Enforce
Empowering Citizens for Environmental Action

D3.1 Data collection tools & Data Space compliance platform

WP3- ENFORCE Plaza Tools Development

Date: 28 February 2026

Authors: Linda See, Benjamin Proß, Stamatia Rizou, Nikos Monios

Work Package	WP3 – ENFORCE Plaza Tools Development
Dissemination Level	PU
Deliverable name	D3.1 Data collection tools & Data Space compliance platform
Author(s)	Linda See, Benjamin Proß, Stamatia Rizou, Nikos Monios
Primary Contact and Email	Linda See, see@iiasa.ac.at
Due Date	28/02/2026
Date Submitted	28/02/2026
File Name	D3.1 ENFORCE Data collection tools and Data Space Compliance platform.docx
Status	Submitted
Reviewed by (if applicable)	Singular Logic and all ENFORCE Case Studies
Suggested Citation	See, L. et al. (2026) Data collection tools & Data Space compliance platform. ENFORCE Deliverable 3.1, Horizon Europe grant no. 10113447

Deliverable Abstract

The ENFORCE Plaza is comprised of four pieces, where the ENFORCE Tools is one key part that is being developed by WP3 in the ENFORCE project. The ENFORCE Tools are comprised of a number of components including (i) Citizen Science Data Collection Tools (T3.1) and (ii) the Data Space Compliance and Provenance Mechanism (T3.2), which are described in this deliverable. The high level architecture of the ENFORCE Tools Plaza is first presented to place these two components within the broader Tools Plaza. This is followed by a summary of the barriers to data collection that have been identified as part of the review of environmental compliance in D2.1 and the initial road map for the case studies in D4.1, outlining how some of these barriers are being addressed through developments in the ENFORCE project. The Citizen Science Data Collection Tools in each Case Study are then presented, including the existing data collection protocols and tools and developments in the ENFORCE project. The remaining part of the deliverable describes developments in the mechanisms for collecting data from each Case Study, and how data provenance and Data Space compliance are handled. This is followed by a brief demonstration of how the data collection is being operationalized, using examples from different Case Studies. The deliverable concludes with a summary and the next steps related to T3.1 and T3.2.

Keywords

Citizen science, data collection tools, EU Data Spaces, FAIR data, provenance, high level architecture

Project Summary

Assuring environmental compliance requires a strong network of stakeholders, from citizens and researchers to governments and environmental organisations. Through creative toolkits and protocols, ENFORCE aims to tackle the frequent mismatch between the environmental data gathered by citizens and what authorities require for enforcement purposes. The project will address the challenges in data reporting coming from both the citizens side and the authorities' side, in order for the obtained data to be usable for environmental enforcement. In this line, ENFORCE introduces the concept of Data Readiness Level (DRL) to assess the maturity of data to be used as evidence in environmental compliance cases. In addition, the project will capitalize on the use of geo-spatial intelligence and AI-enhanced tools, strengthening their capacities, promoting good practices and preparing an inventory on geo-spatial intelligence and AI use. The proposed solution will ensure alignment with the Green Deal Data Space to ensure trustworthy data exchange among the relevant stakeholders. The project encompasses 8 case studies that involve all relevant actors including grassroots organizations, local and regional authorities and a diverse group of experienced researchers forming a scientifically robust interdisciplinary team. The lessons learnt and evaluation results from the case studies will feed the replication guidelines that will be promoted through the ENFORCE capacity building programme and associated policy recommendations to create a multiplier effect for the adoption of citizen science data to support environmental compliance.

Table of Contents

Table 1: List of abbreviations

Abbreviations	Meaning
API	Application Programming Interface
CI/CD	Continuous Integration/Continuous Delivery/Deployment
CS	Case Study
DISP	Data Intermediation Service Provider
DRL	Data Readiness Level
DSSC	Data Spaces Support Centre
EPR	Extended Producer Responsibility
FAIR	Findable, Accessible, Interoperable, Reusable
GDPR	General Data Protection Regulation
IDSA	International Data Spaces Association
PFAS	Per- and Polyfluoroalkyl Substances
PFOS	Perfluorooctane Sulfonate
REST	Representational State Transfer
TDS	Total Dissolved Solids
xAI	Explainable Artificial Intelligence
WWF	World Wildlife Fund

Executive Summary

The ENFORCE project aims to bridge gaps in environmental monitoring and enforcement by creating a sustainable framework that integrates citizen involvement and technological innovation. Its primary objectives include empowering communities through Living Labs, standardizing citizen-generated data for policy and legal support and utilizing advanced techniques like geospatial intelligence and explainable AI (xAI) to ensure data reliability. Central to this is the ENFORCE Plaza, a hub for pan-European collaboration, which includes the Tools Plaza, where two components are specifically addressed in this deliverable: (i) the **Citizen Science Data Collection Tools** and (ii) **Data Space Compliance & Data Provenance Mechanism**.

ENFORCE Plaza Tools
The ENFORCE Plaza Tools consists of a modular, interoperable architecture comprised of six core layers where the first two are addressed in this deliverable:

- **Data Acquisition & Ingestion:** Collects data from apps, sensors, and satellites.
- **Data Governance & Processing:** Ensures data is trustworthy, compliant, and documented through Data Readiness Level (DRL) evaluations.
- **Intelligence & Analytics:** Uses AI to detect environmental hotspots and anomalies.
- **User Engagement & Visualization:** Provides dashboards and maps for stakeholders.
- **Integration & API / Infrastructure:** Cross-cutting layers that ensure secure communication and scalable deployment.

Barriers to the Use of Citizen Science for Environmental Compliance
Barriers to using citizen science for environmental compliance have been identified in two previous deliverables (D2.1 and D4.1) and include concerns over data quality, citizen engagement, and technical interoperability. Some of these barriers are addressed by the development of standardized methodologies and automated validation protocols, gamification and feedback mechanisms to maintain volunteer motivation, and Data Space connectors to harmonize diverse data streams with official systems..

Citizen Science Data Collection Tools
The deliverable provides an inventory of tools across eight diverse case studies:

1. **Valle Galeria (Italy):** Monitoring illegal fires and smells using the Athena web app and extended to field based data collection using the Geo-Quest mobile app.
2. **Brasov (Romania):** Identifying illegal logging using the Geo-Quest Forests module.
3. **Heraklion (Crete):** Updating the THEMIS app for reporting environmental crimes in protected areas.
4. **Barcelona (Spain):** Monitoring marine biodiversity and marine litter (cigarette butts and wet wipes) using the MINKA and MARNOBA platforms.
5. **East Devon (UK):** Fusing citizen-collected water quality data from an established citizen science project with satellite imagery to map soil erosion risk.

6. **Puglia (Italy):** Citizen reporting of illegal waste dumping using a mobile app developed by the local waste company.
7. **North Sea (Netherlands):** Developing an early warning system for marine pollution based on citizen labelling of satellite imagery.
8. **Flanders (Belgium):** Measuring PFAS contamination in soil and plants grown by local farmers and citizens to support phytoremediation efforts related to decreasing soil contamination.

Data Space Compliance and Provenance

To ensure legal robustness, the platform implements a Data Space Compliance mechanism. This involves adhering to FAIR principles (Findable, Accessible, Interoperable, Reusable) and using Data Space connectors for secure, federated data sharing. Provenance is tracked by storing all input data with calculated hash values to ensure a traceable, unalterable record of every processing step.

Operationalization

The platform has been prototypically implemented using open-source modules and REST APIs, allowing for "plug and play" integration of different Case Study data. Current mechanisms support data ingestion through files and API crawling, ensuring that information is accessible and ready for display in the Plaza's visualization tools. Examples of each of these operational mechanisms from different case studies are provided.

Next Steps

During the next 18 months of the project, T3.1 will continue to support each Case Study, ensuring that the appropriate data collection tools and protocols are in place for carrying out citizen-based data collection campaigns during implementation. T3.2 will continue to support ingestion and cleaning of data from each Case Study for display, analysis and compliance purposes (where relevant) within the ENFORCE Plaza Tools.

1. Introduction and Objectives

The ENFORCE project aims to bridge the gaps in monitoring and enforcement with a sustainable framework, improving environmental compliance through citizen involvement and innovation. This aim will be achieved through five main objectives: (i) empowering communities in environmental monitoring using Living Labs; (ii) integrating data collected by citizens for policy decisions and to support legal actions through official standards; (iii) assessing the data readiness of citizen-generated data for regulatory use; (iv) utilizing advanced monitoring techniques including geospatial analyses and explainable AI to improve the quality and reliability of citizen-generated data in near real-time; and (v) promoting sustainable development through aligning efforts with the United Nations Sustainable Development Goals (SDGs), in particular promoting sustainable cities and communities through improved environmental compliance and governance.

One of the key outputs of the project is a pan-European collaboration and innovation hub to mainstream the use of citizen science for environmental compliance assurance, referred to as the **ENFORCE Plaza**. Shown in Figure 1, the ENFORCE Plaza consists of four main components, where the **Tools Plaza** is the specific component that is addressed by Work Package 3 in the ENFORCE project. The **Tools Plaza** is comprised of five different elements where the first two (**Citizen Science Data Collection Tools** and **Data Space Compliance & Data Provenance Mechanism**) are addressed in this deliverable, which correspond to Tasks 3.1 and 3.2 in Work Package 3.

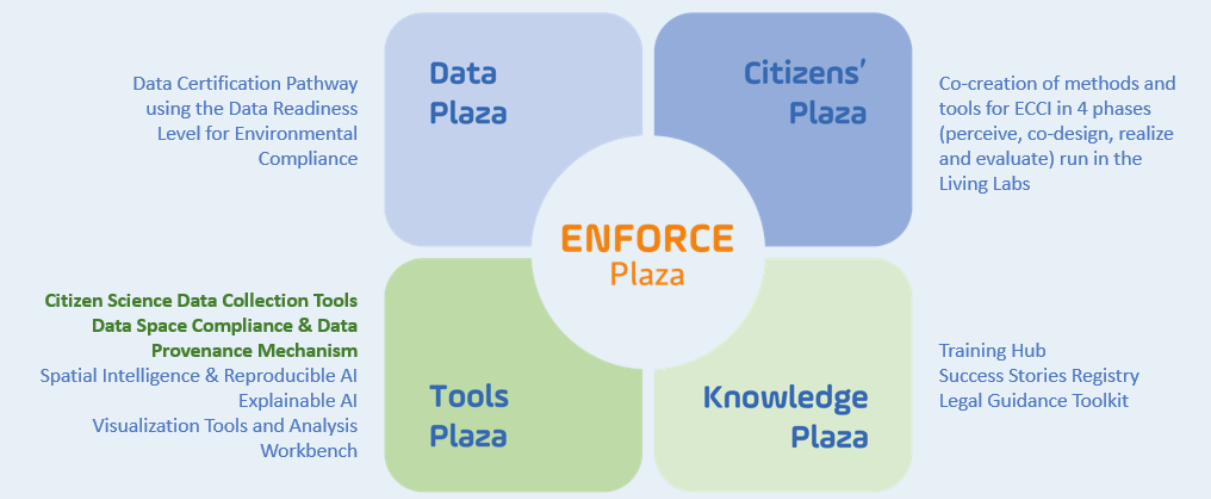


Figure 1: The components of the ENFORCE Plaza. The Tools Plaza is being developed as part of Work Package 3, with the first two elements (in bold green text) addressed in this deliverable

This deliverable is organized as follows. The next section positions the Citizen Science Data Collection Tools and the Data Space Compliance and Provenance Mechanism within the high level architecture of the ENFORCE Tools Plaza. This is followed by a section on the barriers to data collection that have been identified as part of the review of environmental compliance in D2.1 and the initial road map for the case studies in D4.1, as well as how some of these barriers are being addressed through developments in the ENFORCE project.

Each Case Study is then presented in Section 4, covering the Case Study context, the existing data collection protocols and tools, and the developments being made in the ENFORCE project. Sections 5 and 6 address the second part of the deliverable, i.e., the Data Space Compliance and Provenance Mechanism and how the data collection is being operationalized. Finally, a summary is provided along with next steps.

2. Contribution to ENFORCE Tools Plaza

ENFORCE will deliver a modular toolkit design, which is being developed to ensure seamless integration of components from T3.1 to T3.5. The key characteristics of the toolkits are:

- **Pluggable Architecture**: Each WP3 tool functions as an independent module exposing APIs, which the Plaza Toolkit orchestrates via service connectors.
- **Standardized Metadata & Provenance**: T3.2 contributions will ensure all data pipelines include traceable metadata, in compliance with FAIR principles.
- **User-Centric Interfaces**: The Plaza interface will support dashboards, maps, and explainable visual outputs.

The ENFORCE Plaza Toolkit is envisioned as a modular, interoperable, and extensible technical system enabling citizen-generated environmental data to become actionable evidence for environmental compliance. Its architecture is designed to align with both the user needs captured early in WP3 and the technical constraints revealed through interaction with the eight Case Studies in ENFORCE.

Figure 2 presents the High-Level Technical Architecture of the ENFORCE Plaza Toolkit. The architecture consists of the following core components:

1) Data Acquisition & Ingestion Layer

The Data Acquisition & Ingestion Layer is responsible for collecting all incoming data from citizen science apps, sensors, satellite sources, cloud repositories, and external APIs. It supports both real-time and batch ingestion while capturing essential metadata at the source to ensure traceability. This layer harmonizes heterogeneous inputs—ranging from georeferenced photographs and environmental measurements to legacy datasets—cleaning, anonymizing, and structuring them before passing them to downstream services. It establishes the foundation upon which high-level analytics and governance components operate.

2) Data Governance & Processing Layer

The Data Governance & Processing Layer ensures that all data entering the ENFORCE ecosystem is trustworthy, compliant, and properly documented. It manages metadata, provenance, versioning, access rights, and Data Readiness Level (DRL) evaluation, enabling traceable and legally robust data flows. This layer incorporates cleansing operations, policy enforcement, and secure interaction with Data Space connectors to align with European standards such as GAIAX and IDSA (International Data Spaces Association). It acts as the backbone for ensuring interoperability, quality control, and ethical handling of citizen-generated and external datasets.

3) Intelligence & Analytics Layer

The Intelligence & Analytics Layer transforms raw and curated data into actionable insights through geospatial intelligence, machine learning, and explainable AI (xAI) pipelines. It supports tasks such as environmental hotspot detection, anomaly identification, land use change analysis, species or object recognition, and predictive modelling using Earth Observation data. Designed for reproducibility and transparency, the layer enables stakeholders to understand not only what the system predicts but why, supporting enforcement processes, scientific validation, and informed policymaking.

4) User Engagement & Visualization Layer

The User Engagement & Visualization Layer provides the primary interface through which users interact with the Plaza Toolkit. It offers intuitive dashboards, interactive maps, timelines, alerts, and reporting tools tailored to diverse personas such as citizens, researchers, administrators, and inspectors. By integrating data from all backend layers, it enables users to explore observations, monitor environmental trends, validate information, and contribute feedback. This layer emphasizes accessibility, clarity, and engagement, ensuring that complex analytics are presented in understandable and actionable formats.

5) Integration & API Layer (Crosscutting)

The Integration & API Layer functions as the middleware enabling secure, standardized communication across all Plaza components and external systems. It exposes REST and GraphQL APIs, manages authentication and authorization, applies access policies, and ensures that every data interaction is provenance aware. By harmonizing service interfaces and enforcing governance rules, this layer guarantees interoperability, modularity, and scalability across the federated architecture of ENFORCE.

6) Infrastructure & Deployment Layer (Crosscutting)

The Infrastructure & Deployment Layer ensures robust, scalable, and maintainable operation of the Plaza Toolkit through containerized services (e.g., Docker, Kubernetes), CI/CD pipelines, and cloud-agnostic deployment strategies. It supports logging, monitoring, data backup, disaster recovery, and compliance with security and GDPR requirements. This layer underpins the platform's reliability and facilitates smooth updates, testing, and deployment across central or Case Study specific environments.

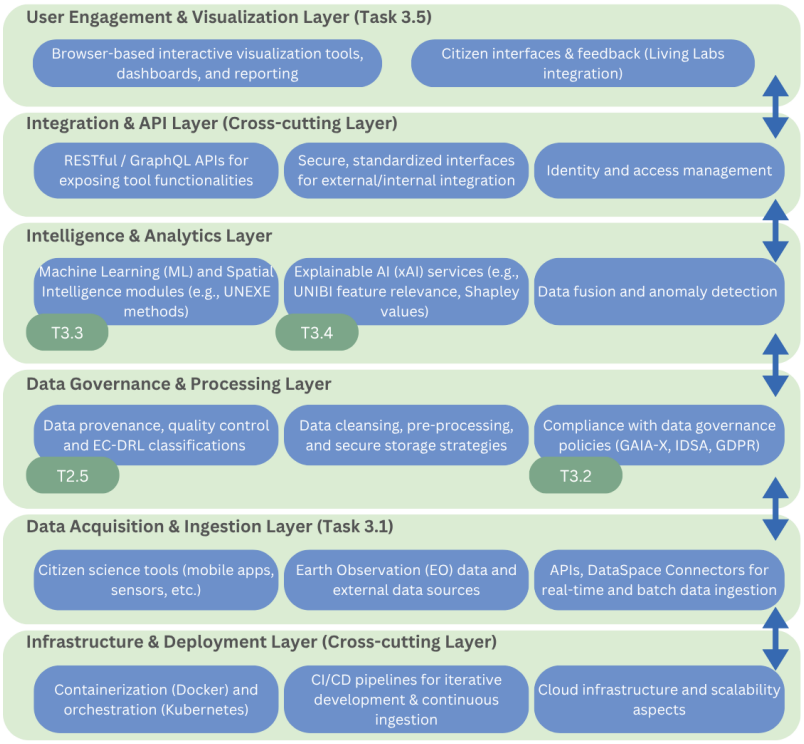


Figure 2: Components of the High-Level Technical Architecture of ENFORCE Plaza Toolkit

Deliverable D3.1 focuses on the data acquisition and data governance layers (Layer 1 and 2), which provide the foundational components of the ENFORCE Plaza, enabling data collection.

3. Barriers to Citizen Science Data for Environmental Compliance

There are barriers to the use of citizen science data for environmental compliance, which are being used to guide the development and optimization of the citizen science data collection tools in the ENFORCE project. Some more generic barriers have been identified as part of **D2.1 Environmental Compliance: A Review** while Case Study specific barriers have been identified as part of **D4.1 Initial Roadmap and Monitoring Plan for the Activities and Actions at the Case Studies** in relation to their current data ecosystems and specific challenges identified. These are summarized in Table 2 along with how these barriers are being addressed by the tools outlined in this deliverable.

Table 2: Barriers to the use of citizen science data for environmental compliance identified in D2.1, D4.1 and how they are being addressed

Barriers identified	**Description**	**Case studies identifying similar barriers in D4.1**	**How these barriers are being addressed**
Data quality and reliability (D2.1, D4.1)	Concerns about data credibility, bias, inconsistency, and the lack of validation protocols so there is a need for standardized methodologies, quality control procedures, and expert review to ensure data reliability.	CS1, CS2, CS3, CS4, CS7	There are different ways of addressing data quality including automated checking of anomalous data, checking by experts, comparison with authoritative data, and checking by peers. Each Case Study is addressing data quality using their own methods, but the Data Space Compliance Platform can flag entries with missing or anomalous data and feed this back to the Case Studies. The Data Readiness Level, currently being developed in WP2, represents a standardized method that will be used to assign a level of data reliability to each Case Study dataset.
Citizen motivation and engagement (D2.1)	Declining or inconsistent engagement, limited motivation, or low long-term commitment among citizens and ensuring representativeness.	CS3, CS5	Gamification methods can be used to improve citizen engagement and motivation, which are built into the Geo-Quest app. Visualizing the data collected and providing feedback to citizens is a strong motivator, which will be part of the broader Plaza Tools.
Political and economic pressures (D2.1) versus complete anonymity (D4.1)	The risk of political or corporate backlash against citizen science actors who monitor sensitive sites including lobbying, intimidation, bureaucratic obstruction, and threats. Emphasis on anonymity for data collection so limits ability to follow up with users for additional information, creating barriers to successful prosecution and long-term deterrence	CS3	Data will be pseudo-anonymized in Case Studies where this is relevant so that identification of individuals will not be possible. To be GDPR-compliant, a minimum amount of personal data will be collected.
Data interoperability and integration (D2.1)	The lack of technical compatibility between citizen science data and official datasets, or the absence of mechanisms to integrate citizen science data into public systems and workflows including accurate metadata	CS1, CS2, CS3, CS6, CS7	The Data Space Compliance platform has developed different data connectors to ingest diverse data streams from the eight case studies. There is also metadata associated with all datasets.
Lack of user-friendly tools and lack of data access (D4.1)	Need for user-friendly tools to communicate complex data to non-technical audiences. Multiple actors are involved in collecting, storing and managing data and evidence, which is not always publicly available or easily accessible.	CS1, CS5	The Plaza Tools are intended to integrate data from diverse data streams and present the information in a user-friendly way, working with each Case Study to fulfil their user requirements. Where possible, the data will be publicly accessible.

Connectivity issues (D4.1)	Connectivity issues in rural and mountainous areas that prevent real-time data submission and reduce timeliness of enforcement actions.	CS3	The mobile apps being developed in ENFORCE have offline data collection functionality to allow the data to be uploaded once the user has a connection.
Data verification (D4.1)	Data verification process is manual and time consuming.	CS3	Manual data verification will be made easier through integration with satellite data, which is being addressed in WP5.
Lack of soil-plant PFAS measurements (D4.1)	There is a lack of data on the uptake of PFAS by plants. To determine the uptake, measurements of PFAS concentrations are needed from both the soil and the plants.	CS8	Protocols for data collection and analysis have been developed in CS8 that collect both soil and plant samples (see section 4.8).
Sparse sampling of Citizen Science data, particularly in remote areas.	Citizen Scientists tend to collect water samples from convenient locations, leading to an uneven distribution both spatially and temporally.	CS5	Supplement Citizen Scientist water quality samples with water quality samples taken by the Environment Agency (EA). Both water quality samples measure the key metric of interest: turbidity, but the EA data collection is automated and regular, repeated at regular intervals in the same water sampling stations. These water samples are to be used to build a model of water quality from Earth Observation data, so are only required for the model development stage.

Other barriers were identified in D2.1 that will be addressed in other places within the ENFORCE project. For example, there is an absence of clear legal frameworks, standardized procedures, and regulations that hampers the admissibility and operational use of citizen science data in compliance cases. These types of legal issues are being dealt with specifically in WP2. Another barrier is the lack of trust or openness from public authorities, legal professionals, courts, and scientists toward citizen science, including institutional reluctance to accept non-institutional data and perceived threats to institutional authority. The Living Labs taking place within each Case Study address this barrier as well as the barrier related to the lack of awareness and education since citizens are part of these Living Labs. Case Studies are also organizing outreach, training, and educational programs as part of their citizen science engagement strategies. Finally, there are barriers related to funding, staffing, scalability, and long-term sustainability since projects rely solely on volunteer work or short-term grants, which will be addressed in WP6 under exploitation.

4. Inventory of Data Collection Tools

During the first year of the ENFORCE project, several meetings were held with the Case Study leaders to elicit their requirements and to identify their data collection tools and needs. Table 3 summarizes the data collection tools identified and the thematic area for the types of data that will be collected. In addition, as a horizontal development, the ENFORCE Plaza Tools will include a progressive web app (without sign in restrictions) that can be used by any of the Case Studies as an ad hoc 'opportunistic' data collection tool; this tool will be reported on in a later deliverable.

Table 3: Data collection tools identified in each Case Study along with developments in ENFORCE

Case Study #	**Data collection tools identified**	**Thematic area**	**Developments in ENFORCE**
1	Community-built web application called ATHENA for reporting fires and smells online	Illegal fires and noxious smells Possible future extension to soil contamination and biodiversity	Geo-Quest ENFORCE-Valle Galeria app for reporting fires and smells in the field, with linkage to ATHENA Lab analyses of soil Biodiversity monitoring
2	SUMAL platform and Forest Inspector mobile app	Illegal logging and status of the forests	Geo-Quest ENFORCE-Forests app for reporting
3	Themis mobile app and web application	Any environmental crimes, e.g., land clearing, waste dumping	Updated version of THEMIS mobile app and platform
4	MINKA mobile app and web application	Marine biodiversity and marine pollution (cigarette butts and wet wipes)	Modified version of MINKA for marine pollution Use of MANORBA mobile app and web application Use of JRC Floating Litter Monitoring app (still under discussion)
5	West Country Citizen Science Investigations paper-based survey, Cartographer data platform, and equipment for water quality monitoring	Water quality, soil erosion	Risk probability maps of soil erosion based on citizen science data, available regulatory data, and remote sensing and protocol for identifying soil erosion pathways to validate risk probability maps
6	SANB mobile app to report waste collection (currently not working)	Illegal fires, illegal waste dumping	Working version of SANB mobile app and access to the data OR Geo-Quest ENFORCE-Waste mobile app
7	Co-Creation Navigator, T-Factor Guide for Temporary Placemaking and Urban Ecology Field Atlas but nothing related specifically to this Case Study	Water quality, marine biodiversity	Early warning system for citizen identification of changes in ocean colour and oil spills using satellite imagery
8	Lab analysis of soil samples and protocols for soil biodiversity analysis	PFAS contamination of soils and plants	Protocol for manual data collection of plant materials and soil/groundwater samples for lab analysis of PFAS

The data collection tools for each Case Study are now described in more detail in the sections that follow. Note that more detailed information on the data variables and the modelling requirements of each Case Study is provided in **D4.4 Implementation of ECCI tool and Living Labs in all Case Studies—Initial**.

4.1 Case Study 1: Valle Galeria, Italy

4.1.1 Context

This Case Study is located within two neighbourhoods of Valle Galeria in the 11th and 12th districts of the city of Rome, Italy. This area is heavily polluted with industrial and chemical waste and includes the site of the former Malagrotta landfill, which is now closed and under remediation. There is an already well-established grassroots organization comprised of citizens living in the area called the Valle Galeria Committee. They have been monitoring key environmental parameters related to air pollution and fires, but they are also interested in monitoring soil and water contamination and the impact of the pollution on biodiversity, because the Case Study borders a protected area that is part of the World Wildlife Fund (WWF) of Italy's network of Oases as well as containing an Oasis for bird life. The Case Study aims to improve the environmental quality of the area by utilizing citizen-collected data to apply pressure on institutions to remedy the pollution problem, particularly if the pollutants are proven to exceed maximum legal limits.

4.1.2 Existing data collection protocols and tools

One of the Valle Galeria Committee members has developed a web application called Athena, which allows citizens to make online reports of either fires or smells. A screenshot from the Athena app is shown in Figure 3. The app allows users to visualize reports made about the location of illegal fires (Figure 4) and smells (Figure 5) as well as making reports and uploading photographs and videos of the fires. All data are uploaded through this online platform as there is currently no mobile application for field-based data collection.

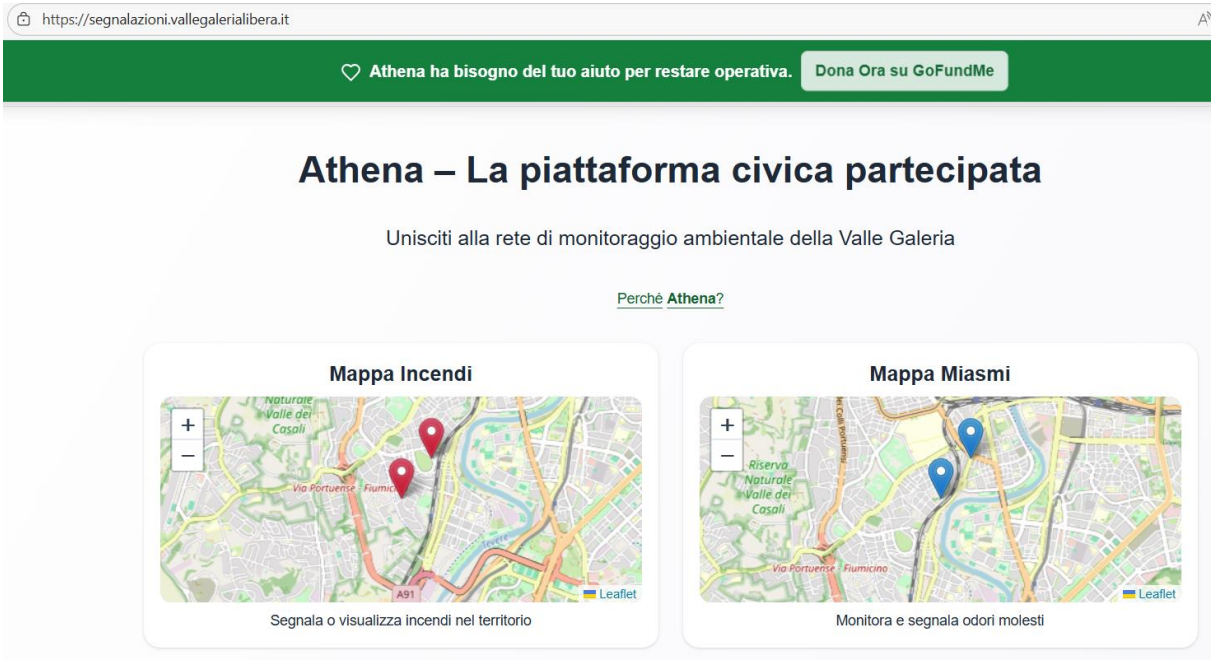


Figure 3: Screenshots from the ATHENA web application for report illegal fires and noxious smells

(a) (b)

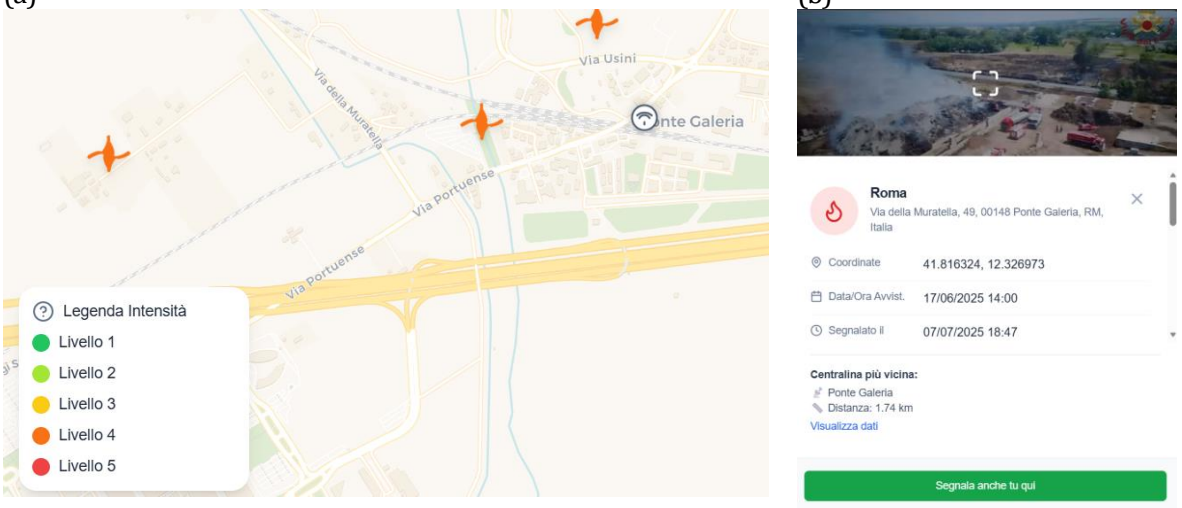


Figure 4: Visualization of data on (a) illegal fires including the level of intensity and (b) the information about the fire when clicking on one report.

(a) (b)

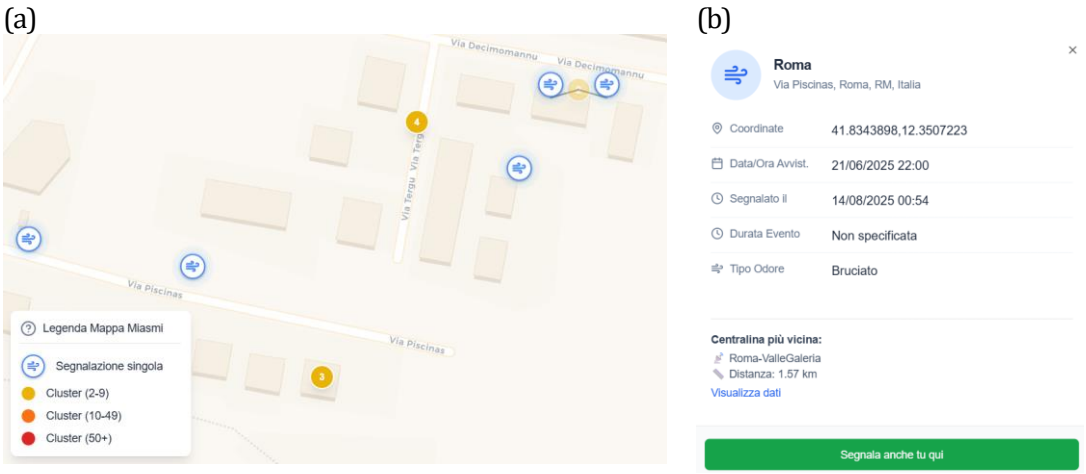


Figure 5: Visualization of data on (a) noxious smells and (b) the information about the type of smell when clicking on one report, in this case a burning smell.

Any user can also download all the reports made to the application by going to the system dashboard. This dashboard summarizes the data collected and has an export option, which downloads the data as an Excel file. The file contains the data listed in Table 4.

Two other sources of information that are consulted by the Valle Galeria Committee are air quality and water quality. Air quality data are available from four independent, non-institutional air quality sensors, built and calibrated by an independent fablab. Data on PM10 and PM2.5 can be viewed on the Che Aria Tira website and the data can be downloaded from the Ready Data website of the Che Aria Tira project. Authoritative measurements of air quality (PM10 and PM 2.5) are also available for one station (control unit nr 53 Malagrotta) maintained by the Regional Environmental Protection Agency of Lazio (ARPA Lazio), available at: https://sira.arpalazio.it/web/guest/banche-dati/visualizzazione/aria#/.

Table 4: Data on illegal fires and noxious smells downloadable from the Athena web application

Name	Description	Format
Type	Indicates whether this is a fire or a smell	Text
Municipality	Indicates the area such as Rome	Text
Location	Full address including postal code and city	Text
Date	Date and time of the report	Date and time format
Type of smell	The choices are: Discharge gas/Fuel; Burnt trash/plastics; Chemical/Solvent ; Sewage/ Rotten eggs; Decomposition/Organic waste; Asphalt/Tar; Burnt vegetation: Other, which users can then specify; applies only to smells	Text
Intensity of the fire	Five levels of intensity from 1 (very low) to 5 (very high); applies to fires only	Integer
Area affected by the fire	Area in hectares; applies to fires only	Floating point
Visible smoke	Yes or no; applies to fires only	Text
Media Link	URL to the storage location of the photographs or videos; applies to fires only	URL
Coordinates	Geographical coordinates of the report	Latitude, Longitude

ARPA Lazio also publishes water quality data from two water monitoring stations on the River Galeria. Data for 2020 to 2024 can be downloaded from this link:

https://sira.arpalazio.it/banche-dati/visualizzazione/acqua/#/

The Case Study would like to see these data integrated into a single place so they can be viewed together.

4.1.3 Developments in ENFORCE

A face-to-face meeting was held with ASud and members from the Valle Galeria Committee on 18 November 2025 to discuss the development of a mobile app that could be used by members to collect data in the field. This would complement the Athena application, which would also be able to display data from the mobile app. It was proposed to develop a module in IIASA's Geo-Quest mobile app for field-based data collection. The Geo-Quest app contains different modules for data collection (referred to as 'quests'), so an ENFORCE-Valle Galeria module has been added to the app and is currently being tested. The survey questions in the app were based on inputs provided by ASud and the Valle Galeria Committee, available in both English and Italian. Figure 6 shows screenshots from the mobile app.

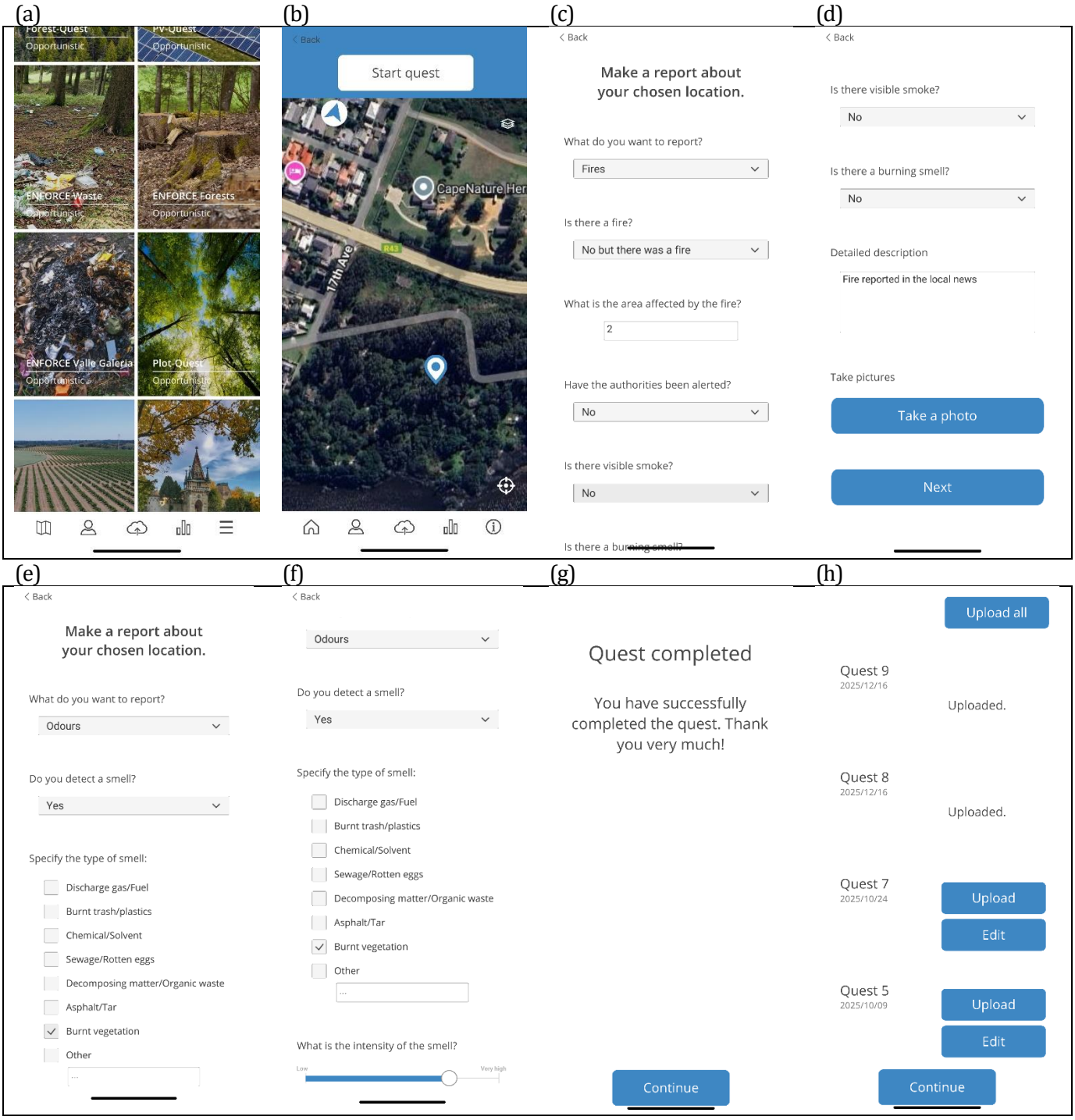


Figure 6: Screenshots from the Geo-Quest ENFORCE-Valle Galeria mobile application

Data from Geo-Quest are openly exposed via an API. Two different types of data are collected. The first are related to the user and the device. These include:

- Username / alias
- Email address
- Password stored in hashed form
- App identification and version
- Smartphone operating system and version
- Device make and model
- Device identifier (e.g., serial number), where available
- Language used in the app during submission
- Position (latitude/longitude and reported accuracy)
- Compass heading and/or device orientation (e.g., tilt/angle)

The second type of data are related to the Valle Galeria module in Geo-Quest, which contains a modified version of the data listed in Table 4.

The air quality and water quality data will be display in the Plaza Tools. The collection of data on soil contamination is ongoing as members of the Valle Galeria Committee have taken samples. Biodiversity monitoring is still under discussion within this Case Study and will either be undertaken using the MINKA app (see Case Study 4) or a popular biodiversity citizen science app such as iNaturalist. Both applications have APIs that would allow any data collected in ENFORCE to be ingested in the Plaza Tools.

4.2 Case Study 2: Brasov, Romania

4.2.1 Context

Forest governance in Romania, particularly regarding timber harvesting, environmental compliance, and transparency of forest management practices, has become a subject of increasing societal attention. This concern is characterised by a high degree of polarization at the societal level, marked by suspicions regarding any activities related to tree cutting and timber transport from the forest.

Public discussions frequently reveal diverging perspectives among stakeholders, including forest managers, authorities, local communities, environmental organisations, and market representatives. These divergences highlight the need for improved communication, trust-building mechanisms, and accessible information tools that support collaborative decision-making and sustainable forest management. In this context, a transparent and accessible monitoring method can contribute to both compliance with environmental provisions and the restoration of trust between forest managers and civil society.

The aim of this Case Study is to identify illegal logging and to support local sustainable forest management in the forests of Brasov in Romania. The Forest Guard operates at the national and regional levels in Romania, but there is a delay in providing relevant forest-related information to local forest managers, while timely information is needed. An additional aim of this Case Study is to involve citizens in identifying illegal logging and providing updates on the forest's status, thereby involving local authorities, forest managers, and citizens in the environmental protection of the forest.

4.2.2 Existing data collection protocols and tools

The SUMAL system is Romania's national forestry management and tracking platform, which is designed to monitor the entire wood management supply chain and reduce illegal logging. The SUMAL system has been used since 2008, enabling real-time monitoring and accountability by requiring forestry operators to log all harvesting and transport activities. The fully digitized tool was implemented in 2021, integrating data from multiple sources, including transport permits, wood valuation documents, forest management maps, and protected natural area boundaries. The vulnerabilities detected by making use of the tool are currently addressed by a strategic project financed within the National Recovery and Resilience plan. SUMAL 3.0 will include a completely redesigned structure for large data volumes, optimization of data traffic between the server and mobile applications, an advanced reporting module for detecting abnormal behaviour by economic operators, and integration of the National Forest Guard (established in 2023) as an official user.

Linked directly to the SUMAL system is the Forest Inspector application, a mobile and web tool that is accessible to the general public. The Forest Inspector application provides real-time information on timber harvesting and transport activities. It can be used to track the movement of timber on public roads, e.g., the licence plate of a wood transport truck can be reported, along with the date, time and a photograph. This information is needed as part of any indictments for illegal logging. The Forest Inspector mobile app (SUMAL Inspectorul padurii) is available for Android phones from the Google Playstore.

Several limitations have been identified with the Forest Inspector app and the SUMAL system, such as user-friendly features and access to the raw data. Additionally, there is no option for citizens to receive any feedback on their reports (e.g., was the logging illegal, did it lead to enforcement, etc.), so this has demotivated citizen participation. Finally, the Forest Inspector app works well in identifying wood transports on public roads, but it has not been designed to monitor illegal activities inside the forest or provide information on the forest status, which could be helpful for local forest managers.

4.2.3 Developments in ENFORCE

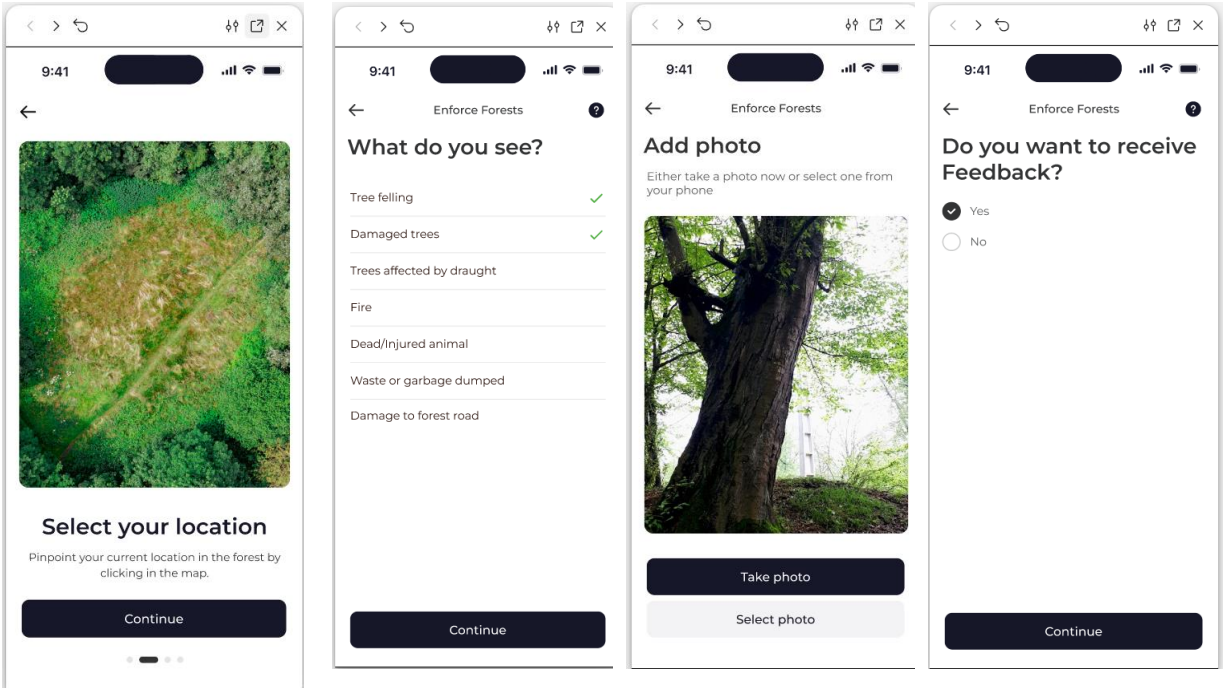
Within the ENFORCE project, the Brașov Case Study focuses on the development and testing of a participatory digital tool designed to complement existing national monitoring infrastructures and strengthen stakeholder engagement in environmental compliance processes. While national systems such as SUMAL and the Forest Inspector application provide important transparency and traceability functions, they are primarily oriented toward administrative monitoring workflows and require specialised knowledge for effective interpretation.

During the initial phase of the project, the Case Study team initiated discussions with developers and institutional stakeholders responsible for the SUMAL platform to explore potential collaboration and technical integration between national monitoring tools and ENFORCE digital solutions. Several requests were submitted to establish cooperation mechanisms and assess opportunities for interoperability. However, despite these efforts, formal collaboration could not be established during the current project phase. This situation meant that the Case Study decided to adopt an alternative strategy focused on developing complementary tools that operate independently while remaining conceptually aligned with existing national infrastructures.

The core development within the Brasov Case Study is the ENFORCE Forests Geo-Quest module, a participatory digital tool designed to facilitate structured citizen reporting, improve information flow between stakeholders, and strengthen collaborative environmental governance.

The Geo-Quest platform enables users to document forest-related disturbances through a guided workflow that includes selecting a location, classifying the issue, providing geo-tagged photographic documentation, and optional feedback requests. To encourage citizen involvement and enhance communication between the interested parties, the forest managers have to validate the reported event and provide feedback to citizens, which will be part of the functionality of the Plaza Tools. This structured approach ensures consistency in reporting while improving the usability of collected data for validation and decision-making processes.

Screenshots from the ENFORCE Forests Geo-Quest module are shown in Figure 7, illustrating the sequential reporting workflow.



(a) (b) (c) (d)

Figure 7: Screenshots from the Geo-Quest ENFORCE-Forests mobile application showing (a) an instruction screen (b) the information to be collected on the forest (c) adding a geo-tagged photograph and (d) indicating whether the user would like feedback on their report.

In the first instance, the user has to mark the location where they want to make the report. The next step is to define the issue identified (Figure 7b), then take a photograph of the observed event and indicate whether they want to receive feedback on their report. The feedback variable is currently only collected by the mobile app and needs to be linked to some type of interface in the Plaza Tools whereby authorities can provide feedback and citizens can read the feedback. Two types of data are recorded by the app. The first type is the same as that listed in Case Study 1, while Table 5 shows the data that are specific to the ENFORCE Forests module in Geo-Quest; these data will be made available by an API.

Table 5: Data on forests collected by the ENFORCE Forests Geo-Quest mobile app

Name	Description	Format
ID	Unique ID for the observation	Integer
Location	Latitude and longitude of the observation	Floating point
Report	One or more variables selected that describe the forest including deforestation, fires, waste, etc.	Text
Photograph	One or more photographs of the location	Blob
Feedback	User indicates if they want to receive feedback on their observation (Yes/No)	Integer
Timestamps	Timestamps of key actions (e.g., start, capture, submit)	Date/time format

The mobile app also has a glossary containing forest management terminology and illustrative photographs as an educational tool for citizens. The app is currently being tested by NIRDF and BDG. In the future, near-real-time fire and deforestation alerts will be ingested into the app from Global Forest Watch, providing an additional information layer. These alerts could be used as locations where citizens and local managers could make reports in a more location-driven data collection approach.

A central innovation of the ENFORCE methodology is the establishment of an empowerment feedback loop, whereby validated information is communicated back to users and relevant stakeholders. This mechanism aims to increase trust, reinforce citizen engagement, and support continuous learning among participants.

4.3 Case Study 3: Heraklion, Crete

4.3.1 Context

The main aim of this Case Study is to identify cases of land clearing in the Regional Unit of Heraklion based on environmental complaints from citizens (logged via a mobile app) that would lead to the identification of illegal activities. The participation in environmental monitoring is intended to raise citizen awareness of these environmental problems but also helps to identify incidents that could remain unnoticed. The competent authorities involved in addressing these issues are then informed so that action can be taken, which may include court procedures.

4.3.2 Existing data collection protocols and tools

This Case Study builds upon the LIFE Natura THEMIS mobile app, which was developed in a previous project (LIFE14/GIE/GR/000026 project). This app empowered citizens to report on environmental crimes that occurred in Crete, especially within Natura2000 protected areas. It provided data on habitat destruction, wildlife crimes, and unauthorized waste disposal including descriptions (optional) and geotagged photographs, with an emphasis on the anonymity of reporting.

Figure 8 shows the step by step data collection process through screenshots from the original version of the app (the new version is going to be more user friendly). Figure 8a shows the home screen, where the user can choose the operating language (Greek/English) since the app was also targeted at tourists. The next step (Figure 8b) allows the user to take up to 4 photographs, which are georeferenced. In Figure 8c we can see an example of a photograph of illegal waste disposal. In this report, Figure 8 the user provided 4 different

photographs of the environmental violation and additionally provided a short description (optional) to document it, within a specially designed text box (Figure 8d).

(a) (b) (c) (d)

Figure 8: Screenshots from the THEMIS mobile app for data collection of environmental crimes including (a) the home screen (b) a screenshot of the step when the user is asked to upload at least one photo of the environmental violation and briefly describe it (c) an example of a photograph uploaded to the app and (d) a screenshot showing an example of a report with photographs and a detailed description.

Data collected by citizens from the previous LIFE project have been provided by the University of Crete (UoC). The reports were/will be filtered by the UoC and only the ones concerning illegal actions linked to land clearing in the Regional Unit of Heraklion were/will be provided to ENFORCE. Examples of activities directly or indirectly associated with land clearing include the removal or burning of natural vegetation, waste disposal activities, road construction, and the extraction or removal of inert materials. The main fields, a description and the formats of the data provided per report are listed in Table 6.

In order to examine, evaluate and file the reports, the THEMIS app is linked to an online management platform, where the data received during the LIFE project were manually examined by staff at UoC and other partners, and then classified by the type of environmental violation/crime. This classification is useful to determine which relevant authority should be contacted. A letter was then prepared with the details of the environmental crime and sent to the relevant authority. During the project lifetime, the operation of the application has led to restoration activities by the relevant authorities as well as the imposition of one fine. Since February 2021, only the UoC has been managing reports from the citizens.

Table 6: Data on environmental crimes collected using the THEMIS mobile app

Name	Description	Format
Fictionary	Unique ID for the observation from 1 to 20	Integer
Date of report	Month and year of the report	Date format (MM-YY)
Description	Description of the activity (waste disposal, road construction, etc)	Text
Coords	Latitude and Longitude of the report	Floating point pair
Municipality	Municipal zone within the Regional Unit of Heraklion	Text
Protection status	Inside/outside a designated Natura 2000 area	Text
Outcome	If any. For example: answers from authorities who received the report or a potential penalty (if the person who made the violation is identified, i.e. imposition of a fine)	Text

4.3.3 Developments in ENFORCE

The THEMIS app and the management platform are currently being technically rebuilt and updated in the ENFORCE project by the same company that produced the app during the LIFE project. Apart from technical solutions that will make the application compatible with most smart devices, the new version will provide more precise instructions for use. In this way, efforts are being made to have new users prepared for a couple of tricky spots in the application including the necessity for georeferenced data so that we do not miss important inputs from the citizens. The data transfer chain from citizen → UoC → authorities → Plaza Tools includes potential plans to expose a subset of the original reports (land clearing cases) via an API so that the data can be directly accessed via the ENFORCE Plaza Tools. The exact role of the Plaza Tools in supporting this Case Study is still under consideration but the data could be visualized by the public or the competent authorities in an aggregated or blurred format to preserve confidentiality of the reports.

4.4 Case Study 4: Barcelona Urban Beaches, Spain

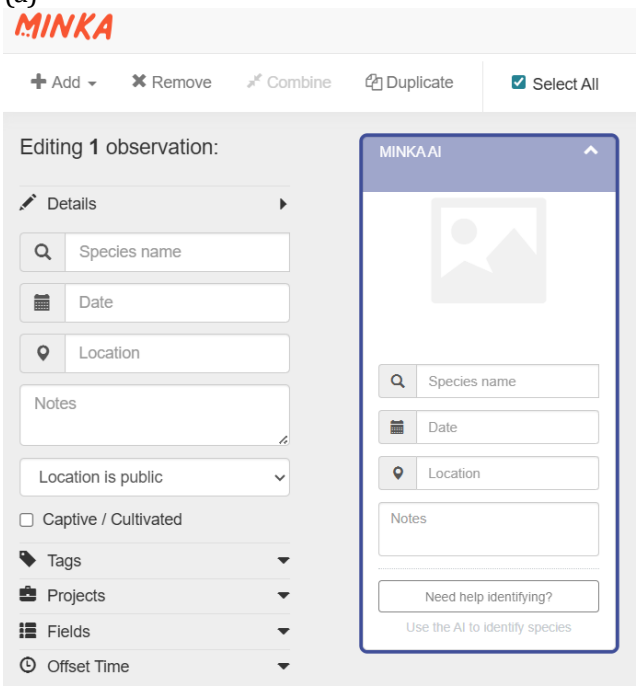
4.4.1 Context

This Case Study is concerned with environmental monitoring of biodiversity and marine litter found on the urban beaches of Barcelona to support monitoring obligations set out in the EU Marine Strategy Framework Directive (MSFD), in particular D1 and D2 (biodiversity and alien species) and D10 (marine litter), as well as providing support to planning by monitoring the smoke-free beach regulations of the local authorities in the Barcelona area. Marine litter in the form of cigarette butts are of particular interest so that data from smoke-free and regular beaches can be compared to evaluate the effectiveness of no-smoking legislation. Wet wipes are also being considered in this Case Study so that the findings can be evaluated as part of the Extended Producer Responsibility (EPR) framework of the EU Waste Directive, which requires producers to pay for the management of any waste produced.

4.4.2 Existing data collection protocols and tools

There is a well-established citizen-based community of practice already operating in Barcelona, where citizens have been collecting data on marine biodiversity using the MINKA platform, developed by the EMBIMOS research group of the Institute de Cienciès del Mar (ICM-CSIC). Screenshots from the platform are provided in Figure 9, showing a screen for uploading an observation (Figure 9a) and the results from a query on biodiversity monitoring projects in Barcelona (Figure 9b).

(a)



(b)

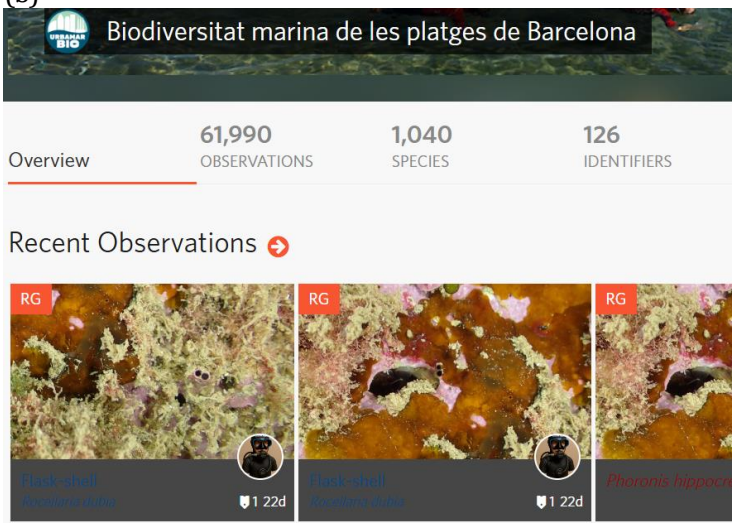
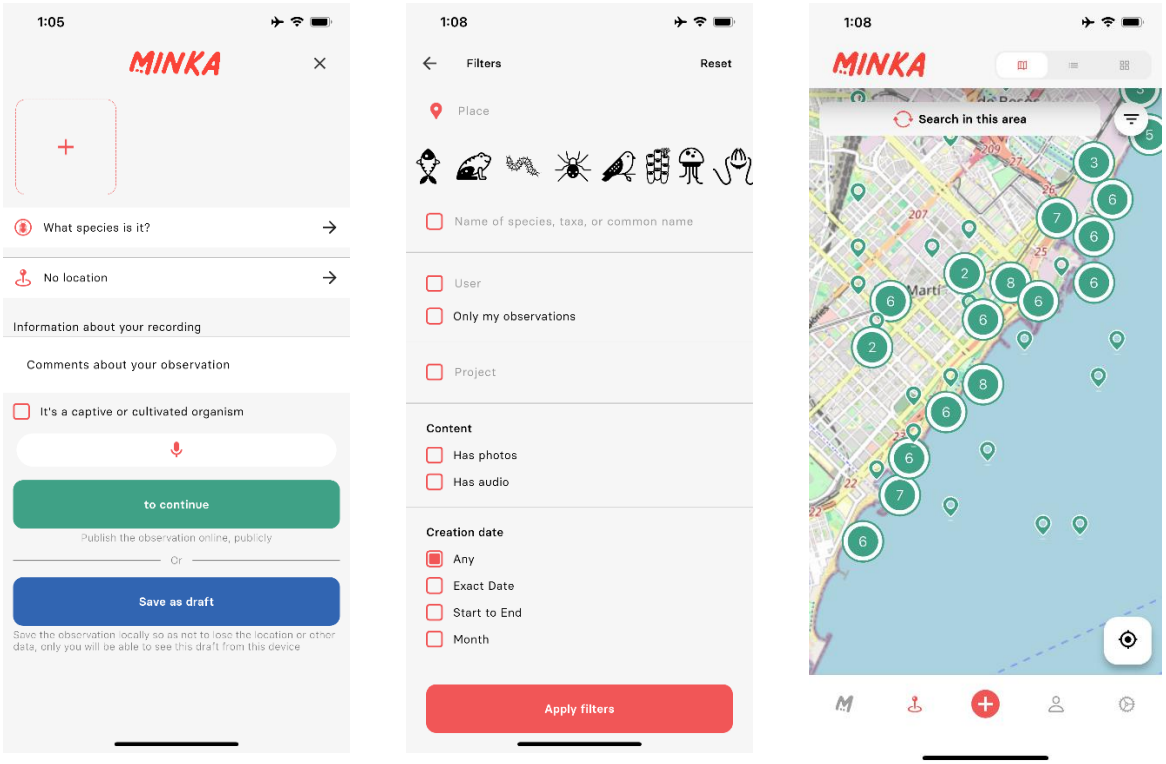


Figure 9: Screenshots from the MINKA platform: (a) The screen for uploading an observation and (b) an example of an ongoing project on marine biodiversity monitoring on the beaches of Barcelona

Data can also be uploaded via the MINKA mobile app, which is available in both the AppStore and the Google Playstore. The mobile app has similar functionality to the online platform (Figure 10), but it automatically records the date, time and location from the photograph uploaded, if available, or the user can select a location on the map (Figure 10a). The app can also be used to visualize data with filters available for the types of observations, whether the user wants to see only their observations or others, temporal filters and whether observations should include photographs or sound (Figure 10b). Once the user applies the filters, a map is shown with observations. Zooming into the Barcelona area, the observations are shown on a map (Figure 10c) and can be further queried.



(a) (b) (c)

Figure 10: Screenshots from the MINKA mobile app showing (a) the data collection screen for uploading observations, (b) the filters for visualizing data on the MINKA platform (c) observations shown on a map in the Barcelona area

Data can be accessed from the MINKA platform, documented in the Swagger specification: https://api.minka-sdg.org/v1/swagger.json, which provides a list of endpoints. A full description is provided in the following documentation: https://api.minka-sdg.org/v1/docs/.

4.4.3 Developments in ENFORCE

Volunteer groups are being established for each of the 10 beaches in Barcelona that are to be included in this Case Study, where each group will focus on a specific environmental parameter. For those groups who will focus on marine biodiversity, they will use the MINKA platform and mobile app with already established protocols for data collection.

For those groups focusing on marine litter, the underwater and floating monitoring of wet wipes and cigarette butts will be supported by the MINKA platform and app. With current consideration of an infrared camara for floating litter analysis, the Case Study is planning to integrate the use of the Floating Litter Monitoring app deployed by the Joint Research Centre (JRC) of the European Commission and is managed by the University of Cadiz in Spain. The app is designed to monitor floating macrolitter (>2.5 cm) in seas and rivers based on the visual observations of volunteers. The data are automatically connected with EMODNet. The data obtained from the citizens will be compared with the information collected by the TV camera at the combined sewer overflow (CSO) point of Bogatell beach. The categories used are harmonized with the EU Joint List of Litter Categories for Marine Macrolitter Monitoring. The protocols for data collection of the items of marine

litter selected are currently being developed within the Case Study's Living Lab. As the community of practice collects the data during the ENFORCE project, it will become accessible via the MINKA API for ingestion in the Plaza Toolkit.

Other volunteer groups will focus on the monitoring of cigarette butts on the beaches (i.e., dry beach litter), so the MARNOBA application will most likely be used. The MARNOBA mobile application and viewing platform have been developed by an external party, the Asociación Vertidos Cero. The mobile app supports marine litter monitoring by citizens, organizations and professionals in coastal beach clean-ups or marine debris surveys that require standardized data collection in the field. The reason for choosing this app is that it already provides a protocol for the collection of data on cigarette butts and wet wipes on the beaches (and many other types of dry beach marine litter).

Aggregated data by beach cleanup can be downloaded from the MARNOBA platform. An example of a beach cleanup in the Barcelona area is shown in Figure 11.

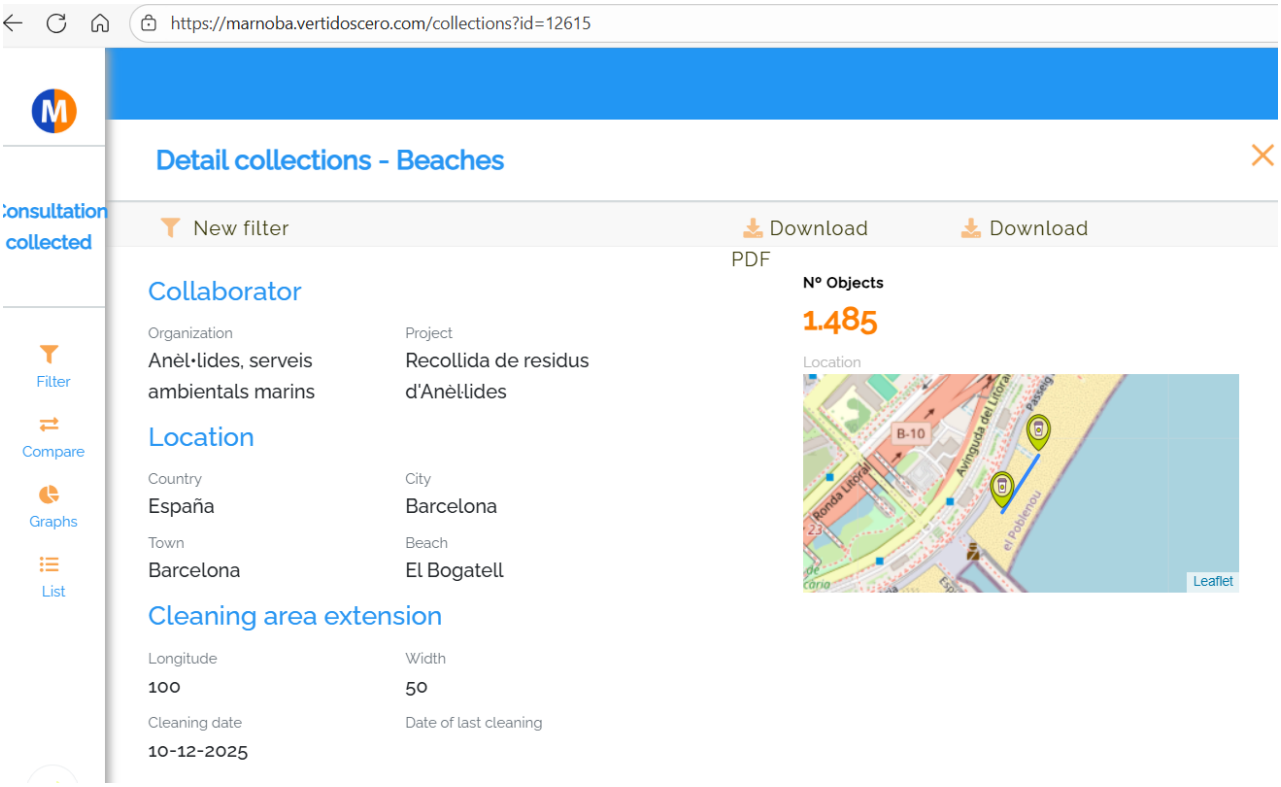


Figure 11: Screenshot from the MARNOBA platform showing data for one beach clean-up in Barcelona

The main fields, a description and the formats are provided in Table 7. Note that it is not possible to obtain individual observations of cigarette butts and wet wipes on a beach as this requires payment, and there is currently no API available to access the data. However, the aggregated data show the total number of wet wipes collected as a category of pollution types, which can be displayed in the Plaza Toolkit.

Table 7: Aggregated data on marine pollution collected via the MARNOBA app

Name	Description	Format
Location	The name of the beach	Text
data_Id	Unique identifier	Integer
Entity	Organization or individual that organized the beach clean-up or marine survey	Text
Cleaning date	The date of the clean-up or marine survey	Date format (dd/mm/yyyy)
Country	The country in which the clean-up took place	Text
Community	The name of the community	Text
Province	The name of the province	Text
Municipality	The name of the municipality	Text
Collection type	The type of collection, e.g., along beaches	Text
Project	Whether the clean-up/survey is linked to a project	Text
Monitoring length (m)	The length of the beach surveyed	Integer
Initial coordinates	Latitude and longitude of the start of the clean-up	Floating point pair
Final coordinates	Latitude and longitude of the end of the clean-up	Floating point pair
Total items	Total number of items collected from the beach	Integer
Plastic	Number of plastic pieces collected, 27 categories	Integer
Paper / Cardboard	Number of paper/cardboard pieces collected, 6 categories	Integer
Wood (machined)	Number of wooden pieces collected, 6 categories	Integer
Metal	Number of wooden pieces collected, 11 categories	Integer
Glass	Number of wooden pieces collected, 3 categories	Integer
Sanitary Waste	Number of wooden pieces collected, 4 categories where one of the categories is wet wipes	Integer
Medical Waste	Number of wooden pieces collected, 3 categories	Integer
Others	Number of wooden pieces collected, 7 categories	Integer
Remarks	Comments that accompany the clean-up/survey	Text
Weight fractions of the collection (kg)	The weight of the waste collected according to category (packaging, paper/cardboard, glass, general waste, municipal waste point, pharmaceutical and local entity)	Floating point

Alternatively, the MINKA app could be modified to monitor also dry areas and not just floating or underwater items. These data collection protocols are still under development and will determine which app is used to collect the data in future campaigns with the volunteer groups.

4.5 Case Study 5: East Devon Catchment, UK

4.5.1 Context

This Case Study is concerned with monitoring water quality, in particular related to water pollution from agriculture. The two main variables of interest that are collected by citizen scientists are phosphates and turbidity, which can both be indicative of agricultural pollution. However, these data are not intended for use in direct legal actions. Rather this Case Study focuses on how the citizen generated data can be incorporated into regulatory processes and also fused with authoritative data on water quality and remote sensing to develop maps of soil erosion risk, which will be displayed in the Plaza Tools. The target audience of these risk maps is regulatory authorities (e.g., the Environment Agency, Natural England) and other organisations such

as wildlife trusts and farming advisory groups that are helping to improve catchment management and planning as well as supporting sustainable agricultural practices.

4.5.2 Existing data collection protocols and tools

In terms of citizen science, this Case Study already has a very well-established community that collects data on a wide range of environmental parameters from rivers and streams across the South West of England, including prominent representation in East Devon (https://wrt.org.uk/westcountry-csi/). Interested citizens participate by first registering on a third-party volunteer management platform (Assemble). This platform provides training videos, news articles, survey advice, links to webinars and a personal login to the Cartographer website. Cartographer is a third-party data management platform that allows citizen scientists to upload and view the data that they have collected, and for Westcountry Rivers Trust (WRT) staff to access and manage these data.

A water quality data collection kit sent through the post and data are recorded using a paper-based form, accessible from the platform and shown in Annex A. This includes visual observations of the general environment (including flora and fauna), river channel observations and evidence of pollution and potential pollution sources. Citizen scientists then use a bucket to collect 1 to 1.5 litres of water, followed by measuring the turbidity with a turbidity tube/Secchi disk, Total Dissolved Solids (TDS) and temperature with a TDS meter and finally determining phosphate levels using phosphate strips and a colour tube. Once completed, the citizen scientist uploads the survey data manually to the Cartographer website, and surveys are then reviewed and approved by qualified and trained WRT staff. Training videos are available that show the citizen scientists how to make these measurements.

The Cartographer platform can be used to view individual measurements (which are currently closed to the public but planned for open access via ArcGIS Online integration). Scorecards, which aggregate information collected by the citizens, document the status of different catchments and are open to the public. An example of a scorecard is shown in Annex B. It aggregates all the measurements that have been taken in the catchment during one calendar year and provides a water quality score along with a summary of other information that has been collected by the citizens.

4.5.3 Developments in ENFORCE

There are no requirements for further support to the existing citizen science data collection tools in ENFORCE as the current system for data collection already works very well. The Cartographer website also allows citizens to view their observations, so a visualization platform is not needed. Instead, the focus will be on the erosion risk maps that are being developed by the University of Exeter (UNEXE). UNEXE have built a pipeline for combining the water quality data from citizen scientists with authoritative measurements (Environment Agency water quality monitoring data) and remote sensing data from Sentinel-2 to produce risk maps in near-real-time. Sample raster maps of risk have been ingested for display in the Plaza Tools. It will also be possible to display the citizen science data on phosphates and turbidity in the Plaza Tools as an additional layer, if required, as these will be available through an API being developed by UNEXE. WRT will also be openly publishing citizen science data via a live integration between Cartographer and ArcGIS Online. On this

platform, data will be accompanied by appropriate metadata (licensing, attribution, etc) and accessible using a range of approaches.

Another potential development in ENFORCE is engaging citizen scientists in helping to validate the soil erosion risk maps. Westcountry Rivers Trust have discussed the potential to use a protocol developed in the Mud Spotter project, in which citizen scientists could sample those locations identified as high risk. The data collection tool is a paper-based form that allows citizens to record the sources and pathways of mud being transported into rivers during or shortly after rainfall. However, following negative feedback from citizen scientists, the use of this protocol to support this Case Study is unlikely.

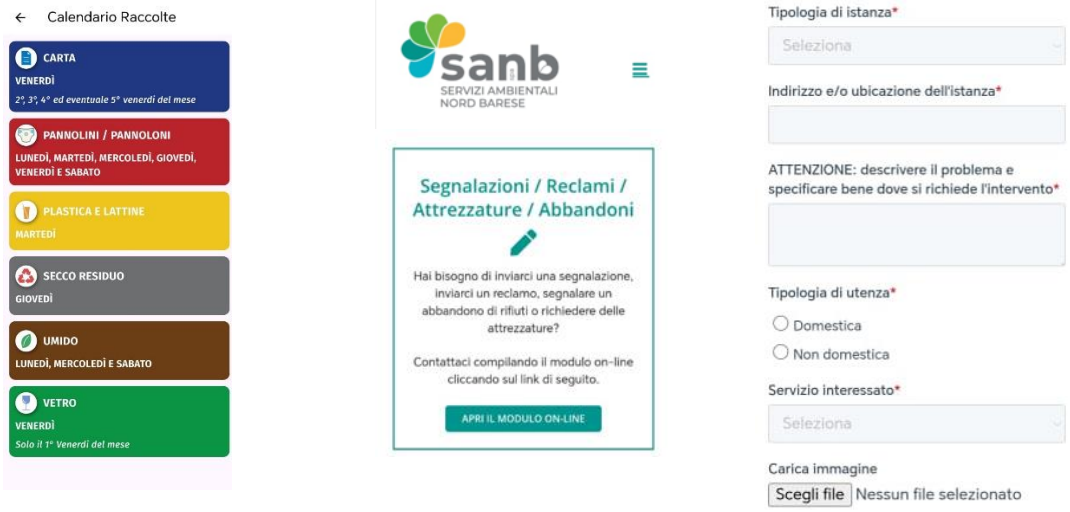
4.6 Case Study 6: Puglia, Italy

4.6.1 Context

The primary objective of this Case Study is to prevent illegal dumping by ensuring proper waste management and enforcement by the relevant regulations. A key data source is citizen complaints, which provide real-time alerts to enforcement agencies regarding potential violations. These complaints are currently made through a conventional reporting mechanism, i.e., telephone calls, which contribute to municipal police reports that document observed incidents and provide critical evidence for enforcement. In addition, there is a local waste management company, which also compiles reports that capture discrepancies in waste collection and unauthorized deposits.

4.6.2 Existing data collection protocols and tools

The waste management company has an Android mobile application called SANB (Servizi Abientale Nord Barese), which has been developed by TS Innovation S.R.L.S. The mobile app allows citizens to view their waste collection schedules, set reminders and make reports of illegal waste dumping (see Figure 12). In particular, Figure 12b and Figure 12c show the reporting functionality.



(a) (b) (c)

Figure 12: Screenshots from the SANB mobile app showing (a) the calendar for waste pickups (b) the screen that allows users to make a report, a complaint or a request for equipment and (c) part of the online form in which citizens can report a problem such as illegal waste, including the ability to upload a photograph

4.6.3 Developments in ENFORCE

Unfortunately, the participants in Case Study 6 (CIHEAM) have confirmed that the reporting function of the app is currently not working. The waste management company is aware of this issue and is currently working with TS Innovation to fix this issue.

The second problem related to the use of the app by citizens for reporting illegal waste dumping is whether the ENFORCE project (and the Plaza Toolkit) will be able to access the data collected by the waste company once the reporting feature is resolved. As a backup, IIASA has created a module in the Geo-Quest app (called ENFORCE Waste) that could be used by citizens to report illegal waste dumping and illegal fires (Figure 13) should this be required by the project. This module was developed in collaboration with CIHEAM and has also been translated into Italian. Ongoing discussions within the Living Labs of Case Study 6 will determine which citizen science data collection tool will be used in the ENFORCE project.

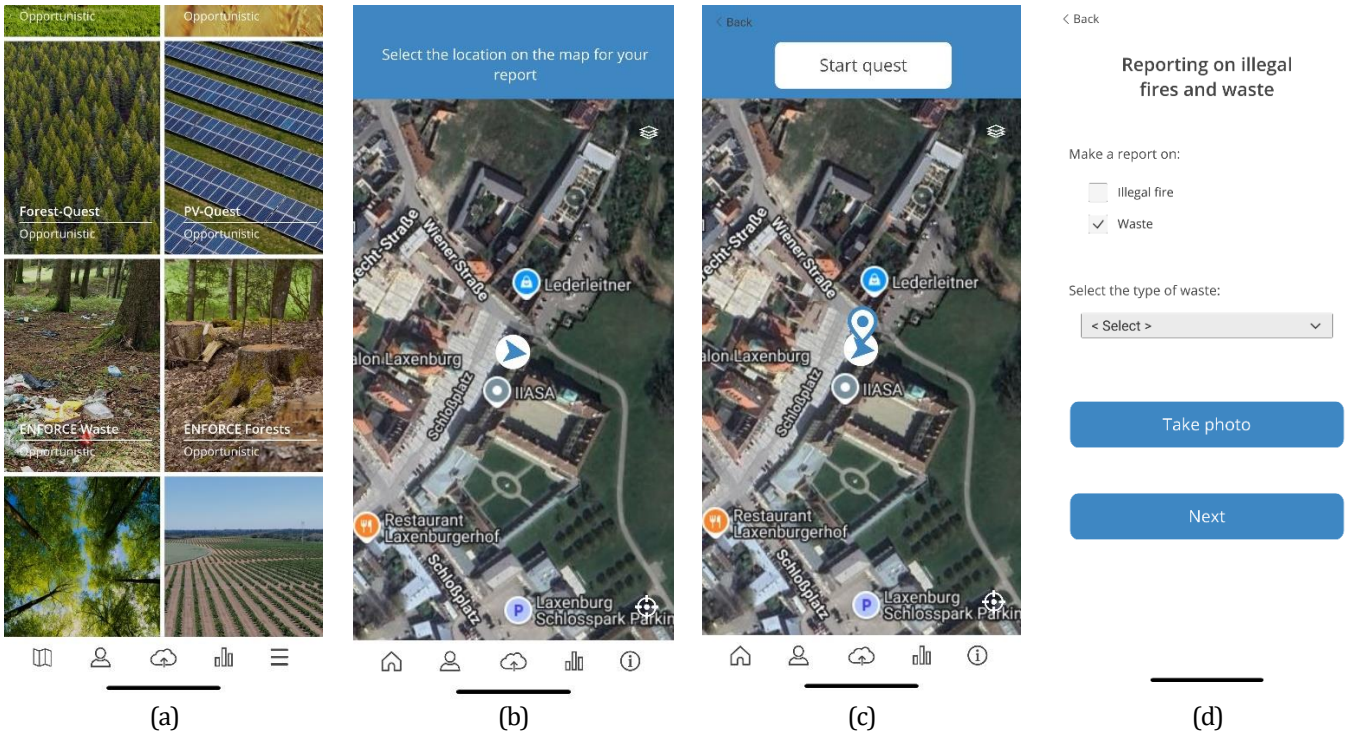


Figure 13: Screenshots from the ENFORCE Waste module in the Geo-Quest mobile app showing (a) the front screen where the user chooses the Waste module (b) a map showing the user's location where they want to make a report (c) the screen to start the report (or quest) as the user has clicked on their location, and (d) the questions about whether the user is reporting an illegal fire or illegal waste and what type of waste. Users can then take photographs and upload these with their report.

As with other case studies that are using the Geo-Quest app, the first type of data collected is the same as that listed in Case Study 1, which includes very limited personal data and mobile device data, while Table 8 shows that data that are specific to the ENFORCE Waste module in Geo-Quest; these data will be made available by an API.

Table 8: Data on forests collected by the ENFORCE Waste Geo-Quest mobile app

Name	Description	Format
ID	Unique ID for the observation	Integer
Location	Latitude and longitude of the observation	Floating point
Report	One or more variables that describe if the user is reporting an illegal fire or illegal waste dumping. If the latter the user chooses what type of waste.	Text
Comment	Free form comment box to enter further details	Text
Photograph	One or more photographs of the location	Blob
Timestamps	Timestamps of key actions (e.g., start, capture, submit)	Date/time format

If the Geo-Quest mobile app is to be used in this Case Study, near-real-time fire alerts can be ingested into the app from Global Forest Watch, similar to Case Study 1 and 2.

4.7 Case Study 7: North Sea region, The Netherlands

4.7.1 Context

The area of interest for environmental monitoring in Case Study 7 is the Natura 2000 protected area called the Dogger Bank, which is a large sandbank in a shallow area of the North Sea. At present, the Dutch government's management plans for the North Sea allow industrial activities to dump polluted water in the sea, which will have an impact on water quality, on the marine biodiversity, and on human health (as this area is a source of fish for human consumption). However, very little is known about the effect of these activities or the impact of the pollutants.

The variables of interest include heavy metals, hydrocarbons and man-made chemicals (biocides/PFAS) discharged into water bodies directly by industry, as well as the occurrence of oil spills from oil rigs operating in the North Sea. Data on the concentration of these chemicals is available from government agencies on an annual basis for a section of the North Sea that borders the Netherlands. Unfortunately, these concentrations cover the entire area and cannot be attributed to individual oil platforms or companies because this information is not publicly available.

Of indirect interest is the impact on biodiversity. There is currently a rewilding project starting in the Dogger Bank to improve the ecosystem for Zebra Mussels. Water quality measurements are being taken as part of this project. Understanding the impact of this rewilding project is of additional interest to this Case Study.

In relation to ENFORCE, this Case Study aims is to develop an early warning system for pollutants to raise awareness among citizens and public authorities, to alert authorities regarding locations that should be further investigated for marine pollution, and to make the case to openly publish data on the discharge of chemicals by companies in the North Sea.

4.7.2 Existing data collection protocols and tools

Waag has a set of generic citizen science tools and methodologies that they use to co-create solutions with communities. This includes their Citizen Sensing Method and their Co-Creation Navigator tool, which are used

to develop community-driven environmental monitoring initiatives through a bottom-up, participatory approach. The underlying objective is the transformation of environmental data into actionable insights, whether in a policy context or for enforcement activities. They also have a T-Factor Guide for Temporary Placemaking, which is concerned with creating urban regeneration initiatives, with a focus on the role of temporary spaces in making positive contributions to cities, and the Urban Ecology Field Atlas, which is a platform that integrates data from diverse sources including measurements from citizens and fosters the development of community-driven urban planning.

In the case of the ENFORCE project, this Case Study does not have an established data collection protocol or tool for marine pollution monitoring. Instead, the protocols and tools will be developed within the ENFORCE project.

4.7.3 Developments in ENFORCE

The proposed solution is an early warning system for pollution driven by input from citizens; the solution will be implemented in the Plaza Tools. Satellite imagery (from Sentinel 3 and/or solutions organized by EARSC in WP5) will be ingested in near-real time (updated weekly or bi-weekly), which will indicate the ocean colour. Citizens will examine the imagery and label any changes in colour that they see over time as well as identifying any oil spills. The publicly available time series on pollutant concentrations in the North Sea area will also be available for display as part of a dashboard within the Plaza Tools. Furthermore, the solution includes aggregating all the pollution data in one easy-to-access database for citizens. In addition to this, the satellite data can help to monitor different data sources and their potential effects on the environment, and all the data can be cross-referenced so the case can be made for source point data to be made public. These data are available from three different sources (Table 9):

- Rijkswaterstaat (Ministry of Infrastructure and Water Management): they publish pollutant concentrations for the North Sea based on declared discharges from companies as aggregated classes, e.g., heavy metals.
- Rijksoverheid (Dutch government): they publish a time series (1990 to 2022) of pollutant concentrations for the North Sea disaggregated by the type of heavy metal.
- OSPAR (Oslo and Paris Conventions, "OS" for Oslo and "PAR" for Paris): They publish marine data and guidelines for monitoring, information collection or other work for the Contracting Parties to carry out.

Table 9: Variables of interest available for the North Sea from three different authoritative sources

Source of data	Variables of interest	Units of measurement
Rijksoverheid	Heavy metals	kg
	Paks	kg
	PCBs	kg
	Other man-made chemicals	kg
Rijkswaterstaat	Heavy metals	ug/l & mg/kg
	PCBs	ug/l & mg/kg

	Other man-made chemicals	ug/l & mg/kg
OSPAR	Discharged oil and spills	m^3, mg/l & tonnes
	Potentially heavy metals, PCBs, PAKs, PFAS and other man-made chemicals	ug/kg

Public authorities that access the Plaza Tools will be alerted to areas of pollution that require further action. The outputs from the tools might also be used to create a case for authorities to demand more detailed monitoring by the industry and for citizens to demand more open publication of pollution discharged by each company in the North Sea (rather than as an aggregated value for the whole area).

There is the possibility for some validation through laboratory testing of water quality from the previously mentioned rewilding project, which would allow comparison with officially reported values to see if they match the observed water quality measurements. These could also be integrated into the citizen science application within the Plaza Tools.

4.8 Case Study 8: Flanders Region, Belgium

4.8.1 Context

This Case Study, led by Hasselt University (HU), is focussed on the collection of data on Per- and Polyfluoroalkyl Substances (PFAS) contamination, which are man-made chemicals (e.g., in non-stick pans, firefighting foam, waterproof fabrics, etc.) that do not break down in the environment. In particular, the concentration of PFOS (Perfluorooctane Sulfonate) is measured, which is a key type of PFAS that can accumulate in the environment, water, food, and human bodies, and they have been linked to serious health issues like cancer, immune system problems, and developmental effects (OECD, 2021).

The aim of the Case Study is to monitor 10 ha of PFAS contaminated agricultural land, located in the municipality of Zwijndrecht, which needs to be remediated. The land is close to the 3M plant, which has made products with PFAS in the past. In 2008, 3M stopped producing PFAS, phasing it out of their products, but contamination from historical pollution (from 3M but also other industrial sources) has only been discovered more recently. Environmental monitoring in the Case Study involves measuring PFAS concentrations in the soil and groundwater, but a secondary aim is to investigate the efficacy of phytoremediation as a remediation method. Phytoremediation is the uptake (or cleaning) of PFAS by plants, which then reduces the PFAS concentration in the soil over time. It is an alternative approach to excavation and replacement with new soil, which is too costly to do in all areas with soil contamination.

In addition, the Case Study is engaging with the lack of legislation that defines legally binding PFAS food norms in Belgium as well as legal PFAS remediation thresholds. Some thresholds exist in EU legislation, but they are not currently adequate or detailed enough, e.g., foods grown in areas with PFAS contamination should not be consumed yet there may be thresholds that are not harmful to health that are currently not defined. Data on PFAS concentrations may help to build a case for better legislation and a greater understanding of PFAS in relation to food safety so that more tailored advice can be given to growers.

4.8.2 Existing data collection protocols and tools

In 2023 and 2024, HU was involved in a citizen science project called Bodemleven to monitor soil health and soil biodiversity in the province of Limburg. Around 1,000 citizens monitored their gardens with soil sensors (measuring temperature and humidity), buried tea bags to quantify microbial activity, and took soil samples that were analysed in a laboratory for nutrients, pH, organic carbon and microbial diversity. This project was undertaken to produce soil-health indicators and soil-biodiversity characteristics at scale to align with the EU Soil Monitoring Law that entered into force in December 2025. Measurements of PFAS were not part of this citizen science project but protocols were developed to collect the data, engage with citizens and collect and analyse large numbers of soil samples.

4.8.3 Developments in ENFORCE

In the ENFORCE project, the focus is working with farmers and citizens to undertake phytoremediation experiments in the 10 ha of agricultural land identified for remediation. The farmers that took part grew hemp on their fields (along with other plants) to measure how much PFAS the plant extracts from the soil. Each field was sampled three times during 2025. Soil and groundwater samples were taken twice before the growing season started and then again after the hemp was harvested. The hemp (and other) plants were then sent to a laboratory for analysis using HPLC-MS (High-Performance Liquid Chromatography-Mass Spectrometry), which extracts the chemicals from the samples and determines the PFAS concentrations in different parts of the plant and in the soil/groundwater. These concentrations can then be compared to the maximum threshold set by the government of Flanders to determine if concentrations exceed legal limits. The data collected during 2024 are provided in Table 10. The data collection protocol, which is provided in Annex C, addresses one of the key challenges identified by Case Study 8 in D4.1, which was the need collect pairs of PFAS data, i.e., data from both the soil and from plants grown on that soil. Such data are summarized in a report that goes to the national agency for soil clean up and companies like 3M, but they will also be displayed in the Plaza Tools.

Table 10: PFAS data collected in case Study 8

Name	Description	Format
Name/alias of farmer and type of measurement	Name to identify the farmer plus other information about when the measurement was taken OR what type of plant the measurement was taken from	Text
Name/alias of farmer	Name to identify the farmer	Text
Compartment	Origin of the measurement including ground, root, skin, stem, leaf, flower, seed or other	Text
Coordinates	Latitude and longitude	Floating point
PFOS	PFOS concentration	Floating point

A campaign is planned for next year (depending upon resources) where farmers will grow other plants and measure PFAS in the biomass, soil and groundwater to understand what the best plants are for phytoremediation, how many crop cycles are needed to reduce the PFAS concentration below an acceptable limit, and to understand how agricultural practices can influence PFAS removal by plants. The results from this Case Study and future phytoremediation trials could also be used to support the uptake of this type of

clean up technology, helping to develop a financial model whereby farmers are paid to grow the crops while polluting companies pay for the destruction of the PFAS in the plants.

This Case Study is also aimed at stimulating citizen science efforts by motivating similar growing initiatives in urban vegetable gardens and community gardens, raising awareness through dissemination activities in ENFORCE.

5 Data Space Compliance Platform

In this section, we will describe the mechanisms for data collection, the ensuring of data provenance and Data Space compliance of the prototypical ENFORCE platform.

5.1 Mechanisms for data collection

Based on the evaluation of the Case Studies, three general mechanisms for collecting data were identified.

1. Fetch data from (open) APIs:

Data collected from citizens is exposed through an Application Programming Interface (API). The access mechanisms to the data and the data format(s) are described in a standardized way. For well described APIs, automated creation of clients and data schemas can be applied. This allows for implementation of clients to collect the data and periodically check for updates. However, this allows for only a limited control over the data/metadata, as the workflow is dependent on service uptime of the API. Also, data models and endpoints could change without notice and this could lead to errors while fetching.

2. Push data to ENFORCE environment:

Data is uploaded from a Case Study environment to an endpoint exposed by a service within the ENFORCE environment. The data schema needs to be evaluated beforehand, and endpoints for accepting the data need to be implemented. This approach would only allow for a low control over the data/metadata. There is a dependency to the collector to regularly upload new/updated data and for this data to be in the same format as with previous uploads.

3. Collect data using ENFORCE components:

Data is collected using tools provided by ENFORCE and/or stored exclusively within the ENFORCE environment. This approach requires more effort due to the implementation work needed on the client side as well as on the server side. This would allow for full control over the data/metadata.

Currently, the first and second data collection mechanisms are implemented. To enable end-to-end provenance, all data are stored in the ENFORCE environment.

5.2 Data provenance

To ensure data integrity, all input data are stored as a file, and the hash value is calculated. The information is stored in the database (DB schema), shown in Table 11. Each data update and processing step will result in a separate file/hash combination.

Table 11: Provenance schema

Id	**Unique identifier, auto generated**
Source	The source of the dataset
License	License information
acquisition time	The time the data was acquired
Creator	The creator of the data
processing step	Information about the processing step that created this data
path to file	Path to the data file
Hash	Hash value of the data file

The provenance will be tracked by an Observation Service that monitors the data collection and updates as well as processing steps.

Also, human interaction with data/metadata, e.g. manually updating the state of a case from open to closed, is monitored by the Observation Service.

5.3 Data Space Compliance

A Data Space compliance mechanism involves a set of rules, technical standards, and governance processes to ensure adherence to relevant legal frameworks and data space policies throughout the entire data lifecycle. Key components include regulatory analysis, clear identification of actors and responsibilities, robust security and privacy measures, and the creation of trust-based technical and contractual frameworks, such as standardized data usage agreements and machine-readable policies.

The key components and concepts of Data Spaces are described in the following:

Regulatory Framework Analysis

Mapping Legal Provisions: Identify and outline all relevant legal requirements, such as the GDPR, Data Act, and Data Governance Act, which are triggered by specific data types, actors, and use cases.

Understanding Key Actors: Recognize the specific roles and obligations of entities within the Data Space, including Data Intermediation Service Providers (DISPs).

Governance and Policies

Data Space Governance Authority: Establish a governing body that guides participants on EU values, regulations, and the creation of internal policies for compliance.

Roles and Responsibilities: Clearly define the roles, responsibilities, and associated rights and obligations for all participants.

Contractual Frameworks: Develop standardized, machine-readable agreements for data use (e.g., Data Exchange Agreements or Data Processing Agreements) that are aligned with technical standards.

Technical and Security Measures

Dataspace Protocol: Implement standards and protocols for data cataloguing, contract negotiation, and data sharing that ensure interoperability and trust.

Cyber Resilience: Incorporate robust cybersecurity and organizational security measures, **such as data encryption and access controls, to protect data and infrastructure.**

Policy Enforcement: Implement technical mechanisms to automatically enforce data access and usage policies, ensuring compliance during data transactions.

Trust and Attestation

Identity and Membership Attestations: Use Verifiable Credentials to confirm the identities and membership status of participants within the data space.

Trust Anchors: Engage accredited organizations to issue attestations that verify claims regarding identity, security, and compliance, ensuring the integrity of data-related services.

FAIR principles

The four FAIR principles were introduced to improve the management and reuse of research data:

Findable: Data are discoverable with unique identifiers, metadata, and search functionalities.

Accessible: Data can be accessed under clearly defined conditions, including appropriate licenses and authentication.

Interoperable: Data can be exchanged and reused by different applications and systems through the use of standardized vocabularies and metadata.

Reusable: Data are well-described, with clear information on their origin and use, allowing for their future use in other research or applications.

Dataspaces and their connection to FAIR principles

Dataspaces create the technical infrastructure for sharing data across organizations. They provide mechanisms to implement the FAIR principles, making data discoverable and accessible while ensuring control over its usage. Dataspaces establish legal and technical frameworks for secure, federated data sharing, where participants can maintain control over their data.

Technical Aspects of Data Space Compliance

The architecture of the Data Governance and Processing Layer is shown in Figure 14.

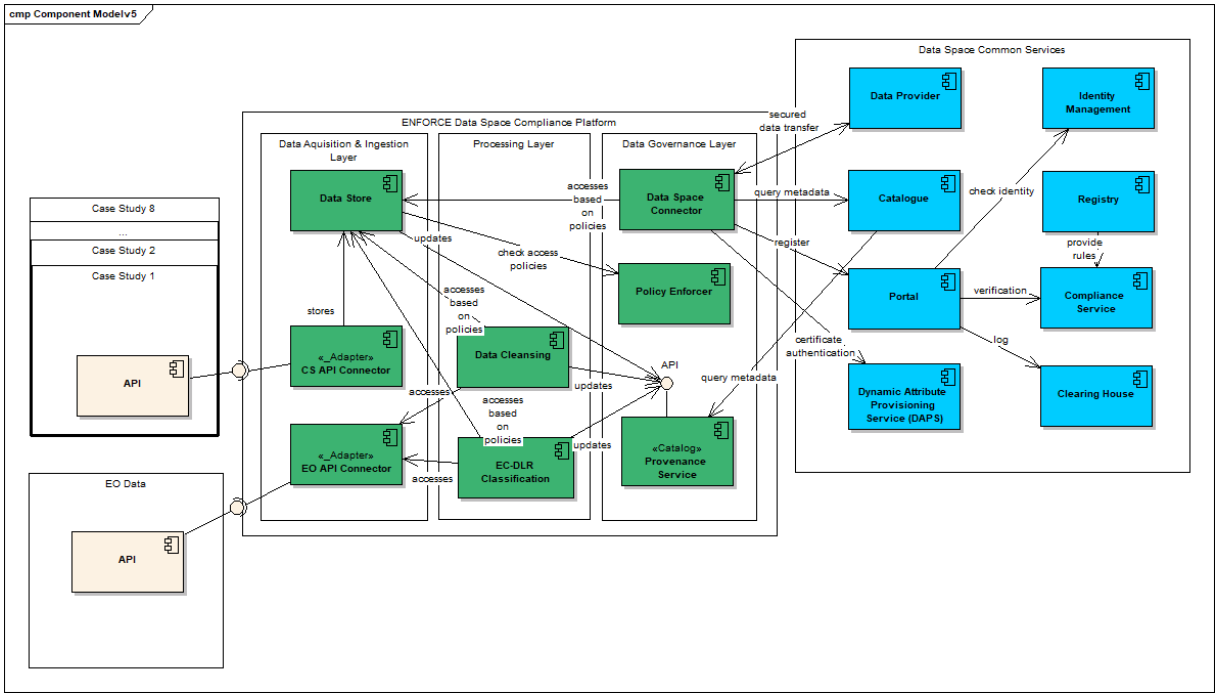


Figure 14: Architecture of the Data Governance & Processing Layer

The Services of the Data Space Compliance Platform are described in detail as follows:

Data Store

This component stores either references to or the actual data coming from the different Case Studies.

CS API Connector

This component deals with collecting the data from the Case Studies. Due to the different methods of data sharing, this will probably be divided into sub-components.

EO API Connector

This component handles the connection to EO data portals.

Data Cleansing

This component is responsible for initial data cleansing.

EC-DLR Classification

This component tracks the different stages of the Data Readiness Level classification. Parts of the classification could be done by internal processing (e.g., cleansing), while other parts could come from external expert analysis.

Provenance Service

This component stores provenance information about the data coming from the Case Studies.

Policy Enforcer

This component handles the enforcement of access policies for the data.

Data Spaces Connector

This component handles the connection to Data Spaces. This includes querying of metadata, authentication and finally the secured transfer of data.

The Data Space Connector, either as Data Provider or Data Consumer is the central access point for communication with third parties. The catalogue would need to be registered in a federated catalogue. The connector can process policies and contracts as a Data Consumer and can also provide them as a Data Provider. Identities need to be registered for contract negotiation.

Figure 15 shows the interaction of the Eclipse Data Space Connector with key Data Space components.

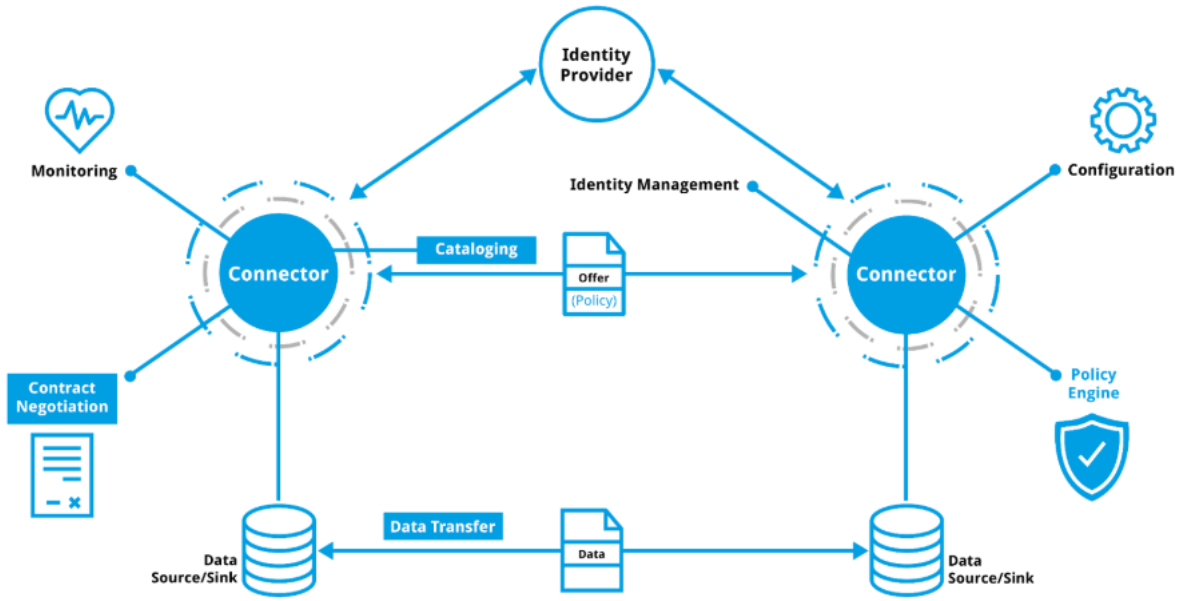


Figure 15: Interaction of the Eclipse Data Space Connector with key Data Space components (source: https://docs.internationaldataspaces.org/ids-knowledgebase/dataspace-protocol)

A set of basic services provided by Data Spaces is shown in the architecture. Depending on the Data Space implementation, other components might be added, such as the family of P*P services, a vocabulary hub, or a metadata broker.

To enable secure data sharing with Data Spaces, the offered data assets need to be registered in a federated catalogue, along with policies on how to access them. Within the ENFORCE environment, we will use open standards for data/metadata cataloguing and access.

The Data Spaces Support Centre (DSSC), which supports the deployment of the common European data spaces, defines blueprints for Data Space Components. shows the technical pillars specified by the DSCC (Figure 16).

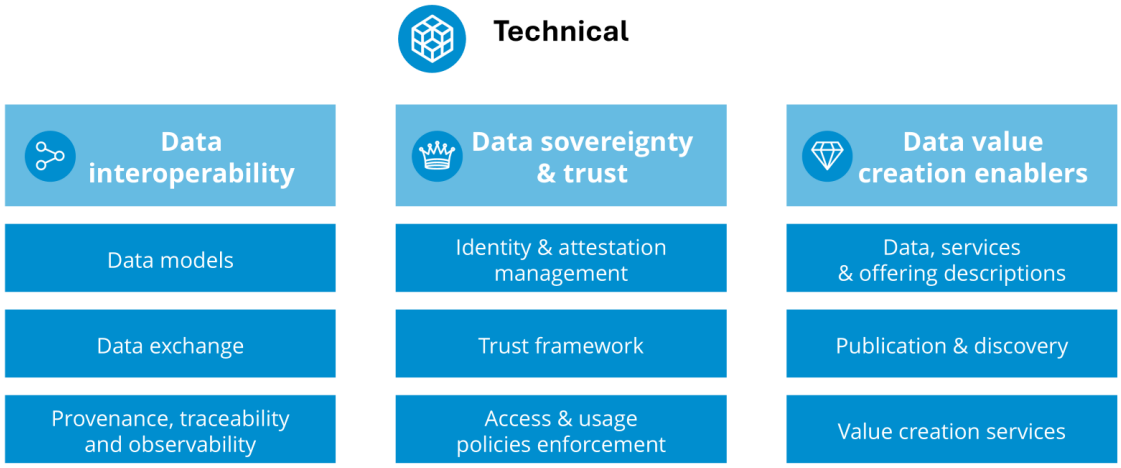


Figure 16: Data Spaces Blueprint v2.0 Technical Pillars (https://blueprint.dssc.eu/?pane=technical, accessed 16.02.2026)

The components of the ENFORCE Data Space Compliance Platform can be classified into these pillars as follows:

Data interoperability:

The data models are specified by the ENFORCE Data Store, which also handles the secured data exchange.

The ENFORCE Provenance Service takes care of provenance, traceability and observability.

Data sovereignty and trust:

Identity management is handled by the ENFORCE Data Space connector, based on a trust framework. The ENFORCE Policy Enforcer holds and describes policies created by ENFORCE stakeholders and enforces them on data access within the Data Space Compliance Platform.

Data value creation enablers:

Data, services and offerings are described by the ENFORCE Provenance Service, which in the current version of the architecture, also serves as a catalogue service. The Provenance Service also takes care of publication and discovery of data/metadata.

Currently, the ENFORCE Data Cleansing and EC-DRL Classification service add value to the collected data within the Data Space Compliance Platform.

6. Operationalization of the Data Collection

The ENFORCE Data Space Compliant Platform was prototypically implemented. For Case Studies 1, 3, 4, 5, 7 and 8, Java projects, called modules, were created based on the Spring Framework. The specific projects for

each Case Study consist of a REST API specification, data schemas and methods for data ingestion, preliminary data cleansing and provenance capturing, as well as data storage and access. In addition, all Case Study modules have their own demo page.

The code for the projects is open source and available on the GitHub platform:

- CS 1: https://github.com/enforceproject-eu/cs1-module
- CS 3: https://github.com/enforceproject-eu/cs3-db-model
- CS 4: https://github.com/enforceproject-eu/cs4-db-model
- CS 5: https://github.com/enforceproject-eu/cs5-module
- CS 7: https://github.com/enforceproject-eu/cs7-module
- CS 8: https://github.com/enforceproject-eu/cs8-module

The modules are used by an overarching project, called CS API Connector (https://github.com/enforceproject-eu/cs-api-connector). Within this project, the configuration for exposing the REST APIs of the modules as well as provenance and security aspects are defined. This enables adding and updating of modules on a plug and play basis. The CS API Connector with the available modules was deployed on the 52°North demo server using Kubernetes: https://enforce.dev.52north.org/swagger-ui/index.html (credentials available upon request). Figure 17 shows the API definition using the Swagger UI.

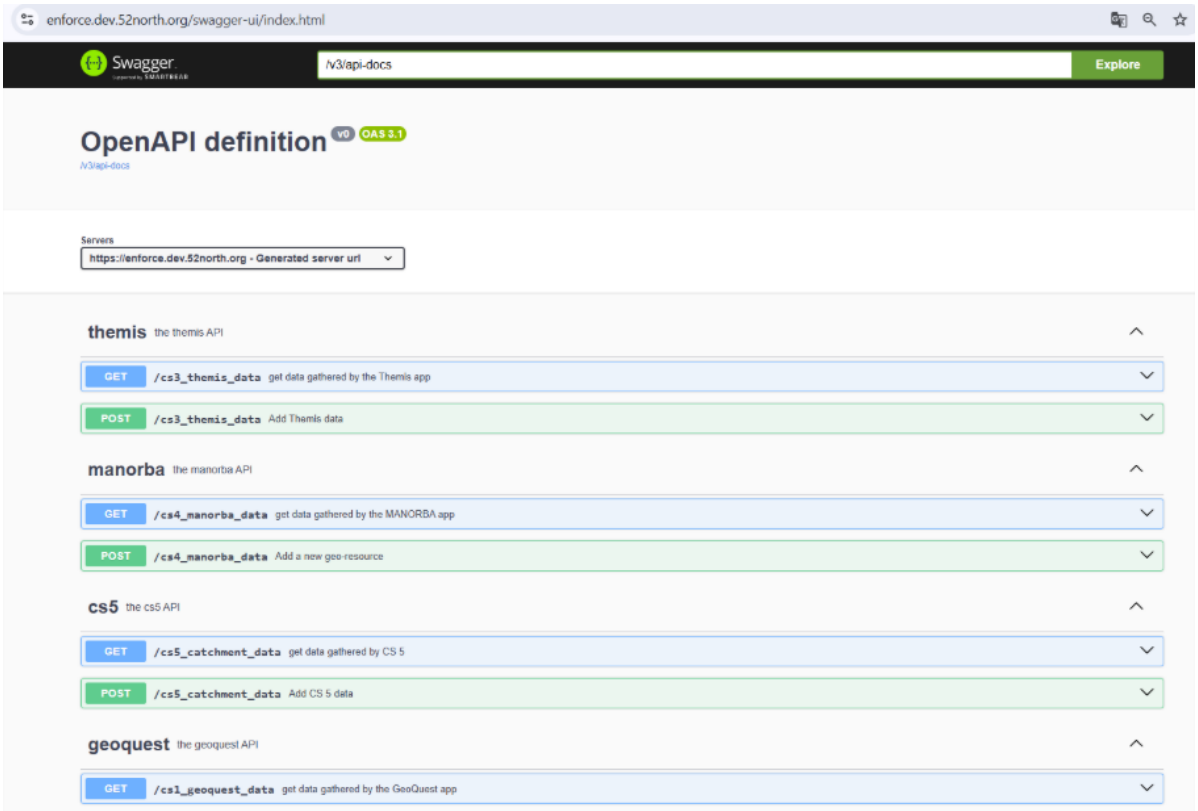


Figure 17: CS API Connector Swagger UI

The HTML landing page of the CS API Connector is shown in Figure 18.

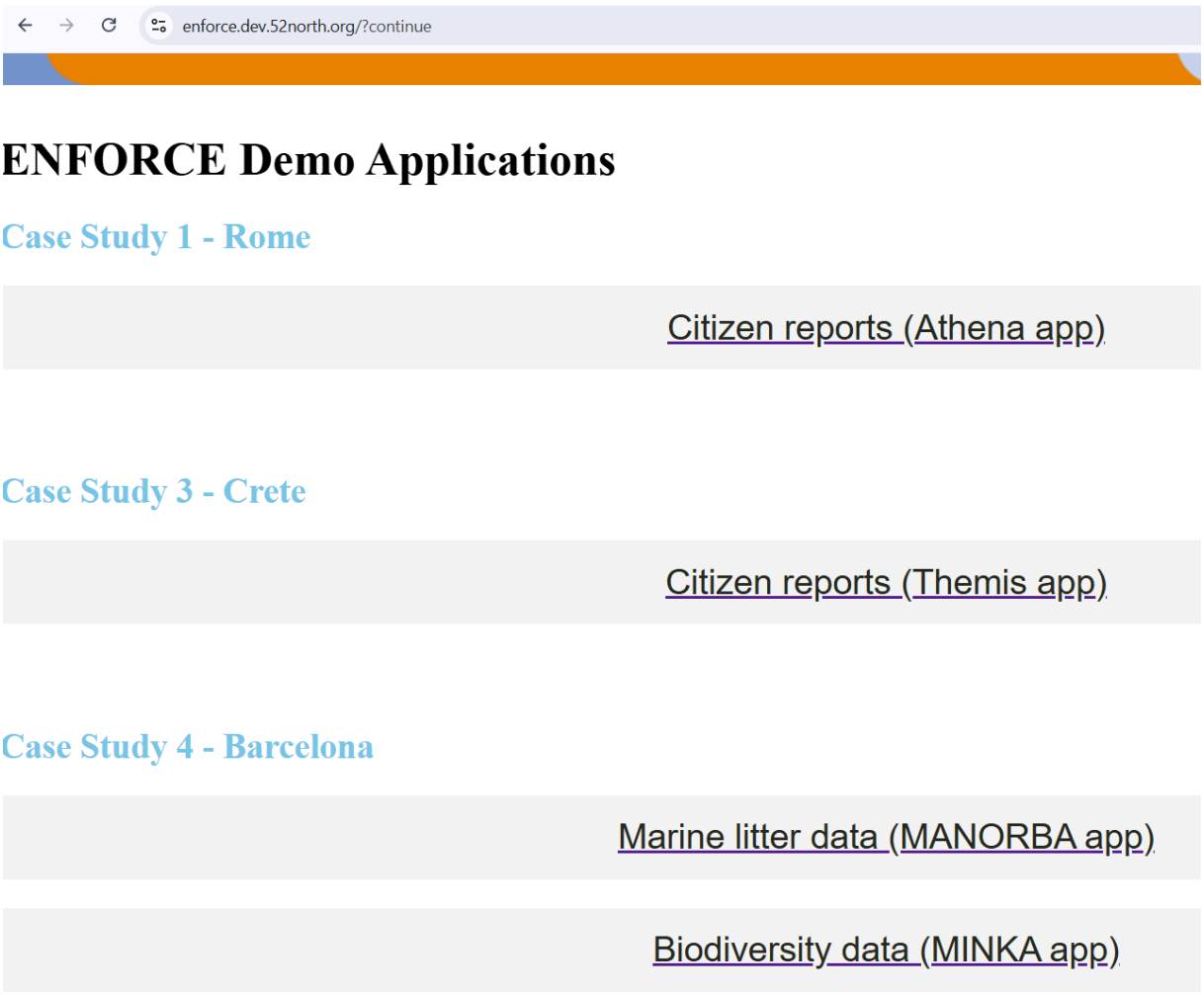


Figure 18: CS API Connector HTML landing page

6.1 Data ingestion through files

For Case Studies 1, 3, 4 (MARNOBA data), 5, 7 and 8, a common mechanism for data ingestion through files was implemented.

The schema of the input data needed to be analysed beforehand. For each of the Case Studies, an API was then created, exposing the HTTP methods GET, for data access, and POST, for data ingestion. The ingested data can be retrieved in the standardized GeoJSON format, which makes it easy to display the data for demo purposes. An example of data ingested from a file and displayed on a map is shown in Figure 19 from Case Study 1.

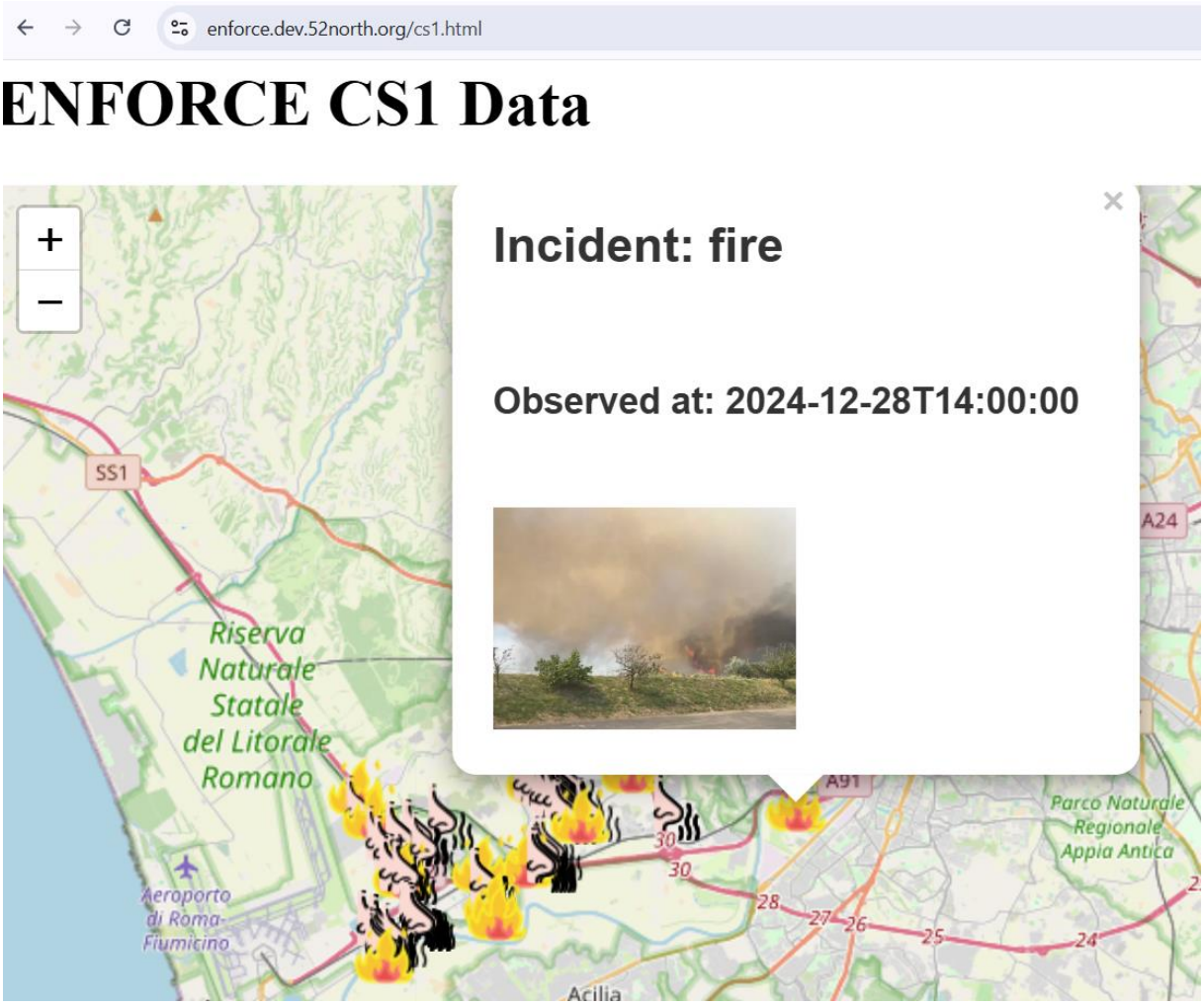


Figure 19: Demo of data from Case Study 1

7.2 API Crawling

For Case Study 4 (MINKA data), a mechanism for data API crawling was implemented. The endpoint and data schema of the API needed to be specified. The API is accessed on a periodical basis and (1) new data are added and (2) existing data are updated, if changes are detected. An example of data access through the data crawling API and displayed on a map is shown in Figure 20 from Case Study 4.

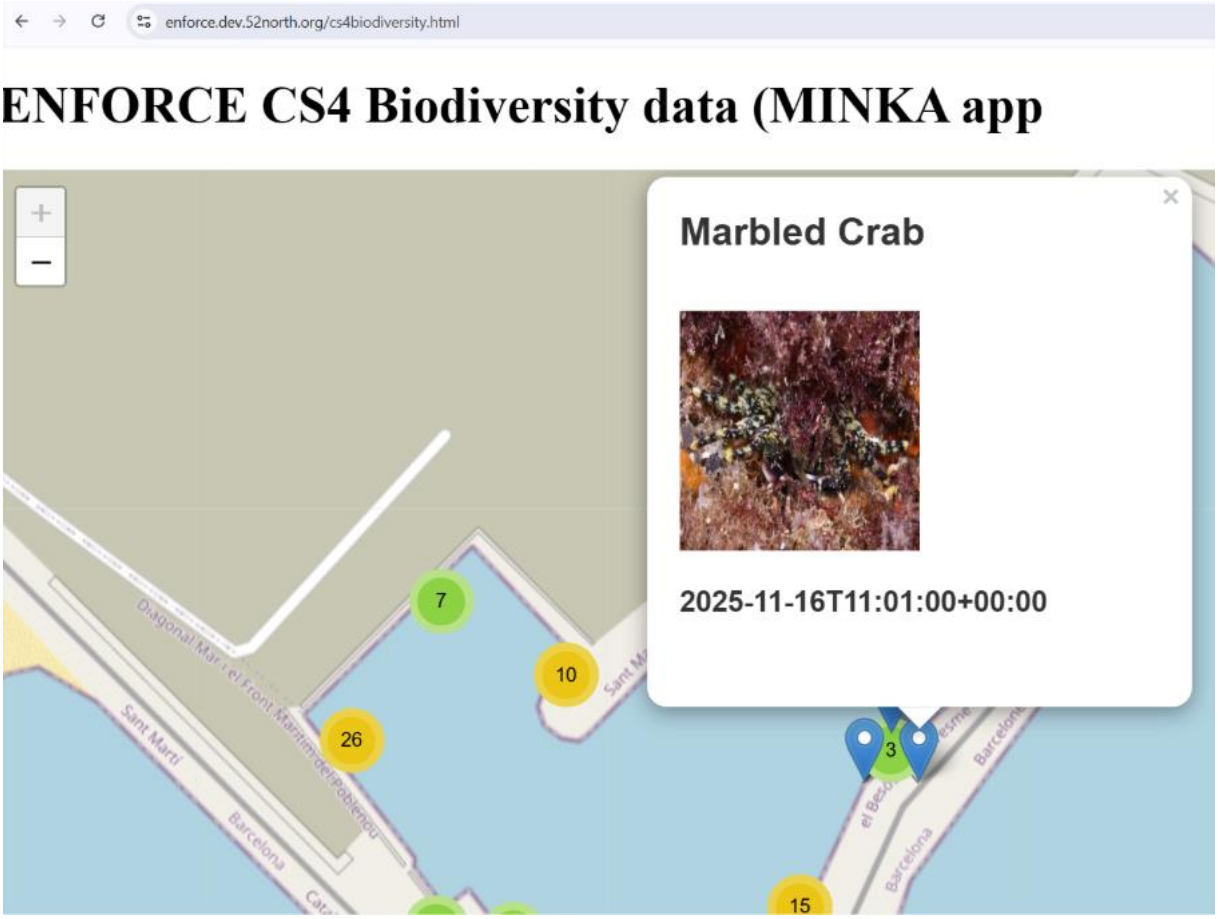


Figure 20: Demo of data crawled from the MINKA app for Case Study 4

7. Summary and Next Steps

In this deliverable, the citizen science data collection tools that will be used in the eight ENFORCE Case Studies have been outlined, along with developments that are taking place as part of the project. These tools cover a diversity of different methods and protocols from paper-based forms to mobile and web apps for data collection. To complement these tools, a generic web-based data collection tool is being developed as part of the Plaza Tools. In addition, the mechanisms for ingesting the data from the Case Studies, how data provenance will be ensured and the Data Space compliance of the prototypical ENFORCE platform were outlined. Demonstrations of data sets collected from various Case Studies have been implemented to demonstrate how the data ingestion will be operationalized as part of the ENFORCE Plaza Tools.

During the next 18 months of the project, T3.1 will continue to support each Case study, ensuring that the appropriate data collection tools and protocols are in place for carrying out citizen-based data collection campaigns during implementation. T3.2 will continue to support ingestion and cleaning of data from each Case Study for display, analysis and compliance purpose (where relevant) within the ENFORCE Plaza Tools.

References

Organisation for Economic Co-operation and Development (OECD). (2021). Reconciling terminology of the universe of per- and polyfluoroalkyl substances: Recommendations and practical guidance (Series on Risk Management No. 61; ENV/CBC/MONO(2021)25). OECD. https://one.oecd.org/document/ENV/CBC/MONO(2021)25/en/pdf

Annex A: The Paper-based Survey Form used by Citizen Scientists in Case Study 5 (East Devon)

WESTCOUNTRY
CITIZEN SCIENCE INVESTIGATIONS

Survey Details

Site Name – River/Stream:_____ at Location: _____

Grid Reference:_____

Date: _____ Time: _____ Observer Name:_____

Type of waterbody (tick one)

☐ River ☐ Stream ☐ Lake ☐ Pond ☐ Estuary/tidal

☐ Other:

Rain in previous 24 hours (tick one) _____

☐ None ☐ Light rain/showers ☐ Heavy or prolonged rain

Please take up to four photos to go with your survey data. One photo should be taken from the same place on each visit to capture some of the waterbody and surroundings.
Other features where photos would be useful are highlighted with the camera icon.

General Ecosystem Observations

Dominant land use within ~50m (tick all that apply)

☐ Woodland ☐ Moorland/ heath ☐ Urban residential ☐ Industrial/ commercial ☐ Parkland/ gardens

☐ Grassland/ pasture ☐ Agriculture (crops) ☐ Tilled land ☐ Other : _____

Dominant bankside vegetation (tick all that apply)

☐ Trees/shrubs ☐ Grass ☐ None (impermeable surface) ☐ None (bare earth)

☐ Other: _____

Problem plant species (tick all that apply)

☐ Himalayan balsam ☐ Japanese knotweed ☐ Giant hogweed ☐ Skunk cabbage ☐ Curly waterweed ☐ Floating Pennywort

☐ None ☐ Other: _____

Wildlife spotted (tick all that apply)

☐ Otter ☐ Dipper ☐ Water vole ☐ Kingfisher ☐ Grey Wagtail

☐ Heron ☐ Dragonflies/ damselflies ☐ Fish ☐ None

☐ Other: _____

If you spot signs of pollution, damage or danger to the natural environment, such as dead fish or fish gasping for air – call the Environment Agency 24-hour incident hotline **0800 80 70 60.**
If you spot anything you think could be a sewage leak/pollution across Devon or Cornwall, call South West Water 24-hour hotline on **0344 346 2020**. This is manned 24-hours.
Please note any incident reference number(s) you are given in the 'Notes' box on the survey form.

Evidence of Pollution

Pollution sources (tick all that apply)

☐ Outfall present not discharging ☐ Outfall present discharging ☐ Outfall causing odour ☐ Outfall causing discolouration

☐ Collapsed river banks ☐ Cattle/stock access to river ☐ Grey water (misconnection) ☐ Road run-off

☐ Soil run-off ☐ Farm run-off (slurry/silage) ☐ None ☐ Other: _____

Evidence of recent pollution (tick all that apply)

☐ Sewage-related litter ☐ Litter/ fly-tipping ☐ Unpleasant odour ☐ Oily sheen ☐ Sewage fungus ☐ Foam

☐ Smothering algae ☐ None ☐ Other: _____

River Channel Observations

Channel dimensions

Estimated Width at water level (m): _____ Estimated average depth (m): _____

Flow conditions (tick one)

Where 'steady' is walking speed, 'surging' is faster and 'slow is slower than walking speed.

☐ Surging ☐ Steady ☐ Slow ☐ Still

Obstacles to fish or flow (tick all that apply)

Water and fish need to move freely. Is there an obstruction in the channel (within 50m) which might stop or inhibit natural flow or fish movement?

☐ None ☐ Weir ☐ Fallen or Submerged Tree ☐ Debris Dam ☐ Bridge/Culvert (with step) ☐ Other Artificial Structure

Water level (tick one)

☐ High ☐ Average ☐ Low

Predominant substrate (tick one)

☐ Boulders >25cm (football size) ☐ Stones 25cm - 6cm (tennis ball size) ☐ Gravel 4mm - 6cm ☐ Sand Up to 2mm ☐ Silt/mud Identify by eye (looks like mud not sand) ☐ Bedrock

☐ Artificial ☐ Not visible ☐ Other: _____

Water quality observations

Temperature (°C): _____ Dissolved Solids (TDS – ppm): _____ Turbidity: _____

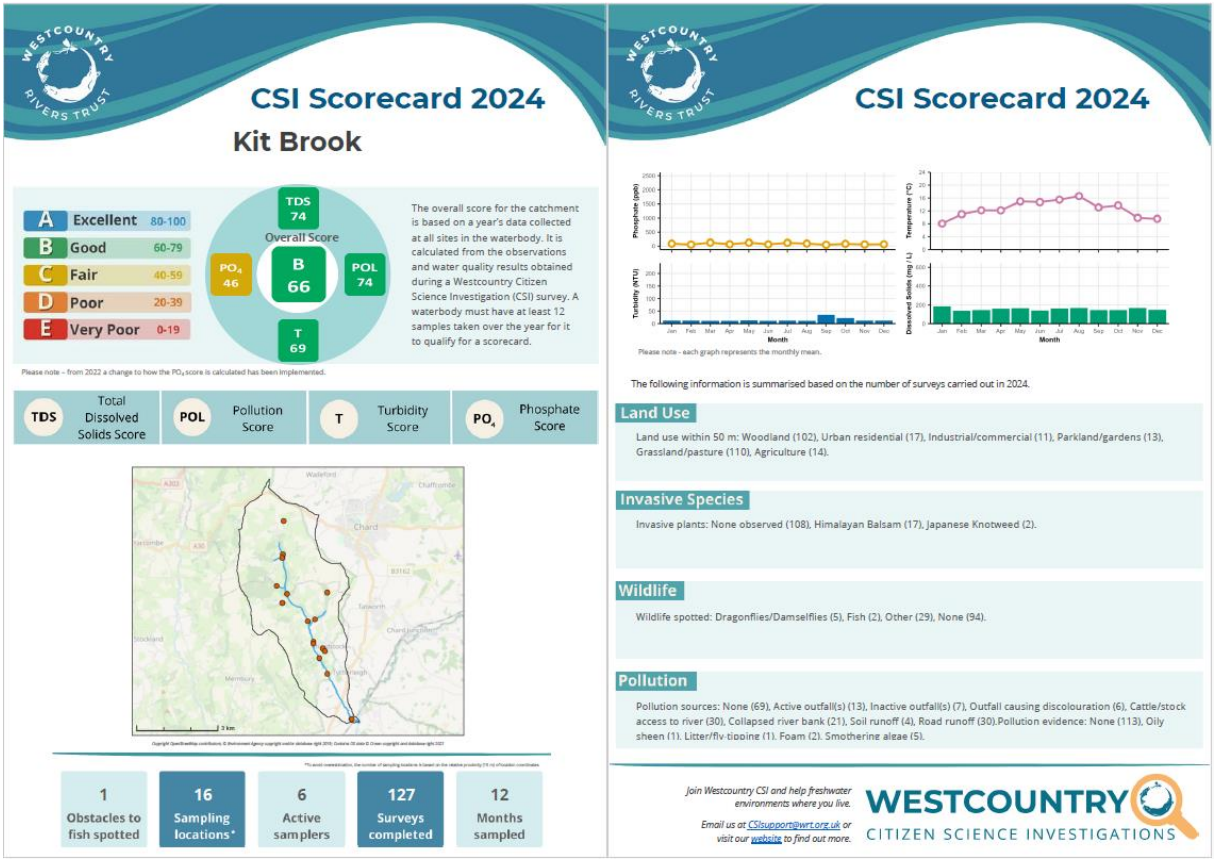
Phosphate (ppb): ☐ 0 ☐ 100 ☐ 200 ☐ 300 ☐ 500 ☐ 1000 ☐ 2500

Additional test : _____ Result: _____ Units: _____
(only fill out if you have an added test to complete, such as pH, Nitrate, Bacteria or Ammonia)

Notes

Westcountry Rivers Trust, Rain Charm House, Kyl Cober Parc, Stoke Climsland, Callington. PL17 8PH.
Phone: 01579 372140 · Email CSIsupport@wrt.org.uk

Annex B: Example of a Catchment Water Quality Scorecard based on Citizen Science Data



Annex C: Protocol of Sampling Plants and Soil for PFAS Analyses

Protocol by Sofie Thijs (HU)
Last update: 19/09/2025

Purpose. Provide a reproducible protocol to collect soil and plant biomass samples for PFAS analyses across different crop types (e.g., grasses, maize, tomato, potato) while preventing cross-contamination.
Scope. Applicable to agricultural plots, grasslands, experimental trials (mesocosms), or greenhouses. Soil samples are typically collected from the upper 0–10 or 0–20 cm; plant biomass samples are collected from above-ground or below-ground tissues, depending on crop type.

A. Materials and safety

1. Tools: stainless steel corers/probes, stainless scissors or pruning shears, stainless knives or spatulas, stainless bowls.
2. Containers: HDPE, LDPE, or PP bags/jars. No PTFE/Teflon®.
3. Cleaning: PFAS-free water, 1% Liquinox® or Alconox® solution, paper towels.
4. QC: PFAS-free water for blanks; field log sheets; CoC forms
5. Transport: coolers with ice/ice packs
6. **Safety: Avoid PFAS-containing clothing and materials (PTFE-treated fabrics, waterproof notebooks, cosmetics with PTFE).**

B. Define sampling plots

1. Define units (plots/fields). Use a quadrat frame or transect to standardize the sampled area.
2. **Minimum triplicate samples per treatment**/plot for statistical robustness.
    a. For duplicate soil samples: transect (grondbank: 50 steken (+-300 gram/steek) are required; a mixed sample of minimum 18kg, divide in 2, 2 x 9 kg soil.
3. **For fruits:**
    a. Small fresh products (< 25 g per unit), e.g. berries, peas, (fruit) leaf samples: minimum 500 g
    b. Medium-sized fresh products (25–250 g per unit), e.g. apples, potatoes, (chicory) roots: minimum 1 kg, at least 10 units
    c. Large fresh products (> 250 g per unit), e.g. cabbage, sugar beets: minimum 2 kg, at least 5 units
4. Soil depths: 0–10 cm and/or 0–20 cm (record exact depth).
5. Containers: HDPE, LDPE, or PP bags/jars. No PTFE/Teflon®.
6. Cleaning: PFAS-free water, 1% DECONEX® solution, paper towels.
7. QC: PFAS-free water for blanks; field log sheets.

C. Plant Biomass Sampling (crop-specific guidance)

1. **Grasses/cereals (e.g., maize, wheat, ryegrass):** cut plants at ~5–8 cm above ground using stainless scissors/shears; collect whole above-ground biomass or subsample by tissue type (leaf, stem, grain).
2. **Leafy crops (e.g., lettuce, spinach):** harvest representative leaves from each plant within the frame.
3. **Fruiting crops (e.g., tomato):** collect leaves and fruits separately if needed, noting developmental stage (lower truss, or n^{th} truss)
4. **Root/tuber crops (e.g., potato, carrot):** carefully excavate roots/tubers with stainless tools, brush off soil gently (wash or do not wash/depends).

D. Soil Sampling

1. From the same frame, collect at least three cores (≈5 cm Ø) to the target depth.
2. Composite cores in a stainless bowl, homogenize, remove large stones/roots.
3. Transfer 300–500 g to a labelled PE/PP container.
4. Store on ice

E. Decontamination

1. After each sample: rinse tools with PFAS-free water → wash with 1% Deconex® → rinse → dry
2. Change gloves when necessary (between a batch of samples)
3. Proceed from least to most contaminated areas when possible.

F. Quality control

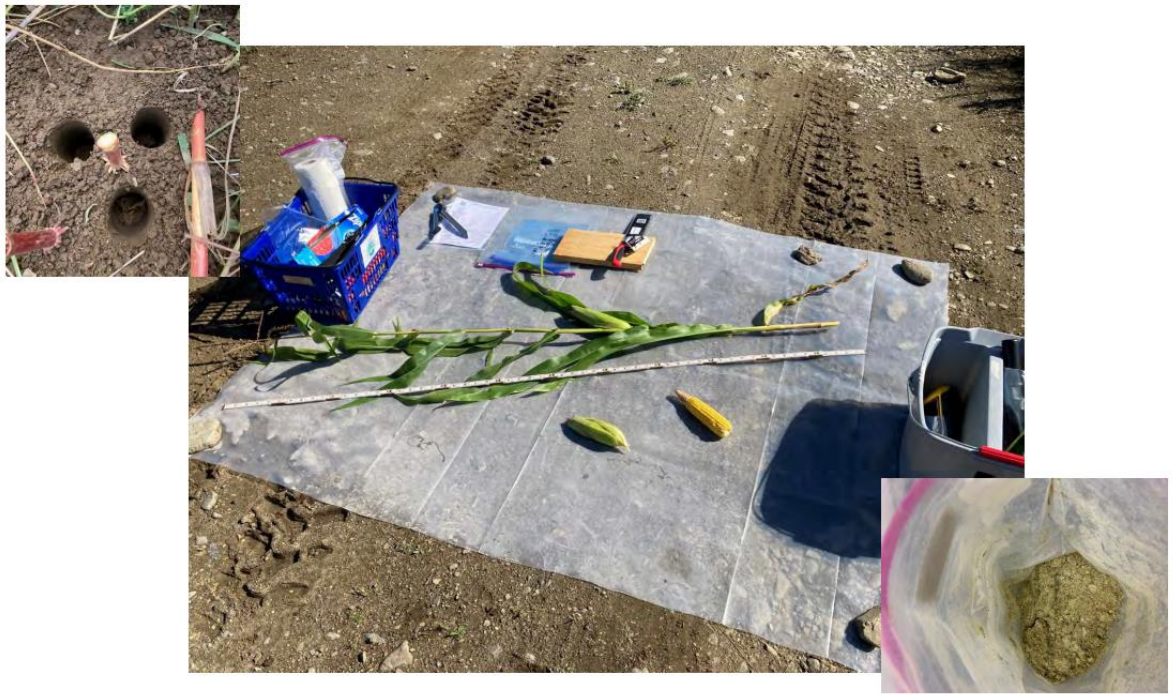
1. **Field replicates:** triplicates per plot: 50 grabs (+- 300 gram) for 1 homogenous sample of 18 kg (scale down to be feasible)
2. **Equipment blanks:** rinse after decon and collect as QC (≥1 per 10–20 samples).
3. **Field blanks:** expose PFAS-free water in bag/jar at site.
4. Record all QC in the log.

F. Labelling and metadata

1. Sample ID should include matrix (SOIL/PLANT), crop, plot, replicate, and depth
2. Record date, GPS, crop species and growth stage, depth, irrigation/fertilizer events, weather.
3. Barcoding: add barcode sticker form Eurofins on the bag, duplicate in lab book, later note down barcodes in excel for order sheet online

G. Packaging, storage, shipping

1. **Fresh samples**: place biomass in labelled zip lock bags; target ≥100 g fresh weight per sample. Keep cool (4°C) till pickup.
2. **Dry samples**: put the plant material in paperbags and place in the 60 °C oven (soil lab), doors bit open, and ventilation on
3. Double-bag samples; separate soil and biomass.
4. Keep ≤6 °C in the field; freeze (−20 °C) within 24 h if not analysed immediately.



Source of photographs: Sofie Thijs

Enforce

Empowering Citizens for Environmental Action

Funded by the European Union

UK Research and Innovation

Project funded by

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Department of Economic Affairs, Education and Research EAER
State Secretariat for Education, Research and Innovation SERI

This project has received funding from the European Union's Horizon Europe programme under grant agreement 101134447— ENFORCE. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them. Co-funded by UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding Guarantee. This work has received funding from the Swiss State Secretariat for Education, Research and Innovation (SERI).