TREEADS

A Holistic Fire Management Ecosystem for Prevention, Detection and Restoration of Environmental Disasters

TREEADS D3.5. Live doc. Platform technological, Architecture and data model and fusion V1

Work package	WP3: Organisational, Structural, and Sociotechnical Factors for TREEADS Ecosystem Building and modular approach
Task	Task 3.6: TREEADS Platform Technological Requirements, Architecture, Data Fusion and Data Model
Authors	**USAL**
Dissemination level	Public (PU)
Status	Final
Due date	24/11/2023
Document date	22/11/2023
Version number	2.0
	TREEADS project has received funding from the European Union's Horizon 2020 research & innovation programme under grant agreement No 101036926.

Revision and history chart

Version	Date	Main author	Summary of changes
0.1	16/05/2022	USAL	Draft outline
0.2	13/06/2022	USAL	Architecture schema
0.3	04/07/2022	USAL	Draft for first internal review
0.4	29/07/2022	ALL	Draft with synthesis from Technical Leaders (TL) inputs
0.5	15/08/2022	USAL	Draft for second internal review
0.6	19/8/2022	SIMAVI	AR/VR inputs
0.7	29/8/2022	USAL	Draft for final internal review
1.0	31/08/2022	USAL	Final submitted version
2.0	22/11/2023	USAL	Revised based on reviewers' comments (see details in table below).

Table of contents

Index of figures

Index of tables

LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation	Meaning
ACL	Access Control List
AD	Administrator
AI	Artificial Intelligence
AP	Application Protocol of ISO 10303
AN	Anonymous
BaaS	Backend as a service
BUI	Build Up Index
CCS	Command and Control System
CFD	Computational Fluid Dynamics
CLI	Command line interface
COP	Common operation picture
DC	Drought Code
DMC	Duff Moisture Code
DoA	Description of the Action
DSS	Decision Support System
EDM	EXPRESS Data Manager (JOTNE product)
EO	Earth Observation
EFFIS	European Forest Fire Information System
FBB	Forest black box
FLEI	Federated Learning Edge Infrastructure
FFMC	Fine Fuel Moisture Code
FOFEM	First Order Fire Effects Model

FOV	Field of view
FPS	Fire Prevention System
FWI	Fire Weather Index
GEE	Google Earth Engine
GIS	Geographic Information System
GPS	Global Positioning System
HDWind	High-Definition Wind field model
IoT	Internet of Things
IPv4	Internet Protocol version 4
ISI	Initial Spread Index
ISO	International Organization for Standardization
LAU	Local Administrative Units
LiDAR	Light Detection and Ranging
MCC	Mission Control Centre
ML	Machine Learning
MQTT	Message Queuing Telemetry Transport
NBR	Normalized Burn Ratio
NDVI	Normalized Difference Vegetation Index
NUTS	Nomenclature of Territorial Units for Statistics
ODC	Open Data Cube
PCS	Portable Communication System
PFP	Passive Fire Protection
PhyFire	Physical Forest Fire spread model
PhyNX	Multilevel atmospheric pollutant dispersion model

PLCS	Product Lifecycle Support (ISO 10303-239, AP239)
PLM	Product Lifecycle Management
PR	Provider/manager
PWA	Post-wildfires Wood ashes
RE	Registered
RMS	Resource Management System
RoI	Region of Interest
SCC	Seed Container Capsules
STEP	ISO 10303, Standard for the Exchange of Product Model Data
UAV	Unmanned Aerial Vehicle
VR	Virtual Reality
webGIS	Wildfire app
WMS	Web Map Service
WRE	Wildfire Response Engine
WRF	Weather Research and Forecasting
WUI	Wildland-Urban Interface
XR	Extended Reality

EXECUTIVE SUMMARY

This document defines the first version (V1) of the TREEADS ecosystem architecture, based on the functional requirements of the Description of the Action (DoA), the technical meetings with TREEADS partners and the D2.9 for the definition of requirements for each pilot for the action phases prevention & preparation, detection & response and restoration and adaptation defined in D2.3, D2.5 and D2.7, respectively. The document defines a conceptual design of the main modules, components, functionalities, and the data model according to user requirements. The document details the functionalities, data in-/output, and technical solutions for building the block-based TREEADS ecosystem. The system performs along the three phases against forest fires and gives support to the actions of different users involved in fighting fires.

The platform design is conceived from a global perspective, in such a way that the versatility of the system architecture design allows the use of the platform both for a specific area or for global reach. However, due to the project capabilities, in TREEEADS the scope is set at the level of the pilot areas, since most of the modules and/or services of the system require specific information, which can be compiled specifically for those areas (adapting the sources of information to the different data models) by the corresponding pilot leaders. In addition, some tools involved in TREEADS focus on a local or regional scale, with the aim at being useful by the fire brigades acting in each case.

The platform has been designed from a high-level perspective to provide the user with tools and a global vision of updated information, with the aim at contributing to the implementation of integrated fire management but being conscious of the limitations due to the complexity of including specific or detailed information for the complete European territory. This means that the four-layer approach is applied for completing the spatial and time scales of the TREEADS Platform: satellite data provides knowledge at a global scale with 5 – 10 days frequency, zeppelin and mid-attitude drones perform data acquisition at regional level at monthly or annual frequencies; and low-attitude drones can provide information at higher resolutions and perform actions at local scale, in fire season and in case of fire events.

TREEADS Platform entails a contribution to Integrated Fire Management by including tools for all the three phases of wildfires, although the contribution in the prevention and restoration phases is more complete because their management can be entirely performed with the ad-hoc designed tools incorporated in TREEADS. It can be considered that the detection and response phase is a more complex phase that requires external elements, quick decision making and where human knowledge and experience is key to respond to the fire event. Thus, considering this limitation for the detection and response phase, the TREEADS Platform has been designed in such a way that the expert user can be supported with the ad-hoc designed tools together with other third-party tools to complete the Integrated Fire Management System. The platform contributes to the user to have the best information available, updated, as well as provides innovative elements of intercommunication, support and information from drones, wearables for rescue teams, etc. The technology presented as TREEADS Platform lays a foundation in the action phase, but there is room for improvement.

The main user roles have been identified in collaboration with the partners in charge of WP2. Based on the specifications of the document D2.9, four user profiles have been defined. These are structured in two blocks, so they cover the different stakeholders. The groups that can access to the webGIS are: Anonymous (AN), Registered (RE). The second block is for data loading, model parameterization and system administration: provider/manager (PR) and administrator (AD).

Another noteworthy aspect is the description of the main functionalities of the system based on the three phases of action against forest fires. A summary table of the main functional and non-functional requirements of the main Web platform "Wildfire App (webGIS)" that interacts with the TREEADS ecosystem has been defined.

The architecture has been articulated on a client-server architecture as it is considered the most efficient for the project scope. The document describes each of the modules of the system architecture distributed in four main blocks: frontend, backend, data storage and hardware support.

The frontend describes the main interfaces for interaction with the TREEADS system, mainly the Wildfire app (webGIS), the data and sensor management desktops, and the virtual training client application. This frontend also includes the main elements where the user can interact according to roles, in addition to contemplating the adaptation to mobile devices of the application to the needs of planning agents, firefighters, agencies, and/or other stakeholders.

The backend describes the TREEADS Web Services and tools, designed in blocks to be functional containers within the TREEADS ecosystem.

Data Storage is the Data Access layer service for access to spatial information, repository, sensors, and other sources from which the backend modules are fed. In particular, a hierarchical structure has been designed, based on two levels. A first level on a matrix database using a NoSQL scheme for flexibility, aimed at system metadata, model settings, and user information. And a second level of databases, highly specialized in the persistence of time series data and georeferenced images where data from sensors and multispectral images are stored. Standard data models, like ISO 10303, are applied to resolve data interoperability and long-term data accessibility issues using an ISO 10303 compliant data repository.

Hardware support is the block representing communications hardware, aircraft, external data sources, and non-software elements in passive fire protection. This set of blocks forms the architecture design of the TREEADS ecosystem with the aim of supporting all users involved in fighting forest fires in the three action phases (prevention and preparation; detection and response; restoration and adaptation).

This initial design of the architecture is arranged through modules oriented to data analysis and specialized tools to cover the objectives of TREEADS in the three phases. The use of standards will facilitate the development of a sustainable modular system architecture. Standards for, among others, data representation, service definition and domain terminology will help avoid vendor lock in and will enable long-term accessibility of the domain data.

The risk analysis tool will be made up of various components that will help make risk estimates from different sources. These indicators will be calculated taking into account different sources and/or factors, which will allow the agents involved, through spatial analysis tools, to detect fire risks and establish preventive and preparation measures. In addition to the indicators, the execution of different models of fire simulation and smoke propagation will be integrated into the platform where they can be executed in prevention and detection phases.

The detection and response module is divided into various sub-modules, of which the most prominent ones are context-based fire detection using machine learning (ML), through events of user actions, established metrics, satellite images and other data inputs for analysis. In this context, the information provided by embedded systems in aircraft for edge computation is also supporting hotspot detection and object recognition. All these data will feed the evacuation routes tool.

The restoration and adaptation module has software and hardware elements. At the service level, modules have been designed for postfire environmental assessment and decision-making for sustainable management and restoration of burned areas. In this phase there are also hardware elements referring to new materials, seed, and reforestation capsules, etc.

The document does not contemplate an infrastructure specification, but it does realize that it is a modular architecture design, very focused on a cloud environment, where all the elements form an ecosystem based on microservices. Communication with the TREEADS services has been established over a public OpenAPI to be consumed by third-party applications. The document in this version does not contain sketches of the main interface of the system, nor details at a low level of the data model, due to the length of the document and the deadline of the deliverables of functional requirements linked to this D3.5. These aspects will be detailed in future iterations of the document.

INTRODUCTION

BACKGROUND

TREEADS Project, financed with European funds to the LC-GD-1-1-2020 call, aims to develop new products and integrate them in a holistic Fire Management platform. It aims at optimising and reusing the existing socio-technological resources to prevent, detect and restore forests at risk of wildfire.

The project consists of a consortium of 47 partners from Europe and Taiwan, combining extensive expertise to develop the 10 Work Packages into which TREEADS is structured.

Working Package 3, entitled Organisational, Structural, and Sociotechnical Factors for TREEADS Ecosystem Building and modular approach is led by the Copenhagen Business School (CBS), beginning in month 1 of the project, and ending in month 41. The main objectives of WP3 are:

- To gather data on the Ecological and environmental wildfire related services.
- To support the development of a series of concepts of operations (CONOPS) to be analysed and validated by users.
- To analyse and validate the requirements and recommendations for the TREEADS Platform's development, use and associated policy.
- To establish the TREEADS guidelines for supporting pan-European management and delivery of wildfire related services in a holistic continuum that is designed according to all stakeholders needs over time and across different levels of the fire management system to ensure optimal green outcomes.
- To involve consultation between user representatives from individual, community, first responders, industrial and commercial providers and policymakers to identify the optimal form of insurance and risk model governance with all fire related stakeholders' participation in mind.
- To establish the governance model and requirements for the creation and management of the TREEADS Ecosystem, aiming to achieve sustainability after the end of the project, and will foster an open and creative discussion forum to generate a common understanding of the TREEADS vision, concepts and work.
- To identify relevant innovations and trends evaluating their results when available, and how they fill gaps, meeting the TREEADS Action's needs and priorities and preventing unnecessary duplications.
- To identify the relevant existing standards for implementation as part of the TREEADS Platform.
- To produce contributions to ongoing and future pre-normative activities of suitable standardization bodies.
- To produce the technical architecture and detailed technical specifications of the TREEADS holistic wildfire management systems, as well as of the accompanying services.

WP3 contains 6 Tasks, of which USAL is leading Task 3.6 TREEADS Platform Technological Requirements, Architecture, Data Fusion and Data Model. This document is centred on this task.

PURPOSE AND SCOPE

The objective of this deliverable is the design of the technical architecture and detailed technical specifications of the TREEADS holistic wildland fire management systems and complementary services. This deliverable is the main result of the work carried out in the context of Task T3.6 (TREEADS Platform Technological Requirements, Architecture, Data Fusion and Data Model), the preliminary results and summaries of the first design phases. Here we present the first version of the design (V1), based on the analysis of the user requirement process defined in D2.9 and the general axes defined in the DoA. The second and third (final) versions of the TREEADS system architecture will be delivered in M21 and M34 also considering the feedback collected from TREEADS stakeholders.

The design of the holistic TREEADS ecosystem for wildland fire management describes a complex system involving hardware components based on a four-layer geospatial coverage (satellite, zeppelin, mid and low altitude drones), materials, software components, various data sources and services. The TREEADS architecture must contemplate the integration of all these parts, also taking into account the different requirements regarding spatial and temporal resolutions of the data provided by the hardware components.

TREEADS has been designed to tackle wildland fire management in the three phases: prevention, detection, and restoration. The document is focused on defining a set of actions based on four points; 1) definition of the platform architecture according to a first establishment of the system requirements (functional and non-functional) that form the technical baseline of the platform, 2) technological requirements, 3) description of the system components, characteristics, functions, and information inputs/outputs, and 4) the data model.

The user requirements will be detailed in greater detail in successive versions of the document, considering the results of WP2 and WP3. This deliverable also details the main risks that could affect the development and integration processes.

APPROACH

The approach adopted for the architecture design relies on an overview of the main functional and non-functional requirements to help the reader identify the main functionalities of the TREEADS ecosystem, and on an overview of the main blocks of the architecture design and the modules that form it. Thus, the bulk of the document focuses on the architecture modules, and the technical aspects and input/output information of each component. Additionally, the present document introduces the external and internal Web services to be incorporated in TREEADS, as well as data accessibility and the identification of the main base layers required for the data model. Finally, a risk analysis assessment and management, a plan for the integration of the modules, and some preliminary conclusions of the first version of the design have been included.

DOCUMENT STRUCTURE

This document is structured based on the Guidelines on FAIR Data Management in Horizon 2020, Version 3.0, 26 July 2016, and contains the following information:

- Executive summary
- Introduction
- Section 2 – System requirements: defines the functional and non-functional requirements of the system in its first version (WP2)
- Section 3 – TREEADS architecture design: presents the first version of the TREEADS platform and the design of the main technical modules.
- Section 4 - TREEADS data workflows and data model: provides information on the architecture of the data design as well as the workflow of the services. The current specifications are based on the requirements of the first version.
- Section 5 – Risk Analysis: summarises the main risks related to the system design and related developments, in combination with a mitigation strategy to manage the risks in case they occur.
- Section 6 – Integration Plan: presents the integration plan towards the initial development of components and prototypes.
- Section 7 - Conclusions of the deliverable and brief presentation of the following steps towards the next iteration of the Live doc TREEADS Platform technological, Architecture and data model and fusion.

RELATION WITH OTHER DELIVERABLES

The D3.5 deliverable within the WP3 completes the first version of the TREEADS architecture design. This process starts from the definition of the technical requirements for the 8 pilot areas in each of the three main wildland fire phases (prevention and preparation; detection and response; restoration and adaptation) (D2.3, D2.5 and D2.7).

The results of the above-mentioned deliverables will be integrated into the D2.9 "Live doc Holistic Management systems and resource re-utilisation report V1" for M9. As a result, the global user requirements for the design of the system architecture and data model will be delivered. This is a live document, which forms the basis of the iterative approach adopted in the project, through which users will be structurally involved in the implementation process, in order to provide their feedback on the project results. The results of this process will be reflected in the TREEADS technical deliverables (WP4-WP7), as well as in the design of the next iteration of WP3 (D3.6).

FUNCTIONAL AND NON-FUNCTIONAL REQUIREMENTS

This section presents a summary table of the functional and non-functional requirements of the TREEADS system.

In this first version, the functional requirements have been inferred from the DoA characteristics and the deliverables D2.3, D2.5 and D2.7.

USER PROFILES AND ROLES

The definition of the user profiles for the webGIS platform requires the identification of the stakeholders. The main stakeholders are government and agencies, universities and research organizations, partners like companies and industries, citizens, firefighters and local authorities, and finally, investors and VCs. The set of stakeholders has been grouped based on functional requirements by role in the platform based on our analysis and input from partners. A set of roles is defined by gathering the stakeholders' interests in order to simplify the operation of the application for satisfying the functional requirements.

Anonymous (AN): Unregistered or anonymous users who can use the webGIS tool to consult layer information, visualize IoT sensors, meteorology and visualize the sources of active fires.

Registered (RE): Registered users can perform all the tasks available to unregistered users, as well as evaluating burned areas, simulations, etc. that require session data for simulations and/or tools.

Provider (PR): This role is meant for universities and/or Research & Technology Organizations that want to run wildfire propagation models, wind models, etc.

Administrator (AD): The super-administrator would be responsible for providing access and control to the system, by being responsible for the management of the entire system.

This webGIS tool entails the authentication and security services that will be described in the next sections.

MAIN FUNCTIONALITIES

Main functionalities expected in the full-fledged TREEADS tool (Fire Management Platform)

Table 1: Main functionalities

Accessibility	1. A compatible client with desktop computer and mobile devices (responsive). It will also include a role-based access for Administrator and Stakeholders Services users to login and interact with the TREEADS platform via web-based access in order to perform activities specific to their roles, and communicate with TREEADS Services
	2. Login & Authorization: Individualized connection based on unique users and password
Functionalities related with visualization	3. Implementation of a set of basic functionalities for managing the map viewer, such as zoom, pan, display layer list, turn layers on/off, select base layer, location finder and coordinate indicator.
	4. Consultation of layer and feature information. Allow visualization of layer legends and consultation of attribute information of a vectorial feature
	5. Fire and smoke propagation model simulation run interface, such as; fire starting point, firebreak lines, wind points, area of interest, etc.
	6. Visualization of raster and vector layers from the TREEADS repository on a map viewer. The vector layers can represent action zones, IoT sensors, etc. The layers in raster format of multispectral cameras that represent products of; Colour Composition, Normalized Burn Ratio (NBR), NDVI, etc. with adequate spatial resolution (10-20 m pixel) to be used in forest fires.
	7. Web viewer of 3D models for LiDAR point clouds. LiDAR point clouds with a high resolution helps in the characterization of forest fuels for further wildfire prevention and management.
	8. Web viewer for VR training.
Accessibility to existing data sources	9. Navigation in time series of images (historical products). The ability to view historical data (time-series) on previous catastrophic fires will help to better understand the behaviour of fire. Deliver a downscaled burnt scar mapping product by fusing Sentinel-2 with MODIS and VIRRS satellite data.
	10. Geolocation and basic navigation capabilities. The applications of this functionality are the possibility to evaluate the wildfires limits over base maps (ortho-photographs and satellite images) and the exploitation of satellite data navigating to the areas where vegetation anomalies are identified.
	11. Visualization and query of coverage layers in different resolutions in certain areas of action. • Satellite images: Higher frequency of images, large areas and low resolution. • Zeppelin images (High Altitude airships). Multispectral photogrammetry day and night: • Drones (Medium-altitude and Low-altitude) images. Image spectrometry and LiDAR images

	12. Connection to external WMS services. Visualize maps served in WMS together with the own information of TREEADS.
Main Functionalities	13. Fire Simulation Services toolkit to provide the ability to simulate a computerized system for fire and smoke spread, assess air pollution, propose evacuation plans for citizens and animals, and provide full DSS for first responders • **PhyFire**: physical forest fire spread model. • **HDWind**: high resolution wind field model. • **PhyNX**: multilevel atmospheric pollutant dispersion model. • **Analysis of Fire Behaviour and Spread for the Development of Safety Measures** • **Machine Learning for Fire Risk Analysis and Fire Spread** • **Air Pollution Modelling for Source Apportionment** • **Specialized sampling and chemical analysis for air toxics** • **Air Quality and health impacts estimation using chemical transport models**
	14. IoT communication services for the monitoring of time series of sensor data based on the LoRaWan network. The system must be able to retrieve, store and manage the information generated by all the sensors.
	15. Map Service: Retrieve, store and manage the spatial information based on Data Cube approach using different devices (cameras, infrared, multispectral, VR, LiDAR...) and resolutions.
	16. Resource management system (RMS). Retrieve, store, and manage the inventory of firefighting resources available in an area. This will allow the management of the inventory of vehicles, drones, roads, hydrants, personnel contacts, etc. to be used in the emergency plan and restoration.

Functionalities related with Prevention & Preparedness	17. Risk Analysis and management Tool: Tools to include Forestry management regarding forest fire prevention through the use of decision-making supporting tools. It should provide fire risk indices and a support tool for decision-making. • Potential fire risk maps: Generator maps of Risk factor indicators based on different data sources. The maps should allow to identify and locate at a regional scale, those areas in which the frequency or virulence of forest fires and the importance of the threatened values make special fire protection measures necessary. o Earth Observation based toolkit for Fire Exposure and Risk Assessment o Territorial assessment tool to evaluate climate related risks and vulnerabilities. o Agroforestry Index: Map of agroforestry indices (Canopy Height Model, species, soil...) at European level and neighbouring countries through the use of Earth Observation data. o Early Warning System: Alert maps that complement the indexes of the European Forest Fire Information System (EFFIS). o Fire hazard forecasting using satellite data and machine learning models: predictions at a local level, through the fusion and exploitation of multi-modal Earth Observation imagery with human activities, festivities, etc. are key in a fire hazard forecast, as they increase the risk of fire.
	18. Fire Prevention System: Prevention tools that integrate heterogeneous, accurate and updated geospatial information to delimit the urban-forest zones and monitor their condition.
	19. Accurate Forest Mapping: Retrieval and storage of forest mapping with image spectrometry and LiDAR scanning to provide information in the pilot areas about species of plants and trees in the forest, physical characteristics, fuel models, etc.
Functionalities related with Detection & Response	20. Hotspot detection in a very short time. Implementation of advanced fire detection algorithms capable of detecting critical points through computer vision.
	21. Visual Object Recognition on embedded systems for edge environments. This device will incorporate cognitive capabilities and recognition of specified objects, sending pre-processed information to the TREEADS services.
	22. Resilient, event-driven, context-aware fire detection. The detection will be based on events of user actions, sensor parameters, satellite images, etc. using machine learning for its detection.
	23. Wildfire Response Engine (WRE). Real-time analysis methods to anticipate a critical situation and recommend action steps to mitigate them.
	24. Social Media Analysis: analysis of social network information to detect and locate possible fire incidents and identification of key user accounts that play an important role online during a fire.
Functionalities related with Restoration & Adaptation	25. Decision Support system: Conceptual development of a Decision support system for adaptive postfire management (DSS-APM) Manager agroforestry areas in recovery.
	26. The system will offer protocols to estimate fire severity, postfire vulnerability of soil and vegetation and identification of biodiversity refuges.

	27. The system will offer postfire management recommendations in the form of technical guidelines for defined areas.
	28. The platform will show the areas of non-intervention, restoration, salvage logging and reforestation by drone seed spread and other interventions.
Functionalities related with the Administrator	29. User Management. The system must allow defining and managing users as well as assigning them roles of actions.
	30. Layer manager. The system must offer some mechanism for loading data into layers for updating information and for exporting information for use by external tools.
Non-functional requirements	31. A scalable infrastructure and a georeferenced database
	32. The system will be interoperable, by applying open APIs and standard data representations. Data that shall be shared among tools or that shall be stored for long periods of time shall be made available in standard data formats and shall be uploaded and retrieved using an Open-Source Framework.
	33. Simulation models are not required on the fly. These will be launched, notifying the user when they are complete.

TREEADS ARCHITECTURE DESIGN

TREEADS SYSTEM OVERVIEW

The objective of the TREEADS architecture design is to develop a hardware and software ecosystem capable of managing wildfires, covering the three phases of action: prevention and preparedness; detection and response; restoration and adaptation. The design of the architecture is based on different tools and information, distributed in modules that intervene in one or several phases of wildfire action and provide valuable information to the system for its analysis. During the design process of the architecture, the software has been considered, in addition to hardware parts and differentiating elements such as passive protection and response processes. For a better understanding of the system architecture, the system has been divided into logical modules, composed of different elements with the aim of providing a specific response to TREEADS.

A **module** groups together a set of artifacts, such as components, scripts, services, etc. that are part of that same module. This represents a logical grouping, which could be called a functional area of the application (e.g., authentication module, risk analysis tools module, etc). These modules differ in their complexity and can be executed in different ways, including data analysis through machine learning, index generation and data processing, simulations, technical and communication support, dependence on external data and/or hardware, etc.

The system is organised into components that will act as independent containers providing microservices.

A **component** is an element of the system, which represents a functionality within the environment. It could be said that components are the business pieces of the system's logic. In the design, the components have been represented as a container where they solve an application need. In this way, data can be exchanged between components and higher structures, such as modules, allowing a block design of the system that confers scalability.

Through a set of Web services, access to tools and information is facilitated, as well as the orchestration of services to provide a holistic response. The design is based on a main access endpoint, called TREEADS OpenAPI, which manages the different endpoints of specific services, orchestrating modules, organizing information, access, and execution.

Following the analysis of user requirements in this first iteration and in line with the TREEADS DoA and with the first WP2 requirements analysis, the system architecture has been distributed in four main blocks:

B-01 – FrontEnd: This block contains the web interfaces to interact with the TREEADS system. Several web applications will be available for the visualization of TREEADS ecosystem resources. The main access applications will be the webGIS, the Manager Dashboard and the 3D viewer for the virtual training of scenarios. The web-client of the ISO 10303 repository for configuration control, data exchange and long-term archival will be integrated into the FrontEnd, too. The main application will be a webGIS to access spatial information focused on managing the three stages of intervention during forest fires. This application will not only display information in the form of layers, but it will also allow launching specific analysis tools in each management phase. In addition, the front-end contains two standalone applications, one VR client application (Android-based) targeting VR Headsets and one XR application targeting XR Headsets.

The VR application's role is to provide VR Training for the first responders. The training programme will include several scenarios (derived from pilots). Specific users will have access to configure or create training scenarios. The application will allow several users to interact via a multiplayer module. The training app also assures easier usage and accommodation for the users when using the XR headsets. A reporting module will be added to monitor the user's performance and decisions.

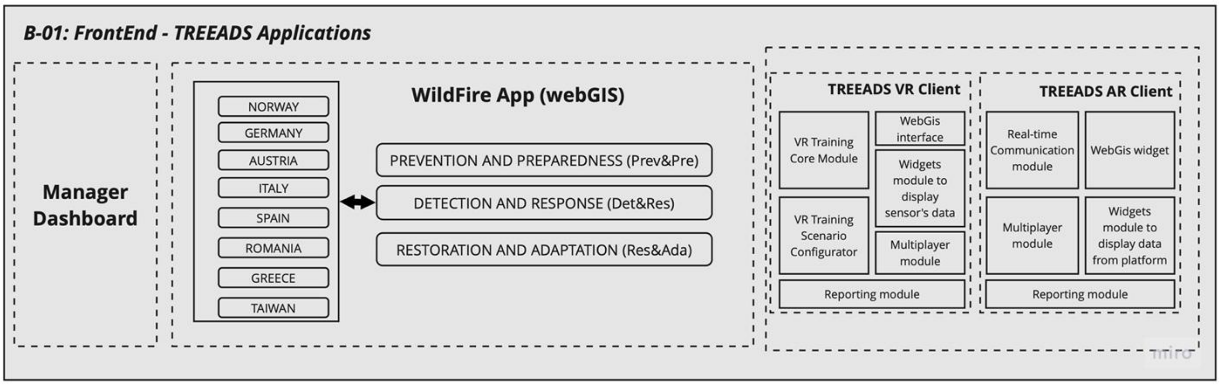

Figure 1: TREEADS FrontEnd.

B-02 – BackEnd: The Backend block describes the Web services required to support the TREEADS data and tools. The Backend is the core of the system and contains the system logic, except for the external logic of the "Federated Learning Edge" modules. This block is a compendium of modules that form the logic of the TREEADS ecosystem accessible through microservices and/or command line interface (CLI) to communicate between modules. These blocks are mainly fed with information from the four layers (i.e., satellite, zeppelin, drones), user interactions and information coming from third party services (meteorology, social networks, models, layers, etc.).

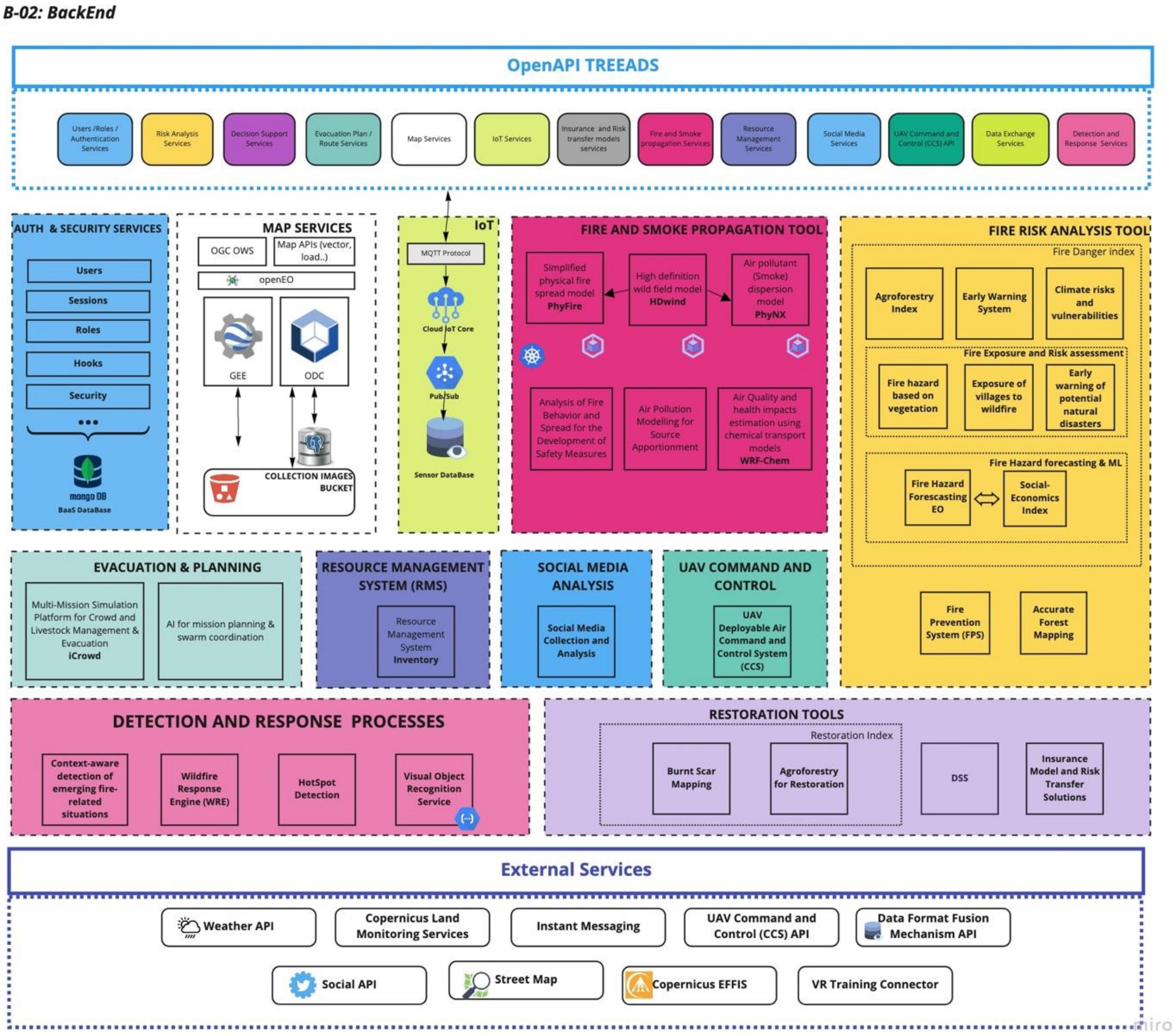

Figure 2: TREEADS BackEnd.

B-03 – Data Storage: This block combines the data storage in two parts: (i) the storage of data in the cloud, particularly images and files, and (ii) the storage of databases for information exploitation and queries. This separation is needed due to the high variety of data compiled for the performance of the different modules of the TREEADS Platform and their different formats and frequencies of incorporation to the platform: satellite data will be included every 5 – 10 days according to the revisit time of the platform selected with the aim at being used for general purposes and preliminary analysis; while data from zeppelin, mid- and low-attitude drones will be incorporated when acquired, for its use in detail-studies, consequently being analysed in the moment of incorporation.

This block represents an abstraction to the data access layer, designed at various levels and arranged in a hierarchy to help filter and analyse information. A main database of the "BaaS Database" system has been defined, under the NoSQL scheme to allow flexibility in the database schemes. For each specialized data model, a module with its own databases has been designed; storage of time series of images (i.e., image sequences) and layers (Spatial Database) and another database of sensor data (Sensor Database). Standard data models, such as ISO 10303, will be used to support data interoperability and system modularity.

B-03: Data Storage

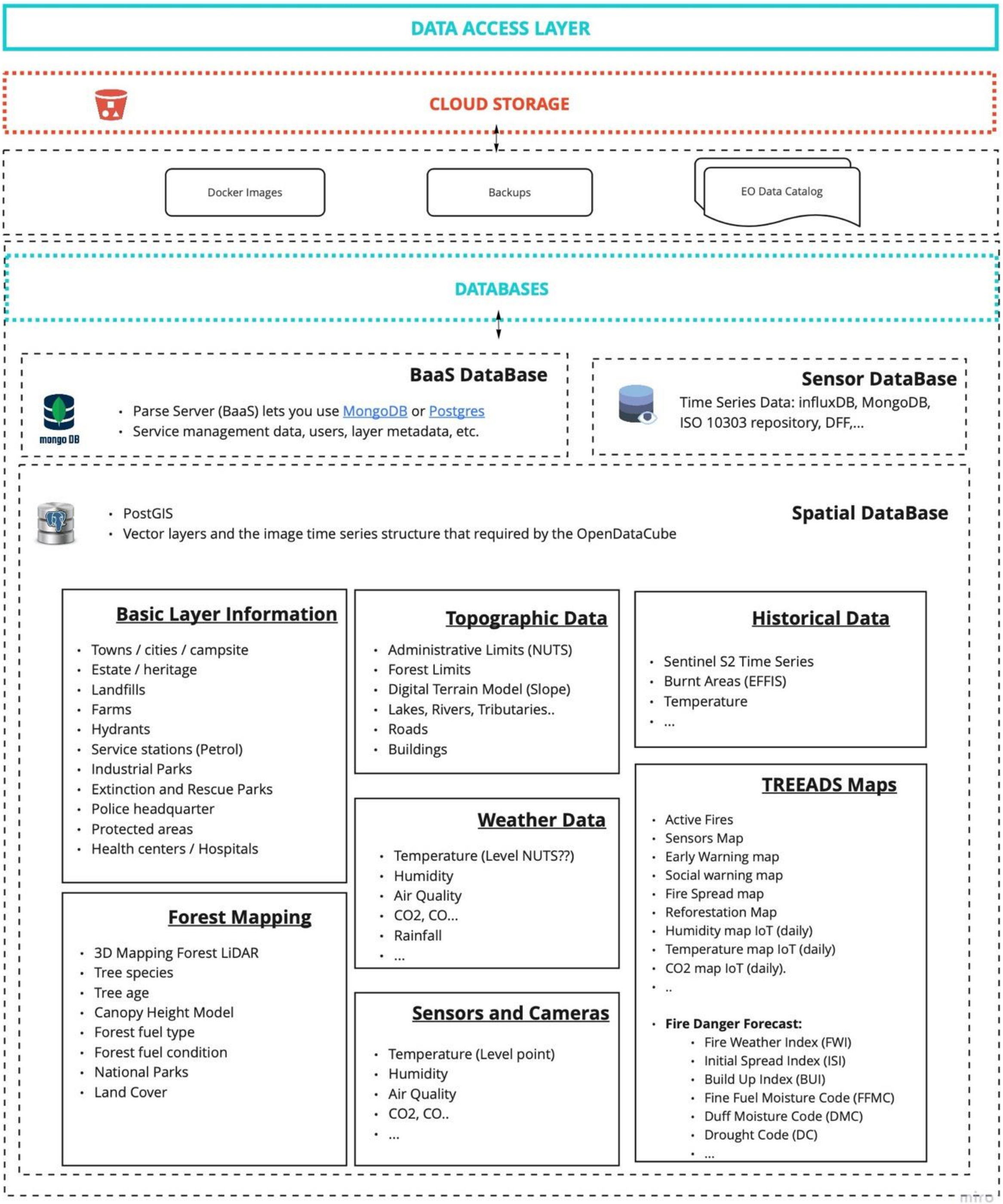

Figure 3: TREEADS Data Storage.

B-04 – Hardware support: This block represents mainly external data sources from cameras located in satellites, zeppelins, and drones, as well as mobile communication and IoT sensor network devices, intelligent sensing, and edge learning developments. VR devices can be used as external data sources and AR devices will be used to display the data sources. Additionally, here we include those TREEADS differentiating elements related to research and development but without a software application, such as reforestation capsules and passive protection elements e.g., fire resistant materials.

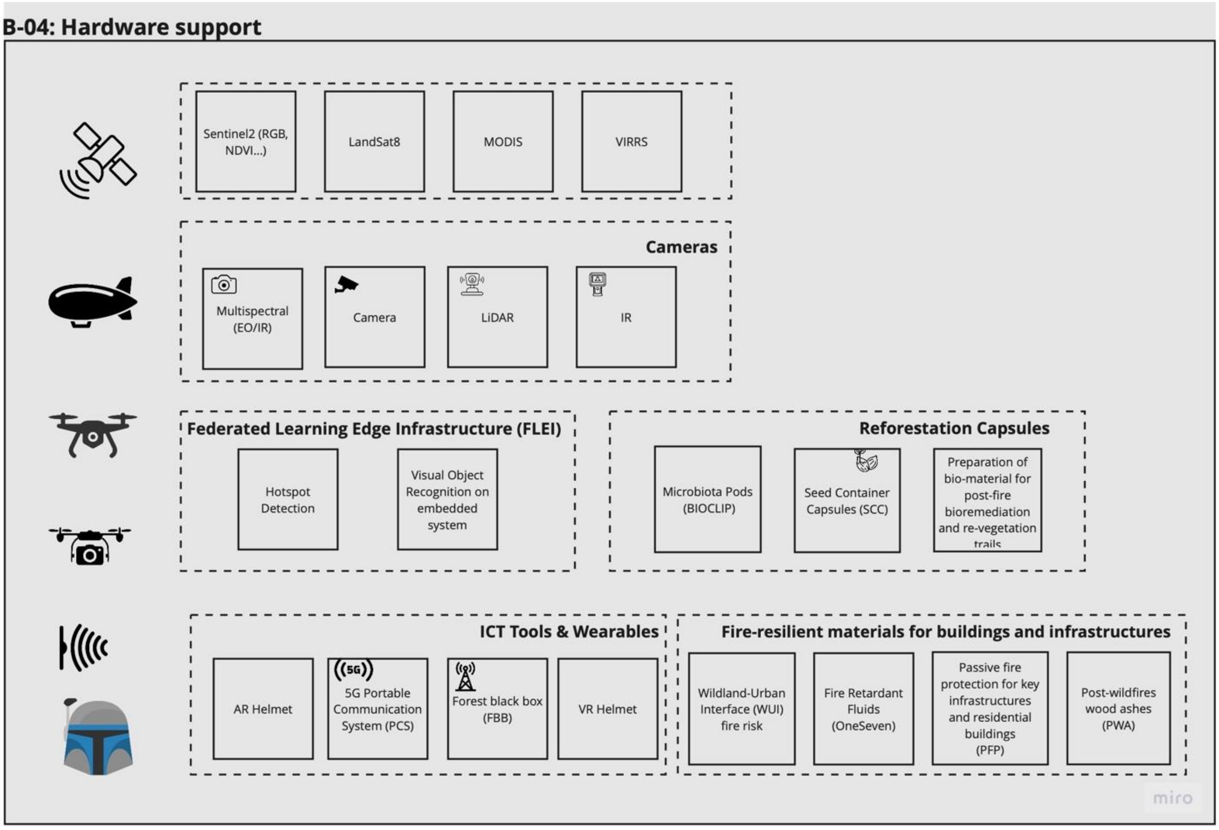

Figure 4: TREEADS Hardware support.

For a detailed view, the following link can provide more information: https://miro.com/app/board/uXjVOtmRSxI=/

FRONTEND:

This section defines the main TREEADS Web interfaces. It will consist of different Web applications according to their functionality and/or the role of the user.

The main application is the "WildFire App (webGIS)", which will be a Web map viewer for displaying information layers. It will also give access to the different tools for each pilot area and for each action phase: prevention and preparation; detection and response; restoration and adaptation.

The Dashboard manager will be a web interface designed for system management, where system administrators will have access, allowing the management of layers, users, permissions, etc.

The AV/VR training applications interface will be connected with the 3D virtual training simulator for firefighters and will give access to virtual simulation environments of 3D scenarios on a Web environment.

The system will be open for new interfaces or dashboards that may be necessary, such as sensor monitoring, control management, drone management, etc.

TREEADS APPLICATIONS

After an initial requirements analysis, the TREEADS ecosystem has been described to provide different web interfaces for TREEADS management and operation. In this first version, the main elements of the interface have been defined schematically. A first graphic design will be available through the development of demonstrators, mock-ups, prototypes, or future additional artifacts, once the functional requirements of D2.9 have been defined, which in turn will allow users to provide feedback.

- Wildfire App (webGIS)
- Manager Dashboard
- VR/AR Client
- Sensor Dashboard

WILDFIRE APP (WEBGIS)

Wildfire APP is a Web interface for end user's access to TREEADS platform, based on a map viewer, which will allow spatial information management mainly through the visualisation of maps, risk indices and routes. In addition, it will serve as a dashboard to connect with the main tools involved in the three phases of intervention during wildland fires. For the development of the web interface, some of the most popular frameworks for web development in JavaScript (Angular, React, Vue, etc.) will be evaluated. These frameworks make working with JavaScript easier, offering interactive options, such as the response of the applications to the device.

Regarding the visualization of maps and GIS functionality in the web browser, the most popular web map libraries (OpenLayers, Leaflet, mapbox, Google maps, Cesium, etc.) will be evaluated in order to identify which one suits best the needs of TREEADS.

The main modules of the interface will be:

- Signup/Login/Recovery credentials
- User profile
- Map module:
  - View map
  - Location
  - View layer
- **Tools:**
  - Risk Analysis Tool
  - Forest Fire Spread Simulation
  - Atmospheric Pollutants Dispersion Simulation
  - Resource management – inventory
  - Restoration DSS
  - Evacuation & planning tools

– Notification manager (predictions, risks and resilient, event-driven, context-aware fire detection)

MANAGER DASHBOARD

The Manager Dashboard is a Web interface for system administration, data management, user management, model configurations etc. The main modules of the interface will be:

- User Manager (Users, roles, and sessions)
- Viewer data model
- Webhooks
- Logs
- Config
- Managing layers module
- Load data module

VR/ AR Client App

TREEADS Virtual Reality (VR) application will be used as an online training and modelling system that allows users to build experience pre-built VR training resources but also to create interactive training content for training purposes.

The application will have several internal modules:

1) Simulations
2) Lessons
3) Scenario builder
4) Reporting

The simulations will include at least two virtual locations that were selected for the actual pilot's location. The locations are developed to look photorealistic and include topological map data, the actual flora and fauna but also the possibility to simulate environmental parameters. The areas will be 3D mapped and constructed to replicate the actual environment.

During the simulations, the users will be able to experience different roles within the simulation. The users will be able to choose between different roles (with different sets of actions, each according to thir own methodology). The users will be able to fly a drone to scan the incident area; they will be able to drive to the incident scene and start performing steps for extinguishing the fire, and they will be able to cut down trees to prevent fire propagation. There will be a commander's role as well that will be in charge of the whole operation.

The fire propagation within simulations will take into consideration all the environmental parameters.

The lessons will include short training materials for handling a specific tool (a chainsaw, a fire extinguisher), present fire truck functions, drone piloting training, mapping procedures, cutting procedures, as well as a list of lessons created using the scenario builder tool.

The scenario builder will allow a specific set of users based on specific roles (trainers) to assemble a custom simulation based on the existing environments. There will be tools to add elements, hazards, pieces of equipment, and avatars to create personalized simulations. The scenarios will be stored on the server and other users will be able to access them.

The reporting module will allow the users to check their progress/statistics. The main goal is to view their performances in different activities and be able to compare them to other team members. Furthermore, by using gamification elements, the users will precisely spot the areas where they can improve their actual training and knowledge thus improving their abilities and decisions in real-life conditions.

SENSOR DASHBOARD

Web interface to visualise time-series data. This interface will visually present the data collected by IoT sensors in the field through different graphical dashboards and store them in a database, such as Graphite, Prometheus, Influx DB, ElasticSearch, MySQL, PostgreSQL, and others. In addition to visualisation, the interface will enable the study, analysis, and monitoring of data over a period of time on the basis of consultation.

BACKEND: TREEADS MODULES

This chapter defines the modules that make up the TREEADS system, highlighting their main characteristics and interconnection. Each module is a fundamental piece of the system, where the whole set forms the holistic TREEADS system. Modules are logical groupings in the system division, formed by one or several functional components, which fulfil an objective and/or functional requirements within the system. The architecture design is based on modules with the objective to provide independence and computational scalability to each section, so that the ecosystem can work on a container platform, such as Kubernetes. A component are elements of the system, which represent a functionality and have been designed as business pieces of logic. A component has been thought as a container where they solve an application need. These containers interact through data input and output microservices. In this way, data can be exchanged between components and modules, allowing the exchange of information between different tools and processes available in TREEADS platform.

The interaction of the different components of the system will be performed through the TREEADS OpenAPI, where the components will be distributed in a subset of web services according to the functional blocks. This section describes the main functional blocks and their components, as well as the required inputs and obtained outputs.

Synthesized and grouped according to the three phases of a wildfire, the blocks of the TREEADS software ecosystem have the following scheme:

General level:

- TREEADS Web applications.
- Authentication and Security
- Resource Management System (RMS): Inventory of elements.

- Sensor data service (IoT).
- Map Services.
- Fire, Wind, and Smoke propagation simulator.
- UAV Deployable Air Command and Control.
- VR/AR Client.

Prevention and preparedness

- Fire Risk Analysis Tool.
- Fire Prevention System (FPS): Risk map in urban-forest interface area.
- Fire, Wind, and Smoke propagation simulator.
- Social Media Analysis: Collection of tweets that contain indications that could lead to the generation of a fire and identification of key user accounts that could be a source of rich information during an event.
- Early Warning System update/improvement.
- Improved resilience of key infrastructures and buildings to wildfires using fire-resilient materials.

Detection and response:

- Context-awareness: A robust and intelligent framework for event-based fire detection that considers temporal, semantic and spatial correlations between events.
- Wildfire Response Engine (WRE): The WRE will manage the execution of fire response workflows. The WRE shall be equipped with prescriptive analysis methods.
- Hotspot detection and Visual Object detection.
- Social Media Analysis: Collection and analysis of fire-related Twitter posts in order to timely detect possible fire incidents and warn the interested parties.
- Evacuation and planning.
- Resource management system (RMS).
- Fire, Wind, and Smoke propagation simulator.

Restoration and adaptation:

- Burnt Scar Mapping.
- Restoration Decision Support System (DSS)
- Agroforestry for Restoration.
- Insurance Model and Risk Transfer Solutions

AUTHENTICATION & SECURITY SERVICES

TREEADS will require a set of User Authentication services to define the different levels of access according to the user's role. This block will manage the different user roles to adapt the functionality to the stakeholders. The security service that manages the access to data and functionalities according to access control list (ACL) is a transversal component of the OpenAPI of TREEADS. For this purpose, the use of a backend as an open-source service platform (BaaS) is proposed, which facilitates the development of self-hosted mobile applications and/or providers that offer hosting solutions.

BaaS offers generic features of a comprehensive back-end model that provides modular solutions for common infrastructure functions such as server configuration, user authentication, database integration, notification services or scalability, among others. This allows for an agile way to build OpenAPI TREEADS features, which, in turn, allow communications and data validation to be secured through access verification middleware in all the components of the system.

For the implementation of the BaaS architecture, there are various options, both commercial (AWS, Firebase, etc.) and open source (Parse Server AppWrite, strapi, etc.), which offer features that allow them to be integrated into the construction of the TREEADS service skeleton. Some of the most outstanding features of TREEADS are:

Authentication: Supports 3rd party authentication with Facebook, Google, Instagram, Twitter, OAuth, etc.

Object-based data model: Permits flexible data schemas to be defined via the REST API data storage, which is usually based on a JSON encoding of the object data. This data is schema-less, which implies the specification of the object keys in advance by setting the key-value pairs to be stored by the backend. These services will be used in TREEADS for the definition of layer metadata, simulation configuration parameters, etc.

User Management: User, session, and role management services, offering security mechanisms for registration, login, etc.

Cloud functions & WebHooks: Functions running in the cloud that allow the generation of functions common to all platforms.

Security: Provides security features to protect data, using unique user keys before performing any action. The service provides class-level permissions and ACLs to manage the data model.

RISK ANALYSIS TOOL

The Risk analysis tool module is a set of tools and risk indicators from real time monitoring of fuel, atmosphere, and ground by a web information system. In particular, data from the Copernicus Land Monitoring Service will be combined with other observations such as multispectral and LiDAR sensors, as well as historical wildfire data (causes, spreading, damages, timeline), to improve the decision-making process. Historical fires will be exploited as labels in deep learning models to forecast fire hazards by using satellite, meteorological and biomass data as input. The tool is a set of components, where the synergies of the different elements form the analysis tool:

- Fire exposure and risk assessment
- Agroforestry index
- Climate risks and vulnerabilities

- Early Warning System
- Accurate Forest Mapping
- Fire Hazard forecasting
- Fire Prevention System

FIRE EXPOSURE AND RISK ASSESSMENT

This component will be an Earth Observation based service kit for fire exposure and risk assessment. Using Copernicus time-series, it will provide services related to wildfire exposure and risk estimation. The services will be based on forecasting techniques and will be implemented as follows:

a) Periodically (e.g., weekly) estimate of fire hazard based on vegetation conditions (forest fuel types, vegetation moisture conditions), terrain conditions, climatic conditions of the target territory. The information collected in existing municipal prevention plans shall be evaluated during the risk specification. One approach will consist of the development of a Deep Learning model which will take as input satellite, meteorological and elevation data, in order to provide a fire risk map for specific dates. A different approach will be the processing of time series of images as video sequences, as can be seen in the following Figure 5.

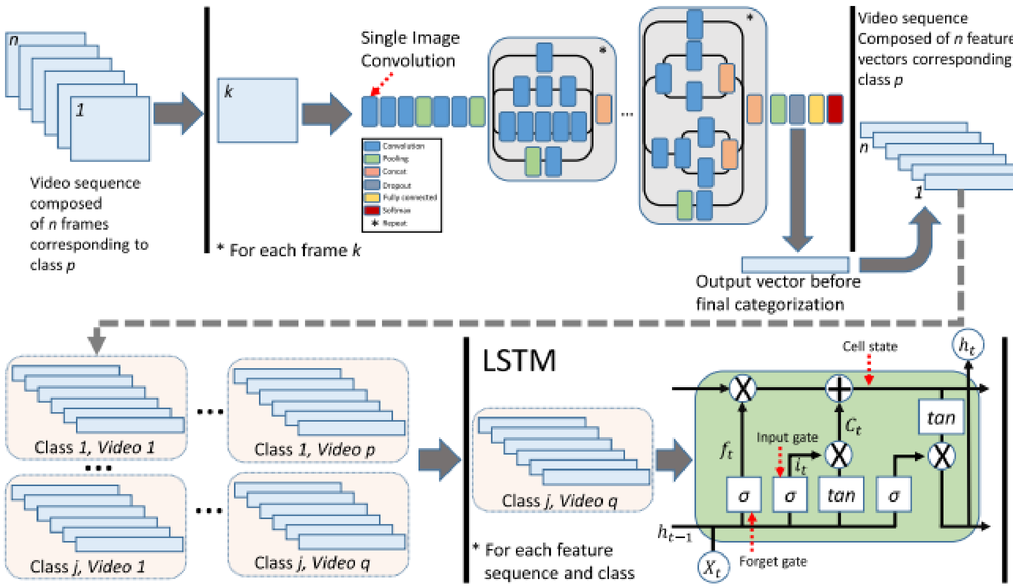

Figure 5: Processing of time series of images as video sequences.

The features of each frame will be extracted using convolutional networks (ResNeXt, ViT-32 and most probably ConvNeXt). In this way, we go from n frames (e.g., 1024x 768x3 channels) to n feature vectors (e.g., 2048 elements). This technique is carried out by discarding the CNN classification layers. This serves to: 1) Reduce the dimensionality and be able to work with the video and 2) Extract the most salient features. From the *n* feature vectors, LSTM (Long -short-term memory) and GRU (Gated Recurrent Unit) windows are composed, and a temporal model is trained whose output would be either a classification problem (risk/no risk exists) or a regression problem (risk probability), depending on the data available.

b) A service that evaluates the exposure of a given village or property to wildfire, estimating whether a fire starting at a given point in the vicinity is expected to affect it, as well as the available time for suppression and evacuation actions. By combining Sentinel-1&2 images and other publicly available cross-sectoral data, such as Copernicus services and Corine Land Cover (minimum mapping unit area of 25ha and width of 100m), will allow to develop high-resolution (10m) land-use raster map at local scale, to be enriched by additional information or Key Performance Indicators (KPIs). The developed grids will provide a detailed characterization of land-use units, where risks and vulnerability indicators, vegetation conditions and management activities will be identified. In addition, this module will be further enhanced to a medium-high resolution data (using drone and zeppelin imagery), which considerably increases the level of detail of the available data and enables the extraction of more complete information (e.g., number of specific land uses, areas with neglected vegetation, threats, etc.). In this way, it will be possible to accurately estimate the territorial vulnerability of a village and its surroundings.

c) A service to provide early warning of potential natural disasters, based on the monitoring of vegetation cover and other features available in the Earth Observation (EO) Browser. The diversity of image sources would provide different levels of warnings: from drought warnings over wide or regional areas to detection of new constructions or activities in protected areas.

Table 2: Technical aspects of the Fire exposure & Risk Assessment component.

Fire exposure & Risk Assessment	
Input parameters	Copernicus data: forest fuel types vegetation moisture conditions soil conditions climatic conditions plant cover social factors
Output parameters	Fire hazard map (weekly and daily in fire periods) Map of activities in protected areas (weekly) Detection of new constructions (annually) Drought areas (monthly/annually)
Time scale	Daily / weekly

Spatial scale	Local and regional
Technology used, libraries, software	Deep learning techniques (ConvNeXt networks, LSTM/GRU RNN) by means of Tensorflow, Pytorch
Storage	Depends on available data but several terabytes of data are expected
Computing resources	Specific machine learning computers for model training and image processing
Module's integration	The output will be in the form of temporary maps that will be integrated in the Open Data Cube, which can be visualised in the GIS platform based on the web.
Used by	Local and regional government; fire brigades

AGROFORESTRY INDEX

This component will provide an accurate value for each forest area involving information about physical characteristics such as plant and tree species at European level (e.g., canopy height model). Available public data from various sources: Copernicus Land Monitoring Services[1] (Tree cover density, Dominant leaf type and Forest type product), Forest Information System for Europe[2], European Agroforestry Federation[3], Global Forest Watch[4] (information on deforestation processes and fire alerts), CORINE[5] land cover data (agricultural/forestry interfaces that are highly relevant in fire prevention management) Agroforestree Database[6] from the Center for International Forestry Research and World Agroforestry and national databases (e.g. Spain forest inventory[7], LiDAR databases[8], etc.), in conjunction with pattern recognition using computer vision will be used to make a comprehensive classification of forest species and agroforestry information. Thus, each cluster in this classification will be associated to an agroforestry index.

---

[1] https://land.copernicus.eu/pan-european/high-resolution-layers/forests

[2] https://forest.eea.europa.eu/topics/forest-basic-data/basic-data

[3] https://euraf.isa.utl.pt/resources/

[4] https://www.globalforestwatch.org/map/

[5] https://land.copernicus.eu/pan-european/corine-land-cover

[6] https://www.worldagroforestry.org/output/agroforestree-database

[7] https://www.miteco.gob.es/es/biodiversidad/temas/inventarios-nacionales/inventario-forestal-nacional/default.aspx

[8] https://pnoa.ign.es/productos_lidar

The TREEADS simulator will need this data to assess the fuel capacity of the forest, create additional layers of data for a better simulation of fire spread, achieve better estimations of climate change, estimate the rate of forest reduction or rate of forest restoration.

Table 3: Technical aspects of the Agroforestry Index component.

Agroforestry Index	
Input parameters	Copernicus Land Monitoring CORINE Land cover Forest Information System Sentinel
Output parameters	Agroforestry Index: plant and tree species
Time scale	Annual
Spatial scale	Pixel (e.g., 10 m for Sentinel 2)
Technology used, libraries, software	GDAL, Python or Cloud services such as GEE.
Storage	Depends on available data but several gigabytes of data are expected
Computing resources	Image processing computer. The level of hardware resources has not yet been quantified
Module's integration	The output will be in the form of maps integrated in the Open Data Cube that can be visualised and employed by other components of the TREEADS platform.
Used by	Local and regional government; fire brigades

CLIMATE RISKS AND VULNERABILITIES

This component will be responsible for the territorial assessment of climate-related risks and vulnerabilities. It will be based on the Copernicus Climate Services (C3S) Analytics to identify metrics and KPIs related to existing territorial vulnerabilities and threats (baseline and projections). These analytics are based on artificial intelligence techniques (AI) applied to Sentinel and Copernicus imagery to extract knowledge.

EO data and GIS analysis are key to define local land-use and local climate scenarios mappings to analyse climate change risks and vulnerabilities. The European Regional Climate Model has a spatial resolution range from 11 to 44km, which is too coarse for local assessments of climate change. In a similar way, land-use maps are too coarse to support adaptation and mitigation measures in planning activities at local and EU level. For this reason, the TREEADS project will complement the publicly available information with layers of additional information based on observations from drones and zeppelins that will serve to obtain more precise metrics using computer vision techniques for the processing of the acquired images.

Table 4: Technical aspects of the Climate risks and vulnerabilities component.

Climate risks and vulnerabilities	
Input parameters	Climate data from Copernicus.
Output parameters	Map of climate vulnerabilities
Time scale	Monthly or annual
Spatial scale	Local and regional
Technology used, libraries, software	Deep learning techniques (ConvNeXt networks, LSTM/GRU RNN) by means of Tensorflow, Pytorch
Storage	Depends on available data but several terabytes of data are expected
Computing resources	Dedicated machine learning computers (powerful GPUs) for model training
Module's integration	The output will be in the form of temporary maps that will be integrated in the Open Data Cube and which can be visualised in the GIS platform based on the web.
Used by	Local and regional government; fire brigades

EARLY WARNING SYSTEM

The TREEADS Early Warning System will provide fire hazard indicators similar to those currently presented in the European Forest Fire Information System (EFFIS). The EFFIS network adopted the Canadian Forest Fire Weather Index (FWI) System as the method to assess the fire danger level in a harmonized way throughout Europe. However, given the different climatic conditions in Europe, EFFIS publishes two indicators that provide information on the local/temporal variability of the FWI compared to a historical series of approximately 30 years. These indicators are the ranking, which provides percentiles of occurrence of the values, and the anomaly, computed as a standard deviation from the 30-year historical mean values. Currently, the fire danger forecast module of EFFIS provides access to fire danger indices using numerical weather forecast from two deterministic models i.e., ECMWF (8 km) and MeteoFrance (10 km), and one probabilistic model, the ECMWF Probabilistic model, at 18 km spatial resolution. FWI is computed from the ECMWF model (8 km), which provides 1 to 9 days forecasts, and from the MeteoFrance model (10 km), which provides up to 3 days forecasts. The Fire Weather Index is mapped in 6 classes (very low, low, medium, high, very high and extreme) [9].

The aim is to improve the indicators provided by EFFIS by improving the coverage by relying on the coverage of the four-layer approach: satellite, zeppelin, high drone, low drone and using deep learning techniques to extract more accurate information.

Table 5: Technical aspects of the Early Warning System component.

Early Warning System	
Input parameters	EFFIS & FIRMS indices black carbon carbon dioxide sulphur dioxide four-layer approach API from the different services
Output parameters	Visualization of all TREEADS functionalities, and of pilot-specific functionalities
Time scale	Real time status data / offline
Spatial scale	Local, regional and European scale
Technology used, libraries, software	Python, GDAL, etc.
Storage	Dependent on available data, but several gigabytes of data are expected
Computing resources	Image processing computer. The level of hardware resources has not yet been quantified.
Module's integration	New layers to be added to the data model
Used by	Local and regional government; fire brigades

ACCURATE FOREST MAPPING

The objective of this component is to provide a set of basic vegetation mapping products to be used for high-precision forest mapping. Mapping provides information on plant and tree species in the forest and their physical and geometrical characteristics (e.g., Canopy Height Model). The aim is to obtain an accurate representation of the forests to improve the current knowledge of forested areas, using the four-layer approach of TREEADS: satellite, zeppelin, high drone, low drone.

[9] https://effis.jrc.ec.europa.eu/about-effis/technical-background/fire-danger-forecast

Advanced forest mapping technology based on hyperspectral imagery derived from Earth Observation satellite data (PRISMA) and LiDAR scanning coming from drones or existing databases will be used to create the most accurate analysis of the current state of the forest. LiDAR will provide the geometry of the digital twin of the forest, while hyperspectral imagery will provide the functionality of the digital twin. Hyperspectral data will be used to discriminate between fuel type and condition, while LiDAR data will be applied to provide additional information on the 3D structure of fuels and the ground surface for further forest fire prevention and management. LiDAR data from drones allow the detection, measurement, and characterisation of individual trees, as well as the analysis of shrubs.

The individual tree segmentation process needs a canopy height model, and LiDAR-derived models of shrub cover can be used to characterize the vegetation in the strips and the urban forest interfaces.

As a result, physical and geometric characteristics of the forest based on more precise calculations of vegetation indices can be provided (e.g., tree species, tree height, biomass, fuel type, fuel conditions, etc.). In addition, a more precise physical and geometric characterization of the forest close to the evaluation date will allow for more accurate simulations. These physical and geometric characteristics will serve as data input to the simulation models, providing a differential value in the three phases of intervention, beyond the 3D representation.

Table 6: Technical aspects of the Accurate Forest mapping component.

Accurate Forest Mapping	
Input parameters	LiDAR point cloud Sentinel- NDVI PRISMA-Hyperspectral Forest Map of Spain (Fuel Type)
Output parameters	Point cloud 3D Forestry Map with physical information Canopy Height Model (CHM)
Time scale	Annual. (Every fire season)
Spatial scale	Local, regional and European scale
Technology used, libraries, software	Scripts for downloading and preprocessing Copernicus imagery QGIS plugin for PRISMA
Storage	Depends on available data and pilot areas but several terabytes of data are expected
Computing resources	High
Module's integration	No integration is required. The generated data will be stored in the database and repository of TREEADS to be later used to feed models, modules, for visualization purposes, etc.

Used by	Fire brigades

FIRE HAZARD FORECASTING USING SATELLITE DATA AND MACHINE LEARNING MODELS

This component will provide an operational fire hazard forecasting tool offering next day predictions at a local level, through the fusion and exploitation of multi-modal Earth Observation imagery, Copernicus datasets and ground sensors. The period of daily fire risk forecast system at municipality level will be during the fire season (maximum radiation period - May to October approximately) based on a "traffic light" approach. This forecast would be similar to the one provided by the Spanish AEMET service but at European scale, where besides considering key values of surface temperature and other soil moisture values, socio-economic aspects of the municipalities will be addressed. These socio-economic aspects, such as human activities, festivities, etc., are key in a fire hazard forecast, as they increase the risk of fire. An example of this are municipalities that largely multiply their population (e.g., by 7) during the summer season.

This component will also provide uncertainty estimates for the predictions (i.e., provide information about how confident the model is for its output). The output of this module will be potentially used for fire management activities and actions from the authorities. So, having uncertainty estimates for the outputs can play a significant role in better understanding the problem and help in better decision making.

Table 7: Technical aspects of the Fire Hazard Forecasting component.

Fire Hazard forecasting & ML	
Input parameters	Time-series of climate Time-series of vegetation Historical burnt Areas (EFFIS) Biomass Meteorological Satellite imagery Land Cover Elevation Social Data (population, festivities calendar...) Distance to Roads
Output parameters	List of municipalities and/or WMS map based on a "traffic light" approach (red, orange and green) indicating the risk index and the uncertainty associated with the predictions.
Time scale	Daily during fire season
Spatial scale	LAU
Technology used, libraries, software	Python (pyTorch library) and assisting Python modules
Storage	Dependent on the pilot data

Computing resources	32 GB RAM, 1 GPU
Module's integration	No integration is required. The generated data will be stored in the database and repository of TREEADS to be later used to feed models, modules, for visualisation purposes, etc.
Used by	Local and regional government

FIRE PREVENTION SYSTEM (FPS)

It will use the different risk indicators generated for TREEADS (e.g., social indicators, complex indicators of climate factors, meteorology, human activity, etc.) to delimit the urban-forest zones/interfaces in a first approach, as well as to monitor their condition. These areas are especially critical since they are often not properly maintained and have neglected or overgrown vegetation, which poses a high potential risk considering their proximity to inhabited areas. A second approach will extend this application to other critical areas. Most of the population in rural and urban-forest areas, tend to be elderly, which can complicate evacuation. In addition, people living in these areas are often unaware of the risk and do not know the best evacuation routes or the basic protocols to follow in case of fire. There are of course other factors that need to be considered (e.g., in housing estates there are often a lot of decorative hedges that are highly flammable). This tool will help to generate risk and priority maps for cleaning and maintenance purposes in these areas based on the detailed information and indicators provided by TREEADS.

Table 8: Technical aspects of the Fire Prevention System module.

Fire Prevention System	
Input parameters	Sensor data. Real time data of fuel, Atmosphere Ground Digital Elevation Model land cover maps satellite imagery meteorological data, cartographic maps IoT data Fire Risk Forest Land and urban planning Climate Meteorological Human activities Cultural traditions
Output parameters	Potential risks in urban-forest interface
Time scale	Annual
Spatial scale	Local and regional
Technology used, libraries, software	QGIS
Storage	Depends on available data and pilot areas but several gigabytes of data are expected.

Computing resources	High. Out of TREEADS platform
Module's integration	No integration is required. The generated data will be stored in the database and repository of TREEADS to be later used to feed models, modules, for visualisation purposes, etc.
Used by	Local and regional government; fire brigades

MAP SERVICES

Map services are responsible for making maps available on the Internet. A map service makes maps, entities, and data attributes available within many types of client applications and at different levels. A common use of a map service is to display data on a set of basemap tiles similar to that of Google Maps.

The TREEADS architecture has been designed to allow connecting N satellite image data cubes and to facilitate processing a wide variety of Earth Observation datasets, through the openEO API.

The openEO API currently supports up to seven providers, such as Google Earth Engine, EODC or Sentinel Hub, which provide access to satellite imagery used for on-map visualisation and on the fly operations. Following this scheme, a TREEADS own OpenDataCube (ODC) could be implemented for the construction of the enhanced four-layer detection system. The TREEADS ODC will store layers, base information, forest mapping of pilot areas, topographic data, and historical data, among others, in addition to the map products and/or indices generated from the TREEADS data analysis components.

The aim of this map service system is to leverage the computing potential of platforms such as Google Earth Engine, together with its immense catalogue of satellite imagery and planetary-scale geospatial data. This design will greatly enhance TREEADS by providing access to historic imagery and to the visualisation of time series of global and real-time imagery. Cloud map services are optimised for data visualisation without using resources in the management of the storage system infrastructure. On the other hand, classic models based on data downloading, granule storage and image pre-processing for product generation (RGB, NDVI, or others) are costly, as they require infrastructure resources (storage and computational), as well as maintenance and present a limited scalability.

The TREEADS ODC will host spatial information, necessary for further operations. Much of the TREEADS ODC data will be based on the collection of spatial information (LiDAR, hyperspectral, IR, etc.) that will then be stored in a layered format. The ODC layers will be part of the inputs for component processing and analysis, as well as for the TREEADS ecosystem tools that will serve the generation of new products (maps and data) for wildfire prevention and detection, warnings and forecasts.

The central spatial database, that will feed the data cube, will be a PostGIS type geospatial database. This database will contain the spatial data model and all the necessary information for raster image cubes and vector layers management, including base information, administrative boundaries, protected areas, hydrants, service stations, etc.

The map publication standards of the TREEADS services will follow OGC standards, where mainly WMS, WMS Time and GeoJSON will be employed for vector data.

Table 9: Technical aspects of the Map services.

Map Services	
Input parameters	Sentinel 2 LandSat 8 MODIS VIIRS
Output parameters	WMS TIF
Time scale	Daily
Spatial scale	Pixel and region
Technology used, libraries, software	openEO, ODC, Node.js, GEE
Storage	Dependent on the layers that are required in each pilot zone, but several terabytes of data are expected
Computing resources	32GB of RAM, 8 CPU cores
Module's integration	The result will be available through services to be integrated with third-party tools and modules
Used by	Local and regional government; fire brigades

FIRE AND SMOKE PROPAGATION TOOL

The Fire and Smoke Propagation Module is a toolbox designed for the simulation of some of the most important physical processes in the framework of forest fires. It will be composed of three different simplified physical models that can work independently or coupled, namely, a fire spread model, PhyFire; a smoke dispersion model, PhyNX; and a high-definition wind field model, HDWind. These tools can be used to support the complex decision-making process, since depending on the size of the simulation area and the level of precision, the aforementioned physical model processes can be simulated in real time.

In addition to the physical models, an Analysis of Fire Behaviour and Spread for the Development of Safety Measures will be carried out. Improvement techniques will be used, employing Machine Learning for Fire Risk Analysis and Fire Spread.

PHYFIRE:

The PhyFire model is a simplified 2D one-phase physical wildfire spread model based on the energy and mass conservation laws. This model considers the two dominant thermal transfer mechanisms in wildfires: convection and radiation. It takes into account heat loss by natural convection, the effect of wind or slope on the flame tilt, and the influence of fuel moisture content and fuel distribution and type. It has the option of incorporating random phenomena such as fire spotting.

It depends on meteorological data, temperature, humidity and wind intensity and direction. These data can be provided from measurements and/or forecasts from meteorological services. However, wind information can be improved through the use of the HDWind tool, which allows the consideration of local effects from point and scattered wind data.

The spatial information that this model requires is made up of three types of geographic data: a digital elevation model, a fuel load distribution map, and a land cover map (fuel type). Currently, it uses the Rothermel fuel classification, but can be adapted to another type of classification.

The tool is prepared to update data during the simulation process, from meteorological data to intermediate perimeters, actions by firefighting teams or new sources of fire.

To initiate the simulation process, the simulation area must be selected, and the mentioned spatial information and meteorological conditions of the simulation area must be provided. The level of precision must be determined, which varies from level precision 0 corresponding to 50 m cell size, to precision level 5, corresponding to 2.5 m cell size. The total simulation time and the number of intermediate outputs must be decided, taking into account that the process might need to stop in order to update the data (meteorological conditions, firebreaks, etc.) and relaunch again.

The source of the fire must also be provided, be it a point, a line, an intermediate perimeter, etc.

The model depends on three parameters that affect convection, radiation, and natural convection respectively.

The model provides, at the selected time steps, the burned area, and the area that is burning, that is, not only the perimeter of the fire as a line but also the position and thickness of the fire front. It also provides the mass fraction of consumed fuel to feed the smoke diffusion model PhyNX.

Table 10: Technical aspects of the PhyFire module.

PhyFire	
Input parameters	Simulation area Ignition points/line/area Topography Fuel type and load Meteorological data: -temperature -humidity -wind intensity and direction (Windfield from HDWind) Firebreaks
Output parameters	Burned area Burning area Mass fraction of consumed fuel
Time scale	OnFly
Spatial scale	from 2.5m to 50m cell size
Technology used, libraries, software	C++, Neptuno++, Parallel computing
Storage	100MB- 500MB per model
Computing resources	32GB of RAM, 8 CPU cores
Module's integration	Map Services, HDWind need to be integrated for the correct performance of PhyFire
Used by	Fire brigades

PHYNX:

The PhyNX model is an urban scale Eulerian non-reactive multilayer air pollution model, describing convection, turbulent diffusion, and emission. The model equations are solved using an Adaptive Finite Element Method with characteristics in the horizontal directions and Finite Differences in the vertical direction and splitting techniques. Precision and computational costs are improved by parallel computing techniques. The wind field used in this air pollution model is provided by the HDWind model.

The PhyNX model was initially designed for punctual emissions with no deposition, with the aim of providing pollutant concentration and Acute Exposure Guide Levels (AEGLs) values at different heights above ground.

This model is currently being adapted to simulate the dispersion of smoke from forest fires by incorporating some important parameters: combustion efficiency, fuel moisture and emission factors, for the four most important components of smoke from forest fires: CO_2, CO, CH_4 and $PM_{2.5}$.

To initiate the simulation process as a smoke diffusion model, the simulation area is defined during the PhyFire simulation, and the spatial data, the meteorological data, the mass fraction of consumed fuel from PhyFire, and eventually HDWind wind data, should be provided.

The model will provide the concentration of CO_2, CO, CH_4 and $PM_{2.5}$ in the different air layers and for the selected time steps.

Table 11: Technical aspects of the PhyNX module.

PhyNX	
Input parameters	Simulation area Topography Mass fraction of consumed fuel (provided by PhyFire) Meteorological: -wind intensity and direction (Windfield from HDWind)
Output parameters	concentration of the chosen species in each air layer
Time scale	OnFly
Spatial scale	Depends on the adaptive method
Technology used, libraries, software	C++, Neptuno++, Parallel computing
Storage	100MB- 500MB per model
Computing resources	32GB of RAM, 8 CPU cores
Module's integration	HDWind, Map Services need to be integrated for the correct functioning of PhyNX
Used by	Local and regional government; fire brigades

HDWIND:

A crucial factor for both the simulation of fire spread and the dispersion of emitted smoke is the wind. The toolbox proposed has its own wind field model that tries to improve the available wind information and/or wind predictions by incorporating local orography and temperature effects.

The HDWind model is a mass-consistent vertical diffusion wind field model, based on an asymptotic approximation of the primitive Navier-Stokes equations. The most salient feature of this asymptotic approach is that it provides a three-dimensional velocity wind field (which satisfies the incompressibility condition in the air layer) governed by a two-dimensional equation. Therefore, it can be coupled with the temperature surface distribution to account for thermal effects. Terrain slope, surface roughness and buoyancy forces are taken into account by the model. This model adjusts a three-dimensional velocity wind field in a layer under the influence of topography and temperature distribution, with a minimum computational cost. The wind velocity field obtained by the model is adjusted to several wind velocity measurements at different points in the 3D domain by solving an optimal control problem. These specific wind data can be known meteorological data, or predictions from some wind forecasting system such as WRF or HARMONIE-AROME, that is, the HDWind local model can be coupled with mesoscale predictive models to improve wind forecasts at the local level.

The model depends on a single parameter, the friction coefficient, which is related to the surface roughness length.

To initiate the simulation process independently, the simulation area must be selected. The input data needed in the simulation area are topography, roughness, and surface temperature. A set of georeferenced point wind measurements (direction and intensity) in the simulation area is also needed. When this model is coupled with PhyFire of PhyNX, the simulation area and the corresponding cartographic and meteorological data are provided by these models.

The model provides wind intensity and direction at each point of the simulation domain, which can be used in the models PhyFire and PhyNX as wind input data, so that the mesh size for HDWind model resolution is the one previously set in PhyFire or PhyNX models.

Table 12: Technical aspects of the HDwind module.

HDWind	
Input parameters	Simulation area Topography Roughness Meteorological data: -temperature -punctual wind intensity and direction
Output parameters	Wind direction and intensity on each point of the mesh of the simulation area
Time scale	Previously set in PhyFire or PhyNX
Spatial scale	Depends on the adaptive method.
Technology used, libraries, software	C++, Neptuno++, Parallel computing
Storage	10MB- 100MB per model
Computing resources	32GB of RAM, 8 CPU cores
Module's integration	PhyFire, PhyNX should be linked for the functioning of HDWind
Used by	Local and regional government; fire brigades

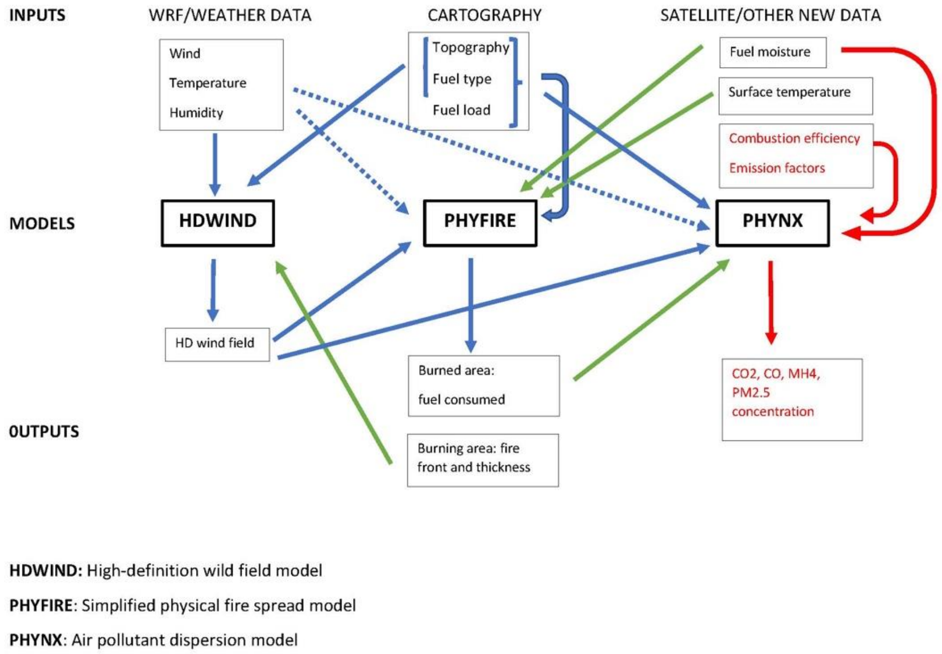

Figure 6: Flow diagram of fire, wind, and pollution propagation simulation models.

The input and output of the three models are raster files in ASCII format, but there is also the option of using MEDIT output files (format for Finite Element Method) and VTK.

It is also possible to generate simulation videos in *avi* format for non-stationary problems (PhyFire and PhyNX).

Regarding their design, it has been proposed that the models should be packaged in docker images, to allow the execution of independent container models and the ability to launch different models at the same time. The execution of the docker images will be performed through the command line interface. The set of inputs and outputs of each simulation will be defined in the workspace for the defined simulation area.

AIR POLLUTION MODELLING FOR SOURCE APPORTIONMENT (PMF)

Receptor models aim to re-construct the contribution of emissions from different sources of atmospheric pollutants (e.g., particulate matter PM), based on ambient measurement data (i.e., PM chemical composition) registered at monitoring sites. One of the most successfully applied receptor models is Positive Matrix Factorization (PMF) (Paatero and Tapper, 1994).

PMF introduces a weighting scheme taking into account errors of the data points, which are used as point-by-point weights. Adjustment of the corresponding error estimates also allows it to handle missing and below detection limit data. Moreover, non-negative constraints are implemented in order to obtain more physically meaningful factors. PMF users provide files of sample species concentrations and uncertainties and the number of sources. The model calculates source profiles or fingerprints, source contributions, and source profile uncertainties. PMF Model results are constrained to provide positive source contributions, and the uncertainty weighted difference between the observed and predicted species concentration is minimized.

The PMF Model can analyze a wide range of environmental sample data: sediments, wet deposition, surface water, and ambient air. EPA’s PMF Model reduces the large number of variables in complex analytical data sets to combinations of species called source types and source contributions. The source types are identified by comparing them to measured profiles. Source contributions are used to determine how much each source contributed to a sample. In addition, PMF provides robust uncertainty estimates and diagnostics.

In some cases, other auxiliary equations can be added in order to include a priori information such as well-known chemical profiles for certain sources. The auxiliary equations can be applied to the selected solution in the form of constraints, which can lead to a free rotation of the solution with better physical meaning than the original one. Further, a number of rotations blocking zero values can be introduced to the matrix increasing the rotational stability of the solution.

Table 13: Technical aspects of the PMF model.

Positive Matrix Factorization (PMF) model	
Input parameters	Air pollution data (Particulate chemical analysis data) / Specialized sampling and chemical analysis for air toxics
Output parameters	- Chemical profiles of potential sources contributing to measured concentration at the receptor - Estimated contribution of each source
Time scale	Dependent on measurements data, usually daily variation
Spatial scale	Dependent on measurements data (1 sampling site selected for local and regional sources contribution)
Technology used, libraries, software	US.EPA PMFv.5 software SOFI-tool
Storage	
Computing resources	4 CPU, 3.5GHz, 32GBRAM
Module's integration	
Used by	Local and regional government; fire brigades; national health agency

AIR QUALITY AND HEALTH IMPACTS ESTIMATION USING CHEMICAL TRANSPORT MODELS (WRF-CHEM):

WRF-Chem is the Weather Research and Forecasting (WRF) model coupled with Chemistry. The model simulates the emission, transport, mixing, and chemical transformation of trace gases and aerosols simultaneously with meteorology. The model is used for investigation of regional-scale air quality, field program analysis, and cloud-scale interactions between clouds and chemistry.

WRF through the WRF Pre-processing System uses interpolated data from either an external analysis or forecast for real-data cases.

The WRF/Chem model has the advantage of being totally integrated into the whole WRF system. As a consequence, the meteorological /air quality interface in terms of CPU and computational time, is almost eliminated. Moreover, WRF/Chem being an extension of WRF model, the logic software procedures are more streamlined. Pre-processors and modules are developed under the same philosophy, leading to a more compact solution, less prone to errors. The use of the same model family (meteorology and air quality) gives us more flexibility for advanced options and configurations.

The WRF Pre-processing System is a set of programs that takes terrestrial and meteorological data and transforms them into appropriate input for WRF. For the selected simulated period the meteorological data (RCP4.5), including variables, such as Air

Temperature, Boundary Layer Winds Geopotential Height are downloaded from NCAR/UCAR database. For Air Quality, the data are derived from MOZART-4 database.

The model overview with the available pre-processors is shown in Figure 7.

Table 14: Technical Aspects of the WRF-Chem.

Weather Research and Forecasting (WRF) model with Chemistry (WRF-Chem)	
Input parameters	Weather data (FNL, RCP etc, NCAR Database) Topography data Biogenic emission data (MEGAN) Anthropogenic emission data Initial and boundary conditions data (CAM Chem)
Output parameters	Gridded Air pollutants hourly concentrations (NETCDF format)
Time scale	Usually, hourly output data
Spatial scale	European domain (12kmX12km) Local domain (2kmX2km)
Technology used, libraries, software	Fortran based model in Linux environment. Various libraries required (e.g., Netcdf, mpich, zlib etc.)
Storage	2T
Computing resources	RAM: 64 GB RDIMM 32 CPU Cores
Module's integration	Linux based Cluster computer
Used by	Local and regional government; fire brigades; national health agency

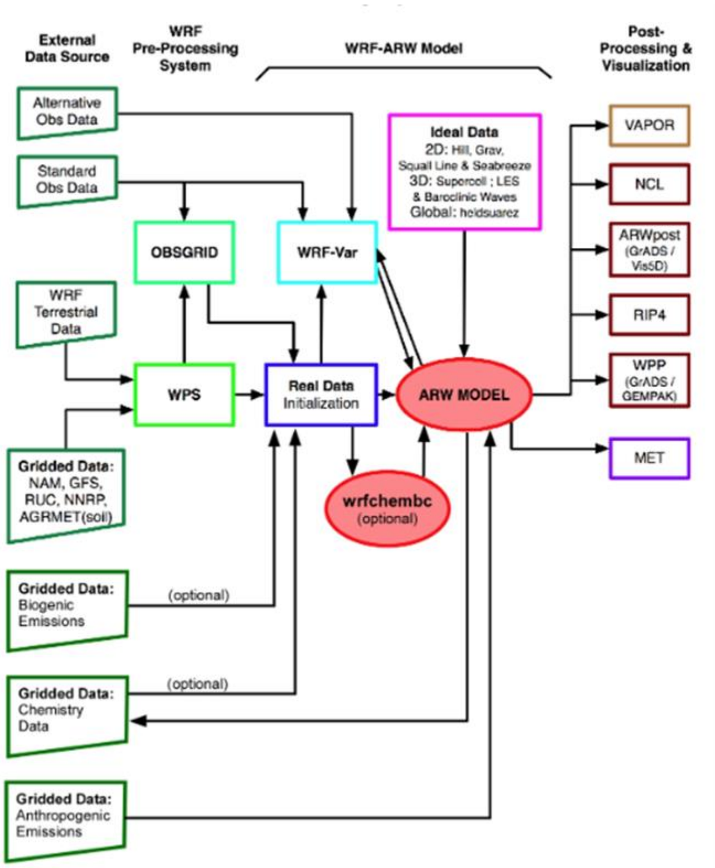

Figure 7: WRF-Chem model overview.

ANALYSIS OF FIRE BEHAVIOR AND SPREAD FOR THE DEVELOPMENT OF SAFETY MEASURES, MACHINE LEARNING FOR FIRE RISK ANALYSIS AND FIRE SPREAD

A combination of experimental and numerical investigation will be used to understand the fire behaviour, especially for fires moving on the ground. Experiments of specimens of forest and grassland ground specimens with a variation of parameters is the basis for detailed modelling of the mechanisms of fire. Small and medium scale experiments are the basis to develop a numerical model capable of predicting the fire propagation. Large-scale experiments will be used to validate the numerical models. The combination of experiments and numerical investigation allows a quantitative assessment of the influence of different heat transfer modes and therefore will significantly improve the understanding of fire propagation.

The underlying physical phenomena in a combustion process are not only very complex but also three-dimensional and non-linear. For the prediction of fluid flow field variables in a combustion process e.g., temperature, pressure, and velocities, the use of a Computational Fluid Dynamics (CFD) Code is required. The numerical simulation of turbulent fluid flows, as well as the heat and mass transfer and chemical reactions, are based on physical models of fluid mechanics. The fundamental equations of numerical fluid computation are the continuity equation (conservation of mass), the Navier-Stokes equations (conservation of momentum), the energy equation (conservation of energy) and the turbulence equations.

Ansys CFX software is a general fluid flow program to solve three-dimensional friction flows with heat transfer. For discretisation, ANSYS CFX uses the finite volume method to treat the transport phenomena like convection and diffusion. It allows the conversion of the integrated governing equations for each control volume in a system of algebraic equations, which can be solved with iterative methods.

Fire Dynamics Simulator (FDS) is a field model which is based on the finite difference method (second order accurate in space and time). Its discretisation is based on a rectangular grid. All objects included need to be integrated into the basic cell grid adopted. Main features of the Fire Dynamic Simulator concerning fire modelling are the sub models for involving combustion, heat radiation and flow turbulence. The combustion model is based on the mixture fraction approach. In detail, the mixture fraction is a scalar quantity defined as a fraction of gas at a point in the flow field that originates from fuel. This approach also includes heat and smoke production due to the combustion reaction.

Principally, the mixture fraction combustion approach assumes infinitely fast combustion reactions and controlled mixing of fuel and oxygen in the combustion processes. As an essential input for gas phase modelling the rates of reactants and products need to be established for the chemical reaction equation

For solid and liquid combustible, a pyrolysis sub model is also included in FDS. This pyrolysis model is based on the solution of a one-dimensional heat transfer equation and can be applied on boundary surfaces of the flow field.

The numerical models are used to enhance the knowledge about the physics and chemistry of wildfires. Input data for numerical calculations are generated by small and bench scale fire experiments and the German Pilot use case. Results of the numerical calculations are temperatures, velocities, smoke components, smoke yields, smoke and fire development as well as heat release rates, smoke densities and smoke layers as an approximation in space and time. These results can be used to assess different sets of fire scenarios to evaluate which fire scenarios are extremely hazardous for fire fighters and civilians.

For practical purposes, the various CFD set-ups can be used to gain knowledge for the tactical approach or for the efficient evacuation of localities. Results of CFD calculations can be used for comparison or calibration of other sets of prediction methods. This expertise can be used in TREEADS Platform.

Further, the CFD simulations form the basis for a Machine Learning model for real-time fire and smoke spread predictions. We will translate physical models into machine learning models, which are becoming popular for solving physical models at much lower computational cost. For instance, physics-informed neural networks encode the governing equations directly into the network and, in practice, rely on automatic differentiation to efficiently compute solutions. The machine learning model is intended to incorporate knowledge about vegetation and environmental conditions. The detailed input and output parameters of the ML model depend on the data that are available to train the model. They will be specified in the phase of the model construction, in collaboration with the related task partners.

Table 15: Technical aspects of Analysis of fire behavior and spread for the development of safety measures.

Analysis of Fire Behaviour and Spread for the Development of Safety Measures, Machine Learning for Fire Risk Analysis and Fire Spread	
Input parameters	Raw materials Materials properties
Output parameters	Temperature, velocity, soot fraction, smoke gas components, heat release rate in each grid point of the computational domain, smoke layer height, flame thickness
Time scale	Discretisation of time, time stepping
Spatial scale	Discretisation of space, CFX: FVM, FDS: FDM
Technology used, libraries, software	Ansys CFX, FDS, Pyrosim
Storage	3 GB per model
Computing resources	Workstation, HPC (High Performance Computation) Cluster
Module's integration	Adapting numerical models with advanced approach to wildfires, especially to ground fires (simulation of fire and smoke spread). Generating a logics table with the knowledge about fire behaviour extracted from the fire simulations ran.
Used by	Local and regional government; fire brigades

REMOTE SENSORS - IOT

A system that consists of a multitude of low-cost IoT platforms consisting of sensors strategically spread in the forest which will be able to monitor nearby flammable gas and smoke emissions (such as LPG), local temperature and humidity, capture images and sounds and detect motion. This component is in charge of the cloud based IoT system. It collects information from the environmental sensor network, using LoRaWAN, the Internet of Things and MQTT protocols. This part has been designed using the IoT cloud services offered by the main Cloud providers, i.e., Google, for the communication of the services and the storage of temporary sensor data.

For the connection to LoRaWAN, hardware developed by the different partners of this task will be used, while MQTT will be the cloud-based backend manager of Google IoT Core. Cloud IoT Core will publish the events received from LoRa® Gateway via Cloud Pub/Sub of Google Cloud Platform.

Those components that need sensor data inputs can perform queries in the NoSQL database "sensor Database". The database technology of mongoDB or influxdb have been proposed for this first design. The ISO 10303 repository can also host sensor data, both descriptions of the sensors and the collected sensor measurements, that is, all measurements or a filtered selection for long term storage in a configuration-controlled environment. The repository is currently set up to work with the cloud based IoT Eclipse Arrowhead Framework, a result of the Horizon/ECSEL project Arrowhead Tools.

Table 16: Technical aspects of the Remote Sensors module.

Remote Sensors	
Input parameters	Sensor data: Temperature, humidity, Air Quality, C02, CO…
Output parameters	Data in a temporary database
Time scale	Minutes
Spatial scale	Dependent on the distribution of the sensors in the pilot areas
Technology used, libraries, software	LoRaWAN, MQTT, Google IoT Core
Storage	Dependent on the number and frequency of sensors, but several gigabytes of data are expected
Computing resources	It will depend on the hardware sensor. In the backend it is estimated 4GB RAM, 2 Core
Module's integration	Message Queuing Telemetry Transport (MQTT)
Used by	Local and regional government; fire brigades

EVACUATION & PLANNING

This module will implement the tools that help those responsible for managing a fire scenario, for optimization of route management and patrol in the area. To optimize decision making processes, detailed ground and air information will be required and obtained from real-time fuel, atmosphere and ground monitoring that will enable the integration of heterogeneous, accurate and up-to-date tools. This component will combine information regarding the spread of the fire, the direction of the wind, the condition of the road network, in order to estimate the evolution of the incident and potential evacuation routes, and additionally will use input from the object detection component, regarding potential presence of humans, animals or vehicles that are trapped in the scene and need to evacuate.

ARTIFICIAL INTELLIGENCE FOR MISSION PLANNING & SWARM COORDINATION

It will include an optimized component for general ecosystem behaviour, based on a model-free tool, developed, and validated in previous EU projects (NOPTILUS, RAWFIE, ROBORDER, CREST and ARESIBO), that will exploit its self-learning cognitive capabilities towards establishing a real-time, adaptive calibration and operational framework for optimized surveillance coverage. The main focus will be to exploit fused and raw real-time data towards producing usable knowledge and cognition that will be leveraged in order to establish a fully autonomous action controller for all the surveying assets (e.g. UAVs, Airships, cameras on site etc.). Based on the embedded machine learning algorithm, this component will be able to periodically re-calibrate a certain set of parameters outlining the navigation control strategy adopted at each given instance. The aforementioned have as an ultimate goal to provide an increased situational awareness to the corresponding authorities, assist to fully utilizing the assets available and remove human error from making decisions under pressure and any possible delays. Summarily, we see that such contributions may benefit all the aspects of TREEADS via three well defined tools:

- Path Planning for Fire Prevention and Damage Estimation/Restoration:
- Resource Management System for Optimal Situational Awareness During the Fire
- Decision Support System for Optimal Guidance of the Fire Suppression Units

Table 17: Technical aspects of the Evacuation & Planning component.

Artificial Intelligence for Mission Planning & Swarm Coordination	
Input parameters	The waypoints each drone has to visit, so as to provide an effective coverage of the area. Drone parameters
Output parameters	Report including the evacuation plan. Location map similar to Google Maps API Directions Service
Time scale	Seconds
Spatial scale	Meters
Technology used, libraries, software	DARP (Divide Areas Algorithm for Optimal Multi-Robot Coverage Path Planning): Python, OpenCV, Pygame, Scipy
Storage	Dependent on the simulators, megabytes are estimated for your component
Computing resources	12 GB RAM, 4 Core
Module's integration	The integration would be through microservices
Used by	Local and regional government; fire brigades; rescue brigades

ICROWD – MULTI-MISSION SIMULATIONS PLATFORM FOR CROWD AND LIVESTOCK MANAGEMENT & EVACUATION

The iCrowd platform is an agent-based crowd simulator, capable of simulating small- (tens of agents) and large-scale (thousands of agents) crowds. It can be utilized for scenarios in any bounded area, such as buildings' interior and exterior, stadiums, open-air festivals, and public areas of increased traffic.

Features:

- fully featured simulation tool regarding the physical level of behaviour modelling, based on biometric attributes like mass, velocity, geometry cognition as well as the interaction between agents during their movement by performing collision avoidance among them, for a realistic representation.
- allowing fully customizable experiments.
- iCrowd utilizes the concept of Behaviour Trees. Behaviour Trees is a well-established modelling technique widely used in Artificial Intelligence and game development domains.

The iCrowd Simulation platform has evolved into a complete domain-independent agent-based behaviour simulator with an emphasis on crowd behaviour and evacuation simulation. It reflects an effort to implement a modern, multithreaded, data-oriented simulation engine employing state-of-the-art programming technologies and paradigms. It is based on an extensible architecture that separates core services from the individual layers of agent behaviour, offering a concrete simulation kernel designed for high-performance and stability. Its primary goal is to deliver an abstract platform to facilitate implementation of several Agent-Based Simulation solutions with applicability in several domains of knowledge, such as:

(i) Social Behaviour Simulation and Modelling

(ii) Non-Player Character AI for Game-oriented applications and Gamification activities.

(iii) Crowd behaviour simulation during [in/out] door evacuation.

(iv) Urban and Highway Traffic and Transportation Simulations.

Some key technical features are the following:

- High performance parallel execution model developed in C++17, with a standards-compliant, cross-platform (Win32, Linux, MacOS) codebase.
- Data-oriented approach (prefer concrete, statically allocated, memory-aligned structures over pointer-based heap-allocated structures intended for polymorphic calls).
- Intelligence model using Behaviour-Trees.
- High-precision movement model based on ClearPath.
- Scriptable through an embedded Lua interpreter.
- Extended connectivity support through TCP/UDP.

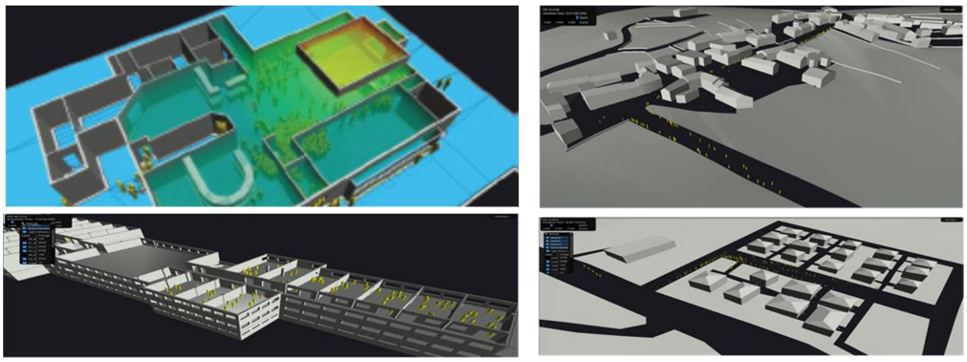

Figure 8: iCrowd Visualizations in diverse scenarios including indoor & outdoor evacuation.

Table 18: Technical aspects of Crowd & Evacuation Simulation.

iCrowd Crowd & Evacuation Simulation	
Input parameters	Scenario parameters (config file) Fire & Smoke simulation models, livestock behaviour models
Output parameters	Multiple parameters and KPIs related to the scenario and upon agreement. These can be related to time and spatial information with regards to evacuation of crowd, vehicles and potentially livestock or other mission related behaviour (e.g., first responders) and behaviour model (e.g., bottleneck detection, evacuation time, delays, injuries and other)
Time scale	Seconds
Spatial scale	Meters
Technology used, libraries, software	High performance parallel execution model developed in C++17, with a standards-compliant, cross-platform (Win32, Linux, MacOS) codebase. Unity based 3D visualization
Storage	-
Computing resources	Workstation, HPC (High Performance Computation)
Module's integration	REST API
Used by	Local and regional government; fire brigades; rescue brigades

UAV DEPLOYABLE AIR COMMAND AND CONTROL SYSTEM (CCS)

This component will manage the airship command and control system (CCS) that represents the main interface for users to access to the functionalities deployed in the HAPS via MCC, allowing the monitoring of the airship, the request of multispectral images (EO/IR), and the image processing. MCC, connected with the airship, could be connected to a 4G/5G network to serve this functionality.

The CCS API will use telemetry to collect system information such as operational status, location, orientation, battery level and service history.

The CCS will specify, design, integrate and test all on-board and ground communication hardware, software and protocol components for a consistent and versatile airship connectivity and communication infrastructure that will essentially be based on 4G/5G and satellite communication technologies.

The system will support VLOS (Visual Line of Sight) - actual laws in Spain does not allow BVLOS-, remote monitoring and telemetry, image/video reception and also pre-processed media reception.

The airship will only have manual avoidance available.

Table 19: Technical aspects of the Command and Control System module.

Command and Control System	
Input parameters	Pending to be defined (API Requests)
Output parameters	EO/IR Images/video Processed EO/IR images/video ECOSAT telemetry
Time scale	Seconds
Spatial scale	Meters
Technology used, libraries, software	Epsilon 140 HD EO/IR with the following features: - Hitachi global shutter HD sensor with 30x continuous optical zoom and 1.3°nFOV - Flir Tau2 IR 640x512 sensor with 50mK sensitivity- 60mm. Thermal lens with 7.7° fixed FOV - Integrated onboard video processing unit - Electronic Image Stabilization - Object tracking - Scene Steering - Analog video output (PAL or NTSC). Flir TAU2 30mK detector upgrade 1 IR sensor upgrade to Flir Tau2 with sensitivity of 30 mK instead of standard 50 mK sensitivity. Human target detectability ranges 2000 meters. Onboard recording and snapshot (compatibleE135/140/175, all detector configurations) High precision Geo-Location incl. INS module with Dual GPS 1 Turnkey solution for automatic steering of the gimbal towards chosen geographic coordinates. Including IMU module with two GPS antennas.
Storage	-32 Gb flash drive in HAPS. Video can be downloaded in flight. Internal HDD - Internal HDDs in MCC's workstation

Computing resources	- Workstation (EDGE Controller software available if required) in MCC
Module's integration	REST API
Used by	Fire brigades

RESOURCE MANAGEMENT SYSTEM (RMS)

The resource management component is responsible for enabling end-users to coordinate resources and efficiently manage the available material and human resources in an area, in order to have an Optimal Situational Awareness during a fire. This information is of interest in order to coordinate tactical, strategic and operational activities in the event of an alarm.

This resource management system is key in TREEADS, as it acts transversally during the three main phases of a fire. Different modules of the system will require the results and information from the RMS.

The data foundation of the RMS may be provided by the ISO 10303 repository; managing and browsing RMS data is possible through the web-client of the repository or through its REST API.

Table 20: Technical aspects of the RMS module.

Resource Management System	
Input parameters	The GPS position of the operational area.
Output parameters	Sheets containing the resources and means available
Time scale	Seconds
Spatial scale	Meters
Technology used, libraries, software	Spatial Database
Storage	About 100MB per province
Computing resources	4 GB of RAM, 2 CPU cores
Module's integration	REST API or Open Database Connectivity (ODBC) connection.
Used by	Local and regional government; fire brigades; rescue brigades

RESTORATION TOOLS

This module comprises the tools to create pre-fire condition models for accurate post-fire restoration. As well as key indicators in the evaluation of burned areas and soil restoration.

RESTORATION DECISION SUPPORT SYSTEM (DSS)

The TREEADS Restoration Decision Support System (DSS) for adaptive post-fire management (DSS-APM) will be a central component of the proposed ecosystem. Post-fire mapping, satellite and drone imagery, cartographic databases, on site environmental measurements, social factors, and management objectives will be the input to the restoration DSS.

The DSS component will also define the protocol for the use of remote sensing with drones for immediate post-fire environmental assessment of burned areas (BA).

The DSS will estimate fire severity and environmental vulnerability of the burned area from ground level sensor data, field work, satellite data and remote sensing. Additionally, the DSS will be able to provide information on the locations and extent of the fire refuges (e.g., unburned, or low-severity vegetation patches) remaining after the fire event.

The DSS will provide the generation of early post-fire management maps with recommended interventions depending on the main objectives of managers and landowners (e.g., to preserve biodiversity, to maintain forest productivity, to control risk of subsequent fire); the map will illustrate management recommendations in at last four categories: no intervention areas, salvage logging and natural generation, and drone seed spread.

The DSS will define a methodology for sampling and monitoring wildlife in burned areas. The use of drones, equipped with thermal cameras, together with sensors, will allow remote sampling of mammals and birds.

Table 21: Technical aspects of the Decision Support System module.

Decision Support System	
Input parameters	Post-fire mapping (e.g., fire perimeter EFFIS) Satellite images Cartographic databases (e.g., DEM, Land Cover maps...) Social factors (e.g., property structure, protected areas) Management objectives Sensor data (RGB, IR, multispectral, thermal images, LIDAR)
Output parameters	Fire severity map Environmental vulnerability map Map of wildlife refuges Map of recommended interventions Protocol for the use of sensors
Time scale	On-fly
Spatial scale	ROI (Region on Interest) - Landscape level and patch level
Technology used, libraries, software	Appropriate libraries and software to perform the task will be selected soon.
Storage	Dependent on the resolution and the size of the datasets; storage requirements cannot be calculated at this moment.
Computing resources	
Module's integration	Still under development.
Used by	Local and regional government; forest managers

AGROFORESTRY FOR RESTORATION

This component will develop a wildfire model that will utilize UAV to provide evaluating indicators for soil assessment. Those indicators will be basic soil physical and chemical characteristics such as soil pH, carbon, and the selected plant micro- and macro- nutrients. As long as those indicators are evaluated using multiple data sources from the TREEADS sensors, an Artificial Intelligence approach will be used to evaluate the soil state. The obtained soil characteristics and the evaluated indicators will be used as input, for the optimisation of the seed pods that will be deployed to create more fertile soil conditions.

In addition, this component will allow to improve the management of the animal evacuation plan in the pre-forest phase. The animals will be able to re-enter the post-fire area after they are fed with specific IoT feeders able to contribute to the restoring or improving soil fertility.

Table 22: Technical aspects of the Agroforestry for restoration module.

Agroforestry for restoration	
Input parameters	This model will use Satellite datasets for the implementations of the first iterations of the models. With the maturity of the project and the availability of TREEADS technology, the model will use data coming from the project drones and sensors.
Output parameters	The outcome will be certain indicators that the corresponding partners will define, regarding soil properties and characteristics, that are necessary for the development of their technologies.
Time scale	Temporal Resolution will be defined in a more mature stage of the module.
Spatial scale	Spatial Resolution and Region of interests will be defined in a more mature stage of the module.
Technology used, libraries, software	Appropriate libraries and software to perform the task will be selected later; but initial indications point to the use of Python programming language and corresponding libraries.
Storage	Dependent on the resolution and the size of the datasets, it is not easy to calculate storage requirements at the moment. However, a storage space of 2TB should be enough.
Computing resources	The development of the algorithms requires the use of a GPU workstation, which has been foreseen in the costs of TUC partner and is currently being procured.
Module's integration	At the moment, it is not possible to define the module's integration, as this will be affected by the results and the need of the pilots.
Used by	Local and regional government; forest managers

BURNT SCAR MAPPING

This component will provide an accurate and timely mapping of the affected area soon after a wildfire event. It will exploit multi-resolution satellite data as well as auxiliary data inputs (e.g., DEM, land cover maps, etc.) which will assist the detection and mapping of the burnt area. The final output will be a binary mask of the scar in a high spatial resolution.

Table 23: Technical aspects of the Agroforestry for restoration module.

Burnt Scar Mapping	
Input parameters	Satellite data from Copernicus (and other auxiliary sources)
Output parameters	A binary mask of the burnt area.
Time scale	Daily. Multiple products can be produced per day (quality will vary depending on cloud/smoke contamination).
Spatial scale	Better than MODIS (500m) and close to Sentinel-2 (20m or 60m)
Technology used, libraries, software	Python (pyTorch library) and assisting Python modules.
Storage	Dependent on the pilot.
Computing resources	for training: 32 GB RAM, 1 GPU for production: to be defined
Module's integration	REST API
Used by	Local and regional government; forest managers

INSURANCE AND RISK TRANSFER SOLUTIONS

The Insurance and risk transfer component will collect data on fire risks, hazards, exposure, and vulnerability from the different modules embedded in the TREEADS system. These are complemented by select case-based results (e.g., for demonstration) derived from a probabilistic wildfire model developed for retrospective, current and future (climate change) analyses on basis of the collected data as well as data from external data providers, including Copernicus and EFFIS.

The component will collect data related to the insured and non-insured costs of wildfire activity (both direct and indirect) related to different key sectors, including insurance, infrastructures, buildings, forestry, and biodiversity/ecosystems. Based on these findings, a GIS-based economic damage cost and loss estimation assessment tool will be developed and integrated into the TREEADS system. This spatial tool will be based on an econometric analysis and allow stakeholders to assess the economic efficiency of different risk management options, including restoration, adaptation, and prevention measures from a multi-sectoral perspective.

Table 24 - Technical aspects of the Insurance and risk transfer solutions

Insurance and Risk Transfer Solutions	
Input parameters	Hazard, exposure, vulnerability, fuel and/or risk maps produced by the PhyFire, Fire Exposure & Risk Management, Decision-support System modules and/or the embedded probabilistic fire model (present and future) Climate data from Copernicus (climate projections and ERA5 Land reanalysis)
Output parameters	Fire damage cost and economic cost estimates for selected sectors (including insurance, infrastructures, buildings, forestry, biodiversity/ecosystems) Map of insurable assets Estimates of potentially insured costs
Time scale	Event-based, expected annual damage (EAD)
Spatial scale	Local and regional
Technology used, libraries, software	QGIS, Python
Storage	Depends on whether it will be seamlessly possible to import GIS information directly from the other modules, e.g. PhyFire, to avoid data redundancy. The size of the economic part of the database is fairly moderate; the storage capacity needed for storing the results of offline runs with a probabilistic fire model will depend on how many pilot experiments will be carried out.
Computing resources	A QGIS system with an associated GIS database system, which is able to run moderately heavy Python code and seamlessly access data from other modules on the TREEADS Platform,
Module's integration	The output will be in the form of temporary maps that will be integrated in the Open Data Cube and which can be visualised in the GIS platform based on the web.
Used by	Local and regional government; insurance companies

Based on a process involving external insurance and other experts, desk research and the identification of best practices in Europe, Australia and the US, the GIS tool will also identify the locations of insurable assets and based thereupon the potentially insured costs.

DETECTION AND RESPONSE PROCESSES

The present module belongs to the detection and response phase.

HOTSPOT DETECTION

TREEADS proposes to perform the hotspot detection following a coarse to fine approach that can take advantage of the four layers used.

The hotspot detection will integrate the EFFIS (European Forest Fire Information System) services from Copernicus and FIRMS (Fire Information for Resource Management System) from NASA for mapping active fires based on MODIS and VIIRS. The MODIS and VIIRS satellites make it possible to detect hotspots and thus identify active fires. The MODIS sensor on board the TERRA and ACQUA satellites identifies areas on the ground that are clearly hotter than their surroundings and marks them as active fires. The difference in temperature between areas that are actively burning compared to neighbouring areas makes it possible to identify and map active fires. The spatial resolution of the MODIS active fire detection pixel is 1 km. VIIRS on board the NASA/NOAA Suomi National Polar-orbiting Partnership (SNPP) uses similar algorithms to MODIS to detect active fires. VIIRS active fire products complement MODIS active fire detection and provide improved spatial resolution compared to MODIS. The spatial resolution of the active fire detection pixel for VIIRS is 375m. In addition, VIIRS is capable of detecting smaller fires and can help delineate the perimeters of large fires in progress.

The objective of this component is to integrate these services into the platform and offer differentiating functionality in hotspot detection, for which several improvement stages have been proposed:

1. Integrate the EFFIS and FIRMS services in TREEADS to offer a better fire warning service based on a focused area (polygon or bounding box).
2. The identification of smoke plumes for a given polygon or bounding box based on satellite images.
3. High-resolution hotspot detection from drones and zeppelins through thermographic analysis of smoke and fire plumes. The results obtained from the computer vision and artificial vision of the cameras will be provided to the hotspot detection service, for the registration of hotspots when detected. This task will develop the dimensional analysis software of edge elements in vehicles, drones, and fixed cameras in the field.

Table 25 - Technical aspects of the HotSpot Detection module.

Fire Ignition Detection	
Input parameters	EFFIS - Active fire FIRMS- Active fire Thermographic images
Output parameters	Active Fires Layer
Time scale	On fly
Spatial scale	Meter
Technology used, libraries, software	Thermographic images Statistical analysis
Storage	100MB
Computing resources	1 CPU, 128MB
Module's integration	No integration is required. The generated data will be stored in the database and repository of TREEADS to be later used to feed models, modules, for visualisation purposes, etc.
Used by	Fire brigades

VISUAL OBJECT RECOGNITION ON EMBEDDED SYSTEMS

This component will acquire visual data, including RGB and thermal images, from various sources such as drones, zeppelin and ground cameras and will employ Machine learning algorithms, in order to perform object detection, tracking and localization. The main utilities of object detection component will be to detect and track people, animals, or goods in danger, on one hand, and, on the other hand, to detect objects that could possibly pose a threat. Additional functionalities will be considered, such as traffic monitoring, assisting in vehicle and personnel monitoring, search and rescue missions, overseeing evacuation missions etc. Object classes and specific functionalities will be further defined through user requirements during the development phases.

Deep learning architectures will be utilized, with a special focus on minimizing computational burden, especially for the algorithms that will be integrated to edge devices. Therefore, the main challenge involves the design of efficient models with minimum cost on computational resources. For this reason, one-stage object detection architectures will be employed and enhanced, such as MobileNet and YOLOR algorithms, that are significantly faster than two-stage architectures, ensuring at the same time, high precision results in real operational scenarios.

Table 26 - Technical aspects of Visual Object Recognition on Embedded Systems component.

Visual Object Recognition on Embedded System	
Input parameters	RGB and Thermal images
Output parameters	Types, bounding boxes and location of detected objects
Time scale	Real-time
Spatial scale	Meters
Technology used, libraries, software	One-stage Deep Learning Object Detection architectures, such as YOLOR TensorFlow machine learning platform
Storage	At least 100GBs, for the storage of high-resolution RGB and thermal images from different sources.
Computing resources	1 GPU/device of 8Gb for edge devices Multiple GPUs of 12-16Gb for algorithms running on the server
Module's integration	It will be installed on embedded devices, and it can be dockerized for visual sources without embedded processor.
Used by	Fire brigades

CONTEXT-AWARE DETECTION OF EMERGING FIRE-RELATED SITUATIONS

This component will be developed in a resilient and intelligent framework for event-driven, context-aware fire detection that will identify emerging critical situations that require specific actions, such as adaptation or control of the fire response process. The adoption of an event-driven computing paradigm is envisioned, through the modelling and detection of critical situations based on the temporal, semantic and spatial correlations between events. The detection, prediction and analysis of context related situations that may affect decision making and actions will be based on a real-time model applying machine learning algorithms.

Table 27: Technical aspects of the Context-aware Detection of Emerging Fire-related Situations module.

Context-aware Detection of Emerging Fire-related Situations	
Input parameters	Data from IoT sensors (e.g., smoke detectors, environmental sensors etc.). Data generated by other TREEADS services that are useful for detecting emerging fire-related situations (e.g., outputs of wildfire propagation simulator, image-inferred fire severity through the analysis of images from drones, UAVs, Satellites, social media data etc.)
Output parameters	Emerging fire-related situations. Rules in the form of complex event patterns for modelling and detecting critical situations that represent knowledge elicited from the main crisis management actors.
Time scale	Almost every second, 24/7
Spatial scale	Depends on the geolocation information provided by the event producers (see input parameters above)
Technology used, libraries, software	Complex Event Processing system (CEP) able to digest real-time and heterogenous sensor data to detect (crisis) situations that require specific response actions
Storage	Depending on IoT sensor availability at the pilot.
Computing resources	8 GB of RAM, 8 CPU cores
Module's integration	The integration will be done through an event middleware allowing event producers to push new input parameters in the form of events.
Used by	Fire brigades

WILDFIRE RESPONSE ENGINE (WRE)

The WRE will manage the execution of fire response workflows. The WRE will be equipped with state-of-the-art prescriptive data analysis methods, which will provide the ability to analyse real-time data, anticipate and predict a critical situation and recommend courses of action to mitigate them.

Table 28: Technical aspects of the Wildfire Response Engine module.

Wildfire Response Engine	
Input parameters	Emerging fire-related situations generated by previous component (see Table 27) Rules defining how to respond to different emerging situations.
Output parameters	Actions that the various stakeholders should perform as a response to an emerging fire-related situation detected by the previous module. Such actions which are part of a business process management workflow, are consumed by other modules of the platform that are responsible for communicating the message to the various stakeholders (first responders, citizens, authorities etc.)
Time scale	This module is activated upon the identification of an emerging fire-related situations.
Spatial scale	Depends on the spatial scale of fire response workflows in the pilot.
Technology used, libraries, software	Business Rules Management System Business Process Management Engine
Storage	Depending on IoT sensor availability at the pilot.
Computing resources	8 GB of RAM, 8 CPU cores
Module's integration	The integration will be done through an event middleware allowing the context-aware detection of emerging fire-related situations module, to trigger the Wildfire Response Engine upon the detection of a situation of interest.
Used by	Local and regional government; fire brigades

SOCIAL MEDIA ANALYSIS

This module will focus on the monitoring of fire events as they are expressed on social media (Twitter, in particular) by individuals, such as online users that are noticing a fire or indications of a potential fire, e.g., smoke. Based on well-defined search criteria (keywords, accounts, bounding boxes), social media data will be collected in a real-time manner using Twitter API and will be further analysed in order to filter out irrelevant information (reducing noise) and to enrich them with geo-information. The estimation of relevance of a post will be achieved with classification techniques that use textual and/or visual features, while the automatic geotagging will involve the recognition of words that refer to locations and their association to exact coordinates. Moreover, this module will include density-based approaches for discovering user communities on social media and identifying key-players in these communities, i.e., user accounts that play an important role during a fire event and affect other users. Another subtask will be the fusion of social media data with alternative types of information, such as satellite images, aiming at a more sophisticated assessment of the severity of the incident.

Table 29 - Technical aspects of the Social Media Analysis module

Social Media Analysis	
Input parameters	• JSON file with credentials (API keys) • JSON file with search terms • Data from Twitter
Output parameters	• Tweets in JSON format (both original information coming from Twitter and analysis outcomes, e.g., detected location) • Vector with geotagged tweets as points
Time scale	Almost every second, 24/7
Spatial scale	Twitter geoinformation is disregarded completely, because it is quite rare (less than 2% of collected tweets) and its reliability is questionable according to recent literature. Instead, OpenStreetMap API is used for retrieving the latitude and longitude of the locations detected in the tweet text with NLP techniques (usually in country/city/neighbourhood level, not street-level).
Technology used, libraries, software	• Python 3 • R • pandas • TensorFlow • MongoDB
Storage	More than 5m posts are expected to be collected (~50GB of hard disk) and will be stored in a MongoDB.
Computing resources	10GB RAM (for all involved services)
Module's integration	Can be dockerized (the same applies to involved services, e.g., geotagging).
Used by	Local and regional government; fire brigades

COMPLEMENTARY SERVICES

The TREEADS System will feed itself with different external services to obtain information or incorporate specific functions.

WEATHER API

There are dozens of services for accessing large databases of weather and historical meteorological information, such as: Weatherstack[10], Dark Sky[11], OpenWeather[12], AccuWeather[13], Weatherbit[14], Meteomatics[15], HERE[16], etc. The objective in TREEADS is to integrate some of these APIs to generate maps, input parameters for models and modules that require meteorological information to generate results.

SOCIAL API

The Social Media Analysis component will collect social network data from Twitter to track real-time posts and perform analytics to extract further knowledge and ingest enriched information into the TREEADS system. To this end, it will heavily rely on Twitter API[17], which allows establishing an open connection and retrieving matched tweets in real time. The various endpoints (e.g., Tweets, Users, etc.) and access levels (i.e., Essential, Elevated, Academic) will be selected according to the project's needs that will arise. A Twitter developer account is required to use Twitter API and all related activities will comply to Twitter Development Agreement and Policy[18].

OPENSTREETMAP

There is a variety of public and private map services where it is possible to find detailed and up-to-date information about points of interest, streets, bus lines, etc. around the globe. An example of this is OpenStreetMap[19] (OSM) which includes tools to model such information, to obtain map "mosaics", for data download with Overpass API[20] and even query language for data mining. OSM is more than a map of the globe, for searching and

---

10 https://weatherstack.com/

11 https://darksky.net/

12 https://openweather.co.uk/

13 https://www.accuweather.com/

14 https://www.weatherbit.io/

15 https://www.meteomatics.com/en/weather-api/

16 https://developer.here.com/documentation/destination-weather/dev_guide/topics/overview.html

17 https://developer.twitter.com/en/products/twitter-api

18 https://developer.twitter.com/en/developer-terms/agreement-and-policy

19 https://api.openstreetmap.org/

20 http://overpass-api.de/

navigation. It provides free and unlimited access to the dataset, with information about the history of changes, without limitations. It also emphasizes local knowledge which can be helpful during an event. Basically, the result is a map made by local experts.

Moreover, different options of map services will be evaluated and if necessary, will complement the basic OSM Tool to ensure that the basic layer information, not only for a representation of a base map, is supplied to the TREEADS Ecosystem.

The basic TREEADS OSM Tool by EFB will be an external complementary tool available in the TREEADS Ecosystem and it will be developed with open-source technologies and services. Its main functionalities will be the following:

1) Serving data from OSM database to the relevant services/ modules of TREEADS Ecosystem. The OSM Tool will have a built-in API available, created according to the needs of the collaborative TREEADS partners. Through this API partners can receive the data needed, processed, and formatted in valid JSON format to use them on their apps and services.

2) Offering information to involved individuals and/ or authorities through an interactive map. An interactive map will be developed in which information from the OSM database will be displayed. Additionally, local authorities and individuals with proper rights will be able to add/ edit features and their relevant information, available to all involved parties.

In the case of an event, the proper features, around a point of interest, can be highlighted on the map to provide useful information. The available features can involve points, routes (linestrings), and areas (polygons and or multipolygons). The development will be based on the information of the OSM database and a proper Javascript framework (e.g., OpenLayers or Leaflet) for handling the features and the layers of the interactive map. On the backend proper server-side technologies (e.g., PHP and MySQL) will handle the storing and serving of this information from and to the interactive map.

COPERNICUS LAND MONITORING SERVICES

Copernicus is the European Union's Earth Observation programme, where information is provided through six thematic services: terrestrial, marine, atmospheric, climate change, emergency management and security. All information is open access. The Land Service is divided into four main components: Global, Pan-European, Local and Imagery and reference data.

In TREEADS, information layers from the Copernicus Land Service[21] will be used to assess the evolution of land areas, land use and land use changes. This information will be part of the analyses and models used in different TREEADS modules.

[21] https://land.copernicus.eu/

COPERNICUS EFFIS& NASA FIRMS

EFFIS - European Forest Fire Information System[22] - supports the services in charge of the protection of forests against fires in the EU and neighbour countries and provides the European Commission services and the European Parliament with updated and reliable information on wildland fires in Europe.

EFFIS includes a set of access applications, such as a viewer of active wildfires; a statistical data portal; a news portal; a monthly and seasonal forecast of temperature and rainfall anomalies; and a data service. The latter data service is of most interest to TREEADS, as it provides access to various indicators of fire danger forecasts, active fires, burned areas and fuel maps. EFFIS will be an essential input information source in certain modules. Additionally, TREEADS will include an early warning system component based on the use of the 4-layered approach that will ultimately provide a more detailed and better understanding of EFFIS systems, while also incorporating some improvements to the GWIS through the addition of variables such as black carbon, carbon dioxide, sulphur dioxide.

FIRMS[23] - FIRMS US/Canada is a joint effort by NASA and the USDA FOREST SERVICE to provide access to low latency satellite imagery and science data products from EARTH OBSERVATION SYSTEM (EOS) satellite assets to identify the location, extent and intensity of wildfire activity and its effects.

(FIRMS) distributes Near Real-Time (NRT) active fire data from the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard the Aqua and Terra satellites, and the Visible Infrared Imaging Radiometer Suite (VIIRS) aboard S-NPP and NOAA 20 (formally known as JPSS-1). Globally these data are available within 3 hours of satellite observation, but for the US and Canada active fire detections are available in real-time.

INSTANT MESSAGING

X/BELLO is a VoIP and instant messaging (IM) application that supports voice chat, real-time video calling and multimedia delivery over the Internet. TREEADS will count on 8BELLS instant messaging services, the secure integration of innovative multimedia applications with smart devices and sensors, AR devices, smart watches, and flexible displays. In addition, 8Bells DFF platform can work in collaboration with X/BELLO in order to collect data from all those end-user devices and store them in a centralized platform.

VR TRAINING CONNECTOR

[22] https://effis.jrc.ec.europa.eu/

[23] https://firms.modaps.eosdis.nasa.gov/

This component is responsible for the TREEADS Enhanced Reality, UX Design, Training, including virtual reality simulators for air fleet and ground resources.

TREEADS Scenario-Based Training platform will build upon Interactive Virtual Scenarios (VS) or simulations (i.e., Scenario-Based Learning; SBL) which are recognized by many teaching and learning communities as effective tools for developing reasoning and for safe training in workplace competency. The TREEADS Virtual Reality (VR) platform will be used as an online activity modelling system that allows users to assemble training activities.

The TREEADS VR training application will leverage SIMAVI's existing VR infrastructure, while the TREEADS serious game environment will be a web application that run on most modern web browsers. In order to add or edit cases, the TREEADS VR Training application will search for access on a server running the Scenario-Based Training (SBT). The SBT's platform will propose game flows to add a variety of different activity designs, going way beyond isolated virtual victim cases.

Table 30 - Technical aspects of the VR Training Connector

VR Training Connector	
Input parameters	User logging support for providing access within the VR app. Scenarios from the Scenario-Based Training online platform (SBT) Sensor's data to be shown and monitored within the VR Training program (heart rate)
Output parameters	User reports
Time scale	-
Spatial scale	-
Technology used, libraries, software	Unity3D, Photon Engine SDK, Game Creator, Oculus SDK, Blender, Studio Max, Adobe Creative Suite
Storage	About 1GB (for the scenario configuration files in jSon format)
Computing resources	Meta Quest 2 internal resources
Module's integration	-
Used by	Fire brigades

TREEADS PLATFORM

The Platform will be a set of Web services accessible from an OpenAPI formed by the integration of all the system modules and will provide front interfaces for TREEADS users.

The architecture of the system has been designed primarily to meet the functional objectives set out in the TREEADS DoA. It is based on a client-server architecture, composed of different modules with specific functionalities that are part of a whole. Those modules that offer specific Web services will offer their functions through microservices that will be linked to the TREEADS OpenAPI, which, in turn, will provide the end-user with a single data endpoint, where fire management operations can be performed considering three phases: prevention, detection and restoration.

The TREEADS client-server architecture is synthesised in Figure 9 where the main components of the system can be distinguished.

The platform design is conceived from a global perspective. Due to the project capabilities, in TREEADS the scope is set at the level of the pilot areas, since most of the modules and/or services of the system require specific information, which can be compiled specifically for those areas (adapting the sources of information to the different data models) by the corresponding pilot leaders.

However, despite the availability of data, the versatility of the system architecture design allows the use of the platform both for a specific area or for global reach. The design of the architecture is based on containers and microservices, which allows the scalability of the system. This design is ideal to be deployed on cloud infrastructures (AWS, Azure, Oracle, IBM, ...). One of the main handicaps when working in Geographic Information System (GIS), is to have the necessary infrastructure to provide the capacity needed, both in terms of storage and of daily processing of imagery acquired from satellite, drones, or UAV platforms. This process involves downloading, processing, storage, and publication through map services. In the project, these processes are focused on the pilot areas, where value-added products such as risk maps, detailed forest mapping, hotspots, sensor data, drones, etc., are produced. Regarding complementary layers, such as Digital Terrain Models, administrative limits, details of roads, cadastral data, and vegetation maps, their role is mainly to support the decision making with additional data. These layers come from satellites and/or public services (Copernicus, EFFIS, ...), and are consumed by the platform from EO cloud platforms, such as GEE, SentinelHub, DIAS, etc., allowing to have a global reach, minimizing the deployment infrastructure of cloud services.

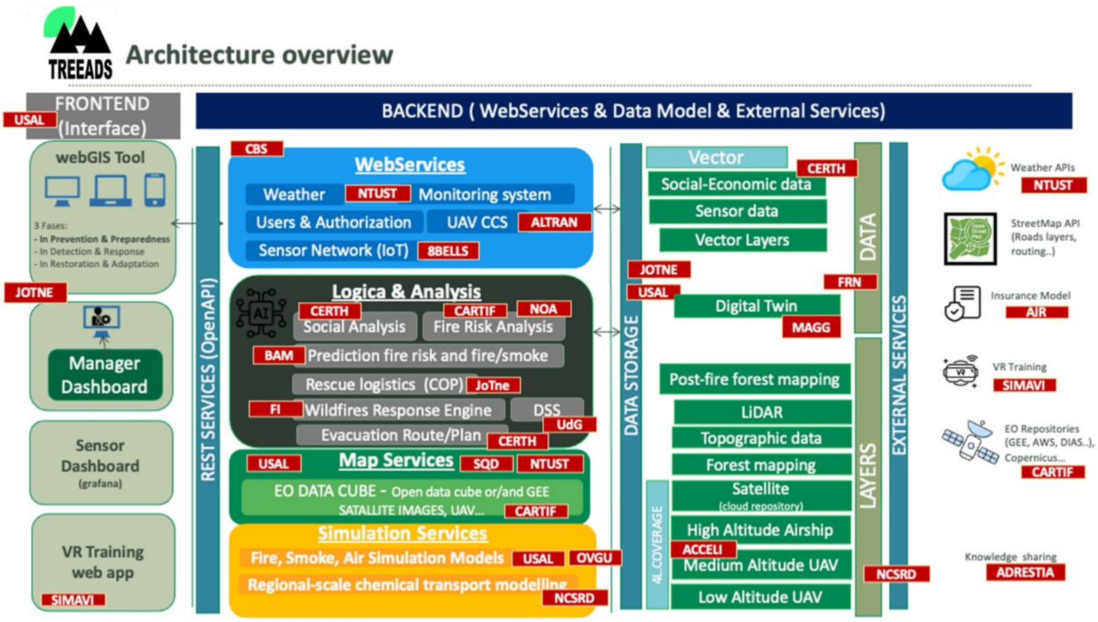

Figure 9: Schematic Simplified TREEADS client-server architecture.

CLOUD-BASED SERVER ARCHITECTURE

The architecture design is based on functional and interconnected modules, composed of one or more components developed by partners with expertise in the field. Current technologies allow the development of containers and/or services where the execution of the different parts can be communicated. The successful operation of TREEADS will depend on its design, the information available and the infrastructure on which it relies. Given the size and availability requirements of TREEADS, it is recommended that the architecture design is provided through a cloud platform. The main advantages of a cloud infrastructure are cost reduction, greater accessibility and mobility, security, unlimited storage capacity, scalability, automatic updates, and optimisation of resources, among others. On the other hand, the main disadvantages of using a cloud platform are the mandatory connection to the Internet, the dependence on a cloud provider[24], or possible cyber-attacks.

To mitigate the disadvantages, TREEADS' own ICT Tools systems will be employed in the field and solutions in the design of applications will be developed to mitigate connection losses, as well as to minimize the dependence on the cloud service provider. To this end, TREEADS will rely on the use of free software, visualizations, and platforms for the organization of automation processes involved in the implementation, management, and adjustment of their integrated applications.

[24] Cloud provider dependence is related to the use of their own solutions and services, which increase the dependence: e.g., serverless, APIs, security systems, proprietary databases, etc.

TREEADS OPENAPI – SERVICES WORKFLOW

According to the system specifications, TREEADS must be designed to have an open API and an interoperable and scalable system, where the same data format is employed for all data sources. The OpenAPI must satisfy the interoperability of TREEADS to achieve holistic European cross-border and cross-country communication.

The proposed design for TREEADS OpenAPI builds on the functionality offered by the BaaS framework, which will allow inheriting functionality, using middleware and other mechanisms offered by the back end, such as information access management, logs, etc. The design is based on the generation of different service subsets grouped by functionality, with the OpenAPI being the only public endpoint for managing the TREEADS ecosystem. In this way, new third-party applications can query information and interact to enrich the system's database.

In this first version, the following groups of services have been proposed:

- BaaS Services
- Fire Risk Analysis Service
- UAV Air Command Control API
- Decision Support Service
- Evaluation and Planning Service
- Map Services
- Insurance model services
- Fire and smoke propagation services (simulation services)
- Resource Management Services
- IoT Services
- Detection and Response Services
- Data exchange services
- Data configuration services

DATA ACCESS

The TREEADS platform will distribute the data in different databases, depending on the nature of the information (satellite, metadata, sensors, etc.). The connection and data transfer between the Platform and the databases will be provided by a customized Data Access Layer, defined as block B-03. The customized Data Access Layer will be built on top of the BaaS Framework and will act as a gateway to the databases. The data access layer shall implement a set of security mechanisms to prevent unauthorized access.

DATA FUSION AND DATA MODEL

CONFIGURATION CONTROL, DATA EXCHANGE AND LONG-TERM ARCHIVAL – ISO 10303 REPOSITORY

Collaboration across the TREEADS system is critical. Collaboration introduces challenges concerning the integrity and consistency of shared information. The TREEADS system brings together multiple companies, each of which with their own systems and processes.

The ISO 10303 repository establishes a unified common or master database in which resources and process information from many sources (such as systems, companies, etc.) can be merged and consolidated. The repository is designed to handle many product versions and configurations and to distinguish between information packages received from multiple suppliers and partners. Using the ISO 10303 standards the repository addresses TREEADS requirements of data interoperability and Long-Term Archiving and Retrieval (LOTAR).

The repository can optionally be used with the Eclipse Arrowhead Framework, which supports Cloud-to-Cloud communication in an IoT setting. Thus, sensor measurements can be streamed to the digital twin and its digital sensor representations in the ISO 10303 repository.

DATA ACCESS LAYER

The system will have a hierarchical data source composed of different levels making data filtering and data analysis easier. The implementation of a Data Access Layer is considered to give access both to data from system databases and to repositories containing images acquired within the TREEADS Project.

The main database of the system "BaaS Database" has been designed with a NoSQL schema with the aim at providing flexibility in the definition of the data model. This database will be used by the central back end for the system data management. The database will store base data, configurations, users, data schemas, and metadata of the TREEADS imagery, distributed among cloud storage.

The main objective of the division of information in several databases is to provide space to the different types of data of the TREEADS project, coming from sensors, satellite, drones, and simulation tools. This structure facilitates the design of the architecture, allowing the distribution of the data with the architecture and preventing the possibility of the size of the data becoming a problem in the future.

The organization of the data will be as follows:

- Metadata: NoSQL database focused on the metadata of the layers, schemas, and parameterization of the system and user management.
- Temporal data series: NoSQL database or time series data to store data coming from sensors towards its posterior use for monitoring. All or some of the sensor measurements may be stored in the semantically rich ISO 10303 repository for configuration with related resource data and for long-term storage.

- Spatial information: SQL database with geospatial functions. The design proposed is based on the image cube Open Data Cube for the use of geospatial and analysis data.
  - Spatial Database: spatial database with layers with basic information, forest mapping, topographic and historical data, and TREEADS maps. This database will perform a hierarchical management of the data, together with the image cube schema.
  - Satellite and drone image repository: cloud repository with Earth Observation (EO) data such as DIAS, Google Cloud and AWS for accessing satellite imagery. Cloud services with EO datasets present several advantages, such as minimizing the infrastructure, requiring less access time and providing global coverage. The download, processing and storage of satellite data is not necessary because all services are available in the TREEADS infrastructure through the cloud services. In this way, the size and computation effort required by the TREEADS infrastructure is reduced.
- External services data: social media APIs (such as Twitter API), weather, sensor data, and other services providing necessary data for TREEADS system. This point requires data harmonization, to facilitate the integration of all data in the system and for all modules to be able to use the data for the generation of layers and products for the TREEADS system such as risk evaluation, alerts, wind data for the simulation tools, humidity maps based on sensors and temperature maps.

Note: In Annex I, the data model schemas for the spatial layers of webGIS have been defined.

SUMMARY TABLE OF THE SYSTEM INFORMATION LAYERS

List of the main layers required by the TREEADS system in order to provide information to the phases: prevention and preparedness, detection and response, restoration. This table specifies each layer, the group of the layer in the hierarchical structure, its typology, spatial and temporal scale, the source of the layer and the entity that is responsible for its generation.

Table 31: Table of the system information layers.

ID	Layer	Group	Type	Time Scale	Details	Sources
L01.0	Administrative Limits	Cartography	Vector	once	NUTS Resol.	GADM
L02.0	Forest mapping	Vegetation Mapping	Vector	annual	Species, Age, Fuel type	CORINE Land Cover (CLC) Forest Map of Spain National Forest Inventory (IFN-III) IFN-4 EFI
L03.0	Digital Terrain Model	Orography	Vector	annual		SRTM Digital Elevation Data
L04.0	Lakes, Rivers, Tributaries…	Topographic	Vector	once		CLC
L05.0	Roads	Topographic	Vector	annual		OSM
L06.0	Canopy Height Model (CHM)	Orography	Raster	annual		PNOA (image + LiDAR)
L07.0	Forest fuel types – Fuel model	Vegetation Mapping	Raster	annual		IFN4 MODIS. MCD12Q1.006 EFFIS fuel map
L08.0	National Parks	Vegetation Mapping	Vector	once		
L09.0	Land Cover	Vegetation Mapping	Raster			CORINE Land Cover
L10.0	Towns / Cities / campsite	Topographic	Vector	annual		CLC UCDB Urban Atlas EarthWorks Stanford Eurostat efrainmaps OSM
L11.0	Emergency points	Civil Resources	Vector	annual	Pharmacies, police, hospitals	OSM and Local authorities
L11.1	Hospitals	Civil Resources	Vector			OSM and Local authorities

L11.2	Pharmacies	Civil Resources	Vector			OSM and Local authorities
L11.3	Police	Civil Resources	Vector			OSM and Local authorities
L12.0	Hydrants	Civil Resources	Vector	annual		OSM
L13.0	Service stations (Petrol)	Civil Resources	Vector	once		OSM
L14.0	Industrial Areas	Civil Resources	Vector	annual		Local authorities OSM
L15.0	Extinction and rescue parks	Others	Vector	once		Local Management OSM
L16.0	Landfills	Others	Vector	once		
L17.0	Black carbon concentration	Others	Vector	once		ESA
L18.0	Carbon dioxide concentration	Others	Vector	once		ESA
L19.0	Sulphur dioxide concentration	Others	Vector	once		ESA
L20.0	Firebreaks	Others	Vector	annual		ESA
L21.0	Protected areas	Vegetation Mapping	Vector	annual		Protectedplanet WDPA EFFIS
L22.0	RGB	Vegetation Mapping / Historical Data	Raster	daily		GEE (Sentinel2)
L23.0	NDVI	Vegetation Mapping / Historical Data	Raster	daily		GEE (Sentinel2)
L24.0	NDMI	Vegetation Mapping	Raster	daily		GEE (Sentinel2)
L25.0	Hyperspectral–PRISMA	Vegetation mapping	Raster	daily		PRISMA
L26.0	Temperature	Weather	Vector	daily		Weather service (transform data)
L27.0	Humidity	Weather	Vector	daily		Weather service (transform data)

L28.0	Air Quality	Weather	Vector	daily		Weather service (transform data)
L29.0	CO	Weather	Vector	daily		Weather service (transform data)
L30.0	CO2	Weather	Vector	daily		Weather service (transform data)
L31.0	Precipitation	Weather	Vector	daily		Weather service (transform data)
L32.0	Active Fires	TREEADS	Raster	daily		EFFIS FIRMS – Active Fire data
L33.0	Sensors Map	TREEADS	Vector	annual		Sensor location
L34.0	Early warning map	TREEADS	Raster	daily		
L35.0	Fire hazard map	TREEADS	Raster	weekly		
L36.0	Map of activities in protected areas	TREEADS	Raster	weekly		
L37.0	Drought areas	TREEADS	Raster	monthly		
L38.0	Map of climate vulnerabilities	TREEADS	Raster	monthly/ annual		
L39.0	Potential Risk urban-forest	TREEADS	Raster	annual		
L40.0	Fire spread map	TREEADS	Raster	daily		
L41.0	Fire Weather Index (FWI)	Fire Danger Forecast	Raster	daily		EFFIS
L42.0	Initial Spread Index (ISI)	Fire Danger Forecast	Raster	daily		EFFIS
L43.0	Build Up Index (BUI)	Fire Danger Forecast	Raster	daily		EFFIS
L44.0	Fine Fuel Moisture Code (FFMC)	Fire Danger Forecast	Raster	daily		EFFIS
L45.0	Duff Moisture Code (DMC)	Fire Danger Forecast	Raster	daily		EFFIS
L46.0	Drought Code (DC)	Fire Danger Forecast	Raster	daily		EFFIS

L47.0	Normalized Burn Ratio (NBR)	TREEADS	Raster	dates		
L48.0	Slope	Topographic	Raster	once		
L49.0	Fire perimeter	TREEADS	Vector	daily		EFFIS
L50.0	Inventoriable resources	Civil Resources	Vector	annual		Local authorities
L51.0	Firebreaks	Others	Vector	annual		OSM, BTN

RISK ANALYSIS

This section describes the main risks detected during the design of the TREEADS system architecture: One of the risks could be the lack of input data to the components for their adequate performance; this is an important issue that should be mitigated. What is more, the harmonization of the data is especially important for its input in the system components, with a minimum coverage of the pilot areas, and reaching the whole Europe and surrounding countries if data are available for them. Another risk is the incorrect or incomplete definition of those modules that are transversal to the whole system, such as the resource management, the emergency plan, and the map and evacuation services, which results and functionality are needed in other modules. The functioning of the transversal modules mentioned, together with the quality of the information and its simplicity are key for their interoperability.

The impossibility of structuring the elements of the system in modules, or not being able to design the elements with independent computing capabilities, can imply a risk in the performance of the TREEADS ecosystem. This could be a problem for the functioning of services in different components and/or in the central unit of the OpenAPI. For this reason, the integration and design strategy should be well-delimited and described with detail in the section of functional requirements.

The table below presents the major risks per TREEADS component, their consequences, probabilities, as well as mitigation strategies. This risk table is additional to the project's risk management table and analyses further the risks regarding the design and development activities. It is subjected to updates based on the development progress. These updates are going to be included in technical deliverables submitted in the context of WP4-WP7 as well as the second iteration and the final TREEADS architecture (D3.6, D3.7).

Table 32 - Risk analysis

System	Risk	Consequence	Probability	Mitigation
Auth & Security service	Security level	Vulnerabilities Open Access	Low	Application of increasing restriction measures
Fire Risk Analysis Tool	Insufficient data input in the component for index computation. No valid tool if no data is available. Scale for risk analysis (European, national, local, etc.) Access to raw satellite data	Unavailability of risk index	Medium	Detailed definition of the risk index and their temporal and spatial scales. Dockerizable risk analysis tool
Map Services	Integration of data cubes ODC- openEO Map publication OGC Data loading OpenEO limitations with external services GEE	Functionality limitations with openEO vs Platform Non compatible with OGC Obligation to create an own ODC: this implies having a big-size infrastructure.	Medium	Limitation of the products needed for the adequation to the platform. Limitation in output data format. External storage
Fire and Smoke propagation tool	Data not available for all Europe High-computation processes	High computation time	Low	Close collaboration with end user partners and rely on Standard.
IoT	Communication standards. Data losses	Data not available in real time	Low	Close collaboration with end user partners and rely on Standard Use of cloud infrastructures for the management of IoT data

Fire ignition detection	Edge computing. Data delivery from the edge to TREEADS system	Big size data. Lack of data in real time	Medium	Close collaboration between partners for the detailed definition of the data model to be sent to TREEADS services.
Federated Learning Edge	Specialized domain	Non adequate hardware	Medium	Tested domains. Hardware + UAV testing plans
Reforestation capsule				
ICT Tools	Disconnection. Areas out-of-range	Disconnection between hardware units and the TREEADS ecosystem. Processing interruptions. Visualization of information not available in real time	High	APP design strategies for real time (pooling, events, websocket, …)
DSS	Decision algorithms design. Data no available or not updated.	Lack of information for decisions in the restoration phase	High	Close collaboration between partners. Well-defined model. Specification of the system outputs. Simple interface.
Evacuation & Planning	Update routes and vehicles for routing computation. Design of evacuation plans.	Lack of data resources in the area. Not having an adequate evacuation route. Not having evacuation areas and protocols in the different countries for the establishment of evacuation plans.	High	Definition of routing sources in rural cartography, according to type of vehicle and node restrictions. Harmonization of evacuation protocols at European level.

UAV CCS	Protocols. Communication integration with Back-end	CCS as an external service to TREEADS. No integration of the UAV flight planning functionality in TREEADS platform.	Medium	Outsourcing the CSS service. Creation of a set of data services for UAV. Close collaboration with end user partners and rely on Standard.
RMS	Data model. Integration with other modules (DSS, Evacuation…) Harmonization	Lack of data in an area. Data not usable for neither DSS nor evacuation routing	Medium	Simple but accurate model for data input and output. Design of an indexed system for geographic information. Simple management interface.
Detection and response processes	Definition of data and processing flows. Domain definition. Pattern definition. Data complexity.	No timely detection of ignition points	High	Definition of hierarchical levels of alerts to reduce execution time. Collaboration with the partners to define specific flows and domains according to the different experiences and know-hows.
Social Media Analysis	Lots of noise in the collected tweets (e.g., metaphorical usage of keywords)	Low-quality data	High	Constant refinement of search terms and ML to automatically filter out noise.
Social Media Analysis	Limited number of tweets in particular languages or areas of interest (due to low popularity)	No data available	Medium	Creation of synthetic tweets for demonstration purposes and more focus on other languages/areas.
Data Interoperability	Data from different source systems use different data definitions and formats	Not possible to merge or correlate data from different sources	High	Agree on a standard terminology and data model that all sources will map their data definitions to

Insurance and risk transfer solutions	Availability of relevant insurance and other loss data is limited (e.g., due to confidentiality)	Not possible to derive damage cost curves for key sectors including insurance	High	An indicator-based approach will be employed. Close connections to the insurance sector

INTEGRATION PLAN

The integration plan will be developed in WP7, which objective is to consider all the toolsets and solution construction in the three phases of TREEADS, to create an ecosystem optimized for the use of each technology solution and service.

From WP7, D7.1, D7.2 and D7.3 are developed with the following objectives:

- To build an Incremental deployment strategy that follows a step-by-step procedure, for enhancing per phase toolsets towards the improvement of current fire Management systems.
- To produce all necessary interfaces during the integration process.
- To define and specify a detailed interoperability plan among the TREEADS Ecosystems mechanisms.
- To integrate the developed software components to form the final TREEADS Ecosystem.
- To build a Continuous Integration and Deployment approach.
- To deploy and operate a code maintenance repository with enhanced version control and continuous integration capabilities.
- To establish the governance model and requirements for the creation and management of the TREEADS Ecosystem, aiming to achieve sustainability after the end of the project.

The Integration Plan aims at creating a TREEADS Platform that covers a wide variety of aspects towards the Integrated Fire Management:

From a software perspective, TREEADS Platform focuses on user interaction with the platform, and the main contribution of TREEADS is the ability to have a set of tools for expert users. These tools intuitively monitor alerts, display layers of information, simulate fires, contact rescue teams, etc., from a web environment to provide a solution to the three phases (prevention, detection, and restoration) in wildfires. A great contribution is the availability of daily information, as well as ready-made products that complement current services in firefighting.

One of the major bottlenecks in other solutions is the preparation of the data sets for the posterior analysis of the layers of information, calculation of routes, fire simulation, vegetation status, analysis of indexes over time, etc., which implies an enormous effort, when the time for action is crucial in this environment. Therefore, having updated information (vegetation humidity, satellite data, meteorological data, etc.) and accurate information is key in many aspects to help in making the best possible decision.

Certainly, provided the perception of an integrated fire management, the TREEADS Platform does not satisfy some needs. The heterogeneity of information at the European level, and even the absence of information, may make unfeasible the implementation of solutions for some situations, for example, having a detailed inventory of human and material resources at each point of the territory.

Therefore, the platform has been designed from a high-level perspective to provide the user with tools and a global vision of updated information. In this way, the expert user can be supported by the ad-hoc designed tools together with other third-party tools to form the Integrated Fire Management System. The platform clearly contributes to all three phases of action in wildfires, but perhaps the contribution is more significant in the prevention and restoration phases through the incorporation of ad-hoc designed tools. The detection and response phase is a more complex phase that requires external elements, quick decision making and where human knowledge and experience is key to respond to the action.

The platform contributes to the user to have the best information available, updated, as well as provides innovative elements of intercommunication, support and information from drones, wearables for rescue teams, etc. This technology lays a foundation in the action phase, but there is room for improvement.

CONCLUSIONS AND IMPLICATIONS

This deliverable contains the first version of the design of the TREEADS System. The design started from the specification of the functional, operation and technical requirements, following with the definition of the TREEADS Platform architecture and the design of its main components and subsystems.

This deliverable also includes the description of the components of the TREEADS Platform architecture, and the first set of technical risks that can affect the implementation tasks, from design to integration.

The current document is considered as a picture of the design and progress decisions taken up to this month in the TREEADS project. However, the process remains active, in such a way that the results in this deliverable can be subjected to changes and updates. Following decisions and further design details for different parts of the system will be included in the following deliverables D3.6 and D3.7, in months M21 and M33, respectively.

The platform design is conceived from a global perspective. Thus, despite the availability of data, the versatility of the system architecture design allows the use of the platform both for a specific area or for global reach.

TREEADS System is based on the client - server architecture. The design also includes non-software elements, since the TREEADS ecosystem also consists of hardware elements that have been taken into consideration in the design of the architecture.

The front-end design consists of web interfaces, which will focus on different functionalities and roles according to the purpose of the user; as well as with a viewer API for maps with general purpose for the three phases (prevention and preparedness; detection and response; restoration and adaptation), an interface for interaction of 3D virtual scenarios, and an administration dashboard, among others.

The back-end has been designed as a set of modules with independent operation, either organized in containers, web-services (external services or micro-services) or integrated with the logics of the services back-end. These modules will use as input the necessary data for their operation thanks to the connection between the data and the modules based on micro-services and / or a hierarchical data access through the data access layer. The set of modules will be unified in one access endpoint named OpenAPI TREEADS. One of the core parts of the system will be the map service, based on a four-layered temporary image cube that will allow the publication and the demand of spatial data so that the other modules of the system (simulation tools, risk analysis tool, sensors, and others) can interact with the data loading and consultation.

This client - server design has been selected because it allows the implementation of the TREEADS architecture in a cloud infrastructure. This will enable the scalability of the system and the maintenance of the system and its modular architecture. One of the most important points to be considered is the accessibility to EO datasets such as DIAS, AWS, and Google Earth, to minimize the data volume in the system and to make use of global coverage of historical data from satellite imagery.

Data interoperability issues will be addressed by using standards for data exchange, sharing and archival, like ISO 10303 (STEP).

Regarding the technical risks, the analysis of the first design of TREEADS Platform identifies risks mainly related to the input and output data elements for the modules and components. This is a key issue because of the risks it can imply to the requisites of the system, that cannot be previously evaluated. The requisites, resources and data specifications can also imply a risk if their suitability and adaptability is not deeply analysed in this first step, leading to the impossibility of integration of all components in the system.

The design process will consist of the following steps:

- Integration Plan for the first prototype and roadmap for the implementation of the final TREEADS prototype.
- Design of the first set of wireframes and visual elements.
- Update of the architecture based on the implementation experience (WP4 - WP7) and the challenges identified during the integration phase. This update may also require a change in the system requirements, as minor updates. The results of this process will be included in D3.6.
- Updates and more detailed specifications related to the TREEADS infrastructure.
- Definition of complete workflows for each component.

Regarding the contribution of TREEADS Platform towards an Integrated Management System for Wildfires, this lies on the ability to have a set of tools for expert users. These tools intuitively monitor alerts, display layers of information, simulate fires, contact rescue teams, etc., from a web environment to provide a solution to the three phases (prevention, detection, and restoration) in wildfires. Another contribution of the TREEADS Platform is that it provides daily information, as well as ready-made products that complement current services in firefighting, solving one of the major bottlenecks in other solutions that is the preparation of data sets.

Thus, the platform contributes to the user to have the best information available, updated, as well as provides innovative elements of intercommunication, support and information from drones, wearables for rescue teams, etc. This technology lays a foundation in the action phase, with room for improvement regarding the inclusion of novel tools and more aspects to study.

ANNEX I

ANNEX – TRACEABILITY MATRIX: COMPONENTS VS PARTNERS

Table 33 - Traceability matrix: components vs partners

		DTU	JOTNE	CBS	NOA	8BELLS	USAL	OVGU&BAM	NCSRD	CARTIF	CERTH	FR	Woodify &	STRESS	OneSeven	ACCELI	ALTRAN	DRONEHOPPER	SIMAVI	FI	TUC	UdG	Global	LAMMC	EFB	SQD
1	**Insurance Model and Risk Transfer Solutions**	X																								
2	**Interoperability Environment for Rescue and Logistics Processes using ISO standards**		X																							
3	**Social parameters analysis**			X																						
4	**Auth. & Security Service**						X																			
5	**Fire Exposure and Risk assessment**									X																
6	**Agroforestry Index**						X																			

7	**Climate Risks and Vulnerabilities**									X																
8	**Early Warning System**									X																
9	**Fire Hazard Forecasting & ML**				X																					
10	**Social-Economics Index**				X																					
11	**Accurate Forest Mapping**						X																			
12	**Fire Prevention System (FPS)**						X																			
13	**Map Services**						X																			
14	**Simplified physical fire spread model (PhyFire)**						X																			
15	**High-definition wild field model (HDwind)**						X																			
16	**Air pollutant (Smoke) dispersion model (PhyNX)**						X																			
17	**Analysis of Fire Behavior and Spread for the Development of Safety Measures**							X																		
18	**Air Pollution Modelling for Source Apportionment (PMF)**								X																	

19	**Air Quality and health impacts estimation using chemical transport models - WRF-Chem**								X																	
20	**Remote Sensors**					X																				
21	**Artificial Intelligence for mission planning & swarm coordination**										X															
22	**iCrowd - Multi-Mission Simulation Platform for Crowd and Livestock Management & Evacuation**								X																	
23	**UAVs for surveillance / seed pod launcher**															X										
24	**UAV for surveillance / 5g node**																X									
25	**UAV for firefighting / prevention**																	X								
26	**UAV Deployable Air Command and Control**																X									
27	**Resource Management System (RMS)**										X														X	

28	**Restoration Decision Support System (DSS)**																				X				X
29	**Agroforestry for restoration**																			X					
30	**Hotspot detection**						X																		
31	**Visual Object Recognition on embedded systems**										X														
32	**Context-aware Detection of Emerging Fire-related Situations**																		X						
33	**Wildfire Response Engine (WRE)**																		X						
34	**Social media collection and analysis**										X														
35	**Forrest black box**					X																			
36	**One Seven fire-fighting extinguishing foam**														X										
37	**AR HELMET**					X																			
38	**VR HELMET**					X																			
39	**Data Format Fusion Mechanism**					X																			

40	**5G Portable Communication System (PCS)**					X																				
41	**Instant messaging**					X																				
42	**Manager Dashboard**						X																		X	
43	**Wildfire App (webGIS)**						X																			
44	**Sensor Dashboard**																								X	
45	**VR Client - TRAINING**																		X							
46	**AR Client**																		X							
47	**Fire-resistant wooden construction materials for increased fire-safety in areas of wildland-Urban Interface (WUI) fire risk**											X														
48	**Passive fire protection for key infrastructures and residential buildings**												X													
49	**Nature-based and fire-resilient solution for prevention and restoration**													X												
50	**Infrastructures fire emergency management strategy**													X												

51	**Reforestation/ Drones for Agriculture - using SCC for aerial mass releases**																					X				
52	**Restoration of ecological balance - using Bioclip release principles**																					X				

ANNEX II

ANNEX – TRACEABILITY MATRIX: COMPONENTS VS PHASES

Table 34 - Traceability matrix: components vs phases

		Prevention and Preparedness	Detection and Response	Restoration and Adaptation	Partner
1	**Insurance Model and Risk Transfer Solutions**	(X)		X	DTU
2	**Interoperability Environment for Rescue and Logistics Processes using ISO standards**	X	X	X	JOTNE
3	**Social parameters analysis**	X	X		CBS
4	**Auth & Security Service**	X	X	X	USAL
5	**Fire Exposure and Risk assessment**	X			CARTIF
6	**Agroforestry Index**	X			USAL
7	**Climate Risks and Vulnerabilities**	X			CARTIF
8	**Early Warning System**	X			CARTIF
9	**Fire Hazard Forecasting & ML**	X			NOA
10	**Social-Economics Index**	X			NOA
11	**Accurate Forest Mapping**	X			USAL
12	**Fire Prevention System (FPS)**	X			USAL
13	**Map Services**	X	X	X	USAL
14	**Simplified physical fire spread model (PhyFire)**	X	X		USAL
15	**High-definition wild field model (HDwind)**	X	X		USAL
16	**Air pollutant (Smoke) dispersion model (PhyNX)**	X	X		USAL

17	**Analysis of Fire Behavior and Spread for the Development of Safety Measures**	X	X		OVGU&BAM
18	**Air Pollution Modelling for Source Apportionment (PMF)**		X		NCSRD
19	**Air Quality and health impacts estimation using chemical transport models - WRF-Chem**		X		NCSRD
20	**Remote Sensors**	X	X	X	
21	**Artificial Intelligence for mission planning & swarm coordination**		X		CERTH
22	**iCrowd - Multi-Mission Simulation Platform for Crowd and Livestock Management & Evacuation**	X	X		NCSRD
23	**UAVs for surveillance / seed pod launcher**			X	ACCELI
24	**UAV for surveillance / 5g node**	X	X	X	ALTRAN
25	**UAV for firefighting / prevention**	X	X		DRONHOPPER
26	**UAV Deployable Air Command and Control**	X	X	X	ALTRAN
27	**Resource Management System (RMS)**	X	X	X	CERTH, EFB
28	**Restoration Decision Support System (DSS)**			X	UdG, SQD
29	**Agroforestry for restoration**			X	TUC
30	**Hotspot detection**		X		USAL
31	**Visual Object Recognition on embedded systems**		X	X	CERTH
32	**Context-aware Detection of Emerging Fire-related Situations**		X		FI
33	**Wildfire Response Engine (WRE)**		X		FI
34	**Social media collection and analysis**	X	X		CERTH
35	**Forrest black box**				8BELLS

36	**One Seven fire-fighting extinguishing foam**		X		OneSeven
37	**AR HELMET**	X	¿		8BELLS
38	**VR HELMET**	X	¿		8BELLS
39	**Data Format Fusion Mechanism**	X	X	X	8BELLS
40	**5G Portable Communication System (PCS)**	X	X	X	8BELLS
41	**Instant messaging**	X	X		8BELLS
42	**Manager Dashboard**	X	X	X	USAL, EFB
43	**Wildfire App (webGIS)**	X	X	X	USAL
44	**Sensor Dashboard**	X	X	X	EFB
45	**VR Client - TRAINING**	X			SIMAVI
46	**AR Client**	X			SIMAVI
47	**Fire-resistant wooden construction materials for increased fire-safety in areas of wildland-Urban Interface (WUI) fire risk**	X			FR
48	**Passive fire protection for key infrastructures and residential buildings**	X			Woodify & Trelleborg & FRN
49	**Nature-based and fire-resilient solution for prevention and restoration**	X			STRESS
50	**Infrastructures fire emergency management strategy**	X			STRESS
51	**Reforestation/ Drones for Agriculture - using SCC for aerial mass releases**			X	Global Biodesign
52	**Restoration of ecological balance - using Bioclip release principles**			X	Global Biodesign

ANNEX III

ANNEX – LAYER DATA MODEL SCHEMAS

These sub-schemas represent the data model for spatial layers of webGIS. These schemas will be stored in the Spatial Database. The annex contains the diagrams of the most representative layers of the system.

L01.0- ADMINISTRATIVE LIMITS

Vector layer that represents the administrative limits at the European level, this layer will be formed at four levels; country (L0), region/autonomous communities (L1), province (L2) and municipality(L3) based on the Eurostat Nomenclature of Territorial Units for Statistics (NUTS) hierarchical system. The data model will allow associating tables of statistical or interest information for each of the levels.

Source: cartography obtained from the GADM provides maps and spatial data for all countries and their sub-divisions.

COUNTRIES – VECTORMODEL

This Layer represents the countries worldwide in vector format:

Type: vectorModel

Source: GADM – Level 0

Group: BACKGROUND CARTOGRAPHY > Administrative Limits

Column	Type	Description
_id	STRING UNIQUE KEY	Unique identifier
_created_at	DATETIME	Creation date
_updated_at	DATETIME	Update date
_acl	JSON	Access permissions in JSON
ogc_fid	INTEGER PRIMERY KEY	Unique feature identifier
GEOMETRY	MULTIPOLYGON	Feature geometry
CNTR_ID	TEXT	Country ID

CNTR_NAME	TEXT	Country Name – Original Name
CNTR_NAME_ENG	TEXT	Name in english
ISO3_CODE	TEXT	ISO 3 Code
AREA	FLOAT	Area of feature

REGIONS

This Layer represents the autonomous communities or regions worldwide in vector format:

Type: vectorModel

Source: GADM[25] – Level 1

Group: BACKGROUND CARTOGRAPHY > Administrative Limits

Column	Type	Description
_id	STRING UNIQUE KEY	Unique identifier
_created_at	DATETIME	Creation date
_updated_at	DATETIME	Update date
_acl	JSON	Access permissions in JSON
ogc_fid	INTEGER PRIMERY KEY	Unique feature identifier
GEOMETRY	MULTIPOLYGON	Feature geometry
REGN_ID	TEXT	Region ID
REGN_CODE	TEXT	ISO region code
CNTR_CODE	TEXT	ISO country code
CNTR_NAME	TEXT	Country name
CNTR_NAME_ENG	TEXT	Country name in english
ISO3_CODE	TEXT	ISO 3 code
AREA	FLOAT	area

[25] https://gadm.org/download_world.html

PROVINCES

This Layer represents the provinces worldwide in vector format:

Type: vectorModel

Source: GADM– Level 2

Group: BACKGROUND CARTOGRAPHY > Administrative Limits

Column	Type	Description
_id	STRING UNIQUE KEY	Unique identifier
_created_at	DATETIME	Creation date
_updated_at	DATETIME	Update date
_acl	JSON	Access permissions in JSON
ogc_fid	INTEGER PRIMERY KEY	Unique feature identifier
GEOMETRY	MULTIPOLYGON	Feature geometry
PROV_ID	TEXT	Province ID
PROV_NAME	TEXT	Province Name
CNTR_CODE	TEXT	Country code
CNTR_NAME	TEXT	Country name
CNTR_NAME_ENG	TEXT	Country name in english
REGN_NAME	TEXT	Region name
AREA	FLOAT	area

MUNICIPALITIES

This Layer represents the municipalities worldwide in vector format:

Type: vectorModel

Source: GADM – Level 3

Group: BACKGROUND CARTOGRAPHY > Administrative Limits

Column	Type	Description
_id	STRING UNIQUE KEY	Unique identifier
_created_at	DATETIME	Creation date
_updated_at	DATETIME	Update date
_acl	JSON	Access permissions in JSON
ogc_fid	INTEGER PRIMERY KEY	Unique feature identifier
GEOMETRY	MULTIPOLYGON	Feature geometry
NUTS3_CODE	TEXT	Nomenclature of Territorial Units ofr Statistics
LAU_CODE	TEXT	Local Administrative Units
MUN_NAME	TEXT	Municipality name
MUN_NAME_ENG	TEXT	Municipality Name in English
PROV_NAME	TEXT	Province Name
REGN_NAME	TEXT	Region Name
CNTR_CODE	TEXT	Country Code
CNTR_NAME	TEXT	Country Name
AREA	FLOAT	Area

L02.0- MAP FOREST – FOREST MODEL

This Layer represents the European forest map or forest model. It is a layer with a tileIndex structure that allows space-time indexing of image cubes:

Type: tileIndexModel

Sources: MFE[26], IFM[27] (Spain), Forest Map of Europe[28]

Group: LAND USE > FOREST MODEL

[26] https://www.miteco.gob.es/es/cartografia-y-sig/ide/descargas/biodiversidad/mfe.aspx

[27] https://datos.gob.es/es/catalogo/e05068001-inventario-forestal-nacional-ifn-iii

[28] https://efi.int/knowledge/maps/forest

Column	Type	Description
_id	STRING UNIQUE KEY	Unique identifier
_created_at	DATETIME	Creation date
_updated_at	DATETIME	Update date
_acl	JSON	Access permissions in JSON
ogc_fid	INTEGER PRIMERY KEY	Unique feature identifier
location	VARCHAR	File path
src_srs_	VARCHAR	EPSG
GEOMETRY	MULTIPOLYGON	Feature geom. Image bbox
PROV_NAME	TEXT	Province Name
REGN_NAME	TEXT	Region Name
AREA	FLOAT	Area
STRUCTURAL_TYPE	STRING	Structural Type. land uses within forest use
FRAC_COVERED_SPACE	INTEGER	Tree cover fraction
SPECIES	STRING	Species
SPECIES_STATUS	STRING	State of the species
LAND_USE	STRING	Land Use

L03.0- DIGITAL TERRAIN MODEL (DTM)

Orography representation layer, digital terrain model in raster format that represents the digital terrain model

GRAY_INDEX= ALTITUDE

Type: rasterModel

Sources: USGS[29]

Group: OROGRAPHY > Digital Terrain Model

L06.0 - CANOPY HEIGHT MODEL

The Canopy Height Model (CHM) dataset is a high-resolution (1 meter) raster layer that maps the tree height as a continuous surface. Each pixel in the CHM represents the tree overstory height above the underlying ground topography.

CHM= TREE HEIGHT

Type: rasterModel

Sources: PNOA[30] (image + LiDAR)

Group: VEGETATION GEOMETRY > CHM

L07.0 –FUEL MODELS

This Layer contains fuel type according to the Rothermel classification, vegetation states to be used in simulation models:

Type: vectorModel

Sources: National Forest Inventory, IFN-4, EFI

Group: VEGETATION STATE > Rothermel FUEL MODEL

Column	Type	Description
_id	STRING UNIQUE KEY	Unique identifier
_created_at	DATETIME	Creation date
_updated_at	DATETIME	Update date
_acl	JSON	Access permissions in JSON
ogc_fid	INTEGER PRIMERY KEY	Unique feature identifier
GEOMETRY	MULTIPOLYGON	Feature geometry

29 https://earthexplorer.usgs.gov

30 https://pnoa.ign.es

FUEL	INTEGER	fuel type classification according to Rothermel
AREA	FLOAT	Area

L09.0 – LAND USE

Cover layer and land use:

Type: rasterModel

Sources: CORINE Land use

Group: LAND USE > CORINE LAND USE

L10.0 - CITIES, TOWN & SUBURB, RURAL AREA

This Layer represents the population centers of cities, towns, and suburban and rural areas. Identify classes of urban to obtain the limits:

Type: vectorModel

Sources: CLC[31], UCDB[32], Urban Atlas[33]

Group: BACKGROUND CARTOGRAPHY > Cities, Suburban & Rural.

Column	Type	Description
_id	STRING UNIQUE KEY	Unique identifier
_created_at	DATETIME	Creation date
_updated_at	DATETIME	Update date
_acl	JSON	Access permissions in JSON
ogc_fid	INTEGER PRIMERY KEY	Unique feature identifier
GEOMETRY	MULTIPOLYGON	Feature geometry
MUN_CODE	STRING	Municipality code

31 https://land.copernicus.eu/pan-european/corine-land-cover/clc2018

32 https://ghsl.jrc.ec.europa.eu/ghs_stat_ucdb2015mt_r2019a.php

33 https://land.copernicus.eu/local/urban-atlas/urban-atlas-2018

CITY_NAME	STRING	City Name
CITY_NAME_ENG	STRING	City Name in english
YEAR	STRING	year of cartography
POPULATION	STRING	Population
CITY_TYPE	STRING	Type of city {city, town, rural}
CITY_DATA	JSON	year of cartography
AREA	FLOAT	Area

L11.0 - CIVILIAN EMERGENCY POINTS

This vector layer represents the emergency points of interest available to civilians, such as pharmacies, police, hospitals, etc.:

Type: vectorModel

Sources: OSM filtered by amenity[34], Local authorities

Group: CIVIL RESOURCES > EMERGENCY POINTS

Column	Type	Description
_id	STRING UNIQUE KEY	Unique identifier
_created_at	DATETIME	Creation date
_updated_at	DATETIME	Update date
_acl	JSON	Access permissions in JSON
ogc_fid	INTEGER PRIMERY KEY	Unique feature identifier
GEOMETRY	POINT	Feature geometry
NAME	STRING	point of interest name
ADDR_CITY	STRING	City
ADDR_HOUSENUMBER	STRING	Address house number

[34] https://www.openstreetmap.org

ADDR_POSTCODE	STRING	Postcode
ADDR_STREET	STRING	Address Street
PHOTOS	TEXT	photos attached
AMENITY	STRING	Amenity
PHONE	STRING	Phone Number
SCHEDULE	STRING	Opening hours
TAGS	JSON	List of tags

L12.0 - HYDRANTS

This vector layer represents the hydrants points for firefighters:

Type: vectorModel

Sources: OSM filtered by amenity, Local authorities

Group: CIVIL RESOURCES > HYDRANTS

Column	Type	Description
_id	STRING UNIQUE KEY	Unique identifier
_created_at	DATETIME	Creation date
_updated_at	DATETIME	Update date
_acl	JSON	Access permissions in JSON
ogc_fid	INTEGER PRIMERY KEY	Unique feature identifier
GEOMETRY	POINT	Feature geometry
NAME	STRING	point of interest name
HYDRANT_CONNECTOR_TYPE	STRING	Connector type
HYDRANT_TYPE	STRING	Hydrant type
SOURCE	STRING	Postcode

DATE	DATE	Date update
DATE_SETUP	DATE	Date of operation
PHOTOS	TEXT	photos attached
NOTES	TEXT	Notes
PHONE	STRING	Phone Number
TAGS	JSON	List of tags

L14.0- INDUSTRIAL AREAS

This vector layer represents the industrial areas:

Type: vectorModel

Sources: OSM filtered by amenity, Local authorities

Group: CIVIL RESOURCES > INDUSTRIAL AREAS

Column	Type	Description
_id	STRING UNIQUE KEY	Unique identifier
_created_at	DATETIME	Creation date
_updated_at	DATETIME	Update date
_acl	JSON	Access permissions in JSON
ogc_fid	INTEGER PRIMERY KEY	Unique feature identifier
GEOMETRY	POINT	Feature geometry
NAME	STRING	point of interest name
SECTOR	STRING	Connector type
COMPANY	STRING	Hydrant type
ADDR_CITY	STRING	City
ADDR_HOUSENUMBER	STRING	Address house number
ADDR_POSTCODE	STRING	Postcode

ADDR_STREET	STRING	Address Street
ACTIVITY	STRING	Postcode
IS_FARMING	DATE	Date update
PHOTOS	TEXT	photos attached
NOTES	TEXT	Notes
PHONE	STRING	Phone Number
TAGS	JSON	List of tags

L15.0- EXTINCTION AND RESCUE PARKS

This vector layer represents the fire stations:

Type: vectorModel

Sources: OSM filtered by amenity, Local authorities

Group: CIVIL RESOURCES > FIRE STATIONS

Column	Type	Description
_id	STRING UNIQUE KEY	Unique identifier
_created_at	DATETIME	Creation date
_updated_at	DATETIME	Update date
_acl	JSON	Access permissions in JSON
ogc_fid	INTEGER PRIMERY KEY	Unique feature identifier
GEOMETRY	POINT	Feature geometry
NAME	STRING	point of interest name
ADDR_CITY	STRING	City
ADDR_HOUSENUMBER	STRING	Address house number
ADDR_POSTCODE	STRING	Postcode

ADDR_STREET	STRING	Address Street
SERVICE	STRING	Service
WEIGHT	STRING	Weight
ENABLED	STRING	Enabled
TYPE	DATE	Industry type
PHOTOS	TEXT	photos attached
NOTES	TEXT	Notes
PHONE	STRING	Phone Number
TAGS	JSON	List of tags

L23.0- NORMALISED DIFFERENCE VEGETATION INDEX (NDVI)

This Layer represents time series of vegetation indices:

Type: tileIndexModel

Sources: Sentinel[35]

Group: VEGETATION STATE > NDVI wildland urban interface

Column	Type	Description
_id	STRING UNIQUE KEY	Unique identifier
_created_at	DATETIME	Creation date
_updated_at	DATETIME	Update date
_acl	JSON	Access permissions in JSON
ogc_fid	INTEGER PRIMERY KEY	Unique feature identifier
location	VARCHAR	File path

[35] https://sentinels.copernicus.eu/web/sentinel/home

src_srs_	VARCHAR	EPSG
GEOMETRY	MULTIPOLYGON	Feature geom. Image bbox
TIMEITEM	TIMESTAMP	Time Item

L24.0- NORMALIZED DIFFERENCE MOISTURE INDEX (NDMI)

Time series layer of vegetation moisture indices:

Type: tileIndexModel

Sources: Sentinel,

Group: VEGETATION STATE > NDMI

Column	Type	Description
_id	STRING UNIQUE KEY	Unique identifier
_created_at	DATETIME	Creation date
_updated_at	DATETIME	Update date
_acl	JSON	Access permissions in JSON
ogc_fid	INTEGER PRIMERY KEY	Unique feature identifier
location	VARCHAR	File path
src_srs_	VARCHAR	EPSG
GEOMETRY	MULTIPOLYGON	Feature geom. Image bbox
TIMEITEM	TIMESTAMP	Time Item

L26.0- TEMPERATURE

TileIndex layer that represents a cube of raster images of temperatures over time. Each layer represents a temperature map for that day, each image could have several bands with the minimum, average and maximum temperature:

Type: tileIndexModel

Sources: windy service

Column	Type	Description
_id	STRING UNIQUE KEY	Unique identifier
_created_at	DATETIME	Creation date
_updated_at	DATETIME	Update date
_acl	JSON	Access permissions in JSON
ogc_fid	INTEGER PRIMERY KEY	Unique feature identifier
location	VARCHAR	File path
src_srs_	VARCHAR	EPSG
GEOMETRY	MULTIPOLYGON	Feature geom. Image bbox
TIMEITEM	TIMESTAMP	Time Item

L31.0- PRECIPITATION

This Layer represents rainfall, based on a TileIndex cube structure of raster images over time:

Type: tileIndexModel

Sources: AEMET

Group: METEO > PRECIPITATION

Column	Type	Description
_id	STRING UNIQUE KEY	Unique identifier
_created_at	DATETIME	Creation date
_updated_at	DATETIME	Update date
_acl	JSON	Access permissions in JSON
ogc_fid	INTEGER PRIMERY KEY	Unique feature identifier

location	VARCHAR	File path
src_srs_	VARCHAR	EPSG
GEOMETRY	MULTIPOLYGON	Feature geom. Image bbox
TIMEITEM	TIMESTAMP	Time Item

L50.0- INVENTORIABLE RESOURCES

This vector layer represents the points of inventory of means and resources points:

Type: vectorModel

Sources: Local authorities

Group: CIVIL RESOURCES > INVENTORY OF MEANS AND RESOURCES

Column	Type	Description
_id	STRING UNIQUE KEY	Unique identifier
_created_at	DATETIME	Creation date
_updated_at	DATETIME	Update date
_acl	JSON	Access permissions in JSON
ogc_fid	INTEGER PRIMERY KEY	Unique feature identifier
GEOMETRY	POINT	Feature geometry
NAME	STRING	point of interest name
HM_IS	BOOLEAN	Human: Has human means?
HM_NUM_FIRE_PRO	NUMBER	Human: number of professional firefighters
HM_NUM_VOL_PRO	NUMBER	Human: number of professional volunteers
HM_NUM_CIV_PRO	NUMBER	Human: number of civil protection firefighters
HM_NOTES	TEXT	Human means notes
SC_IS	BOOLEAN	SCALE DATA ARE KNOWN

SC_TYPE	STRING	Scale type
SC_DIM_M	NUMBER	Scale dimensions (height x width)
SC_YEARS	NUMBER	Scale years
SC_NOTES	TEXT	Scale notes
PU_AUTO_IS	BOOLEAN	Is Auto Pump?
PU_AUTO_TYPE	STRING	Pumper type
HO_NUM	NUMBER	Hoses number
HO_TYPE	STRING	Hoses type
HO_NUM_25MM	NUMBER	Hoses number 25mm
HO_NUM_45MM	NUMBER	Hoses number 45mm
HO_NUM_70MM	NUMBER	Hoses number 70mm
LC_NUM	NUMBER	Number of lances
LC_FLOW	NUMBER	Lance flow
PU_TYPE	STRING	Pump type
PU_AUTO_M3	NUMBER	Auto Pump capacity (m3)
PU_AUTO_YEARS	NUMBER	Auto pump years
PU_AUTO_NOTES	TEXT	Auto pump notes
PU_MOTO_IS	BOOLEAN	Is motor pump?
PU_MOTO_TYPE	STRING	Motor pump type
PU_MOTO_M3	NUMBER	Motor pump m3
PU_MOTO_YEARS	NUMBER	Motor pump years
PU_MOTO_NOTES	TEXT	Motor pump notes
RES_TRAFFIC_IS	BOOLEAN	Traffic accident data is known
RES_TRAFFIC_ACCESSORIES	BOOLEAN	Traffic accessories
RES_TRAFFIC_WINCHES	BOOLEAN	Traffic: Winches

RES_TRAFFIC_IPE	BOOLEAN	Traffic: Individual protection equipment
RES_HEIGHT_IS	BOOLEAN	Is Height rescue?
RES_ HEIGHT_IPE	BOOLEAN	Height rescue: Individual protection equipment
RES_ HEIGHT_ACCESSORIES	BOOLEAN	Height rescue: accessories
FE_IS	BOOLEAN	Is Fire equipment?
FE_DATE_TIV	DATE	Fire equipment: Vehicle technical inspection date
FE_IPE	BOOLEAN	Fire equipment: Individual protection equipment
FE_TECHNOLOGY	STRING	Fire equipment: technological material
FL_IS	BOOLEAN	FLOOD EQUIPMENT
FL_CLEANING_PUMP	BOOLEAN	Flood Equipment: Cleaning pump
FL_BILGE_PUMP	BOOLEAN	Flood Equipment: Bidge pump
FL_TYPE_OF_BILGE_PUMP	STRING	Flood Equipment: Type of bilge pump
FL_IPE	BOOLEAN	Flood Equipment: Individual protection equipment
CH_IS	BOOLEAN	Chemical accidents
CH_BREATHING_EQUIPMENT	BOOLEAN	Chemical: BREATHING EQUIPMENT
CH_IPE	BOOLEAN	Chemical: Individual protection equipment
CH_CBRN_SUITS	BOOLEAN	Chemical: CBRN suits
PHONE	STRING	photos attached
TAGS	JSON	List of tags

L51.0- FIREBREAKS

Firewall layer that indicates to the model those areas that are resistant to fire or with difficulty in fire propagation, and that will be taken by the model for fire propagation:

Type: vectorModel

Sources: OSM, BTN

Group: OTHERS > Firebreaks

Column	Type	Description
_id	STRING UNIQUE KEY	Unique identifier
_created_at	DATETIME	Creation date
_updated_at	DATETIME	Update date
_acl	JSON	Access permissions in JSON
ogc_fid	INTEGER PRIMERY KEY	Unique feature identifier
GEOMETRY	MULTIPOLYGON	Feature geometry
FIREBREAK	INTEGER	Firewall elements
AREA	FLOAT	Area

TREEADS

A Holistic Fire Management Ecosystem for Prevention, Detection and Restoration of Environmental Disasters

The Members of the TREEADS Consortium:

Short Name	Country	Short Name	Country	Short Name	Country
FRN	NO	**INNOV**	CY	**DCNA**	AT
Jotne	NO	**FI**	EL	**IFR**	AT
BAM	DE	**GBD**	BE	**FF GPK**	AT
CAPGEMINI	ES	**EFB**	EL	**DdA**	ES
LAMMC	LT	**STRESS**	IT	**ACaMIR**	IT
USAL	ES	**OS**	DE	**Sorrento**	IT
SQD	BE	**VIPO**	NO	**PUI**	FR
CARTIF	ES	**WAS**	NO	**FAFCYLE**	ES
UdG	ES	**CBS**	DK	**BFG**	AT
NCSRD	EL	**K3Y**	BG	**TUC**	EL
SIMAVI	RO	**MAGG**	IT	**MAICh**	EL
OVGU	DE	**NOA**	EL	**NTUST**	TW
ADRESTIA	EL	**MEWF**	RO	**DTU**	DK
CERTH	EL	**ASFOR**	RO	**DAAC**	EL
8BELLS	CY	**SMURD**	RO	**DH**	ES
ACCELI	CY	**JOAFG**	AT		

Contact:

Project Coordinator: **Kemal S. Arsava** RISE Fire Research AS	kemal.sarp.arsava@risefr.no

Disclaimer