D2.1 CSs System Requirements and Functional Specification

31/12/2024

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Abstract	This deliverable documents and reports on the collaborative definition and formalisation of the identified user needs, requirements and specification of functionalities for the Early Warning System and digital tools for the PLANET4HEALTH Case Studies. It presents the approach and key steps of the applied methodology, as well as the contents, interactive feedback and outcomes of the co-creation sessions and workshops with the stakeholders, formulated usage goals and scenarios, and the resulting requirements systematisation.
Keywords	Early Warning Systems, digital tools, requirements engineering, functional specification, co-design, goal-directed-design, user interface, interactive board, figjam, SOPHIST MASTeR method

PLANET 4HEALTH

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Statement on mainstreaming gender

The PLANET4HEALTH consortium is committed to including gender and intersectionality as a transversal aspect in the Project's activities. In line with EU guidelines and objectives, all partners – including the authors of this deliverable – recognise the importance of advancing gender analysis and sex-disaggregated data collection in the development of scientific research. Therefore, we commit to paying particular attention to including, monitoring, and periodically evaluating the participation of different genders in all activities developed within the Project, including workshops, webinars, and events but also surveys, interviews, and research, in general. While applying a non-binary approach to data collection and promoting the participation of all genders in the activities, the partners will periodically reflect and inform about the limitations of their approach. Through an iterative learning process, they commit to plan and implement strategies that maximise the inclusion of more and more intersectional perspectives in their activities.

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WP	Work Package
EWS	Early Warning System
CS	(PLANET4HEALTH) Case Study
UI	User Interface
UX	User Experience
PEU	Project End User
RE	Requirements Engineering
PFAS	PerfluoroAlkyl and PolyfluoroAlkyl Substances
EU	European Union
EC	European Commission
EEA	European Environmental Agency
EFSA	European Food Safety Authority
WHO	World Health Organisation
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organisation
FAO	(United Nations) Food and Agriculture Organization
USAID	United States Agency for International Development
CDC	Center(s) for Disease Control
HMIS	Health Management Information System
RASFF	(EU) Rapid Alert System for Food and Feed[1]

[1] https://food.ec.europa.eu/food-safety/rasff_en

EXECUTIVE SUMMARY

The Deliverable 2.1, *Case Studies System Requirements and Functional Specification*, documents and reports on the collaborative definition and formalisation of the identified user needs, requirements and specification of functionalities for the Early Warning System and digital tools for the PLANET4HEALTH Case Studies, having been performed during the first year of the Project.

It presents the approach and key steps of the applied methodology, as well as the contents, interactive feedback and outcomes of the co-creation sessions and workshops with the stakeholders, formulated usage goals and scenarios, and derived functional and non-functional requirements systematisation and specification for the tools (explained and described in Chapter 5).

The collaborative work undertaken during the internal joint definition sessions has involved all 17 PLANET4HEALTH consortium partners, and the subsequent consultation and co-creation workshops also involved external stakeholders and actors. These sessions and workshops have played a crucial role in formulating the objectives and functionalities of the EWSs and digital tools, ensuring they meet the diverse needs and requirements of the end users and other involved stakeholders on the four PLANET4HEALTH Case Studies, including the initial identification, systematisation and segmentation of these stakeholders per types and roles, and degree of involvement and influence on the development and usage. The overview of identified key constraints and barriers affecting the requirements and specified features, as well as preliminary insights into the available datasets, foundations for the EWSs and tools, have also been provided, concluding with the overview of next planned steps.

These comprehensive collaborative and co-design efforts pave the way as crucial inputs driving the upcoming development of the PLANET4HEALTH EWSs and digital interactive tools in the parallel and continuing Task 2.3 (*Development of the Early Warning System and Digital Tools for CSs*).

1 Introduction

PLANET4Health provides new knowledge and tools on environment degradation and its impact on human animal and ecosystems health (with "health" denoting the state of complete physical, mental and social well-being, as defined in the principles set out in the preamble to the WHO Constitution[2]). The Project results will support policy making process and citizens awareness on sustainable planetary health, climate and environmental policies and adaptation and mitigation strategies to natural hazards, based on the One Health approach. The drivers and impacts of climate and environment degradation are to be studied and the gained knowledge and developed digital tools are to facilitate learning and practice on the interaction between the natural system and human health in four tailor-made Case Studies:

- CS1) One-health effects of vector-borne diseases (in the Iberian Peninsula)
- CS2) Air pollution and health (in South Africa)
- CS3) Food contamination arising from soil and water contamination by PFAS (in Central Europe), and
- CS4) Mental wellbeing linked to environmental and climate stressors (in Spain and South Africa).

The collected knowledge and case-specific insights will drive the development of the mentioned digital tools, primarily EWS and early-communication and response frameworks for more accurate environmental and health modelling, prognosis and assessments of risks and spreading of the listed degradations, and proactive informed avoidance or mitigation options.

The "system" in the title of this deliverable consequently implies and denotes the Early Warning System (or systems), as well as other types of suitable digital tools to be developed for the CSs.

This document presents the definition and formalisation of the identified user needs, requirements and preferred UI mock-ups having been performed in the scope of the Project task (T)2.1 within the WP2 - ***Technological Platforms and Digital Tools for OneHealth***. These requirements and functional specification as inputs are to drive the upcoming development of the PLANET4HEALTH EWSs and digital interactive tools in the task 2.3 (*Development of the Early Warning System and Digital Tools for CSs*), and the subsequent evaluation of their working status and effectiveness in WP3 (*Social and Economic Studies, Risk Reduction, and Policy Adoption for Planetary Health*).

[2] https://www.who.int/about/governance/constitution

1.1 The Goal and Scope of the Task 2.1, Relations to Other Work

The realisation of this task - definition of user needs, functional and non-functional requirements, and UI mock-ups - has been the first step in consultations with end users and other key stakeholders towards the creation of effective digital tools and services. This co-creation of essential elements of the Project-generated interactive tools has first been undertaken by the Project partners (especially PEUs engagement) during the initial 6 months of the Project, and then complemented by the engagement of the external stakeholders targeted as intended user or prospective early-adopters of the tools (during months 7-12). The task has consisted of:

1) the definition of user needs and requirements for the EWSs and digital tools, and

2) conducting a series of meetings and workshops involving the Project partners and key external stakeholders to identify their needs and requirements,

all towards defining the new and adapted functionalities and features of the EWSs design based on the stakeholder inputs. The meetings and the workshops have included introductions to, and examples of, existing similar or related EWS and tool designs, assessment of the essential needs and challenges that Project partners, and especially PEUs, deem should be addressed by the developed tools, elaborating use case scenarios and using them to drive the discussion on the details of the services that are going to be provided, registering new knowledge that partners bring to refine the designs, and recommendations for targeted messages for specific stakeholders (such as health and veterinary care, public authorities, affected and vulnerable groups and citizens, researchers, surveillance organisations, and others).

The initial Project's stakeholder identification and segmentation (based on their influence, involvement, and interests in the Project, as elaborated under methodology in Chapter 2 and in the relevant Section 4.1) has also been performed for the ones of interest for the WP2 scope and objectives, in synergy with the connected tasks in WP4 (*Communication, Dissemination and Policy making*), and the first external stakeholder engagements (interactive collaborative workshops) conducted. This also included the elicitation of non-functional regulatory, public-authority-related, and other requirements, to the extent of the stakeholders knowledge and ability to provide the groundwork and sources for them.

The produced requirements specification should help in better understanding of the state of the art in addressing the problems for end users in each CS, the extent to which they are addressed (to be evaluated in WP3), and the state of the art of relevant technologies, applications, procedures and conditions/constraints of use. The process ensures as clearest possible understanding of the requirements that the digital tools need to meet in each CS, and is a basis for further refining their design.

2 Methodology

The employed methodology is based on four key pillars and steps of the Goal-Directed Design (GDD) approach:

1. Comprehensive analysis of the state of the art and existing landscape of similar and related EWSs and digital tools designs and implementation, and adoption and advancement of proven best practices and effective working examples.

2. Analysis and systematic identification of stakeholder types and roles, to contextualize the PLANET4HEALTH digital solutions and understand potential interests and needs from all affecting actors that operate in the real world related to environmental degradation and climate change.

3. Central co-creation approach for the solution design, involving the end users and key influencing stakeholders in collaborative and interactive designing of the system functionalities and UX features. This co-creation process can be considered a practical continuation of the initial PLANET4HEALTH collaborative concept ideation that had involved a number of key stakeholders and end users already from the Project proposal preparation stage before the funding had been granted. These stakeholders and users have subsequently become the consortium partners and Project beneficiaries, now continuing the co-creation efforts more focused on elaborating in detail the user needs and the corresponding required features and functionalities, using the appropriate collaborative tools and involving additional external stakeholders.

   The aim is also to demonstrate how it helps the end users to get a better understanding of the context of the new technology and how they may contribute to the development of design concepts.

4. Structured formalisation of the defined requirements, based on widely used standardised state-of-the-art Requirements Engineering (RE) elicitation method and structuring templates, in this case the MASTeR templates of the Sophist group, derived from knowledge and experience in a wide range of projects [1], and additionally familiar and understandable for most of the involved in the inherently German-speaking CS3.

These process steps are commonly initiated in the exact sequence as listed above, each feeding the results as inputs to the next, but in practice also overlapping in time, executed in parallel, particularly steps 3 and 4, and generally in the conclusive systematisation stage. The methodology aims at fulfilling user needs and goals while satisfying "business" or work process requirements [10], and the listed process steps are a subset of the generic six phases (diagram on the FIGURE 1 below), with the latter extending into the systems and tools development stage.

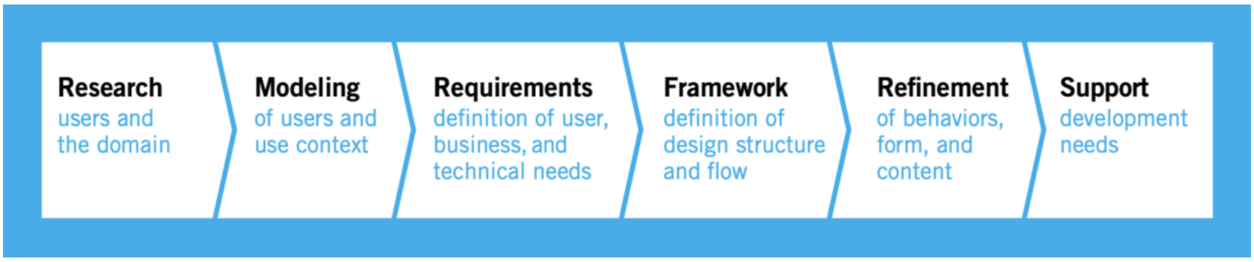

FIGURE 1: GOAL-DIRECTED DESIGN/DEVELOPMENT (GDD) MAIN PROCESS FLOW

This specific direction of goal-centred design approaches considers as fundamental to start designing "beyond" just the end-user perspectives, taking into account also the more complex real-world interactions of the other stakeholders that contribute to a product's ultimate feasibility and success.

The cornerstones of the approach in practice are co-creation, joint conceptualisation and design of the solution together with the stakeholders, and drafting the requirements to fulfil the unmet needs and tailor the user interactions to optimally fit the stakeholder profiles and routines, all the while ensuring that the developed technology will be robust and feasible to deploy on the Case Study sites.

3 State of the Art Overview and Benchmarking

This chapter summarises the key applicable results and findings of the initiating "research" phase - comprehensive analysis of the state of the art and existing landscape of the legacy similar and related EWSs and other digital tools already used in the fields covered by the four PLANET4HEALTH CSs, and other related areas (pandemics/epidemics and natural hazards monitoring, exploration, coordination, awareness and alerting systems, various participative and citizen science projects and initiatives, etc.).

3.1 EWS Examples

In this section, we benchmark the various examples of EWS to provide a comprehensive overview of the current scientific and technological landscape in this field. The purpose is to explore and present documented instances of EWS, offering detailed insights into their functionalities, applications, and impact. By examining these examples, we can gain a deeper understanding of the diverse range of EWSs and their implementations and significance in various domains.

We have considered a diverse range of fields where EWSs are essential in detecting and alerting potential hazards or threats. For example, in the field of food security, EWSs can help predict crop failures due to weather events (such as droughts and floods), pests, or diseases, enabling timely interventions to mitigate the impact on farmers and consumers. In the mosquito-borne diseases field, EWSs can predict potential conditions suitable for mosquitos, and prevent the spread of mosquito-borne diseases, such as dengue or Zika, by monitoring mosquito populations and their infection rates. Similarly, in the air quality monitoring field, EWSs can alert people to harmful pollutants or airborne particles, enabling them to take preventive measures to protect their health.

Early warning systems for extreme weather events, such as hurricanes, floods, or droughts, can help enable timely evacuation and emergency response. In Europe, the European flood awareness system (EWS8, TABLE 1) and the European forest fire (EWS9, TABLE 1) information system use satellite data and weather forecasts to provide early warning alerts to local authorities, helping them prepare for and respond to emergencies. In the field of pet health, EWSs can detect diseases or illnesses in pets, allowing for timely treatment. Similarly, in the world health platform (EWS12, TABLE 1) and parasite platform (EWS13, TABLE 1), EWSs can predict and prevent the spread of infectious diseases, such as COVID-19 or malaria, by monitoring outbreaks and identifying potential hotspots [2].

In summary, we provide a comprehensive, though not exhaustive, overview of the applications and significance of EWS in different contexts. Through the selected examples, it illustrates the key role of EWSs in detecting and alerting potential hazards or threats, enabling timely intervention to protect lives and livelihoods. The documentation of these examples was conducted systematically, with each selected EWS analysed to capture details about its unique features and functionalities. This documentation process was carried out by gathering specific information for each system and organizing it according to the sections presented in TABLE 1. It came out through the preparatory process for stakeholder workshops, in constant communication with project partners during months 1-6 of the project.

TABLE 1: LIST OF EXISTING EARLY WARNING SYSTEMS RELATED TO PLANET4HEALTH

Code	EWS Type	URL	Relevant for
EWS1	Vector-borne disease platform	https://maps.vectorsurv.org/arbo	CS1
EWS2	Food security platform	https://fews.net/	CS3
EWS3	Mosquito (vector-borne disease) platform	https://mueckenatlas.com/	CS1
EWS4	Air quality platform	https://www.eea.europa.eu/themes/air/air-quality-index	CS2
EWS5	Extreme weather events	https://www.meteoalarm.org/en/live	CS1,CS2, CS4
EWS6	African flood and drought monitor	https://hydrology.soton.ac.uk/apps/afdm/	CS1,CS2, CS4
EWS7	Global disaster alert and coordination system	https://www.gdacs.org/default.aspx	CS1,CS2, CS4
EWS8	European flood awareness system	https://www.efas.eu/efas_frontend/#/home	CS1-CS4
EWS9	European forest fire information system	https://effis.jrc.ec.europa.eu/apps/effis_current_situation/index.html	CS1-CS4
EWS10	Climate information and disaster management	https://cidmews-sl.solutions/	CS1,CS2, CS4
EWS11	Informative platform	https://campaign.elanco.com/en-us/cvbd/	CS1-CS4
EWS12	World health platform	https://apps.who.int/neglected_diseases/ntddata/leishmaniasis/leishmaniasis.html	CS1
EWS13	Parasite platform	https://www.myvbdmap.com/es?disease=Leishmaniosis	CS1

EWS14	Mosquito observation platform	https://vectrack.avia-gis.com/	CS1
EWS15	Pollen, allergy platform	https://www.polleninfo.org/GB/en.html?iframe=0%27a%3D0	CS1,CS2
EWS16	Air quality platform	http://www.amskv.sepa.gov.rs/index.php?lng=en	CS2
EWS17	Copernicus Atmosphere Monitoring Service (CAMS), air quality platform	https://policy.atmosphere.copernicus.eu	CS2
EWS18	Malaria (vector-borne disease) threats platform	https://apps.who.int/malaria/maps/threats	CS1,CS2

Five EWSs out of the listed in TABLE 1 have been found of primary relevance for PLANET4HEALTH and therefore extensively documented with their descriptions are provided below in more comprehensive detail. This surveying of the state-of-the-art EWS and tools examples is continuously underway, and will extend throughout the subsequent following development tasks, particularly related more to the mental and overall well-being aspects relevant for the CS4 and the remaining upcoming stakeholder consultation workshop dedicated to it, still undergoing extensive preparation. The EWS developments in general are also rapidly progressing, expanding and evolving literally over months, or even weeks - for example, the European Air Quality Index geomapping visualisations, listed as EWS4 in the table above, are just one in the set of various similar interactive data visualisations dashboards featured by the EEA platform covering diverse environmental fields and issues[3], many of which are being continuously enriched with new short- and medium-term forecasting, trending, monitoring or indexing features, requiring constant follow-up and empirical empirical research (testing in actual usage, as elaborated for the selected examples following below).

EWS1 VectorSurv Maps – A Vector-Borne Disease Platform

VectorSurv Maps is a key component of the Vector-borne Disease Surveillance System (VectorSurv), a cutting-edge tool supporting real-time surveillance and decision-making for vector control and public health agencies. Initially launched in 2006 as CalSurv in California, the platform expanded in 2017 to include 12 U.S. states and territories, including Guam and U.S.-affiliated Pacific Islands [7]. Developed collaboratively by the Mosquito and Vector Control Association of California, the California Department of Public Health, and the University of California Davis Arbovirus Research and Training (DART) Laboratory[4][7], VectorSurv Maps

[3] https://www.eea.europa.eu/en/analysis/maps-and-charts

[4] California Department of Public Health (CDPH): https://cdph.ca.gov

serves as a centralized system for tracking mosquito populations, conducting pathogen testing, and providing actionable insights to guide vector control efforts[5].

The platform offers several advanced capabilities that are critical for vector-borne disease management. It provides real-time monitoring of mosquito species distribution and abundance, integrating laboratory data such as mosquito pool testing and sentinel chicken results into an interactive geospatial interface[5]. This allows public health agencies to identify high-risk areas, plan targeted interventions, and assess the effectiveness of control measures. For example, during a Zika virus outbreak in Hawaii, VectorSurv Maps enabled the identification of high-risk zones, allowing for the efficient allocation of resources to mitigate the disease's spread[6].

In addition to its surveillance features, VectorSurv Maps includes operational tools that enhance decision-making and intervention strategies. These tools support pesticide application tracking, insecticide resistance testing, and arboviral risk estimation. In California, data collected through the platform informed adjustments to insecticide application strategies, leading to improved outcomes in vector control[7]. Its focus on day-to-day operational data entry ensures faster response times compared to traditional post-season reporting, enabling more proactive decision-making[7].

The relevance of VectorSurv Maps to the PLANET4HEALTH project is particularly pronounced in CS1, which focuses on vector-borne diseases in the Iberian Peninsula. By leveraging the methodologies of VectorSurv Maps, PLANET4HEALTH can develop a localized Early Warning System (EWS) tailored to predict and mitigate vector-borne disease risks in Mediterranean region[6].

Compared to other Early Warning Systems, VectorSurv Maps is distinguished by its specialized focus on vector-borne diseases. While platforms like the African Flood Monitor and the European Forest Fire Information System (EFFIS) address environmental hazards such as floods or wildfires, VectorSurv Maps integrates geospatial data with pathogen detection to enable real-time decision-making specific to vector control[6,7]. Despite its strengths, the platform does face limitations, including restricted access to its database and the need for adaptation when applied to non-U.S. regions.

As a model for integrating data-driven tools into vector-borne disease management, VectorSurv Maps offers valuable lessons for adapting surveillance systems in other regions, such as Europe. Its comprehensive features and geospatial capabilities provide a foundation for developing robust EWS under the PLANET4HEALTH project. As climate change continues to alter vector dynamics and expand the geographic range of vector-borne diseases, adopting and adapting platforms like VectorSurv Maps can enhance public health preparedness and resilience.

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[5] VectorSurv Overview: https://vectorsurv.org
[6] VectorSurv Maps: https://maps.vectorsurv.org
[7] VectorSurv Gateway: https://gateway.vectorsurv.org

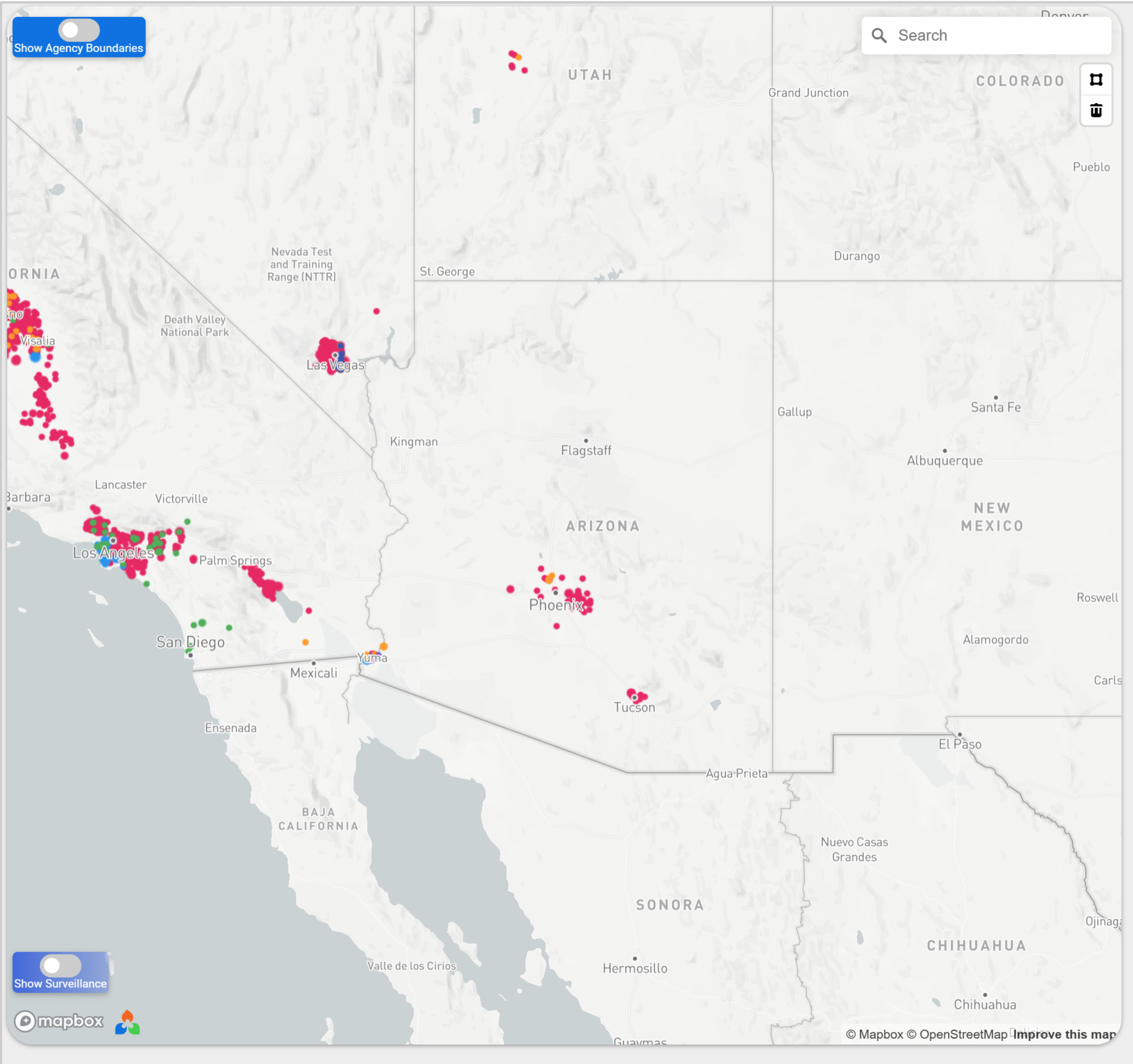


FIGURE 2: VECTORSURV MAIN MAP VIEW

EWS6 – African flood and drought monitor

The African Flood and Drought Monitor is an early warning system developed collaboratively by Princeton university, Princeton Climate Institute, University of Southampton, UNESCO Intergovernmental Hydrology Programme and the International Center for Integrated Water Resources Management. This system incorporates a wide range of data from ground observations, satellite imagery and modelling data. It also includes both short-term and seasonal forecasts, providing valuable information for monitoring flood and drought conditions in Africa (FIGURE 3).

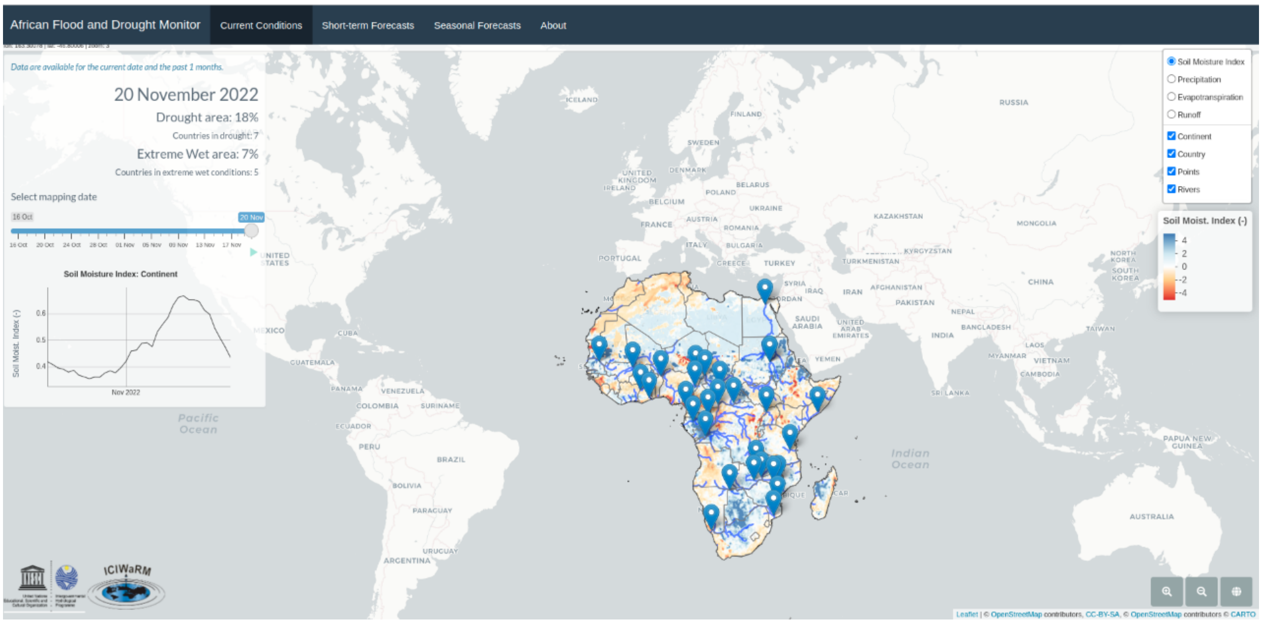


FIGURE 3: MAIN MENU OF THE AFRICAN FLOOD AND DROUGHT MONITOR

The system utilizes downscaled precipitation and temperature data, corrected to eliminate any biases from climate forecast models. These data are presented at a resolution of 5 km, allowing for detailed analysis. The user tool interface of the African Flood and Drought Monitor features a map interface with four tabs: Current Conditions, Short-term Forecast, Seasonal Forecast, and Project Information.

In the Current Conditions tab, raster data representing different variables can be displayed on the map. Users have the option to view the African continent with country polygons and can select individual countries to add points indicating major cities and rivers. The map interface also allows users to interact with the left panel, which provides time series data for the selected variable in the chosen country. Additionally, the panel shows the data's evolution over the last month and the percentage of countries experiencing extreme conditions.

The Short-term Forecast tab provides detailed information on current conditions and short-term (7-day) forecast conditions. The focus is on hydrological variables at the national and district scale, along with streamflow at specific points of interest. The tab also includes information on the uncertainty represented by the ensemble's 5th and 95th percentiles, aiding in understanding the range of potential outcomes. In the Seasonal Forecast tab, users can access more detailed information on current conditions and seasonal (6-month) forecast conditions for districts. The focus here is primarily on precipitation, although hydrological forecast variables and indices are also under development. However, the probability maps within this tab are currently non-functional.

To facilitate data visualization, the African Flood and Drought Monitor employs a Web Map Service, enabling the display and exploration of the data in a user-friendly manner. This feature enhances the accessibility and usability of the system, making it easier for users to analyse and interpret the information presented.

EWS7 – Global disaster alert and coordination system

The Global Disaster Alert and Coordination System (GDACS) was established as a collaboration between the United Nations and the European Commission in 2004. The participating institutions include the Joint Research Centre of the European Commission, UN Office for Coordination of Humanitarian Affairs (OCHA), United Nations Satellite Centre (UNOSAT), Dartmouth Flood Observatory, and SAR Weather service.

GDACS is an early warning system designed to provide real-time information and coordination for the early stages of climate disasters (Figure 4). It offers global coverage and features a user-friendly interface with two main tabs. The first tab displays all events happening in real time, such as risk eruptions, cyclones, tsunamis, and more. The second tab contains alerts (with the design that could benefit from clarity and visual organisation improvements). Additionally, GDACS offers a smartphone app for easy access and convenience.

GDACS consists of three main tools: Disaster Alert, On-Site Operations Coordination Centre (OSOCC), and Maps and Satellite Imagery.

- The Disaster Alert tool provides a map interface that offers automated early warning and preliminary impact estimates for natural disasters. It displays the alert level of each disaster, along with a summary of past events. Clicking on a specific disaster on the map provides access to more detailed information, such as magnitude, depth, longitude and latitude, date of the event, exposed population, maps, and related news. The Disaster Alert tab also includes a menu that allows users to make specific requests based on dates, filter by alert level, severity, country, and disease type.
- Virtual OSOCC is a password-restricted online platform that facilitates real-time information exchange and cooperation among all actors involved in the initial phase of a disaster. It serves as a hub for coordinating efforts and sharing vital information.
- The Maps and Satellite Imagery tool offers a communication and coordination platform where organizations can monitor and inform stakeholders about their ongoing mapping activities for ongoing emergencies. It provides a global map interface that showcases past events and current disasters. Clicking on individual points on the map allows users to zoom in and view the geographical map of the affected area.

The GDACS is currently in working status, ensuring that the system is functional and operational. It operates in real time, providing up-to-date information on climate disasters as they occur. The system offers global coverage, enabling users to access information and alerts from around the world. It covers a range of disaster variables, including earthquakes, tropical cyclones, floods, volcanoes, droughts, and forest fires.

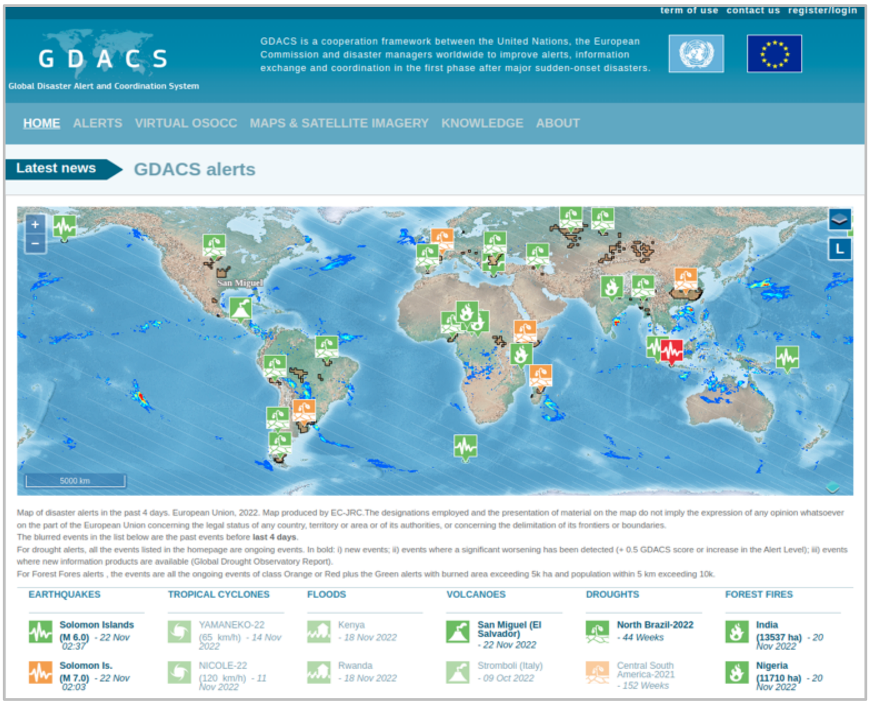


Figure 4: Main menu of the Global Disaster Alert and Coordination System

EWS9 - European forest fire information system

Copernicus EMS Early Warning system provides geospatial data across Europe and globally, it develops continuous observations and forecasts for floods, droughts and forest fires.
The European Forest Fire Information System (EFFIS) plays a crucial role in safeguarding forests against fires in the EU and neighbouring countries (Figure 5). It serves as a valuable resource for the European Commission services and the European Parliament, providing them with up-to-date and reliable information on wildland fires across Europe. EFFIS has been in operation since 1998 and is supported by a network of experts known as the Expert Group on Forest Fires. This group, registered under the Secretariat General of the European Commission, comprises experts from 43 countries in Europe, the Middle East, and North Africa. In 2015, EFFIS became an integral part of the Emergency Management Services within the EU Copernicus program.
One of the main tools is the “Current Situation Viewer”, which provides accurate and up-to-date data on the current fire status. This tool includes weather maps showing fire danger for both the current day and the next six days, allowing for advance planning. In addition, the tool is updated daily with maps of hot spots and fire perimeters, providing an accurate view of the situation in real time.

The system is composed of a set of raster layers that are dynamically loaded based on user requests. This means that users can customize their visualization by selecting different weather data sources, fire index types and time periods for predictions. This flexibility allows the system to be tailored to the specific needs of each user, providing a personalized experience and greater efficiency in decision making related to fire management and prevention.

FIGURE 5: MAIN MENU OF THE EUROPEAN FOREST FIRE INFORMATION SYSTEM

EWS17 – Copernicus Atmosphere Monitoring Service (CAMS)

The Copernicus Atmosphere Monitoring Service (CAMS) is a comprehensive platform designed to monitor and forecast atmospheric conditions and air quality across Europe and globally. As a core component of the Copernicus Programme, CAMS provides detailed, reliable data and analyses to support environmental and public health decision-making. CAMS integrates diverse data sources, including satellite observations, ground-based monitoring systems, and advanced numerical models, to deliver a continuous stream of high-resolution air quality information[8].
CAMS offers a variety of tools and products for policy support[9], including real-time monitoring of key air pollutants such as particulate matter ($PM_{2.5}$, PM_{10}), nitrogen dioxide (NO_2), and ozone (O_3), as well as greenhouse gas concentrations. Through its interactive web portal, users can access dynamic maps, forecast animations, and historical data analyses to assess pollution levels and their potential impacts. The service also provides daily and multi-day forecasts, enabling public authorities, researchers, and citizens to take preventive or adaptive measures to mitigate air pollution risks.

[8] https://atmosphere.copernicus.eu/observations
[9] https://atmosphere.copernicus.eu/policy-tools

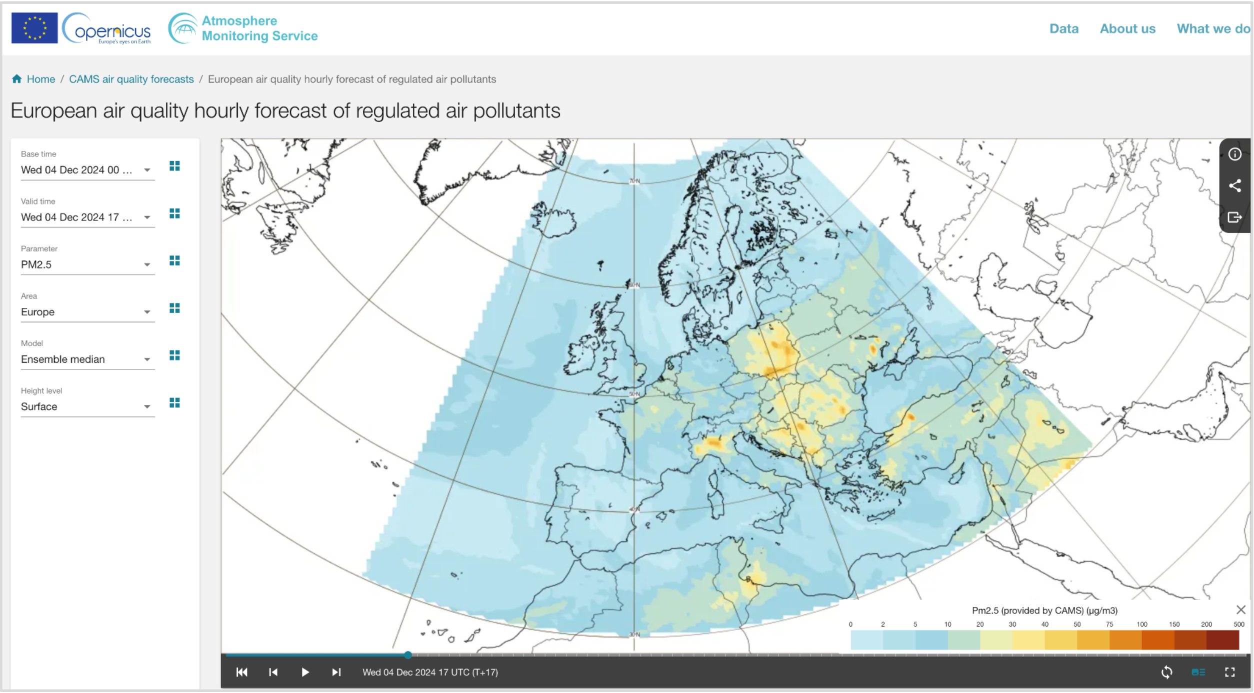


FIGURE 6: CAMS MAIN MAP VIEW WITH HOURLY FORECASTS OF REGULATED AIR POLLUTANTS

Notably, CAMS contributes to public health by issuing air quality alerts and supporting urban planning for pollution control measures. Its applications extend to various domains, including health impact assessments, climate policy development, and educational awareness campaigns. The relevance of CAMS to PLANET4HEALTH is exemplified in CS2, which investigates the health effects of air pollution in South Africa. The platform's capabilities align with CS2 objectives by providing actionable insights into pollutant distribution, health risk modeling, and early warnings for hazardous air quality episodes. CAMS exemplifies the integration of advanced remote sensing, modeling, and data dissemination technologies into an effective EWS.

3.2 Other Relevant Systems, Tools, and Visualisation Types

As noted above in the previous section, the COVID-19 pandemic has spawned the development of various **comprehensive spatio-temporal data exploration and analytics tools** that can not be considered EWS as such, enabling mainly post-hoc study of retrospective data, but still featuring different types of rich interactive visualisations and even predictive analytics and what-if scenarios exploration. Among the most comprehensive and advanced such tools is the PERISCOPE COVID Atlas, developed by the PERISCOPE project funded from the Horizon 2020 programme from 2020 to 2023, described in more detail immediately below and publicly available at https://periscopeproject.eu/covid-atlas.

Other prospectively relevant type of **solutions** are the specific ones **dedicated to One Health or similar holistic and synergistic multisectoral approaches, like HiAP** (Health in All Policies[10]). Such is, for example the PHO (Public Health

[10] https://www.who.int/activities/promoting-health-in-all-policies-and-intersectoral-action-capacities

Organisation) Observatory analytics, data visualisation and monitoring platform described in some more detail further below, as well as some other tools produced by the PULSE project (like the Personal Air Pollution Exposure Calculator, or the PULSAir mobile application for citizens)[11], funded from the Horizon 2020 programme from 2016 to 2020. The PHO Observatory application is again not declaratively an EWS, but it combines extensive GIS and geo mapping features with temporal and multivariate advanced combined interactive visual analysis, relevant examples for all the four PLANET4HEALTH CSs.

DHIS2 (District Health Information Software 2) is another notable comprehensively developed, maintained, and widely used multisectoral open-source web-based platform implementing the One Health integrated approach[12], supported by an international globally cooperating community of academia, major international organisations like WHO, UNESCO and USAID, foundations like Gates Foundation, and other NGOs, as well as national governments and public health institutions (like the US CDC), and sponsoring technology partners. It integrates human, animal, and environmental health from diverse data sources to address emerging public health challenges, and features integrated rich visual analytic dashboards and early warning functionalities like automated alerting driven by real-time monitoring. DHIS2 has been instrumental in monitoring and controlling outbreaks such as Ebola, COVID-19, and cholera. Its capabilities align with the One Health approach by bridging gaps between sectors (data sharing among ministries and authorities in health, agriculture, and environment, essential for a cohesive One Health strategy), and has as such been directly applied on zoonotic disease surveillance and early warning (like rabies or bird flu), by integrating veterinary and human health data with environmental indicators like water quality or deforestation, also critical in understanding vector-borne disease dynamics and all highly relevant for CS1. More detailed description with the specific DHIS2 examples follows further below at the end of this section.

PERISCOPE COVID Atlas

The Atlas provides advanced visual analytics about several key aspects of the COVID-19 pandemic, with a focus on information regarding the pandemic progression, its impact on health, economics and society. It is developed over a database composed of data integrated from different external sources of health, socio-economic and socio-political data, including both data taken from public repositories (John Hopkins University, Google, Facebook, ECDC, OECD, CoronaNet project, various local sources) and data from institutions that supported the project, as well as from other parallel projects and initiatives (like 4CE[13]). The Atlas allows to visualise results of specific data analytics and models, and includes a WebGIS with multi-layer support for geographic data inspection. The tool is particularly useful for policy makers, researchers, health authorities and other stakeholders interested in understanding the impact of the pandemic [3].

[11] https://www.project-pulse.eu/results
[12] https://dhis2.org/one-health
[13] https://covidclinical.net

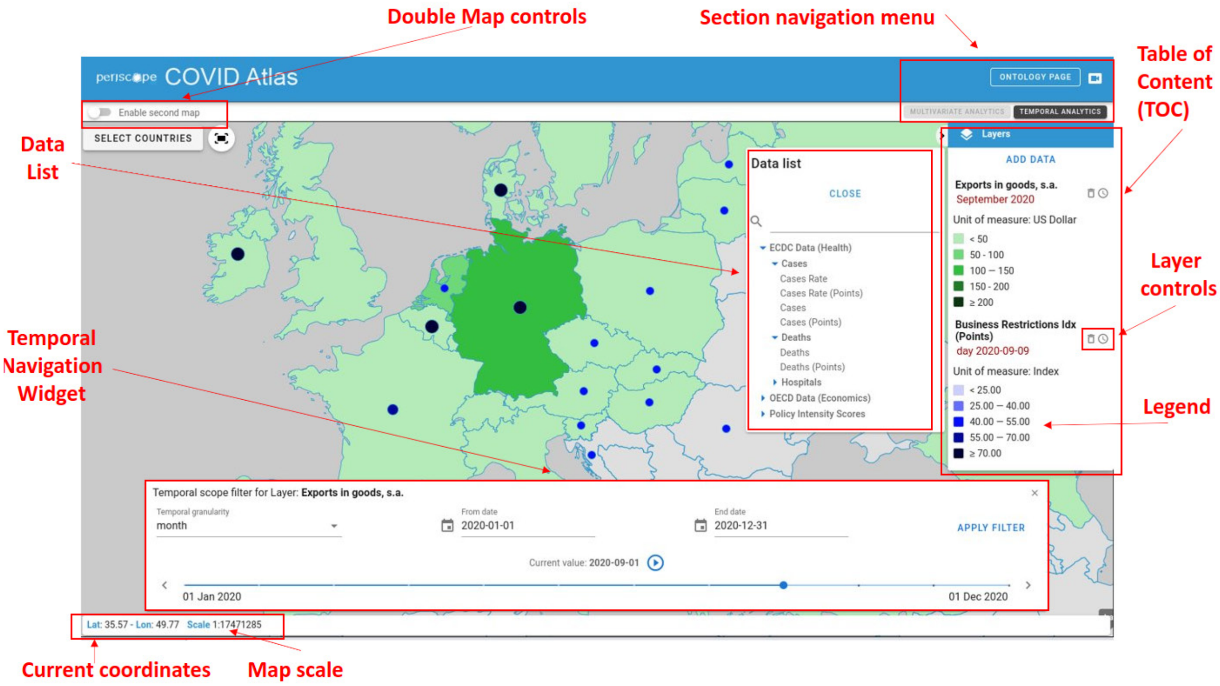


FIGURE 7: PERISCOPE COVID ATLAS - MAIN GEOMAP VIEW AND MASTER UI CONTROLS LAYOUT

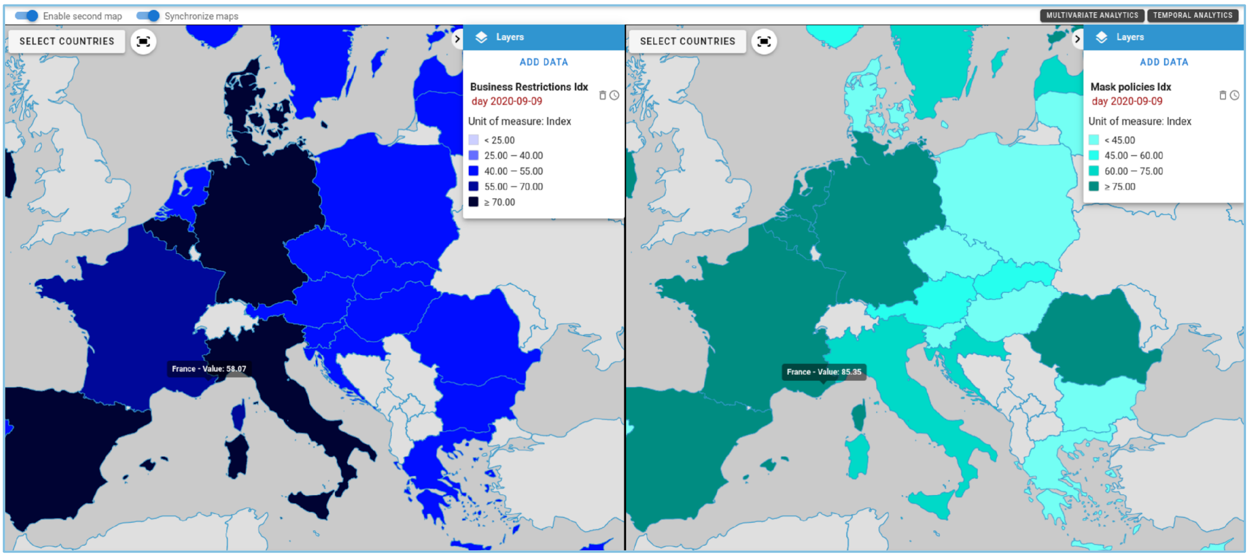


FIGURE 8: PERISCOPE COVID ATLAS - DOUBLE PARALLEL MAPS COMPARATIVE SYNCHRONISED VIEW

FIGURE 9: PERISCOPE COVID ATLAS - TEMPORAL ANALYTICS WITH REGRESSIVE PREDICTION PLOT

Temporal diagrams and analytic visualisations like on FIGURE 9 above, as well the composite combined and multivariate visualisations exemplified on FIGURE 10 and FIGURE 11 below, have been found relevant and applicable in particular on the CSs where the EWS is not the preferred tool option (CS3 and CS4, as will be explained in next Chapter), and generally where exploration or comparison of more than five data variables together in parallel over time, additionally stratified into data series or subcategories, or enriched with plotted potentially affecting events in time, is needed.

FIGURE 10: PERISCOPE COVID ATLAS - MULTIVARIATE ANALYTICS RADAR DIAGRAM WITH STACKED FILTERS AND TIMELINE CONTROLS

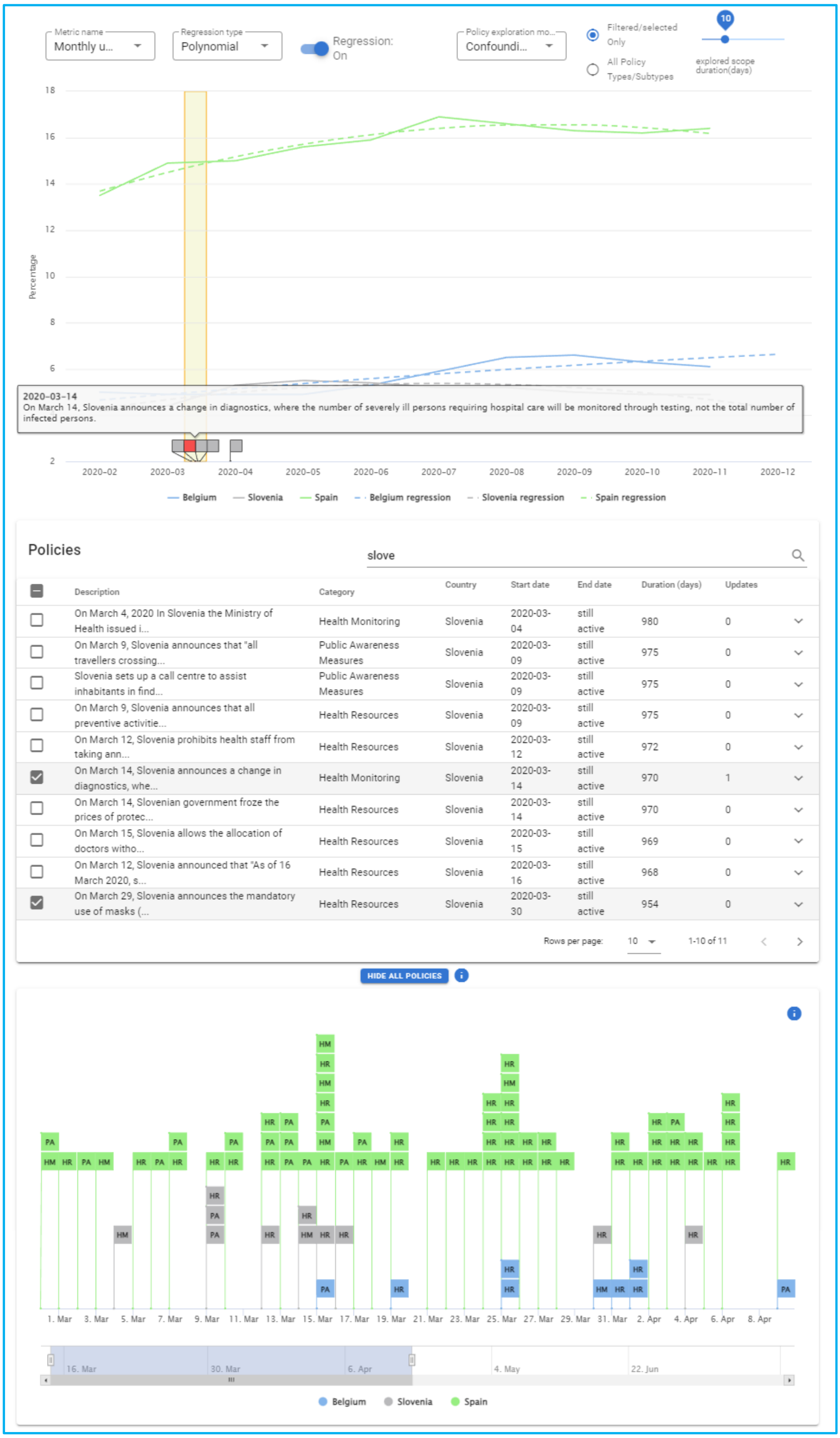


Figure 11: PERISCOPE COVID ATLAS - policy event flags plotted on the timeline

PULSE PHO Observatory Dashboards

These interactive analytics visualisations are also mainly composite and multi-faceted, combining heterogeneous data and visualisation types (health/preventive care, well-being, pollution and environmental, socio-demographic) with model-computed risks in the respective domains into a unified rich interactive data visualization and online analytics tool that delivers PULSE "health intelligence" to the end-user organisations and potentially other related authorities or policymakers (environmental, traffic, epidemiologic…) of cities and communities, following the holistic overarching HiAP approach (Figure 12). As this is a web application available only to registered users, not a publicly accessible tool, the interactivity and level of supported underlying data manipulation and control is more comprehensive, featuring not only business-intelligence-type workbench visual UI interactivity but also more powerful exploratory like Cohort Management (panel on the right of Figure 12) - support for defining, creating and comprehensively monitoring over time the arbitrary subset cohorts within the populations participating in the studies, all saved and with changes audited in the PULSE Data Store, potentially applicable for CS1, CS2 and CS4 in PLANET4HEALTH.

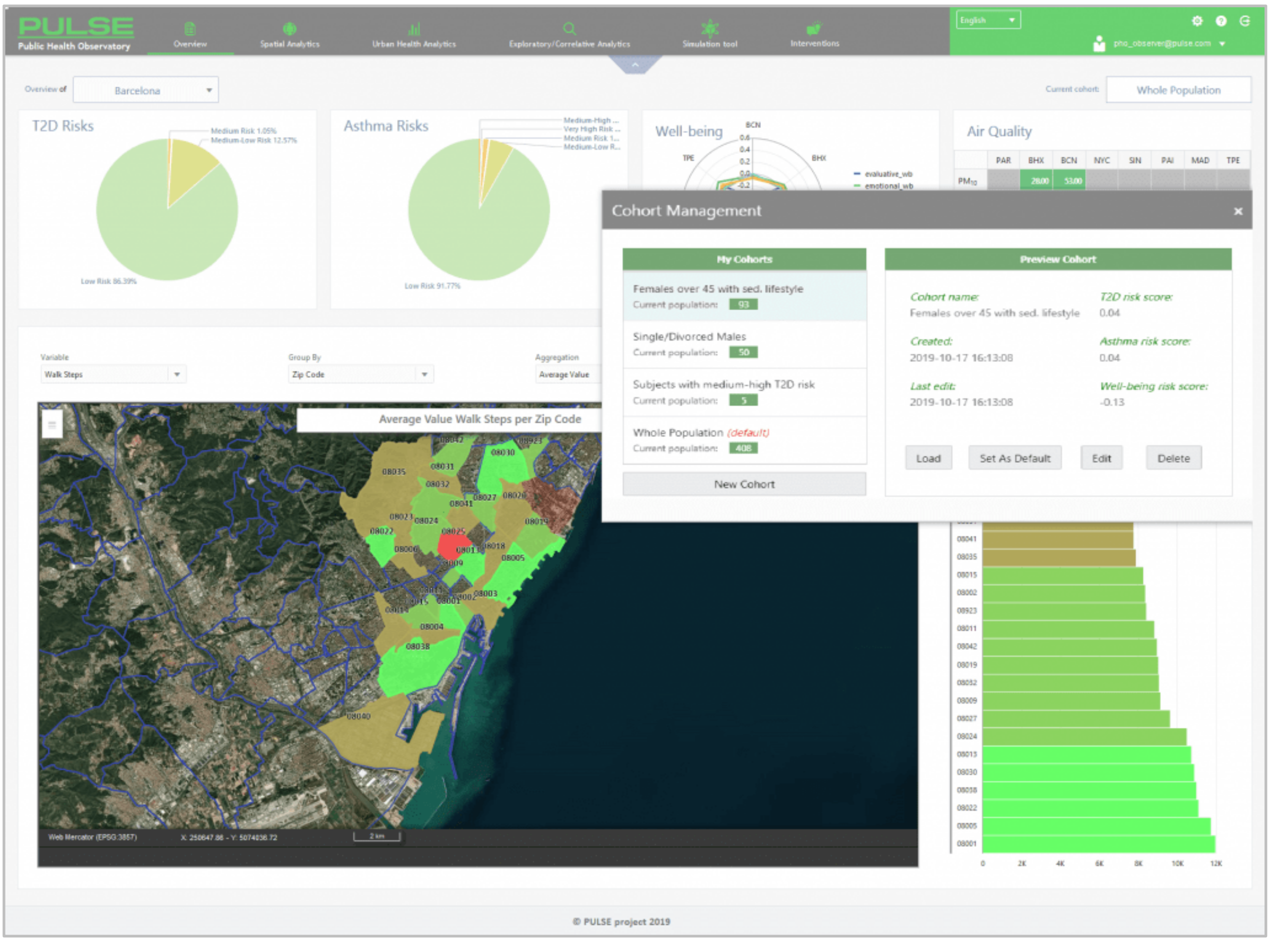


Figure 12: Main page of the PULSE PHO Observatory Dashboard, with the overlaid Cohort Management panel

The dedicated extensive air quality monitoring and analytics controls with multiple stacked time-series diagrams (FIGURE 13) below the coupled geomap view of the pollution distribution feature detailed parallel comparative and multi-series breakdown per pollutants, measurement stations/points and their types, level threshold and seasonal and event markers, predictive trends plotting, UI zooming and display toggling controls, on-hover contextual metadata view panes, and other rich UX features, have been found favourable and highly applicable for the CS2 EWS.

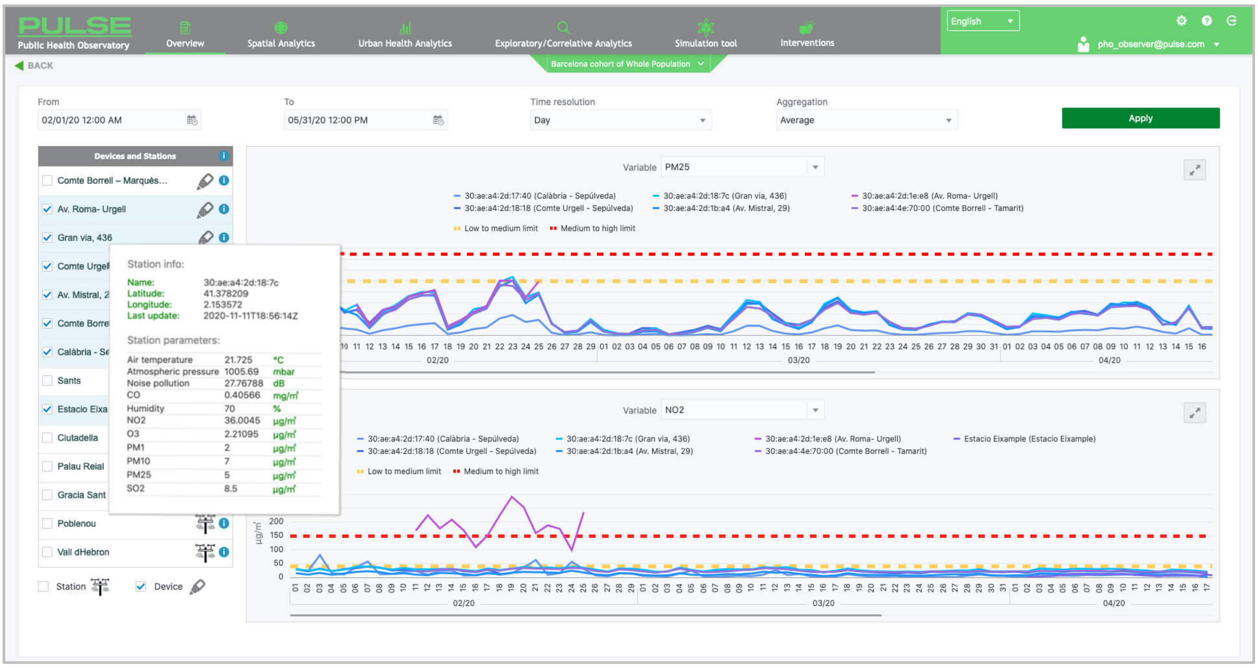


FIGURE 13: PULSE PHO OBSERVATORY DASHBOARD AIR QUALITY MONITORING AND ANALYTICS

The most interactive and flexible analytics feature of the Dashboards - *Exploratory Correlative Analytics* - supports visual exploratory correlation or crosstabulation and pivoting of selected two to 8 (imposed performance-concerned limit) explored variables or dimensions (chosen from the hierarchical model tree-view control), all stratified per up to three baseline socio-demographic factor variables (such as age ranges, gender, marital status, ethnicity or educational level).
The results are rendered on the interactive multivariate 3D columns diagram able to present the variations of both continuous and categorical variables (as grouped and stacked series of columns) over time or across stratification categories, and featuring interactive UI manipulations - 3D rotation, zooming, show/hide of granular elements - necessary for obtaining clarity and analytic focus on the key data features from such an apparently complex view and abundance of rendered data (FIGURE 14 below).

This composite view is complemented with the 2D grouped bar and matrix of computed correlation factors across the socio-demographic stratifications in the bottom section, with high correlations already visually suggesting potential connections or causality of the relevant explored variables with specific data subsets or categories, to be explored further using more precise and robust statistical or ML models and methods.

FIGURE 14: PHO OBSERVATORY EXPLORATORY CORRELATIVE ANALYTICS COMPOSITE 3D RESULTING VIEW

DHIS2 Dashboards and Tools

DHIS2 integrates geospatial tools to map disease outbreaks and environmental hazards, with interactive charting and pivot tables, all supported by the analytics toolset modules[14], as exemplified on the figures below.

The system is highly customizable for national, regional or local contexts, being adapted tailored to specific needs in almost 70 countries, including examples of direct applications on zoonotic diseases monitoring and early warning, like the DHIS2 national One Health pilot in Indonesia[15], or the initiative for the unified system on zoonoses in the livestock sector in Zanzibar [8].

14 https://www.youtube.com/@DHIS2org/videos
15 https://dhis2.org/indonesia-one-health

FIGURE 15: DHIS2 COMBINED TEMPORAL BAR & LINE INTERACTIVE DIAGRAM EXAMPLE

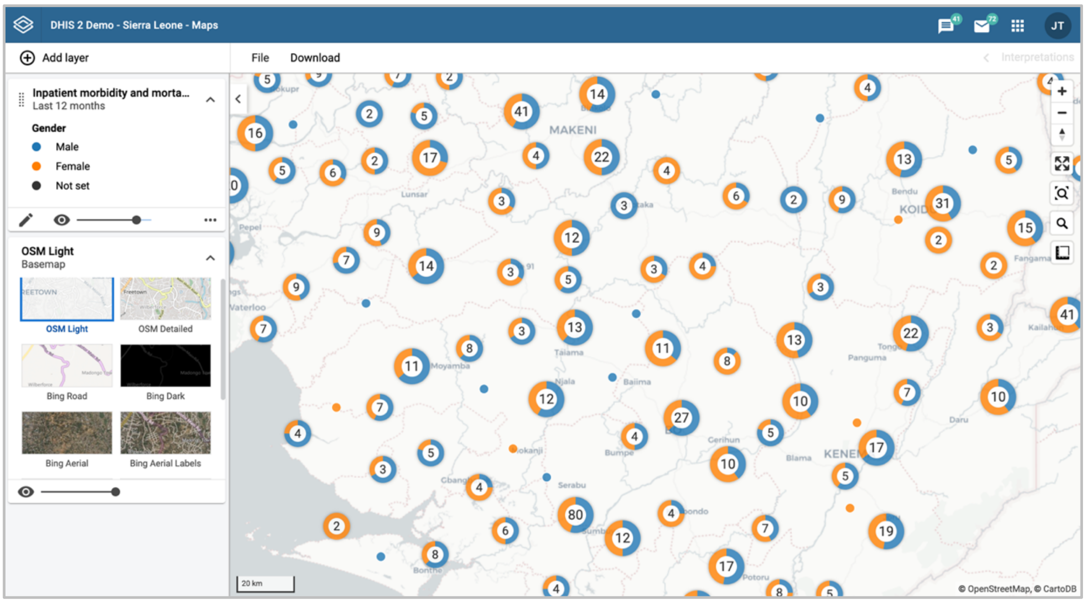


FIGURE 16: DHIS2 BUBBLED GEOMAP VISUALISATION EXAMPLE

The first version of the dedicated DHIS2 toolkit for Animal Health, developed in partnership with CDC and FAO and supporting the improved early warning and detection of zoonoses and other animal diseases, has recently been released this June[16], and a USAID-supported tailored implementation from other earlier adapted DHIS2 tools and modules (like individual patients tracking module, analytical tools, and Android applications for events handling) is in use in Burkina Faso in the last 5 years for 5 critical priority zoonoses (rabies, anthrax, brucellosis, highly-pathogenic avian flu (HPAI), and dengue), integrated with the national HMIS and the information systems of the three ministries [9] (FIGURE 18).

16 https://dhis2.org/health-data-toolkit/#animal-health

FIGURE 17: DHIS2 COMPOSITE DASHBOARD EXAMPLE

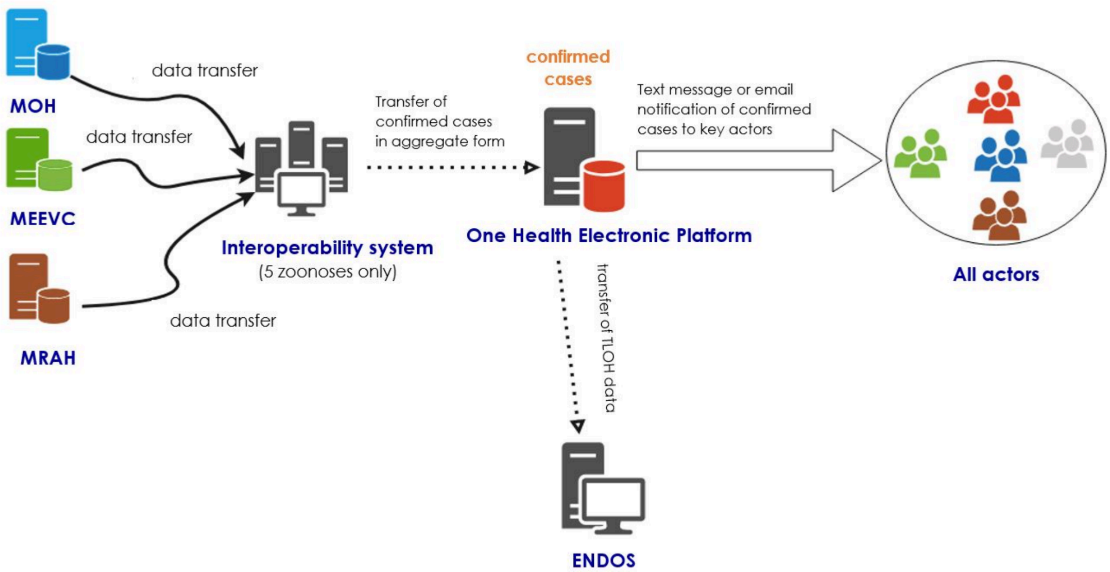


FIGURE 18: INTEGRATION, INTEROPERABILITY, AND MAIN DATA FLOWS OF THE DHIS2 ONE HEALTH ELECTRONIC PLATFORM SUPPORTING ZOONOSES SURVEILLANCE IN BURKINA FASO

DHIS2 is a comprehensive and extensively developed ecosystem of tools with the flexibility, cross-disciplinary indicators support and robust predictive modeling and trend analysis providing evidence-based insights for decision-making, preparedness and response strategies crucial for One Health EWS, highly relevant for CS1 with given referent examples in zoonotic and vector-borne diseases, but also applicable to CS2 and CS4. Consequent disadvantages in comparison to the online EWSs and other highly relevant tool examples described above, are:

- the complexity and significant customization needed for DHIS2 implementations (often with on-premises and private infrastructure hosting)
- less built-in real-time monitoring live input/ingestion data streams (like from satellites and other EO sources, sensing/measuring stations infrastructure...).

3.2.1 Advanced Analytical and Visualization Tools Supporting Effective EWS

The development of an EWS requires seamless integration of advanced analytical tools and powerful visualization platforms to process complex datasets, enabling insights to be effectively communicated to stakeholders and ensuring timely, informed decision-making. Leveraging state-of-the-art analytics—such as artificial intelligence (AI), geospatial tools, and epidemiological modeling—combined with dynamic visualization interfaces, EWS can address multifaceted challenges like vector-borne diseases, pollution, and environmental risks.

AI and Machine Learning (ML) models form the predictive backbone of EWS, analyzing historical and real-time data to forecast potential disease outbreaks and environmental hazards. These models excel at identifying transmission hotspots and anticipating trends with high accuracy. Long Short-Term Memory (LSTM) networks, for instance, capture long-term dependencies in sequential datasets, such as vector-borne disease patterns influenced by seasonal and climatic variations, enabling outbreak predictions weeks in advance. Graph Neural Networks (GNNs) extend these capabilities by modeling spatial relationships, such as disease spread across interconnected regions driven by human mobility or ecological factors. Complementary approaches like Recurrent Neural Networks (RNNs) and Ensemble Methods (e.g., Random Forests) provide robust and adaptable predictions for complex scenarios, enabling EWS to anticipate risks and inform stakeholders in real time.

To further enhance decision-making, probabilistic time-series forecasting incorporates uncertainty by representing predictions as probability distributions rather than single-point estimates. This facilitates interval prediction, offering confidence levels (e.g., 80% or 95%) for pollutant concentrations, disease incidence, or intervention impacts (Figure 19-Figure 21). Such insights, combined with advanced visualization platforms, allow stakeholders to assess a range of potential outcomes, prioritize interventions, and optimize resource allocation. Together, these AI-driven models, analytical tools, and visualization platforms transform raw data into actionable insights, enabling EWS to forecast trends, assess environmental risks, and mitigate public health threats with precision and foresight.

The system also excels in environmental risk mapping, identifying geographic areas that are more susceptible to One Health outcome of interest due to climate, environmental, and ecological factors. Using data such as temperature, rainfall, vegetation cover, and human activity, the EWS can pinpoint regions of heightened

risk. These maps, when layered with population density or healthcare access data, help prioritize intervention efforts in the most vulnerable areas.
These applications empower an EWS to move beyond static surveillance, enabling dynamic, proactive responses to public health threats. By providing real-time data analysis, predictive insights, and intuitive visualizations, the system ensures that decision-makers are equipped to mitigate the impact of vector-borne diseases effectively.

TABLE 2: LIST OF TEMPORAL MODELS WITH POTENTIAL APPLICATIONS IN EWSS

Name	Description	Potential Application
ARIMA	A statistical model for analysing and forecasting univariate time-series data.	Forecasting disease case counts, temperature patterns, and pollutant concentrations.
SARIMA (Seasonal ARIMA)	An extension of ARIMA that incorporates seasonal components for time-series data.	Long-term forecasting of seasonal disease trends, pollutant levels, and intervention impacts.
Transformers	A deep learning architecture for sequence modeling with long-range dependencies.	Predicting complex disease and environmental interactions.
LSTM	A neural network model capable of handling long-term dependencies in sequential data.	Predicting vector-borne disease trends and modeling environmental variable interactions.
Time Series Analysis	Decomposes time-series data into time-dependent-time-frequency components for localised analysis.	Identifying cross-correlations between climate, environmental, and pollution or disease data.
Species Distribution Modelling	Uses various (including ML) techniques to integrate environmental, climatic, and socio-economic datasets to allow for understanding of different drives of species distributions.	Understanding global distribution of species.
Other classical statistical approaches	Distributed nonlinear lag modelling and regression models.	Understanding correlations between climate and environmental variables and related one health outcomes.

Models for Latent Variables	Various latent variables approaches.	Understanding vulnerabilities and health self-perception in relation with climate change and environmental risk.

Dynamic Alerting Mechanisms: AI-driven EWS enhances real-time alerting by automating the detection of risk thresholds based on dynamic environmental and epidemiological data streams. This includes:

- Continuous monitoring of environmental conditions, such as temperature surges, that favor vector proliferation.
- Automated alerts tailored for specific stakeholders, such as public health departments or vector control teams.
- The inclusion of uncertainty quantification, providing stakeholders with confidence intervals for predictions.

Geospatial Visualization and Risk Mapping: Geospatial analysis strengthens the visualization capabilities of EWS by creating interactive maps to represent data in real time. These tools enable stakeholders to identify high-risk areas dynamically:

- Interactive Maps: Layers of vector density, pathogen prevalence, and environmental risks are visualized, providing a clear spatial understanding of outbreak dynamics.
- Real-Time Tracking: Continuous updates highlight changes in disease spread, vector activity, or pollutant levels.
- Integration with Socioeconomic Data: Additional overlays, such as population density or healthcare infrastructure, refine intervention planning.

Geospatial maps can, for example, pinpoint vector hotspots during peak breeding seasons, guiding targeted vector control efforts like insecticide spraying.

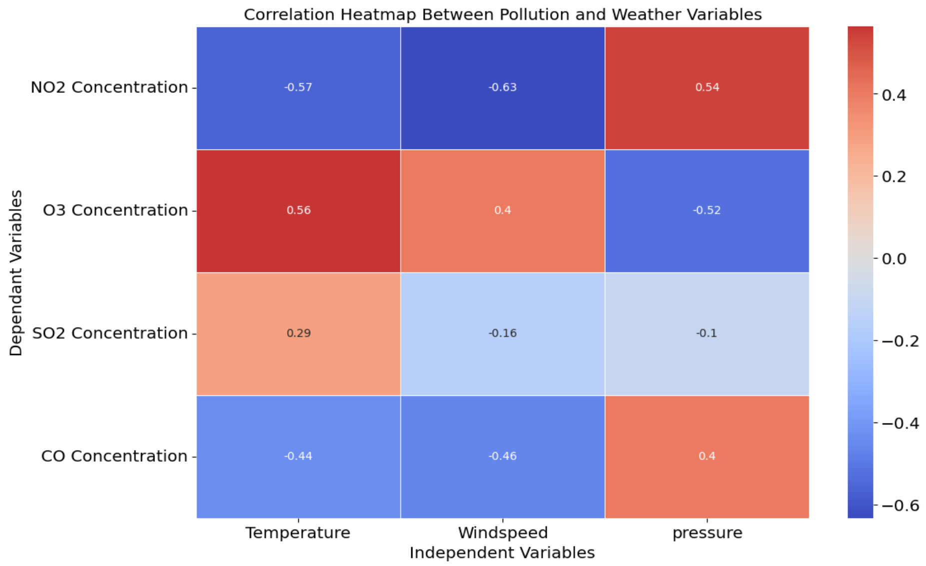


FIGURE 19: CORRELATION HEATMAP BETWEEN TARGET VARIABLES (POLLUTANT CONCENTRATION) AND OTHER DYNAMIC VARIABLES (WEATHER CONDITIONS)

Case Study Applications (TABLE 2): The integration of advanced analytics into EWS supports tailored applications for specific case studies:

- CS1: Spatiotemporal predictions of sand fly and canine leishmaniasis trends, guiding the allocation of vector control resources and preparedness for veterinarians.
- CS2: Analysing air pollution trends by mapping relationships between weather conditions and pollutants (FIGURE 19), such as how weather conditions (e.g., high temperatures and low wind speeds) relate to ozone and $PM_{2.5}$ level. These models also identify delayed impacts, like temperature inversions causing pollutant build-up, and forecast future scenarios. By integrating meteorological data with historical trends, the system enables timely public advisories and policy actions, ensuring targeted, data-driven interventions to mitigate health risks and improve air quality.
- CS3: Forecasting of certain groups of PFAS contamination enables targeted remediation efforts and the development of long-term environmental policies.

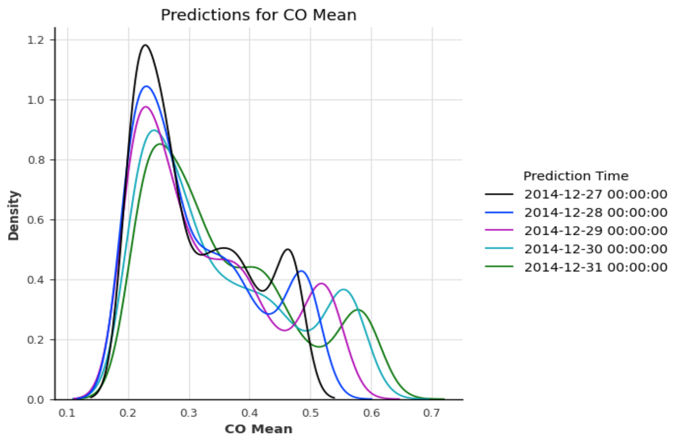


FIGURE 20: PROBABILITY DISTRIBUTION FUNCTIONS OF THE MEAN DAILY CO CONCENTRATION AS PREDICTED FOR DIFFERENT TIME STEPS IN THE FORECASTING HORIZON

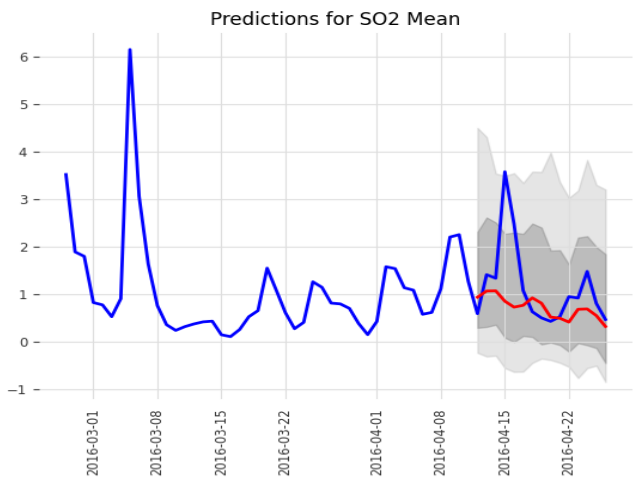


FIGURE 21: THE MEAN DAILY SO_2 CONCENTRATION (BLUE LINE) AND THE PREDICTED MEAN DAILY SO_2 CONCENTRATION (RED LINE) WITH THE 80% PREDICTION INTERVAL (DARK GRAY AREA) AND 95% PREDICTION INTERVAL (LIGHT GRAY AREA)

The EWS can simulate the potential impact of public health measures, such as vector control campaigns or vaccination drives, on disease transmission. By modeling different scenarios, the system provides policymakers with evidence-based recommendations for resource allocation and intervention planning. For example, it might suggest the most effective timing and locations for insecticide spraying or identify clusters where vaccination campaigns would have the greatest impact. Visualizing these scenarios ensures that stakeholders can easily understand and evaluate trade-offs between different strategies.

Visualization as a Decision-Making Catalyst is critical in ensuring that the outputs of these analytical tools are accessible and actionable. Custom dashboards equipped with geospatial overlays, time-series graphs, and interactive tools allow stakeholders to interact with data intuitively. For instance, a public health officer could use the system to identify a high-risk region based on predictive models, visualize vector density trends on an interactive map, and evaluate the projected impact of deploying additional vector control teams. These visual tools not only enhance situational awareness but also promote collaboration among diverse stakeholders by providing a shared understanding of risks and responses.

By integrating advanced analytics with visualization technologies, the EWS can empower stakeholders with a holistic view of vector-borne disease dynamics. This approach ensures that insights derived from AI, geospatial analysis, and epidemiological modeling are effectively communicated, driving timely and precise interventions. Such a system not only enhances the capacity to predict and respond to outbreaks but also builds long-term resilience against emerging public health threats. Visualization tools act as the bridge between complex data analytics and actionable public health decisions, ensuring the system’s relevance and utility across diverse scenarios.

4 Co-creation of the EWS and Digital Tools

The co-creation approach, also known as participatory design (PD), is the root foundation of user-driven innovation, involving end users in the development of new technology and framing it around the user and influencing stakeholder goals. Originating in the 1970s in Scandinavia, this approach has aimed to improve product outcomes by integrating the user's perspective into all phases of the development process. The co-creation process is based on a democratic vision that empowers users, challenging the traditional notion that system developers are the sole experts and users should be passive recipients, and overcoming the complexities of taking into account the unarticulated aspects of end-user's experience, often difficult for system developers to identify and address in the system design [4].

The co-creation methods extend beyond workplace systems [4] to diverse settings, such as urban [5] and rural environments, schools and training settings, as well as other fields comprising the four PLANET4HEALTH Case Studies. Understanding the specific contexts in which the technology will be used is crucial for ensuring its relevance and utility. The end users and stakeholders are involved early in the design phase as well as planned in the CSs evaluation, countering the risks of focusing on a narrow context due to limited participation, together with the other employed methods stated above as the pillars of the methodology under Chapter 2 (applications and tools landscape surveying, literature review, questionnaires, quick design mock-ups and prototypes).

The participatory design methods and techniques for involving the stakeholders in design and system development are continuously evolving [6], enabling increasingly efficient collaboration and effective contributions to the design of both the system developers and the stakeholders. Tools like interactive collaborative online board environments, combined with static and animated mock-ups, allow participants to visualize prototypes, test their functionality in real-world settings, and refine the design in more effective co-creation iterations, with continuous feedback and improvements towards meeting the real (often complex) needs of users.

We have therefore been utilising the FigJam interactive online collaborative whiteboard[17] already from the initial internal concept development and ideation among the Project partners participating in the task T2.1, which turned out additionally convenient for streamlining collaboration considering the significant number of contributors (namely, all PEUs and Project beneficiaries participate in T2.1). FigJam is a tool for visual interactive brainstorming, ideation, and team collaboration developed by Figma, currently the globally leading cloud platform for collaborative UI design and prototyping. It is a part of the broader Figma ecosystem to be used in the Project for the UI and UX design, workflow, prototypes and mock-ups, and optimally integrated with it, a significant advantage over alternatives still in more widespread use, like Miro board, along with more streamlined user experience and richer set of features in the free version (templates including huge community portfolios, generative-AI-supported JamBot assistant, and others).

[17] https://www.figma.com/figjam

A common available board template for user goals and needs definition has been used for all four case studies, extended with relevant panels for additional Constraints or Barriers, Datasets and existing Examples of interest, and complemented by the "onion" diagram with the systematisation and segmentation of stakeholders (described in more detail in the next section) also included on the board. Modelling and definition of user and actor archetypes has thus been performed in parallel with the identification and formulation of their goals and needs (formally second and third phase respectively in the GDD process flow shown on Figure 1 above). Additional conveniences of this are the possibility of connecting the specific user/stakeholder types or roles to the relevant goals or needs, as evident on the screenshots (Figure 23 and Figure 24), and having the users and stakeholders segmentation constantly in view of the developers and analysts as a reminder who should do and aim for what.

A slight drawback is that this unified single board for everything inevitably produced redundancies and duplicates across the different CSs - but it enables to have a general overview of the ideas and results for all the CSs and extract or group common features and elements where relevant, while still maintaining a composite template for each CS a standalone sub-board, possible to focus and work on each one separately. The mentioned common features and elements have by the end of the exercise mainly turned out to be the available datasets and existing examples of used methods, techniques and visualisation types potentially applicable to or useful for all four CSs, grouped in the central area of the board (Figure 22 below), as well as some of the Constraints.

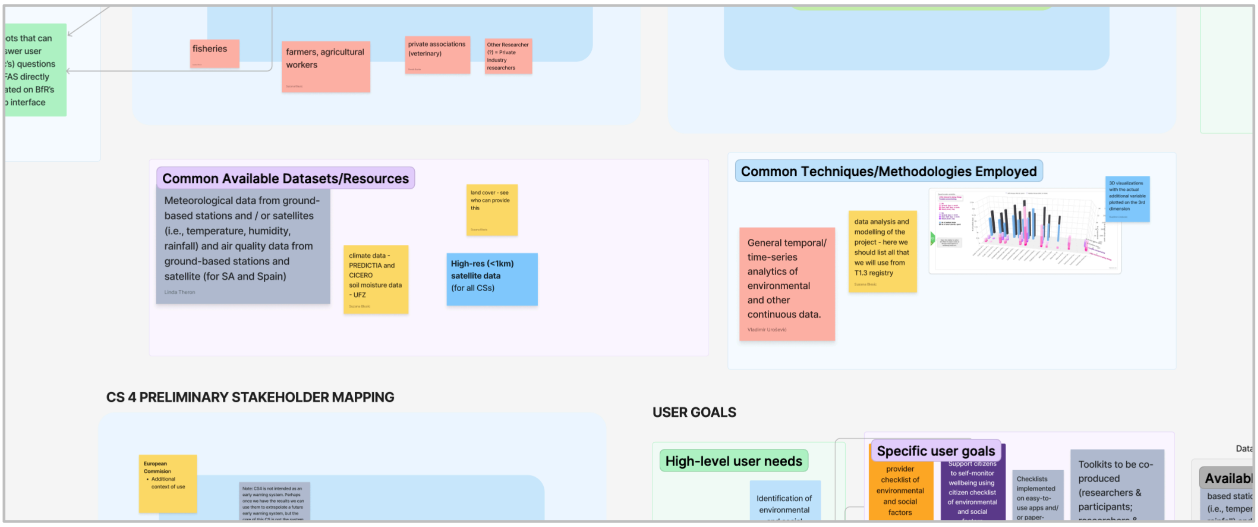


Figure 22: Grouped identified common resources and examples applicable for all four CSs on the board

The example systems, tools, and techniques and models of interest collected mostly as links and some screenshots on the board through this collaborative exercise (both in the common central panel and for separate CSs), have been explored and their functionalities analysed in more detail in the course of work, contributing to the results presented in Chapter 3 above. Key representative and characteristic example visualisations have also been included in the introductory presentations and on the collaborative interactive boards for the CS-specific consultation workshops involving also the external stakeholders, that followed in the final quarter of the Task (2.1) and are described in section 4.2 further below (as exemplified on Figure 31).

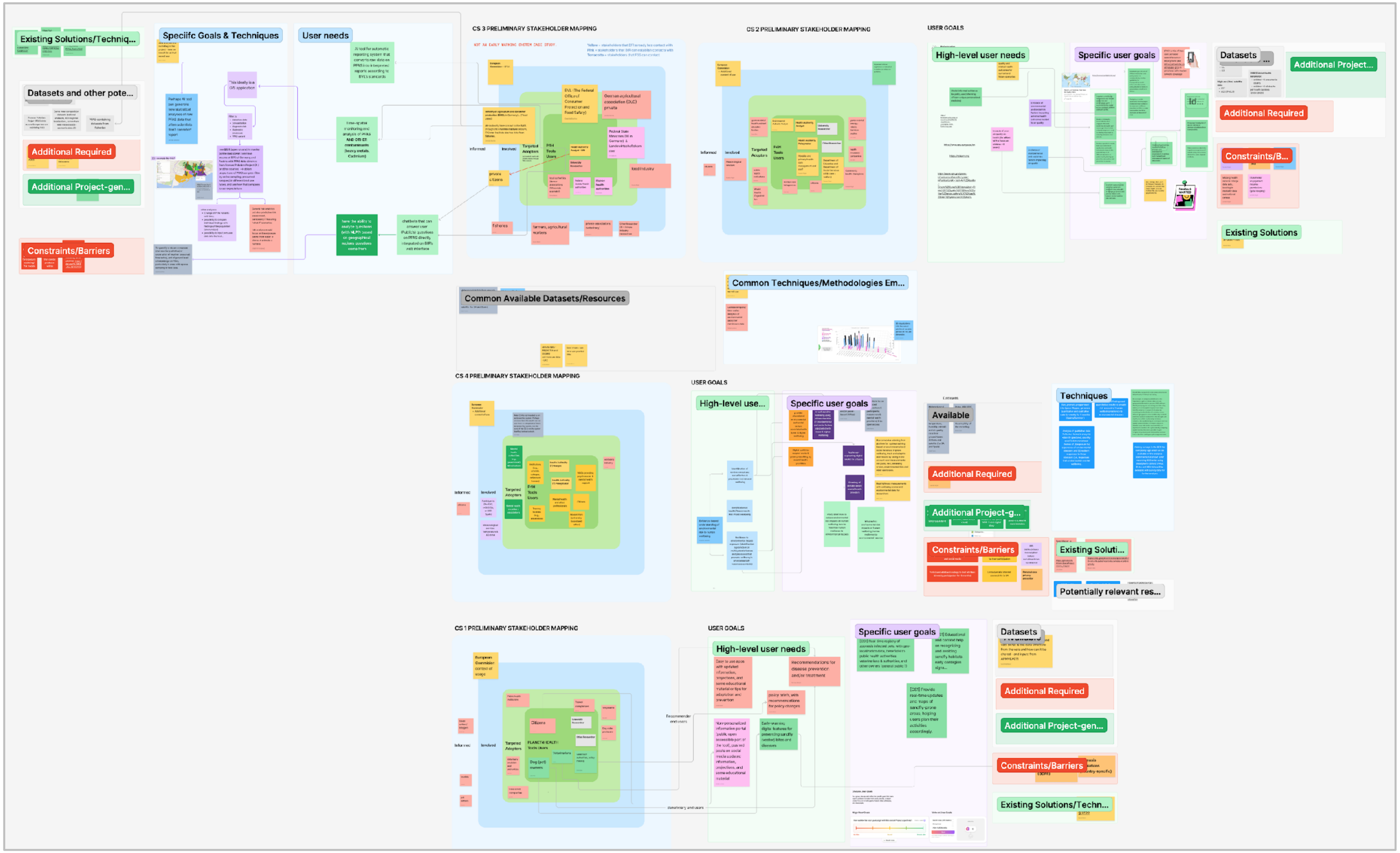


FIGURE 23: THE COMPLETE PROJECT-INTERNAL FIGJAM BOARD FOR THE COLLABORATIVE ELICITATION OF USER GOALS, NEEDS & REQUIREMENTS

Case Study 1 EWS

The main formulated high-level needs - **core early warning and monitoring features for prevention**, **public non-personalized informative/educational Portal**, and the **policy and preventive recommendations and briefs** - are in this case systematically connected to the relevant targeted user and adopter types on the left diagram (with distinctions per beneficiary and recommender roles in these relations), and highly relevant constraints/barriers and available example datasets and solutions are provided in context (FIGURE 24) at the leftmost panels.

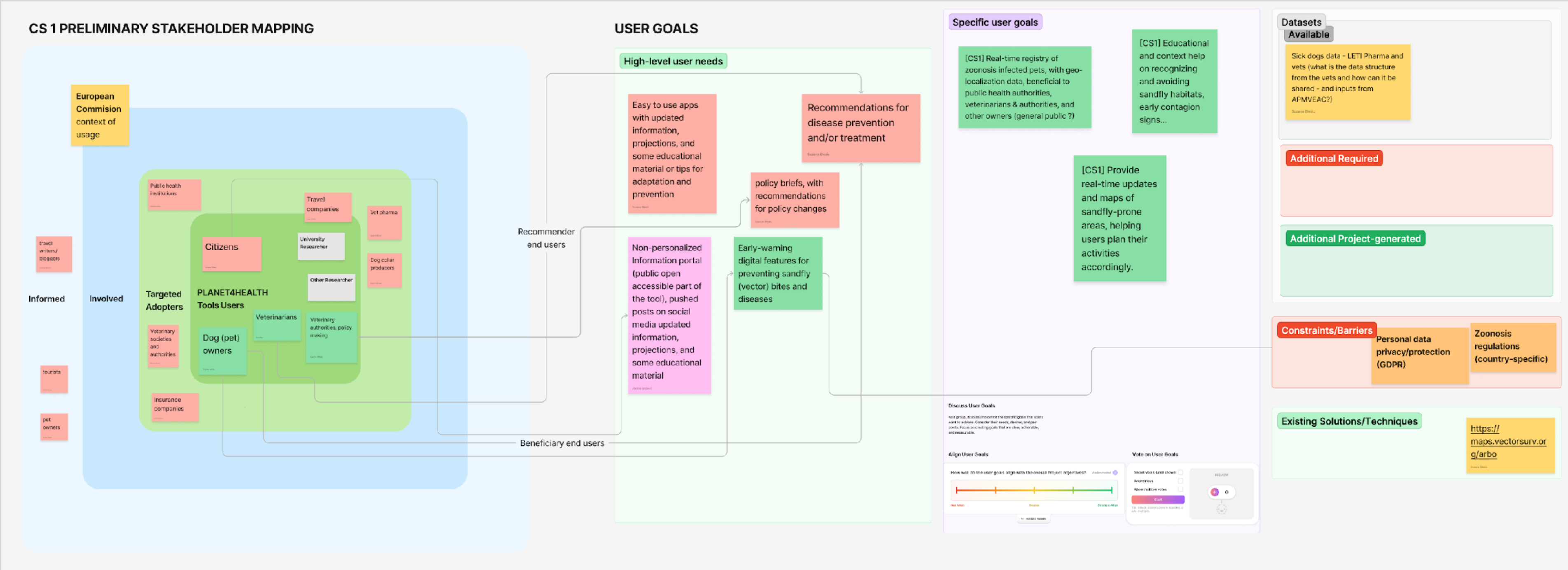


FIGURE 24: ZOOM-IN - THE BOARD WITH THE ONION DIAGRAM TEMPLATE FOR STAKEHOLDERS IDENTIFICATION AND SEGMENTATION (ON THE LEFT) AND THE EXTENDED USER NEEDS AND GOALS IDEATION TEMPLATE (ON THE RIGHT) FOR CS1

In the **Specific user goals** panel on the left, the ones derived or decomposed from the needs are practically almost actionable requirements, and have consequently been slightly refined and presented structured per the needs for confirmation and discussion on the later following CS1-dedicated co-creation and consultation workshop involving also the key external stakeholders, described in section 4.2.1 below (as has mostly been the case with the resulting needs and specific goals formulated on this complete unified internal Figjam board for the other CSs as well).

The pivotal identified and derived specific user goals and requirements for CS1:

- Registry/database containing the geo-localized zoonoses monitoring data (cases and related information),
- Interactive map (geographical, heatmap or other, or combined) visualisations of these data, supported by exploratory and analytics features, directly benefitting authorities, veterinarians, and possibly also pet owners, and
- Tips, notifications and warnings for recognising and avoiding sandfly-prone areas/habitats in planning activities or travel,

can all be directly implemented through features of a common spatially enabled EWS, or integrated with it, as can other identified needed features, like contextual educational info, summary recommendations, or help.

It has therefore been internally agreed that spatial EWS implementation is the preferred solution for CS1 (with the required generally user-friendly interface, and supporting visualised predictions and projections), left for the key external stakeholders to confirm on the following consultation workshop, along with expressing their preferences and discussing on eventual suitable implementations of additional or complementing needed features like evidence-based generation of policy briefs and influencing recommendations for reducing zoonotic risks, or non-personalized tips and prevention strategies.

Case Study 2 EWS

Main internally identified needs for CS2 have been focused on modelling, exploring and establishing evidence for impacts and interconnectedness of air quality, adverse health effects and the influencing environmental and social risk factors, understood as a prerequisite for the key goals of implementing prediction and alerting of critical air pollution events and effects.

These main high-level needs:

- **exploring and establishing evidence of air quality and its relations to health outcomes for current and future scenarios**, as well as
- **evidence of environmental and social risk factors impacting adverse health outcomes related to air quality (and impacting air quality itself)**, and

- **model-informed evidence for policy use (and generating briefs or recommendations)**,

have been developed into more granular specific needs aimed also towards improving monitoring, mitigation and compliance measures and interventions, and consequently resolving what is exactly required to achieve these goals.

The provided **Constraints/Barriers** and challenges to be overcome are quite comprehensive and insightful, spanning from regulatory, data privacy, protection and quality issues to real-life practical and technical onsite usability and user engagement or retention issues (like limited internet connectivity and access of mobile devices in South Africa).

The provided existing data and solution/visualisation examples are also ample and diverse, considering a lot of efforts and developments being globally and locally dedicated to the increasingly critical air quality monitoring and improvement nowadays, and all the available and prospective data envisioned to be utilised (including the health/medical datasets) are more or less accurately geolocalized, so the spatially enabled EWS is again the preferred solution type, as for CS1.

The provided results on the board (figure below) have been transformed to initial inputs for the additional key external stakeholders to discuss and confirm on the following CS2 co-creation and consultation workshop (section 4.2.2), expected to involve and complement with some more diverse and varied stakeholder perspectives from the mainly researcher and data scientist views and standpoints having contributed (though very elaborately, precisely and constructively) to this internal exercise.

The users and stakeholders systematisation and segmentation "onion" diagram has therefore, for CS2 only, been included also on the board of the workshop with external stakeholders, intended for them (the invited diverse range from various sectors - health, environmental and general public administration, agencies and NGOs) to categorise themselves and potentially contribute to identification of additional key stakeholder types or groups. The final resulting diagram with all provided contributions for CS2 is therefore provided and described on FIGURE 44 in the subsection 4.2.2.

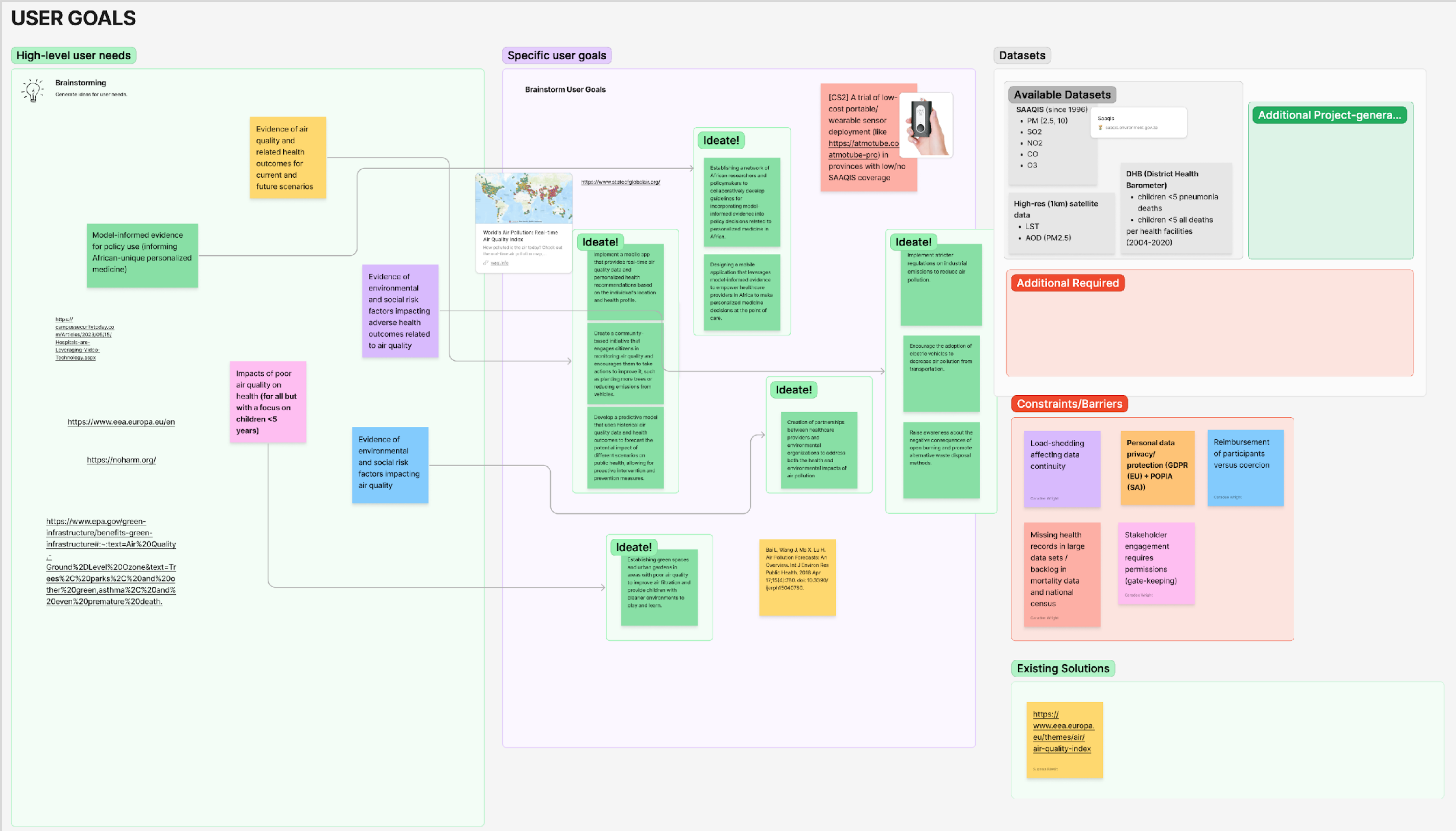


FIGURE 25: THE BOARD SECTION WITH THE USER NEEDS AND GOALS IDEATION TEMPLATE FOR CS2

Case Study 3 Tools

Before examining the PFAS monitoring datasets available in Germany and Austria and collaborating with external and all stakeholders of Case Study 3, the study coordinators from BfR and AGES were tasked with identifying the stakeholder and user archetypes and their goals and needs for the tools to be developed, ensuring they are relevant and effective for this case study.

One of the primary identified needs was the **spatio-temporal monitoring of PFAS groups and subgroups** and possible other relevant contaminants in Germany and Austria across various environmental matrices (e.g., water, soil, meat, fish, fruits, and vegetables), and a GIS-type spatial EWS has from the outset been identified as optimal solution for specific requirements to achieve such monitoring, as evident from the middle panels of the collaborative ideation board shown below (FIGURE 26).

However, high-quality, granular and geolocalized data are essential to develop the EWS and predictive models like this for PFAS in different regions, but it turned out it could not be consistently guaranteed that the main PFAS source data will be available, due predominantly to emerged considerations and administrative and societal policy restrictions imposed on the opening and/or sharing of relevant data and metadata. Given the overboarding media emphasis specifically on PFAS, detached from the generic "microplastics", the authorities and national ministries have formalised the need for restricting information granularity and flow available to the public in order to protect the local industries and prevent potential excessive or not fully grounded safety concerns or assumptions among the local populations. The available main body of data from Germany and Austria (including the historical time series) may be just very crudely geolocalized, on the level of originating country or region of Europe, and the temporal granularity, accuracy and consistency of the data has also been found generally low and/or sparse, often with only annual or semestral aggregations available. The "classic" geo-enabled EWS implementation, like for CS1 and CS2 and the representative examples provided in section 3.1 above, has consequently proven not feasible, and combined time-series with plotted event flags, or multivariate visualisations with timelines are considered more suitable for this monitoring need.

Considering the mentioned authorities and institutional preference for releasing highly controlled and mediated information on PFAS presence to the public and other interested parties, the development of an **AI-supported Early Reporting System** has emerged as a primary need in the subsequent direct consultations with the prospective and targeted key data mediating and controlling users. This tool would enable authorities like the Federal Office of Consumer Protection and Food Safety (BVL) to generate timely reports and communicate early warnings about food safety (and related) contaminations within German Federal States, Austria and across the European Union, as key specific requirements, and could be more widely applicable as an open-source AI tool for automatic report generation over scientifically validated data for other types of pollutants as well. It could also support the relevant following, or preferably even getting automatic updates, on the dynamic legislation updates changing the compositions of PFAS families/groups (specific compounds get banned or re-classified, different or new ones emerge or get regulated).

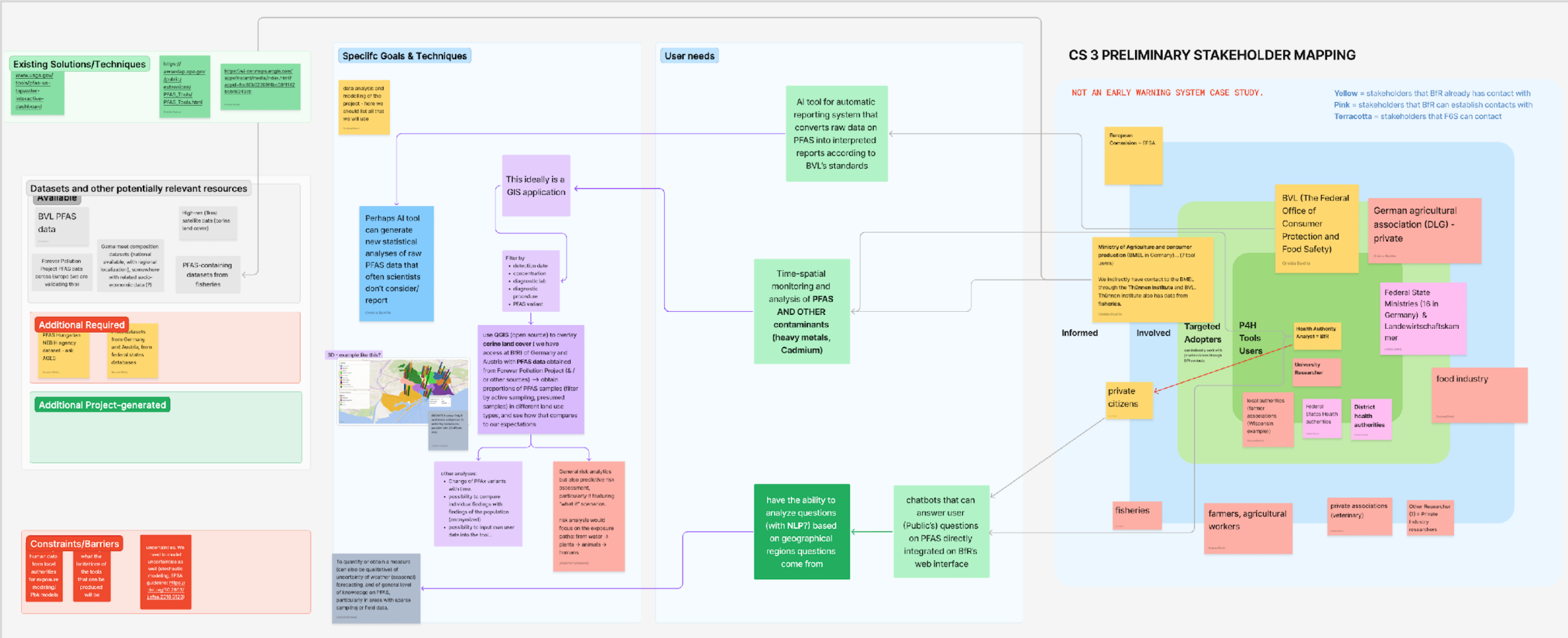


FIGURE 26: THE BOARD SECTION WITH USER NEEDS AND GOALS IDEATION TEMPLATE, AND THE STAKEHOLDERS SEGMENTATION CHART, FOR CS3

Case Study 4 Tools

FIGURE 27: THE BOARD SECTION WITH USER NEEDS AND GOALS IDEATION TEMPLATE FOR CS4

As evident from the high-level user needs and overarching goals formulated on the board on the FIGURE 27 above, partner's focus is more on evidence-based understanding of heterogeneous environmental risks to human wellbeing (identifying the influencing environmental and social factors, processes, and health/fitness results) and promoting and enhancing resilience to environmental hazard exposure, than on pervasive monitoring, situational analytics and early warning features.

After the initial consultations with project partners, particularly partners involved in CS4, it was obvious that the preferable target solution type for this CS may not be an EWS at all, but rather personalized tools (applications) supporting qualitative and subjective data collection and feedback, self-monitoring, and interventions towards improving well-being and resilience. The targeted potential tool outcomes for ***specific user goals*** are broken down per key stakeholders in the corresponding panel on the board:

- for mental health providers - checklists and toolkits to assess environmental/social factors and their relationship with wellbeing,
- for citizens - tools to self-monitor wellbeing and receive advice on improving it using data on environmental factors,
- for the research and healthcare providers - open-access, co-produced toolkits for data-driven interventions,
- and for policy and outreach in general the resources like the directory of climate-aware mental health providers to be endorsed, policy briefs on reducing environmental risk impacts, or interactive educative/guidance infographics or quizzes to communicate resilience strategies to the public.

The most relevant available datasets are the meteorological and air quality data as for CS1 and CS2. Additional required data are participant-reported wellbeing and resilience, measured via the **Space Mapper** application. Any available PFAS data from CS3 may also be considered. Given the personal nature of this data, high level ethics clearance is required (granted by now for the study work in South Africa from the Faculty of Health Sciences Ethics Committee, document ref. EDU092/24), emphasizing the need for secure data-sharing agreements and voluntary participation, itself a practical constraint concerning data privacy protection requirements, and potentially affecting participant recruitment and retention.

The above-mentioned data will be collected and generated using a mixed-method approach combining quantitative and qualitative data collection, including adapted standardised instruments like the WHO-5[18] and ARM-R[19] questionnaires, and a digital diary [11].

4.1 Systematisation and Segmentation of Stakeholders

The stakeholders composition, breakdown and characterisation per types/roles have been analysed with CS leading partners, PEUs and other consortium beneficiaries, using the visual "onion" diagram tool for analysis and segmentation based on their

[18] https://www.who.int/publications/m/item/WHO-UCN-MSD-MHE-2024.01
[19] https://resilienceresearch.org/home-cyrm

influence, involvement, and interests in the Project, separately for each CS, due to their specifics (Figure 28).

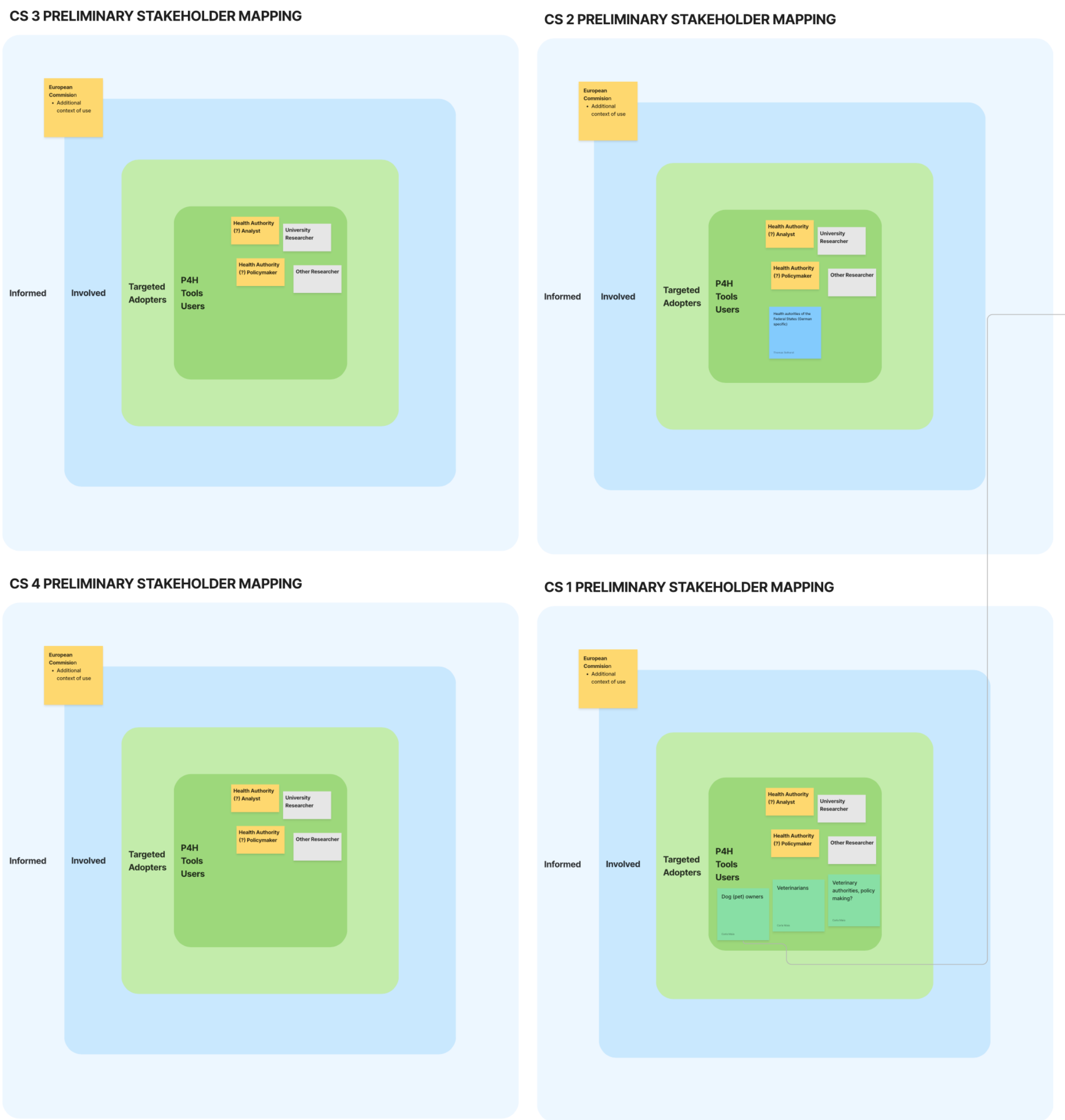


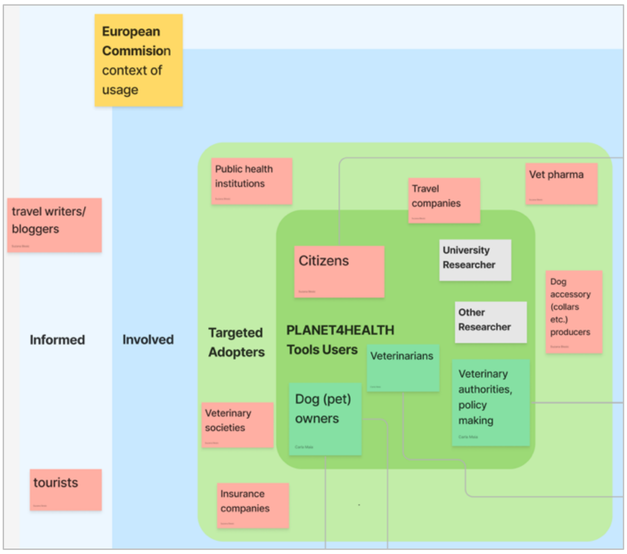
Figure 28: Initial FigJam board layout of onion diagram templates for stakeholders identification and segmentation for each CS

The diagram represents the stakeholder types or roles as layers of an onion, with the most critical and influential stakeholders at the center, and others placed in concentric bigger circles (in our case squares) around them. This resulted with a classification breakdown to:

- Core stakeholders of highest interest (green on the diagrams), comprising the definitely confirmed identified **end-users of the EWS and the tools**, and **directly targeted adopters**, on green inner squares on the diagrams.
- Secondary stakeholders, with notable **involvement/influence** or **informing** the development and features of the EWS and tools, on blue outer squares.

Brief summary of the stakeholders segmentation for each CS (except for CS2, which is in section 4.2.2) follows below.

Case Study 1 Stakeholders



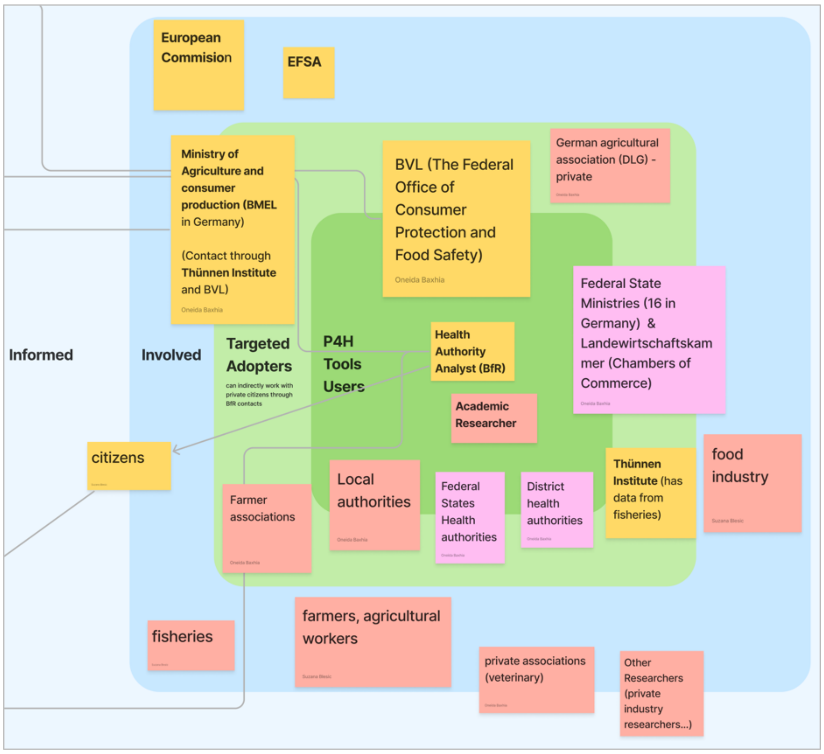
Main planned identified users of the EWS are to be the **citizens** (general public), particularly the **pet (predominantly dog) owners**, **veterinarians** and **veterinary authorities** engaged in policy making and execution, **researchers**, and specific concerned industry actors, like **travel companies/agencies**, with high interest in early warnings, minimisation of exposure to vector-borne disease risk and avoidance of sand-fly prone areas and habitats.

Targeted prospective adopters, with a direct role in using and benefiting from the tools, further include related industry actors involved in more elaborate and wider risks assessment, like **insurance companies**, or manufacturers/vendors of preventive or treatment products and solutions, like **veterinary pharma** or **pet/animal accessories industry**, as well as the authorities and organisations involved or in charge of preventive and mitigating health/safety policy measures and interventions, like **public health institutions/authorities** or **veterinary societies or associations**.

Involved stakeholders category will likely not be engaged nor benefit from direct usage of the EWS/tools, but can influence, even to a significant extent, their development and specification of the features and functionalities, like the **EC**.

Finally the informed stakeholders category is generally kept informed on the developments and their promotion, being recognised to have potential for becoming adopters or valuably contributing to the specification. In this case, as the general public/citizens are already a direct user, specific groups or sub-populations of general citizens, like **travel writers/bloggers** and **tourists**, are identified as primary target recipients of non-personalized information (general updates and awareness materials) that can potentially contribute with valuable content and feedback, in a *Recommender end-user* relation to specific identified content-authoring needs and features (as shown on the left of FIGURE 24).

Case Study 3 Stakeholders

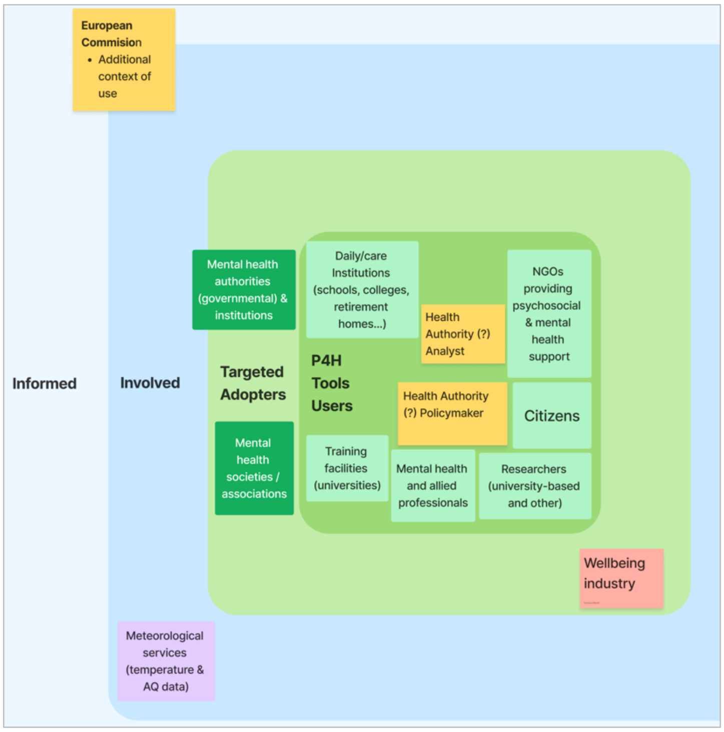


Main confirmed identified users and target adopters are **institutional, national authorities and agencies** like BVL, national, **local and federal state Ministries and health authorities** etc. (including BfR and AGES). Other notable suggested actors for tools adoption and involvement are the relevant **institutes, associations** and **research and experts or practitioners organisations specialised in soil, food, livestock, animal health or agriculture in general, and food industry**, as categorised on the diagram on the right. As mentioned above, tools usage and communication exposed towards the **citizens** is intended to be mediated to a high degree, mainly by these actors in the green central layers of core closely managed users.

Contacting and involving those actors in this specification definition and development process is ongoing, taking substantial time in formalities, and will consequently have to continue in parallel with the EWS & tools development task, and throughout the WP4 tasks dedicated to Project stakeholder network and ecosystem buildup (T4.2) and communication with the end users and data storytelling (T4.5). Just the several of presented institutional actors directly contacted and involved from the Project start have managed to attend the CS3 stakeholder co-creation and consultation workshop in Month 10.

Case Study 4 Stakeholders

Given that CS4 is rooted in empirical work that must be completed before stakeholder engagement can proceed,the identification of CS4 stakeholders is currently preliminary. While it will still be refined (particularly in overall health & well-being), but the potential key primary core user and adopter archetypes - **citizens, researchers, mental health and related professionals, NGOs** and other stated organisations - are clear and distinctive enough for their goals and needs identification and elaboration, performed as described above in the previous section.



4.2 Co-creation Workshops Involving External Stakeholders

Three such workshops have been held in months 10 and 11 of the Project, dedicated to CS1, CS2, and CS3 - each lasting 2-3 hours, most of which taken by the interactive co-creation exercise engaging all the participants, and particularly the invited external stakeholders, in the joint verification and further elaboration of the needs and requirements (initially internally identified by the Project partners as described above), utilizing the FigJam board again.

The board layout used for these workshops setup has been somewhat more focused and detailed (consequently keeping the contributors feedback "tighter" on track until the end), based on the extended **work breakdown structure template** in the central area of each board, decomposing the higher-level identified needs into specific requirements to be confirmed, updated or extended. Voting widgets and stamp emoticons have been used for expressing stakeholder preferences or verifying the provided options (Figure 29 and Figure 30). Thumbs-up and thumbs-down emoticon stamps are respectively for confirming or refuting that a specific need or requirement is relevant and should be supported, and a star denotes it as a perceived priority for implementation in the tool or EWS (FigJam stamp emoticons input control wheel shown on the right). The yellow click-voting activity widget as shown on the bottom of Figure 29, is tailored for closed-type questions, supporting single- or multiple-option selection by clicking on the round "**+**" (plus sign) button next to each

response option, and showing the live updated counts and voters for all options. Bright yellow panes are by convention also used for instruction cards in relevant positions before or next to each key section of the board, instructing and guiding the participants how to use the interactive UI controls and widgets to provide feedback, and what kind of feedback is generally expected in each section. Instructive walkthrough tutorial of main board functionalities required for interaction from FigJam has been included as a link[20] in the invitation letters for the workshops, so the participants could familiarise themselves with using and navigating around the tool beforehand.

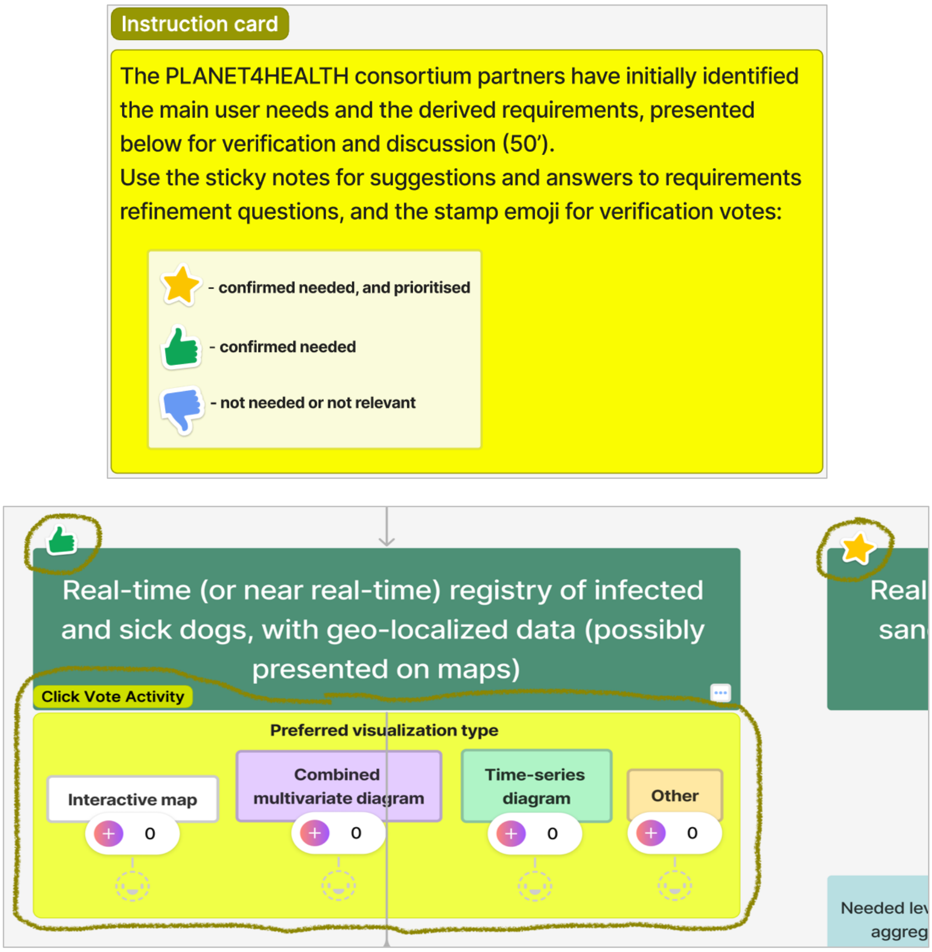


FIGURE 29: ZOOM-IN - VOTING WIDGET AND EMOTICONS ON THE BOARD, AND THE INSTRUCTION CARD ABOVE

Above this central and instrumental interactive feedback section is the starting introductory top section (FIGURE 31) with images and screenshots (including playable animations and videos) from example systems/tools, and of interactive visualisations relevant for each CS, as noted under Chapter 4 introduction above. This has enabled the participants to also directly upvote or connect specific favoured visualisation type examples to their sticky note responses and suggestions provided in the interaction sections below, and add specific preferences and remarks on these connections and images pertaining to UI mock-ups and front-end controls design, as done on the CS3 workshop and can be seen on the right side of FIGURE 45.

[20] https://help.figma.com/hc/en-us/articles/1500004362321-Guide-to-FigJam#h_01J2HDY679SE208R7ND3R7PY0Z

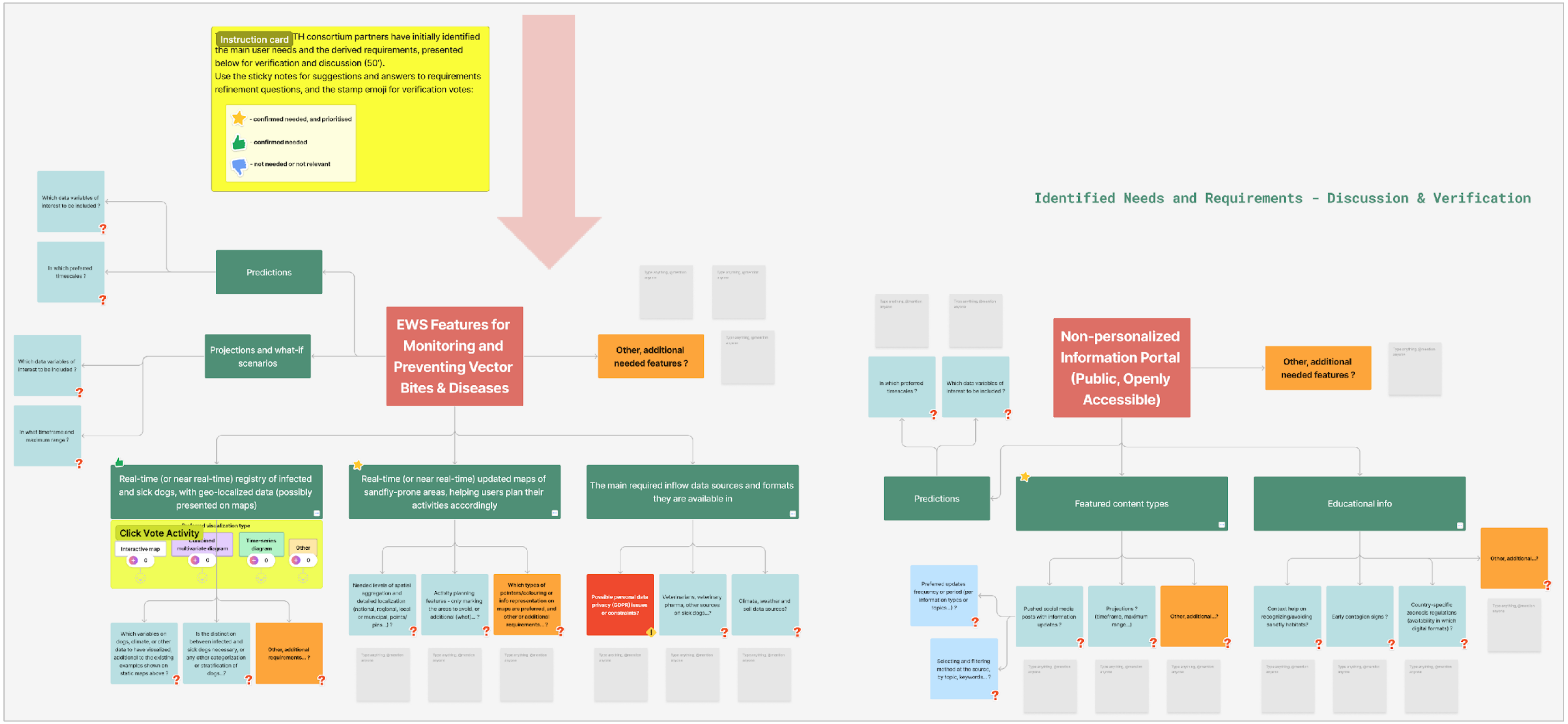


FIGURE 30: EMPTY CENTRAL WORK BREAKDOWN STRUCTURE TEMPLATES PREPARED READY FOR THE CS1 STAKEHOLDER CONSULTATION WORKSHOP

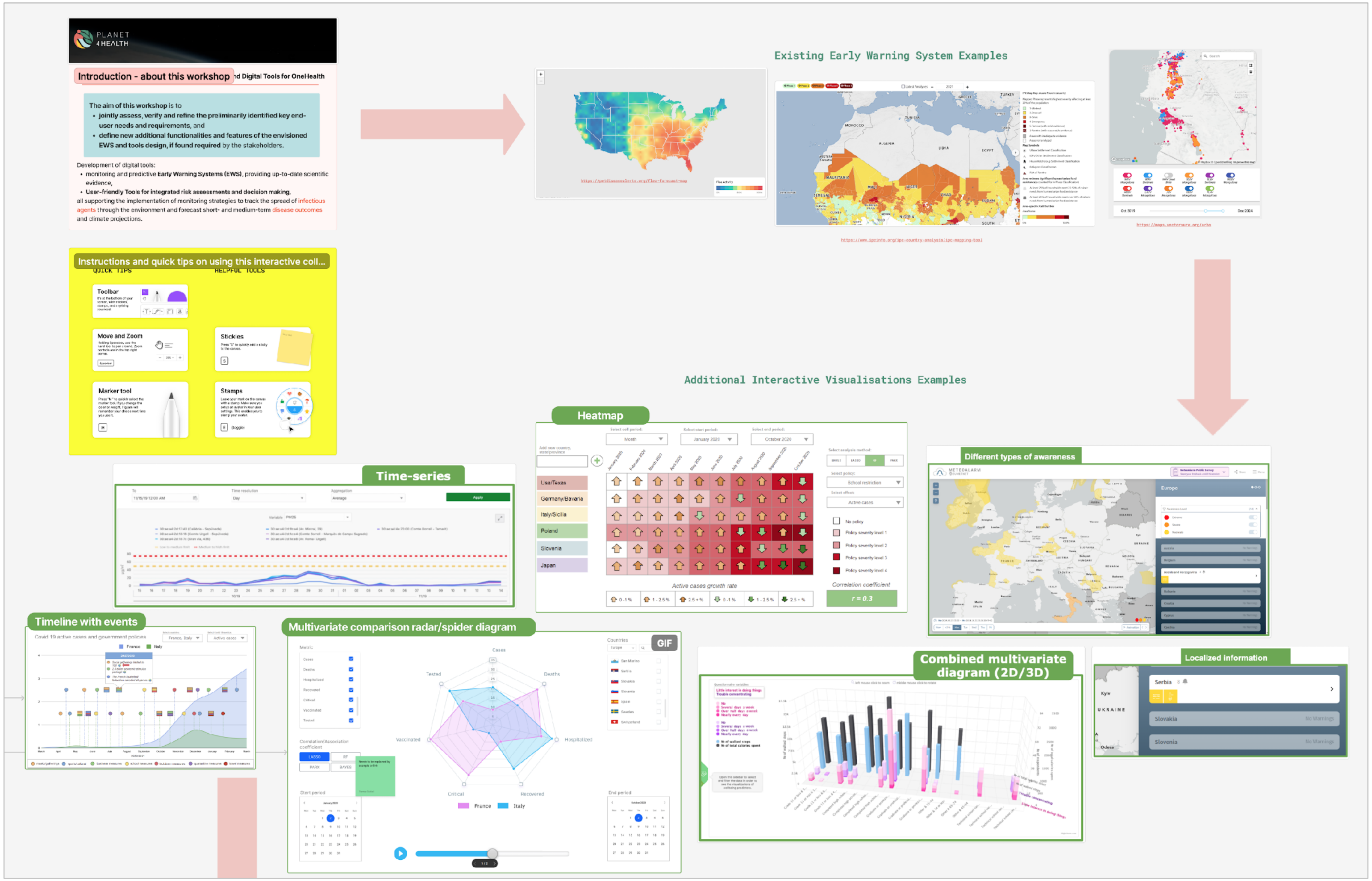
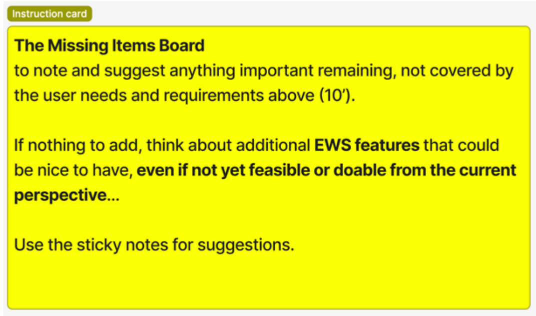


Figure 31: Introductory starting top section of the (CS3) workshop board with general instructions and relevant examples

FIGURE 32: CONCLUDING BOTTOM SECTION OF THE (CS2) WORKSHOP BOARD WITH THE FREEFORM INPUT OF MISSING ITEMS, IDEAS AND EVENTUAL ADDITIONAL KEY STAKEHOLDERS ON THE ONION DIAGRAM ON THE RIGHT

The concluding final bottom third of the board for each workshop contains the "**missing items**" template, left open for the participants to note anything remaining important that has eventually been omitted, or provide freeform suggestions, even looking into the future or their visions of currently not feasible but possibly desirable EWS/tool functionalities.



Detailed description of specifics and results of each of the three held workshops are presented in the following subsections.

These CS1, 2 and 3 initial workshops have generally been deemed successful, constructive and engaging exercises by most of the Project partners, and some valuable lessons were learned (mainly possible organisational improvements), relevant for the prospective remaining similar workshop to be dedicated to the CS4. They may also be repeated later for any or all of the CSs in other subsequent implementation, deployment and study validation and evaluation tasks, in a different more suitable form and layout focused on refinement and user acceptance assessment feedback rather than collaborative design and ideation.

Finally, as explained, the CS4 workshop was not held under the realization of this task, and will be held when the empirical work (scheduled for Year 2) has been completed and results are ready to be shared with relevant stakeholders.

4.2.1 CS1 Stakeholder Co-creation & Consultation Workshop

The generally preferred solution and development direction for the CS1 has been confirmed to be a fully-fledged geospatially enabled EWS (a primarily web or hybrid application), as initially identified and planned. The detailed functional breakdown of this main identified need into the specific required features related to the monitoring, data inflow and registries for the EWS, and the preferences and feedback of the workshop participants to the raised key issues and points needing to be resolved for their implementation on the interactive board, is presented on the Figure 37 below.

The same decomposition and obtained feedback for the EWS features that are to provide predictive and scenario projection/simulation functionalities, also confirmed high-priority needs by the stakeholders, is presented on Figure 34. As evident, the stakeholder preferences regarding the key variables to be presented and the related crucial features and metadata necessary for the setup and development (prioritisation, prediction horizons, temporal granularities and frequencies, aggregations, etc.) have been comprehensively and clearly expressed and captured.

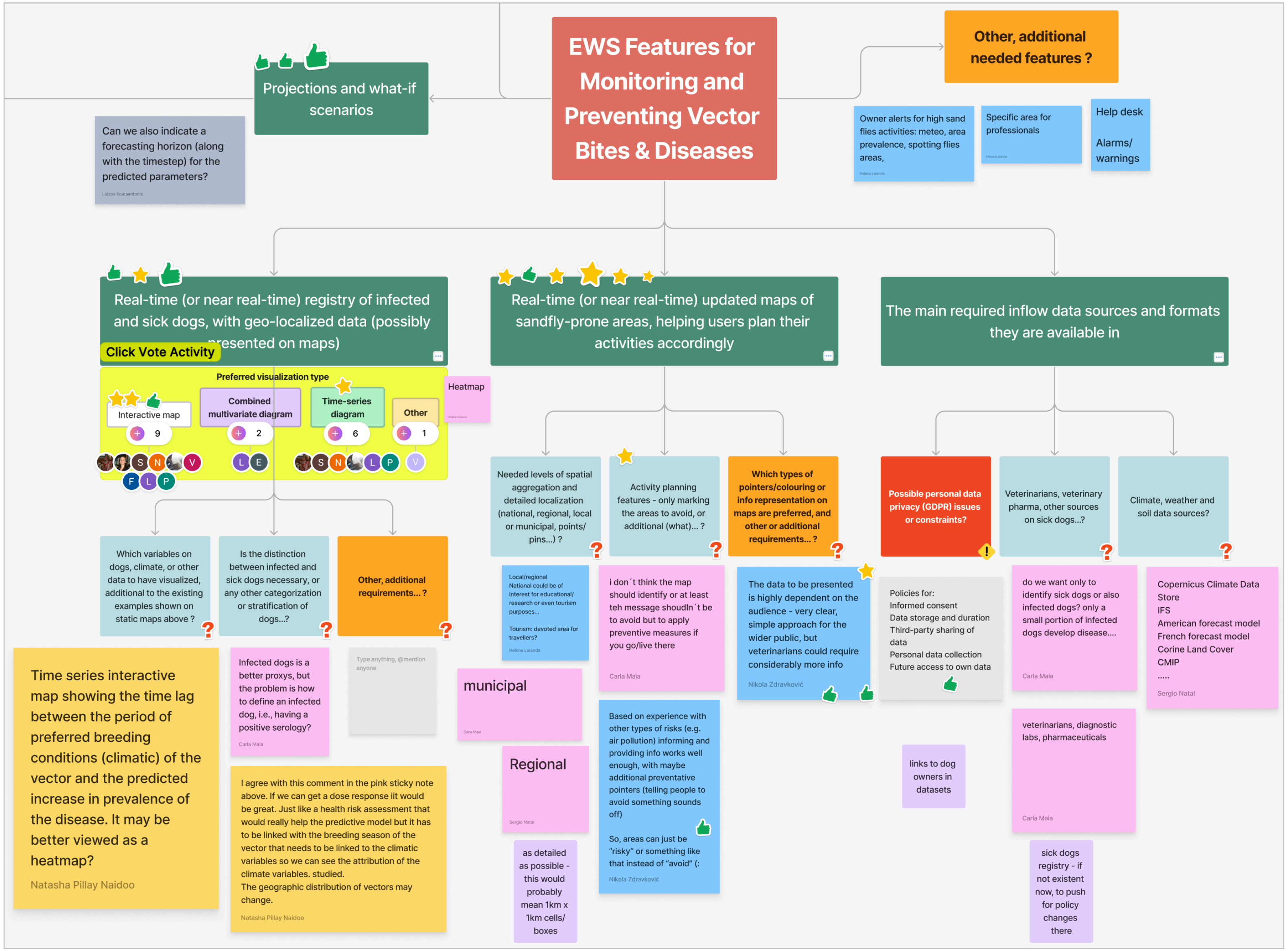


FIGURE 33: FUNCTIONAL DECOMPOSITION OF THE MAIN IDENTIFIED GROUP OF NEEDED EWS-RELATED FEATURES AND THE PARTICIPANTS PREFERENCES AND FEEDBACK

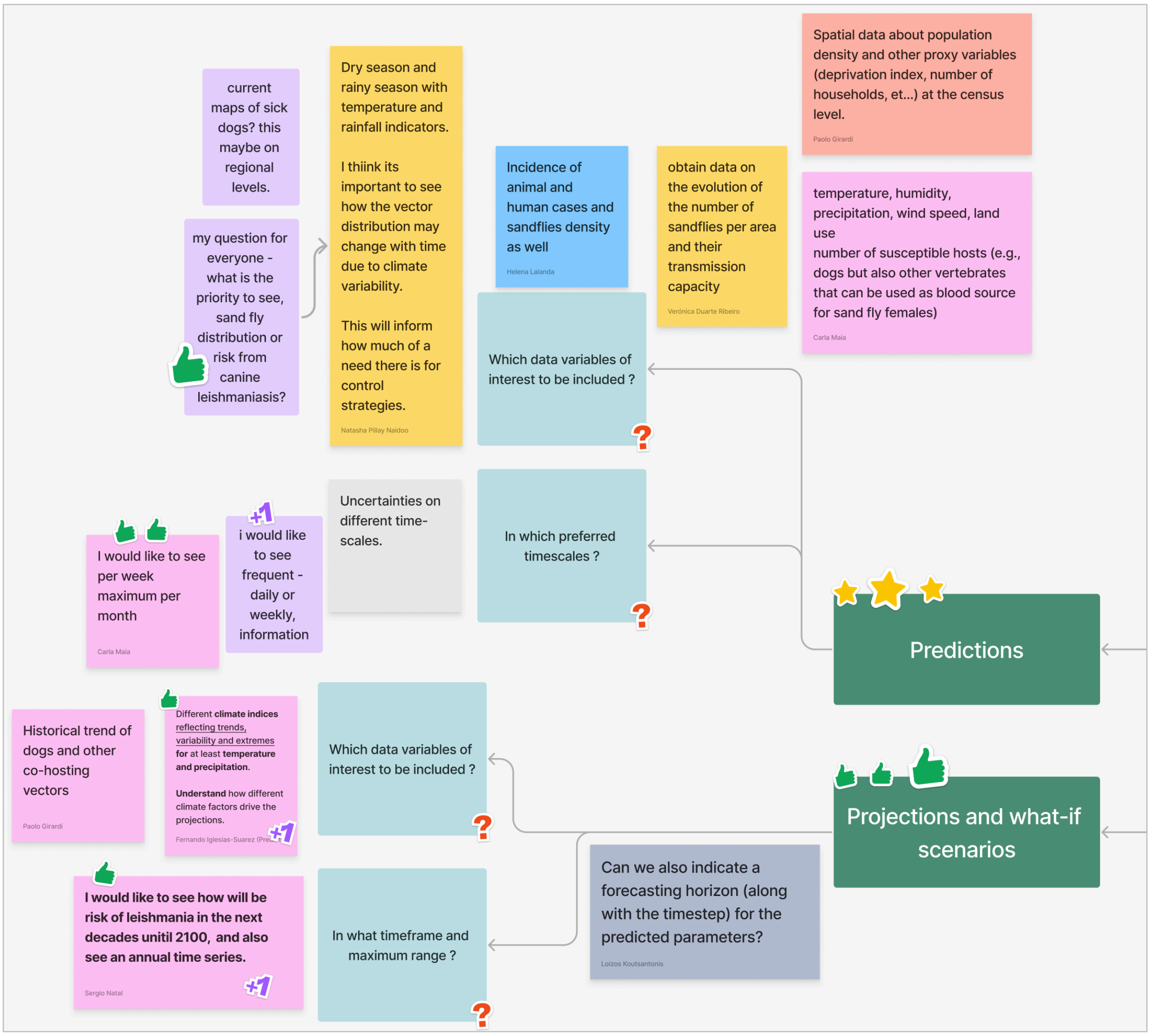


Figure 34: Functional decomposition of the needed EWS features related to predictions and projections, with the participants preferences and feedback

Functional decomposition and the participants preferences and feedback for the second-highest desirable group of needed features as identified and confirmed by the stakeholders - the open non-personalised information portal - is provided on Figure 35 below, with clear and actionable feedback provided mainly on featured content types and educational information and content to be presented. As the most favoured and prioritized features marked on the board:

- contextual help information for recognition and risk assessment,
- social media post updates and their integration, and
- structured information and guidance excerpts from the country-specific zoonosis regulations,

can generally be implemented as quite granular, modular and independent, this indicates they may even be optimally implemented inetgrated into the main EWS for CS1 (its prospective completely public and openly accessible section), not requiring a dedicated portal, but this is yet to be decided resulting from the analysis of linkages, usability and capacity of the available educational and informative content being gathered and consolidated to bridge gaps in knowledge and accessibility.

Further suggestions for modular and loosely coupled implementation of focused granular contextual features or served content able to be integrated with, or invoked from, other existing platforms and tools already widely used by the stakeholders, have also been provided in the final "Missing items" section for freeform unguided inputs at the end of the workshop session - integration with commonly used weather apps/widgets, reporting to WHO/WOAH systems, and others documented on FIGURE 38 further below.

FIGURE 35: FUNCTIONAL DECOMPOSITION OF THE SECOND IDENTIFIED GROUP OF NEEDED FEATURES FOR THE OPEN NON-PERSONALISED INFORMATION PORTAL, AND THE PARTICIPANTS PREFERENCES AND FEEDBACK

Similarly, for the third main broad identified group of features - recommendations and tips for vector-borne diseases prevention and treatment - concrete, specific and granular examples and feedback have been provided on the relevant content to be incorporated (how to prevent the pets and domestic animals being bitten, how to stimulate their immune systems in case of contracting the disease, avoidance of sand fly breeding sites, etc.), and confirmed by the stakekolders that it could be generated and delivered, as shown on FIGURE 36. Personalisation and tailoring of the UI towards the specific user roles or population strata (like children) has been confirmed as desired, though the implementation of this will still be considered deeper on the system middle tier and content composition and control levels.

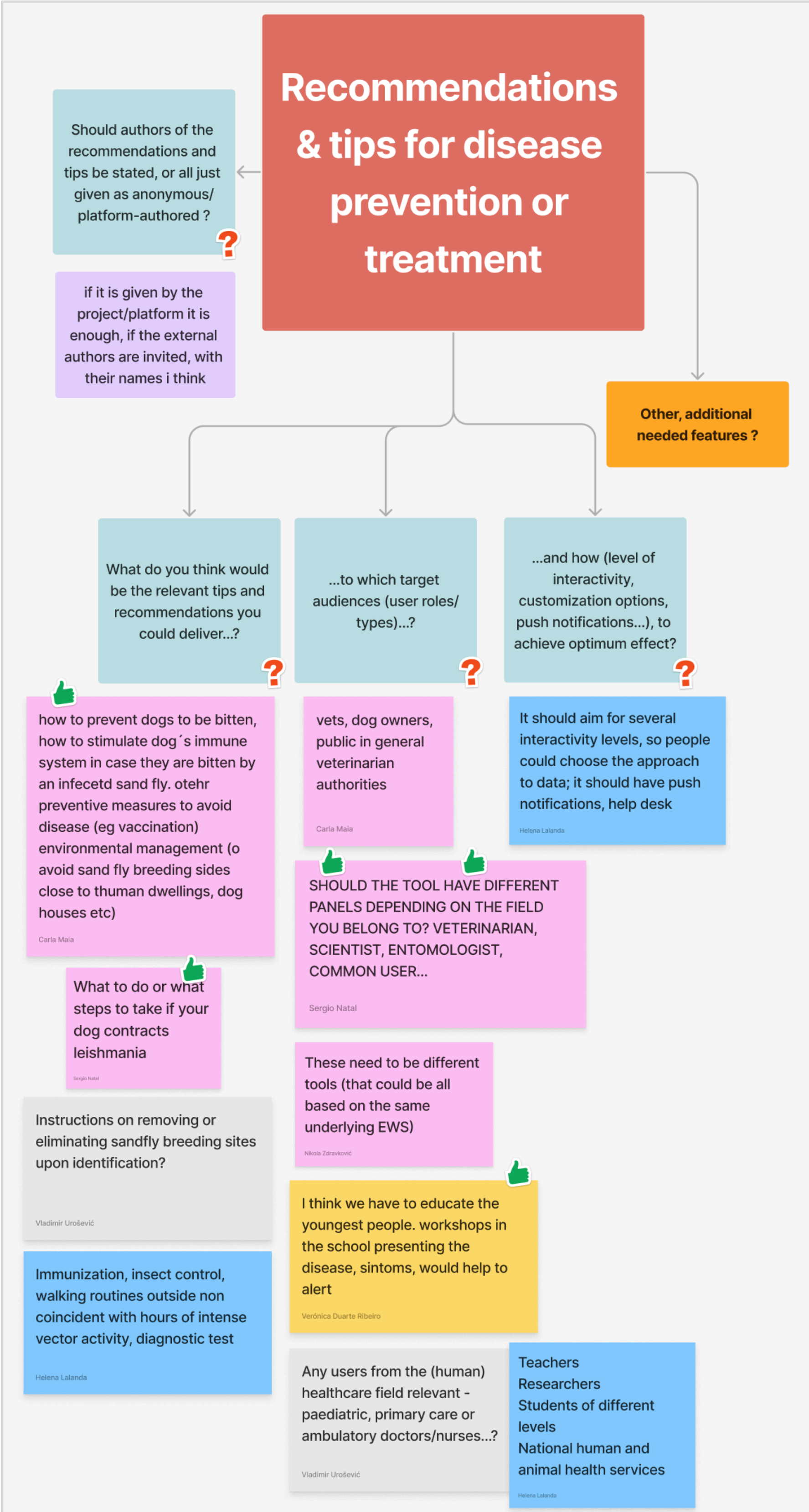


FIGURE 36: FUNCTIONAL DECOMPOSITION OF THE THIRD IDENTIFIED GROUP OF NEEDED FEATURES FOR THE PREVENTION AND TREATMENT RECOMMENDATIONS & TIPS, AND THE PARTICIPANTS PREFERENCES AND FEEDBACK

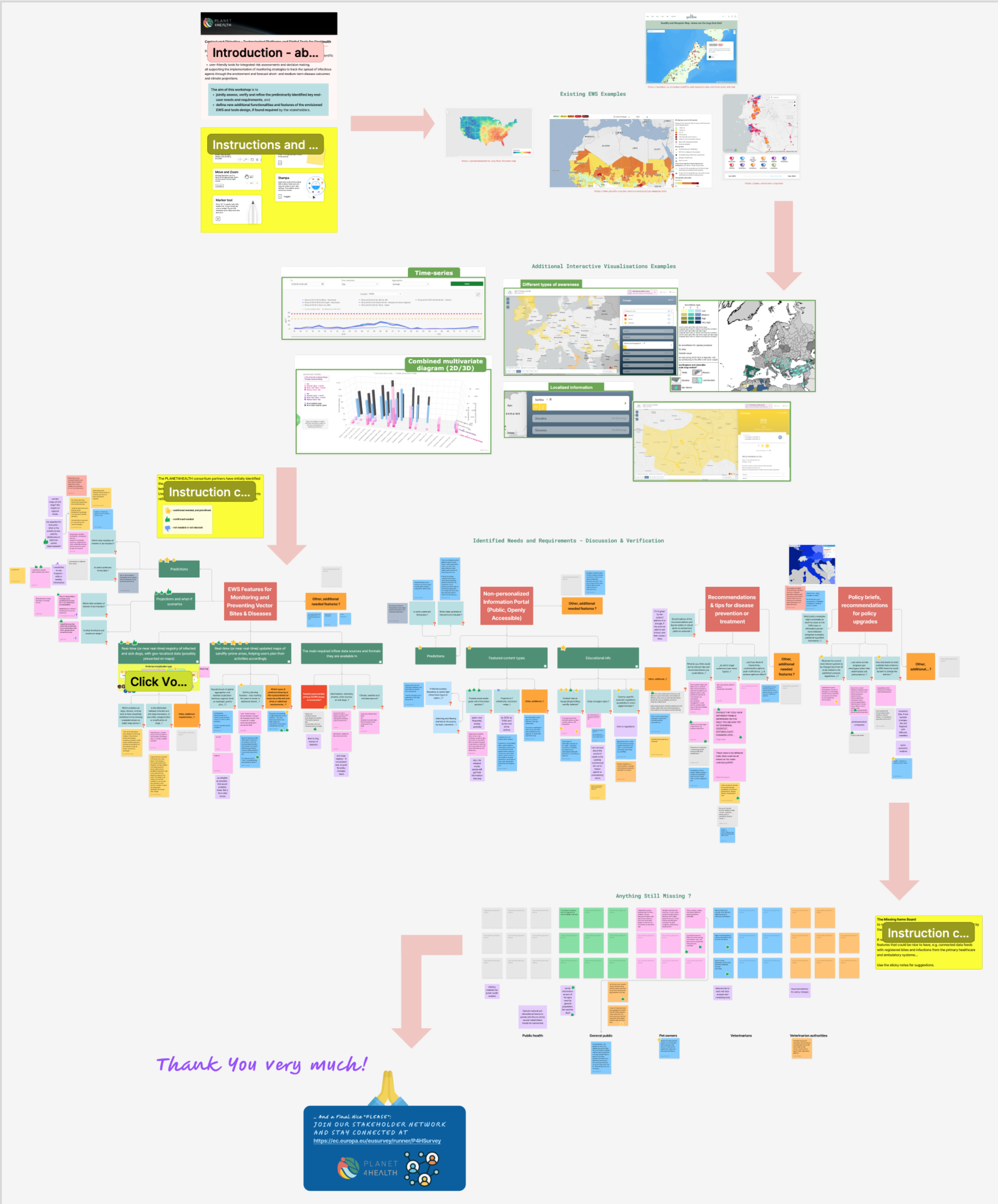


FIGURE 37: THE COMPLETED FILLED INTERACTIVE BOARD OF THE CS1 WORKSHOP

Figure 38: Grouped summary of the missing items board in the final bottom section

4.2.2 CS2 Stakeholder Co-creation & Consultation Workshop

The generally preferred solution and development direction for the CS2 has also been confirmed to be a fully-fledged geospatially enabled EWS, as initially identified and planned, and illustrated (with fairly extensive and detailed user feedback and preferences) on the Figure 40 further below with the main confirmed group of highest-interest functionalities decomposed in detail into specific questions and the corresponding feedback defining the individual features to be supported, and needs, inputs and constraints related to them. Following the presentation flow as for the CS1 workshop results in the previous subsection, the next Figure 41 focuses on the decomposition and obtained feedback for the extracted EWS features that are to provide predictive and scenario projection/simulation functionalities, and then the following figures, ending with Figure 44, subsequently the remaining identified broad groups of key functionalities for the EWS supporting the CS2 and general exploration and mitigation of air quality and the affected adverse health outcomes.

Some panels or notes on the stated figures below have been blacked out as they can reveal specific solution techniques/methods or technology details potentially employed in the development and implementation that are confidential or constitute protected intellectual property of the consortium partners, not to be disclosed to the public (in a deliverable on a "public" dissemination level such as this report).

FIGURE 39: THE COMPLETED FILLED INTERACTIVE BOARD OF THE CS2 WORKSHOP

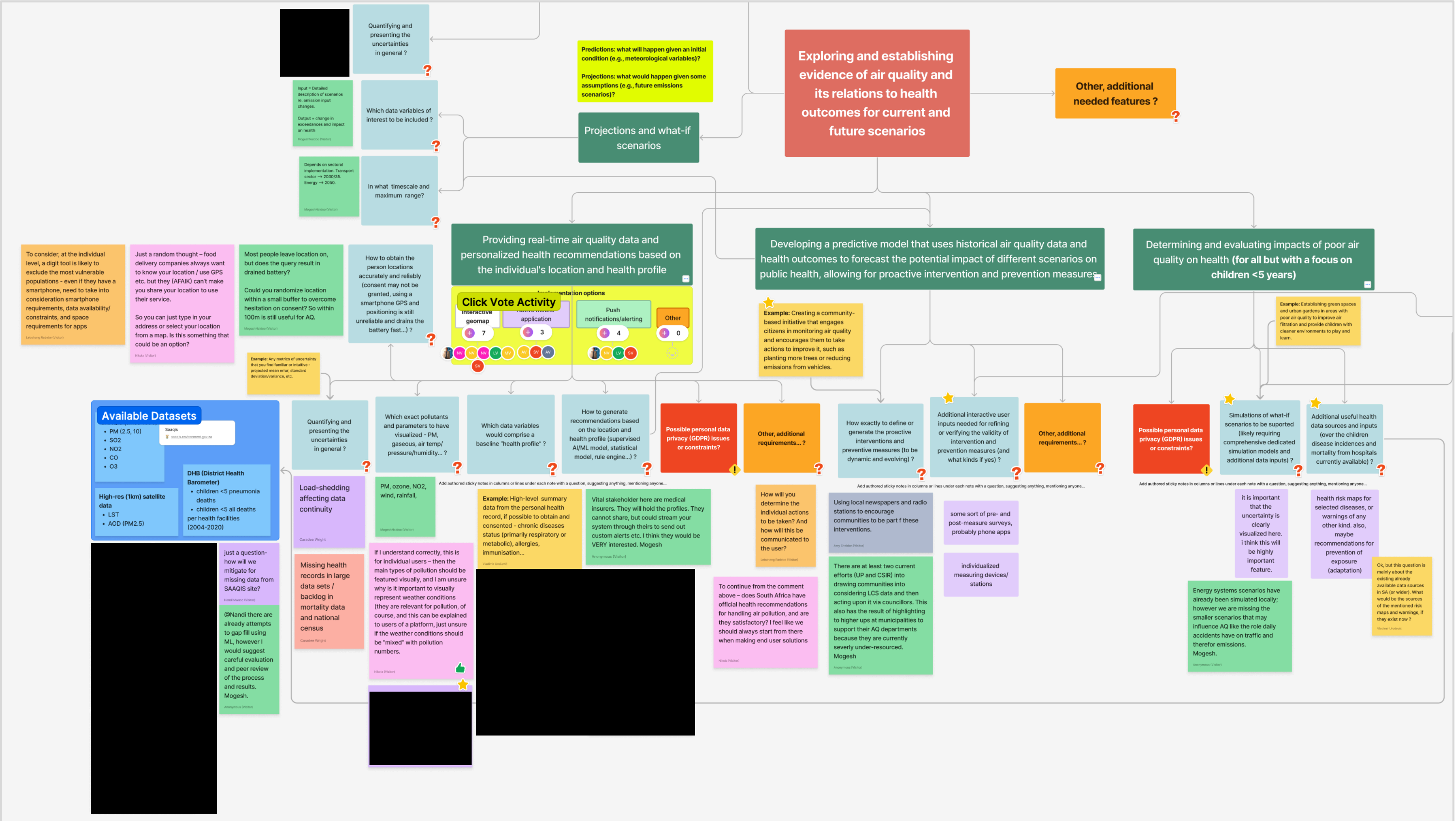


Figure 40: Functional decomposition of the main identified group of needed EWS-related features and the participants preferences and feedback

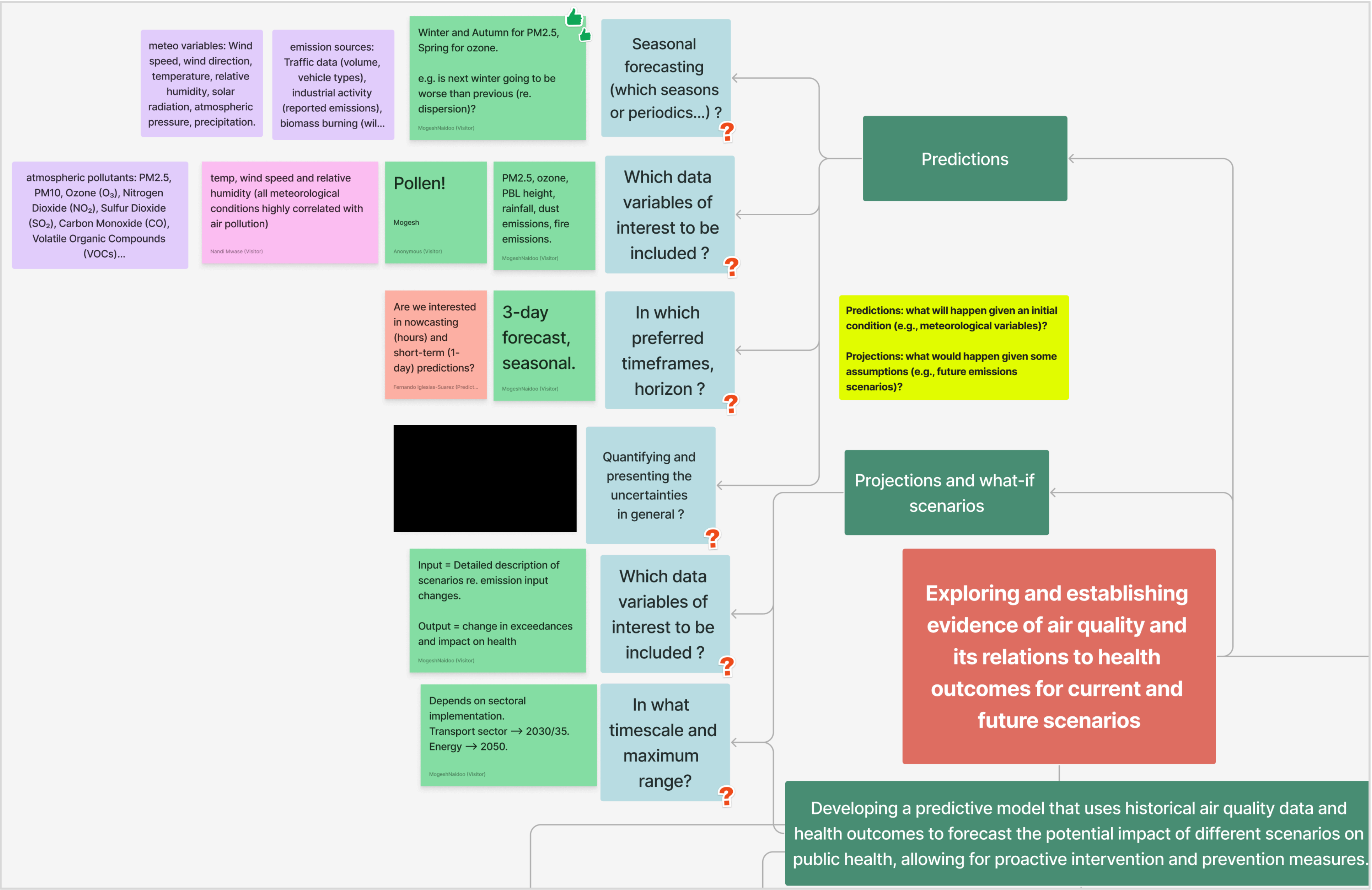


FIGURE 41: FUNCTIONAL DECOMPOSITION OF THE NEEDED EWS FEATURES RELATED TO PREDICTIONS AND PROJECTIONS, WITH THE PARTICIPANTS PREFERENCES AND FEEDBACK

Funded by
the European Union

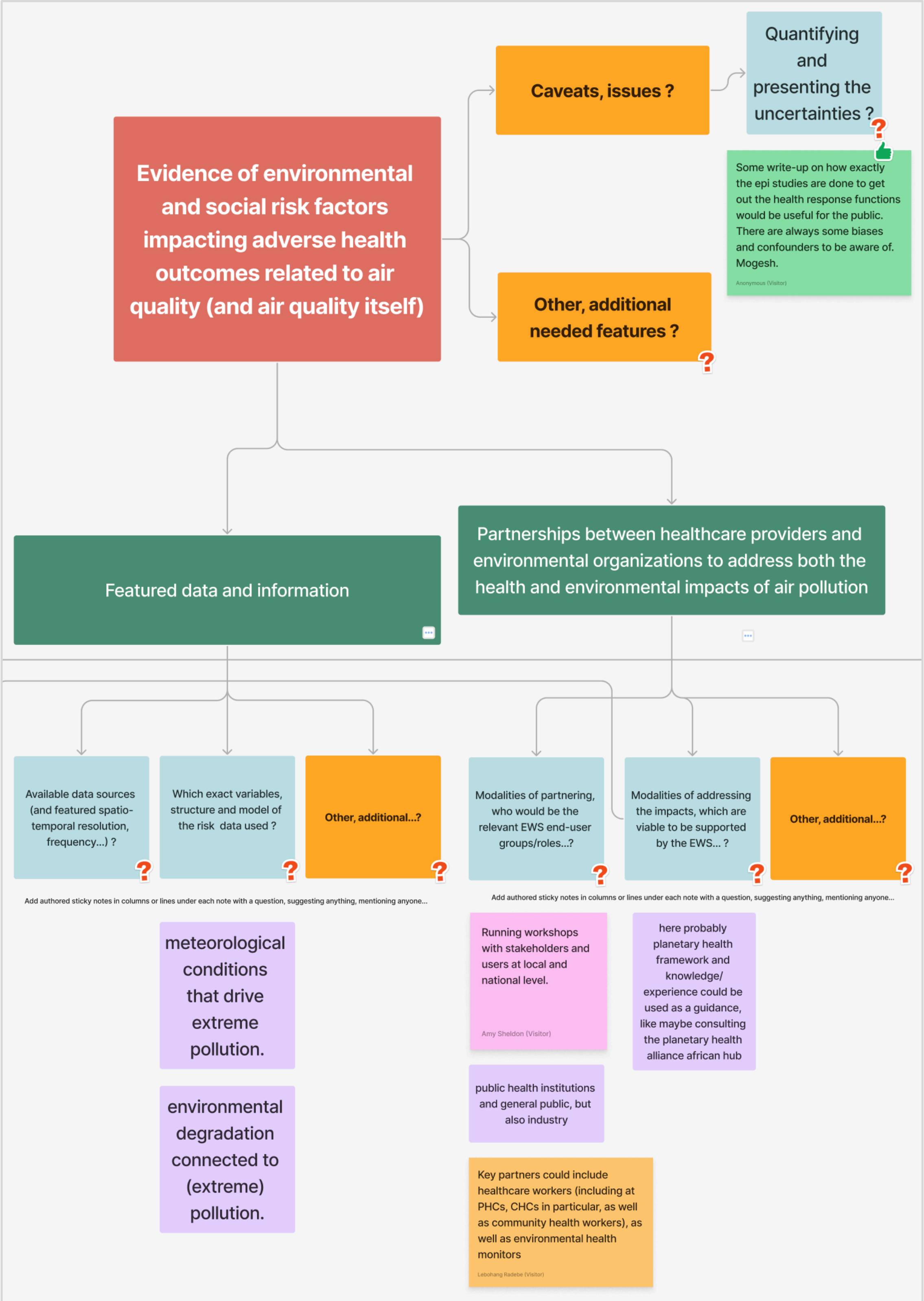


FIGURE 42: FUNCTIONAL DECOMPOSITION OF THE SECOND IDENTIFIED GROUP OF NEEDED FEATURES, EVIDENCE OF IMPACTS OF THE ENVIRONMENTAL AND SOCIAL RISK FACTORS ON AIR QUALITY, AND THE PARTICIPANTS PREFERENCES AND FEEDBACK

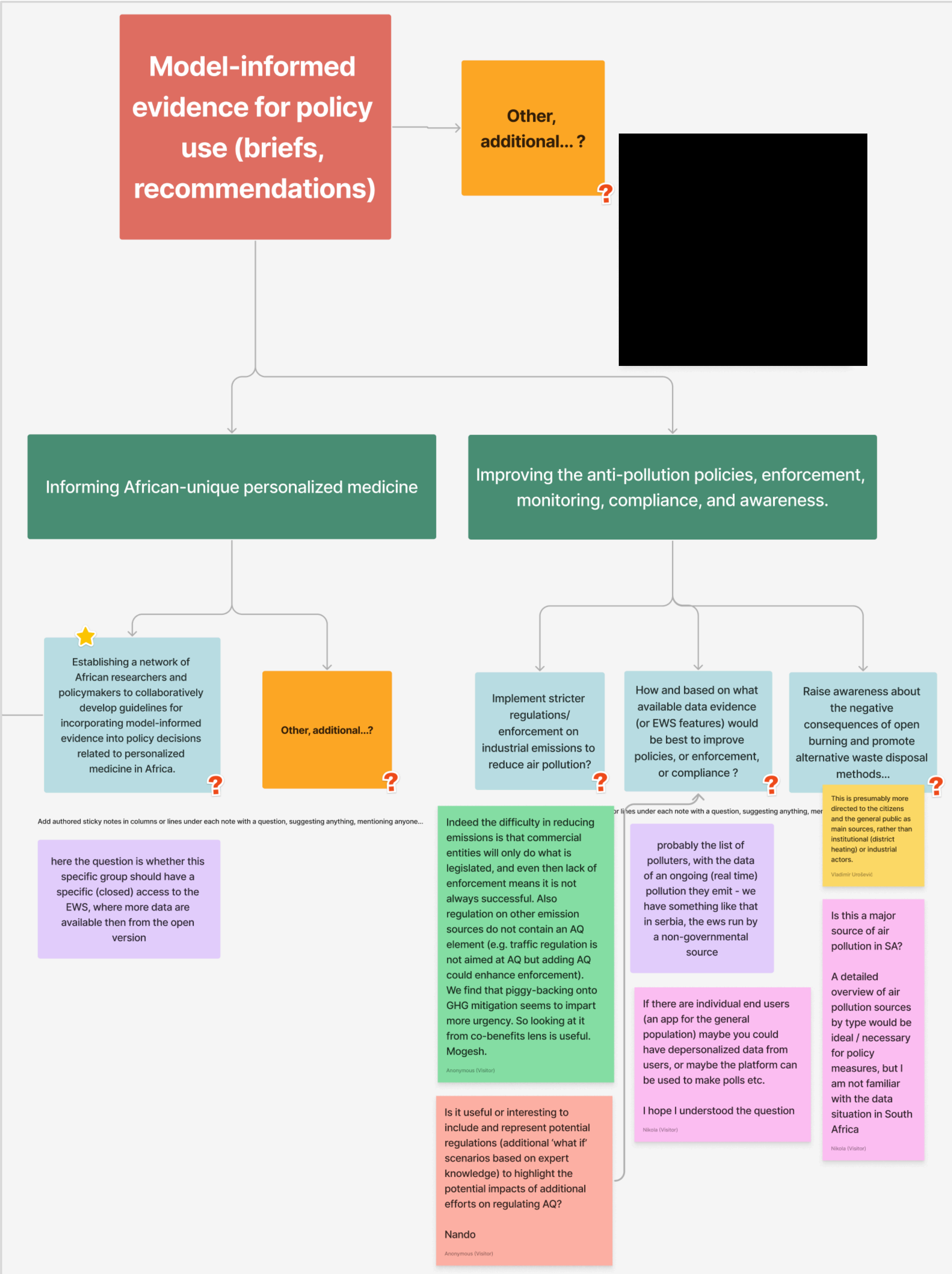


FIGURE 43: FUNCTIONAL DECOMPOSITION OF THE THIRD IDENTIFIED GROUP OF NEEDED FEATURES, MODEL-INFORMED EVIDENCE FOR POLICY USE, AND THE PARTICIPANTS PREFERENCES AND FEEDBACK

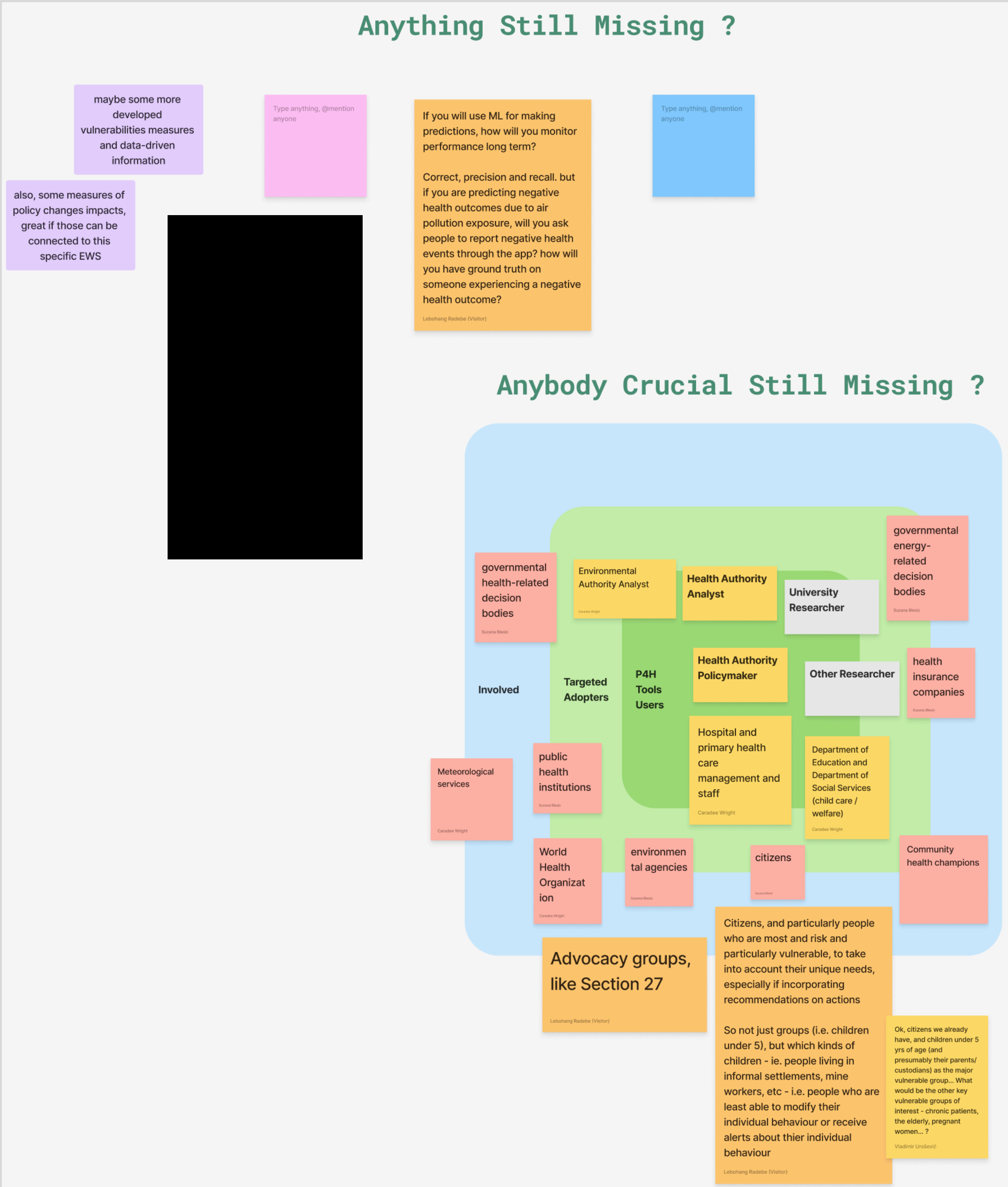


FIGURE 44: MISSING ITEMS AND SUGGESTED ADDITIONAL STAKEHOLDER TYPES IN THE CONCLUDING FINAL BOARD SECTION

4.2.3 CS3 Stakeholder Co-creation & Consultation Workshop

Figure 45: The completed filled interactive board of the CS3 workshop

CS3 is specific and differs from the first two insofar that the preferred solution and development direction is not an EWS, but rather early-communication, reporting and informative/educative tool types, as initially identified by the T2.1-participating Project partners, and confirmed by the stakeholders at the workshop. The inherent key source data characteristics and other major constraints causing this have also been confirmed as identified in the preceding T2.1 internal collaborative sessions, and elaborated further by the responsible stakeholders, mainly:

- Monitoring data on PFAS in Germany, or Central European sampling origin, provided by the stakeholders – the Federal Office of Consumer Protection and

Food Safety (BVL)[21] and Germany's Environmental Protection Agency (UBA)[22] – are available only in aggregated form at the source.

- Over the past 15 years, PFAS monitoring has been temporally inconsistent, relying on risk-based sampling with incomplete data, with the sampling time points not following a regular (monthly/seasonal) pattern.
- Additionally, the (spatial area information of) origin of food containing PFAS compounds is often obfuscated or too broad in these datasets.

As a result, developing an Early Warning System (EWS) may not be feasible at this stage, without spatial/geomap features, and highly sparse or inconsistent critical baseline underlying time-series data for trending and predictions.

Instead, it was suggested by the stakeholders that the stated key research goal to be supported by the developed tools is to analyse changes in PFAS concentration levels or the presence of specific PFAS groups in various environmental matrices over time, particularly in relation to regulatory milestones (the restrictions on PFOS in 2008[23], PFOA in 2020[24], and PFHxS in 2023[25]), requiring the underlying registry of PFAS hotspots to support temporal, and to the available crude extent spatial changes tracking and analytics, as shown expressed on the board on Figure 47 below. To represent the resulting findings, time-series diagrams have been identified by the stakeholders as the primary preferred visualization method. Key filtering features should include sampling methods, laboratory information, and stratification/matrix parameters (e.g., land use type).

To address PFAS contamination in water and soil, stakeholders have highlighted the need for an AI-driven Early Reporting System as primary, documented with the feedback on the interactive board provided on Figure 46 below. This module would automate the generation of reports from monitoring datasets on contaminants in Germany and Central Europe using customized, open-source Large Language Models (LLMs) and AI. It would be crucial for producing timely reports and issuing early communications and warnings about food safety risks, supporting communication efforts across German Federal States and the European Union. Concrete examples of a referent source dataset table provided by BVL and the manually written and compiled target report section to be generated (from the current practice) are included in the bottom of this relevant area on the board, with most of the related concerns, constraints, clarifications, links to further examples, and detailed requirements grouped on notes around these referent example images.

[21] https://www.bvl.bund.de/DE/Arbeitsbereiche/01_Lebensmittel/01_Aufgaben/02_AmtlicheLebensmittelueberwachung/04_Monitoring/lm_monitoring_node.html

[22] Human biomonitoring: https://hbm.vito.be/eu-hbm-dashboard; Specimen bank: https://umweltprobenbank.de/en/documents/investigations/measurement_params

[23] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32022R2388

[24] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32020R0784

[25] https://echa.europa.eu/documents/10162/fdaed5b0-b6e4-9a21-b45d-ca607c05f845

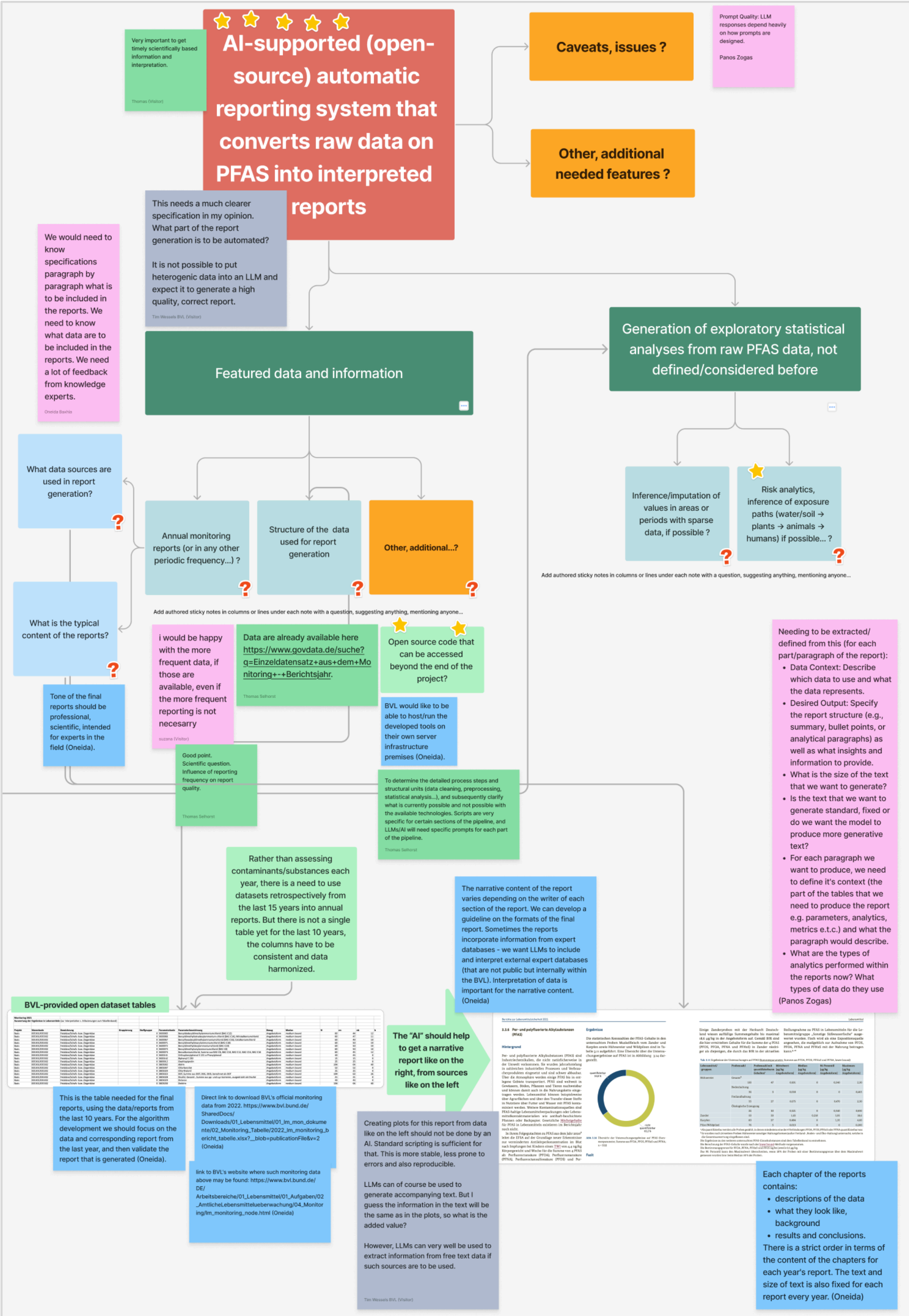


Figure 46: Functional decomposition of the needed AI-driven Early Reporting System, with the participants preferences and feedback, and specific examples in the bottom section

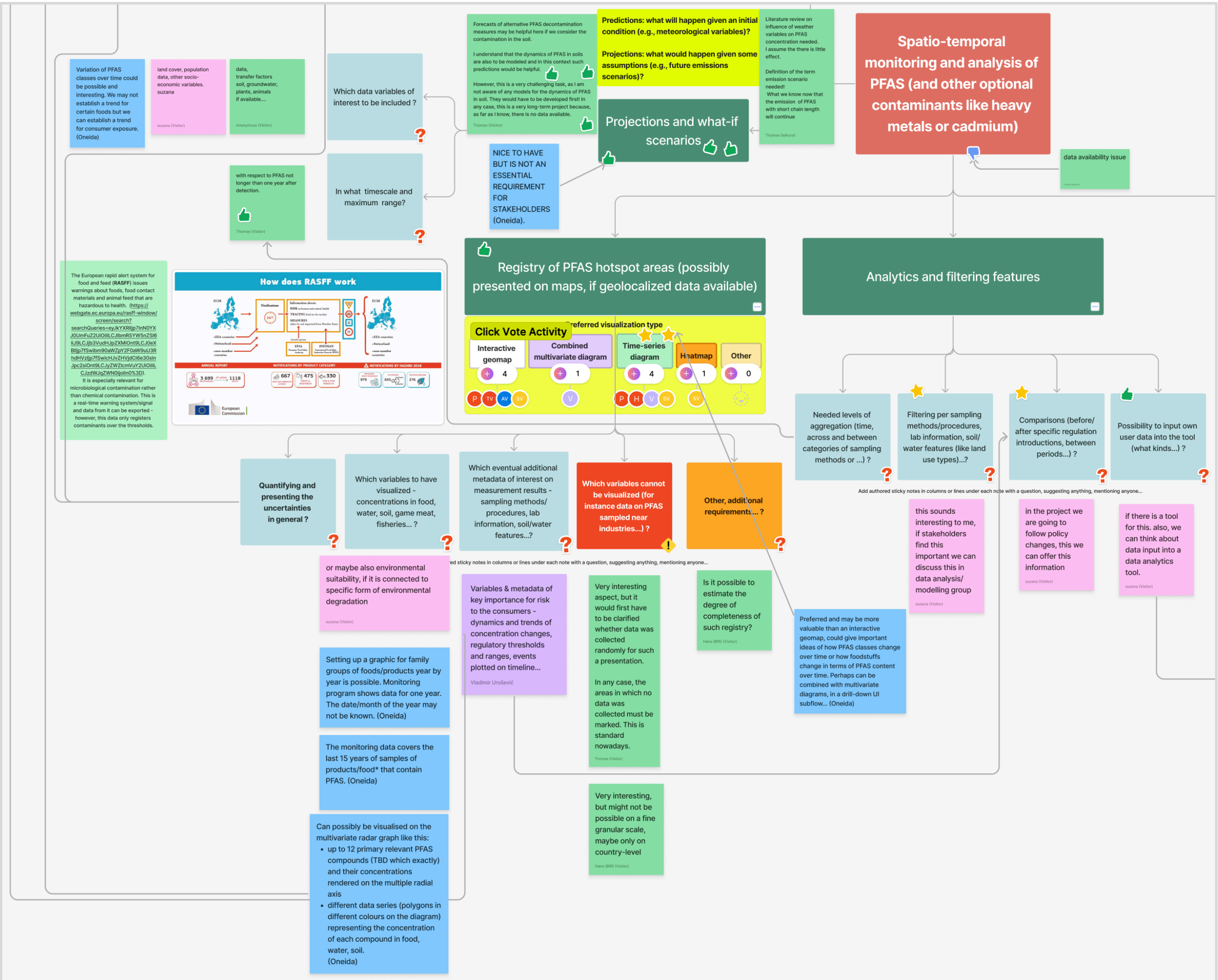


Figure 47: Functional decomposition of the needed spatio-temporal PFAS concentrations monitoring and analytics, with the participants preferences and feedback, and RASFF as a provided example on the left

The third identified high-level need for the tool support towards policy briefs and recommendations for policy upgrades, and the contained specific concerns and requirements, have been unanimously confirmed by the participating stakeholders, a small number but the key ones from BVL, BfR and UBA. The provided feedback addressing these concerns is also highly valuable, regarding the content that is to be linked or integrated and presented in the tool, particularly regarding the regulatory framework and the decontamination practices/innovations and involved industrial actors targeted to be addressed or promoted (Figure 48).

FIGURE 48: FUNCTIONAL DECOMPOSITION OF THE THIRD IDENTIFIED GROUP OF NEEDED FEATURES FOR POLICY BRIEFS AND RECOMMENDATIONS, AND THE CORRESPONDING PARTICIPANTS PREFERENCES AND FEEDBACK

5 The Requirements Systematisation and Specification

The systematisation of the functional (and some non-functional regulatory, privacy- or security-related) requirements expressed and confirmed in the course of the co-creation and collaborative efforts and workshops has finally followed, per the stricter and structured process (even in the employed shortened and simpler form) following the rulebook guidance and structure templating of the SOPHIST MASTeR set method, as stated above in Chapter 2. This consolidating effort has been completed by the Project partners, summarising the information and feedback provided by the key external stakeholders.

The following basic elementary defining criteria and attributes for requirements elicitation have been set out from the method templates and provided to the partners as specification keys, columns of the collaboratively filled requirements specification sheet (example with the exact format provided as TABLE 3 below):

Requirement ID

The unique requirement ID for reference and traceability purposes. It is structured as a 3-4-letter acronym denoting a requirement type or category, followed by an incremental integer counter unique within the type/category (for example, **FUNC1** for a functional, **PROC1** for a non-functional ***process*** requirement, see under ***Type*** following below).

Type

The requirement type categorisation differentiates ***legal***, ***ethical***, and ***technical*** requirements at the high level. Legal requirements are referring to regulations and law and ethical to compliance to ethical standards (regarding data privacy, security, ownership and property rights...). Technical requirements are encompassing:

- ***functional*** requirements, defining the specific functionalities of the developed systems and tools that primarily achieve the user goals identified above, as well as related and underlying interactions between components, implementation technologies or data formats, interfaces or pre-existing services utilized, etc.

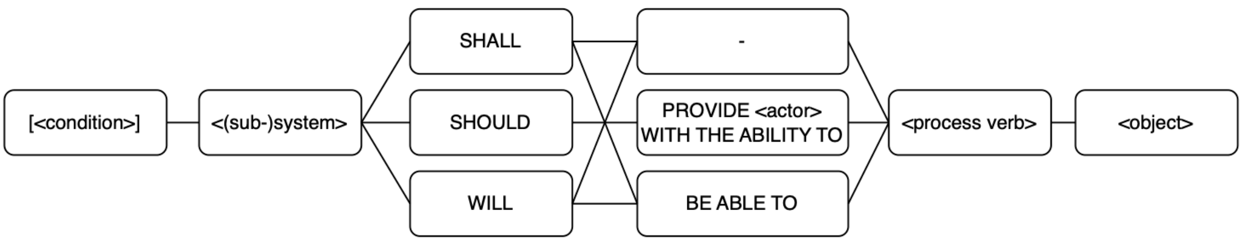


FIGURE 49: MASTeR TEMPLATE FOR A GENERIC FUNCTIONAL REQUIREMENT SENTENCE STRUCTURE FORMULATION

- ***non-functional*** requirements describe more generic system or tool properties, like the operating environment, and requirements for the development and maintenance processes. They can be further divided into:
    - ***process*** requirements, defining procedural flow or obligations for the system development, deployment, and maintenance (for example: *The*

source data providers SHALL comply with the usage policies of the originating institution/organisation).

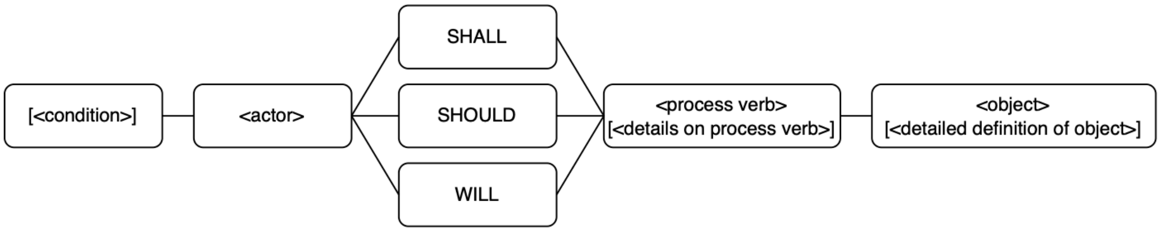


FIGURE 50: MASTER TEMPLATE FOR A NON-FUNCTIONAL PROCESS-TYPE REQUIREMENT SENTENCE STRUCTURE FORMULATION

- ***property*** requirements denote quality and performance criteria that the system must fulfil (for example: *The response time of the user interface SHOULD BE less than 3 seconds*).

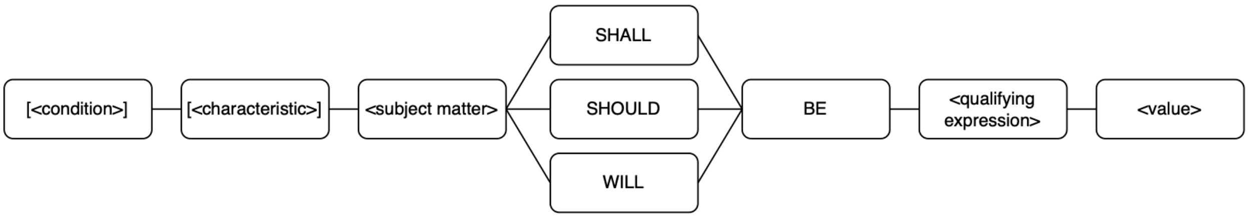


FIGURE 51: MASTER TEMPLATE FOR A NON-FUNCTIONAL PROPERTY-TYPE REQUIREMENT SENTENCE STRUCTURE FORMULATION

- ***environment*** requirements describe conditions that the system and its execution environment must meet (for example: *The data collection app. SHALL BE implemented to run at least on mobile devices with Android or iOS operating systems*).

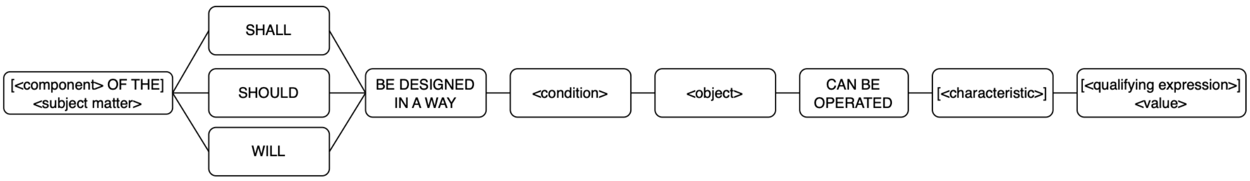


FIGURE 52: MASTER TEMPLATE FOR A NON-FUNCTIONAL ENVIRONMENTAL REQUIREMENT SENTENCE STRUCTURE FORMULATION

- ***document*** requirements (also called meta requirements) address the form and structure of the requirements and the documentation (example: *Every requirement sentence SHOULD be written in active voice*). Meta requirements are fulfilled by the requirements documents themselves, in contrast to ordinary requirements that are to be fulfilled by the system's realisation.

Requirement Sentence

It is the core and substance of the description summarising the key actionability and substance of each requirement in a single sentence structured according to the simple syntactic rules of the MASTeR template system. In the MASTeR templates the parts in capital letters are keywords that appear literally in the sentence, parts in square brackets ***[…]*** are optional, and parts in angular brackets ***<…>*** must be replaced, as illustrated on FIGURE 49 to FIGURE 52. Each requirement sentence must contain one of the liability keywords - ***SHALL*** (mandatory), ***SHOULD*** (optional), or *WILL* (mandatory, but realised in future). Additional sentences may complement or clarify this main verb formulation, but longer descriptions explaining the motivation or justification behind the requirement are advised to be separate in the related comment field instead.

Liability, as noted above, distinguishes mandatory ("*SHALL*") from optional ("*SHOULD*") requirements, preferably already in the main active verb formulation in the requirement sentence, while the categorisation in the **Priority** column (***HIGH, MEDIUM, LOW***) defines the prioritisation according to the development and implementation plan, expressed user or stakeholder preferences (as), or system architecture decisions.

Author (Partner) property - acronym(s) of the consortium partner(s) having written the requirement - and the **Possible Obstacles/Barriers** free text descriptive one, have fairly self-explanatory names.

The "**Relevant for**" column finally denotes for which CSs is the requirement defined.

The complete requirements specification sheet, a live document being under continued expansion and refinement extending into the development phase, is structured as specified above, and like the TABLE 3 provided below with some examples of high-level and generic functional and non-functional requirements, to illustrate the results of the process. The complete filled specification sheet cannot be included in this document as most of the detailed functional requirements contain confidential information potentially revealing the proprietary technology or IP expertise or knowledge of the consortium partners, not to be disclosed to the public in a publicly disseminated deliverable like this document.

Table 3: Example structure and format of the List of requirements for PLANET4HEALTH early warning systems and tools

ID	Type	Requirement Sentence (Description)	Liability	Priority	Author (Partner)	Possible Obstacles/Barriers	Relevant for
PROC1	Non-functional	The system (all included components and tools) SHOULD use open specifications for enhanced interoperability and scalability.	SHOULD	MEDIUM	ZEN		ALL
PROC2	Non-functional	The developed AI/ML algorithms and models code SHOULD be open source, for increased adoption and customisation support.	SHOULD	MEDIUM	BFR		CS3
FUNC9	Functional	Implementation of APIs SHOULD use geospatial and other applicable standards (like OGC) to enhance interoperability, integration and data transfer between different subsystems and platforms, and ensure scalability, flexibility, future-proofing, and long-term sustainability.	SHOULD	MEDIUM	PRED		ALL

6 Conclusions and Next Steps

In summary, this deliverable presents a comprehensive overview of the collaborative activities, developments and progress made and lessons learned in the PLANET4HEALTH Task 2.1, dedicated to the definition and co-creation of the requirements, needed features and essential elements of the interactive digital tools to be generated by the Project.

The approach and key steps of the applied methodology, as well as the contents, interactive feedback and outcomes of the co-creation sessions and workshops with the stakeholders, usage goals and scenarios, and derived functional and non-functional requirements systematisation for the tools, have all been documented in this report.

The complexity and breadth of the collaborative and co-creation efforts undertaken during the internal joint definition sessions involving all 17 PLANET4HEALTH consortium partners, and the following consultation and co-creation workshops with additional various external stakeholders and actors, have been emphasised throughout this document. For CS1-3, these sessions and workshops have played a crucial role in formulating the objectives and functionalities of the EWSs and digital tools, ensuring they meet the diverse needs and requirements of the various end users and other involved stakeholders in the four PLANET4HEALTH Case Studies, including the initial identification, systematisation and segmentation of these stakeholders per groups/roles and types (professionals, researchers, policy makers, citizens, authorities, associations and NGO or advocacy organisations in various fields...), and influence on the design, development and usage of the digital tools. These efforts have additionally initiated the project-wide identification and engagement of stakeholders and buildup of the networks in successful synergy with the dedicated the task T4.2, and work on this will continue expanding, along with the communication with the end users and data storytelling about to start in the task T4.5, leveraging on the successfully performed co-creation and consultation workshops for the first three Case Studies documented here. The collaborative foundational work relating to CS4 has been useful to identify potential stakeholders and potential products. This and the lessons learnt in the CS1-3 workshops will be valuable when stakeholders are engaged to co-create a digital product relating to the results of CS4; these insights will improve organisational and interaction aspects. This is of importance for T4.5 to devise a proper strategy for communicating to the end users the purpose and the outputs of the PLANET4HEALTH ML and AI techniques, processing models and analytics.

The report also provides the overview of identified key constraints and barriers affecting the systemic requirements and specified features, as well as the preliminary insights into the available datasets that are to serve as foundations for the developed EWSs and tools. Further elaboration on them will follow in the deliverable D1.4 (*Technical report on the identified ML and AI techniques for use in OneHealth approaches in environmental and climate context, together with the illustration of usage done in the project*), due for completion a couple of months later in M14, resulting from the parallel ongoing related efforts in tasks T1.1, T1.3 and T3.2.

As the Project progresses, this deliverable is to serve as a valuable reference for the ongoing developments and the resulting study site validations of the deployed EWSs and digital tools in practice, for assessment and ensuring that all are aligned with user expectations and operational needs.

It conveys the benefits of the applied co-design principles and goal-directed user-centred design approach, and the collaborative spirit and dedication of the Project team and stakeholders in advancing our understanding of climate change and environmental deterioration impacts on One Health and enhancing our preparedness and ability to mitigate the impacts and translate applied science into policy through robust and user-friendly Early Warning Systems and digital tools.

Some substantial needed clarifications, refinements and additions on the needs and requirements are still ongoing for CS3 and CS4, the cases where the preferred tool types will likely not be EWSs, and consequently additional consultations and co-design with the end users and targeted adopters are underway, likely to extend shortly within the main development task T2.3 after the end of T2.1 upon the submission of this report.

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