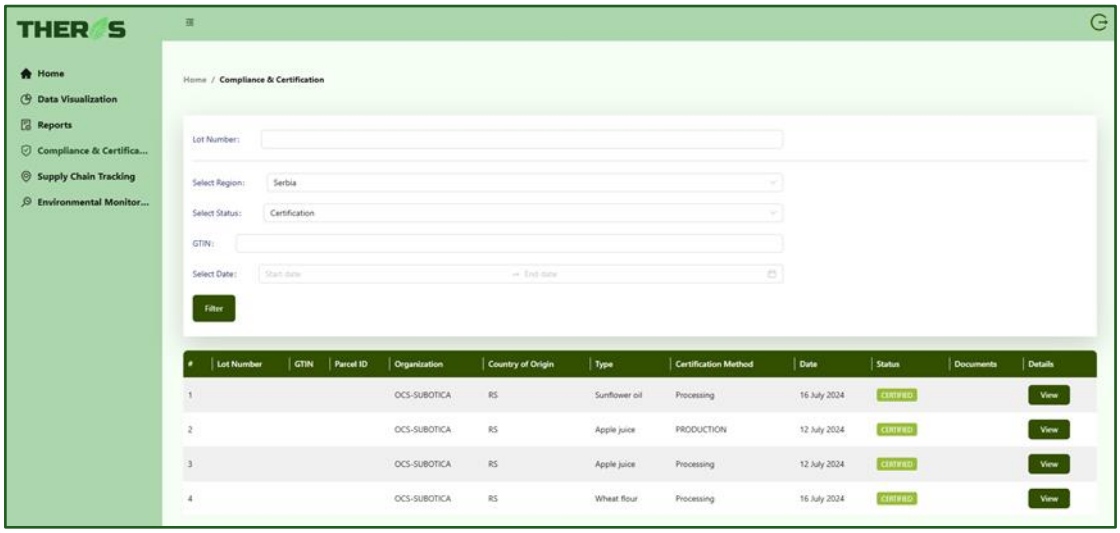
ii. *Data Visualisation Module*
- Provides an overview of all analyses and data within GAT.
- Allows users to view multiple results simultaneously.
- Filters data based on product, region, organisation, and time period.



*Example of data visualisation within green accountability tool/**

iii. *Compliance and Certification Module*

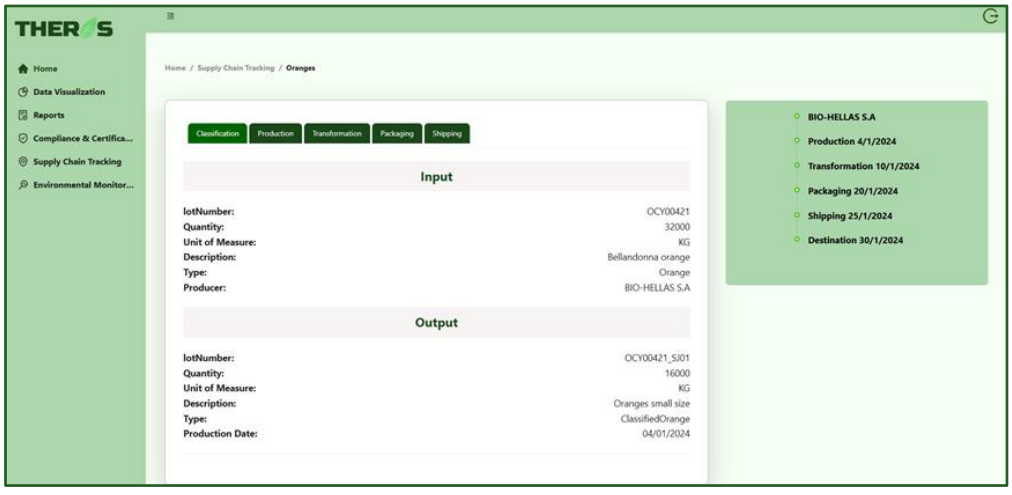
- Allows certification bodies and product owners to observe compliance and certification status.
- Displays certificates in a table format with product details, certification status, and verification by THEROS tools.
- Uses a traffic light system to indicate certification and verification status (green for certified, orange for verified by THEROS, grey for pending).



Example of Compliance and Certification Module

iv. *Supply Chain Tracking Module*

- Allows product owners to track multiple products simultaneously.
- Provides detailed timelines of critical events (production, transformation, packaging, shipping, destination) for selected products.
- Includes hover-over details with time, date, and responsible person, along with descriptions of product states and critical events.



Example of Supply Chain Tracking Module

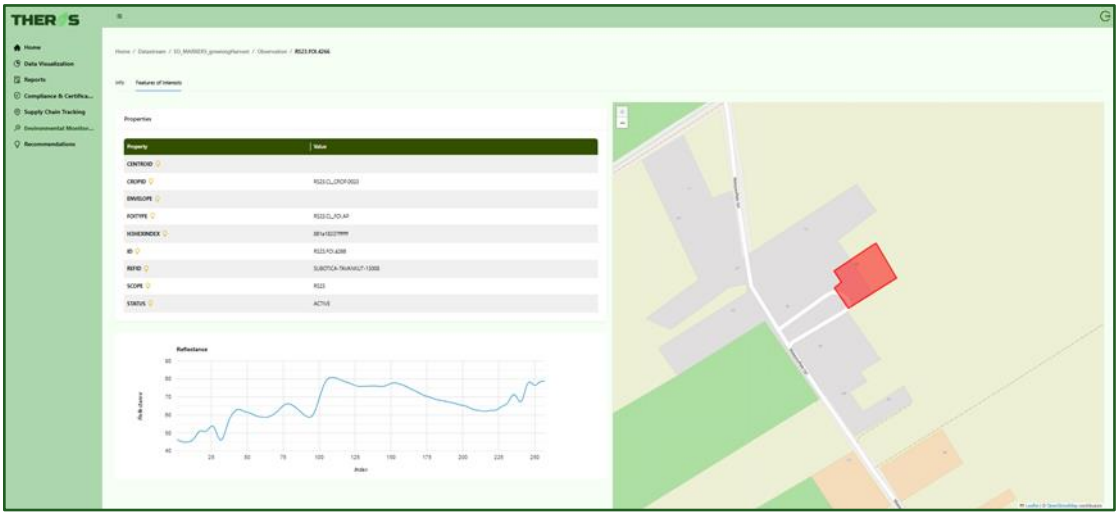
v. *Reporting Module*

- Enables users to generate various reports from THEROS tool analyses.
- Allows exporting of results for further use and documentation.

Example of data report within green accountability tool

vi. *Environmental Monitoring Module*

- Displays data from Earth Observation and MEMS photonics.
- Earth Observation section includes a color-coded map of monitored fields and compliance status, with additional details and analysis plots.
- MEMS photonics section shows spectral analysis results for soil, liquids, powders, and fruits, including purity index and soil organic carbon details.

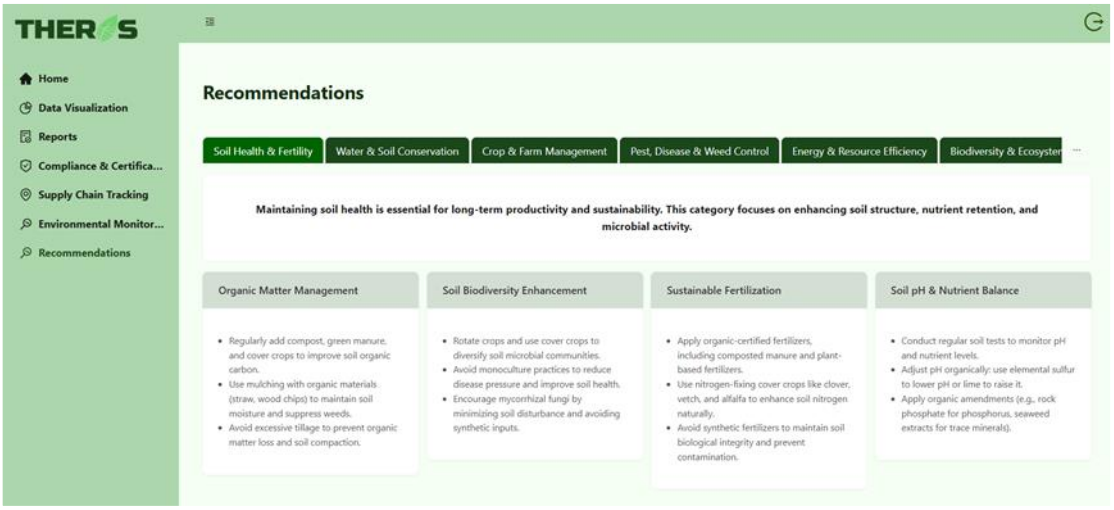


Example of Environmental Monitoring Module

vii. *Farmers' Recommendations Module*

- Displays general and context-specific recommendations for sustainable organic farming.
- The General Recommendations section provides universal best practices on soil health, water conservation, pest management, and organic fertilisation.

- The Contextual Guidance section features pop-up suggestions based on field-specific metrics such as pH, nutrient levels, and organic content, helping farmers take informed action.



Example of Farmers' Recommendations Module

viii. *Interfaces Data Management & Harmonization Platform*

- This interface enables communication between the GAT and the Data Management & Harmonization Platform.
- The GAT receives data from this platform, including various environmental parameter datasets, DNA analysis results, MEMs-based photonics system outputs, and more.
- The GAT relies on this interface to receive harmonised and standardized data from the Data Management & Harmonization Platform, ensuring consistency and compatibility across different datasets.

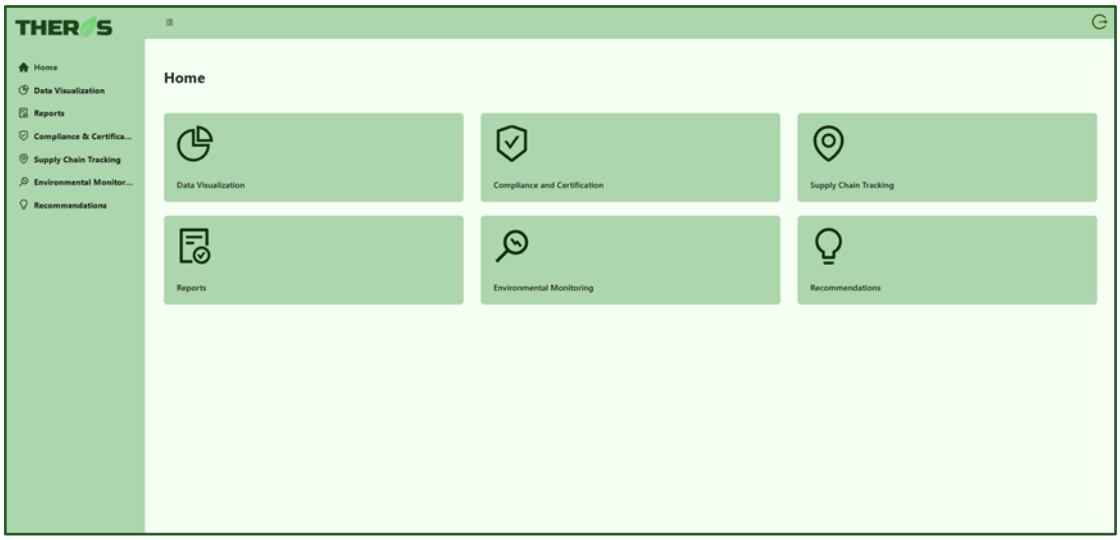
ix. *Verification Engine & Traceability System*

- This interface facilitates communication between the GAT and the Verification Engine & Traceability System.
- The GAT receives verification results from this system, including certification status, verification details, and associated product traceability and authenticity documents.
- The GAT relies on this interface to access verification data, providing users with up-to-date information regarding product certification status and traceability verification.

Services:

- Data Visualization: GAT provides interactive and user-friendly data visualization tools that allow stakeholders to explore and analyse various organic and geographical indication food product datasets. These visualisations help users understand complex data patterns and make informed decisions.

- Reporting: GAT enables the generation of reports summarising the results and insights derived from the analysis of different datasets. These reports can be customised based on user preferences and requirements, providing a comprehensive overview of key findings and trends.
- Compliance and Certification: GAT facilitates monitoring compliance with certification standards and regulations related to organic and geographically indicated food products. It allows users to track certification status, verify product authenticity, and ensure adherence to quality standards.
- Environmental Monitoring: GAT provides tools for monitoring environmental parameters and assessing the sustainability of agricultural practices. It allows users to track soil quality, biodiversity, and ecological impact, promoting responsible farming practices.
- Supply Chain Tracking: GAT offers supply chain tracking capabilities, allowing users to trace products' journeys from production to consumption. This enables transparency and accountability across the supply chain, helping stakeholders identify and address potential issues or inefficiencies.
- Farmers' Recommendations: GAT facilitates farmers' recommendations with guidance to support sustainable and responsible farming practices. It offers tailored recommendations on soil health, biodiversity, and ecological impact, helping farmers adopt practices that align with organic standards and long-term sustainability goals.



Services of green accountability tool

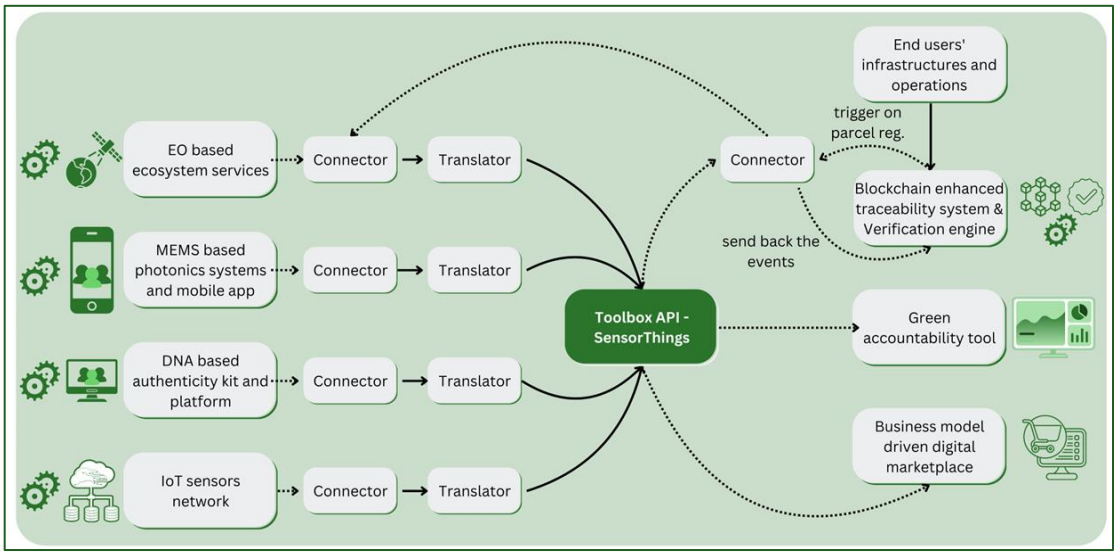
Usage and applications:

The GAT enhances transparency, accountability, and sustainability within the agricultural supply chain. The tool is applicable in various applications, including monitoring compliance with certification standards, verifying product authenticity, and ensuring adherence to quality regulations. By providing interactive data

visualisation tools, GAT enables stakeholders to explore and analyse datasets related to organic and geographical indication food products. This tool facilitates informed decision-making and promotes responsible farming practices and environmental monitoring, allowing users to assess soil quality, biodiversity, and ecological impact. Furthermore, its supply chain tracking module enables the tracing of products from production to consumption, ensuring transparency and accountability throughout the supply chain ecosystem.

Data management harmonisation and interoperability tool

THEROS data management and harmonization platform aims to tackle the heterogeneity and variability of various data sources used for monitoring, verification, and traceability by implementing a comprehensive data management and harmonization platform. This platform will provide essential APIs to facilitate data retrieval from different THEROS components, ensuring seamless integration. A methodology utilizing data translators will be adopted to automatically transform managed resources into standardized digital formats, models, and ontologies. Furthermore, geocomputational and analytical processes will be employed to link outputs from Earth Observation services, photonics, IoT sensing devices, and DNA authenticity kits with transaction data managed by the blockchain traceability system, enabling efficient consumption by the verification engine. The platform will operate on a cloud-based centralized infrastructure, ensuring efficient resource management, scalability, and large-scale monitoring.



THEROS Toolbox infrastructure

Key Components:

i. *Data sources Connectors:*

These components facilitate the data collection from the various data sources of the THEROS project. They are created to match the specific needs and protocols that each data provider support so that data can be retrieved from IoT Sensor Network, Earth Observation Services, MEMS photonics systems and the DNA authenticity kit.

ii. *Data Translators:*

These components convert data received from the connectors into a standardized format so that they can be used by the platform ensuring uniform data access. Each data translator is custom made as each data source has different formats and data fields.

iii. *THEROS Toolbox API*

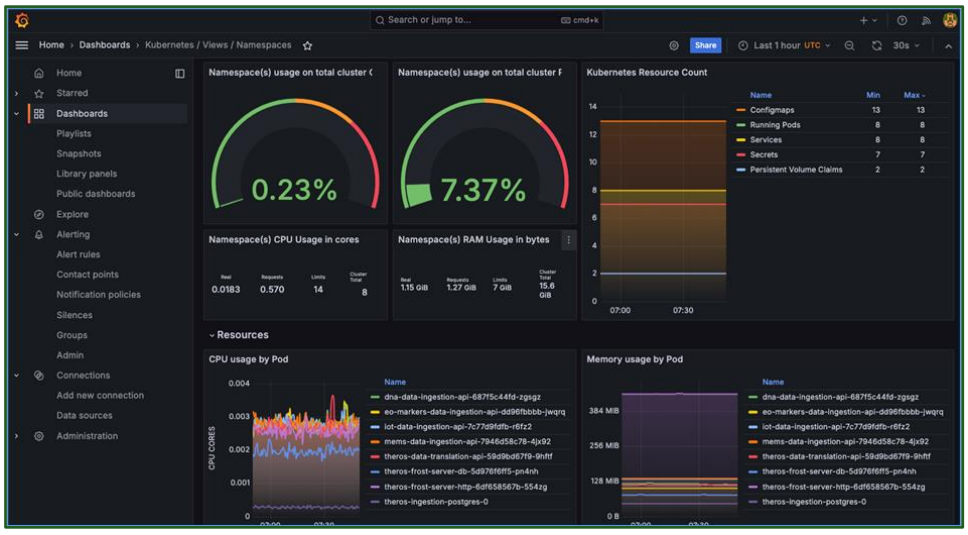
The Toolbox API implements the OGC SensorThings API specification and is the central component that integrates data from all translators. It serves as a single point where all data can be retrieved in a unified way by various data consumers.

iv. *Traceability & Verification Connector:*

This component act as a middleware between the data management and harmonization platform and the blockchain-based traceability and verification engine. This connector's function is to selectively transfer harmonized data to the verification engine based on the needs of the business rules that are going to be applied.

v. *Harmonization Platform Monitor:*

All components of the platform are deployed in a Kubernetes cluster and for each traffic, CPU usage and memory is monitored. By monitoring, these metrics, any performance bottleneck can be detected and actions like scaling the services deployments can be taken.



Monitoring of the deployed harmonization platform components

Interfaces:

i. *Various Data source Connectors each with a unique interface*

- IoT Sensor Network connector implements two APIs one for retrieving raw sensor data and another API that retrieve the output of the IoT analytics engine.

- MEMS photonics systems connector implements one API for retrieving data from the MEMS backend server
- DNA authenticity kit connector implements a graphical user interface that the user imports the data from the portable device and an API to retrieve them to the platform.
- Earth Observation Services connector that consumes data from the Marker provider API and retrieves marker information about each parcel.

ii. *Traceability & Verification Connector*

- This connector is a client to the REST API of the Traceability and Verification Component which sends part of the harmonized data for verification.

iii. *THEROS Toolbox API*

- The main interface from which any data consumer can retrieve data that are collected by all THEROS data producers. It implements the SensorThings API that has a REST API endpoint.

iv. *Keycloak Identity Provider*

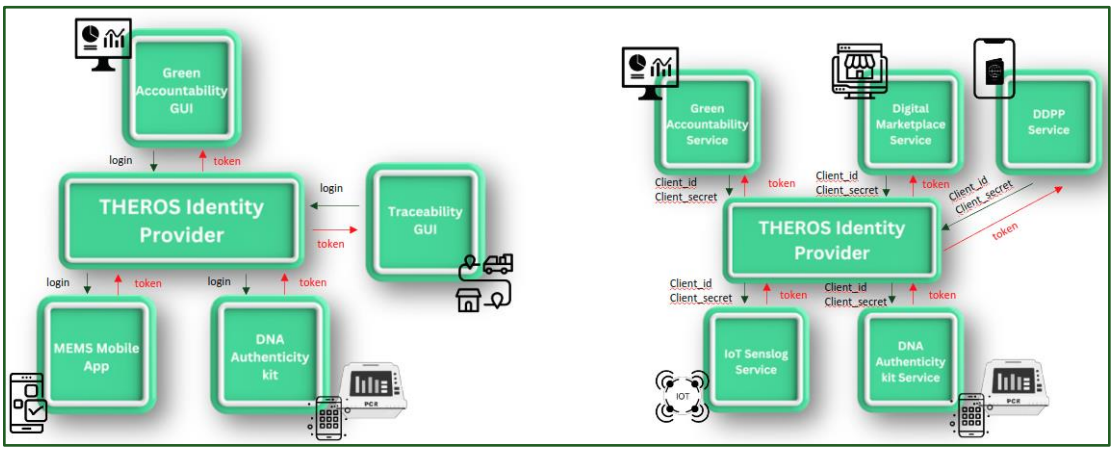
- The interface where all components authenticate requests using its endpoint and ensure that users have rights to access the data and services have permissions to send and receive data.

Services:

i. *THEROS Toolbox API*

The Toolbox API is a core service in the THEROS architecture, integrating diverse data from various sources into a unified system. This centralized API conforms with the Open Geospatial Consortium (OGC) SensorThings API specification, ensuring consistency, interoperability, and accessibility.

ii. *Keycloak Identity Provider*



THEROS Identity provider

Keycloak is an open-source identity and access management solution which provides authentication and authorization services. It supports both user authentication and service-to-service secure communication, ensuring secure access control and identity management. This service supports OAuth 2.0 and OpenID Connect protocols, making it possible to secure APIs and user authentication, using enterprise grade security best practices.

Keycloak is integrated to all graphical user interfaces and services that interact with each other in THEROS.

Usage and applications:

Data consumers can use the Toolbox API to integrate the data streams coming from various sources, into their applications and also further process the data if needed. This unified interface allows for easy access of standardized data, enabling the other digital tools to not worry about the different data formats and protocols that the data providers support. This harmonized approach simplifies data querying and filtering and by using a consistent format, it also simplifies data parsing. Keycloak, deployed as an identity provider, serves as the secure authentication and authorization solution for both user and service-to-service communications. With Keycloak, each digital tool can implement single sign-on (SSO) enhancing user experience and security. By managing user roles and permissions through Keycloak, all appropriate access controls are in one place, reducing the risk of unauthorized access. This identity management solution ensures compliance with state-of-the-art security standards, and secure interactions between users and services.

Annex 6: THEROS Pilot Dossiers

Greece

Organic production & control in the country

In Greece, there are 19 Control bodies for organic products' certification approved by the Ministry of Agricultural Development and Food. BIOHELLAS, having branches all over Greece, certifies about 20.000 organic producers in different fields of production (plant producers, producers of animal stock – especially sheep and goats, aquaculture, animal & fish feeds). All the producers are inspected once a year and up to 10% they are inspected additionally with supplementary inspection, according to the National Legislation of Greece. The certificates issued are valued for a year. Additionally, throughout the year, samples are taken from 10% of the clients in each certification field for analysis under a Risk Analysis protocol. These samples are tested for prohibited substances in accordance with European Regulation 2018/848. Greece shares the EU's objective to ensure that 35% of total production is organic.

Pilot description

In the Greek pilot project, among other participants, is BIONET, a producers' association primarily cultivating citrus trees. This association is located in Western Greece, with additional areas in Central Greece and the Peloponnese. BIONET consolidates the organic production of its members. The majority of this produce is packaged and distributed to various international clients, while a small percentage is supplied to the juice industry.

BIOHELLAS is the largest certification body in Greece (approval No. GR-BIO-03), certifying approximately 20,000 organic producers. BIOHELLAS as a control body will implement and evaluate the different THEROS tools through the inspections and certification process

The regions selected, which include citrus and arable cultivations, are the most representative of these specific types of agriculture.

THEROS toolbox components

The THEROS tools that will be implemented are going to be the EO based ecosystem services, Blockchain enhanced traceability system and Dynamic digital product passport and the Mobile application for MEMS in Oranges, through the BIONET's orange producers.

For the Greek Pilot concerning EO-based ecosystem services, ICCS provided the polygons of the cultivated plots in Greece, while BIOHELLAS has provided, through its records, the "cartographic numbers" for plots with permanent crops—primarily citrus

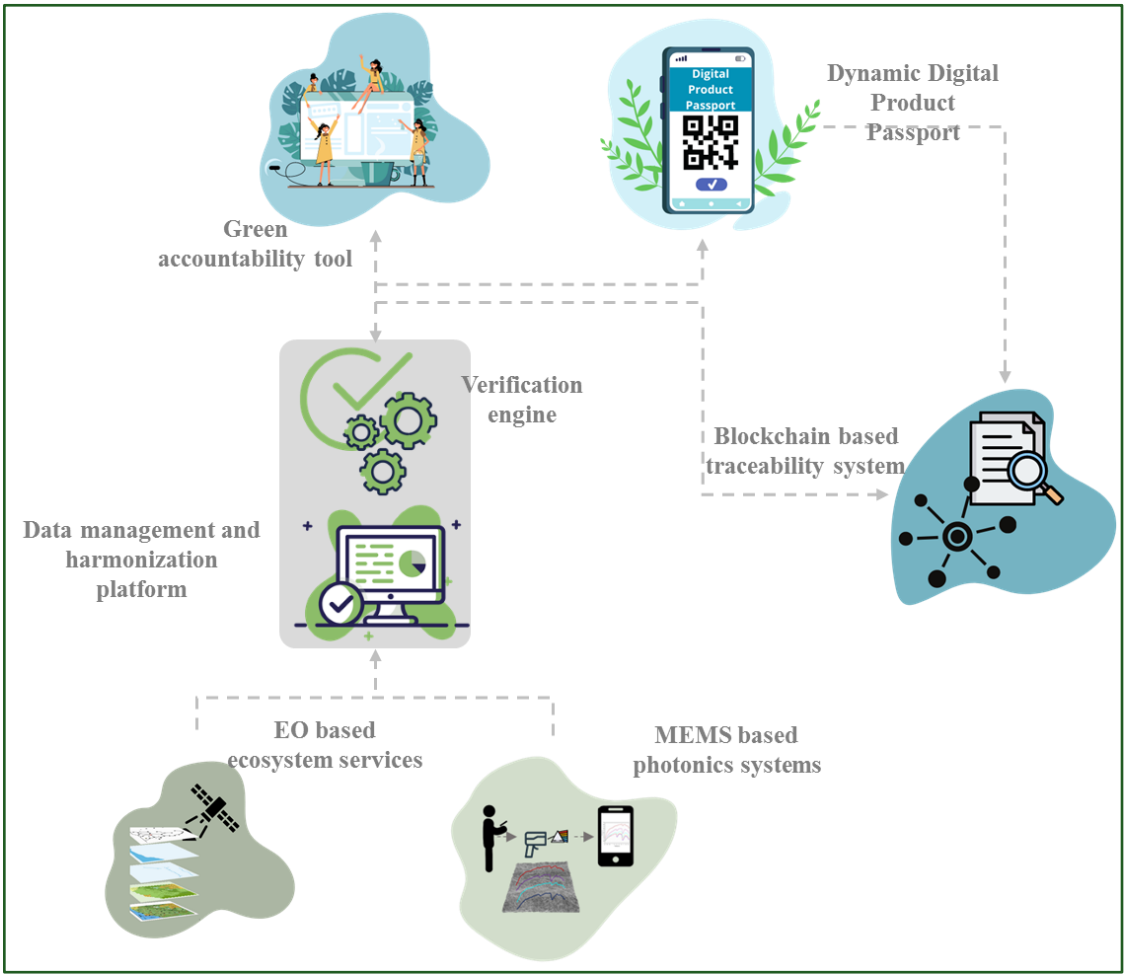
trees—in Central Greece and the Peloponnese. Additionally, BIOHELLAS supplied details for arable crops, including species such as maize, alfalfa, vetch, and wheat, from areas in Central and Northern Greece.

Regarding the blockchain-enhanced traceability system, dynamic digital passport, and mobile application for MEMS, since BIONET's members primarily produce oranges, the focus is on monitoring the products and supply chain associated with oranges.

For the application for MEMS BIOHELLAS has participated to workshops held by AUTH, and BIOHELLAS' inspectors have been trained to the implementation of the MEMS devices, in order to be able to use it during the inspection process.

Blockchain traceability system is following mainly the product of oranges and among the producers – members of BIONET, there are producers who are certified by BIOHELLAS.

The information provided will be enhanced though the THEROS data harmonization platform and verification engine.



THEROS components implemented in Greek pilot

Data collection protocols

Architecture of the Data Collection Platform

BIO-NET, as a co-leader in implementing the THEROS toolbox under real-life conditions in Greece, facilitates the data collection process and provides training to farmers during the pilot phase. The traceability platform for organic oranges, from production to export, is meticulously designed to record, analyze, and ensure compliance across the entire supply chain.

Data Flow – Indicative Collection Example

Harvest: The harvesting process is thoroughly recorded with key data such as the harvest date, number of crates, and total weight. Each batch is assigned a unique code, accompanied by organic compliance certificates that validate the origin and quality of the products.

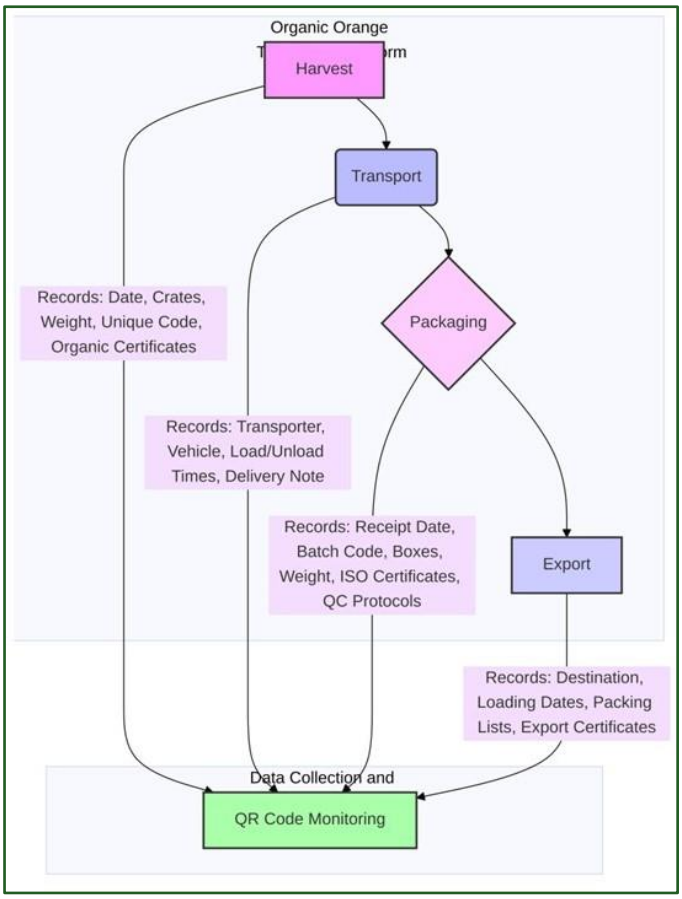
Transport: Transport data includes information about the transporter, vehicle registration number, loading and unloading times, as well as the associated delivery note. These records ensure the integrity and safety of the products during transit.

Packaging: Upon arrival at the processing facility, details such as the date of receipt, packaging batch code, number, and weight of boxes are documented. In addition, ISO certificates and internal quality control protocols are maintained to verify compliance and packaging safety standards.

Export: Export procedures are documented with destination details, loading dates, and accompanying documents such as packing lists and export certificates, ensuring a lawful and smooth export process.

QR Code Monitoring: Each box is equipped with a unique QR code linked to a digital profile. This includes batch information, certifications, dates, transport, packaging, and quality details, along with export documentation. The use of QR code enhances transparency and consumer trust by enabling easy access to the full traceability history.

The data collection platform offers an integrated and interoperable traceability solution, strengthening the reliability and compliance of organic orange supply chains.



Data collection platform for organic oranges traceability

Data analysis plan

The BIONET Data Analysis aims to holistically monitor and document the journey of organic oranges, from harvest to export. Data is systematically collected from all stages of the supply chain. At harvest, the date, number of crates, total weight, organic certificates, and unique batch code are recorded. During transport, data such as the name of the carrier, vehicle number, loading and unloading times, as well as the relevant shipping note, are collected. At the packaging stage, the date of receipt, number of crates, and weight are recorded, along with ISO certificates and the results of internal quality controls. At the export stage, the loading date, destination, packing lists, and required export certificates are included. Each carton has a unique QR code linked to a digital profile, where all the above data is collected.

The analysis is based on data completeness checking, batch matching, time tracking, and verification of compliance with standards. The tools used include the digital platform for the Greek pilot. The result is the production of traceability reports per batch, notifications for possible errors or delays, and the provision of full transparency to the end consumer via QR.

With MEMS based photonic system the primary goal is to give first of all the opportunity to the inspectors to verify the data collected during the inspection by the farmer and in the case that MEMS readings are not the expected can lead the inspector to decisions and actions, such as taking a sample of the product and analysing it for the presence of prohibited substances. This fact permits to the inspection body to discover a possible violation of the European Regulation and Greek Legislation for organic products.

On the other hand, the use of MEMS based photonic system by the farmers gives them the opportunity to verify the organic cultivation practices and to monitor the soil quality and to proceed in different actions, within the framework of organic farming, in order to optimize and maximize their production

Stakeholders' engagement

Greek pilot project, coordinated by BIONET, actively engages a wide range of stakeholders across the entire organic orange supply chain.

Key Stakeholder Groups:

Organic Producers: Certified organic farmers provide primary data at the harvest stage. Their direct involvement ensures that the traceability system captures real-world practices and documentation of compliance (e.g., organic certificates, harvest records).
Logistics and Transporters: Local transport companies (e.g., AgroTrans AE) contribute to traceable logistics by providing vehicle data, loading/unloading times, and delivery documentation. Their integration into the platform supports quality assurance during handling.
Processing & Packaging Facilities: BIONET's packaging station (BIONET WEST HELLAS) records critical post-harvest data such as intake weights, packaging lot codes, Organic and ISO certificates. This stage is crucial for maintaining product transparency and integrity.
Exporters & International Buyers: Stakeholders such as BioMarket GmbH (Germany) receive full traceability documentation, including QR codes linked to digital product profiles. Their feedback helps align the system with international market requirements.
Control Bodies: Control Body plays a vital role in verifying the organic status of the products through the inspection and certification process.
Consumers and End Users: Through QR code access, consumers can see the entire product journey, reinforcing trust, authenticity, and brand value.

Engagement Methods:

- Regular interviews and feedback loops with producers and processors
- On-site visits and training on data entry and traceability tools
- Piloting the digital platform in real harvest and export cycles
- Co-designing dashboards and QR profiles with end users

Impact: Stakeholder engagement in the Greek pilot enhances the acceptance, usability, and scalability of the THEROS traceability model, while creating a strong network of stakeholders committed to transparency and sustainable agri-food systems.

Drivers & barriers

The implementation of THEROS tools gives to the producers the chance to ensure the follow up of their organic products through the supply chain, avoid food fraud and give the opportunity to the consumers to verify the identity of the product they buy. Also is given the change to demonstrate their compliance with the European and National Legislation for organic products and to monitor different aspects, which help them to optimize their production.

To the Certification Bodies gives the ability to ensure that the data given by the producers are accurate and based on the THEROS tools indications can lead the Certification Bodies' inspectors to quick and targeted decision regarding the integrity of the inspected products.

In Greece the different producers, most of them, are not fond of the novel technologies, that are used for the implementation of THEROS tools. This has resulted in difficulties in understanding and implementing them, which is an obstacle to the immediate response of the participants to requirements from the THEROS project's demands.

Serbia

Organic production & control in the country

The country boasts favourable conditions for organic agriculture, with extensive arable land and relatively low levels of industrial pollution. However, the organic sector in Serbia faces challenges related to infrastructure, certification, and market development.

Organic production in Serbia is regulated by the Law on Organic Production, enacted in 2010, which aligns with previous European Union (EU) standards 834/2007 [6] & 889/2008 [7] and now in procedure new regulation, which will align with new EU regulation 848/2018 [8]. This revised law is expected to be published by the end of 2024. The law defines the requirements for organic production, labelling, certification, and control mechanisms. The Serbian Ministry of Agriculture is responsible for overseeing and regulating organic production in the country

The certification process is crucial for ensuring the integrity and quality of organic products. In Serbia, certification is carried out by accredited control bodies, which verify that producers comply with organic standards. These standards encompass various aspects of production, including soil management, crop rotation, pest and disease control, and the non-use of synthetic chemicals and genetically modified organisms (GMOs). There are 6 control bodies authorised by the Ministry of Agriculture for domestic law and 3 of them are authorised for EU organic certification by the European Commission.

There are two main types of organic producers in Serbia: those who contract directly with certification bodies and bear costs independently, and cooperating producers who hold certificates under group certification arrangements. The majority of organic production is export-oriented, with plant production being dominant.

Market development is another area of focus for the organic sector in Serbia. While domestic demand for organic products is increasing, there is also potential for export to EU countries and other international markets. However, to access these markets, Serbian organic producers must comply with strict EU regulations and undergo additional certification processes.

Overall, the organic production and control situation in Serbia is evolving, with efforts underway to overcome challenges and further develop the sector. Increased investment, improved infrastructure, and enhanced market access are key factors that will contribute to the continued growth of organic farming in the country.

Pilot description

Pilot in Serbia covers the whole country. In Vojvodina (Northern Serbia) focus is on tillage crops such as wheat, sunflower, soybean and corn and on the other side, in Central and Southern Serbia where climatic conditions are better for fruits such as raspberry, sour cherry, apple and plum. The project will follow organic wheat flour and organic sunflower oil from Univerexport who is the primary producer, processor, distributor and trader.

Organic control system (OCS) as the control body will follow Univerexport's products from farm to fork, but also all other products from another organic producer, including apple juice. All these products are included in the project, because there is enough relevant data for organic, but also for non-organic products.

Examples of products considered in Serbia pilot

Serbia has developed a transparent efficient and reliable geospatial and real estate management system GeoSerbia through the Republic Geodetic Authority. The Republic Geodetic Authority leads Serbia's digital transformation through modern geospatial innovations, enhancing state transparency. Utilizing advanced satellite imagery since 2015, it sets global standards for cadastral institutions with continuous innovation and reform. Drawing from their experience in Earth Observation (EO) through the previous Horizon project ENVISION [9], they've expedited data preparation, sidestepping the challenges encountered in prior project development.

THEROS toolbox components

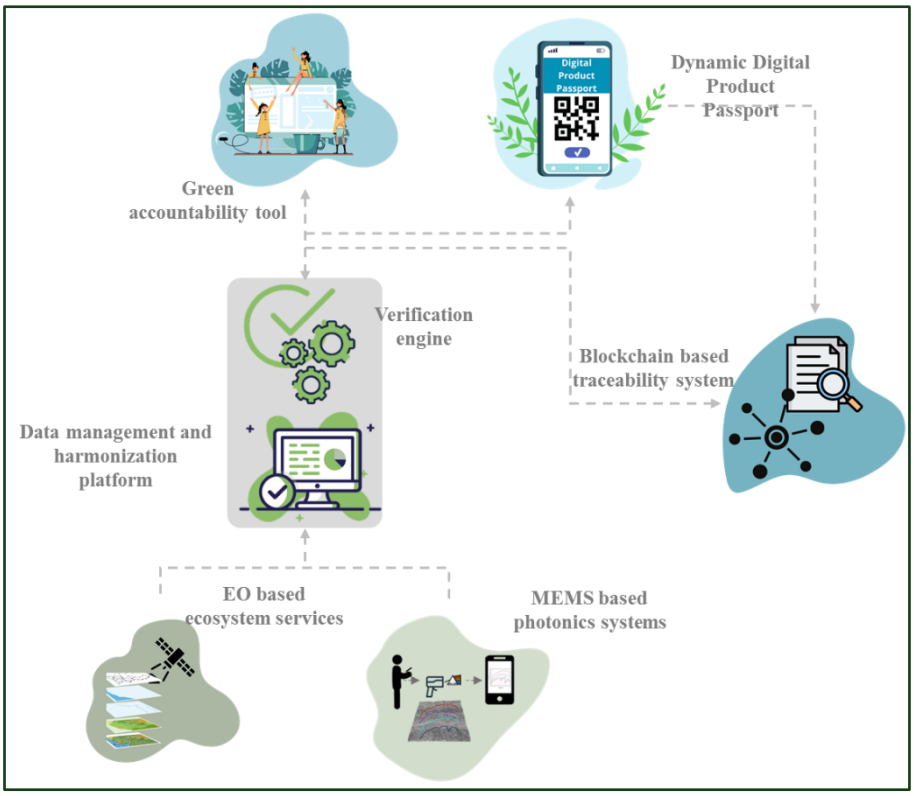
The first one is EO based ecosystem services for the detection and distinction between organic and non-organic farming activities, verification of Ecological Focus Areas, and the use of multiannual crop rotation including mandatory leguminous crops as the main or cover crop for rotating crops and other green manure crops. OCS will, through the project, cross their data (farmer's declarations and data from on-spot inspection) and geospatial data from GeoSerbia. Additionally, intra-field analysis will be conducted, biophysical parameters will be also extracted and analysed by ML models, in order to provide related recommendations to the farmers about the optimal use of organic fertilizers, the best selection of crop, and the estimation of yield.

All the mentioned information will be made available through the green accountability tool and dynamic digital product passport, the communication gap between CBs and farmers. Expectations and requirements for green accountability tool, such as: diverse types of data, the option to easily export data in Excel or Access format, the need to be easy to use, all data need to be in one place, the need to be user-friendly, need to be quick and easy for review, need to be in the real-time data, then privacy on the level of user (username and password), to have a notification about some irregularity, to be an option for online, but also for offline working, etc.

OCS as the organic control body, and Univerexport as wholesaler will be able to use THEROS portable MEMS-based photonics systems, and the respective mobile application for detection of falsified labels. For that purpose, the pilot will follow and test organic wheat flour from Univerexport and organic apple juice from another organic certified producer by OCS. Univerexport prepared and sent 5 kg of organic wheat flour for the first testing and analysis and for the second testing and analysis they sent 3 kg of organic wheat flour. OCS sent 60 and in addition 30 more bottles of organic apple juice, plus 60 bottles of non-organic apple juice from the market for a testing purpose. Both, organic and non-organic apple juice are produced in Serbia from apple concentrate.

Block chain-based traceability system is following product organic sunflower oil, produced from Univerexport and certified by OCS. In the year 2024, about 38 tonnes of sunflower from 12.7 ha and produced quantity of almost 10.000 litres of organic sunflower oil is expected. Generally everything is digitalized and very easy to follow and include in a blockchain system. OCS will also include products, such as organic apple juice in blockchain system.

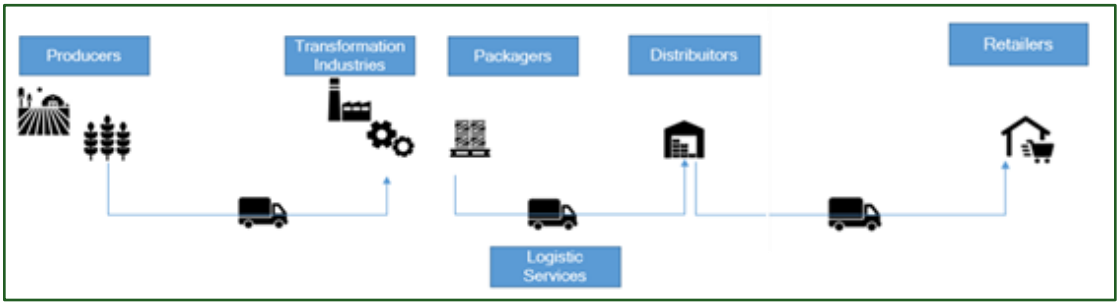
Finally, the information provided will be enhanced through the THEROS data harmonization platform and verification engine, aiming to: 1. Allow rapid verification of the product status and address potential claims; 2. Verify food asset origins, and 3. Validate the execution of transactions across.



THEROS components implemented in the Sebian pilot

Data collection protocols

Example of the flow chart for sunflower oil



Manufacturer: *Agricultural farm Univerexport in Lipar*

Soil cultivation is done with Univerexport doo's own machinery.

Regarding EO-Based Ecosystem Services, OCS sent the data of Univer's plots with organic sunflower to Synergise who validate campaigns for markers to ensure the accuracy of crop classification through market observations. OCS then provides on-spot inspections and validation of crop classifications, with the importance of verifying the information provided by farmers.

The threshing service is performed by the supplier (outsourcing process). The link with the supplier will be the system of electronic invoices (SEF), which is a legal obligation in the Republic of Serbia and will be an integral part of the interface.

After threshing, the transport vehicles of Univerexport doo transfer the entire amount of organic sunflower to a dislocated warehouse. The production of organic sunflower oil is also in the same place.

Provider of logistics services: *Univerexport doo*

Transformation and packer: *Bački Dukat Odžaci*

The dislocated warehouse is located at the supplier Bački Dukat, which oversees storing and squeezing organic sunflowers and packaging organic sunflower oil. The squeezing will take place in several stages, and the product will be packed in 750 ml and 250 ml bottles, according to the needs of the Univerexport system. After pressing the sunflowers and packing the oil in the intended packaging, the entire quantity will be transported to the central warehouse, known as the DC (Distribution Center) of Univerexport doo.

Distributor: *Univerexport doo*

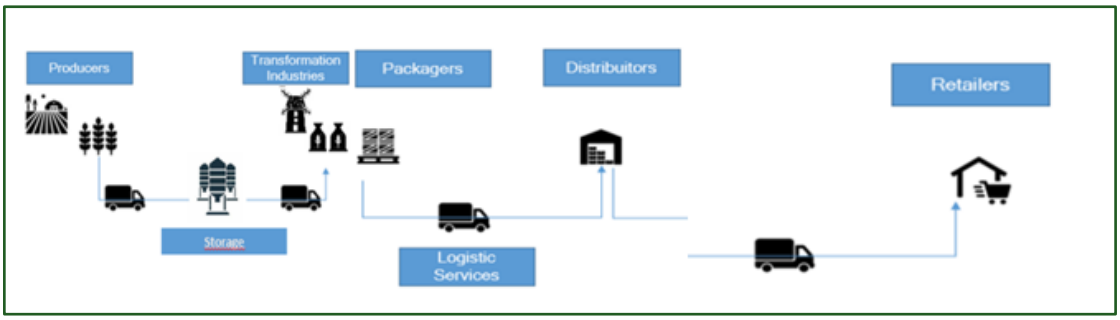
Upon receipt of the DC, the product is assigned an SSCC (Serial Shipping Container Code) code which helps with the tracking of the product movement from its reception to the retail facility. This means that there is a history of the movement of goods from the stage of reception and storage to moving and shipping, that is, it ensures the traceability of goods from DC to RF (Retail Facility). Based on the purchase orders that will be made by the RF to the DC, the delivery to the same will be prepared.

Transport from DC to RF is also carried out by a Univerexport vehicle. The delivery is accompanied by the document Intermediate storage document FROM, which was signed by the commission agent upon arrival at the store.

At the reception of the RF, the delivered goods are checked and if the balance of goods matches, a new document is created by the RF - Intermediate storage transport order document. With this document, the goods are placed on the store balance. The goods are displayed in a pre-defined place intended for organic products and the brand ORGANA, and by purchasing them, a fiscal invoice is issued, which ensures full traceability.

Regarding EO-Based Ecosystem Services, OCS collects data from farmers and sent to Synergise who validate campaigns for markers to ensure the accuracy of crop classification through market observations. OCS then provides on-spot inspections and validation of crop classifications, with the importance of verifying the information provided by farmers.

Example of the flow chart for organic wheat flour



Manufacturer: *Agricultural farm Univerexport in Lipar*

Soil cultivation is done with Univerexport doo's own machinery.

Regarding EO-Based Ecosystem Services, OCS sent the data of Univer's plots with organic wheat to Synergise who validate campaigns for markers to ensure the accuracy of crop classification through market observations. OCS then provides on-spot inspections and validation of crop classifications, with the importance of verifying the information provided by farmers.

The milling service is performed by milling company Spelta Jevtić, our outsourced supplier. The link with the supplier will be the system of electronic invoices (SEF), which is a legal obligation in the Republic of Serbia and will be an integral part of the interface.

After threshing, the transport vehicles of Univerexport doo transfer the entire amount of organic wheat to a dislocated warehouse.

Provider of logistics services: *Univerexport doo*

Transformation and packer: Spelta Jevtić

The dislocated warehouse is located at the supplier Zlatno zrno Šuljam, which is in charge of storing organic wheat. The milling takes place in several stages in Spelta Jevtić, Bačko Gradište and the product is packed in 1kg package. The quantity is determined according to the Univerexport system needs. After milling, the entire quantity is transported to the central warehouse, known as the DC (Distribution Center) of Univerexport doo.

According to the flow chart the total amount of organic wheat from 2024. that is stored in the silo is 123.320,00 kg.

Distributor: *Univerexport doo*

Upon receipt of the DC, the product is assigned an SSCC (Serial Shipping Container Code) code which helps with the tracking of the product movement from its reception to the retail facility. This means that there is a history of the movement of goods from the stage of reception and storage to moving and shipping, that is, it ensures the traceability of goods from DC to RF (Retail Facility). Based on the purchase orders that will be made by the RF to the DC, the delivery to the same will be prepared.

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Data analysis plan

EO based ecosystem services

Through the EO based ecosystem services component which utilizes satellite imagery and machine learning to monitor agricultural activities and compliance with organic farming practices, OCS control body included organic and non-organic plots in Serbia, with perennial and arable crops: Raspberries, blackberries, sour cherries, apple and plum, wheat, barley, sunflower, triticale, rye, spelt etc

The Key markers include homogeneity, greening, harvest, bare-soil, crop type, and organic/non-organic classification markers. These enable large-scale and efficient monitoring of farming parcels.

Within this component markers are showing insights about what is happening on the parcel by applying statistical and machine learning methods to satellite (or other aerial) imagery timeseries.

The first versions of the markers over pilot sites were delivered in early summer of 2024. Then proceed with the next iteration of the markers in 2025 to allow for targeted spot checks by the OCS Control body.

The EO-based ecosystem services module uses Sentinel Hub to efficiently retrieve Satellite Imagery and allow for retrieval of temporal statistics over parcels to generate signals that are used as input for the markers. In early 2025 the markers are run on super-resolved Sentinel-2 imagery in order to try and improve the performance over smaller parcels.

The plots of organic Wheat and Sunflower of Univerexport are also included in testing and observation process as a first step of traceability of the product.

Blockchain technology

Blockchain technology enhanced the traceability system that provides an immutable record of all supply chain events, from production to retail. This system ensures transparency and trust across the supply chain by securely tracking product life cycles, including production, transformation, and transportation.

Serbian participants are supplying their information through APIs and automated integrations with their ERPs. The integration of ERP system with Theros API is currently under testing. Data is retrieved from the SAP database and transferred through the THEROS API using a script. The plan is to send data at certain time intervals, which will be defined later on.

Until now, Serbian pilot manually recorded 3000 units of organic flour, 6500 units of organic cold press sunflower oil but also 150 samples/bottles of organic and non-organic apple juice (200ml) through the blockchain technology including events such as: production, transport, transformation and packaging events. Additionally, those units were verified through certification events by control body OCS.

In 2025, we are expecting more units of organic wheat flour to be recorded.

MEMS based photonics system

With a MEMS-based photonics system, a primary goal is to enable real-time detection of food adulteration, providing retailers with a fast and efficient way to identify compromised products. By integrating MEMS-based photonics systems with mobile applications, the project offers on-the-spot analysis capabilities that enhance transparency and trust in the supply chain.

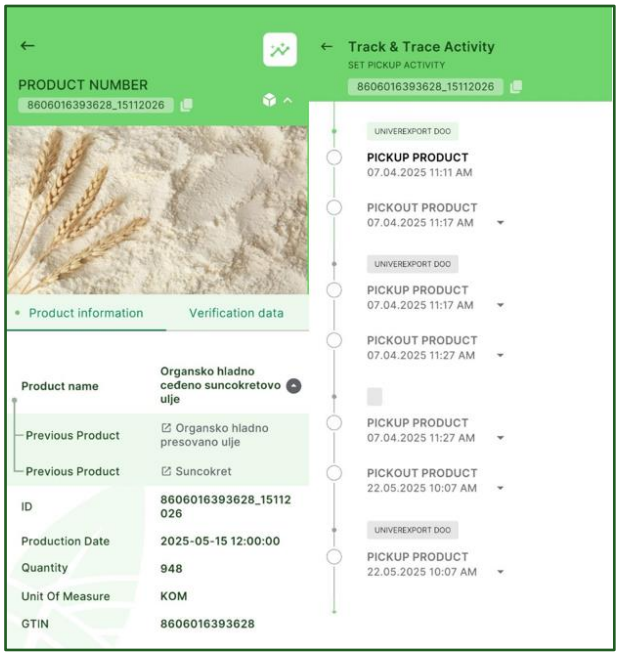
Specifically, retailers using the MEMS-based photonics system will be able to scan food products (I.e. wheat flour and apple juice) in order to detect possible adulteration. A purity index would be displayed via THEROS mobile app which provides an estimate of the detectable adulterant if it exists. Otherwise, an indication marks the product as pure.

This activity was tested and verified with Organic wheat flower and apple juice samples.

dDPP - Dynamic Digital Product Passport

Dynamic digital product passport for organic/GI food assets tracks the product’s journey through the supply chain. It allows users to verify key tracking events, such as pick-up, transportation, and delivery, providing real-time information on the product's status and compliance.

Univerexport and OCS have tested and verified organic wheat flour, organic sunflower oil and apple juice through dDPP tool. The first product in the retail shops of Univer with valid QR code is already in process of verification and will be recognized through dDPP while scanning it.



GAT – Green Accountability Tool

Green accountability tool aims at monitoring and visualizing the environmental performance of food production practices, ensuring sustainable practices are followed.

Through Serbian pilot and GAT the plots of the Organic wheat and Sunflower will be demonstrated trough EO, additionally the EO model is continuing to be developed with the lists of different corps Non-organic (Conventional) vs. Organic. Also, the products of wheat flour, sunflower oil and apple juice will be traceable through the blockchain and seen in dDPP, while the flour and juice were tested through MEMS tool.

Stakeholder engagement

1. **Farmers**: Farmers are primary stakeholders in agriculture, as they are directly involved in implementing farming practices. Their role includes adopting and adhering to organic farming standards, providing information about their practices, and participating in data collection efforts. This step is especially important for Earth Observation where Satellite should analyse with learning models the different management in non-organic (conventional) and organic practice.

2. **Control Bodies**: Control body plays a vital role in gathering and verifying data. Organic Control System will gather data and information about conventional and organic plots in a scope for Earth Observation learning protocols. Also, OCS will verify the data in Blockchain entered by producer (Univerexport)

3. **Government Agencies**: Government agencies are responsible for regulating and overseeing agricultural practices, including organic certification. They set policies, standards, and regulations for organic farming, provide support and incentives for organic farmers, and enforce compliance with organic regulations. Through this pilot, government agencies will be invited to support the data collection process for Earth Observation protocols.

4. **Research Institutions**: Research institutions contribute to the advancement of knowledge and understanding of organic farming practices. Their role involves conducting scientific research, providing technical assistance and training to farmers, and disseminating information about best practices and innovations in organic agriculture. They will participate in Learning History Workshop by testing the tools, afterwards their role will be to share and disseminate the experiences and knowledge among the farmers and other stakeholders. The support of the research institute is crucial in a scope to rise awareness about the tool's importance in agricultural practice.

5. **Consumer Organizations**: Consumer organizations represent the interests of consumers and support for access to safe, healthy, and sustainably produced food. They play a role in raising awareness about the benefits of organic food, promoting consumer education, and supporting for policies that support organic farming. The representative of the consumer organizations will be part of the Learning History Workshop during the project lasting.

6. **Environmental NGOs**: Environmental non-governmental organizations (NGOs) focus on promoting environmental conservation and sustainability in agriculture. Their role includes supporting for environmentally friendly farming practices, monitoring the impact of agriculture on ecosystems, and raising awareness about the importance of organic farming for biodiversity and

ecosystem health. The NGO will be invited to promote this pilot's solution among their farmers members.

Drivers & barriers

The drivers in Serbian pilot represents the way towards to digitalisation process. The paying agencies, within Ministries, had introduced the digital platform "e-Agrar" as a first step of the digitalisation process. From 2023, the farmers and Agribusiness are able to upload their plots, arable surface, non-organic (conventional) or organic crops data into the platform and to apply for subsidies. Within the THEROS tool, especially EO based ecosystems service, these monitoring process could be much effective and efficient and connect the departments within the Ministries itself. OCS will promote these tools among the government and paying agencies in a scope to improve this system with transparency and traceability.

Barriers: Beside the above mentioned, this process needs to be approved by many actors and request the timely and educational effort on all levels from up to down (Government to farmers). All actors must be aware of efficiency of the tools for improvements and be ready to implement them in the future practice.

Spain

Protected Designation of Origin

The production of Mexillón de Galicia, or Galician mussels, occurs in the northwest Spain. The 'Mexillón de Galicia' has Protected Designation of Origin (PDO) status granted by the European Union that ensures these mussels are produced, processed, and packaged within a specific geographic area under stringent quality standards.

Since the first raft (batea) was installed in Galicia, more than 70 years ago, mussel farming has gained such importance in Galicia that become one of the main aquaculture regions in the world. Actually, the Galician mussel culture leads the mussel production in Spain and in Europe, having an annual production of around 250.000 tons. This is more than the 98% of the total aquaculture production from Spain and far above the 55% of the European production.

Mussel culture is a circular process that begins with the spawning of the mussel that grows on the ropes of the bateas or in the rocks and continues with the collection of the seed (both on the rocky coast of the intertidal zone and by means of collecting ropes in the bateas). That small mussel is transferred again, to the bateas so that it grows and fattens. Being placed in the rafts will contribute again to this circular process with the spawning (which restarts the production cycle), and when it will reach the commercial size the mussel would be harvested.

The production of these mussels adheres to strict environmental and quality controls that begin with the selection of the mussel seeds and continue through to the packaging of the final product. The control system for the PDO Mexillón de Galicia involves rigorous standards to maintain the authenticity and quality of the product. The process includes regular inspections and audits, through the 'whole mussel value chain' to ensure compliance with the designated standards of the PDO certification. This includes monitoring the size, texture, colour, and taste of the mussels, which are key characteristics that distinguish them from other varieties.

Pilot description

The Spanish pilot aims to demonstrate that the mussel cultivated in Galicia and which holds a PDO recognized and registered in the EU through the Commission Regulation (EC) No 1050/2007, could be differentiated from other mussel species (e.g Mitilus chilensis) at different stages of the value chain, ensuring transparency and traceability. Utilizing advanced tools like the THEROS DNA tool and a blockchain system, the pilot ensures efficient recording of critical tracking events across the entire supply chain. Kiwa España S.L.U., serving as the certification body, will verify the product's traceability using the blockchain system. The participation of an independent third party in this verification process enhances consumer confidence and reinforces the

control system of the PDO Mexillón de Galicia. Kiwa provides tools and services that help producers and supply chain companies differentiate their products in the market, offering reliable information to consumers.

Location: The cultivation area of the Galician mussel is the internal maritime area of the Galician rías (estuaries) in the provinces of A Coruña and Pontevedra, which are authorised to cultivate mussels using rafts. It will comprise the following areas: Ría de Ares-Sada, Ría de Muros-Noia, Ría de Arousa, Ría de Pontevedra and Ría de Vigo (see Map in Figure below).

The cultivation area of the Galician mussel

Climatic Conditions: a temperate maritime climate with mild temperatures and high humidity. The average annual temperature ranges from 10°C to 15°C, with significant rainfall, particularly during winter. These conditions create an optimal environment for marine life, contributing to the high quality of the cultivated species.

Food Products Targeted: The pilot will focus on the cultivation of Mexillón de Galicia (Galician mussels), which holds a PDO status. This product was selected due to its economic significance, established market demand, and alignment with sustainable aquaculture practices.

Criteria for Selection:

- **Economic Importance:** Mussels are a major source of income for seaside communities in those areas in which is allowed the Galician mussel culture.
- **Environmental Compatibility:** Mussels filter feed on phytoplankton, enhancing water quality and promoting ecological balance. It is well known that along with the mussel, about 100 species of animals and algae coexist in the ropes, and many species (some as highly valued as spider crabs or shrimp)

find food and protection in the areas of rafts. According to the European Commission, the mussel culture generates positive ecosystem services to the areas where it's being cultivated.

- **Market Demand:** There is strong demand for PDO-certified Galician mussels both domestically and internationally.
- **Sustainability:** The project supports sustainable aquaculture practices, minimising environmental impact. Mussel farming is aquaculture that has the lowest footprint. According to the last studies, every Kg of mussel produced withdraws from the environment around 107 gr of CO2 equivalents. Therefore, it can be said that it has a "negative" footprint. This is the production of animal protein with the lowest impact per kg of food produced.

PDO *Mexillón de Galicia* is an example of sustainable and low-carbon aquaculture, a generator of wealth and social well-being, which enriches the European gastronomic heritage with unique, quality, nutritious and healthy food.

Traceability and DNA testing are crucial for the PDO Mexillón de Galicia as they ensure the authenticity and transparency of the product. This rigorous verification framework not only upholds the cultural and economic significance of PDO Mexillón de Galicia but also promotes sustainable and responsible aquaculture practices.

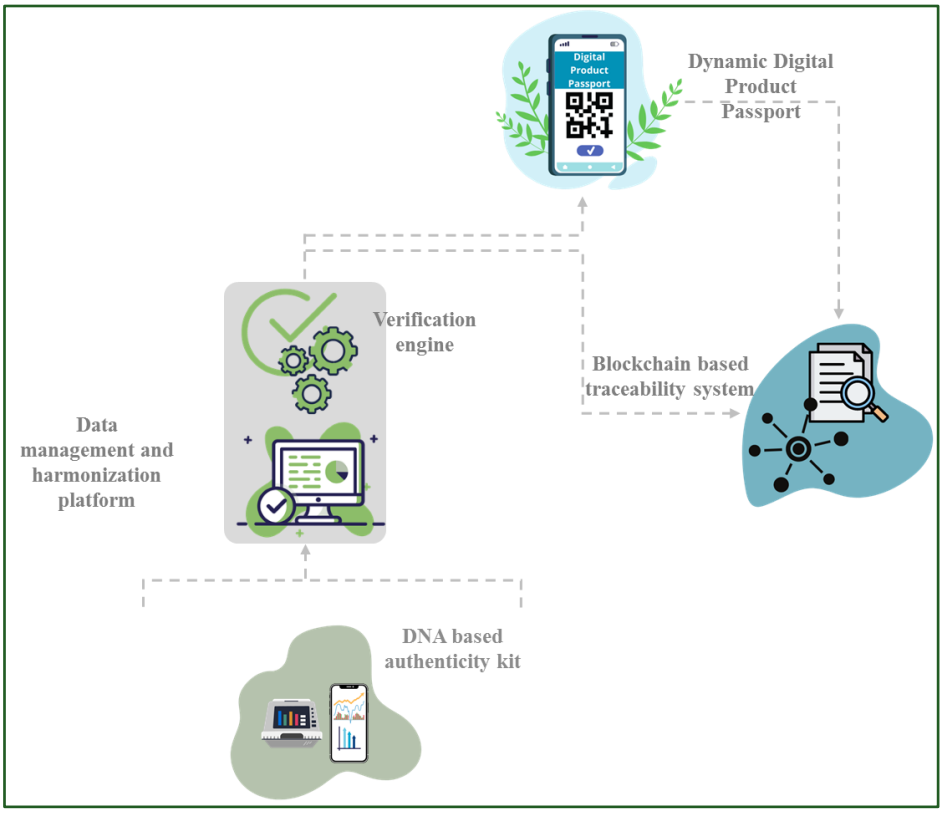
THEROS toolbox components

The Spanish pilot will focus on the deployment and real-life validation of THEROS toolbox components in Spain under the co-leadership of Consello Regulador da D.O.P. Mexillón de Galicia, Kiwa España S.L.U, Institute of Applied Biosciences (INAB) and NTT Data and will use the DNA based authenticity kit and the blockchain-based traceability system.

The DNA based authenticity kit will employ both DNA barcoding and metabarcoding techniques to verify that the mussel cultivated in Galicia, which holds a PDO, is indeed from Galicia. This will differentiate it from other mussel species, such as Mytilus chilensis. The kit is a portable device for the extraction of DNA profiles from different samples. The system will ensure the authenticity of the food asset, including an analytical framework for the prediction of the species analytical framework and origin. The results will be provided in near real-time through a dedicated interface.

The blockchain-based traceability system will ensure efficient recording of critical tracking events across the entire supply chain. Dedicated mechanisms will be employed in order to allow integration of data from end-user systems whilst applicable business rules will be supported. Efficient and standardised data models will be utilised to enable multi-product support, regulatory compliance and scalability.

In addition to the local regulatory framework, the participation of independent third parties in the verification process enhances consumer confidence. Tools like the THEROS DNA tool is used to authenticate the origin of the mussels at various stages of the value chain, ensuring transparency and traceability. Kiwa España SLU, a third-party verification body, provides tools and services that help producers and supply chain companies differentiate their products in the market, offering reliable information to consumers.



THEROS components implemented in Spanish pilot

Data collection protocols

The Spanish pilot project for PDO Mexillón de Galicia employs a comprehensive data collection and verification system to ensure the traceability and origin of the mussels throughout the value chain. This process leverages existing infrastructures and facilities across the production, elaboration and distribution stages.

The pilot site encompasses five primary production estuaries (rías) in Galicia, where a total of 3,387 rafts are distributed, of which 2,083 are registered under the Protected Designation of Origin (PDO) system. These rafts, or bateas, are traditional floating structures used for mussel cultivation, providing a controlled environment that optimises growth and ensures high-quality yields. There are 20 PDO control points strategically located at authorised ports. Samples will be taken at specific checkpoints throughout the entire production chain (see details below).

Checkpoints

The project incorporates multiple checkpoints along the value chain to ensure accurate DNA testing and traceability. The checkpoints are as follows:

i. Harvest and Landing:

At this initial stage, samples of fresh mussels are taken from the PDO control points. These samples undergo DNA testing to verify their origin and ensure compliance with PDO spesifications. In addition, the official traceability records will be uploaded to the blockchain system.

ii. Depuration and Packaging:

At the depuration centre, mussels are purified to meet health and safety standards. During this process, samples of fresh mussels are taken for the second round of DNA testing and traceability verification.

iii. Canning Industry:

Mussels are boiled and processed with sauces at the canning facilities. Samples of processed mussels are taken for the third DNA test and traceability check to ensure they meet the PDO criteria and maintain authenticity.

Data analysis plan

i. Verification Protocol

Kiwa España S.L.U., an independent third-party certification body, oversees the verification process, adding an additional layer of security. Kiwa will establish a detailed verification protocol to ensure the standardisation of the verification process. The outcome of the verification points will be displayed on the blockchain.

ii. DNA Test Analysis:

The DNA test results are analysed by INAB which sends a report that is recorded in the blockchain.

iii. Traceability Checks:

Traceability data is analysed to ensure that the batch of mussels chosen in the sampling can be traced back to its origin. This includes verifying the documentation of movements and handling of the mussels at each stage of the value chain. The blockchain technology provides a secure and immutable record of these transactions, enhancing trust and reliability.

iv. Reporting and Documentation:

Certificates or verification reports would be generated based on the analysed data, documenting the verification and traceability findings. These deliverables are part of the verification records issued by Kiwa and are stored in the blockchain system for future reference. This documentation supports transparency and provides consumers with confidence in the product's authenticity.

Stakeholder engagement

Producers and Processors: These stakeholders are at the forefront of the production process and are responsible for cultivating and processing the mussels. They provide an additional layer of security to ensure that the products meet the stringent requirements of the PDO Mexillón de Galicia.

Verification and Certification Boards: The verification and certification bodies, such as Kiwa España S.L.U., are instrumental in upholding the traceability of mussels throughout different stages of the value chain. Kiwa will verify the origin of the product across these stages. This process includes providing verification documents that are recorded in the blockchain, ensuring a transparent and tamper-proof system. Additionally, these boards address cases of illegal use of protected designations of origin for unauthorised species, upholding regulatory standards and protecting the integrity of the PDO Mexillón de Galicia.

Retailers and Distributors: As integral parts of the value chain, retailers and distributors benefit from the transparency and traceability provided by the blockchain system. This scheme allows retailers to offer significant and trustworthy information about the mussels to their customers. By providing accurate and verified details regarding the goods, retailers help consumers make informed purchasing decisions based on reliable information. This transparency builds consumer trust in the PDO Mexillón de Galicia.

Drivers & barriers

The initial implementation of the platform is accessible and currently serves exclusively as a testing environment populated with test data from different lots which have been actively followed. Validation has been successfully conducted across a range of different events like transport and different elaboration stages.

Ongoing efforts are focused on the integration of this platform with other core components of the THEROS system—most notably, the THEROS blockchain-based traceability system. This integration is pivotal to ensuring secure, tamper-proof data flows that provide comprehensive, real-time visibility across the entire mussel chain. The goal is to enable seamless information sharing among all relevant stakeholders, thereby enhancing transparency, traceability, and trust within the ecosystem.

Technical Integration Challenges and Recommendations

Integrating heterogeneous technologies—such as blockchain infrastructures—into a unified ecosystem introduces considerable technical complexity. Ensuring compatibility across data formats, communication protocols, and system architectures necessitates a high degree of technical expertise.

To address these challenges effectively:

- A **modular system architecture** is recommended to promote flexibility and scalability.
- An **API-first design approach** should be adopted to streamline data exchange and interoperability.

User Experience (UX) and Interface Design Considerations

Designing a user-friendly interface that accommodates the complexities of blockchain technologies, while also managing an average product catalogue, presents a significant challenge. The platform must serve users with diverse levels of digital literacy and technical familiarity.

To enhance usability and engagement:

- **Focused UX research** should guide iterative design decisions.
- **User feedback loops** should be incorporated to continuously refine the interface.
- **Visual aids**, tooltips, and step-by-step guidance can demystify complex processes.

Czech Republic

Organic production & control in the country

In Czechia, organic production and control are well-structured sectors regulated by national legislation and European Union standards. The country has seen a steady increase in organic farming practices, and organic production is increasingly popular with consumers' growing interest in healthy nutrition. Czechia has developed a comprehensive system for the certification and control of organic products, ensuring that all organic goods meet strict organic standards. The oversight of organic production in Czechia is managed by the Ministry of Agriculture, under which several accredited certification bodies operate. These bodies are responsible for ensuring compliance with organic farming regulations, which include the prohibition of synthetic pesticides and fertilizers, the use of environmentally sustainable practices, and the maintenance of high animal welfare standards.

Organic farming in Czechia covers a wide range of products, including crops, dairy, meat, and processed foods. The sector benefits from both government support and a growing consumer demand for organic products, driven by an increasing awareness of health and environmental issues. This demand is supported by various governmental and EU subsidies that encourage farmers to adopt organic practices.

Organic food accounts for around 1% of food consumption in the Czech Republic, presumably due to higher prices and lack of information. Also, the control mechanisms for organic production are rigorous. Certification agencies conduct regular inspections and audits to verify that organic farming practices are adhered to. This includes checking the absence of prohibited substances, ensuring proper record-keeping, and tracing the origin and flow of organic products from the farm to the consumer. Moreover, the Czech organic market is integrated into the broader EU organic market, which allows for the seamless export and import of certified organic goods within the EU, enhancing market opportunities for Czech producers. This integration also means that Czech organic products must meet the high standards set by EU organic regulations, which are among the strictest in the world.

Pilot description

The pilot project in the Klatovy region, the western part of the Czech Republic, is designed to boost awareness about the benefits of organic foods and implement innovative technologies to prevent mislabelling issues. The aim is to ensure the supply of products with the certified protected label Bioproduct, Šumava-original product, regional food of the Pilsen region and Klasa. This initiative focuses on enhancing the availability of organic foods by developing and deploying a new business model. By mapping local suppliers and retailers, the project aims to create a streamlined,

transparent pathway for organic goods “from farm to table”, ensuring they meet stringent quality standards without adulteration.

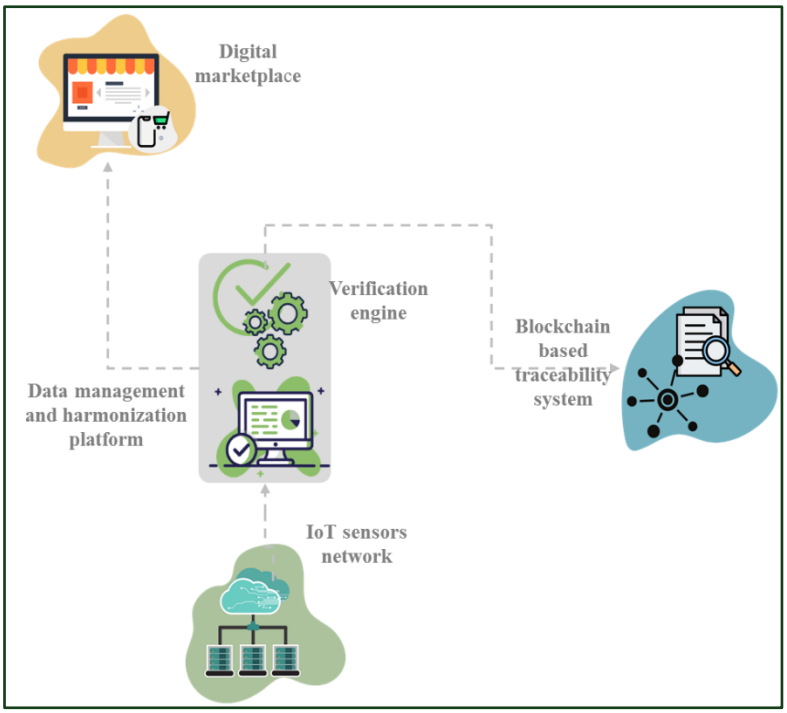
This pilot targets various organic food products, prioritising those most susceptible to adulteration and those with significant demand among local consumers. Criteria for selecting these products include their popularity within the region, the feasibility of implementing tracking and verification technologies, and the need for improved supply chain transparency.

Critical aspects of the pilot also involve integrating advanced tracking technologies such as IoT sensors to monitor the transport and handling of organic foods. The pilot can utilise QR codes to track individual packages from producers to customers. This technological framework is complemented by blockchain technology, which will be utilised to create an immutable record of the origin and journey of each product, thereby ensuring the integrity and traceability of organic goods throughout the supply chain.

This comprehensive approach aims to protect consumers and empower local organic producers by providing them with the tools and visibility needed to compete in a larger market, thus fostering the sustainability of local farming communities. Through this pilot, the Klatovy region could become a model for organic food production and distribution, showcasing how technology can be harnessed to support food quality, sustainability, and local economies.

THEROS toolbox components

In the broader context of the Czech Republic, under the guidance of SUMAVA, the pilot focuses on implementing and validating various components of the THEROS toolbox. The key activities include the roll-out of an innovative business model designed to bolster the availability of organic food via a dedicated Digital Marketplace. This platform integrates advanced monitoring services and tools, utilising IoT sensor networks to track organic food shipments. Furthermore, these components will be integrated into a blockchain-based traceability system to ensure smooth data alignment and harmonization. The project also includes various awareness-raising and promotional activities aimed at engaging customers and gathering their feedback on the new systems.



THEROS components implemented in Czech pilot

Data collection protocols

The Digital Marketplace will be set up on exclusive infrastructure owned by pilot partners, guaranteeing a safe and regulated setting for its initial implementation. This deployment is strategically designed to ensure seamless communication between the marketplace and other essential components of the THEROS ecosystem through well-defined interfaces, promoting robust interoperability and data exchange.

Specifically for the Czech pilot, the marketplace architecture has been meticulously designed to leverage data from the IoT sensor network. This setup enables real-time monitoring and verification of product status during transportation, harnessing the advanced capabilities of IoT technology to enhance product authenticity and traceability. Additionally, the marketplace is integrated with the THEROS blockchain-based traceability system, which verifies the origin, current status, and quality of listed items, ensuring accurate representation and comprehensive traceability of all products.

Data analysis plan

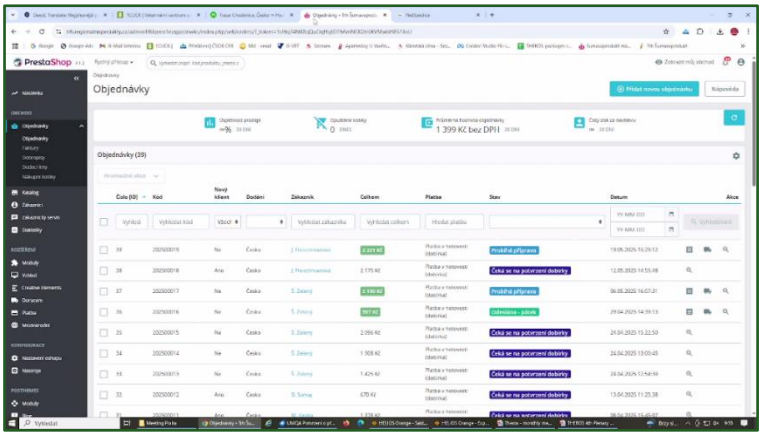
The Czech pilot will gather data from multiple sources, including user interactions, transaction logs, and IoT sensor monitoring. Each data point can be crucial for understanding different aspects of marketplace operations, from user behaviour to supply chain dynamics. The implemented system should be able to summarise the existing data to identify patterns and trends. For instance, transaction data can be analysed to determine the most popular products or peak shopping times. Sensor data

from the IoT network can provide insights into product conditions throughout the supply chain, helping identify potential quality degradation points.

Regular reports can be generated to inform stakeholders of the findings from data analyses. These reports might include performance metrics, progress towards goals (like increasing organic product sales), and recommendations for action.

Stakeholder engagement

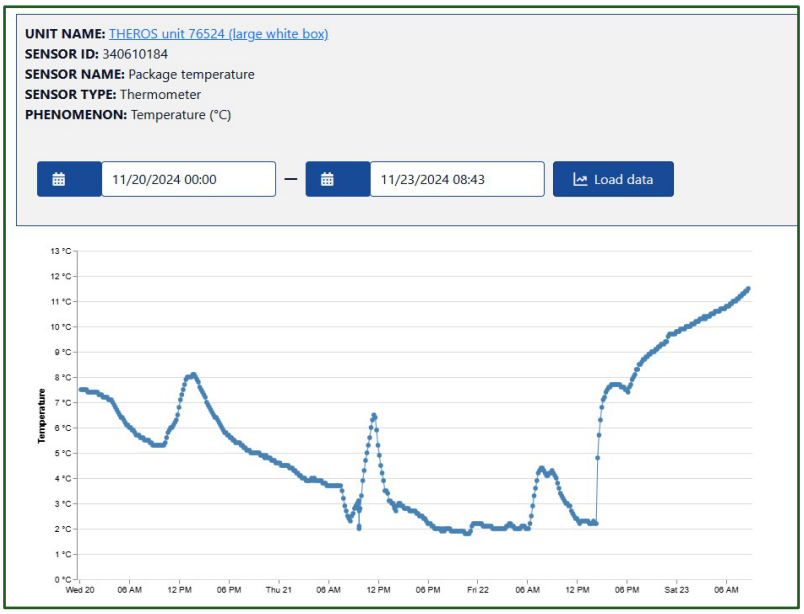
The Czech pilot activities have been deeply rooted in comprehensive stakeholder engagement, reflecting a collaborative approach that integrates all parties' diverse insights and needs. This process began with thoroughly identifying and categorising stakeholders, including organic food producers, distributors, retailers, technology providers, regulatory bodies, and consumers. This foundational work was essential for customizing engagement strategies to correspond with the distinct perspectives and contributions of each group. Surveys and questionnaires have been used, extending outreach to various stakeholders and effectively capturing various opinions and preferences, particularly from end consumers and small organic producers. Moreover, regular engagement meetings provided a dynamic platform for stakeholders to discuss the marketplace's design and functionality, including integrating key technologies like the PrestaShop's Multivendor module and IoT sensors measurements. These interactions facilitated immediate feedback and set the stage for ongoing dialogue through a continuous feedback loop, ensuring that the marketplace evolves in response to stakeholder input. A pivotal phase of this engagement involves pilot testing with selected users to assess the marketplace's performance and suitability before a broader rollout. Throughout the project, regular updates and iterative reviews will continue to shape the development process, ensuring that the marketplace remains aligned with its users' evolving needs and expectations. This structured engagement strategy underscores the project's dedication to developing a marketplace that is not only technologically advanced but also deeply responsive to the needs of the organic food community.

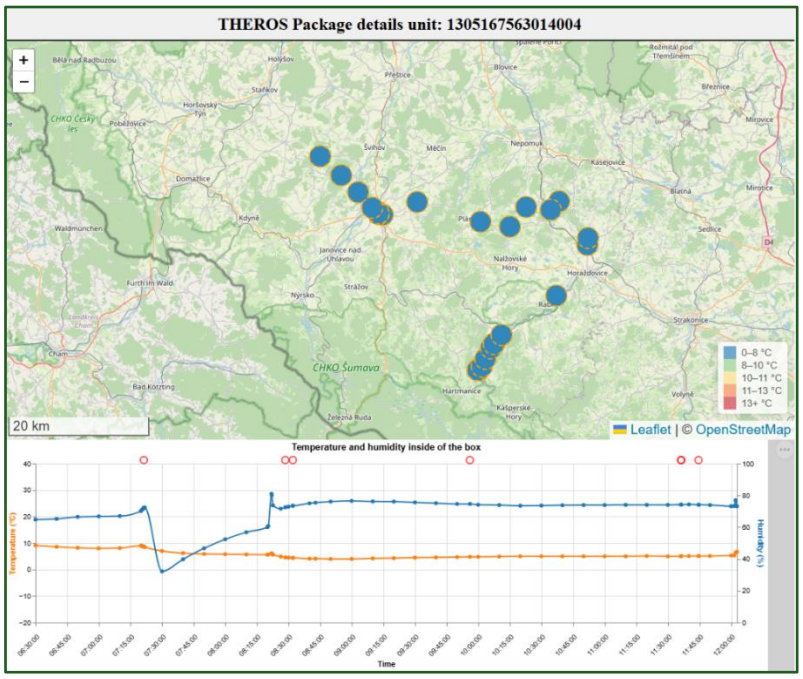


Drivers & barriers

The initial implementation can be accessed at https://trh.regionalnispeciality.cz/, serving solely for testing purposes with test data. Validation has been conducted on various types of boxes and sensors for transport monitoring. Discussions, testing, and resolution are ongoing regarding integration with other components of the THEROS system, particularly the IoT sensor network and the THEROS blockchain traceability system. This integration aims to ensure tamper-proof, reliable information flows, providing comprehensive visibility into the food supply chain. Data from all phases of the food chain will be shared in real-time among relevant stakeholders, thereby enhancing transparency, traceability, and trust. This integrated functionality will be available in the second Digital Marketplace implementation.

Integrating diverse technologies like THEROS blockchain-based traceability systems and IoT devices into a cohesive ecosystem presents considerable complexity. It requires ensuring compatibility across systems, data formats, and protocols, which demands extensive technical expertise. Adopting a modular architecture and employing API-first design principles can facilitate smoother integration. Early and ongoing collaboration with technology providers and experts will be crucial to navigate these challenges effectively.





Creating an intuitive and engaging user experience that accommodates the complexities of blockchain and IoT information alongside a large product catalogue is a significant challenge. The platform must cater to users with varying levels of technical proficiency. Improving user experience can be achieved through focused UX research and design efforts. By integrating user feedback into a continuous cycle of design improvements and making complex processes more user-friendly through clear instructions and visual aids, the overall usability of the interface can be elevated. Additionally, implementing personalisation algorithms can refine and tailor the shopping experience, making it more efficient and tailored to individual preferences.