SILVANUS

D3.1- First report on the formal specification of sustainable and resilient forest management knowledge model

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	The ontology that is used by a system is the actual backbone of the information that the system collects, processes, and produces. However, based on the research performed in this work package we noticed that important pieces of environmental and other types of information that should be collected were not included in state-of-the-art ontologies. Therefore, they were significantly extended and enriched with many "fields" that are necessary when performing inference on data collected from a vast array of sources.

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List of acronyms and abbreviations

ACRONYM	Description
DSS	Decision Support System
DSR	Daily Severity Rating
FWI	Fire Weather Index
KB	Knowledge Base
JRC	Joint Research Centre
RDF	Resource Description Framework
XML	eXtensible Markup Language
OWL	Web Ontology Language

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1 Executive Summary

Deliverable 3.1 represents the outcome of the SILVANUS ontology design effort, which was the result of a critical analysis of both existing technologies and a bottom-up listening methodology that allowed for the identification of SILVANUS-specific ontology classes.
An ontology is an explicit formal description of concepts that make up a single domain of knowledge. For example, a domain describing movies may include the concepts of actor, crew, scene etc.
It is also a consistent way of sharing and reusing knowledge: if an ontology is shared by multiple users working in a domain, they can use it to communicate and act on the included concepts without concerns about confusion and ambiguity.
Moreover, it allows for the semantic fusion of heterogeneous data collected in a single model. When a situation calls for dealing with different type of data at the same time, such as satellite imagery, reports in various formats, posts from social media, videos etc., an ontology allows not only for the correlation of these items and their characteristics together, but also for the inference of new knowledge from such correlations between the data: if some operators are part of a movie crew and that crew works on a movie, the ontology can be used by an inference engine to automatically infer that those particular operators are involved in that movie, even though this information has not been explicitly stated.
The following deliverable is divided in three parts. The first part provides an overview of the state of the art for knowledge and ontologies related to the SILVANUS field of operation. The second part explores the process of picking and choosing the most appropriate resources and methodologies for the task goals. Finally, the ontology that resulted from task 3.1 activity is presented and described in the third part.
The ontology that is used by a system is the actual backbone of the information that the system collects, processes, and produces. However, based on the research performed in this work package it became apparent that important pieces of environmental and other types of information that should be collected were not included in state-of-the-art ontologies. Therefore, they were significantly extended and enriched with many "fields" that are necessary when performing inference on data collected from a vast array of sources.
Regarding the Metadata Index, it will serve to catalogue and provide an expressive search interface to SILVANUS data objects. Combined with the SILVANUS ontology, these components will work in synchronise promoting an expansive, semantically linked view of the forest, from high level concepts and observations to the data objects and lineage that provide new insights. The main purpose of the Metadata Index is to serve as a searchable catalogue of data objects held both internally within the SILVANUS Big-data Framework storage solution, as well as references to data objects contained within external repositories (e.g., Earth Observation datasets).
Once the deliverable was on the verge of completion, different types of ontology visualizations have been proposed:

- Graphical visualization (for all users)
- Tabular visualization (more detailed, meant for developers that are going to use the ontology for their applications)
- Protégé visualization (for those familiar with the ontology editing tool Protégé[1])

To keep the deliverable as easy to navigate as possible, only the graphical visualization will be included inside the corpus, while the other two are made available in the appendixes A and B.

[1] Stanford Center for Biomedical Informatics Research, "A free, open-source ontology editor and framework for Building Intelligent Systems," Protégé. [Online]. Available: https://protege.stanford.edu/. [Accessed: 29-Sep-2022].

2 Introduction

The continuous rise of the Internet made many researchers wonder about the upcoming issues that we will face. As everyone observes, the Internet is full of information that is constantly consumed by humans and machines.
While this information is available to everyone, extracting knowledge out this information is not a trivial task. The information is offered in structured and unstructured forms and can be made available through different formats and protocols. This creates a huge issue as to extract knowledge all this information needs to be homogenized, categorized, correlated.
Therefore, there is a need for a common language, a way to express similar things in the similar way so that entities on the other side, regardless of whether they are human, or machines can easily process them. This need set the basis of what we now call the semantic web, which the W3C defines with the following quote: "The Semantic Web provides a common framework that allows data to be shared and reused across application, enterprise, and community boundaries"[2].
To reach this goal we need to define the "things" of each domain and how they interact with each other. One of the most profound ways is through ontologies, "an explicit specification of a conceptualization"[3] as Gruber defines them.
Ontologies consist of a set of terms, the vocabulary, and the relationships between them. It is worthwhile to notice that the term vocabulary and ontology are often interchanged. In principle there is no difference between the two terms. In practice however, when we have many terms and a lot of complex relationships between the terms, we refer to it as ontology, if not, vocabulary. Thus, an ontology can describe arbitrary things in a way that can be consumed by humans and machines, that is a format that is both machine and human readable. Currently, there are several languages that are specifically designed to describe and annotate data like Resource Description Framework (RDF), Web Ontology Language (OWL), and Extensible Markup Language (XML). The annotation part is important as it allows machines to process information and extract the needed information immediately without the need to use other algorithms to perform e.g., natural language processing to infer what is exchanged.
This deliverable describes the SILVANUS first report on the modelling of a knowledge base. The goal of this phase is to study the ontologies concerning the field of wildfires, crisis, environment, and biodiversity to use them to enrich unstructured data by automatically adding various types of annotations that can help in the prevention and fight of forest fires. These annotations will enable end-user functionalities such as decision support systems (DSS), through the process of automatic reasoning.
This report will be focused on the designing and evolving of one or more ontologies to be leveraged for automatic and manual content categorization and entities extraction.
The whole Task 3.1 is about providing ontologies as a tool to standardize meaning and reason on it.

[2] "W3C," W3C Semantic Web Activity Homepage. [Online]. Available: https://www.w3.org/2001/sw/. [Accessed: 29-Sep-2022].
[3] T. R. Gruber, "Toward principles for the design of Ontologies used for knowledge sharing?," International Journal of Human-Computer Studies, vol. 43, no. 5-6, pp. 907–928, 1995.

An ontology is an explicit formal description of concepts that make up a single domain of knowledge, meaning that if an ontology is shared by multiple users working in a domain, they can use it to talk and act on the included concepts without concerns about confusion and ambiguity.
So, an ontology contains a description of concepts that make up a domain of knowledge. This description consists of a set of:

- Classes, the concepts themselves
- Individuals, which refer to the real-world instance of a concept or class ("The Matrix" is an individual of the class Movie)
- Relations between classes, stating how they are related together (Actor *acts in* Movie)
- Attributes of classes, for example the name of a movie, the birth date of an actor
- Restrictions between classes, stating for example that if a movie is labelled for adults, it cannot also be labelled for kids
- Axioms, stating for example that if a movie is produced by Pixar, it can be automatically labelled for kids

To follow the requirements of the SILVANUS project with special regards to the knowledge model implementation, a list of objectives has been identified:

- formalize the semantic description of different forest landscape models and threats posed by wildfires, based on biodiversity and fire danger index (T2.3)
- agree on and standardize the terminology
- keep the knowledge models modular and scalable

The knowledge model developed in T3.1 and implemented in T5.2 is critical to the successful integration of the SILVANUS platform components. As we all know, the SILVANUS project is a multidisciplinary project involving partners with different expertise. Each partner is specialized in the use of certain data, related to specific concepts, identified by a specific terminology. So, to avoid the project becoming a tower of Babel, a common terminology must be used, and that common terminology is represented by the SILVANUS semantic framework, represented in Figure 1.

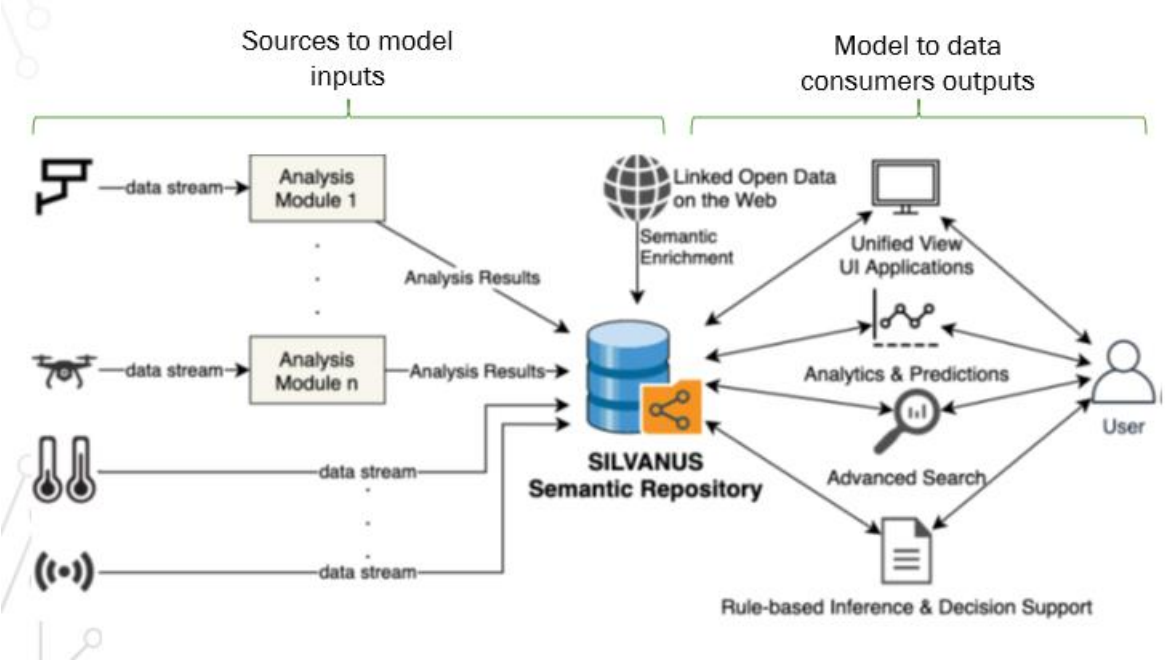


Figure 1 SILVANUS Semantic Framework

The SILVANUS semantic framework will serve as a robust terminological layer, accepting inputs from the sources on the left side of the picture and using them to populate the semantic model. The model will be capable of delivering a unified view of the available information to the end-user.

To achieve this, however, it is paramount that the input data speaks the SILVANUS ontology language, in other words the input data must comply with the SILVANUS ontology schema that will be defined in Task 3.1.
This is the only way we can ensure interoperability between the various modules that will be developed going forward and avoid semantic disambiguation problems both between different concepts in the same language and between different languages.
We divided the endeavour of building the semantic framework in two separate aspects:

- The conceptual aspect (regarding ontologies, knowledge, etc.), which will be the topic of this deliverable.
- The technological and infrastructural aspect of the semantic framework (regarding the underlying infrastructure, databases, queries, etc.) which will be dealt with and described in Task 5.2.

Regarding the conceptual aspect of the semantic framework, a series of subtasks was identified:

- Knowledge collection, the effort to try and gather all the possible areas of knowledge that will need to be formalized
- Ontologies and dictionaries collection, consisting in the search for pre-existing resources that can be leveraged to jumpstart the knowledge formalization
- Domain definition, consisting in identifying the main classes, their relationship, attributes, restrictions, axioms
- Knowledge formalization itself, the building of the SILVANUS ontology.

The task of the conceptual aspect was decomposed in subtasks and each partner was proposed to give their contributions to one or more of such sub sections. In the following chapter, the collection of the state of the art will be described.

3 State of the Art

In this phase the goal is to collect all the latest resources and methodologies that could be useful for the goal of creating the SILVANUS ontology. The section is divided in two subsections: knowledge collection and ontologies/taxonomies collection.

In the knowledge collection section, the goal has been to gather all the possible sources of knowledge that is relevant to the three phases of the SILVANUS project (prevention of fire, detection of fire, restoration of the environment), coming from partners, experts and other deliverables.

In the ontologies and taxonomies section the goal has been to identify already available and well-established schematizations of knowledge to reuse their relevant concepts and relations while allowing the SILVANUS platform to be interoperable with other systems that use such schemas.

3.1 Knowledge Collection

The SILVANUS Knowledge Base can be considered the real backbone of the entire SILVANUS project. It will need to effectively manage all kinds of information from all kinds of sources as well as all the possible interactions between these pieces of information.

In the knowledge collection phase, there has been research for new requirements and information that need to be kept into consideration for the job of the user products that will run on top of the SILVANUS Knowledge Base. The main sources of such information were the following:

- Other deliverables
- Knowledge from partners
- Knowledge from real systems, through the pilots

In particular, Deliverable 2.1 was released in May 2022 and it reports an in-depth description of all the operational scenarios from the pilots in the project, which represent a great source of information.

Moreover, some of the partners left their comments on the ontology draft design which has been presented during the Zvolen assembly in March 2022 and Bari assembly in July 2022, adding their feedback and suggestions.

3.1.1 Knowledge from pilots

The colleagues working on Task 2.1 carried out the collection of Pilot requirements by getting in touch with the experts of the domain. From this activity it was possible to extract a series of relevant concepts, some of them were already included in the SILVANUS ontology, some others that were included in light of this activity.
The following tables from 1 to 6 show all the raw concepts that have been extracted from each pilot description:

Table 1 Raw concepts extracted from French and Italian pilots' description

FRANCE	ITALY
number of active fire fronts	year of low atmospheric precipitation
smoke amount	infrastructures - radio network
Propagation direction	IoT sensors, drones
ground temperature of the flames	geology

identification of access paths	roads
cause - industrial accident	causes - cigarette butts
wind direction	causes - negligence, misconduct
temperature	power lines
wind speed	risk of fires
urbanized areas	power lines
dehydration of plants	Daily map of fire risk
dehydration of plants	prescribed fire
anticipation of fire development and development axes	patrols
UAV sensors	vehicles for the transport of people and extinguishing liquid
intervention area	hydrography
gas sensors	topography
composition of the combustion gases	land use
type of plants	pedology
Fire start	satellite images
Propagation speed	Preventive interventions on the ground
threatened targets	microclimatic data (temperature, precipitation, relative humidity of the air, wind speed, wind direction).
time to reach the installation at risk	cameras
evacuation measures	collection points (evacuation)
time to reach the urbanized area	front intensity
landscape biodiversity	propagation speed
fire danger index metrics	critical points, where the fire increases intensity and / or speed
fuel availability in specific regions of forest	sensitive points (presence of infrastructures and / or works, buildings and interfaces, natural areas of value and / or vulnerability, forecast of economic and environmental losses, forecast of damage and costs of shutdown and restoration
soil types and structure	valid points as areas of control opportunities, also based on the preliminary study of the effectiveness of the various suppression and technical actions
fire ignition sources	meteorological conditions of particular importance for the prediction of complex phenomena
quantifying the damage of forest fire (loss of XX cubic tons of oxygen, etc.)	Imaging laser scanner
chemical composition sensors	antenna

Table 2 Raw concepts extracted from Romanian and Greek pilots' description

ROMANIA	GREECE
causes - human negligence	wind direction and speed
dry vegetation	Surface fuels thick and very dry
meteorological conditions	Medical equipment

Wind speed	summer camps
dry vegetation	Surface fuels thick and very dry
yearly rainfall	Temperature
UGV	dense height-tree forest of Pinus halepensis, with understory of shrubs
temperature	Deep soil covered with needles
Wearable Device, Wearable Sensors, Field Sensors	Air humidity at 65%.
approximate coordinates of the event	Crown-base height at 3 m
humidity sensors	Steep terrain
weather data	Small villages
mountain tourist flow metering sensors	Home properties
biodiversity landscape	churches
Wind direction	Cultivated areas
Air stability class	Power installations
Precipitation	areas of high value
Atmospheric pressure	Fire front distance
Information about vegetation in the area	Active crown fire with flame length of 25 m
Data on humidity	UAVs
flow of mountain tourists	Spirometry measurement
Photo data / Images related to the fire burst area from the camera	Nebulizers and bronchodilators
fire danger index	Satellite Data
Cleaning of felling areas	Topography
Transport of water through a human cordon or 4x4	Weather data
The creation of intervention relays from the base of the slope to the outbreaks that threatened to extend in the direction of the control point	Daily fire risk map
season	Fire vulnerability and risk mapping
degree of humidity of the vegetation and air	Soil moisture
degree of humidity of the vegetation and air	Soil moisture
speed and direction of the wind	Exposure of settlements to wildfires
	Health metrics
	Mapping and maintenance of water resources
	soil types and structure

Table 3 Raw concepts extracted from Portuguese and Czech pilots' description

PORTUGAL	CZECH REPUBLIC
drones	no precipitations
Forester (animal collars used to locate GPS animal position).	Drone
fire danger index metrics	

electrical lines	fire ignition sources, such as human negligence, arson, environment conditions, climate and weather conditions (climate change impact including), impact of power grid lines
Sensors: Temperature, Relative Humidity, Rain, Pression, Solar Radiation, UV Radiation, Wind speed, Wind Direction	Drone degree of autonomy: Level 0 – No Automation
water sources	temperature
UAV	firefighting units
Classified 3D Point Cloud of Overhead Power Lines Corridors	professional and volunteer firefighting unit
Satellite	windy conditions
cameras	Drone is equipped with basic meteorological sensors – temperature, wind velocity, altitude (plus GPS coordinates)
Normalized difference vegetation index	UAV
Water Infrastructures Locations and Protection Perimeters	positioning of deployed firefighters
fire risk at regional and plot level	UGV
water treatment plants	infra-red thermal camera
electrical transformers	
biomass growth	
monitor the growth of different types of vegetation cover in critical infrastructures	
vegetation types	
soil types and structure	
damage of forest fire (loss of XX cubic tons of oxygen, etc.)	
information on fuel availability in specific regions of forest	
visualisation of climate statistics (for historical and future periods; precipitation, temperature, relative humidity etc.)	

Table 4 Raw concepts extracted from Croatian and Slovak pilots' description

CROATIA	SLOVAKIA
fine fuel moisture	causes - burning of dry crop and grasses
fire initiator will be human activity (negligence during prescribed burning	current local weather
information on fire ignition sources	(temperature, precipitations, relative air humidity, wind speed, wind direction
terrain (elevation, terrain slope, aspect	roads
UGV, and UAV	professional firefighters

period without precipitations	types of land use: forests, grasslands, agricultural land
critical infrastructure will be endangered	meteorological fire danger index
Satellite data	UGV
wind	Drones
robot can operate by the pilot up to 500 m from the pilot	incident site
	smoke detection
Camera devices	CCTV based smoke detection
definition of operational areas, engagement plan, alert and exit plan	Monitored area
Susceptibility of territory to wildfire assessment	watercourses and reservoirs
fuel (vegetation type, quantity, and quality)	forest types
power lines, hydrant network and fire brakes	soil types
suitable water sources for extinguishing activities	touristic and cycling routes
critical infrastructure on site	buildings
danger index metrics	sites to be used as heliports
fuel availability in specific regions of forest	fire extinguishing tools placement
soil types and structure	IoT sensors
	moisture content of fine fuel
	moisture content of fine fuel
	5 degrees of fire danger
	CCTV
	Volunteer Fire Brigades
	incident area
	firefighters' position in the field and health state

Table 5 Raw concepts extracted from Australian and Brazilian pilots' description

AUSTRALIA	BRAZIL
bushland	average annual rainfall
UGV	average annual temperate

Table 6 Raw concepts extracted from Indonesian pilots' description

INDONESIA
available data on biodiversity model
soil parameters in post fire
post fire condition images
highest levels of biodiversity
estimation of each species in the observation area
satellite multispectral image
forest growth
To measure the soil parameters during rehabilitation and adaptation, we need to install some instruments with IoT Support.

3.1.2 Other concepts

Apart from the general pilot scenarios descriptions, the Portuguese cluster provided further contributions. The Portuguese cluster partners are EDP, ADP, IST-ID and TP. The first being utilities operating in energy and water, the third a university band the fourth an agricultural society. The main concepts they deal with on a current basis when addressing the fire risk problem are reported in Table 7. These are accompanied by the respective description, and examples of inputs and outputs.

Table 7 Concepts table sent by EDP, ADP, IST-ID and TP

Requirement Name	Requirement Description	Inputs	Outputs
Fire hazard risk (Perigosidade de incêndio)	Map of fire hazard risk at the landscape and farm/local scale (resolution to be adapted to scale requirements). Relevant to identify priority areas for preventive biomass management (Portuguese fire hazard risk reference - https://florestas.pt/sfirefightinga-mais/como-se-calcula-o-indice-de-risco-de-incendio-florestal/)	Updated land cover from UAV or satellite (resolution adapted to mapping scale), topography, infrastructures (to protect) and road accessibility.	Map of fire hazard risk
Fuels	Estimated volume and spatial distribution of fuels per fuel type (litter, dead wood, fire-prone shrub species, young trees and mature tress)	Updated land cover from UAV or satellite (resolution adapted to mapping scale), LIDAR data, in-situ data or estimated volume of fuel classes per land cover type	Map of fuel distribution
Critical Infrastructure (CI) Protection Areas	Areas around critical infrastructure need to be kept clear of combustible biomass. Identification and monitoring of these areas is therefore necessary. They are defined by a perimeter around the critical infrastructure.	CI location, perimeter and vegetation characterization.	Critical Infrastructure Protection Areas displayed on map.
Building Infrastructure	Building's location, type (housing, farming facilities…) and construction/materials.		Building Infrastructure characterized and displayed on map
Electrical Infrastructure Location	Location and type of active electrical infrastructure (HV and MV overhead lines, electrical towers, substations).		Electrical Infrastructure characterized and displayed on map

Electrical Infrastructure Criticality	Criticality, based on grid redundancy and voltage characteristics.		
Water Infrastructures Location	Location of active water intakes, water treatment plants, pumping stations and transmission pipelines.		Water Infrastructures typology displayed on map
Water Infrastructures Criticality	Criticality, based on the design flow and system´s redundancy characteristics		Water Infrastructures Criticality displayed on map
Parish Fuel Management Category	It is given priority to higher risk parishes for the inspection of the fuel management. Classify accordingly with the most updated risk maps prepared by the relevant authorities, as per Portuguese Law Despacho n.º 3403/2021		Map showing parish risk category. Critical infrastructures classified with this category.
Infrastructure's Deforestation Zones	Identifying deforestation Working Zones taking into consideration the operational team's effort	Map with the working zones	Infrastructures within the same working zone displayed on map
Vegetation Clearing Activities surrounding Critical Infrastructures	Record of vegetation intervention activities in the infrastructure's vicinity	Clearing reports will provide the date and location of the activities carried out	
Monitoring systems location	Location and type of the monitoring systems and infrastructure (weather stations, video surveillance).		Monitoring systems characterized and displayed on map
Cattle Grazing Locations	GPS locations of cattle, to produce maps of grazing activity to monitor fuel regulation through herbivory	GPS location points (temporal resolution?)	Maps of grazing activity
Woody Biomass (combustible)	Estimation of the combustible biomass density in a particular area, through remote sensing technologies, that are cheaper and cover a larger area than on terrain sensing methods. This estimation should take into consideration not only the volume of the biomass, but its state of dryness.	Earth Observations, UAV sensing	Proportion of combustible biomass cover per grid cell, or combustible biomass volume per unit area displayed on map

Grazing activity	Report on grazing activity - areas of higher activity; daily, monthly and annual patterns of habitat selection and dominant behaviour per area (resting, grazing, moving/walking)	GPS location points (with high temporal resolution), movement sensor data (x,y,z - to model behaviour), and land cover maps	Maps of grazing activity to support grazing management
Grazing pressure (early warning (?))	Report on areas under and overgrazed to support grazing management and avoid negative impacts from grazing	Grazing activity data, satellite VIs to monitor trends in vegetation cover and vigor, proximal sensors (? - soil water content, ground cover)	List of locations in risk of overgrazing or requiring grazing intervention
Vegetation Growth Prediction	Estimation in the temporal dimension of when the vegetation or biomass, will reach a predetermined size or density, through the development of a vegetation growth rate. This will optimize the clearing interventions.	Earth Observations, UAV/optical sensing, LIDAR sensing, Weather, Soil data, Soil water content, in-situ sensors (cameras)	Date prediction of when the clearing will be necessary.
Land Cover	Up-to-date classification of the land cover. Granularity/resolution will depend on the application.	Earth Observations, UAV sensing	Land cover type displayed on map.
Forest vertical structure (vegetation stratification)	Forest understory growth can greatly contribute to the spread and to severe canopy forest fires. Vegetation management may be required, including the use of livestock grazing coupled (or not) with mechanized interventions. Identification of areas with dense and continuous undergrowth is needed to guide management and plan interventions.	Earth Observations, UAV sensing, LIDAR	Maps with indicators of understory biomass (e.g., understory biomass volume per unit area)
Green infrastructure	Green infrastructure for the delivery of different ecosystem functions (services). Focus on more relevant services (natural fire breaks, wildlife corridors, erosion control, ...)	Land cover from UAV or satellite (resolution adapted to mapping scale), LIDAR data, topography, waterlines, infrastructure	Map of thematic green infrastructure

Early warning of biomass overgrowth around critical infrastructures	Remote monitoring, supported by models of vegetation growth, of estimated biomass volume, continuity and height around critical infrastructures. A warning is issued when a threshold is passed.	Satellite VIs (vegetation indexes), proximal sensors (cameras?), list of dominant species in each monitored infrastructure; climate data (precipitation, temperature). Calibrated models of vegetation growth (uses data from past interventions)	List of infrastructures requiring preventive biomass control
Fire-prone invasive species (Acacia sp., Hakea, Cortaderia, etc.)	Location of patches or individuals of fire-prone invasive species; their presence in the landscape aggravates the potential ecological and socio-economic effects of wildfires, thus requiring preventive measures to remove or control their expansion.	Known locations (from land cover maps, citizen science data repositories and location uploaded by stakeholders); topography and infrastructures to further assess risk of invasion	Map of distribution of invasive species and list of locations requiring preventive action
Biodiversity - wild species occurrence	List and map of wildlife known to be present in the area of interest	Spatial locations (spatial resolution variable) of wild life species occurrence retrieved from public atlas and repositories (GBIF, iNaturalist; locations uploaded by stakeholders)	List of wildlife species potentially present in an area of interest; information on species conservation status (and other relevant information)
Biodiversity - ecological value	Biodiversity indexes - species richness, species irreplaceability, classified habitats, remote/"wilder" areas etc.	Spatial locations (spatial resolution variable) of wildlife species occurrences retrieved from public atlas and repositories (GBIF, iNaturalist; locations uploaded by stakeholders); habitat maps (produced from project or from institutional sources); species locations, habitat data, climate and topographic data can be applied in habitat suitability models to predict	Map of ecological value to identify sensitive areas

		species presence; infrastructure and urban/artificial spatial data required to map "wilder" areas (far from infrastructures)	
Vegetation resilience	Vegetation resilience to climate change - calculated from patterns of stability of vegetation indexes through long-term time series; resilient areas will show more stable patterns and less dependent of climatic fluctuations, thus potentially less prone to drought and to increase fire hazard	Long-term time series (continuous update) of satellite VIs, long-term time series of climate data	Map of vegetation resilience (at different spatial scales), identification of areas more prone to drought and to climate change
Emergency Vehicles Accesses	Identification and localization of accesses for firefighting emergency vehicles, such as roads, drivable firebreaks and other corridors.		
Fire location	Location of the fire ignition	Sensors and cameras	Fire location displayed on map
Fire spreading	Location, direction and velocity of the Fire progression	Sensors, cameras and fire models	Monitoring systems characterized and displayed on map with current location and possible fire evolution
Terrain Topography	Topography of the terrain, as it is important for the modelling of the fire spread behaviour, as well as for the coordination of firefighting crews.		Topography layer available on map.
Firebreaks	The location of firebreaks (natural and man-made) is important for the modelling of the fire spread behaviour, as well as for monitoring the state of the firebreak and if it needs clearing.		
Water Reservoirs	Water reservoir's locations for airborne firefighting water tanks refilling. Include only the possible locations.		Water reservoirs displayed on map

Fire hazard risk (Perigosidade de incêndio)	Developed from RAF_01 it includes also the meteorological conditions, adjusting the Map of fire hazard risk to a real situation	Same as of RAF_01 but also includes mereological data (past and present)	Real time information on fire

3.1.3 Fire

According to the Sardinian pilot, the fire parameters for characterizing the fire event are as follows:

- Linear intensity: heat developed in the unit length (Kw/m);
- Flame length: (m);
- Propagation velocity: (m/min).

Linear intensity turns out to be a fundamental quantity for understanding the characters of the fire and allows for the estimation of the probable effects of the fire on vegetation and the possibilities of intervention by firefighting teams: low values of linear fire intensity indicate the possibility of intervention by manual means; on the contrary high linear intensity values indicate scenarios that are increasingly difficult to control even by mechanical means.
Figure 2 shows a linear intensity map, in which the expected values have been grouped into classes in relation to extinguishing difficulty, parameterizing the 4 classes based on the 3 parameters above:

- CLASS 1: up to 400 KW/m (flame length of about 1 m), the flame front can be attacked directly on the head portion and flanks by manual means
- CLASS 2: 400 to 800 KW/m (flame length between 1 and 2 m), direct attack can be done only by mechanical means
- CLASS 3: 800 to 1600 KW/m (flame length between 2 and 3 m), fire may be attacked only by indirect attack and aerial means
- CLASS 4: over 1600 KW/m (flame length over 3 m), the fire is difficult to control and phenomenon of spotting and jumping of sparks are to be expected.

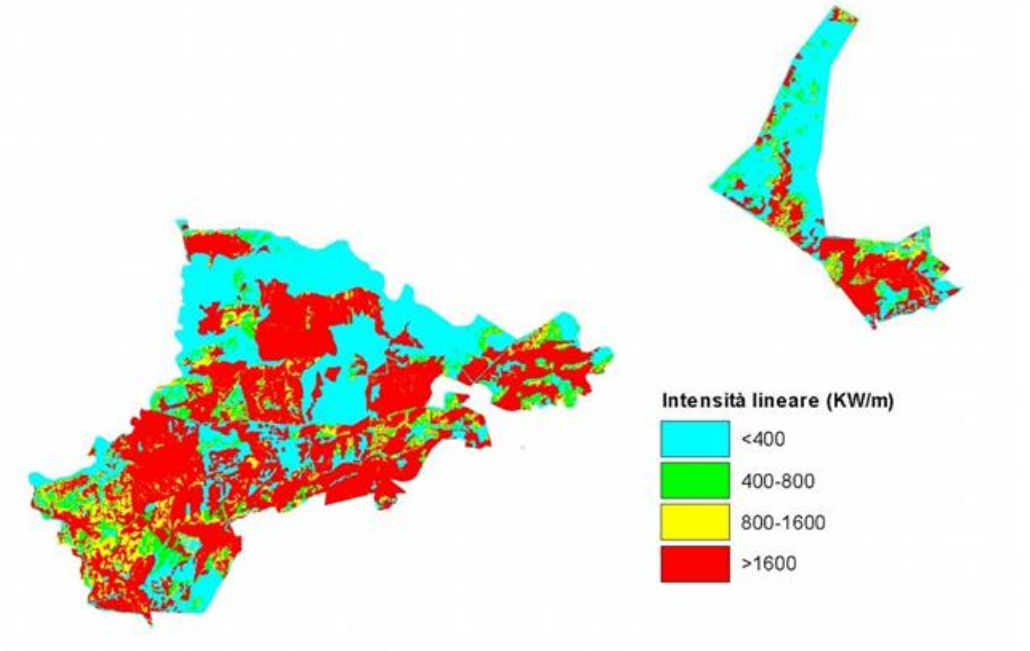


Figure 2 Map of linear fire intensity

As can be seen in the figure above shared by our PNRT partners, the 4 classes are all represented with predominance of class 1 and 4. A class 1 fire (400 Kw/m) can be expected with flames no more

than 1 meter high and therefore can be tackled by ground crews with the use of hand and mechanical tools (flails, rakes, sprayers) without difficulties.

There is then a certain number of areas where class 2 fire behaviour can be expected. In this case, fires with flames of 1-2 meters can be expected that can no longer be tackled solely with hand tools but instead require firefighting vehicles equipped with firefighting modules.

The areas where higher linear intensity is expected (Class 3 and 4) can be expected especially at open shrub and arboreal areas, which could carry fires that are very difficult to control and suppress. These areas have shrub layers, evolved and stable evergreen ilex degradation formations (thickets and garrigue) in which violent fire front behaviour, high propagation velocities and very high flames (even above 10 meters) can be expected. In such types of fires, spotting phenomena, jumping of burning sparks with related danger of multiple ignitions, fire front splitting and loss of control of firefighting operations are common. In these situations, ground crews must be careful and follow protocols to operate safely, and water-heavy ground means, aerial means and indirect front attack must be used.

3.1.4 Causes

According to the Sardinian pilot, to date there are no generalized or otherwise unambiguous models that can be adapted to all levels of fire risk scale, especially in the case of relatively small spatial areas such as the one of the pilot in case.
The risk analysis was, therefore, conducted based on conducive factors, under the assumption that the probability of fire initiation and development is mainly determined by climatic conditions and fuel characteristics, particularly its moisture content.
Given the existence of little information on the causes of past events in the area under study, the focus was therefore mainly on the classification of vegetation into fire behaviour patterns, land characteristics, and meteorological factors affecting the probability of pyrological event spread. Both the quantity and the size of the vegetation fuel depend on the characteristics of the vegetation, and in this sense the different forest types detected during the surveys are a very important element in determining the fire behaviour and the intensity of the flame front.

3.1.4.1 Conducive factors

Conducive factors are those variables that directly affect the conditions conducive to fire spread, namely type of burnable fuel (fuel patterns), topographical conditions (altitude, slope, exposure) and meteorological conditions (air temperature, humidity, precipitation, wind speed and direction).

Table 8, shared by our PNRT partners, shows the spatial distribution of fuel models within the Tepilora Oasis forest complex. As can be seen, the most represented pattern is for subparts in which fire propagates predominantly by green fuel of the shrub component in formations characterized by an almost uniform horizontal continuity (40.4 percent). These are all more or less evolved and stable evergreen ilex degradation formations (patches and garigues).

Table 8 List of fuel models used in field surveys

Model description	Model code	Component that sustains propagation
Low and continuous grassland	1	
Grassland with scattered trees and/or shrubs	2	
Tall grassland	3	Herbaceous layer
Tall, continuous shrub vegetation	4	

Low shrub vegetation	5	Shrub layer
Intermediate shrub vegetation	6	
Vegetation characterized by highly flammable	7	
Compact litter	8	Litter
Non-Compact litter	9	
Litter with undergrowth	10	
Light residues of utilization	11	Residues
Medium residues of utilization	12	
Heavy residues of utilization	13	

The implementation of the mathematical model of fire spread requires the preparation of the following information layers:

- Tree cover: divided into 4 classes: < 20 %, 20 - 50 %, 50 - 80 %, > 80 %
- Slope exposure
- Slope of the terrain
- Altitude

3.1.4.2 The ignition probability map

The ignition probability map shown in Figure 3, shared by our PNRT partners, is closely related to the variation in the moisture content of the fine dead fuel in different sectors of the complex, in relation to the topography and thus to the parameters of exposure, slope, and elevation.

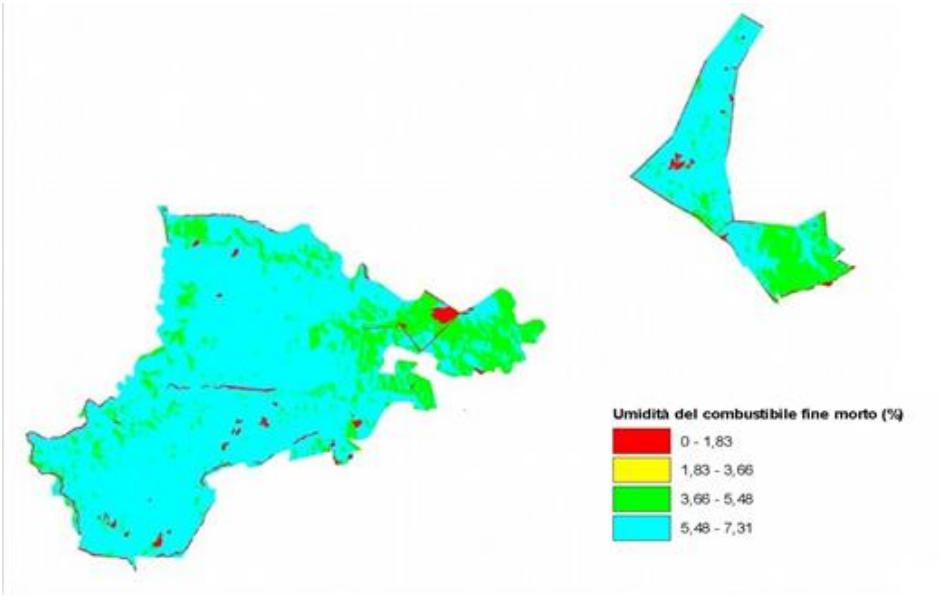


Figure 3 The ignition probability map

To quantify the value of this parameter, two values need to be available: the incidence of solar radiation at each point in the territory in relation to the amount of fine dead fuel. Exposure is an

element of great importance in forest fires and especially in their initial phase of ignition and immediate spread. In the graph shown in Figure 4 (Campbell Prediction System graph) we can see how fuel temperatures vary with time of day and slope exposure. The flammability of the fuel is closely related to its temperature, so for southern and western exposures and the middle hours of the day there is a higher probability of ignition because, evidently, the fuel temperature is higher.

Thus, the ignition risk map expresses the probability of an event developing in the presence of a determining factor, which, in this hypothesis, is assumed to be uniform throughout the investigated area.

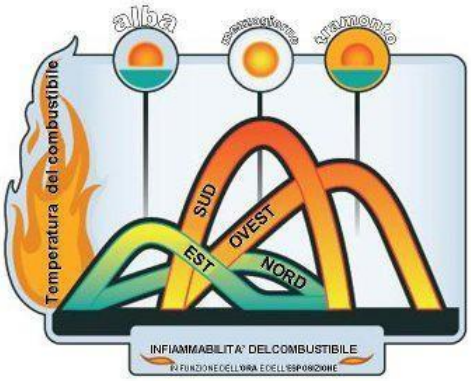


Figure 4 Campbell Prediction System[4]

3.1.5 Tools and resources

3.1.5.1 Preventive actions

According to the Sardinian pilot, prevention actions can be divided into three broad categories (Floris et al. 2004):

- maintenance and/or creation of containment structures
- information, dissemination, awareness raising, education for sustainable development
- active silviculture.

Maintenance and/or creation of containment structures. These activities are to be pursued through the integration of firefighting planning into the forest management plan.

It should be noted that the forest appears to be already equipped with a good number of infrastructures to facilitate active control phases, such as water supply tanks, firebreaks, service roads, and lookout points.

Any new infrastructure, which the forest may eventually accommodate, must be evaluated on a regional or otherwise supra-regional fire plan scale.

Information, dissemination, awareness raising, education for sustainable development.

[4] "The Campbell Prediction System," Emxsys, accessed September 5, 2023, http://www.emxsys.com/doug/default.html.

Information, dissemination, and awareness-raising activities can be carried out using Forests as Centres of Experience, and possibly as laboratories.

In this regard, the Oasis of Tepilora is part of a network of Service Centres, included in the INFEA circuit, which has as a priority objective to organically structure the activity of Environmental Information, Dissemination and Awareness on Forests, ensuring qualified personnel, stable structures and teaching methodologies based on the possibility of acquiring "experience" directly in the field.

Since the causes of fire are mostly anthropogenic, accidental, or culpable, information is an effective means of fire prevention, especially when it is aimed directly at forest users during the peak warning period.

Active forestry. It includes all those interventions aimed at reducing the ignition potential and the amount of fuel, as well as more generally improving the overall forest vegetation structure according to the characteristics of the Mediterranean environment.

It is mainly in direct prevention through silvicultural operations that the action of the detailed forestry plan can take place. Already with the implementation of the silvicultural and infrastructural interventions envisaged in the plan (thinnings, road maintenance, etc.), the fuel load of some high-risk formations should be reduced, and the active control phases made more effective. In addition to these, however, it should be acted upon specific preventive measures aimed at:

- implementing planned, and constant over time, measures to reduce the possibility of vegetation formations to be traversed by fire;
- achieving more easily manageable extinction conditions.

In the context of the Tepilora Oasis possible interventions can be identified in four main activities: prescribed fire, clearing, thinning, and clearing.

Prescribed Fire. Prescribed fire is an expert application of fire on planned surfaces, in which precise prescriptions and operating procedures are adopted to achieve desired effects and achieve objectives integrated into land use planning.

The objective of an intervention with this technique, is to achieve, or avoid, specific effects on the environment and particularly on vegetation. The desired effect, except in special cases, is to transform the structure of vegetation (load, cover, horizontal and vertical continuity), while undesirable effects such as changing soil, air, and water properties or harming wildlife are to be avoided. Some examples of the prescribed fire management scope, in addition to the scope of fire prevention, relate to habitat conservation, wildlife management, and the education and training of forest firefighting personnel in fire handling.

In the area of fire prevention, the prescribed fire technique is generally used for the reduction of fuel load and continuity, and its application, through careful design, can be carried out, for example, for the restoration/maintenance of firebreaks, for the creation of safety strips close to valuable forests, and for the removal of shrub fuel in open areas or under cover, especially in the presence of conifers.

All operations carried out using the prescribed fire technique should be carried out in the winter-spring period, and in any case always within the implementation window provided in the design.

Clearing, thinning, shoveling. Clearing (removal of herbaceous and shrubby undergrowth, with respect to established broadleaf regeneration, and dead fuel), to be beneficial, must extend over significant areas and affect roads, trails, and interface areas.

The urban-rural interface is defined as those zones, areas, or belts, in which the interconnection between anthropogenic structures and natural areas is very close: that is, these are those geographic places where the urban and rural systems meet and interact, so that they are at risk of interface fire, being able to come into rapid contact with the possible spread of a fire originating in combustible vegetation. Such a fire, in fact, can originate either in the vicinity of the settlement (e.g., due to the lighting of fires during recreational activities in equipped areas, sparks caused by power plants, etc...), or as a proper forest fire to then affect the interface areas.

Thinnings are critically important in reducing the likelihood of fire development, especially in coniferous forests, where they are sometimes oriented toward encouraging the establishment of broadleaf trees consistent with local vegetation series. On the other hand, they can also be counterproductive when they favour the development and establishment of scrub species. In such cases, it will be convenient to maintain high tree floor cover at least in areas adjacent to roads where the likelihood of initiation is highest.

Combined with thinning and clearing operations, in coniferous reforestations, scrubbing up to 1/3 of the stem height can provide a degree of prevention, in some cases averting the passage of fire into the canopy.

3.1.6 Biodiversity and Environment

The term biodiversity encapsulates all the diversity of life on Earth - habitats, populations, and genes - and its disruption can have far-reaching consequences for ecosystems and human life. Open space fires and wildfires are a key destabilizing factor for forest ecosystems.

Biodiversity is affected by almost all human activities (e.g., industrialization, transport, tourism, intensive agriculture, forestry, etc.), and it is necessary to predict and prevent the causes of the disappearance of biological diversity on Earth. The protection of biodiversity includes the assessment of the state of endangered species, and the protection of species (plant and animal), i.e., in natural habitats and outside natural habitats - in zoos, arboretums, botanical gardens, seed banks, etc.

Forest fires occur as a natural phenomenon or because of human activity, which often causes fires in continental forests. Every fire has an immense impact on habitats and biodiversity, destruction/reduction of general useful functions of forests and species migration. Although the negative consequences are visible, the positive ones can be observed only after two or three growing years, when pioneer and climate-forming species in that habitat create the conditions for a new start and development of the ecosystem in a common correlation. In the long term, it is the landowner that is the main responsible actor in the creation of a fire resilient environment. They can help prevent the devastating effects of uncontrolled fires by managing the land as well as using fire itself in a controlled way. This is true especially in mountain continental forests, which are among the most vulnerable environments.

The increase in the number of fires affects the natural regeneration of the ecosystem, and as a result, in some areas, this leads to a decrease in biodiversity and an increase in soil erosion. All of this can ultimately lead to the devastation of the land space, which leads to an increase in the cost of restoring these land spaces and returning them to their original state. The activities that should be implemented to strengthen biodiversity from the perspective of fire protection are:

- Application of new technologies and procedures that will contribute to the efficiency of the firefighting and civil protection systems in forest fire management.
- Interoperability of existing procedures and plans that will reduce bureaucracy and increase the efficiency of the firefighting system and civil protection in the field of forest fire management.
- Afforestation activities in groups, covering smaller areas where there are seedlings planted in greater density. The advantages of these fences are reflected in the preservation of the animals of the area, but also of biodiversity in general.

These activities can contribute to a better organized and more efficient suppression of forest fires, reducing the ecological impact and threats to biological diversity.

Key aspects of biodiversity and environment in a context of wildfire management should include and integrate the structural, compositional, and functional dimensions that define the ecological system[5] depicted in Figure 5, including their abiotic environment, and the different stages of wildfire management. Also relevant are the spatial and temporal dimensions (local to regional; daily to annual).

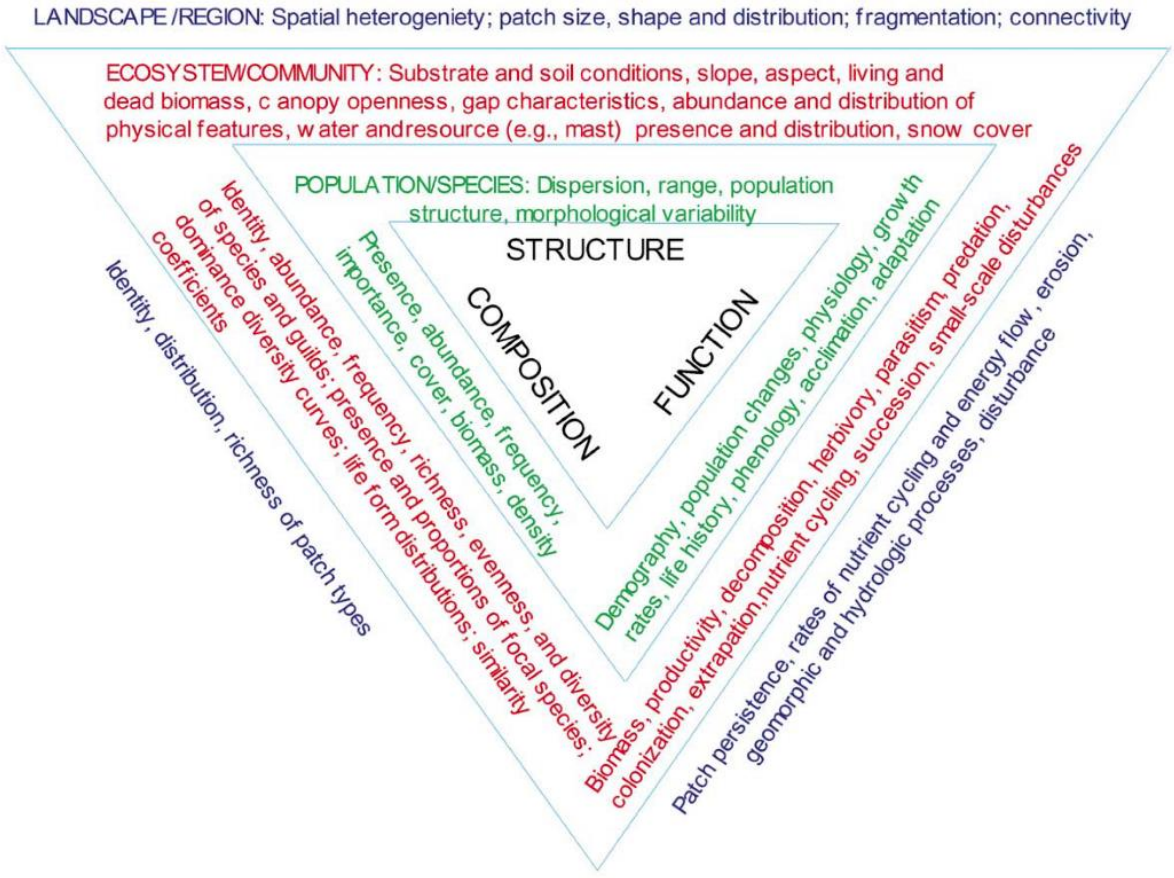


Figure 5 Main dimensions of ecological systems: composition, structure, and function.[5]

The structural dimension is related to data informing on aspects such as landscape structure (e.g., fragmentation and connectivity), forest structure (e.g., vertical continuity, canopy openness, type of

[5] Virginia H Dale and Suzanne C Beyeler, "Challenges in the Development and Use of Ecological Indicators," Ecological Indicators 1, no. 1 (2001): 3–10, https://doi.org/10.1016/S1470-160X(01)00003-6.

fuels), and population structure (e.g., stand age), which may affect dimension of fire risk, fire progression and ecosystem recovery capacity.

The compositional dimension is related to data informing on aspects related to forest and understory composition, which condition the various stages of wildfire management, but also faunal composition, as changes in indicator taxa (e.g., forest birds) may help to assess ecosystem recovery. Moreover, soil composition data (content of soil organic matter, or of key nutrients) may be of interest to evaluate potential ecosystem resilience to fire and to monitor recovery.

The functional dimension is related to data informing on aspects related to natural or human-managed disturbances, such as the use of livestock grazing, mechanized shrub removal, or controlled fires to regulate biomass loads and growth. Other relevant data on ecosystem productivity (biomass growth), phenology (e.g., herb senescence) and vegetation water content can be derived from remotely sensed data and proximal sensors to evaluate fire risk and assess recovery, and on vegetation functional traits, related both to vegetation response to fire (its resistance and resilience to fire) and vegetation effect on the fire regime (e.g., species flammability).

Data on the ecological system can be used to inform on 1) fire risk, related to the wildfire prevention stage, on 2) ecosystem resistance, or ability to endure fire disturbance, and on 3) its resilience, or ability to recover fast (considering the maintenance of ecosystem services to human populations) after fire.

The spatial scale dimension should also be considered depending on the level of ecosystem processes and scale of management, but also the resolution of fire risk projections. The temporal dimension is an important component when evaluating ecosystem resilience and recovery.

3.1.6.1 Environment

The following tables come from the contribution of our partners from PNRT and suggest potentially relevant concepts. Table 9 represents potentially relevant concepts regarding the environment.

Table 9 Potentially relevant concepts regarding environment

Designation	Description	Relates to
Soil properties	Soil properties, namely soil organic matter, can be an important determinant of ecosystem resilience/recovery capacity. Other relevant variables, relevant to inform fire risk, are soil surface temperature and soil water content.	Fire Risk and Resilience
Biomass	Biomass load and distribution can be an important indicator of fire risk, but also an important indicator of resilience and are easy to monitor.	Fire Risk and Resilience
Temperature	Temperature is relevant to resilience if it relates to microclimate (e.g., with/without canopy cover); otherwise, climate variables may be important as auxiliary variables to understand/predict resilience patterns between sites. Temperature should cover both air temperature and soil temperature.	Fire Risk

Wind	Wind is relevant to resilience if it relates to local values (e.g., with/without canopy cover); otherwise, climate variables may be important as auxiliary variables to understand/predict resilience patterns between sites.	Fire Risk
Water Quality	Wildfires increase susceptibility of watersheds to flooding and erosion and can have both short- and long-term impacts on water supplies, such as increased treatment costs, need for alternative supplies, and diminished reservoir capacity. Fires can contaminate streams of water with fine sediments, nutrients and ashes, impacting aquatic ecosystems and water supplies.	Fire Resilience

3.1.6.1 Animal

Table 10 represents potentially relevant concepts regarding the fauna.

Table 10 Potentially relevant concepts regarding animals

Designation	Description	Relates to
Richness	Richness is a basic metric of biodiversity, however, species richness response depends on the taxon; some taxa may even increase after fires.	Fire Resilience
Population	Changes in the abundance of indicator taxa, or of protected species, are an important variable to monitor species responses to fire, and changes in animal community composition.	Fire Resilience

3.1.6.2 Forest/Vegetation

Table 11 represents potentially relevant concepts regarding the vegetation.

Table 11 Potentially relevant concepts regarding forests/vegetation

Designation	Description	Relates to
Tree density	Patterns of tree density may be relevant to assess fire risk and understand natural regeneration processes and heterogeneity in recovery patterns; if a single value for the total area is used it may be redundant with tree population size.	Fire Resistance and Resilience
Tree population	Changes in the abundance of indicator tree species, or of protected species (e.g., listed in the Habitat directive), is an important variable to monitor responses to fire, and changes in forest tree community composition.	Fire Recovery
Tree species composition	Tree species composition (including species relative abundance) is an important indicator of risk, resistance and resilience; diverse forest communities tend to be more resilient.	Fire Risk, Resistance and Resilience
Plant species composition	Plant species composition (including species relative abundance) – idem, but applied to understory communities.	Fire Resistance
Functional diversity metrics	Functional diversity metrics of tree and understory species communities – considering fire-related	Fire Resistance

	traits. Use plant functional traits (fire related) to characterize plant communities, such as, dominant life forms, mean height, density, composition (dominant species), fire strategies (e.g., resprouting, fire stimulated seed germination), etc. This information can be used to assess fire risk and potential resistance and resilience.	
Non-tree vegetation	Shrubs and herbaceous communities are an important component of forest habitats; changes in species abundance and community composition are essential to monitor recovery patterns and detect shifts in community composition driven by gradual environmental degradation (e.g., shrub encroachment, increase in pyrophyte species). Patterns of (fire-prone) shrub cover in the landscape (assessed from landscape structure and metrics) are relevant to assess fire risk.	Fire Risk and Resilience
Tree's mortality rate	Tree's mortality rate, yes, but taking into consideration species traits regarding fire strategies (e.g., resprouters vs. obligate seeders).	Fire Resilience
Moisture content	Moisture content of tree canopy and/or shrub/herbaceous layers.	Fire Risk
Percentage cover and spatial distribution of shrub layer	The shrub layer (of pyrophyte species) is a critical predictor of fire risk, but also an indicator of potential regime shifts from forest habitats to shrublands, which are occurring in the Mediterranean with potential negative effects for biodiversity and ecosystem services.	Fire Risk
Tree/understory productivity and phenology metrics	Tree/understory productivity and phenology metrics (from satellite time series) can be used to monitor forest recovery after fires; data are open-access and algorithms can be implemented in a platform.	Fire Resilience
Landscape composition metrics	Landscape composition metrics (e.g., Fragstats metrics) are important to understand risk, landscape resistance to fire progression and recovery patterns, since source-sink (or metapopulation) dynamics from neighbouring areas are important for recovery at local scale; moreover, landscape composition around a site of interest affect local climate.	Fire Risk, Resistance and Resilience
Population abundance of invasive species	Population abundance of invasive species could be an important indicator to monitor forest recovery after fire, but also to assess fire risk and landscape potential resistance to fire progression in the case of fire prone invasive species (e.g., Acacia sp.).	Fire Resilience
Forest structure	Forest structure, such as canopy height, vertical structure indicators, tree age structure.	Fire Risk, Resistance and Resilience

3.1.6.3 Forest management and restoration activities

Table 12 represents potentially relevant concepts regarding forest management and restoration activities.

Table 12 Potentially relevant concepts regarding forest management and restoration

Designation	Description	Relates to
Road and safety corridors maintenance	Maintenance of road and safety corridors, such as removal of fallen trees, shrub clearing and repairs for vehicle access.	Fire Risk
Plantation and support to regeneration	Plantation and of trees to increase tree species richness; success can be species dependent.	Fire Resilience

3.1.7 Threatened entities

Regarding knowledge about infrastructures, a contribution was collected from EDP and ADP. It is sometimes referenced to Portuguese geography and legal system, but the shared knowledge can be generalized for usage in the context of the SILVANUS project.

Major accidents and disasters have their origins in a wide variety of natural phenomena as well as in technical-technological processes and represent a significant social and economic burden for all countries. Vegetation fires occur as a cause-and-effect relationship between climatic factors, the state of fuel material (humidity, types of plant cover and the amount of wood and other biomass) and human activity. This results in hard-to-compensate economic damages, large reconstruction costs and other indirect and direct losses. Such fires are the cause of disruption of biological and landscape diversity and contaminate the air in a narrow area, but also cause long-term damage through the emission of carbon dioxide.

Forest fires, in addition to all the above, can have an impact on the perception of the global security of the country (especially countries that are popular tourist destinations). Thus, the elements of the entire protection system (preventive and operational) gain importance in the future and must have a development priority. Surely the basis for thinking about reducing the risk of forest fires is the creation of risk assessments in accordance with international guidelines to ensure quality and mutual compliance/comparability.

Risk assessment is primarily the determination of quantitative and/or qualitative risk values, and the risk of forest fires is evaluated more closely. All participants at the national, regional and local level should participate in this process, and the document should specify the basic characteristics of the area, identification of threats and risks, criteria of social values for determining the impact on people's lives and health, economy and social stability and politics, probability/frequency tables, scenarios for wildfires (with the worst possible consequences), matrices for the results of risk assessment, risk evaluation and mapping of forest fire risk.

One of the civil protection measures implemented in case of large fires with the aim of protecting the population and animals is evacuation. Evacuation means the relocation of endangered persons, animals and movable property from endangered objects or areas. It is one of the civil protection measures implemented by all participants in the civil protection system. Evacuation is a very demanding activity to implement and must be planned and carried out as soon as possible to protect people's health and lives. It is extremely important to use the early warning system in a timely manner to inform the public about the potential threat of large open space fires so that the population can prepare for a possible evacuation and evacuate independently in accordance with the situation and in accordance with the instructions of the civil protection.

Recommendations on how to develop capacities for timely evacuation in case of large forest fires:

- Development of early warning and alarm systems with the aim of informing the resident population and tourists in a timely manner about taking the necessary protection and self-protection measures in the event of an open space fire.
- Raising of public awareness through informal education about the implementation of the evacuation by the participants and operational forces of the civil protection system.
- Special care for people with special needs and patients from medical institutions when carrying out the evacuation
- Regular training of the operational forces of the civil protection system in cooperation with legal entities from the tourism sector before the start of the fire season
- Regular inspections before the fire season against legal entities in the tourism sector (e.g., hotels, camps).

The following sections will present some of the critical infrastructures and structures to be safeguarded during a fire event.

3.1.7.1 Electrical Utilities Infrastructure

Electrical infrastructure is a type of critical infrastructure that can be subjected to damages and failure caused by wildfires. Fire damages to electrical infrastructure are particularly critical because these can then have a domino effect on the wildfire, causing disruption on the distribution of electricity, which is used to power several services and equipment, such as communications and water pumping stations, which in turn are essential for coordinated and effective fire response actions by the emergency services and the population. Thus, increasing even further the risk of impact on human lives, ecosystems, and material goods. Therefore, the protection of electrical Infrastructure is imperative. In SILVANUS the partner with the expertise on electrical systems is EDP, the Portuguese electrical utility. So, the analysis on this kind of infrastructures was done for the Portuguese geographical and legal context.

3.1.7.1.1 Distribution Grid Overhead Electrical Lines

Overhead electrical lines are an essential part of the electrical grid that are at particular risk of being affected by wildfires since they spam over thousands of kilometres commonly through rural areas with large amounts of vegetation, that are prone to large wildfires.

According to the Portuguese Decree-Law no. 82/2021, of 13 October, protection areas, defined as fuel management strips, must exist around the overhead lines, with a minimum width of 10 meters on each side, for high voltage (HV) lines, and 7 meters on each side, for medium voltage (MV) lines. E-Redes, EDP Group distribution company manages approximately 68 thousand km in continental Portugal, of which around 59 thousand km are MV lines, and 9 thousand km are HV lines.

The maintenance work to clear vegetation from the fuel management strips is therefore an enormous task, where efficient techniques need to be applied both to keep the schedule of the works and maintenance costs as low as possible.

The use of UAV and helicopters equipped with LIDAR, Multispectral, RGB and Thermographic sensors is currently the most used method to cover and monitor the vegetation in these areas. Additionally, earth observation satellites are also a source that can be used.

Depending on what remote sensing technology is used, the resulting output for the fuel management strips can be the following: 3D point clouds classified on type of vegetation (grass, shrub, trees and other), vegetation species/family, infrastructure (overhead line, line tower and line pole) and other obstacles; or maps of ground cover type and estimated volume of biomass.

Criticality for different sections of the distribution grid also needs to be determined, to coordinate the clearing activities. This criticality can be based on many factors such as the number of clients that a section serves, surrounding vegetation species and technical details (voltage, materials, and others).

3.1.7.1.1.1 Barrier Effect associated with the Fuel Management Strips around Overhead Electrical Lines

Associated with the fuel management strips is a barrier effect on wildfires. This barrier effect is strongly influenced by land uses, for example, water lines, roads, and the fuel management strips, which present lower barrier effect than the previous ones[6]. In the context of agricultural uses, the effect of the fuel management strips around the electrical lines as a fire barrier is null. Pine and eucalyptus have a barrier effect, even so, with lower values than water lines and roads (for the same situation).

Regarding mosaics, the land uses with the highest barrier effect were agriculture, agro-forestry systems, wetlands, and urban. In the context of these land uses, the effect of linear structures is much smaller. Mosaics of these systems alone are one of the most efficient ways to reduce the spread of fires at the landscape level. The barrier indices of linear structures vary greatly depending on the land use context in which they are located, confirming the importance of mosaics as the most significant structures in the context of fire spread. Managing the landscape in a holistic and integrated approach is therefore a more robust solution.

3.1.7.1.2 Hydroelectric Power Plants

Regarding generation, hydroelectric power plants are especially vulnerable to wildfires. This exposure is caused mainly by the impact of fire debris on the waterbodies. Fire debris can impact on the generation assets by putting the turbines out of service, but also can cause indirect exploitation problems by deteriorating the ecological status of the water bodies. To mitigate these situations, hydroelectric power plants must set a protection area and must perform maintenance works in the dams and reservoirs surrounding perimeter.

3.1.7.2 Water Utilities Infrastructure

The integrated management of the urban water cycle includes all the stages, ranging from water abstraction, treatment, and distribution for public consumption to the collection, transport, treatment, and disposal of urban wastewater.

In the Portuguese demonstration subregion, several dozens of facilities are in remote, isolated areas, surrounded by vegetation which maintenance is hard to keep, making them vulnerable to wildfires. Any wildfire can easily put in danger these facilities, destroy the natural heritage, jeopardize the access to water and / or sanitation services for the population as well as for firefighting purposes.

So, keeping the critical facilities surroundings clean of vegetation is a continuing challenge that needs constant fuel management work to minimize the risk.

[6] Duarte, I., Gaião, D., Nunes, L. and Castro Rego, F., 2020. *Análise da eficiência de estruturas lineares e estruturas em mosaicos para serem utilizados pela EDP Distribuição na sua atuação no território*. Instituto Superior de Agronomia, Universidade de Lisboa (ISA-ULisboa).

Water systems may also need to support their customers with interim drinking water during fire recovery and must ensure that the community can trust that tap water is safe as families and businesses return home.

Due to their number and dispersion, the process of gathering, harmonising and processing data that is able to evaluate fire risk on a continuous basis involves spending many work hours and resources that could be replaced by automated and independent risk evaluation solutions, thus, increasing even further the risk of impact on human lives, ecosystems and material goods. Therefore, the protection of electrical infrastructure is imperative.

3.1.7.2.1 Water Intakes, Treatment Plants, Pumping Stations, and Water Reservoirs

In SILVANUS the partner with the expertise on water systems is AdP, the Portuguese water utility. So, the analysis on this kind of infrastructures was done for the Portuguese geographical and legal context.

These are an essential part of the water supply system that are at particular risk of being affected by wildfires since they are located commonly through rural areas with large amounts of vegetation, that are prone to large wildfires.

Considering that all those infrastructures are equipped with electromechanical devices, a fire event can easily impact on their operability and affect the water supply to the populations as well as for firefighting purposes.

The obligation to maintain the fuel management strip networks is one of the preventive measures provided for in the Portuguese Decree-Law no. 124/2006, de 28 de Junho, with the objective of reducing the number of rural fires, with land clearing being the most common practice of fuel management, through the cutting and removal of existing plant biomass in these strips.

In this area, the XXI Constitutional Portuguese Government created the Agency for the Integrated Management of Rural Fires, I. P. (AGIPFR), under the terms of Decree-Law no. (MAAC) would have to report on a weekly basis the evolution of the biomass surrounding the infrastructures.

In addition to the Portuguese legislation, the defense of the forest against fires and the integrated management of rural fires is also regulated by an annual Order that identifies priority parishes for carrying out planning and deforestation work (Portuguese Order No. 3403/2021 of 30 December March), and by the Resolution of the Council of Ministers nº 45-A/2020 that approves the National (Portuguese) Plan for the Integrated Management of Rural Fires. On the other hand, the importance of the executive nature and operational programming of municipal and local planning is also highlighted, which must comply with regional and local guidelines and priorities, in a logic of national contribution.

In the context of Grupo Águas de Portugal (AdP) companies, fire prevention and fuel management involve weekly report of biomass surrounding its infrastructures as well as carrying out deforestation works and reporting them to the MAAC under the terms of the law. In compliance with the provisions of Portuguese Decree-Law no. 12/2018 of 16 February, in February 2019 the Office of the Secretary of State for the Environment requested that AdP, and consequently all the Group's operating companies, provide from that date a report of the areas to be deforested with periodicities defined by the competent authorities, different between weekly and fortnightly, according to the time of year and the inherent risks of ignition.

The visual inspection is currently the most used method to cover and monitor the vegetation in these areas, which makes the process very “heavy” and inefficient considering the large number of infrastructures and their dispersion through the territory.

The maintenance work to clear vegetation from the fuel management is therefore an enormous task where efficient techniques need to be applied both to keep the schedule of the works and maintenance costs as low as possible.

Infrastructures’ criticality also needs to be determined to prioritize the clearing activities. Additionally, to optimize the logistics associated to those activities, the infrastructures are clustered by working areas and the clearing activities will be planned to cover all the infrastructures within the targeted area.

Critical infrastructures are the ones located within or that supplies water to priority areas for prevention and safety (PAPS), which correspond to the ‘high’ and ‘extremely high’ fire danger classes and may include other areas, albeit less hazardous, where there is a recognised interest in protecting them and provided, they are included in the planning instrument.

3.1.7.2.2 Water Piping

Emergency firefighting teams rely in part on operable water pumps and distribution network and must take more ad hoc measures to secure water supply if system fail.

Loss of water service to local hospitals and other vital facilities can compound the impacts of wildfire on a community. Additionally, loss of pressure in water service lines can allow soil and contaminants to enter the piping system. Keeping water systems operable during a wildfire emergency can be difficult, as fire may damage water system infrastructure, spreading fire can leave key parts of water system infrastructure inaccessible and backup power generators may fail.

The water pipes are mostly underground, so those are not the most affected assets in a wildfire scenario, however laboratory tests showed that high temperatures impair the plastic pipes that are used for water distribution and home plumbing. The heat caused the pipes in the experiment to degrade and leach benzene, toluene, ethylbenzene, xylene, and other compounds into water.

Taking it into account, special attention to fuel management shall be paid to critical locations, specially where the plastic pipelines vertical alignment is higher and closer to the surface.

3.1.7.2.3 Wastewater Treatment Plants

Like water systems, wastewater systems are also vulnerable to wildfire events. The malfunctioning of pumping stations and wastewater treatment plants might cause discharge of untreated effluents with potential negative impacts in the environment.

The obligation to maintain the fuel management strip networks is one of the preventive measures provided for in Portuguese Decree-Law no. 124/2006, de 28 de Junho, with the objective of reducing the number of rural fires, with land clearing the most common practice of fuel management, through the cutting and removal of existing plant biomass in these strips.

Fire prevention and fuel management involves weekly report of the biomass´ evolution surrounding the infrastructures and carrying out deforestation works and reporting them to the MAAC under the terms of the law.

Similar to water treatment plants:

1. The visual inspection is currently the most used method to cover and monitor the vegetation in these areas.
2. The maintenance work to clear vegetation from the fuel management is therefore an enormous task.
3. Critical infrastructures are the ones located within priority areas for prevention and safety (PAPS).

3.1.7.3 Infrastructure of silvopastoral interest.

The main infrastructures of silvopastoral interest reported by the Sardinian pilot are briefly described below.

Sloughs and bridges. The most important structure of this type is the bridge over the Riu s'Aragone, in the forest of Sos Littos Sas Tumbas, on the main access road to Sos Littos, which provides access to the Gianni Stuppa Barracks. Just downstream of the bridge is flanked by a ford, in suboptimal condition and for which restoration work is needed, which serves the transit of large vehicles that cannot use the bridge. Another important ford is the one located at Piras, on the Posada River, just outside the Sos Littos forest, which is also used to access the forest (mainly in good season, when the water level of the river allows it). Otherwise, only a few concrete or masonry bridges, wooden footbridges (in the Crastazza forest) are found along the internal road system, generally in fair condition while the fords (also all but one located at Sos Littos, in the Crastazza forest) need maintenance in many cases.

Bars and gates. All the main access roads to the three forests are equipped with functional gates to possibly restrict access (although in many cases they are generally kept open).

3.1.7.4 Firefighting infrastructure.

Fire avenues. In all three forests there are fire avenues arranged along much of the boundaries (including those between Sos Littos and Crastazza) and in some cases there are also fire avenues within the forests themselves.

Small lakes and ponds. Fire-fighting ponds are present in all three forests; in Usinavà there are three artificial ponds (in PF D2 and D11) of which the largest one measures about 3700 m2, in Crastazza there is a pond just over 2000 m2 (in PF C81) while in Sos Littos Sas Tumbas there is the largest pond, in Prammas, of about 7700 m2 (PF A37) in addition to a smaller pond on the slopes of Punta Tepilora. The three larger ponds at Usinavà, Crastazza and Sos Littos, are also surveyed as sub-ponds. In addition to the ponds, there are also two concrete fire tubs at Sos Littos, both along the road in the Badde e' Deremita area.

Fire lookout posts. Overall, there are three fire lookout posts; they are in all three cases buildings and therefore filed as buildings and not as infrastructure, but are treated in this section for homogeneity of function. They are masonry buildings, in good condition and regularly used.

3.1.7.5 Other infrastructures

In this category are included all infrastructures that do not primarily relate to silvo-pastoral and fire management. Brief mentions of those of major importance are given below.

Aqueducts and/or related works and water storage. There are several small constructions, usually made of reinforced concrete, attributable to aqueducts, water catchments and storage, final

diversion and water management serving aqueduct lines or main buildings or even, in some cases serving firefighting facilities.

Equipped rest areas. Equipped rest areas are many, with facilities often limited to wooden and/or stone tables; sometimes there are also fountains and barbecue facilities. These areas are generally located along the roadway and in good condition. Although tourist use of the forest is rather limited, the area deserves to be restored.

Fountains. Fountains are distributed in Sos Littos and Crastazza, along the main roads, either as individual infrastructures or in the context of equipped areas. The masonry fountains present near the Crastazza barracks are particularly used by the population.

Quarries. Several small quarries are present along the main road system (with areas in the order of hundreds or often as little as a few tens of m2) from which material was used in the past for the restoration of that same road system.

Walls and fences. In the forest of Sos Littos and that of Usinavà, there are wildlife fences in varying states of decay

3.1.7.6 Buildings

Each building in the Sardinian pilot was located by GPS or by carryover on a field map (in cases where the location on CTR and orthoimagery was clear and evident) and indexed, as shown in Table 13, by detecting certain parameters that then went on to form the building database. The parameters surveyed are:

1. number. Each building was assigned a unique number

2. toponym. Identifies the building or the location where it stands

3. type of building: dwelling, shelter, service shelter, etc.

4. state of preservation. Good, capable of fulfilling its intended function and not in need of extraordinary maintenance; mediocre, capable of fulfilling its intended function, but in need of extraordinary maintenance in the near future; very bad, can no longer fulfil its intended function; ruins, unsafe; in restoration: affected by renovation, rehabilitation or restoration

5. current use of the building. Permanent dwelling, occasional dwelling, tourist, educational, etc.;

Photographic documentation was also collected for each building.

Table 13 Index of buildings done in the Sardinian pilot

num	topon	Building	State of	Current use
1	P.ta Maccheronis	not classifiable	ruin	abandoned
2	P.ta Maccheronis	fire lookout	good	in use
3	P.ta Pedra Niedda	service shelter	in restoration	in use
4	P.ta Prammas	not classifiable	ruin	abandoned
5	P.ta Prammas	not classifiable	ruin	abandoned
6	P.ta Prammas	fire lookout	good	in use
7	Suburgu	not classifiable	in restoration	turistic
8	Caserma Crastazza	workshop	good	in use
9	Caserma Crastazza	workshop	good	in use

10	Caserma Crastazza	barrack	good	in use
11		not classifiable	ruin	abandoned
12	M. Longu	not classifiable	bad	abandoned
13		not classifiable	ruin	abandoned
14	Ianna De Tandaule	not classifiable	ruin	abandoned
15	Caserma Usinavà	barrack	good	in use
16	Caserma Usinavà	house	good	in use
17	Caserma Usinavà	depot	good	in use
18	Caserma Usinavà	offices	good	offices
19	Caserma Usinavà	restrooms	good	recreational
20	Caserma Usinavà	shelter	good	recreational
21	Caserma Usinavà	fire lookout	good	in use

Service buildings. All three forests have their own barracks, where offices and janitors' quarters are housed in addition to rooms for sheltering vehicles and tools. There is also a workshop in Crastazza, which is currently unused due to lack of testing. In addition to these three main centers, a small equipped service shelter is also worth mentioning in Punta Pedra Niedda, in the forest of Sos Littos Sas Tumbas, which falls in the municipality of Alà dei Sardi (SF B2/3).

Buildings with tourist-recreational functions. At the Usinavà Barracks, along with the service buildings, there are also tourist-recreational facilities, both receptive (guest quarters) and other (toilets, areas with tables and fires), already used in past years through concessions to cooperatives. In the Sos Littos site center, the building of the old Gianni Stuppa barracks has been renovated (work was nearing completion at the time of the survey), which could also have a tourist-recreational destination, with facilities suitable for reception and catering. Similarly, a building has been completely renovated (again, work was nearing completion at the time of the survey) in Crastazza Forest, Suburgo (SF C82/2), with possible tourist-recreational or even educational use.

Buildings with firesighting functions. There are three buildings with functions of fire lookout posts, therefore treated together with the firesighting infrastructure.

3.1.8 Integrated effects

The impact of wildfire events cannot be analysed separately for electrical and water infrastructures and biodiversity. There can be domino, co-joint and cross effects that can change completely the wildfire progression and impact. Most of these effects occur in the wildfire fighting phase, that is, during the prevention phase its impact its negligible.

Domino effects occur when a cumulative effect is produced where one event (or a combination of events) initiates the succession of other events[7], usually not expected when analysing solely by the first. A co-joint effect is when the occurrence of two events has a higher outcome than the algebraic sum of each one occurring separately. Finally, a cross effect occurs when there is an unexpected causal relation between two events.

Affected electrical infrastructures can cause disruption in water supply and communications, thus hindering wildfire prevention and fighting. Water utilities infrastructures can also impact the wildfire prevention and fight. On the other hand, biodiversity and environment can impact on fire

[7] “Domino Effect Definition & meaning,” Merriam-Webster. [Online]. Available: https://www.merriam-webster.com/dictionary/domino%20effect. [Accessed: 29-Sep-2022].

propagation, on firefighting and on landscape restoration after the fire. Potential integrated effects are reported in Table 14.

Table 14 Potential causes and effects of the environment, electrical infrastructures, and water infrastructures

Description	Potential impacts on fire fighting
Operational malfunction in electrical lines due to high temperatures (due to wildfires), causing electrical service disruption.	Water pumps outage due to power failure Communications outage due to power failure.
Electrical lines and transformers outage (due to wildfires) causing electrical service disruption.	Water pumps outage due to power failure Communications outage due to power failure.
Water supply outage (due to wildfires) causing service disruption.	No water available to fight the fire as well as population´s supply, impact on electrical and communication assets.
Bio & Environment Landscape structure and composition – existence and connectivity of areas with fire prone species.	Some species can foster the fire ignitions and spreading causing a co-joint effect.
Bio & Environment Landscape management – existence of areas with fire resistant and resilient species and their spatial distribution; the existence of management measures to regulate biomass loads.	Some species and their distribution in the landscape can hinder fire ignitions and spreading, inhibiting the fire ignition and spreading.
Bio & Environment Landscape planning – road accesses to fire prone areas.	The roads can facilitate the access of firefighters and fire combat consequently mitigate the impact in electrical and water assets and operations. On the other hand, roads (paved or not) may increase the risk of ignitions in remote areas.
Bio & Environment Meteorological conditions – some extreme conditions can cause disruption on wildfires.	For example: extreme conditions can cause downburst and completely change the wildfire progression.

3.1.9 Climate

Regarding climate, the Italian pilot from Sardinia shared some information about combinations of temperature and udometric data.

By combining thermal data with udometric data and calculating factors such as potential and actual evapotranspiration, numerous types of diagrams can be constructed to summarize the thermo-pluviometric components of the considered stations and at the same time provide some information on the water regime of the soils. The diagrams used to define the climatic conditions of the area are as follows:

- monthly and annual average values of precipitation and temperatures.
- Bagnouls and Gaussen diagrams, in which rainfall is compared with temperatures at a scale twice that of rainfall.
- water balance diagrams according to Thornthwaite, which classifies the climate of a region according to the "balance" of a system that receives water mainly from meteoric inflows and gives it back in the form of evapotranspiration.

Other parameters also prove important in estimating the water balance:

- the water deficit (D) i.e., the difference between potential evapotranspiration and actual evapotranspiration, which allows estimating the amount of water needed to balance the losses due to potential evapotranspiration.
- the water surplus (S), which indicates the amount of water that, once the soil water supply is saturated, goes into groundwater and surface runoff.

Having determined these values, indices expressing the degree of aridity and humidity of an area can be obtained: it is precisely based on these indices that the "climate formula" is determined. In addition, according to Thornthwaite, the magnitude of the water balance, but especially the values it takes during the year, are important to understand what conditions of water availability (or deficit) are affecting the plants.

Another important factor for the purpose of calculating the water balance is the amount of water that the soil can store within it (useful water or A.W.C.) and that may be usable for plants. This depends on various factors, including the depth of the soil itself, the amount of skeleton and the organic matter content. Of course, it must be considered that climatic parameters vary as certain factors change, such as exposure, altitude, layering, and orographic pattern.

3.2 Ontologies and Taxonomies

For the instantiation of the proposed semantic component, which was explained in section 3.1, we must create an ontology which attempts to cover the most relevant concepts around the emergency simulation process. Design and modelling phases of our ontology have followed the guidelines and procedures coming from several sources and guides. These will be presented in the following paragraphs.

3.2.1 beAWARE[8]

The beAWARE ontology is the ontology developed, and therefore proposed, by Catalink, partner of Task 3.1. They expanded on the most prominent existing ontologies for crisis management. Such third-party ontologies share the drawback of covering only a subset of the notions involved in climate-related crisis management. Contrary to those, the beAWARE ontology semantically represents all aspects pertinent to crisis management, as indicated in the Table below.

Approach	Disasters/crises/emergencies	Climate parameters	Sensor data analysis	Response units & equipment	Response unit assignments	Incidents	Impacts
BACAREX (2005)	*Only fire*	☑		☑	☑		
ISyCri (2008)	*Minimal*					☑	☑
SoKNOS (2011)				☑	☑	☑	☑
MOAC (2012)	☑					☑	☑
Mescherin et al. (2013)	*Minimal*			☑	☑	*Minimal*	*Minimal*
SOFERS (2014)	☑	☑		☑		☑	☑
Zavarella et al. (2014)	☑						☑
Lauras et al. (2015)	☑			☑	☑	☑	☑
beAWARE v1 (2018)	☑	☑	☑	☑	☑	☑	☑

Figure 6 Areas covered by ontologies considered in the beAWARE project[8]

The beAWARE ontology semantically represents three core aspects, as included in Figure 6: (a) **climate-related natural disasters**, (b) **analyzed data coming from the multimodal sensors**, and (c) **rescue team assignments**.
Thus, the following tables include the competency questions per each of the 3 aspects that served as the foundation for the design of the ontology.

1. Representation of natural disasters and relevant climate parameters, incidents and impacts.
Which natural disasters may lead to natural disaster [X]?
What are the impacts caused by natural disaster [X]?
Which climate parameters characterize natural disaster [X]?
What are the measurements for climate parameter [X] for natural disaster [Y]?
What is the [maximum/minimum/average/…] measurement for climate parameter [X] during natural disaster [Y]?
Where did natural disaster [X] take place?
What incidents are associated with natural disaster [X]?
Where did incident [X], which is associated with natural disaster [Y], take place?
What are the impacts caused by incident [X] during natural disaster [Y]?
What is the location with the [most/least] incidents during natural disaster [X]?
What incidents took place during time interval [t1] to [t2] during natural disaster [X]?

[8] beAWARE-project, "Beaware-project/ontology: This repository contains the crisis management ontology for the beaware H2020 project along with the relevant documentation.," GitHub. [Online]. Available: https://github.com/beAWARE-project/ontology. [Accessed: 29-Sep-2022].

Which incidents during natural disaster [X] are the [most/least] severe?
What is the priority of incident [X] during natural disaster [Y]?
What incidents during natural disaster [X] are the most urgent (i.e. with the highest priority)?

2. Representation of analysed data from the multimodal sensors.
When and where was media item [X] created?
What is the location with the [most/least] media items?
Which vulnerable objects were involved in incident [X]?
What impact do the vulnerable objects involved in incident [X] suffer?
What is the risk suffered by vulnerable objects involved in incident [X]?
What are the vulnerable objects that suffer the [greatest/smallest] risk during incident [X]?
What is the detection confidence level for vulnerable object [X] during incident [Y]?
What are the vulnerable objects with the [highest/lowest] confidence level detected during incident [X]?
Which media items led to the creation of incident [X]?

Figure 7 displays an overview of the core ontology classes

3. Representation of rescue unit assignments.
What is the location of rescue unit [X]?
What is the mission assigned to rescue unit [X] and what is its current status?
What is the location where rescue mission [X] is taking place?
What is the incident that rescue unit [X] is addressing?
What are the vulnerable objects involved in the mission assigned to rescue unit [X]?
What is the potential impact of the mission assigned to rescue unit [X]?
What rescue missions have taken place during time interval [t1] to [t2]?
Where is the most urgent mission (i.e. the one with the highest priority) taking place?
Which rescue unit is assigned the most severe incident?

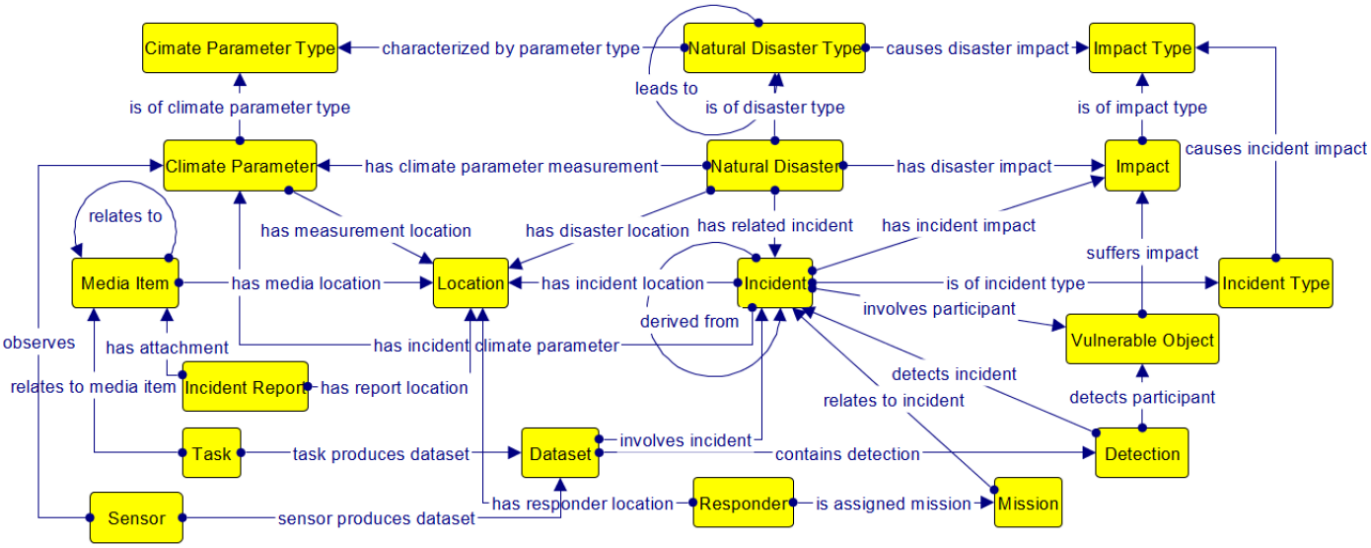


Figure 7 High-level overview of the core classes of the beAWARE ontology[8]

The following subsections present the three core aspects of the ontology, as they were introduced before: (a) representation of natural disasters, (b) representation of analyzed data coming from the multimodal sensors, and, (c) representation of rescue team assignments.

3.2.1.1 Representing Natural Disasters

The representation of natural disasters (including forest fires) in the beAWARE ontology v1 is illustrated in figure 8 below.

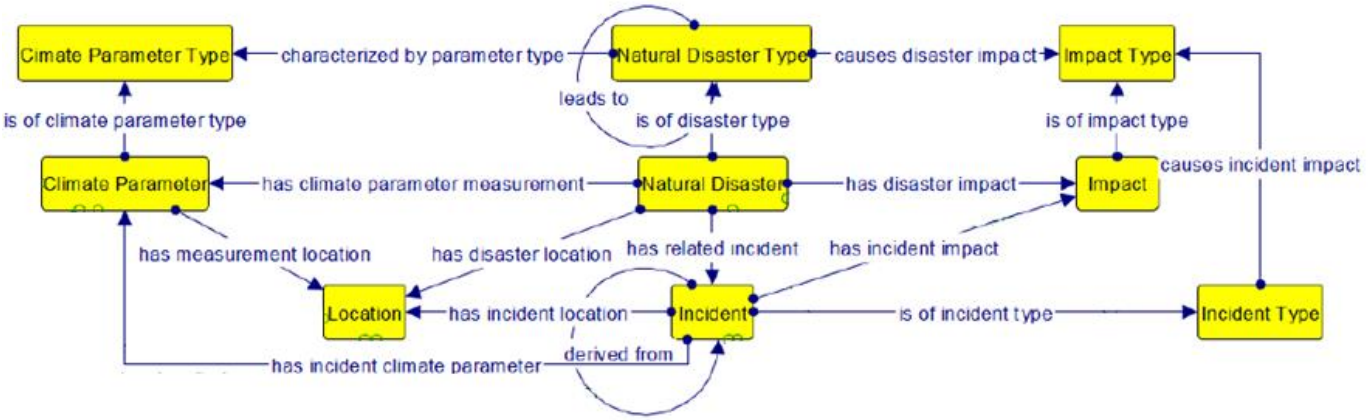


Figure 8 Representation of climate-related natural disasters in the beAWARE ontology.[8]

Class Natural Disaster Type represents the various types of disasters, e.g., floods, forest fires, storms or earthquakes etc. Disasters may lead to other disasters (via property leads to); for instance, a heat wave may lead to forest fires, or storms may lead to floods. Each type of disaster is characterized by certain climate parameters, represented via class Climate Parameter Type. The actual manifestation of a natural disaster is represented via class Natural Disaster, an instance of which has specific climate conditions (via class Climate Parameter) with specific values. Impacts and incidents are also associated to natural disasters, via the respective classes. Figure 9 displays a sample temperature measurement, which was recorded during the 2017 UK heatwave1 (17-22 June).

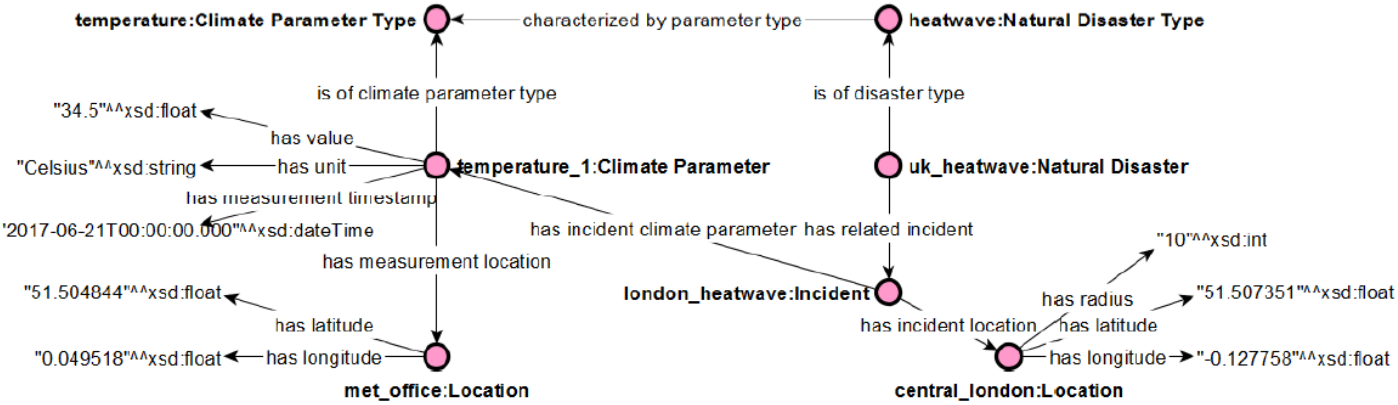


Figure 9 Instantiation of a sample temperature measurement in the beAWARE ontology.[8]

Note that several notions in the ontology come in pairs, <Notion> and <Notion Type>, associated via property <is of type>. This approach allows to integrate two distinct layers of expressiveness into the ontology: <Notion Type> is the more abstract layer for interconnecting notions at a higher level (e.g., what types of impacts are caused by hurricanes? what are the climate parameters that characterize a heatwave?). While <Notion>, on the other hand, allows to represent the actual manifestations of the notions and contains all metadata for the specific event. For instance, the UK heatwave in Figure 9 is a manifestation of the Heatwave natural disaster type. This dual scheme is adopted in the whole beAWARE ontology.

3.2.1.2 Representing Analyzed Data

Besides the representation of climate-related natural disasters and pertinent notions, the beAWARE ontology also encompasses information relevant to the analysis of input data coming from the

various sensors of the framework. This information is fed to the ontology from the analysis components; the core constructs in the ontology are illustrated in figure 10.

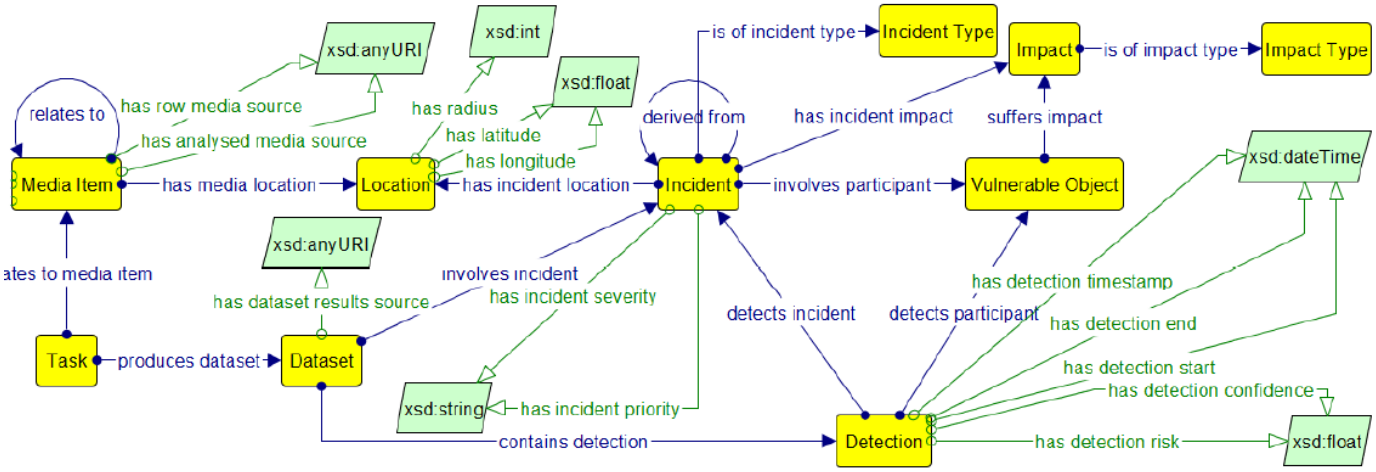


Figure 10 Representation of analyzed data in the beAWARE ontology[8]

Class Media Item represents an item of analyzed data, which is related to some analysis task (via class Task). Media items can be pieces of text, images, videos, or social media posts, all of them submitted during the occurrence of the crisis. The analysis of the respective items (text analysis, image analysis or video analysis) produces a Dataset containing all relevant information (e.g., an object detection task may produce a dataset of detected incidents, objects, and confidence scores)

The following figure 11 demonstrates an example of a video analysis instance, where a vehicle is detected participating in a flood incident. Note that the beAWARE ontology contains a complete typology of media items (text, image, video, social media), vulnerable objects (e.g., assets, stakeholders, infrastructure, buildings etc.), impacts, data analyses, and incidents.

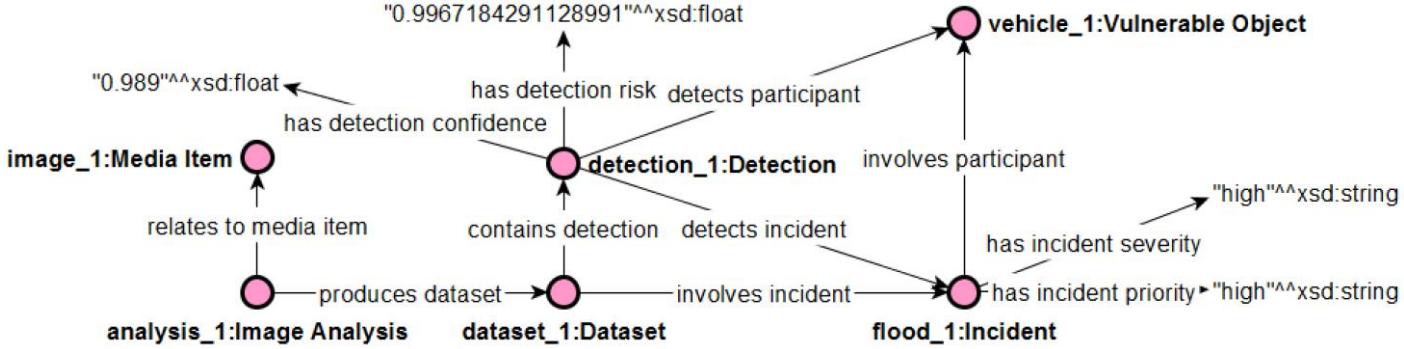


Figure 11 A video analysis example in the beAWARE ontology.[8]

3.2.1.3 Representing Rescue Team Assignments

The third component of the beAWARE ontology is responsible for semantically representing rescue team assignments. This component is not very mature.

The following figure 12 displays the respective concepts in the proposed ontology. First responders (class Responder) are assigned one or more missions (class Mission), which in turn relate to incidents that involve participating entities (class Vulnerable Object). A mission is also characterized by start and end time, status, and mission priority.

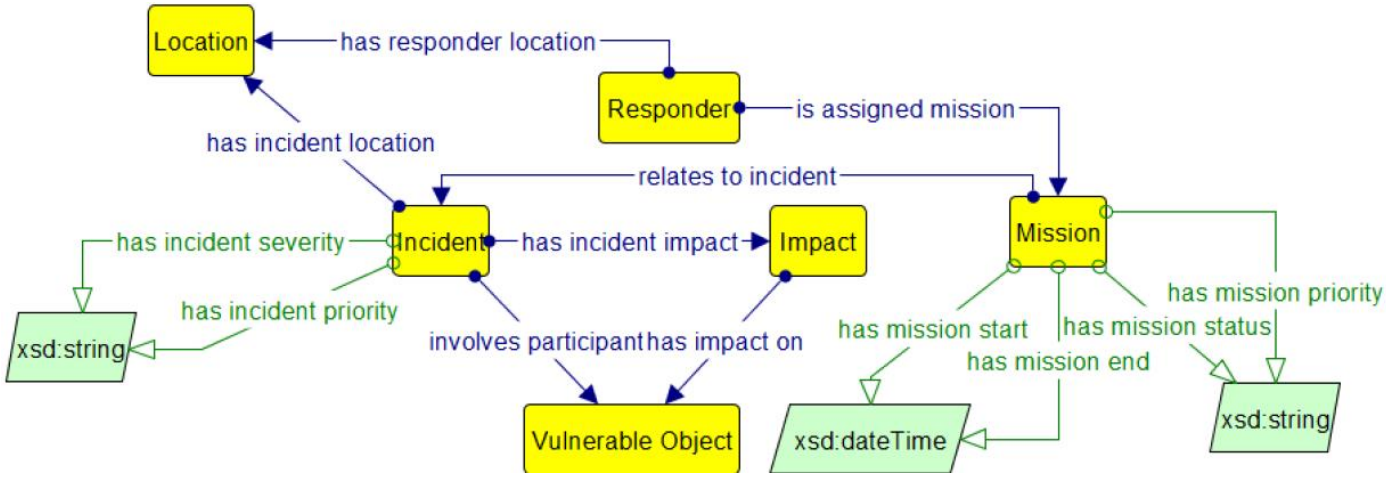


Figure 12 Representation of mission assignments to first responder units in the beAWARE ontology[8]

3.2.2 Bioportal Fire Ontology[9]

The concept of fire is possibly among the most relevant concepts in the SILVANUS ontology. The concept of fire was modelled using the Bioportal Fire ontology as a starting point. Bioportal is the world's most comprehensive repository of biomedical ontologies.
This ontology of Fire was created to represent the set of concepts about the fire occurring in natural vegetation, its characteristics, causes and effects.
The following table 15 and figure 13 show an overview of the ontology:

Table 15 Tabular overview of Bioportal Fire Ontology

Classes	**53**
Individuals	9
Properties	19
Maximum depth	3
Maximum number of children	10
Average number of children	4
Classes with a single child	3
Classes with more than 25 children	0
Classes with no definition	7

[9] "Fire ontology: NCBO Bioportal," Fire Ontology | NCBO BioPortal. [Online]. Available: https://bioportal.bioontology.org/ontologies/FIRE. [Accessed: 29-Sep-2022].

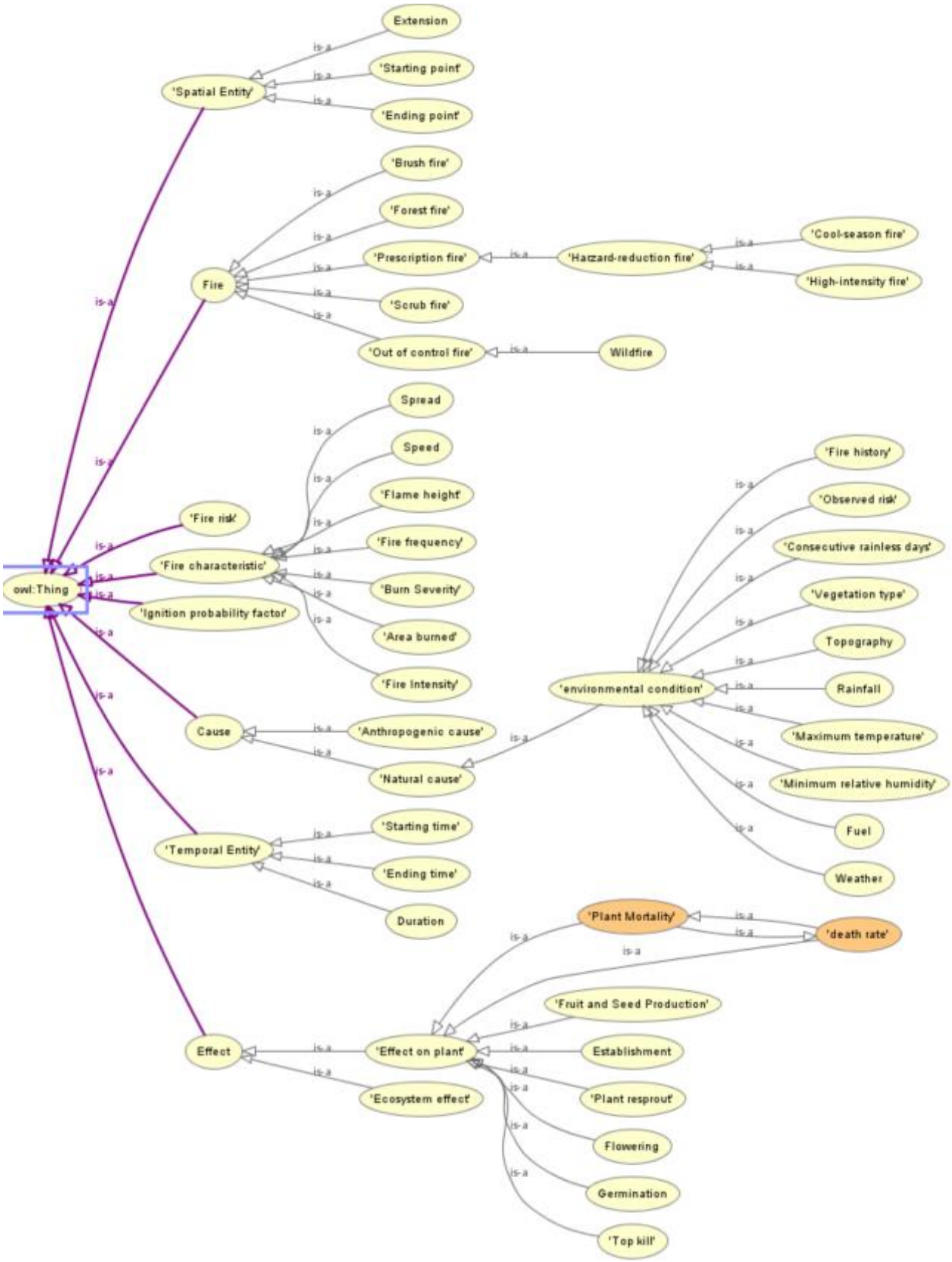


Figure 13 Graphical overview of Bioportal Fire Ontology

3.2.3 European Forest Fire Information System (EFFIS)[10]

For the representation of fire causes we leveraged the EFFIS taxonomy about possible fire causes. It is approved by the EU, it's mentioned in the task description and has been taken into consideration by other partners as well, in particular in Task 3.2.
The information on the causes of forest fires is of great importance to support the environmental and civil protection policies and design appropriate prevention measure. At the European level a simple common scheme with 4 fire cause classes (deliberate, accident/negligence, natural and unknown) has been used to record information on fire causes since 1992.
Up until 2013, European countries used national schemes which in most cases are much more detailed than these simple 4 common classes, but they are not harmonized, and detailed cross-country comparisons are difficult. This led to the need for a new EU scheme that is harmonized across European countries and that is able to improve the information level and the common knowledge on the origin of forest fires in Europe. The scheme is hierarchical and is made of 29 fire cause classes, 8 groups and 6 categories.
This harmonized fire cause classification scheme is expected to be adopted by the countries participating to the EFFIS network in the coming years, and therefore be recorded in the European Fire Database, with a significant added value for the knowledge about the origin of forest fires in Europe. A key feature of the new scheme is that common fire causes categories must be widely agreed/recognized; in addition, clear and unambiguous definitions are integral part of the new classification scheme.
The new fire causes classification scheme has 3 hierarchical levels. At the level with higher detail there are 29 fire cause classes, organized into 8 groups which in turns correspond to 6 generic categories. Within each category, different groups and classes define the lower 2 levels of the classification.
The following table in figure 14 shows the complete list of classes, groups, and categories of the new scheme. Also, definition for each category and class is provided.

[10] A. Camia, T. Durant, and J. San-Miguel-Ayanz, "Harmonized classification scheme of fire causes in the EU adopted for the European Fire Database of EFFIS," European Commission Joint Research Centre. [Online]. Available: https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf. [Accessed: 29-Sep-2022].

CATEGORY	GROUP	CLASS
100 UNKNOWN	100 Unknown	100 Unknown
200 NATURAL	200 Natural	201 Lightning
		202 Volcanism
		203 Gas emission
300 ACCIDENT	300 Accident	301 Electrical power
		302 Railroads (Railways)
		303 Vehicles
		304 Works
		305 Weapons (firearms, explosives, etc.)
		306 Self-ignition (auto-combustion)
		307 Other accident
400 NEGLIGENCE	410 Use of fire	411 Vegetation management
		412 Agricultural burnings
		413 Waste management
		414 Recreation
		415 Other negligent use of fire
	420 Use of glowing objects	421 Fireworks, firecrackers and distress flares
		422 Cigarettes
		423 Hot ashes
		424 Other use of glowing object
500 DELIBERATE	510 Responsible (arson)	511 Interest (profit)
		512 Conflict (revenge)
		513 Vandalism
		514 Excitement (incendiary)
		515 Crime concealment
		516 Extremist
	520 Irresponsible	521 Mental illness
		522 Children
600 REKINDLE	600 Rekindle	600 Rekindle

Figure 14 Classes, groups, and categories of the harmonized fire causes classification scheme[10]

100 UNKNOWN
Wildfire with no cause found.
200 NATURAL
Any wildfire caused by natural origin, with no human involvement in any way.

201 Lightning
Wildfire caused directly or indirectly by lightning.
202 Volcanism
Wildfire caused by volcanism.
203 Gas emission
Wildfire caused by natural emissions of gas (e.g. coming from peat bog) that can self-ignite.

300 ACCIDENT
Wildfire unintentionally and indirectly caused by human without use of fire, connected neither to will nor to negligence rather to fatality.

301 Electrical power
Wildfire caused by sparks due to failure of electric lines or other electric wirings: short-circuits due to contact between two lines or between line and vegetation or bird, fall of the line, etc.
302 Railroads (Railways)
Wildfire caused by sparks emitted by train brakes or fall of catenaries. It has to be linked with the operation of trains. Fires lit intentionally or not by passengers or railway employees (by smoking, managing vegetation, etc.) are not classified in this category and must be

classified in the category corresponding to “what these persons did” to set the fire (and not to “where they were”).

303 Vehicles

Wildfire caused by exhausts (expulsion of glowing carbon deposits, hot catalytic converter) and brakes of vehicles travelling along the road, or by road incidents (Burning motor for example) or traffic accidents

304 Works

Wildfire caused by sparks emitted by engines and machinery (such as chainsaw) in industry, forestry and agriculture or people at work (explosions, welding, grinding, smouldering) or by ignition of flammables and vapours during works in industrial activities.

305 Weapons (firearms, explosives, etc.)

Wildfire caused either by military exercises (firing, explosions) or by citizens using firearms (in hunting activities for instance) or explosion due to explosives during works. This class takes also into account the fires set after explosions due to ammunitions from I and II World Wars buried underground.

306 Self-ignition (auto-combustion)

Wildfire caused by self-ignition of vegetation wastes and other products left in piles.

307 Other accident

Wildfire caused by other accidental cause (Other technical incidents) than those previously defined. In this class are coded the wildfires due to “Sun” because the sun alone does not allow the ignition but needs an object like a piece of glass. Also included are causes such as “Glass”, “Friction energy”, “thermal reaction of chemicals” or “Self-ignition of coal”.

400 NEGLIGENCE

Wildfire unintentionally caused by human using fire or glowing object, not connected to fatality

410 Use of fire

Wildfire unintentionally set by people making fire especially for cleaning or recreation. The difference between “deliberate” and this category is that the fire is initially voluntarily set for a specific purpose and not in order to destroy the natural area. To be classified in this category, the fire has to escape and get out of control.

411 Vegetation management

Wildfire caused by any kind of vegetation burnings for private, forestry, pastoral (pasture regeneration) purposes including prescribed burnings, burning of slashes or of piles of vegetal waste but except for agricultural purposes.

412 Agricultural burnings

Wildfire caused by all types of agricultural burnings (stubble burnings, etc.).

413 Waste management

Wildfire caused by garbage burnings in official or illegal dumps (dunghill) including
private, industrial and commercial.

414 Recreation

Wildfire caused by people engaged in a recreational activity (vacationing, fishing, picnicking, non-commercial berry picking, hiking, and hunting) setting barbecues, bonfires and campfires of any kind (for cooking, heating, etc).

415 Other negligent use of fire

Wildfire caused by other use of fire than those previously defined. In this class are coded the wildfires due to “bonfires at work” “facility fires” and “Candles”.

420 Use of glowing objects

Wildfire unintentionally set by people using glowing objects such as (i) fireworks, (ii) cigarettes, (iii) hot ash handling by residents or (iv) during working activities such as apiculture, fumigation or disinfection or when expulsion of firebrands out of chimney.

421 Fireworks, firecrackers and distress flares

Wildfire caused by fireworks with or without preventive measures, by firecrackers and by distress flares regardless of who lit it.

422 Cigarettes

Wildfire caused by cigarettes and tobacco pipe regardless of the activity or the location of the smoker. It includes the fires set by the match used for lighting the cigarette and negligently thrown away by the smoker, but not cases where a cigarette or matches have been used to set an arson fire.

423 Hot ashes

Wildfire caused by hot ash handling by people after a barbecue or a fire. This class is related to recreational activities. Hot ashes related to work are classified in the following class.

424 Other use of glowing object

Wildfire caused by other use of glowing object than those previously defined. In this class are coded wildfires due to working activities such as apiculture, fumigation or disinfection or due to glowing firebrands expulsed out of chimneys regardless of the building.

500 DELIBERATE (synonyms: intentional, voluntary)

Wildfire intentionally caused by human with the use of fire.

510 Responsible (arson)

Wildfire wilfully ignited by people over the legal age, which burns or spreads to vegetation or property without consent of the owner.

511 Interest (profit)

Wildfire set for profit, either directly for monetary gain or from a goal other than money: fraud, insurance, liquidate property, dissolve business, inventory, employment, parcel clearance, competition for agricultural, forestry, hunting and pastoral purposes to frighten wildlife, to get a job in the fire fighting area, to change land-uses or to get a better salary as fire-fighter, etc.

512 Conflict (revenge)

Wildfire set in retaliation for real or perceived injustice or wrong:

- Personal revenge: (to retaliate for a one-to one or personal grievance, argument, fight, personal affront or any of infinite arrays of events perceived by the offender to warrant retaliation).
- Societal retaliation: (in revenge against the society that the author perceives has wronged him).
- Institutional: (fire against institutions or use of fire to settle grievances with the institution and to intimidate those associated with the institution).
- Group retaliation: (fire as expression of anger towards the group or its members rather than anger at a specific individual within the group).
- Intimidation.

513 Vandalism

Malicious or mischievous fire setting that results in damage to property: wilful and malicious mischief or peer group pressure.

514 Excitement (incendiary)

Wildfires set to gain attention and to meet the needs of being important. Seeking of thrill, attention, recognition, relief of boredom. Includes fires lit in order to admire the spectacle of extinguishing means.

515 Crime concealment
Wildfire set to hide or conceal the primary crime activity: murder, suicide, breaking and entering, embezzlement, larceny, destroying records. Fires set as diversionary tactic fall into this category.
516 Extremist
Wildfire set to further social, political or religious causes: terrorism, discrimination, riots/civil disturbance.

520 Irresponsible
Wildfire caused by people not responsible for their actions because under legal age or mentally ill.
521 Mental illness
Wildfire caused by people in case of pyromania or other mental illnesses.
522 Children
Wildfire set by children (under legal age) for game or entertainment.

600 REKINDLE
Wildfire caused by re-ignition of a previous fire, due to latent heat or embers.

In addition, harmonized classification scheme of fire causes in the EU provides mapping of naming schemes of 22 European countries that were in use before 2013 into the adopted classification in the European Union currently in use, as exemplified in figure 15. On the one hand, this mapping limits semantic uncertainty that can occur at local or state level and provides a common understanding of the classification, but on the other hand it provides an extensive list of the fire causes of greater granularity than the adopted EU classification.

Fire causes and number of fires recorded under the national scheme		Fire causes and number of fires recorded under the new European scheme	
Cause	**Count**	**Cause**	**Count**
0 Unsolved, still under investigation	839	100 Unknown	951
5 No further investigation	112		
99 Other causes (exceptional)	11	1004 Unknown (Reason known but not specified)	11
93 Natural disasters	2	200 Natural	2
90 Lightning/buildings with lightning conductors	-	201 Lightning	46
91 Lightning/buildings without lightning conductors	-		
92 Lightning - other	46		
56 Sparks from exhaust / brakes	22	303 Vehicles	26
94 Traffic accidents	4		
24 Use of flammable liquids, gases	-	304 Works	203
27 Welding, cutting, defrosting	3		
28 Neglect of safety regulations	25		
29 Negligence, error, incorrect control	134		
50 Technical failures	14		
51 Incorrect installation	-		
52 Incorrect maintenance	-		
53 Glowing materials, products	-		
54 Foreign material in machine	5		
59 Other changes of operational parameters	20		
70 Gas explosion	-		
71 Flammable liquids explosion	-		
72 Dust explosion	-		
74 Explosions of pressure vessels, boilers	-		
80 Flammable subs near spraying machines	-		
81 Flammable subs near pumping devices	-		
82 Flammable subs near steeping bowls	-		
83 Flammable subs near long-distance piping and reservoirs	-		
84 Cementing of flooring materials	-		
85 Production of flammable and explosive materials	-		
86 Handling of flammable and explosive materials, chemical cleaning and producing alcohol	-		
87 Storing and preservation of flammable and explosive materials	-		
89 Other (flammable substances)	2		

Figure 15 Example of mapping of the national fire causes classification scheme of Czech Republic to the new scheme[10]

In result, JRC's report provides not only definition of the harmonized taxonomy of the fire causes in Europe, but also details on 22 legacy taxonomies used before.

It is also worth mentioning, that JRC issued another related executive report, focused on technical specification and data model for the European Fire Database[11]. This report specified common rules for the fire incident reporting. Abovementioned classification of fire causes is one of the properties of incidents stored in the database. Other properties of fire with definition of data fields and format include its ID, information related to timing, location, and size of a fire, as illustrated in the following figure 16.

Group	Data field	Field name
ID	Unique Fire identifier	FIREID
TIME OF FIRE	Date of first alert	DATEAL
	Time of first alert	TIMEAL
	Date of first intervention	DATEIN
	Time of first intervention	TIMEIN
	Date of fire extinction	DATEEX
	Time of fire extinction	TIMEEX
LOCATION OF FIRE	Province Code (national nomenclature)	PROVCODE
	NUTS3 code	NUTS3
	Commune Code (national nomenclature)	CODECOM
	Commune Name (national nomenclature)	NAMECOM
	Latitude	NORTH
	Longitude	EAST
SIZE OF FIRE (Ha)	Burned Area FOREST	BAFOR
	Burned Area OTHER WOODED LAND	BAOW
	Burned Area OTHER NATURAL LAND	BAONW
	Burned Area AGRICULTURAL LAND	BAAGR
CAUSE OF FIRE	Certainty of knowledge of Presumed Cause (EU code)	CAUSE_KNOWN
	Presumed Cause (EU categories code)	CAUSE_EU
	Presumed Cause (Country detailed categories code)	CAUSE_CO

Figure 16 Data scheme for individual fire record consists of 19 data items in the EU Fire Database/EFFIS[11]

3.2.4 Canadian Fire Weather Index System[12]

The fire weather index system is another piece of knowledge that was mined from the partners working on T3.2 about fire ignition models. It is useful for formalizing the knowledge concerning climate parameters that might lead to ignition, such as temperature, relative humidity, wind, rain, moisture. Its structure is summarized in figure 17.

[11] Camia A, Durrant T, San-Miguel-Ayanz J. The European Fire Database: technical specifications and data submission . EUR 26546. Luxembourg (Luxembourg): Publications Office of the European Union; 2014. JRC88884
[12] N. R. Canada, "Canadian wildland fire information system: Canadian forest fire weather index (FWI) system," Canadian Wildland Fire Information System | Canadian Forest Fire Weather Index (FWI) System. [Online]. Available: https://cwfis.cfs.nrcan.gc.ca/background/summary/fwi. [Accessed: 29-Sep-2022].

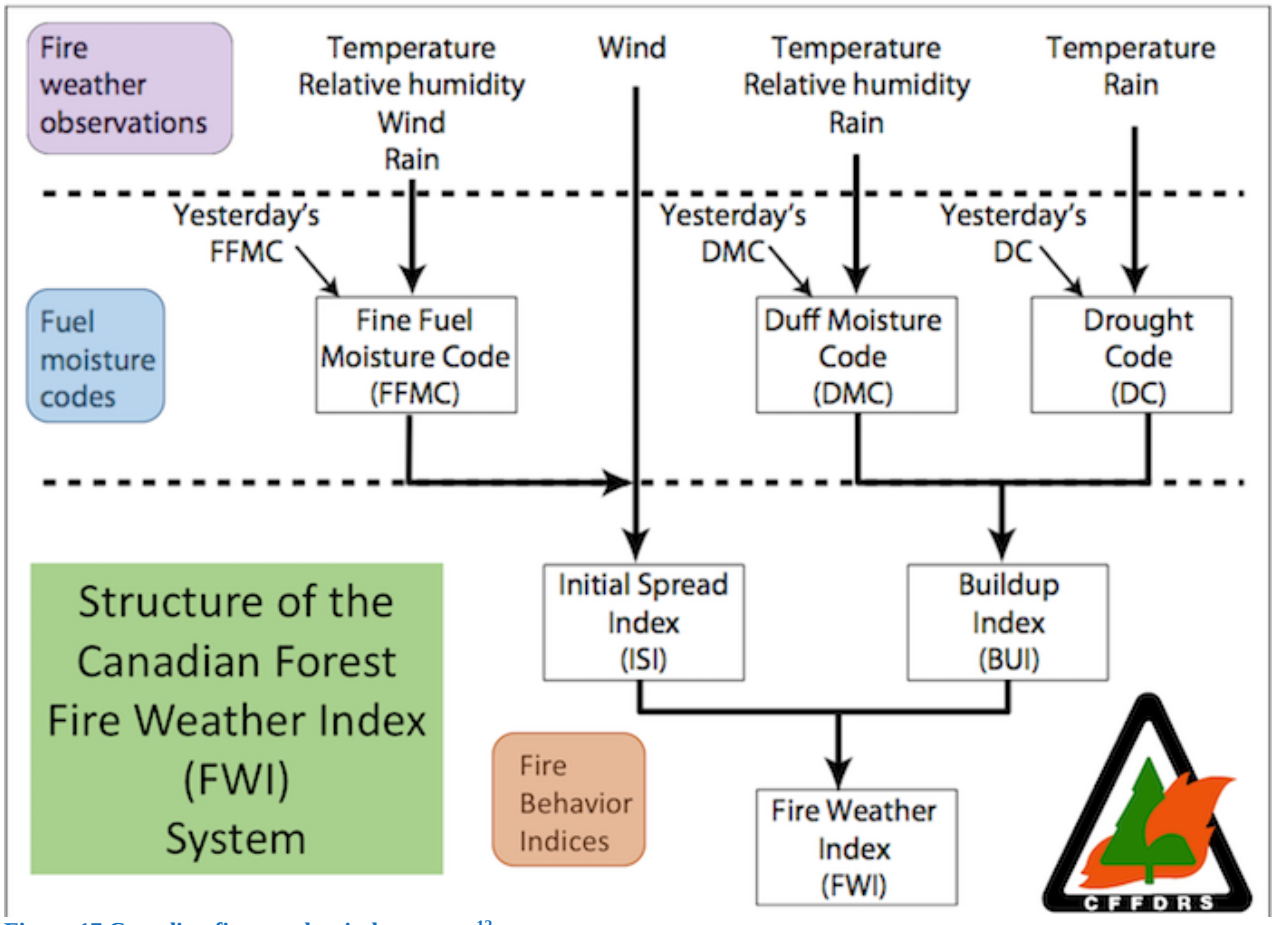


Figure 17 Canadian fire weather index system[12]

The Canadian Forest Fire Weather Index (FWI) System consists of six components that account for the effects of fuel moisture and weather conditions on fire behaviour. The first three components are fuel moisture codes, which are numeric ratings of the moisture content of the forest floor and other dead organic matter. Their values rise as the moisture content decreases. There is one fuel moisture code for each of three layers of fuel: litter and other fine fuels; loosely compacted organic layers of moderate depth; and deep, compact organic layers.

The remaining three components are fire behaviour indices, which represent the rate of fire spread, the fuel available for combustion, and the frontal fire intensity; these three values rise as the fire danger increases.

The diagram in figure 18 below illustrates the components of the FWI System. Calculation of the components is based on consecutive daily observations of temperature, relative humidity, wind speed, and 24-hour precipitation. The six standard components provide numeric ratings of relative potential for wildland fire.

The Daily Severity Rating (DSR), an additional component of the FWI system, is a numeric rating of the difficulty of controlling fires. It is based on the Fire Weather Index, but it more accurately reflects the expected effort required for fire suppression.

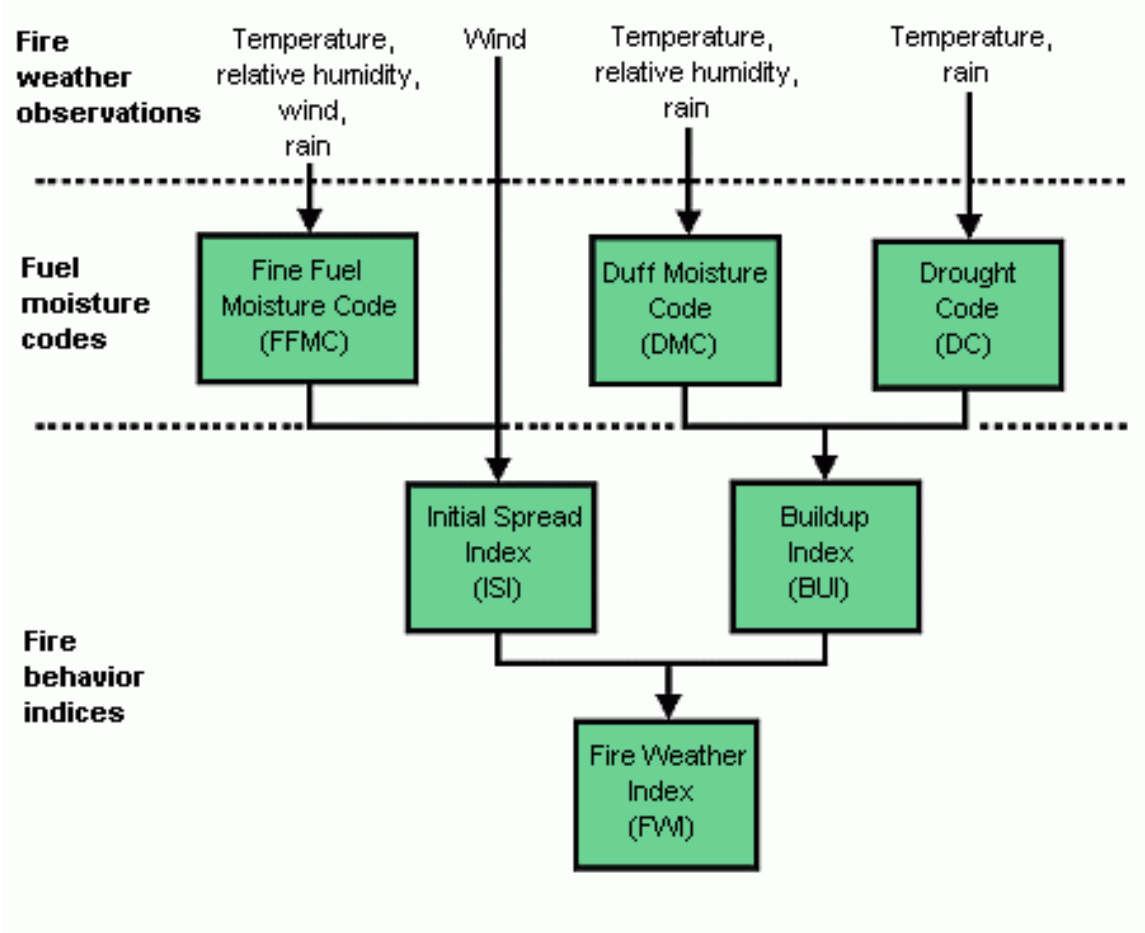


Figure 18 Canadian Fire Weather Index system[12]

The Fine Fuel Moisture Code (FFMC) is a numeric rating of the moisture content of litter and other cured fine fuels. This code is an indicator of the relative ease of ignition and the flammability of fine fuel.
The Duff Moisture Code (DMC) is a numeric rating of the average moisture content of loosely compacted organic layers of moderate depth. This code gives an indication of fuel consumption in moderate duff layers and medium-size woody material.
The Drought Code (DC) is a numeric rating of the average moisture content of deep, compact organic layers. This code is a useful indicator of seasonal drought effects on forest fuels and the amount of smouldering in deep duff layers and large logs.
The Initial Spread Index (ISI) is a numeric rating of the expected rate of fire spread. It is based on wind speed and FFMC. Like the rest of the FWI system components, ISI does not take fuel type into account. Actual spread rates vary between fuel types at the same ISI.
The Buildup Index (BUI) is a numeric rating of the total amount of fuel available for combustion. It is based on the DMC and the DC. The BUI is generally less than twice the DMC value, and moisture in the DMC layer is expected to help prevent burning in material deeper down in the available fuel.
The Fire Weather Index (FWI) is a numeric rating of fire intensity. It is based on the ISI and the BUI, and is used as a general index of fire danger throughout the forested areas of Canada.

3.2.5 USDA Fire Effects Information System

USDA Forest Service's Fire Effects Information System (FEIS) is an online repository of the scientific literature and its reviews regarding fire effects on plants and animals and fire regimes (frequency, intensity, duration, seasonality) of plant communities in the United States. From the

perspective of building SILVANUS semantic scheme, FEIS provides dictionary (terms and definitions) of fire effects[13].

In addition, among scientific papers stored in the FEIS repository, an interesting one describes efforts to conceptualize and parametrize "extreme wildfires"[14]. The authors started with review of terminology related to extraordinary wildfires and classified wildfires as normal or extreme (with seven subclasses reflecting their severity) based on such parameters as: fireline intensity (FLI, quantified in kWm-1), rate of spread (ROS, quantified in meters per minute), flame length (FL, quantified in meters), fire spotting distance (in meters), real-time observable properties (presence of pyroconvective events in the atmosphere, presence of downdrafts) and descriptive characteristics related to type of fire and capacity of fire control.

Finally, the authors defined dependencies between ecological and social processes, conditions and factors interplaying through the wildfire temporal phases, a cycle summarized in figure 20.

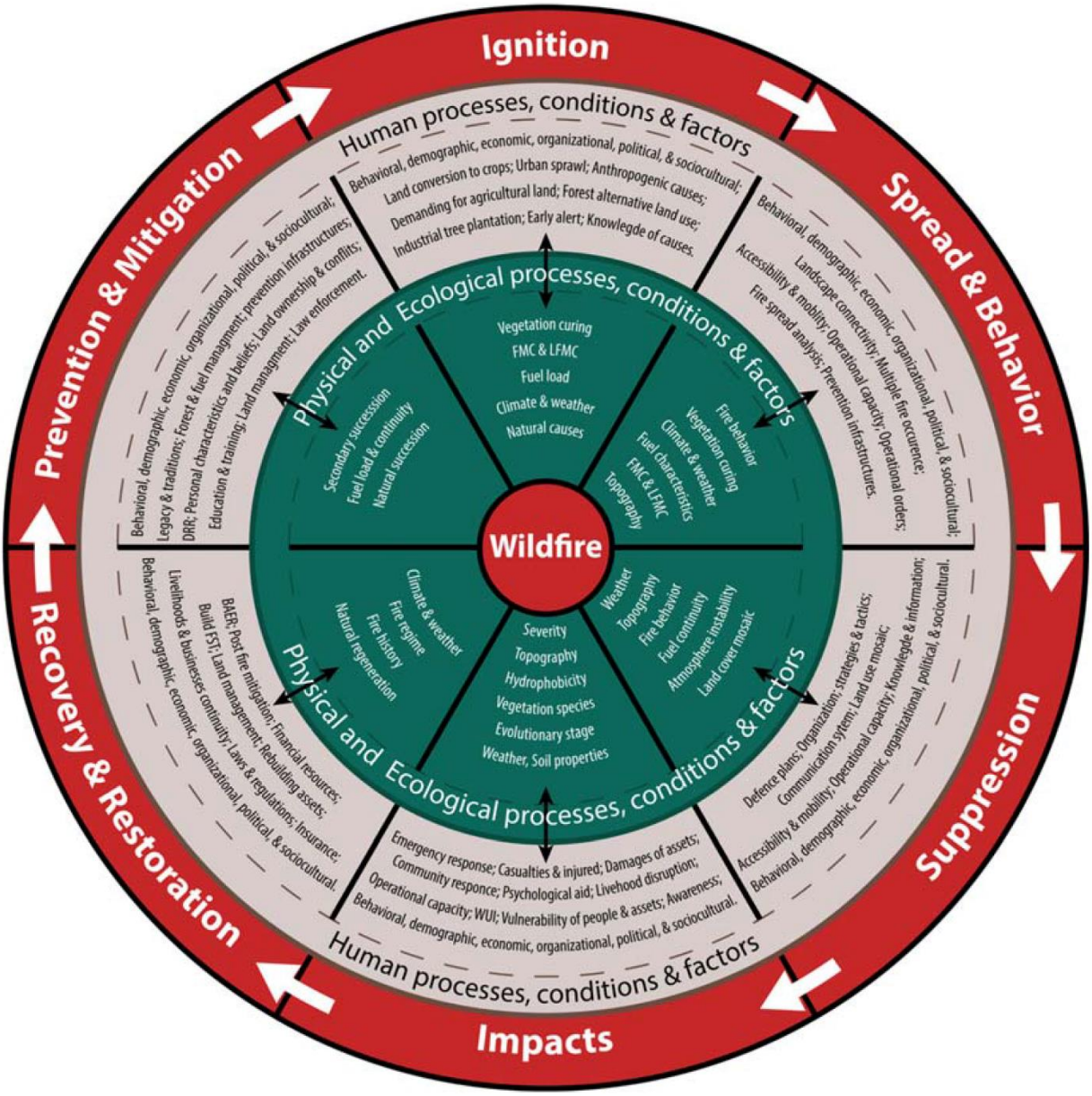


Figure 19 Wildfire as a social-ecological process[14]

[13] Feis Glossary. [Online]. Available: https://www.fs.usda.gov/database/feis/glossary2.html. [Accessed: 29-Sep-2022].

[14] F. Tedim, V. Leone, M. Amraoui, C. Bouillon, M. Coughlan, G. Delogu, P. Fernandes, C. Ferreira, S. McCaffrey, T. McGee, J. Parente, D. Paton, M. Pereira, L. Ribeiro, D. Viegas, and G. Xanthopoulos, "Defining extreme wildfire events: Difficulties, challenges, and impacts," Fire, vol. 1, no. 1, p. 9, 2018.

3.2.6 Bioportal Environment Ontology (ENVO)[15]

The Environment Ontology (ENVO) was found thanks to the EMBL-EBI Ontology Lookup Service (OLS), which is a repository for biomedical ontologies that aims to provide a single point of access to the different ontologies with their latest versions[16]. OLS was supported by CORBEL project funded by the EU's Horizon 2020 and earlier research and development projects co-funded under the EU 7th Framework Programme.

ENVO is an ontology which represents knowledge about environments, environmental processes, ecosystems, habitats, and related entities[17][18]. Forest ecosystem and threats to forestry (including forest fire and wildfire) are nodes in the ENVO ontology, providing basic semantic hierarchy of terms related to the SILVANUS scope. The ontology is easily consultable through an interface shown in figure 20.

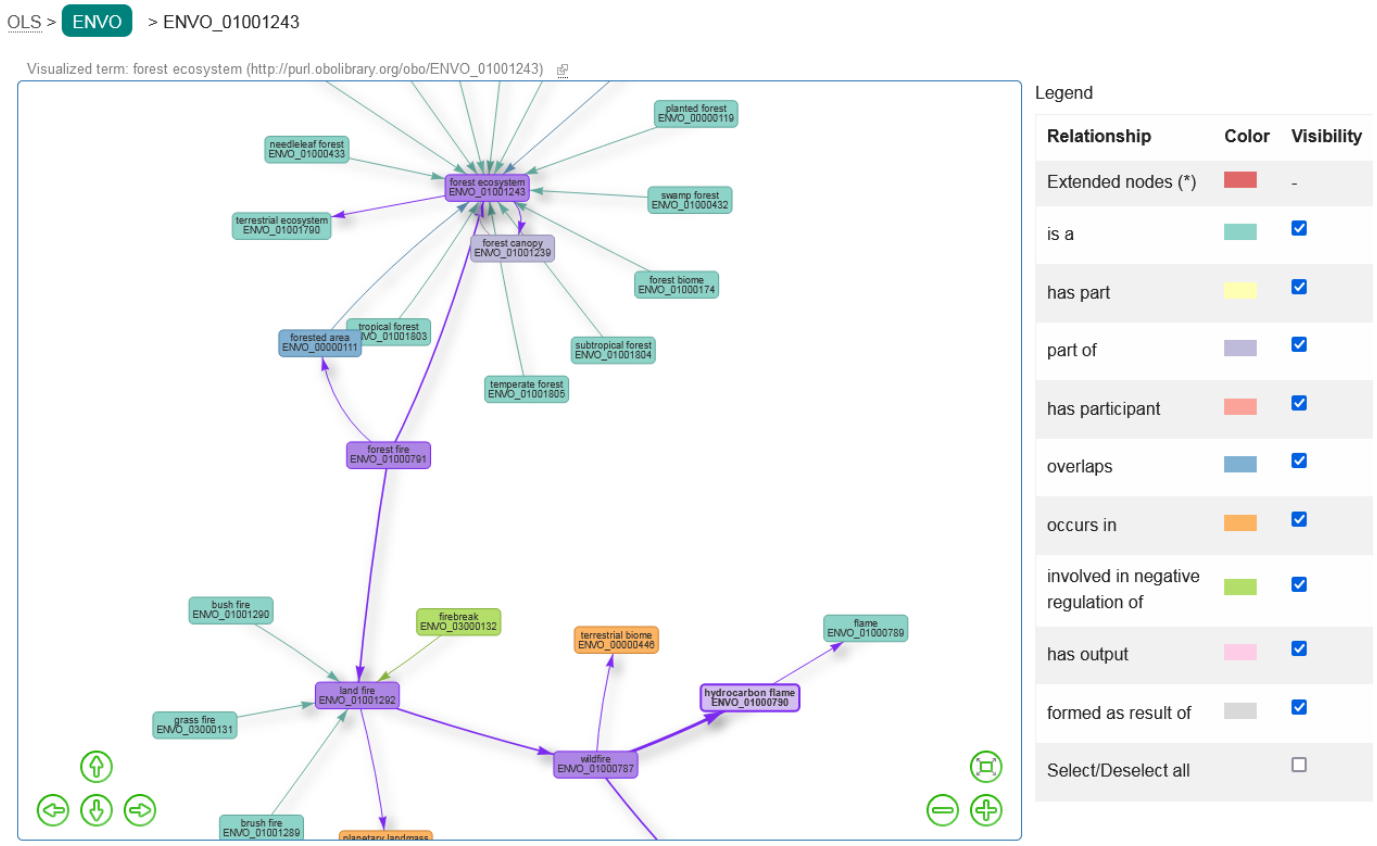


Figure 20 Section of the Environment ontology regarding forest ecosystems and wildfires

It is an expressive, community ontology which helps humans, machines, and semantic web applications understand environmental entities of all kinds, from microscopic to intergalactic scales. As a FAIR-compliant resource, it promotes interoperability through the concise, controlled description of all things environmental.

[15] "Environment ontology: NCBO Bioportal," Environment Ontology | NCBO BioPortal. [Online]. Available: https://bioportal.bioontology.org/ontologies/ENVO. [Accessed: 29-Sep-2022].
[16] "EMBL Ontology lookup service," EBI. [Online]. Available: https://www.ebi.ac.uk/ols/ontologies. [Accessed: 29-Sep-2022].
[17] "The environment ontology," EBI, 20-May-2021. [Online]. Available: https://www.ebi.ac.uk/ols/ontologies/envo. [Accessed: 29-Sep-2022].
[18] The Environment Ontology. [Online]. Available: https://sites.google.com/site/environmentontology/home?authuser=0. [Accessed: 29-Sep-2022].

ENVO aims to promote standardization and interoperability of diverse data sets through the concise, controlled description of environment types across several levels of granularity. It interoperates with a broad collection of other Open Biological and Biomedical Ontology[19] ontologies and is used in a diverse range of projects. It is primarily concerned with environments as encountered in ecological applications but can accommodate alternative needs.
ENVO currently deals with 'environmental systems' (i.e., environments) particularly 'biomes' and environments determined by a material entity that assumes the role of an 'environmental feature' (e.g., a digestive tract environment). It also handles 'environmental materials' like soil, water, and so on.
The following table 16 shows an overview of the ontology:

Table 16 Tabular overview of the Bioportal Environment ontology

Classes	**6,566**
Individuals	44
Properties	136
Maximum depth	35
Maximum number of children	108
Average number of children	2
Classes with a single child	1,400
Classes with more than 25 children	23
Classes with no definition	2,036

3.2.7 CrossForest[20]

In the Cross-Forest project, a set of eleven ontologies was created. These ontologies represent forest inventory and cartographic data and can be reused by any country to publish its forest data, in an open, standard format. These data are self-describing (they contain all the information needed to understand the data) and interoperable, allowing them to be used by the public, and to connect with other data, be it forest data from different locations or any other type of data, enriching its possibilities of use.
The main ontologies published in Crossforest are:

- Third Spanish Forest Inventory (Tercer Inventario Forestal Nacional de España – IFN3 for Spain)
- Spanish Land Cover Map 1:50.000 (Mapa Forestal Nacional de España 1:50.000 – MFE50 for Spain)
- Spanish Soil Erosion Inventory (Inventario Nacional Erosión de Suelos de España – INES for Spain)
- Sixth Portuguese Forest Inventory (Inventário Florestal Nacional – IFN6 for Portugal)
- Portuguese Land Cover Map 2018 (Carta de Uso e Ocupação do Solo de Portugal Continental – COS18 for Portugal),
- Iberian Forest Fires Statistics

These ontologies are interrelated and enriched through links to external ontologies (see figure 21 and 22 below).

[19] "The open biological and biomedical ontology (OBO) foundry," Sitewide ATOM. [Online]. Available: https://obofoundry.org/. [Accessed: 29-Sep-2022].
[20] "Ontologies," Cross Forest, 23-Jul-2021. [Online]. Available: https://crossforest.eu/results/ontologies/. [Accessed: 29-Sep-2022].

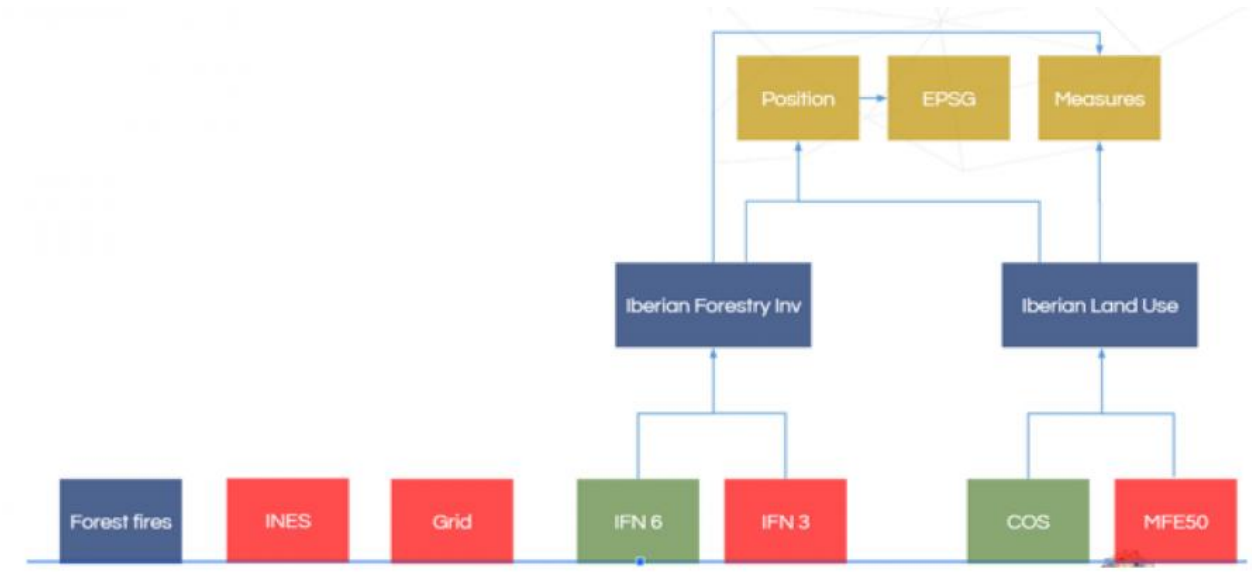


Figure 21 Ontologies in Crossforest[20]

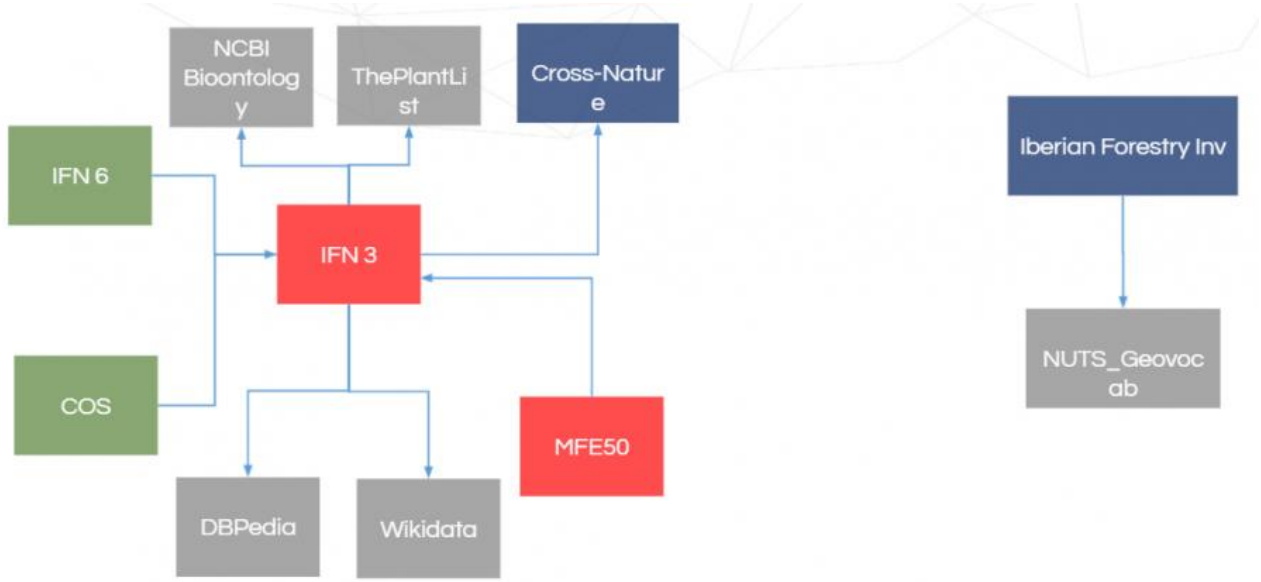


Figure 22 Established links to other ontologies[20]

The ontologies have a modular design. They are divided in four main groups:

- 3 high level ontologies (position-core, measures-core, and epsg-core) that describe concepts about measures and positions, needed across all datasets.
- 6 forestry modules, used to describe the data of forest inventories and land cover maps. There are two general ontologies that provide broad concepts usable by any country (ifi-core and ilu-core), two ontologies that describe Spanish data (ifn-core and mfe-core), and two ontologies that describe Portuguese data (ifn-pt-core and cos-core).
- An ontology for describing data about types of soil erosion (ines).
- An ontology for the publication of data about Iberian Forest Fires Statistics (incendios-forestales).

This design has two main goals:

1. Increase the reuse by external agents: each of the ontologies is easier to understand separately, and the separation makes it possible for any user to load the data they need, disregarding the rest. Additionally, since several ontologies and datasets exist for the

domains we use, by creating our own terms and linking them to several external ontologies, we do not limit the user to one of them: they can choose the set of alignment modules of their preference.

2. Make safe reuse of external ontologies and data. While reuse of data is a well-known principle in the Semantic Web, making explicit alignment (that is, linking the terms of the ontology with terms of the external ontology by means of the properties mentioned before) is considered a better practice that direct reuse of the terms. Direct reuse has the risk of what is known as ontology hijacking, that is, giving additional semantics to external terms that can negatively impact the semantics of the data (e.g., generating undesirable inferences).

3.2.8 BIMERR Weather Ontology[21]

The BIMERR project is related to the Building Information Modelling (BIM) and its main target are stakeholders from the Architecture, Engineering & Construction field. The project has the intention to design and develop a new toolkit to support renovation stakeholders during the renovation process of existing buildings. This project was funded by the European Union's Horizon 2020 research and innovation programme.
Among their objective is the establishing of semantic interoperability among the diverse popular standards, formats and data models in the construction industry and reaching out to standardization bodies with concrete and demonstrated proposals for linking and mapping them toward a unified way to retrieve building information.
The BIMERR ontology network represents the semantic models that describe the different aspects of building renovation processes (e.g., energy efficiency, occupancy, building information models, etc.). Such models are defined following a modular approach, that is in the shape of a network, in which each domain (KPI, materials, building, etc.) could be reuse independently.
Among the various modules of the BIMERR ontology network there is one for weather phenomena and exterior conditions that could be useful in the context of the SILVANUS ontology. Table 17 shows its classes and relations:

Table 17 Tabular overview of the BIMERR Weather ontology

Classes	Relations
Administrative Area	controls property
Atmospheric Phenomenon	has measurement
City	has property
Country	is controlled by device
DataSourceFiles	is defined by
Device	is definition of
EPWFile	is measured by device
ExtremeWeatherPeriodMeasurement	is measured in
Feature of Interest	is measurement of
Ground	is property of
Humidity	located in
Illuminance	location
JSONWeatherFile	make measurement

[21] S. Chavez-Feria, M. Poveda-Villalón, and S. González-Gerpe, "Ontology for weather phenomena and exterior conditions.," BIMERR Ontologies, 06-Mar-2020. [Online]. Available: https://bimerr.iot.linkeddata.es/def/weather/. [Accessed: 29-Sep-2022].

Measurement	measurement made by
Point	measures property
Precipitation	observed in season
Pressure	relates to measurement
Property	relates to property
Radiation	
Season	
Sensor	
Sky Cover	
Snow	
Spatial Thing	
Temperature	
TypicalWeatherPeriodMeasurement	
Unit of Measure	
Weather Property	
WeatherPeriodMeasurement	
Wind	

The following figures 23, 24 and 25 provide a general overview of the BIMERR Weather Ontology and its individuals.

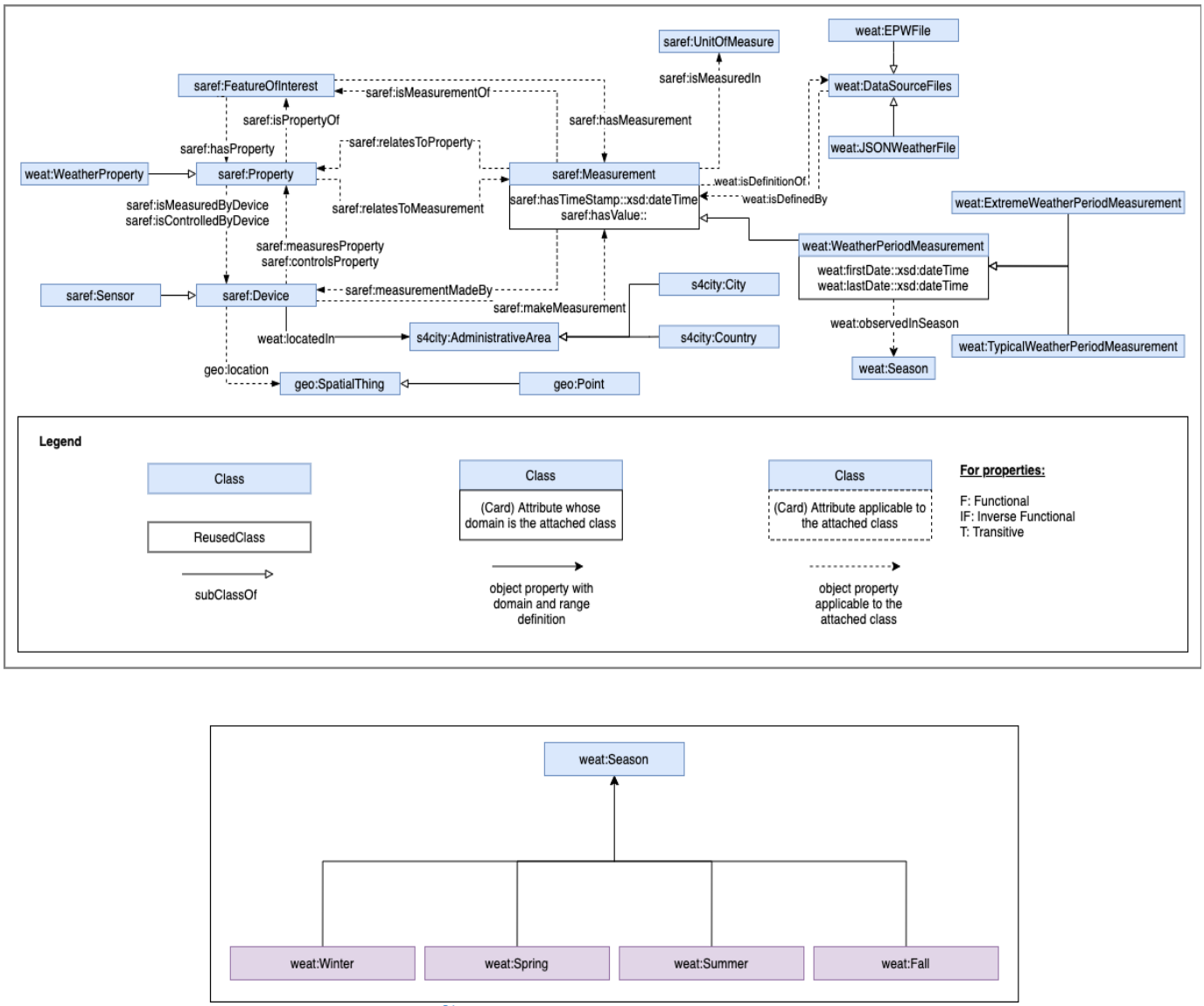


Figure 23 BIMERR Weather Ontology Diagram.[21]

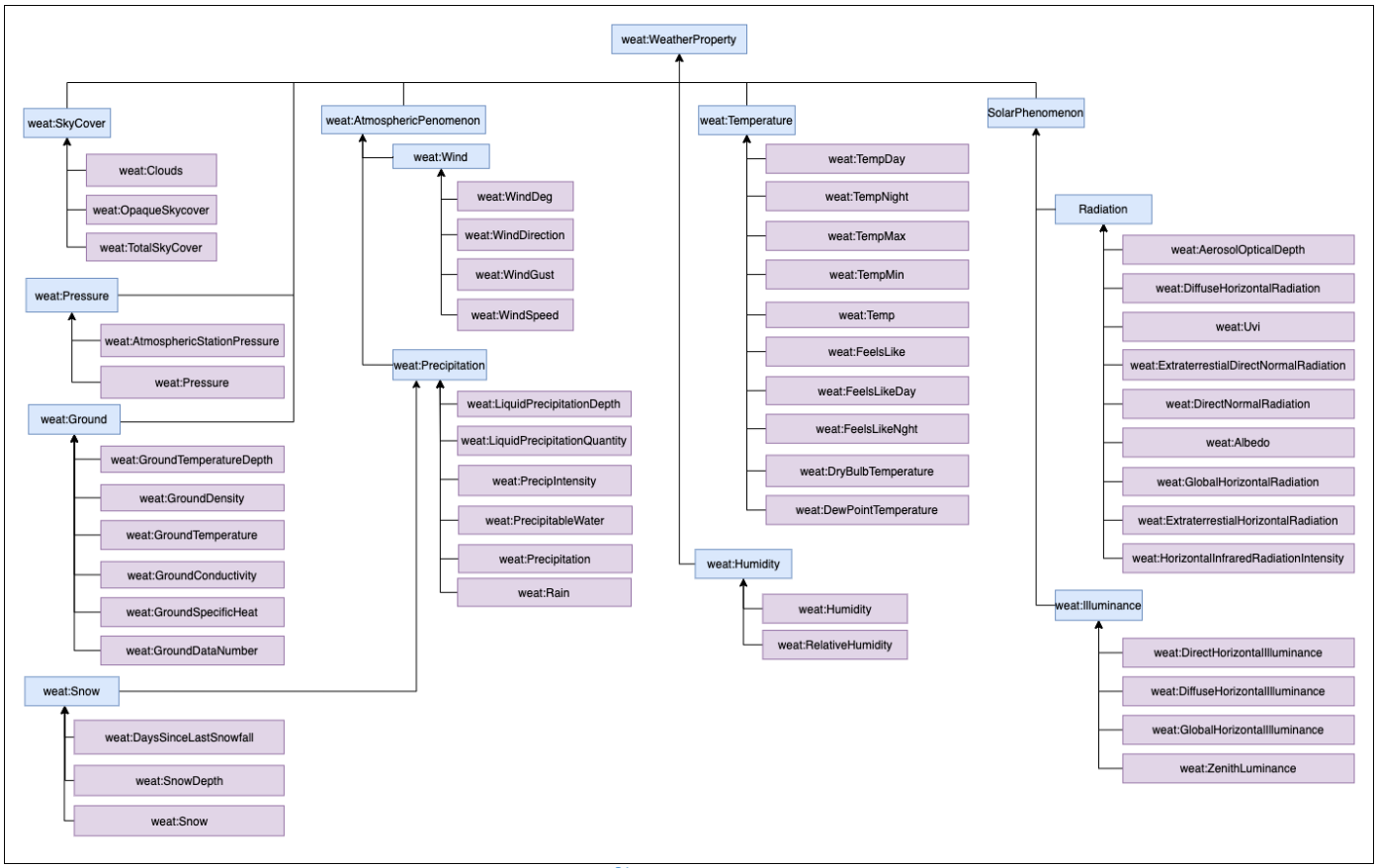


Figure 24 BIMERR Weather Ontology Individuals Diagram[21]

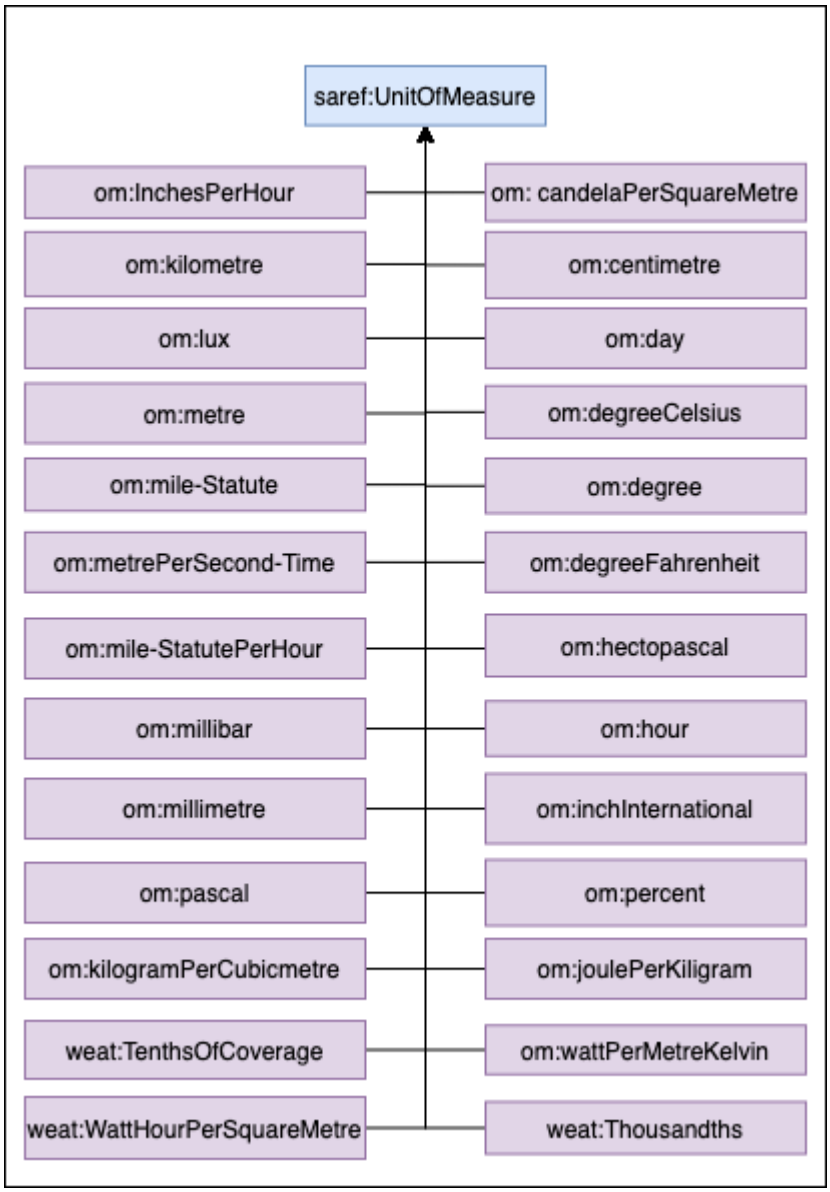


Figure 25 BIMERR Weather Ontology Unit of Measure Individuals Diagram[21]

3.2.9 Bioportal Emergency Ontology[22]

The Bioportal Emergency Situation Ontology (ESO) has been developed to achieve timely decision-making to coordinate the activities of people involved in rescue efforts.
The following table 18 shows an overview of the ontology:

Table 18 Tabular overview of the Bioportal Emergency Ontology

Classes	**346**
Individuals	117
Properties	87
Maximum depth	11
Maximum number of children	23
Average number of children	4

[22] "Emergency ontology: NCBO Bioportal," Emergency Ontology | NCBO BioPortal. [Online]. Available: https://bioportal.bioontology.org/ontologies/ESO. [Accessed: 29-Sep-2022].

Classes with a single child	9
Classes with more than 25 children	0
Classes with no definition	310

Those shown in figures 26 to 34 are some areas of the ontology that could be more relevant in the context of SILVANUS:
Climatological Disasters:

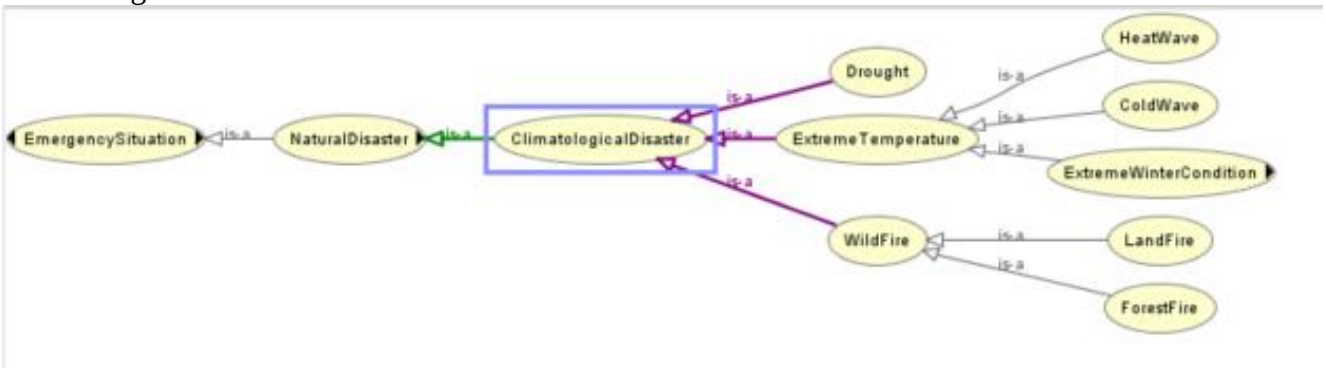


Figure 26 Bioportal Emergency Ontology climatological disasters class

Losses to fires:

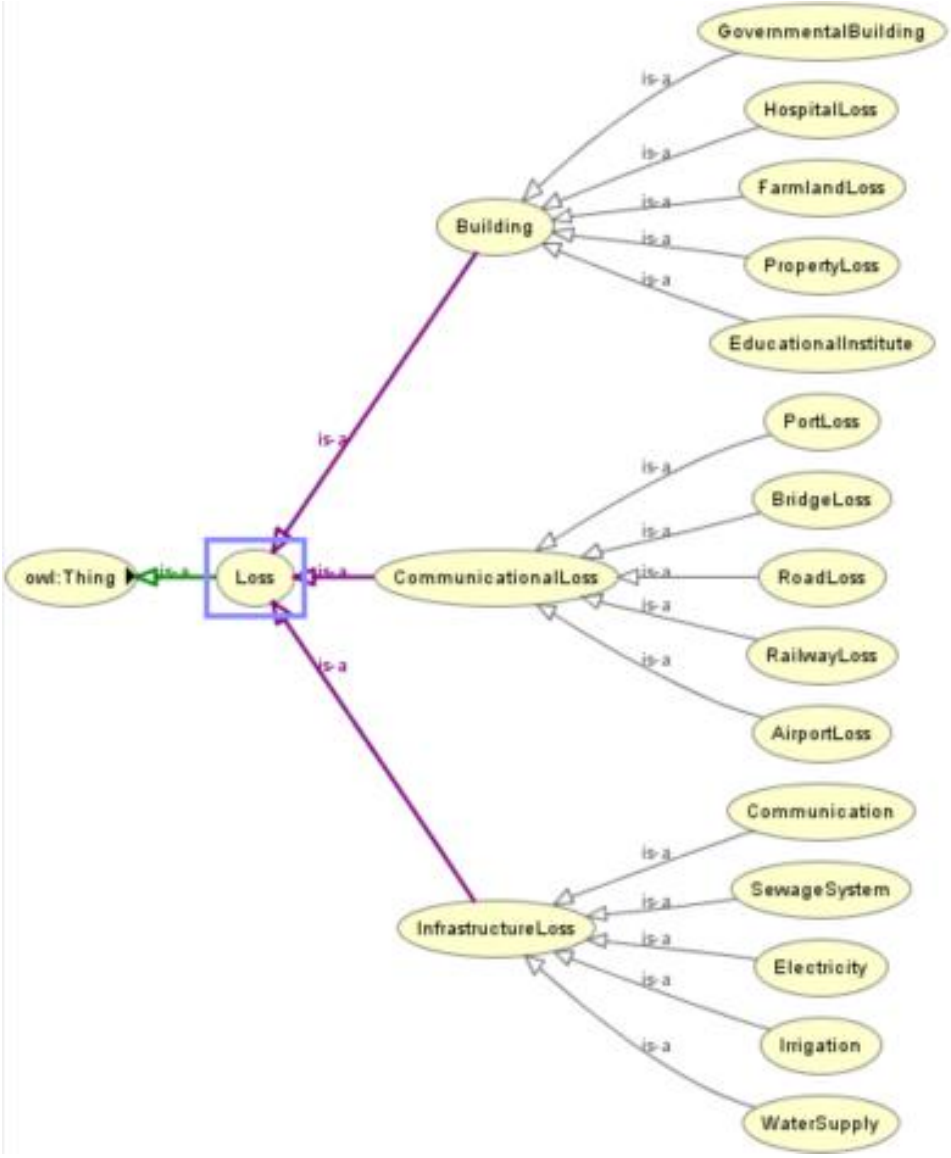


Figure 27 Bioportal Emergency Ontology Loss class

Emergency response:

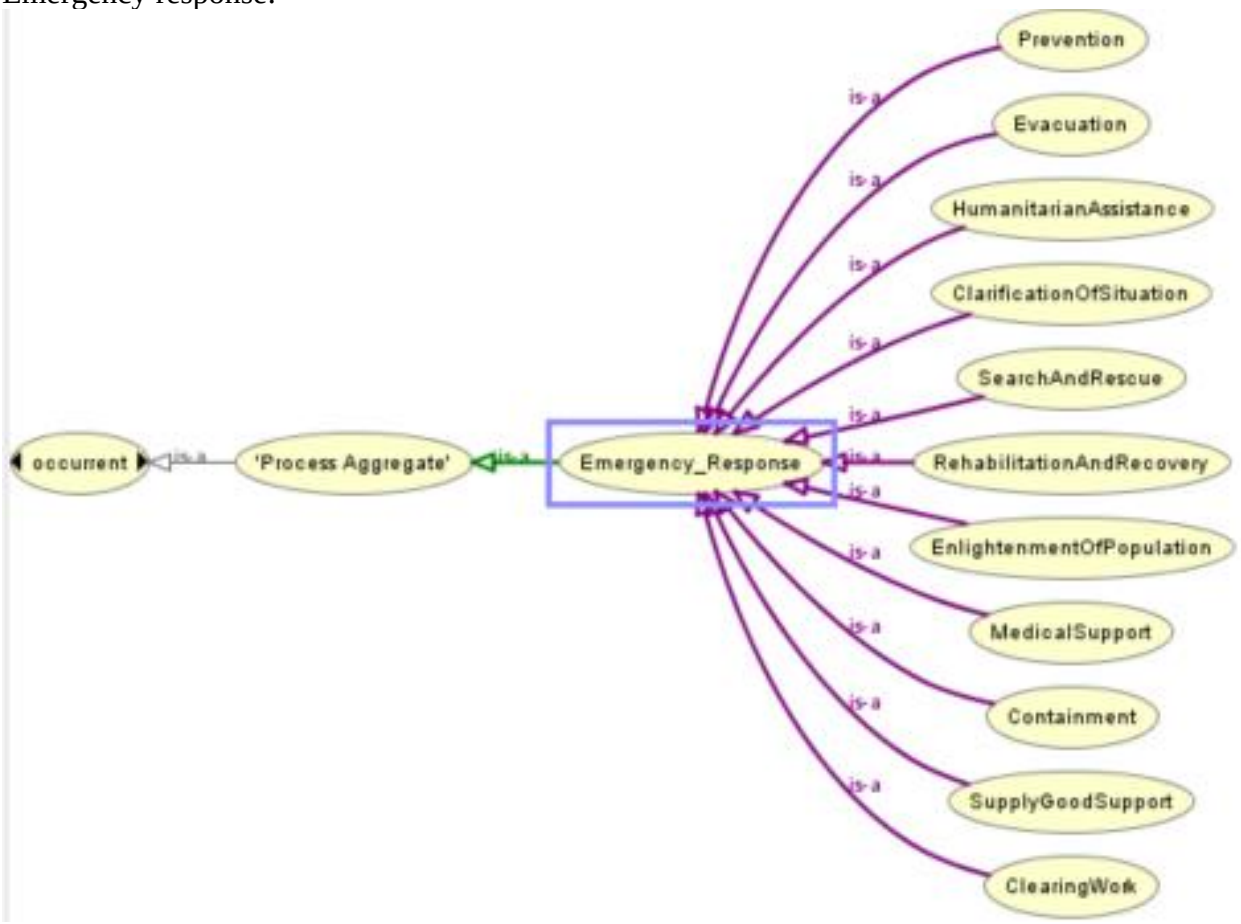


Figure 28 Bioportal Emergency Ontology Emergency response class

Involved response authorities:

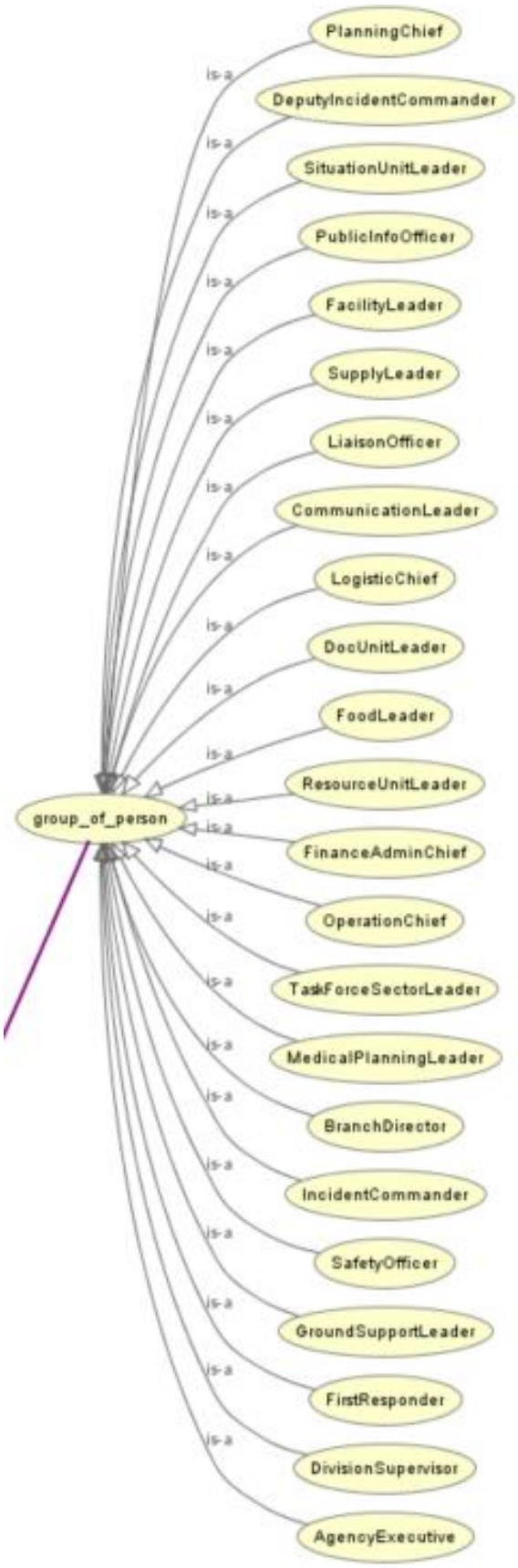


Figure 29 Bioportal Emergency Ontology Involved authorities class

Service providers:

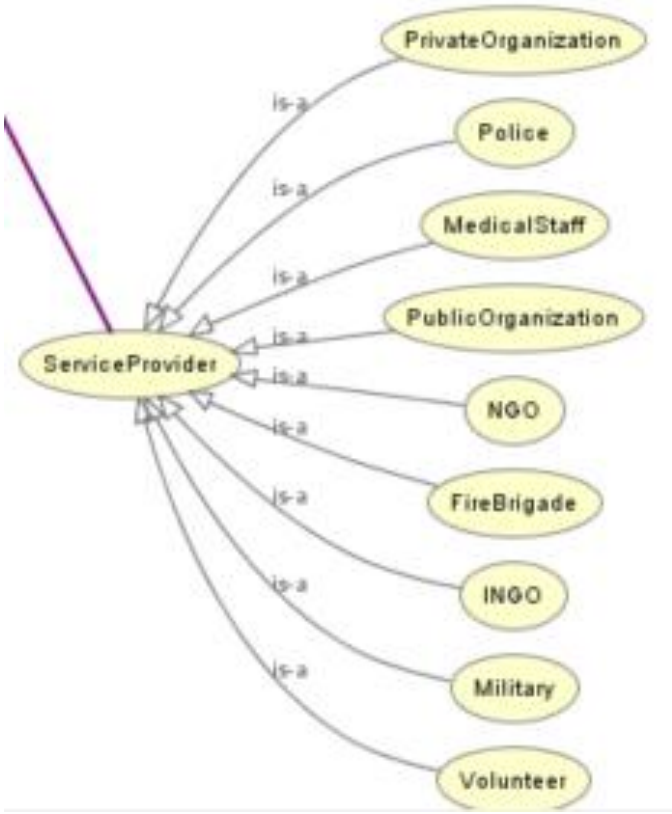


Figure 30 Bioportal Emergency Ontology Service providers class

Environmental features:

Figure 31 Bioportal Emergency Ontology Environmental feature class

Vehicles:

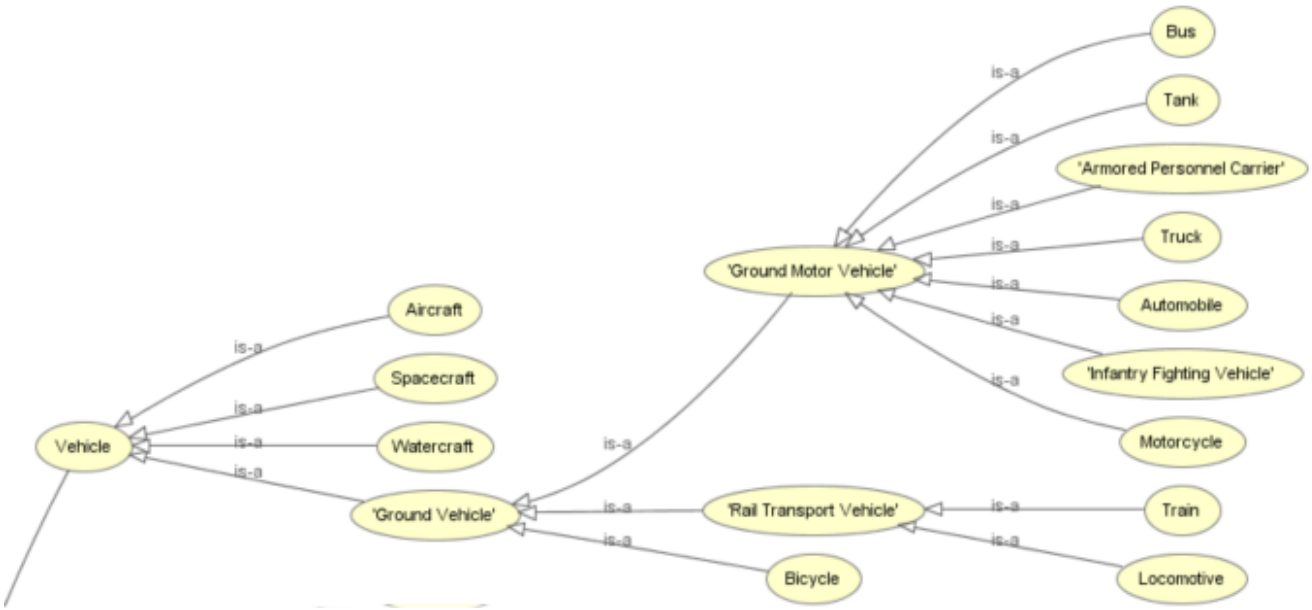


Figure 32 Bioportal Emergency Ontology Vehicles class

Resources:

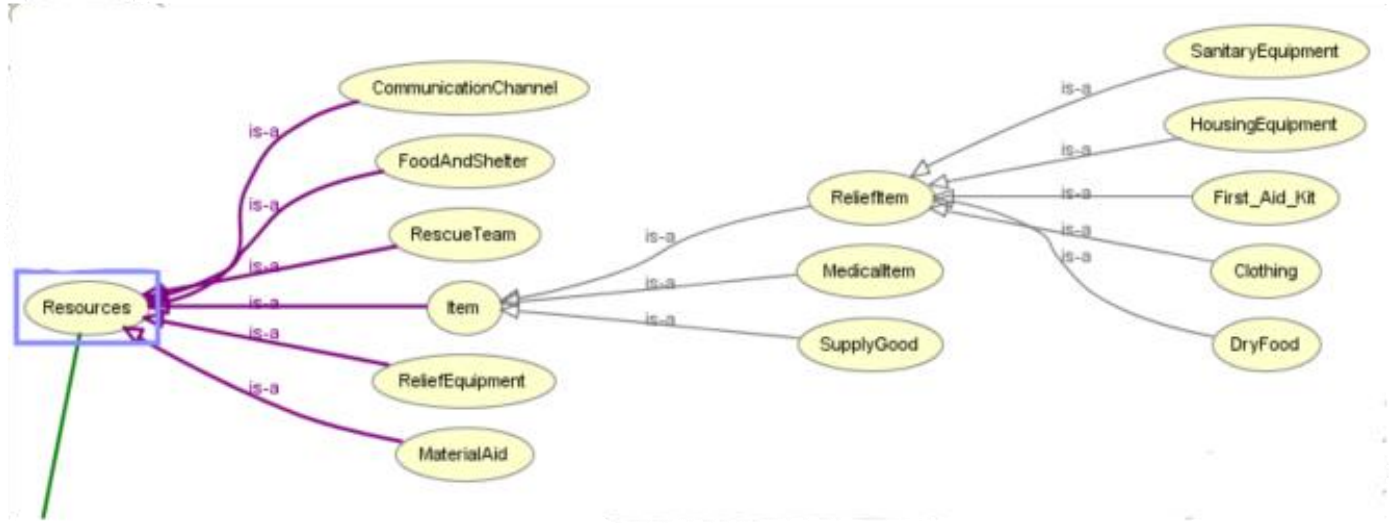


Figure 33 Bioportal Emergency Ontology Resources class

Facilities:

Figure 34 Bioportal Emergency Ontology Facility class

3.2.10 empathi: an ontology for Emergency Managing and Planning about Hazard Crises

Empathi[2324] ontology is a crisis domain archetype that addresses concepts of crisis management, crisis situational awareness, and hazard events during emergency scenarios. Empathi integrates a number of databases and vocabularies available and related to the crisis management field, e.g. geonames for geospatial semantic information, taxonomies of US Federal Emergency Management Agency (FEMA) and Emergency Disasters Database (EM-DAT) and others. The ontology can be downloaded in OWL standard and used under a Creative Commons Attribution 4.0 International (CC By 4.0).

3.2.11 Other taxonomies and dictionaries

Since the early 1980's, the Food and Agriculture Organization of the United Nations (FAO) develops AGROVOC Multilingual Thesaurus[25], that can be described as multilingual and controlled vocabulary with definitions, designed to cover concepts and terminology under FAO's areas of

[23] M. Gaur, S. Shekarpour, A. Gyrard, and A. Sheth, "Empathi: An ontology for emergency managing and planning about hazard crisis," 2019 IEEE 13th International Conference on Semantic Computing (ICSC), 2019.
[24] "Empathi: An ontology for emergency managing and planning about hazard crises," empathi: An ontology for Emergency Managing and Planningabout Hazard Crises Specification. [Online]. Available: https://shekarpour.github.io/empathi.io/#namespacedeclarations. [Accessed: 29-Sep-2022].
[25] " AGROVOC Multilingual Thesaurus," Food and Agriculture Organization of the United Nations. [Online]. Available: https://agrovoc.fao.org/browse/agrovoc/en/page/?uri=http%3A%2F%2Faims.fao.org%2Faos%2Fagrovoc%2Fc_c0e4ff0e. [Accessed: 29-Sep-2022].

interest. This includes also forest ecosystem among many others. AGROVOC consists of over 40 thousand concepts and near one million terms in up over 40 languages. AGROVOC can be used in RDF-SKOS format under CC-BY IGO 3.0 license.

The State Forest - Polish governmental organization that manages state-owned Polish forests published English-Polish Thematic Forest Dictionary[26]. Mapping of English to Polish and Polish to English forest-related terminology is irrelevant from the SILVANUS viewpoint, however, the publication provides a comprehensive index of terms related to forestry, based on different glossaries and a number of forestry encyclopedias.

The GeoNames11 is geographical database available for download under a creative commons attribution license (both as data dump and by using webservices). The database includes 27 million geographical names and consists of over 12 million unique features. All of them are categorized into one out of nine classes, such as administrative boundaries, hydrographic, area, populated places, road/railroad, spot, hypsographic, undersea and vegetation features. These features are further subcategorized into one out of 645 feature codes (forest, valley, specific types of buildings, etc.).

[26] E. Kloc, "Thematic Forest Dictionary," Lasy Państwowe. [Online]. Available: https://www.lasy.gov.pl/pl/informacje/publikacje/in-english/thematic-forest-dictionary-tematyczny-slownik-lesny/thematic-forest-dictionary.pdf. [Accessed: 29-Sep-2022].

4 Analysis and Choices

The previous chapter has been dedicated to the collection of knowledge from experts, concepts used in the pilot scenarios, already existing ontologies and taxonomies.

The goal of this chapter will be to downselect from this collection the relevant parts for the construction of the first version of the SILVANUS ontology. To do so, a 3-phases methodology has been established:

1. Collection of raw concepts from different sources
2. Categorization of raw concepts into macro-categories
3. Definition of ontological classes

In the following sections the 2nd and 3rd phase will be described.

4.1 Categorization of raw concepts into macro-categories

The concepts from the pilot scenarios collected in the tables reported in "Knowledge from pilots" paragraph were reduced to a short list of macro-categories, representing the main areas of knowledge covered by the SILVANUS ontology. These macro-categories are the following:

Each category was assigned a colour, which was used to categorize all the raw concepts in the appropriate area. Tables 19 to 24 show how the concepts tables have changed after completion of this categorization activity:

FIRE
CAUSE
BIODIVERSITY
SENSORS
TOOLS & RESOURCES
VULNERABLE OBEJCTS
CLIMATE

Table 19 Categorized concepts from French and Italian pilots

FRANCE	ITALY
number of active fire fronts	year of low atmospheric precipitation
smoke amount	infrastructures - radio network
Propagation direction	IoT sensors, drones
ground temperature of the flames	geology
identification of access paths	roads
cause - industrial accident	causes - cigarette butts
wind direction	causes - negligence, misconduct
temperature	power lines
wind speed	risk of fires
urbanized areas	power lines
dehydration of plants	Daily map of fire risk
dehydration of plants	prescribed fire

anticipation of fire development and development axes	patrols
UAV sensors	vehicles for the transport of people and extinguishing liquid
intervention area	hydrography
gas sensors	topography
composition of the combustion gases	land use
type of plants	pedology
Fire start	satellite images
Propagation speed	Preventive interventions on the ground
threatened targets	microclimatic data (temperature, precipitation, relative humidity of the air, wind speed, wind direction).
time to reach the installation at risk	cameras
evacuation measures	collection points (evacuation)
time to reach the urbanized area	front intensity
landscape biodiversity	propagation speed
fire danger index metrics	critical points, where the fire increases intensity and / or speed
fuel availability in specific regions of forest	sensitive points (presence of infrastructures and / or works, buildings and interfaces, natural areas of value and / or vulnerability, forecast of economic and environmental losses, forecast of damage and costs of shutdown and restoration
soil types and structure	valid points as areas of control opportunities, also based on the preliminary study of the effectiveness of the various suppression and technical actions
fire ignition sources	meteorological conditions of particular importance for the prediction of complex phenomena
quantifying the damage of forest fire (loss of XX cubic tons of oxygen, etc.)	meteorological conditions of particular importance for the prediction of complex phenomena
chemical composition sensors	Imaging laser scanner

Table 20 Categorized concepts from Romanian and Greek pilot

ROMANIA	GREECE
causes - human negligence	wind direction and speed
dry vegetation	Surface fuels thick and very dry
meteorological conditions	Medical equipment
Wind speed	summer camps
dry vegetation	Surface fuels thick and very dry
yearly ranifall	Temperature
UGV	dense height-tree forest of Pinus halepensis, with understory of shrubs
temperature	Deep soil covered with needles
Wearable Device, Wearable Sensors, Field Sensors	Air humidity at 65%.

approximate coordinates of the event	Crown-base height at 3 m
humidity sensors	Steep terrain
weather data	Small villages
mountain tourist flow metering sensors	Home properties
biodiversity landscape	churches
Wind direction	Cultivated areas
Air stability class	Power installations
Precipitation	areas of high value
Atmospheric pressure	Fire front distance
Information about vegetation in the area	Active crown fire with flame length of 25 m
Data on humidity	UAVs
flow of mountain tourists	Spirometry measurement
Photo data / Images related to the fire burst area from the camera	Nebulizers and bronchodilators
fire danger index	Satellite Data
Cleaning of felling areas	Topography
Transport of water through a human cordon or 4x4	Weather data
The creation of intervention relays from the base of the slope to the outbreaks that threatened to extend in the direction of the control point	Daily fire risk map
season	Fire vulnerability and risk mapping
degree of humidity of the vegetation and air	Soil moisture
degree of humidity of the vegetation and air	Soil moisture
speed and direction of the wind	Exposure of settlements to wildfires
	Health metrics
	Mapping and maintenance of water resources
	soil types and structure

Table 21 Categorized concepts from Portuguese and Czech pilot

PORTUGAL	CZECH REPUBLIC
drones	no precipitations
Forester (animal collars used to locate GPS animal position).	Drone
fire danger index metrics	
electrical lines	fire ignition sources, such as human negligence, arson, environment conditions, climate and weather conditions (climate change impact including), impact of power grid lines
Sensors: Temperature, Relative Humidity, Rain, Pression, Solar Radiation, UV Radiation, Wind speed, Wind Direction	Drone degree of autonomy: Level 0 – No Automation
water sources	temperature
UAV	firefighting units
Classified 3D Point Cloud of Overhead Power Lines Corridors	professional and volunteer firefighting unit

Satellite	windy conditions
cameras	Drone is equipped with basic meteorological sensors – temperature, wind velocity, altitude (plus GPS coordinates)
Normalized difference vegetation index	UAV
Water Infrastructures Locations and Protection Perimeters	positioning of deployed firefighters
fire risk at regional and plot level	UGV
water treatment plants	infra-red thermal camera
electrical transformers	
biomass growth	
monitor the growth of different types of vegetation cover in critical infrastructures	
vegetation types	
soil types and structure	
damage of forest fire (loss of XX cubic tons of oxygen, etc.)	
information on fuel availability in specific regions of forest	
visualisation of climate statistics (for historical and future periods; precipitation, temperature, relative humidity etc.)	

Table 22 Categorized concepts from Croatian and Slovak pilot

CROATIA	SLOVAKIA
fine fuel moisture	causes - burning of dry crop and grasses
fire initiator will be human activity (negligence during prescribed burning	current local weather
information on fire ignition sources	(temperature, precipitations, relative air humidity, wind speed, wind direction
terrain (elevation, terrain slope, aspect	roads
UGV, and UAV	professional firefighters
period without precipitations	types of land use: forests, grasslands, agricultural land
critical infrastructure will be endangered	meteorological fire danger index
Satellite data	UGV
wind	Drones
robot can operate by the pilot up to 500 m from the pilot	incident site
	smoke detection
Camera devices	CCTV based smoke detection
definition of operational areas, engagement plan, alert and exit plan	Monitored area
Susceptibility of territory to wildfire assessment	watercourses and reservoirs
fuel (vegetation type, quantity, and quality)	forest types
power lines, hydrant network and fire brakes	soil types

suitable water sources for extinguishing activities	touristic and cycling routes
critical infrastructure on site	buildings
danger index metrics	sites to be used as heliports
fuel availability in specific regions of forest	fire extinguishing tools placement
soil types and structure	IoT sensors
	moisture content of fine fuel
	moisture content of fine fuel
	5 degrees of fire danger
	CCTV
	Volunteer Fire Brigades
	incident area
	firefighters' position in the field and health state

Table 23 Categorized concepts from Australian and Brazilian pilot

AUSTRALIA	BRAZIL
bushland	average annual rainfall
UGV	average annual temperate

Table 24 Categorized concepts from Indonesian pilot

INDONESIA
available data on biodiversity model
soil parameters in post fire
post fire condition images
highest levels of biodiversity
estimation of each species in the observation area
satellite multispectral image
forest growth
To measure the soil parameters during rehabilitation and adaptation, we need to install some instruments with IoT Support.

4.2 Definition of classes from collected knowledge

The goal of this activity is to find meaningful ontology classes from the concepts collected from the pilot descriptions. Starting from the categorization of the previous step, two additional steps have been carried out:

- the raw concepts that were categorized during phase 2 in the same macro-category were grouped together
- the rows with similar concepts within each category were arranged to be next to each other in the tables.

The following figure will be helpful in exemplifying the passages between these steps.

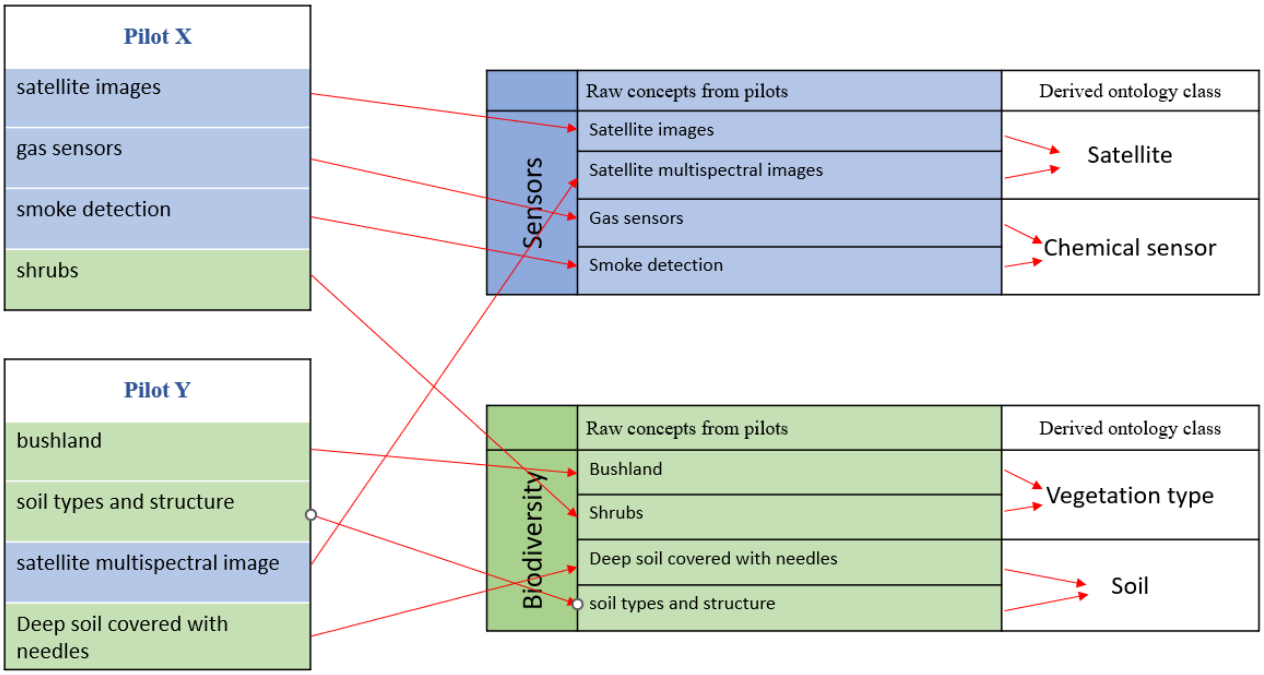


Figure 35 Sample flow from raw concepts to ontology classes

This process allowed for the definition of a common class for such similar concepts, which is reported in the third column in white in the following tables, while also allowing for a harmonization of the different terminologies used across the pilots.

4.2.1 Sensors

The concepts categorized into macro-category "Sensors" were grouped together into the following table 25 and rows containing similar concepts were rearranged to be close to each other in order to be defined into a single class.

Table 25 Class definition from "Sensors" raw concepts

	Raw concepts from pilots	Derived ontology class
Sensors	IoT sensors To measure the soil parameters during rehabilitation and adaptation, we need to install some instruments with IoT Support.	IoT Devices
	Drone degree of autonomy: Level 0 – No Automation Drone is equipped with basic meteorological sensors – temperature, wind velocity, altitude (plus GPS coordinates) UAV sensors	UAVs
	UGV robot can operate by the pilot up to 500 m from the pilot	UGVs
	cameras Photo data / Images related to the fire burst area from the camera infra-red thermal camera CCTV based smoke detection CCTV	Cameras
	Satellite satellite images	Satellite Detection System

	Satellite Data satellite multispectral image	
	gas sensors composition of the combustion gases chemical composition sensors smoke detection	Chemical sensors
	Spirometry measurement Health metrics firefighters' position in the field and health state positioning of deployed firefighters Wearable Device, Wearable Sensors, Field Sensors	Health sensors
	thermometer humidity sensors moisture content of fine fuel	Climate sensor
	Forester (animal collars used to locate GPS animal position).	Biodiversity sensor
	mountain tourist flow metering sensors flow of mountain tourists	People sensor
	imaging laser scanner	Lidar sensor
	antenna	Antenna

4.2.2 Tools & Resources

The concepts categorized into macro-category "Tools & Resources" were grouped together into the following table 26 and rows containing similar concepts were rearranged to be close to each other in order to be defined into a single class.

Table 26 Class definition from "Tool & resources" raw concepts

	Raw concepts from pilots	Derived ontology class
Tools & Resources	patrols firefighting units professional and volunteer firefighting unit professional firefighters Volunteer Fire Brigades	Responder
	vehicles for the transport of people and extinguishing liquid sites to be used as heliports	Vehicles
	Preventive interventions on the ground valid points as areas of control opportunities, also based on the preliminary study of the effectiveness of the various suppression and technical actions Cleaning of felling areas Transport of water through a human cordon or 4x4 The creation of intervention relays from the base of the slope to the outbreaks that threatened to extend in the direction of the control point evacuation measures	Procedures
	approximate coordinates of the event definition of operational areas, engagement plan, alert and exit plan incident site	Event area

	intervention area	
	Monitored area	Monitored area
	Mapping and maintenance of water resources water sources power lines, hydrant network and fire brakes fire extinguishing tools placement suitable water sources for extinguishing activities watercourses and reservoirs	Firefighting resources
	Medical equipment Nebulizers and bronchodilators	Health resources

4.2.3 Biodiversity

The concepts categorized into macro-category “Biodiversity” were grouped together into the following table 27 and rows containing similar concepts were rearranged to be close to each other in order to be defined into a single class.

Table 27 Class definition from "Biodiversity" raw concepts

	Raw concepts from pilots	Derived ontology class
Biodiversity	landscape biodiversity biodiversity landscape available data on biodiversity model highest levels of biodiversity	biodiversity landscape
	type of plants dense height-tree forest of Pinus halepensis, with understory of shrubs Crown-base height at 3 m Information about vegetation in the area fuel availability in specific regions of forest monitor the growth of different types of vegetation cover in critical infrastructures vegetation types forest types bushland information on fuel availability in specific regions of forest fuel (vegetation type, quantity, and quality) fuel availability in specific regions of forest	Vegetation type
	Normalized difference vegetation index	Vegetation index
	soil types Deep soil covered with needles Soil moisture soil parameters in post fire	Soil
	dehydration of plants degree of humidity of the vegetation and air dry vegetation Surface fuels thick and very dry	Vegetation moisture
	geology terrain (elevation, terrain slope, aspect	Geology

	Steep terrain	
	topography hydrography	Topography Hydrography
	pedology	Pedology
	quantifying the damage of forest fire (loss of XX cubic tons of oxygen, etc.) damage of forest fire (loss of XX cubic tons of oxygen, etc.)	Damage quantification
	land use types of land use: forests, grasslands, agricultural land	Land use
	biomass growth forest growth	Vegetation growth

4.2.4 Vulnerable objects

The concepts categorized into macro-category “Vulnerable objects” were grouped together into the following table 28 and rows containing similar concepts were rearranged to be close to each other in order to be defined into a single class.

Table 28 Class definition from "Vulnerable objects" raw concepts

	Raw concepts from pilots	Derived ontology class
Vulberable Objects	urbanized areas Exposure of settlements to wildfires summer camps touristic and cycling routes collection points (evacuation) buildings Small villages Home properties Churches	Urbanized areas
	Peri-urbanisation Meeting place between wildland fuel and human development Transition zone between wilderness and land developed by human activity	Wildland Urban Interface
	Cultivated areas	Agriculture
	areas of high value	High priority area
	critical infrastructure will be endangered critical infrastructure on site	Critical infrastructure
	infrastructures - radio network	Communication towers
	roads	Transportation
	power lines electrical transformers electrical lines Power installations	Energy infrastructures
	Water Infrastructures Locations and Protection Perimeters water treatment plants	Water infrastructure

4.2.5 Climate

The concepts categorized into macro-category “Climate” were grouped together into the following table 29 and rows containing similar concepts were rearranged to be close to each other in order to be defined into a single class.

Table 29 Class definition from "Climate" raw concepts.

	Raw concepts from pilots	Derived ontology class
Climate	windy conditions wind speed and direction of the wind	Wind
	wind direction	Wind direction
	wind speed	Wind speed
	temperature	Temp
	average annual temperate	Average annual temperature
	average annual rainfall year of low atmospheric precipitation yearly rainfall	Average annual precipitations
	Precipitation no precipitations period without precipitations	Time since last precipitation
	Atmospheric pressure	Atmospheric pressure
	Data on humidity degree of humidity of the vegetation and air Air humidity at 65%.	Humidity
	season	Season
	Sensors: Temperature, Relative Humidity, Rain, Pression, Solar Radiation, UV Radiation, Wind speed, Wind Direction visualisation of climate statistics (for historical and future periods; precipitation, temperature, relative humidity etc.) (temperature, precipitations, relative air humidity, wind speed, wind direction weather data microclimatic data (temperature, precipitation, relative humidity of the air, wind speed, wind direction). meteorological conditions of particular importance for the prediction of complex phenomena meteorological conditions current local weather Weather data	Climate parameter

4.2.6 Causes

In the specific context of fire causes, we have meticulously adhered to the original EFFIS (European Forest Fire Information System) causes categories, maintaining them in their entirety without any modifications. This deliberate approach was guided by two fundamental considerations. Firstly, it is important to highlight that the harmonization of fire causes reported among all the countries in the European Union had already been expertly executed within the seminal work of the Joint Research Centre's EFFIS report[10]. Secondly, it is noteworthy that our

project proposal explicitly outlined our commitment to retaining EFFIS as a steadfast reference point with respect to categories pertaining to fire causes. Consequently, it is imperative to emphasize that the causes we reference are exclusively those declared within the EFFIS report. This commitment to the original taxonomy ensures not only terminological consistency but also a comprehensive alignment with the established standards. As such, figure 35, detailing these causes, shall serve as a point of reference, both from a terminology perspective and in terms of the level of detail.

CATEGORY	GROUP	CLASS
100 UNKNOWN	100 Unknown	100 Unknown
200 NATURAL	200 Natural	201 Lightning
		202 Volcanism
		203 Gas emission
300 ACCIDENT	300 Accident	301 Electrical power
		302 Railroads (Railways)
		303 Vehicles
		304 Works
		305 Weapons (firearms, explosives, etc.)
		306 Self-ignition (auto-combustion)
		307 Other accident
400 NEGLIGENCE	410 Use of fire	411 Vegetation management
		412 Agricultural burnings
		413 Waste management
		414 Recreation
		415 Other negligent use of fire
	420 Use of glowing objects	421 Fireworks, firecrackers and distress flares
		422 Cigarettes
		423 Hot ashes
		424 Other use of glowing object
500 DELIBERATE	510 Responsible (arson)	511 Interest (profit)
		512 Conflict (revenge)
		513 Vandalism
		514 Excitement (incendiary)
		515 Crime concealment
		516 Extremist
	520 Irresponsible	521 Mental illness
		522 Children
600 REKINDLE	600 Rekindle	600 Rekindle

Figure 36 Classes, groups, and categories of the harmonized fire causes classification scheme proposed by EFFIS.[10]

4.2.7 Fire

The concepts categorized into macro-category “Fire” were grouped together into the following table 30 and rows containing similar concepts were rearranged to be close to each other in order to be defined into a single class.

Table 30 Class definition from "Fire" raw concepts

	Raw concepts from pilots	Derived ontology class
Fire	Fire start	Starting point
	Propagation direction	Fire spread direction
	propagation speed time to reach the urbanized area	Fire spread rate
	number of active fire fronts	Active fronts number

	front intensity	Front intensity
	Fire front distance	Front distance
	smoke amount	Smoke amount
	Active crown fire with flame length of 25 m	Flame height
	ground temperature of the flames	Flame ground temperature
	identification of access paths	Access path
	critical points, where the fire increases intensity and / or speed	Critical point
	anticipation of fire development and development axes	Fire prediction
	prescribed fire	Type of fire
	fire danger index fire danger index metrics danger index metrics meteorological fire danger index Susceptibility of territory to wildfire assessment 5 degrees of fire danger	Fire danger index

4.3 Definition of classes from Existing Ontologies and Taxonomies

The methodology for this phase involved an analysis of the main relevant ontologies that were considered relevant to the project with the goal of producing a merge between them, bringing order, and highlighting each ontology's strengths. This work came together to give light to the first version of the SILVANUS ontology, which aims at structuring into a single ontology the elements of strength of all the others that were taken into consideration.

Several ontologies have been considered for the task of covering all the knowledge relevant to the SILVANUS project. Many of those only had a limited set of concepts that were relevant. To avoid littering the SILVANUS ontology with many irrelevant classes, relations, and data types, and to keep the full control of its content, it was decided in agreement with Catalink to replicate in the SILVANUS ontology just the relevant entities from other ontologies and to loosely link them to the original ones using the "seeAlso" annotation, containing the original URI.

This procedure allows querying, for example, for both "silvanus:Fire" and "envo:Fire" individuals while avoiding having to import everything from every ontology into the SILVANUS ontology.

This way, results of other projects are reused, and the SILVANUS semantic knowledge base is interoperable with knowledge bases based on these other ontologies because there are loose connections between the two models.

The following paragraphs will describe in more detail the selection process involved in each single ontology considered for the SILVANUS ontology design.

4.3.1 beAWARE

The beAWARE ontology is the ontology curated and suggested by Catalink. Many parts of it have been reused in the SILVANUS ontology, so much that it could be considered the SILVANUS ontology starting base.
It is of particular interest because, among other relevant things, it brings in the picture infrastructure and structures. Even though these elements may seem beyond the scope of preventing and fighting forest fires, wildfires may impact for example a road or an electrical power plant and break a chain of interdependencies that might affect the work of first responders or sensors. So, in our opinion, representing knowledge about these areas brings added value.

BeAWARE also can cover concepts related to first responders and rescue missions. The figure 36 below[8] displays the respective concepts in the proposed ontology. First responders (class **Responder**) are assigned one or more missions (class **Mission**), which in turn relate to incidents that involve participating entities (class **Vulnerable Object**). A mission is also characterized by start and end time, status, and mission priority.

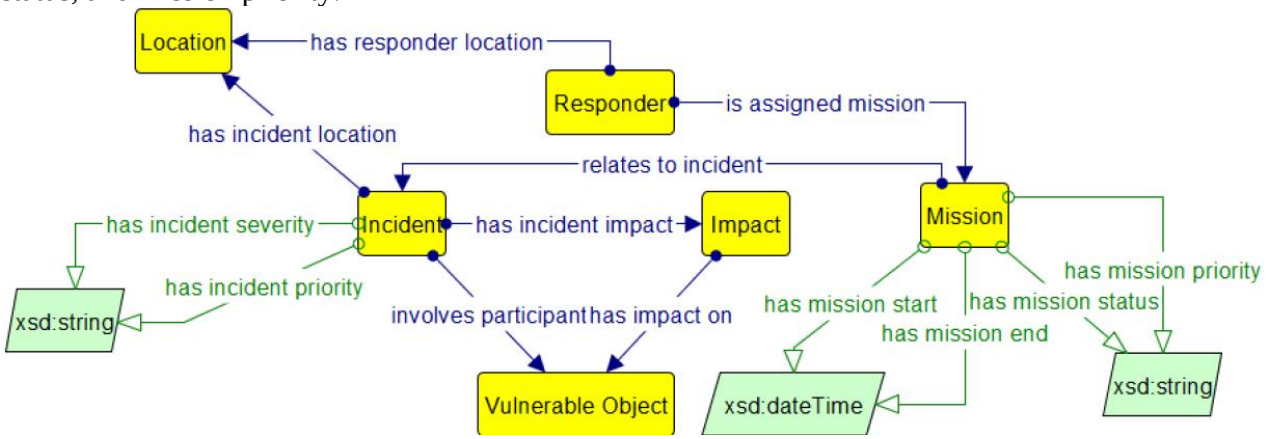


Figure 37 beAWARE rescue operations representation[8]

The following table 31 reports the external ontology classes that have been reused in the SILVANUS ontology and their name in the SILVANUS ontology when different.

Table 31 Classes considered from the beAWARE ontology and their counterpart in the SILVANUS Ontology

beAWARE	SILVANUS
Climate_parameter	
Dataset	
Incident	
Impact	
Incident_report	
Location	
Media_item	
Audio_item	
Image_item	
Video_item	
Text_item	
Mission	
Sensor	
Task	
Vulnerable_object	
Asset	
Ecological_asset	
Agriculture	
Dunes	
Natural_habitat	
Plant	
River	
Infrastructure	
Communication	
Educational_facility	
Energy	

Electric_energy_supply
Fire_department
Garbage_collection
Hospital
Police
Sewer
Transportation
Public_transport
Street
Water_supply
Property
Vehicle
Car
Structure
Bridge
Building
Leevee
Monument
Square
Wall
Living_being
Animal
Human

4.3.2 Bioportal Fire Ontology

The concept of fire was modelled mainly using the Bioportal Fire ontology as a starting point. In particular, the reused classes concern various types of fires, fire characteristics, fire risk, and their spatio-temporal expansion.

The following table 32 reports the external ontology classes that have been reused in the SILVANUS ontology and their name in the SILVANUS ontology when different.

Table 32 Classes considered from the Bioportal Fire Ontology and their counterpart in the SILVANUS ontology

Bioportal Fire	SILVANUS	Difference explaination
Fire		
Brush_fire		
Controlled_fire		
Hazard-reduction_fire		
Cool-season_fire		
High-intensity_fire		
Forest_fire		
Scrub_fire		
Uncontrolled_fire		
Wildfire		
Fire_characteristic		
Area_burned		
Fire_Frequency		

Fire_intensity		
Fire_severity		
Fire_speed	Fire_spread_rate	"Fire spread rate" is the terminology used by NWCG (National Wildfire Coordinating Group)
Fire_spread_direction		
Flame_height		
Fire_risk		
Temporal_entity		
Duration		
Ending_time		
Starting_time		
Spatial_entity		
Ending_point		
Extension		
Starting_point		

4.3.3 European Forest Fire Information System

Paragraph 3.2.3 explored the harmonization work carried out by the European Union to uniform the heterogeneous sets of fire causes used up until 2013 among all the European Countries. Considering this effort made in the recent years, it was decided that the SILVANUS ontology should be ready to adopt this new standard from the start and be interoperable with the systems that already adopted this shared taxonomy. Therefore, all the causes reported in the EFFIS taxonomy were implemented into the SILVANUS ontology.

The following table 33 reports the external ontology classes that have been reused in the SILVANUS ontology and their name in the SILVANUS ontology when different.

Table 33 Classes considered from the EFFIS taxonomy and their counterpart in the SILVANUS ontology

EFFIS	SILVANUS
Cause	
Accident	
Electrical_power	
Other_accident	
Railroads	
Self-ignition	
Vehicles	
Weapons	
Works	
Deliberate	
Irresponsible	
Children	
Mental_illness	
Responsible	
Conflict	
Crime_concealment	
Excitement	

Extremist
Interest
Vandalism
Natural
Gas_emission
Lightning
Volcanism
Negligence
Use_of_fire
Agricultural_management
Other_negligent_use_of_fire
Recreation
Vegetation_management
Waste_management
Use_of_glowing_objects
Fireworks,_firecrackers,_distress_flares
Cigarettes
Hot_ashes
Other_use_of_glowing_objects
Rekindle
Unknown

4.3.4 Canadian Fire Weather Index System

The calculation of the FWI is based on consecutive daily observations of temperature, relative humidity, wind speed, and 24-hour precipitation and on the moisture level of the three types of fuel on the forest floor. Therefore, since the FWI is an important piece of the puzzle, especially in phase A of SILVANUS, all these parameters were included in the SILVANUS ontology.

The following table 34 reports the external ontology classes that have been reused in the SILVANUS ontology and their name in the SILVANUS ontology when different.

Table 34 Classes considered from the Canadian Fire Weather Index and their counterpart in the SILVANUS ontology

FWI	SILVANUS
Fire_weather_index	
Buildup_index	
Initial_spread_index	
Drought_fuel_moisture	
Duff_fuel_moisture	
Fine_fuel_moisture	
Temperature	
Relative_humidity	
Wind_condition	
Wind_direction	
Wind_speed	

4.3.5 USDA Fire Effects Information System

The Fire Effects Information System goes quite in depth in concepts regarding botany.

The following table 35 reports the external ontology classes that have been reused in the SILVANUS ontology and their name in the SILVANUS ontology (often the same).

Table 35 Classes considered from the USDA Fire Effects Information System and their counterpart in the SILVANUS ontology

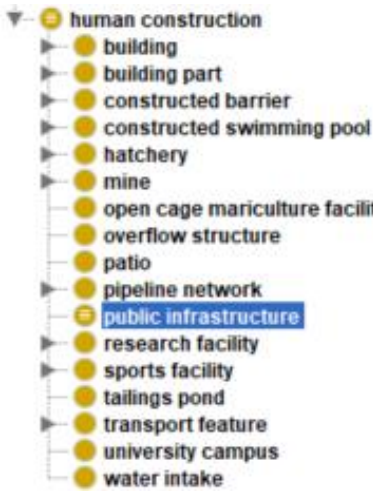
FEIS	SILVANUS	Difference explaination
Active_crown_fire		
Backfire		
Crown_class		
Crown_fire		
Density		
Dominance		
Duff		
Duff moisture code	Duff_fuel_moisture	"Duff fuel moisture" is the terminology used by the Canadian Fire Weather Index, this terminology is in line with other terms from this taxonomy such as "Drought fuel moisture" and "Fine fuel moisture"
Passive_crown_fire		
escaped prescribed fire		
extreme fire behavior		
fire duration		
fire intensity		
fireline intensity		
fire regime condition class		
fire-resistant species		
fire severity		
No fire effects		
Low		
Mixed		
Replacement		
flame length		
fuel		
fuel class		
fuel continuity		
fuel loading		
grassland		
shrubland		
woodland		
wooded shrubland		
savanna		
forest		
high-severity fire		
ground fire		
low-severity fire		

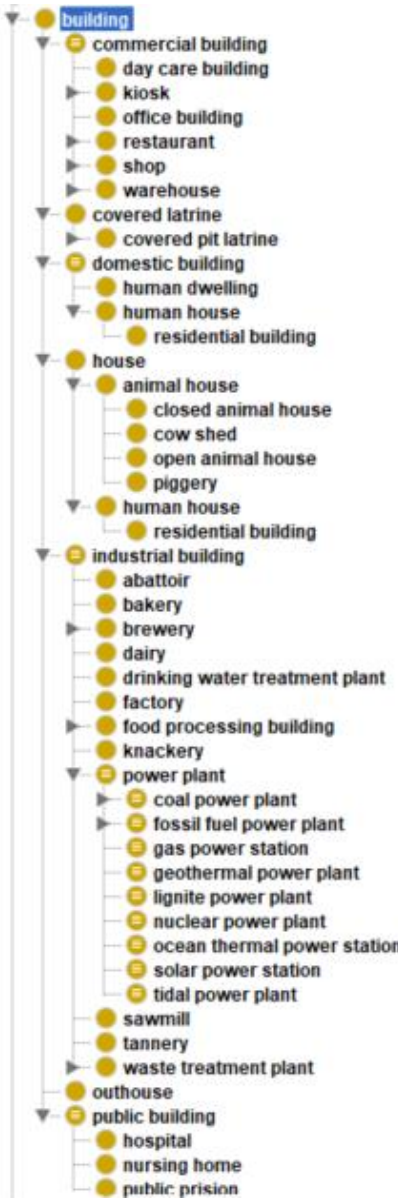
moderate-severity fire		
population index		
prescribed fire	controlled fire	Preferred terminology from Bioportal Fire Ontology since many of the terms related to fire come from it.
reaction intensity		
replacement-severity fire		
species richness		
total heat release		

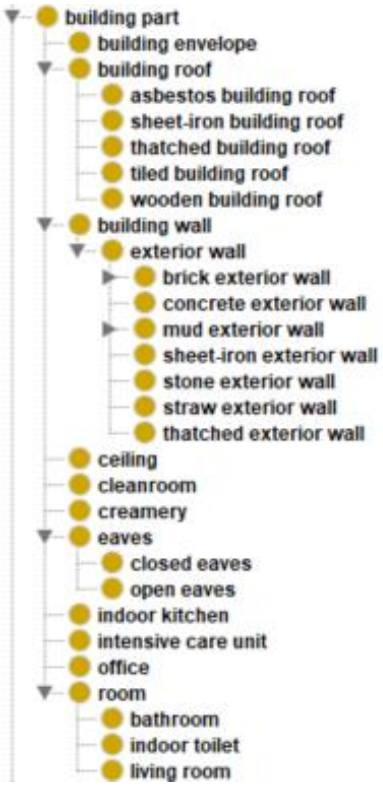
4.3.6 Bioportal Environment Ontology (ENVO)

The following are some areas of the ENVO ontology that could be more relevant in the context of SILVANUS:

The following table 36 reports the external ontology classes that have been reused in the SILVANUS ontology and their name in the SILVANUS ontology when different.







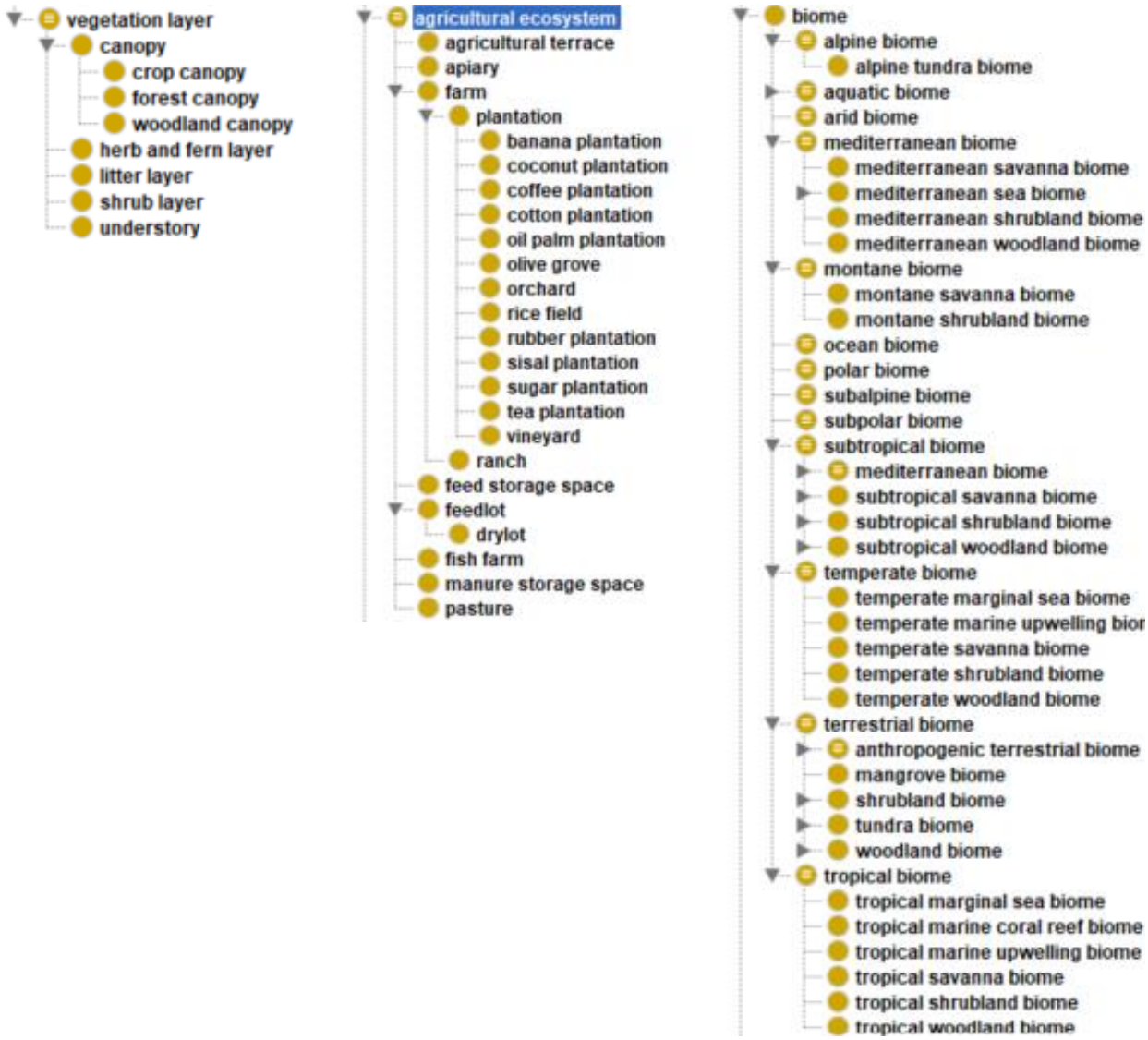


Table 36 Classes considered from the Environment ontology and their counterpart in the SILVANUS ontology

Bioportal ENVO	SILVANUS
All_season_road	
Alpine_Biome	
Anthropogenic_Terrestrial_Biome	
Aquatic_Biome	
Area_Of_Cropland	
Area_Of_Evergreen_Forest	
Area_Of_Lichen-dominated_Vegetation	
Area_Of_Mixed_Forest	
Area_Of_Moss-dominated_Vegetation	
Area_Of_Sedge-_And_Forb-dominated_Herbaceous_Vegetation	
Area_Of_Tundra	
Area_Of_Woody_Wetland	
Arid_Biome	
Asphalt_road	
Biome	
Boundary_wall	

Bridge
Bush_Area
Causeway
Concrete_road
Constructed_barrier
Dairy
Dam
Dense_Settlement_Biome
Drinking_water_pipeline_network
Drinking_water_treatment_plant
Driveway
Factory
Fence
Flower_Strip
Grassland_Area
Heath
Hospital
Industrial_building
Mangrove_Biome
Mediterranean_Biome
Mediterranean_Savanna_Biome
Mediterranean_Sea_Biome
Mediterranean_Shrubland_Biome
Mediterranean_Woodland_Biome
Montane_Biome
Montane_Shrubland_Biome
Oasis
Ocean_Biome
Oil_pipeline_network
Pipeline_network
Polar_Biome
Power_plant
Public_street
Rangeland_Biome
Sawmill
Scrubland_Area
Shrubland_Biome
Street
Structure
Subalpine_Biome
Subpolar_Biome
Subtropical_Biome
Subtropical_Shrubland_Biome
Temperate_Biome
Temperate_Shrubland_Biome
Terrestrial_Biome
Tidal_Mangrove_Shrubland
Track

Tropical_Shrubland_Biome
Tundra_Biome
Village_Biome
Waste_treatment_plant
Wetland_Area
Woodland_Area
Woodland_Biome
Xeric_Shrubland_Biome
food_processing_building
ford
lock
pier
railway
university_campus
water_intake

4.3.7 CrossForest

Out of the 11 ontology modules included in the CrossForest collection of ontologies, the ones considered relevant for the SILVANUS ontology were the following:

Iberian Forestry Inventory Ontology (IFI): ontology to publish data about forestry inventory in the Iberian Peninsula

Iberian Land Usage Ontology (ILU): ontology to publish data about land use in the Iberian peninsula

Spatial Position Ontology: an ontology to publish data about spatial entities and their positions in various reference systems, including relative positions

Simple Measures Ontology: a simple ontology to publish data about measures in different units

The following tables 37 to 40 report the external ontology classes that have been reused in the SILVANUS ontology and their name in the SILVANUS ontology when different.

Table 37 Classes considered from the CrossForest IFI ontology and their counterpart in the SILVANUS ontology

CrossForest IFI	SILVANUS
Erosion	
Altitude	
Basal_Area	
Basic_region_for_the_application_of_regional_policies	
Country	
Diametric_class	
Dominant_formation	
Major_socio-economic_region	
NUTS_unit	
Number_of_trees	
Small_region_for_specific_diagnoses	
Thickness_of_Dead_Layer	
Volume_with_bark	

Table 38 Classes considered from the CrossForest ILU ontology and their counterpart in the SILVANUS ontology

CrossForest ILU	SILVANUS
CanopyCover	
Forest_type	
Land_use	

Table 39 Classes considered from the CrossForest Position ontology and their counterpart in the SILVANUS ontology

CrossForest Postion	SILVANUS
Allocentric_Position	
Axis	
Coordinate	
Direction	
Distance	
Posicion Egocentrica	
Posiction Geocentrica	
LeftBound	
LowerBound	
Polygon	
Position	
Reference_Position	

Table 40 Classes considered from the CrossForest Measure ontology and their counterpart in the SILVANUS ontology

CrossForest Measure	SILVANUS
Hectares	
Measurable_Entity	
Measurable_Entity_in_Centimeters	
Measurable_Entity_in_Decimeters	
Measurable_Entity_in_Degrees	
Measurable_Entity_in_Gradians	
Measurable_Entity_in_Hectares	
Measurable_Entity_in_Meters	
Measurable_Entity_in_Millimeters	
Measurable_Entity_in_Square_Meters	
Measurable_Entity_in_Years	
Measure	
MeasureInUnities	
Measure_In_Centimeters	
Measure_In_Decimeters	
Measure_In_Degrees	
Measure_In_Gradians	
Measure_In_Hectares	
Measure_In_Meters	
Measure_In_Millimeters	
Measure_In_Percentage	
Measure_In_SquareMeters	
Measure_In_Unities	
Measure_In_Years	
Reliability	
Unit	
Years	

4.3.8 BIMERR Weather Ontology

The following table 41 reports the external ontology classes that have been reused in the SILVANUS ontology and their name in the SILVANUS ontology when different.

Table 41 Classes considered from the BIMERR ontology and their counterpart in the SILVANUS ontology

BIMERR	SILVANUS	Difference explaination
Point		
Sensor		
Spatial Thing		
City		
Country		
Feaure_of_Interest		
Measurement		
Unit Of Measure	Unit	Terminology from the Crossforest ontology, which is closer to SILVANUS topics
Pressure	Atmospheric_pressure	Terminology from beAWARE ontology, which share the most classes with the SILVANUS ontology
Humidity		
Precipitation		
Season		
Sky_Cover		
Ground		
Temperature		
Wind	Wind_condition	Terminology from beAWARE ontology, which share the most classes with the SILVANUS ontology

4.3.9 Bioportal Emergency Ontology

The following table 42 reports the external ontology classes that have been reused in the SILVANUS ontology and their name in the SILVANUS ontology when different.

Table 42 Classes considered from the Bioportal Emergency ontology and their counterpart in the SILVANUS ontology

Bioportal ESO	SILVANUS	Difference explanation
Facility	Building	Terminology from beAWARE ontology, which share the most classes with the SILVANUS ontology
Accomodation	Accomodation	
CommunicationFacility	CommunicationFacility	

EducationFacility	EducationFacility	
ElectricFacility	ElectricFacility	
GoodsSupplyFacility	GoodsSupplyFacility	
Medical Facility	Medical Facility	
Military Facility	Military Facility	
NutritionFacility	NutritionFacility	
Public Safety Facility	Public Safety Facility	
Fire Station	Fire Station	
Police Station	Police Station	
RehabilitationFacility	RehabilitationFacility	
Transportation Facility	Transportation Facility	
Airport	Airport	
Heliport	Heliport	
Pier	Pier	
Port	Port	
Rail Facility	Rail Facility	
WaterFacility	WaterFacility	
Instruments	Sensor	Terminology from beAWARE ontology, which share the most classes with the SILVANUS ontology
Resources	Response(Personnel)	Preferred terminology from NWCG
CommunicationChannel	CommunicationChannel	
FoodAndShelter	FoodAndShelter	
Item	Item	
MedicalItem	MedicalItem	
ReliefItem	ReliefItem	
Clothing	Clothing	
DryFood	DryFood	
First_Aid_Kit	First_Aid_Kit	
HousingEquipment	HousingEquipment	
SanitaryEquipment	SanitaryEquipment	
SupplyGood	SupplyGood	
MaterialAid	MaterialAid	
ReliefEquipment	ReliefEquipment	
RescueTeam	RescueTeam	
FirstResponder	Responder	Terminology from beAWARE ontology, which share the most classes with the SILVANUS ontology
CommunicationLeader	CommunicationLeader	
IncidentCommander	IncidentCommander	
LogisticChief	LogisticChief	
MedicalPlanningLeader	MedicalPlanningLeader	
OperationChief	OperationChief	

PlanningChief	PlanningChief	
PublicInfoOfficer	PublicInfoOfficer	
ResourceUnitLeader	ResourceUnitLeader	
SafetyOfficer	SafetyOfficer	
SupplyLeader	SupplyLeader	
TaskForceSectorLeader	TaskForceSectorLeader	
MedicalStaff	MedicalStaff	
Volunteer	Volunteer firefighter	Preferred terminology from NWCG
Police		
Vehicle		
Aircraft		
Ground Vehicle		
Bicycle		
Ground Motor Vehicle		
Armored Personnel Carrier		
Automobile		
Bus		
Infantry Fighting Vehicle		
Motorcycle		
Tank		
Truck		
Rail Transport Vehicle		
Locomotive		
Train		
Watercraft		
WildFire		
ClarificationOfSituation	ClarificationOfSituation	
ClearingWork	ClearingWork	
Containment	Containment	
EnlightenmentOfPopulation	EnlightenmentOfPopulation	
Evacuation	Evacuation	
HumanitarianAssistance	HumanitarianAssistance	
MedicalSupport	MedicalSupport	
Prevention	Prevention	
RehabilitationAndRecovery	RehabilitationAndRecovery	
SearchAndRescue	SearchAndRescue	
SupplyGoodSupport	SupplyGoodSupport	
PropertyLoss	Property	Terminology from beAWARE ontology
PortLoss	Port	Terminology from beAWARE ontology
RailwayLoss	Rail_Facility	Terminology from beAWARE ontology
HospitalLoss	Hospital	Terminology from beAWARE ontology
Building	Building	

RoadLoss	Street	Terminology from beAWARE ontology
SewageSystem	Sewer	Terminology from beAWARE ontology
WaterSupply	WaterSupply	
Loss	Vulnerable_object	Terminology from beAWARE ontology
Irrigation	Irrigation	
InfrastructureLoss	Infrastructure	
Communication	Communication	
BridgeLoss	Bridge	Terminology from beAWARE ontology
AirportLoss	Airport	Terminology from beAWARE ontology
Electricity	Energy	Terminology from beAWARE ontology
EducationalInstitute	EducationalFacility	Terminology from beAWARE ontology

4.3.10 empathi: an ontology for Emergency Managing and Planning about Hazard Crises

The empathi ontologies turned out to be an inconsistent ontology with unique and specialized classes such as 'prayers tonight' or 'help tornado' or 'poisonous gas' under class ‘facility’. Thus, very few classes were considered from it.

The following table 43 reports the external ontology classes that have been reused in the SILVANUS ontology and their name in the SILVANUS ontology when different.

Table 43 Classes considered from the empathi ontology and their counterpart in the SILVANUS ontology

Empathi	SILVANUS	Difference explanation
Age group	Age group	
adolescent	adolescent	
adult	adult	
child	child	
infant	infant	
'children education'	EducationFacility	Terminology from beAWARE ontology
electricity	ElectricFacility	Terminology from beAWARE ontology
'telecommunication, mobile and landline networks, internet'	CommunicationFacility	Terminology from beAWARE ontology
water	WaterFacility	Terminology from beAWARE ontology

5 Design and Description of Results

The following chapter will showcase a first version of the ontology, resulting from the choices made in the previous one. It is envisaged to work as a handbook that is ready for easy consultation by all the project partners. To this end, different forms of visualization will be adopted:

- Static HTML documentation (Powered by Live Owl Documentation Environment[27])
    - Available in the Silvanus website resources section
- Graphical visualization (for all users)
- Tabular visualization (more detailed, meant for developers that are going to use the ontology for their applications)
- Protégé visualization (for those familiar with the ontology editing tool Protégé)

To keep the deliverable as easy to navigate as possible, only the graphical visualization will be included inside the corpus, while the other two are available in the appendixes A and B.

5.1 SILVANUS Semantic Model – Ontology

5.1.1 Terminology unification

Terminology (and thus knowledge) unification allows all parties to share each other's knowledge, enables semantic interrogability and the result is a semantic model populated with input data that delivers a unified view of available info to end user. Various app with different purposes can run on top of such semantic model.
We looked for the main concepts mentioned in the pilots, used in pre-existing ontologies and suggested by partners with domain expertise.
We gathered all the different concepts in one spreadsheet and highlighted them using different colours for different macro-categories (Fire, Tool & resource, Cause, Climate, Biodiversity, Sensor, Vulnerable object).
The most similar concepts in each of these macro-categories have been listed near each other in another spreadsheet and a single common class has been decided to represent them.

5.1.2 Ontologies from scratch

Ontologies can be created to describe any aspect of the human experience. Before setting on to create it, one should ask themselves some questions, for example what the scope of the ontology is, who will use it, how will it be used. This will enable the creator to focus on the relevant entities and relations.
Then, once the required knowledge has been acquired, it needs to be conceptualized in a model that describes the problem and its solution.
The next step is to implement this model in a formal language. This can be done using a description logic representation system (such as the OWL language).
Finally, the model needs to be evaluated with respect to its frame of reference.[28] This process is exemplified in figure 37.

[27] Lode - Live Owl Documentation Environment. [Online]. Available: https://essepuntato.it/lode/. [Accessed: 29-Sep-2022].
[28] M. Fernández-López, A. Gómez-Pérez, and N. Juristo, "AAAI-97 Spring Symposium Series," in Proceedings of the Ontological Engineering AAAI-97 Spring Symposium Series, 1997.

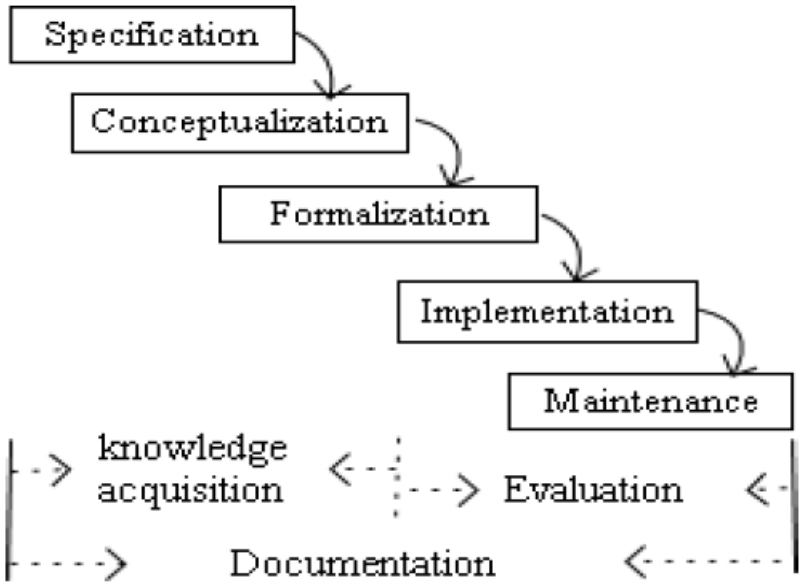


Figure 38 IEEE 1074-2006 Software development life-cycle process[28]

Pros:

- Tailored for the project scope

Cons:

- Prone to errors
- Time consuming
- Not automatically updated as it's the case with references to other ontologies

5.1.3 Expanding existing ontologies

Another approach is to expand on the concepts and knowledge already represented by other ontologies. This allows to start from a solid foundation and to guarantee interoperability with the systems running on the ontologies used for reference.

Pros:

- Saves time
- Keeps standardization and improves interoperability
- Referenced ontologies automatically updated

Cons:

- Missing documentation
- Possible incompatibility of concepts

5.1.4 Ontology design

There are many tools for creating and editing ontologies available online. The editor of choice for Task 3.1 has been Protégé, a free and open-source ontology editor and framework for building intelligent systems. Protégé is supported by a strong community of academic, government, and corporate users, who use it to build knowledge-based solutions in areas as diverse as biomedicine, e-commerce, and organizational modelling.
The main reasons for choosing Protégé where the following:

- Protégé is actively supported by a strong community of users and developers that answer questions, write documentation, and contribute plug-ins.
- Protégé fully supports the latest OWL 2 Web Ontology Language and RDF specifications from the World Wide Web Consortium.
- Protégé is based on Java, is extensible, and provides a plug-and-play environment that makes it a flexible base for rapid prototyping and application development.
- Protégé is used by our technical partner Catalink, and they can help with their experience in using it.

Protégé offers different views for the different components of the ontology: classes, object properties, data properties and individuals. Figure 38 shows the SILVANUS ontology opened in Protégé.

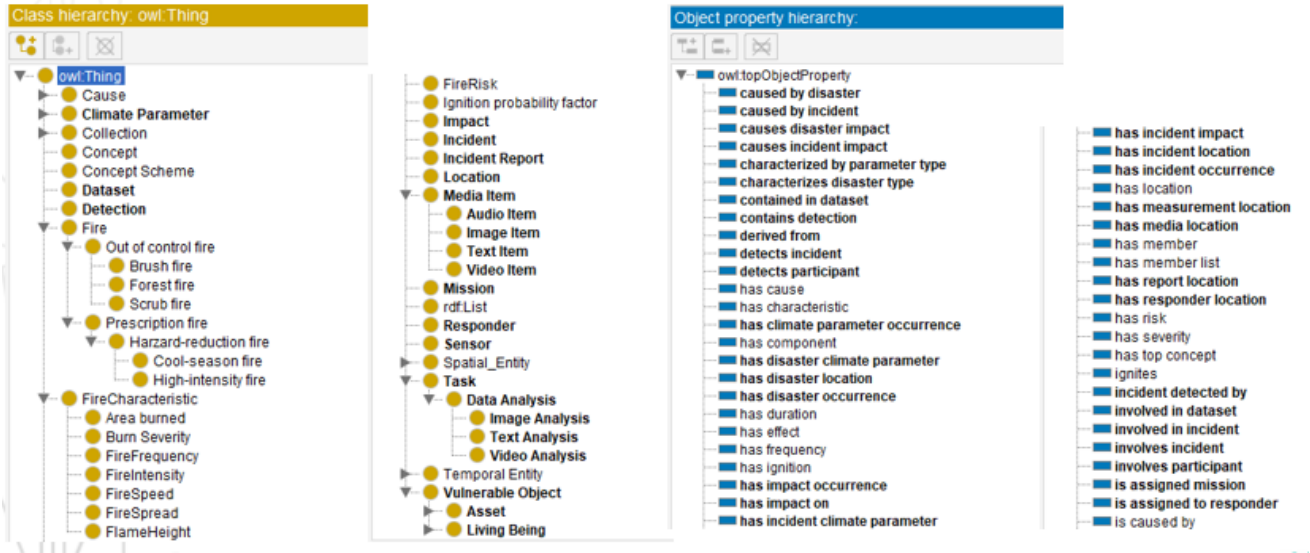


Figure 39 Protegè interface

The first step in creating the SILVANUS ontology was represented by the study of all the information that was circulating at the time and try to organize it in a graphical schema where each concept and field of knowledge was connected in a meaningful way. The first results of this activity carried out on Miro (a digital whiteboard environment) were presented at the Zvolen workshop and partners have been invited to leave comments and feedback on it.

In the following weeks some feedback was received about certain classes and relationship and the suggestions were implemented in the mockup ontology.

Following this, the process of building the real ontology started, at first by establishing all the classes and properties proposed in the mockup. Once this phase was completed, we started looking for potential relations between classes (e.g.: “low moisture level” > “may cause” > fire).

External ontology implementation has been another hurdle to figure out: importing the entire ontology would pollute SILVANUS ontology with too many irrelevant classes and relationships. Thanks to Catalink, we found out that using the property “seeAlso” we can establish a soft link between SILVANUS ontology and the third-party ontology, and this allows for interoperability between the SILVANUS system and a system based on this other ontology.

5.1.5 Ontology Graphical Representation

As mentioned at the beginning of the chapter, there are different ways of representing an ontology. Some are more graphical and easier to understand but less detailed, some others are less graphical but more detailed. To keep the deliverable as easy to consult as possible, only the graphical visualization will be included inside the corpus, while the other two (tabular and Protégé visualization) are available in the appendixes A and B.

The following section proposes a graphical representation of the ontology classes and relationships that are included in the first version of the SILVANUS ontology. The representation was made using the online tool Miro[29], a platform for creating various kinds of flowcharts.
First there will be a bird's eye view representing all the macro-areas that compose the SILVANUS ontology. Then, each macro-area will be showcased in greater detail.
Before proceeding with the visualization, a couple of conventions that have been used:

- Classes with no background colour are old classes that were presented for the version presented at the workshop in Zvolen.
- Classes with turquoise background are classes that have been added for the Bari workshop version.
- Classes with a yellow background are classes under consideration for change or deletion in the future.
- Straight lines represent a parent-child relationship (also known as "is a" relationship)
- Dashed curved lines represent other kind of relationships (also known as properties)

5.1.5.1 Bird's eye view

Figure 39 shows a bird's eye view of the whole SILVANUS ontology. Immediately visible are the seven macro-areas that were identified in phase two: Fire, Cause, Biodiversity, Sensors, Tools & Resources, Vulnerable Objects, Climate. Also visible, although barely, are the relationships between the concepts in each macro-area.

[29] "The visual collaboration platform for every team: Miro," https://miro.com/. [Online]. Available: https://miro.com/. [Accessed: 29-Sep-2022].

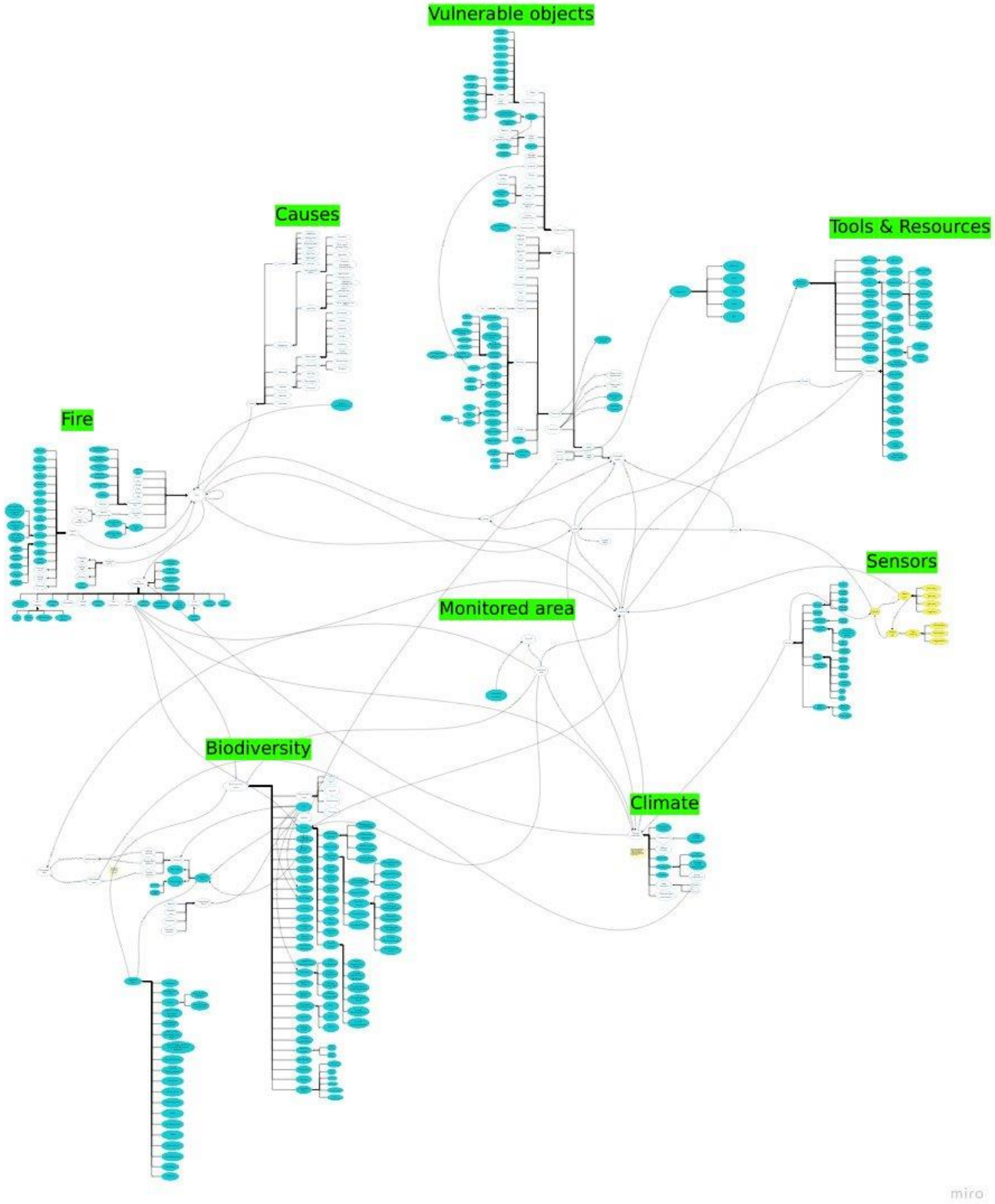


Figure 40 Bird's eye view of the SILVANUS ontology

5.1.5.2 Fire

The fire-related macro-area of the SILVANUS ontology is meant to represent concepts and relationships related to fire.

The Fire class can be considered the “entry point” of this area of the ontology. It includes in its subclasses different kinds of fires with their own subtypes. Figure 40 shows the fire-related macro-area at the time of writing.

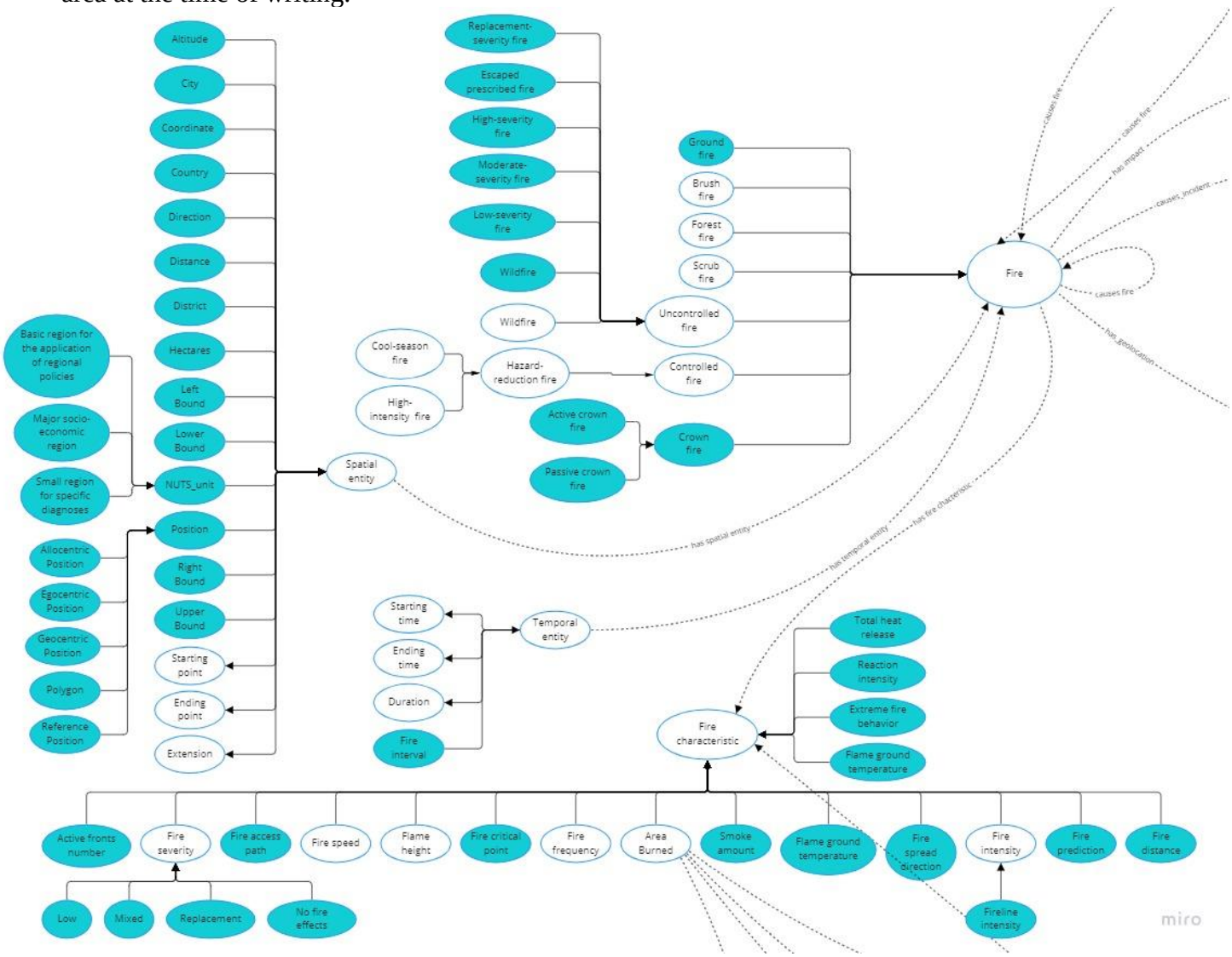


Figure 41 Fire ontology macro-area

The main classes in this area are Fire, Fire characteristic, Spatial entity, Temporal entity.

- "Fire" class contains “Active Fire”, "Crown fire", “Crown Out”, "Controlled fire", "Brush fire", "Uncontrolled fire", "Forest fire", "Ground fire", "Scrub fire". It's the rapid oxidation of a material in the exothermic chemical process of combustion, releasing heat, light, and various reaction products.
- "Spatial entity" class contains "Position", "Altitude", "NUTS unit", "City", "Coordinate", "Country", "Direction", "Distance", "District", "Ending point", "Extension", "Hectares", "LeftBound", "LowerBound", "RightBound", "Starting point", "UpperBound". It represents anything with spatial extent, i.e., size, shape, or position.
- "Temporal entity" class contains "Duration", "Ending time", "Fire interval", "Starting time". It's the entity used to describe the temporal relationships between entities or other elements.
- "Fire characteristic" class contains "Area burned", "Active fronts number", "Extreme fire behaviour", "Fire Frequency", "Fire access path", "Fire critical point", "Fire distance", "Fire intensity", "Fire prediction", "Burn severity", "Fire spread rate", "Fire spread direction",

"Flame ground temperature", "Flame height", "Reaction intensity", "Smoke amount", "Total heat release", “Burning period”, “Combustion rate”, “Flaming front”, “Flame depth”, “Fire behavior”. It represents parameters used to describe the characteristics or behaviour of a fire event.

Regarding properties, those that affect this macro-area are the following:

- Property "causes fire" links class "Cause", "Fire", "Ignition probability factor" to class "Fire".
- Property "causes incident" links class "Fire" to class "Incident".
- Property "has fire characteristic" links class "Fire" to class "Fire characteristic".
- Property "has geolocation" links class "Animal", "Area burned", "Climate parameter", "Fire", "Incident", "Media item", "Monitored area", "Responder", "Response resource", "Sensor", "Vulnerable object" to class "Location".
- Property "has impact" links class "Fire", "Incident" to class "Impact".
- Property "has spatial entity" links class "Fire" to class "Spatial entity".
- Property "has temporal entity" links class "Fire" to class "Temporal entity".

5.1.5.3 Cause

The cause-related macro-area of the SILVANUS ontology is meant to represent concepts and relationships related to fire-inducing causes. It is represented in figure 41.

The Cause class can be considered the “entry point” of this area of the ontology. It includes in its subclasses different kinds of clauses with their own subtypes, as reported in EFFIS.

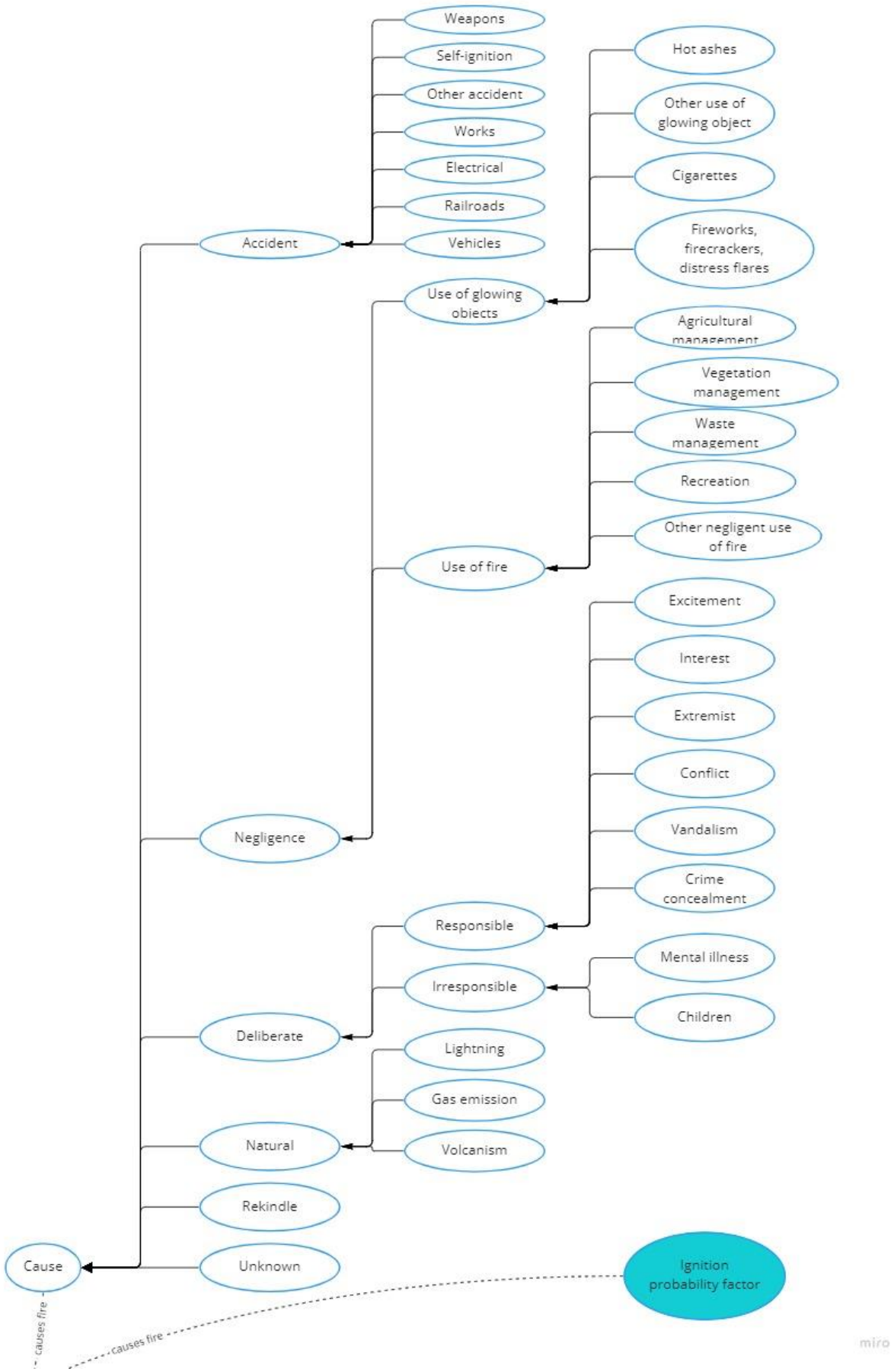


Figure 42 Causes ontology macro-area

The causes taxonomy has already been extensively talked about in the previous chapter. Just as a refresher, the higher level classes will be described here:

- "Cause" class contains "Accident", "Deliberate", "Natural", "Negligence", "Rekindle", "Unknown". Cause that started the fire.
- "Accident" class contains "Electrical power", "Other accident", "Railroads", "Self-ignition", "Vehicles", "Weapons", "Works". Wildfire unintentionally and indirectly caused by human without use of fire, connected neither to will nor to negligence rather to fatality.
- "Deliberate" class contains "Irresponsible" and "Responsible". Wildfire intentionally caused by human with the use of fire.
- "Natural" class contains "Gas emission", "Lightning", "Volcanism". Any wildfire caused by natural origin, with no human involvement in any way.
- "Negligence" class contains "Use of fire" and "Use of glowing objects". Wildfire unintentionally caused by human using fire or glowing object, not connected to fatality.

Regarding properties, those that affect this macro-area are the following:

- Property "causes fire" links class "Cause", "Fire", "Ignition probability factor" to class "Fire".

5.1.5.4 Biodiversity

The Biodiversity index-related macro-area of the SILVANUS ontology is meant to represent concepts and relationships related to biodiversity indexes and parameters related to living beings.
The Biodiversity index class can be considered the “entry point” of this area of the ontology. It includes in its subclasses different kinds of biodiversity indexes with their own subtypes. Other high-level sections of this segment are “Vegetated area”, a geographic feature which has ground cover dominated by plant communities, and “Living being stat”/”Vegetation stat”, concerning parameters related to living beings and vegetation.
Because of size constraints, this area had to be sectioned in different subsections. The following figures 42 to 46 is an ensemble view of the macro-area, which is followed by the respective subsections.

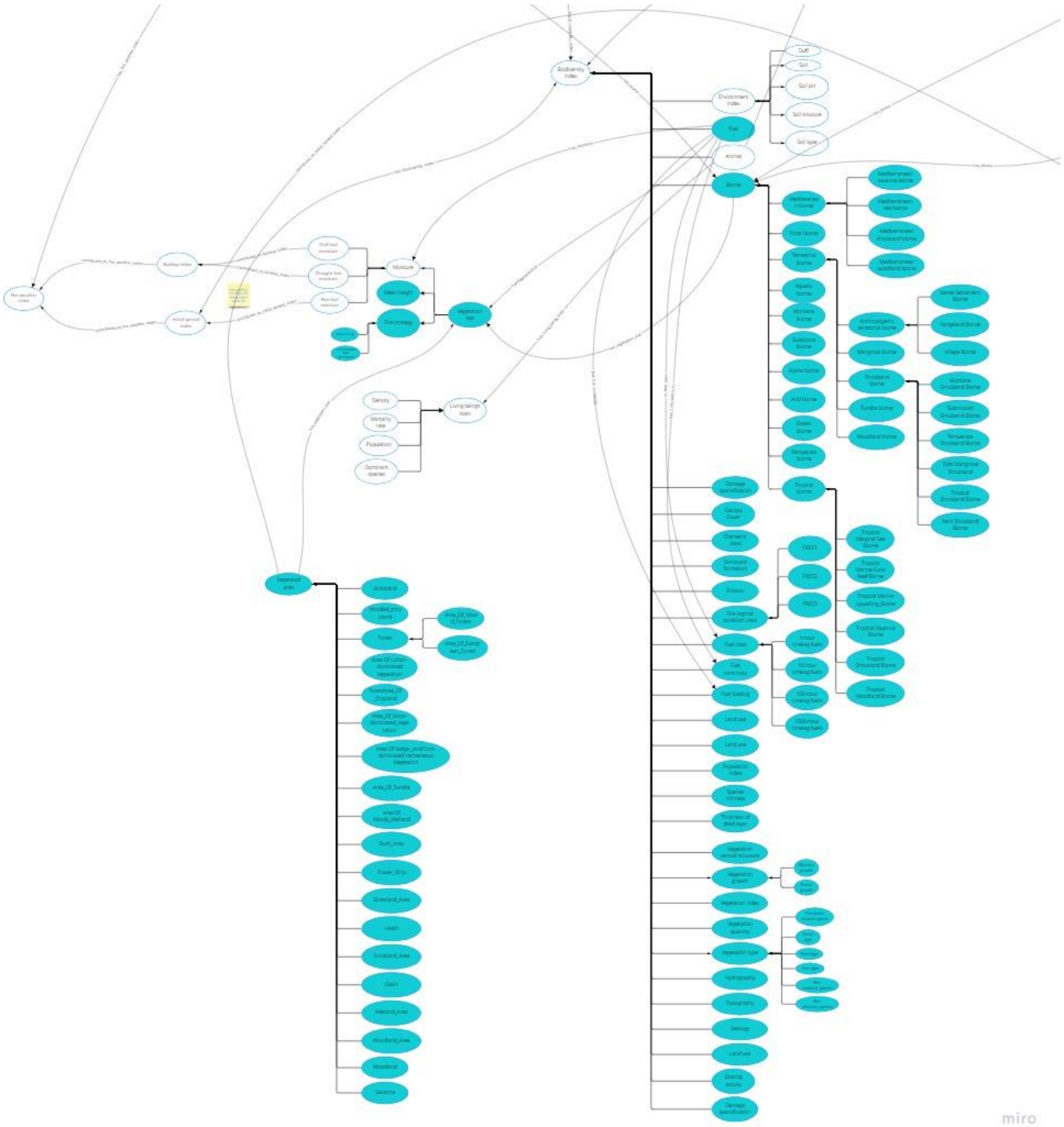


Figure 43 Biodiversity ontology macro-area ensemble view

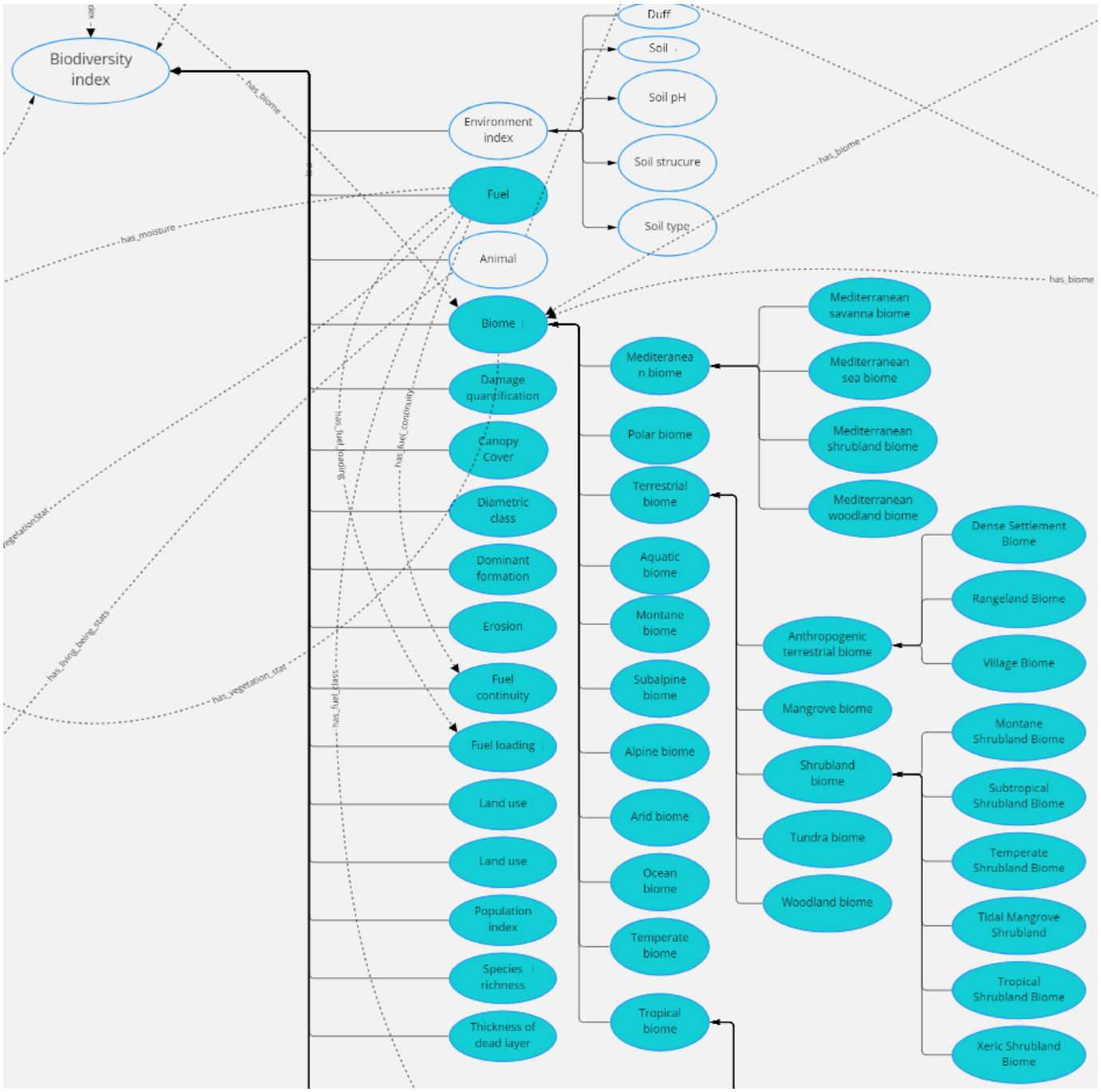


Figure 44 Biodiversity index subsection, part 1

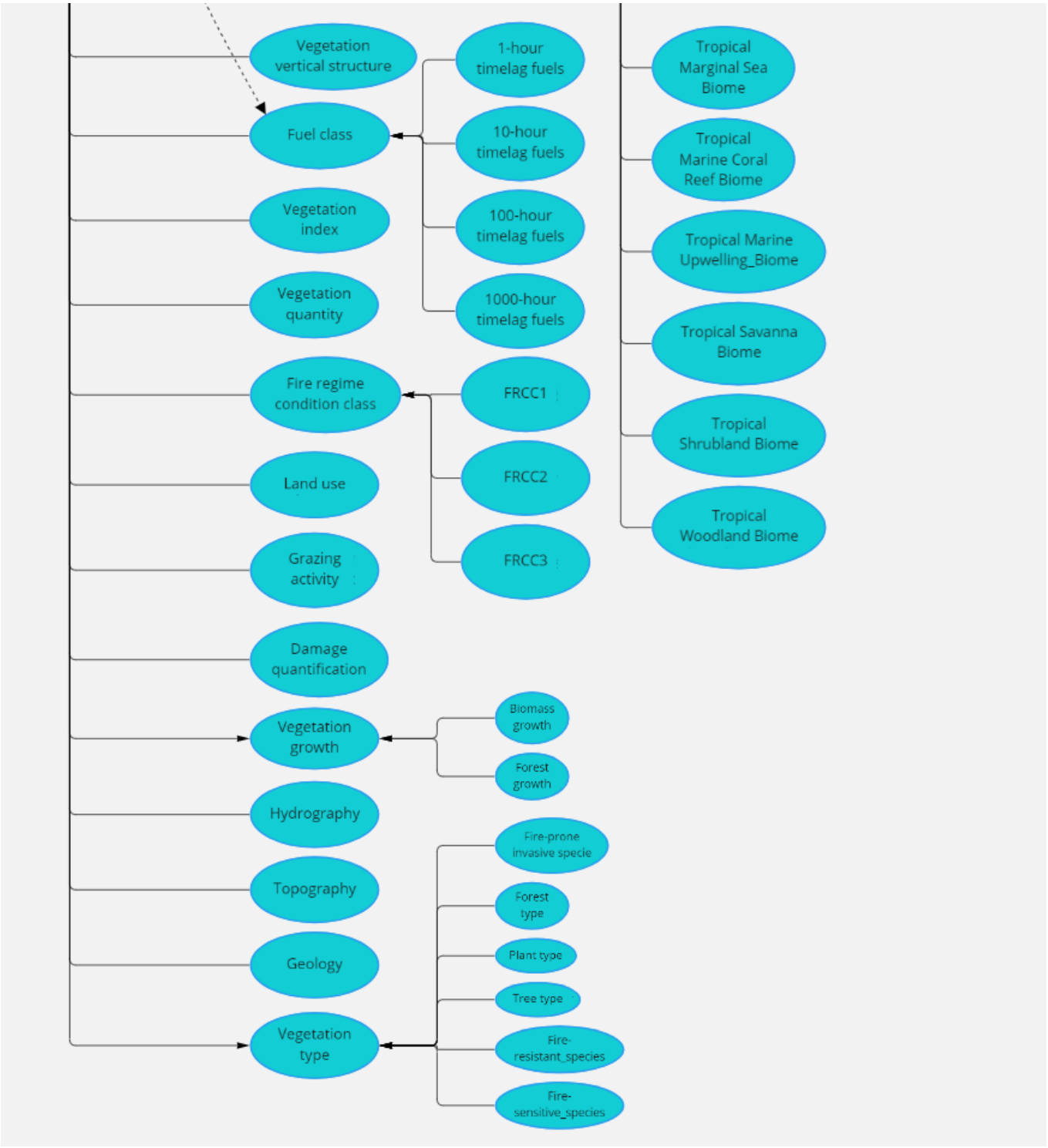


Figure 45 Biodiversity index subsection, part 2

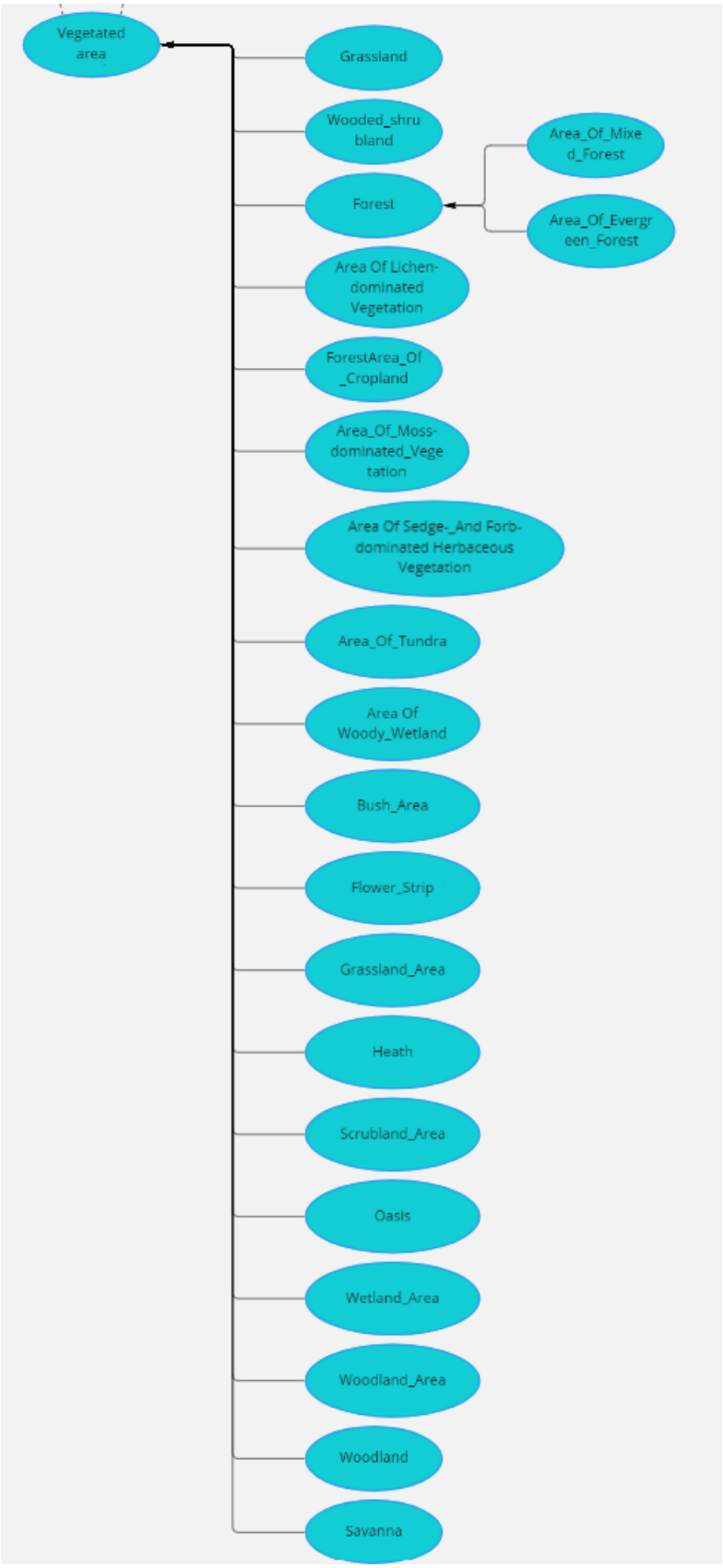


Figure 46 Vegetated area subsection

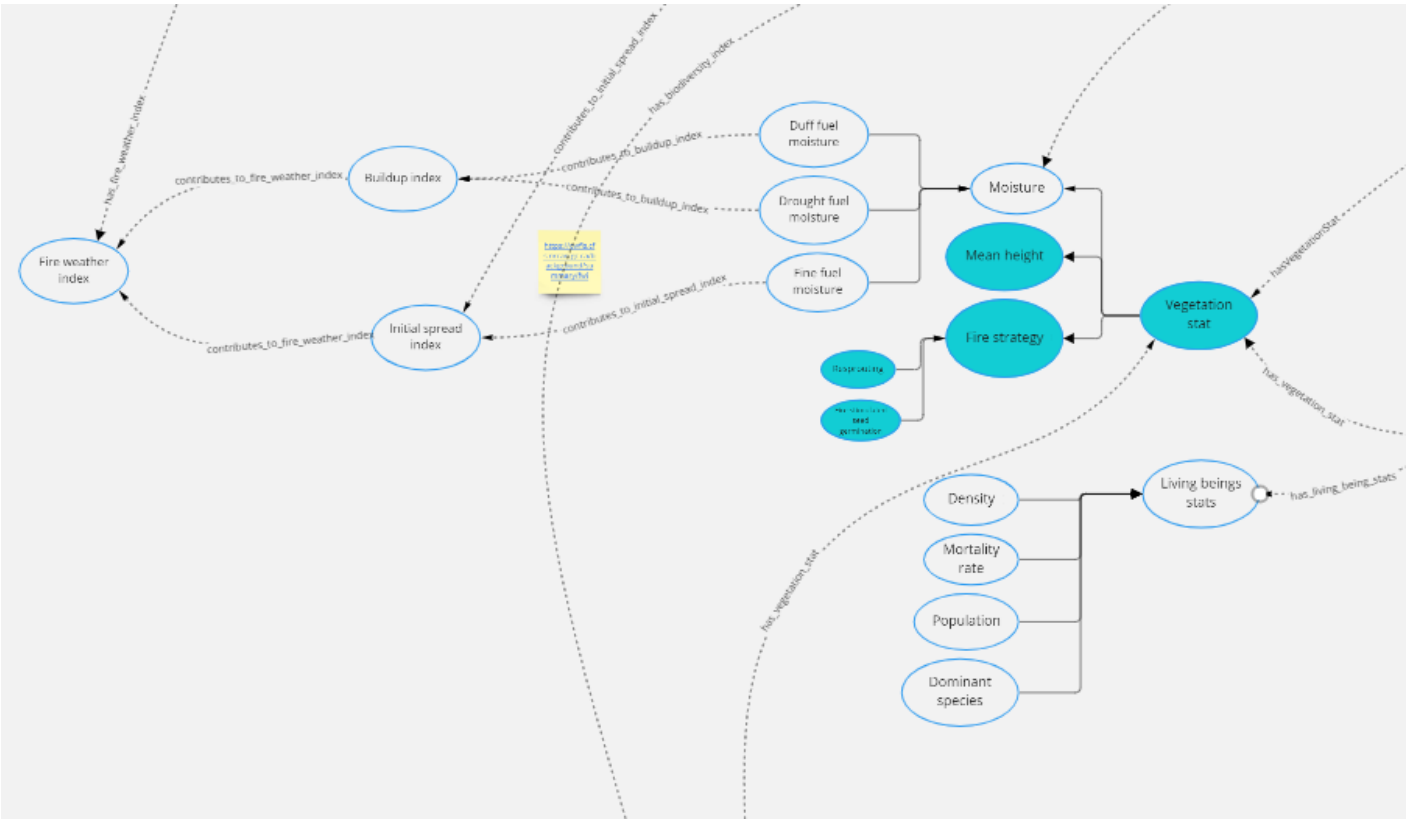


Figure 47 Vegetation stats and Living being stat subsection

The main classes in this area are "Biome", "Fire regime condition class", "Fuel", "Fuel class", "Fuel continuity", "Fuel loading", "Animal", "Canopy cover", "Damage quantification", "Diametric class", "Dominant formation", "Environment index", "Erosion", "Vegetation type", "Geology", "Grazing activity", "Hydrography", "Land use", "MeasureInUnities", "Population index", "Species richness", "Thickness of Dead Layer", "Topography", "Vegetation growth", "Vegetation index", "Vegetation quantity", "Vegetation vertical structure", "Base fuel model".

- "Biome" class contains "Alpine Biome", "Terrestrial Biome", "Aquatic Biome", "Arid Biome", "Mediterranean Biome", "Montane Biome", "Ocean Biome", "Polar Biome", "Subalpine Biome", "Subpolar Biome", "Subtropical Biome", "Temperate Biome", "Tropical Biome". A biome is an ecosystem to which resident ecological communities have evolved adaptations.
- "Fire regime condition class" class contains "FRCC1", "FRCC2", "FRCC3". A standardized, interagency index to measure the departure of current conditions from reference or historical conditions [74]. The fire regime condition classes are [9]:.
- "Fuel class" class contains "1-hour timelag fuels", "10-hour timelag fuels", "100-hour timelag fuels", "1000-hour timelag fuels". A set of fuels with similar traits. Fuels are categorized as herbaceous or woody and live or dead. Dead fuels are classed as 1-, 10-, 100-, or 1,000-hour timelag fuels, based on the time needed for fuel moisture to come into equilibrium with the environment [92]:.
- "Environment index" class contains "Duff", "Soil", "Soil pH", "Soil structure", "Soil type".
- "Vegetation type" class contains "Fire-prone invasive species", "Fire-resistant species", "Fire-sensitive species", "Forest type", "Plant type", "Tree type". Type of vegetation.
- "MeasureInUnities" class contains "Number of trees".
- "Moisture" class contains "Drought fuel moisture", "Duff fuel moisture", "Fine fuel moisture". Moisture is associated with the water content in liquid phase present in any substance.

- "Forest" class contains "Area Of Evergreen Forest" and "Area Of Mixed Forest". A formation dominated by trees, in which the canopy is more closed than open [112]. Generally, overstory trees are >16 feet (5 m) tall and have 60% to 100% cover [75]. When describing forests, use of a dash indicates an overstory/understory relationship (e.g., northern red oak/America witch-hazel forest). Compare with grassland, shrubland, wooded shrubland, woodland, savanna.
- "Fuel" class contains "Live fuel" and "Dead fuel".

Regarding properties, those that affect this macro-area are the following:

- Property "has biodiversity index" links class "Area burned", "Monitored area", "Vegetated area" to class "Biodiversity index".
- Property "has living being stats" links class "Animal" to class "Living being stat".
- Property "has vegetation stat" links class "Biome", "Fuel", "Vegetated area" to class "Vegetation stat".

5.1.5.5 Sensors

The Sensor-related macro-area of the SILVANUS ontology is meant to represent concepts and relationships related to sensors and devices.
The Sensor class can be considered the "entry point" of this area of the ontology. It includes in its subclasses different kinds of sensors with their own subtypes, as well as tasks carried out by such sensors.
The following figure 47 is an ensemble view of the macro-area.

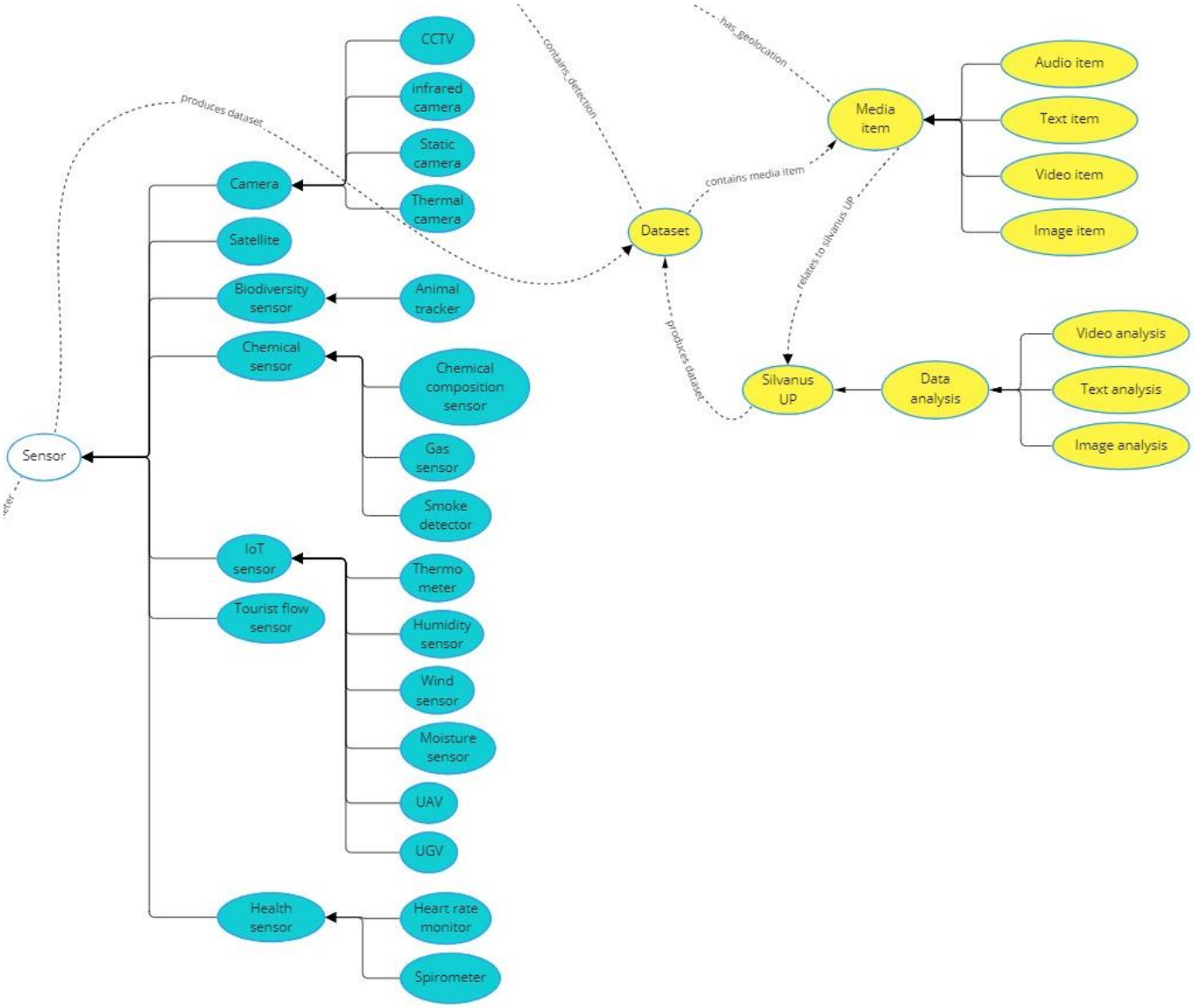


Figure 48 Sensors ontology macro-area

The main classes in this area are "IoT sensor", "Biodiversity sensor", "Camera", "Chemical sensor", "Health sensor", "Satellite detection system", "Tourist flow sensor", "Weather station".

- "IoT sensor" class contains "Anemometer", "Humidity sensor", "Moisture sensor", "Thermometer", "UAV", "UGV". IoT devices are the nonstandard computing devices that connect wirelessly to a network and have the ability to transmit data, such as the many devices on the internet of things.
- "Biodiversity sensor" class contains "Animal tracker". Sensor for detecting biodiversity features.
- "Camera" class contains "CCTV", "Infrared camera", "Static camera". Device for capturing images.
- "Chemical sensor" class contains "Chemical composition sensor", "Gas sensor", "Smoke detector". A chemical sensor is a device that converts a property (physical or chemical) of a particular analyte into a measurable signal that is proportional to the analyte concentration. It recognizes the analyte molecule in a selective way by transforming the response into an analytical electrical signal.
- "Health sensor" class contains "Heart rate monitor" and "Spirometer". A sensor capable of collecting health-related parameters.

Regarding properties, those that affect this macro-area are the following:
Property "has geolocation" links class "Animal", "Area burned", "Climate parameter", "Fire", "Incident", "Media item", "Monitored area", "Responder", "Response resource", "Sensor", "Vulnerable object" to class "Location".
Property "observes parameter" links class "Sensor" to class "Climate parameter".
Property "produces dataset" links class "Sensor", "SILVANUS UP" to class "Dataset".

5.1.5.6 Tools & Resources

The Tools & Resources-related macro-area of the SILVANUS ontology is meant to represent concepts and relationships related to response resources.
The Response resource class can be considered the “entry point” of this area of the ontology. It includes in its subclasses different kinds of response resources with their own subtypes. The following figure 48 is an ensemble view of the macro-area.

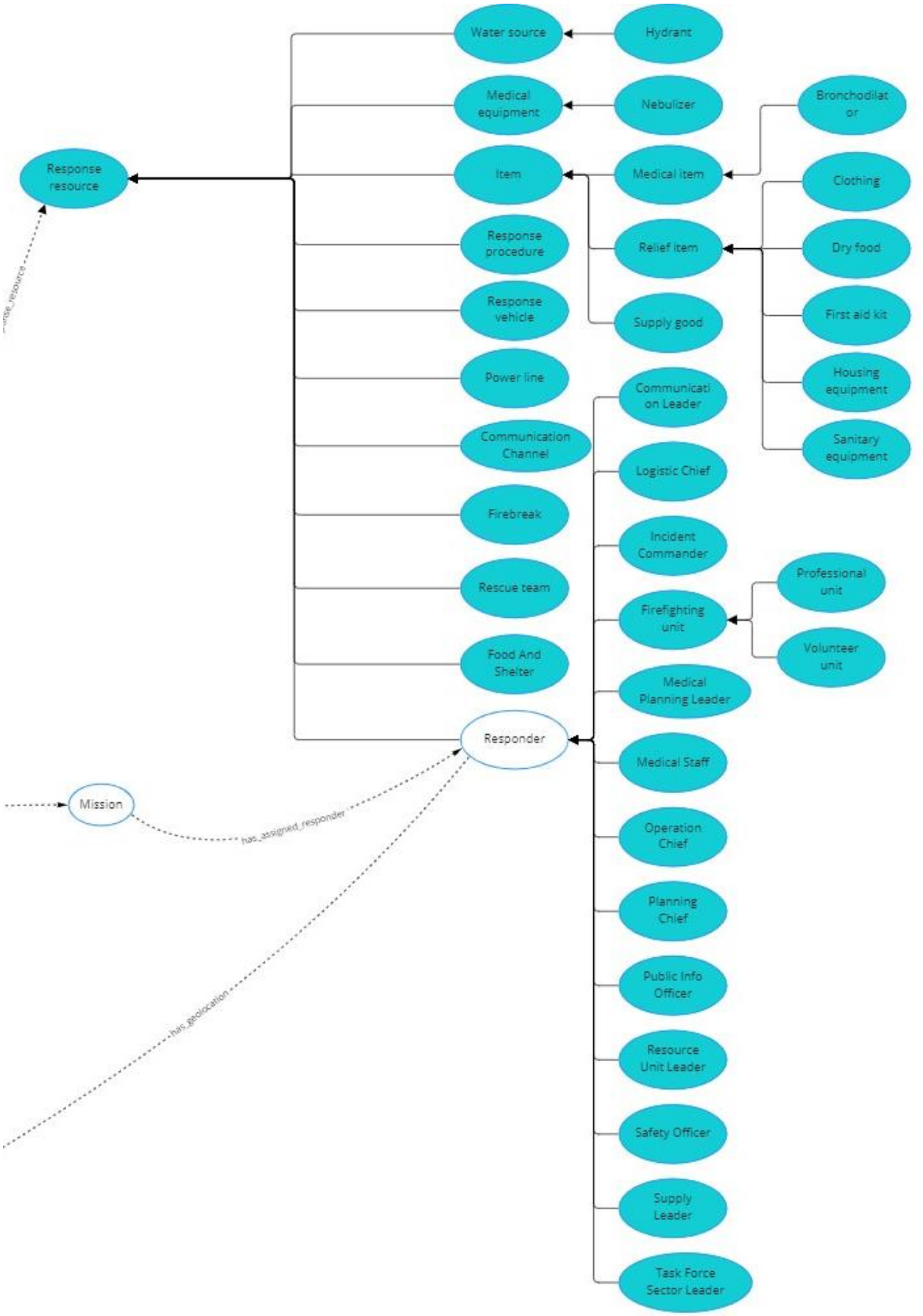


Figure 49 Tools & resources ontology macro-area

The main classes in this area are "Responder", "Response vehicle", "Response procedure", "CommunicationChannel", "Firebreak", "FoodAndShelter", "Water source", "Item", "Medical equipment", "Power line", "RescueTeam", “Early Warning”, “Retardant”, “Retardant Base”, “Lookout Tower”.

- "Responder" class contains "CommunicationLeader", "Firefighting unit", "IncidentCommander", "LogisticChief", "MedicalPlanningLeader", "MedicalStaff", "OperationChief", "Patrol", "PlanningChief", "PublicInfoOfficer", "ResourceUnitLeader", "SafetyOfficer", "SupplyLeader", "TaskForceSectorLeader". Represents a first responder unit.
- "Response vehicle" class contains "Airtanker", "Ground Vehicle", "Watercraft". Vehicle for emergency response.
- "Response procedure" class contains "ClarificationOfSituation", "ClearingWork", "Containment", "EnlightenmentOfPopulation", "Evacuation", "HumanitarianAssistance", "MedicalSupport", "RehabilitationAndRecovery", "SearchAndRescue", "SupplyGoodSupport". Response procedure.
- "Water source" class contains "Hydrant". Refers to bodies of water (such as rivers, streams, lakes, reservoirs, springs, and ground water) that provide water to public drinking-water supplies and private wells. Water sources can include: Surface water (for example, a lake, river, or reservoir) Ground water (for example, an aquifer.
- "Item" class contains "MedicalItem", "ReliefItem", "SupplyGood".
- "Medical equipment" class contains "Nebulizer". Medical equipment to be used on the field.

Regarding properties, those that affect this macro-area are the following:

- Property "has geolocation" links class "Animal", "Area burned", "Climate parameter", "Fire", "Incident", "Media item", "Monitored area", "Responder", "Response resource", "Sensor", "Vulnerable object" to class "Location".
- Property "has response resource" links class "Location" to class "Response resource".

5.1.5.7 Vulnerable Objects

The Vulnerable object-related macro-area of the SILVANUS ontology is meant to represent concepts and relationships related to vulnerable objects.

The Vulnerable object class can be considered the “entry point” of this area of the ontology. It includes in its subclasses different kinds of vulnerable objects with their own subtypes. Due to size constraints, its graphical representation in the deliverable has been split into top and bottom parts, shown in figures 49 and 50.

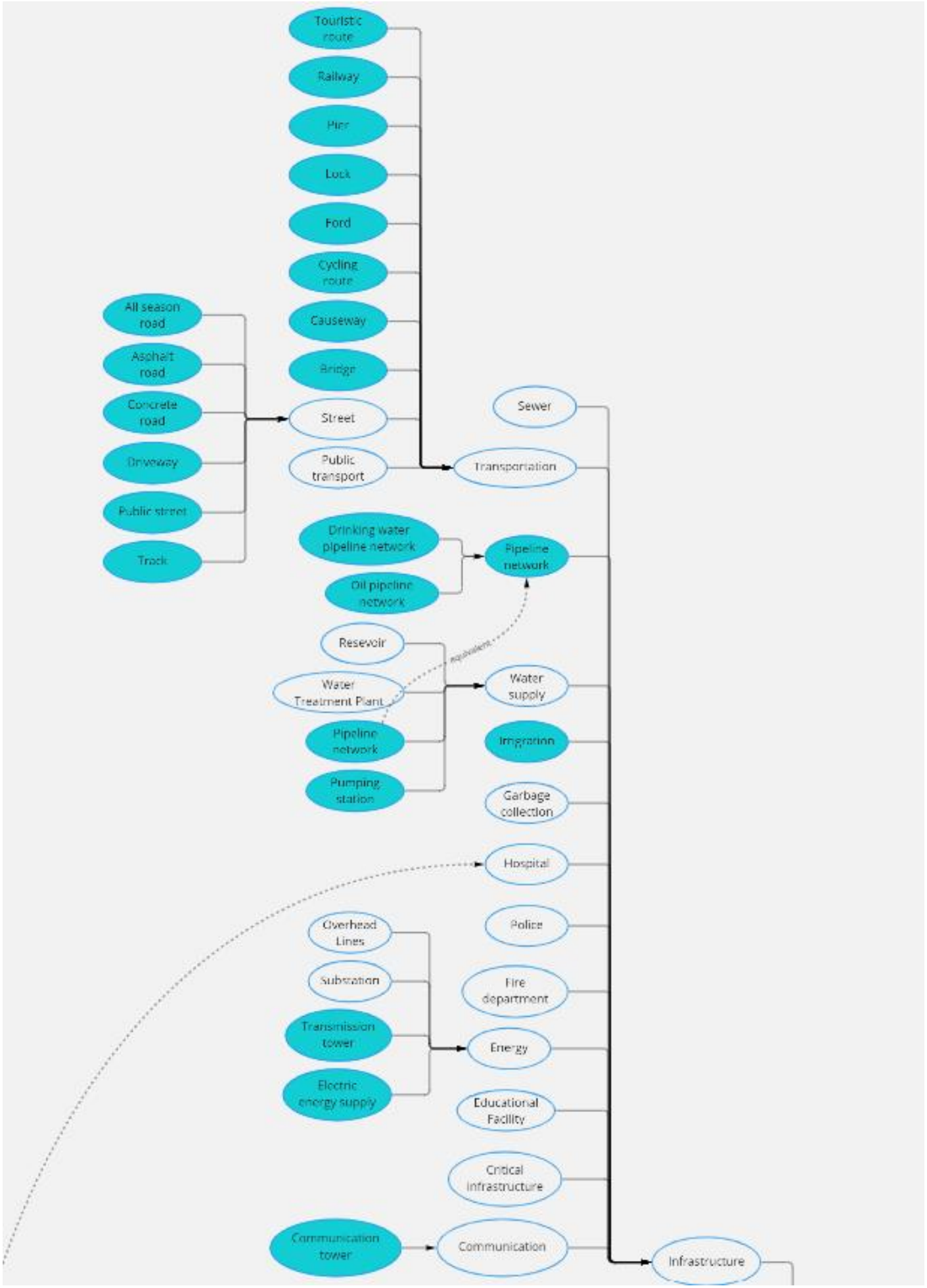

Touristic route
Railway
Pier
Lock
Ford
Cycling route
Causeway
Bridge
All season road
Asphalt road
Concrete road
Driveway
Public street
Track
Street
Public transport
Transportation
Sewer
Drinking water pipeline network
Oil pipeline network
Pipeline network
Reservoir
Water Treatment Plant
Pipeline network
Pumping station
equivalent
Water supply
Irrigation
Garbage collection
Hospital
Police
Overhead Lines
Substation
Transmission tower
Electric energy supply
Energy
Fire department
Educational Facility
Critical infrastructure
Communication tower
Communication
Infrastructure

Figure 50 ulnerable objects ontology macro-area top part

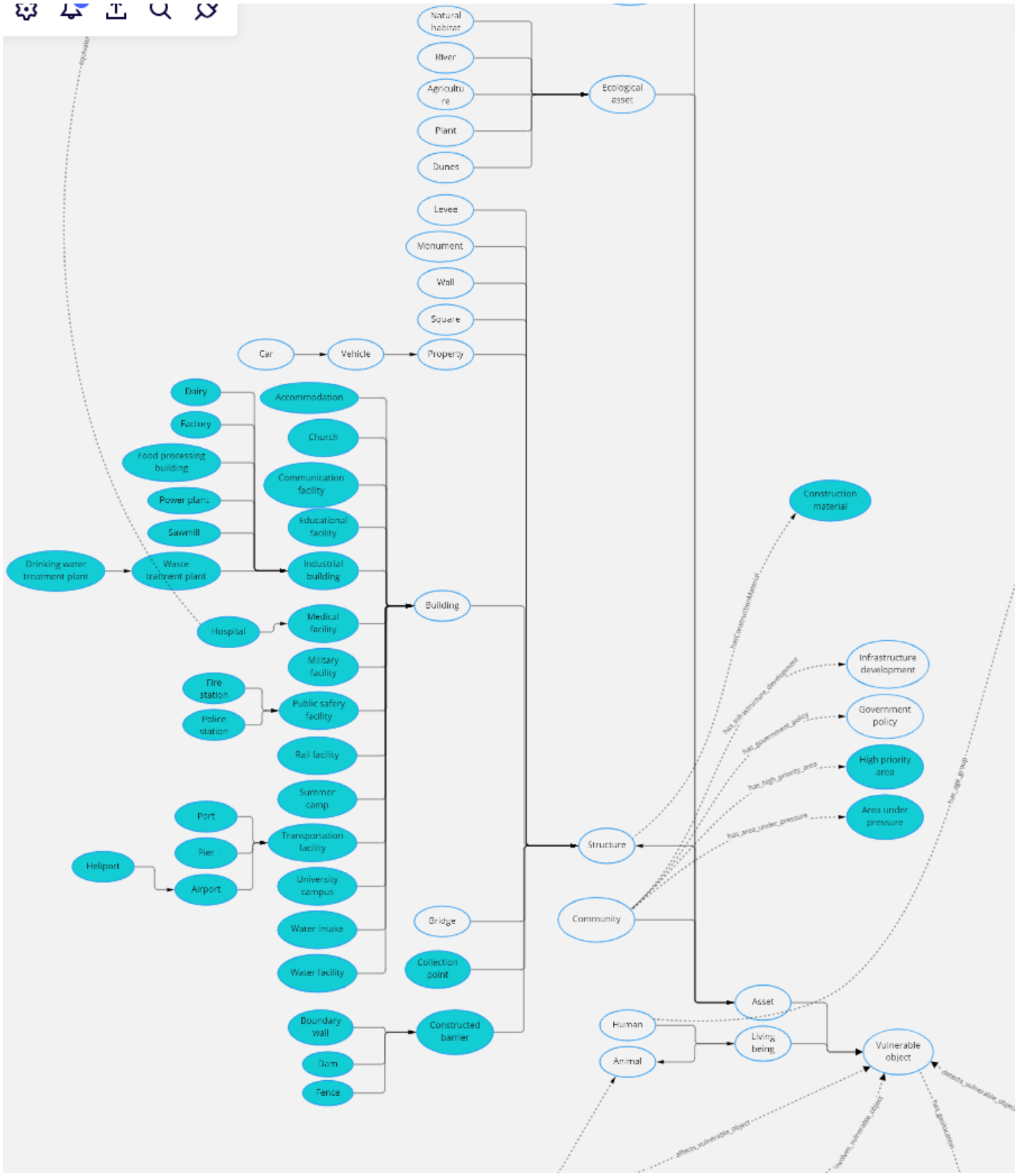


Figure 51 Vulnerable objects ontology macro-area bottom part

The main classes in this area are "Living being" and "Asset".

- "Living being" class contains "Human" and "Animal". Any living being that is in danger during a natural disaster.

- "Asset" class contains "Community", "Structure", "Ecological asset", "Infrastructure", "Property", “Wildland Urban Interface”. Any non-living item of interest.

Regarding properties, those that affect this macro-area are the following:

- Property "affects vulnerable object" links class "Impact" to class "Vulnerable object".
- Property "detects vulnerable objects" links class "Detection" to class "Vulnerable object".
- Property "has geolocation" links class "Animal", "Area burned", "Climate parameter", "Fire", "Incident", "Media item", "Monitored area", "Responder", "Response resource", "Sensor", "Vulnerable object" to class "Location".
- Property "involves vulnerable object" links class "Incident" to class "Vulnerable object".

5.1.5.8 Climate

The Climate parameter-related macro-area of the SILVANUS ontology is meant to represent concepts and relationships related to climate parameters.

The Climate parameter class can be considered the “entry point” of this area of the ontology. It includes in its subclasses different kinds of climate parameter with their own subtypes. The following figure 51 is an ensemble view of the macro-area.

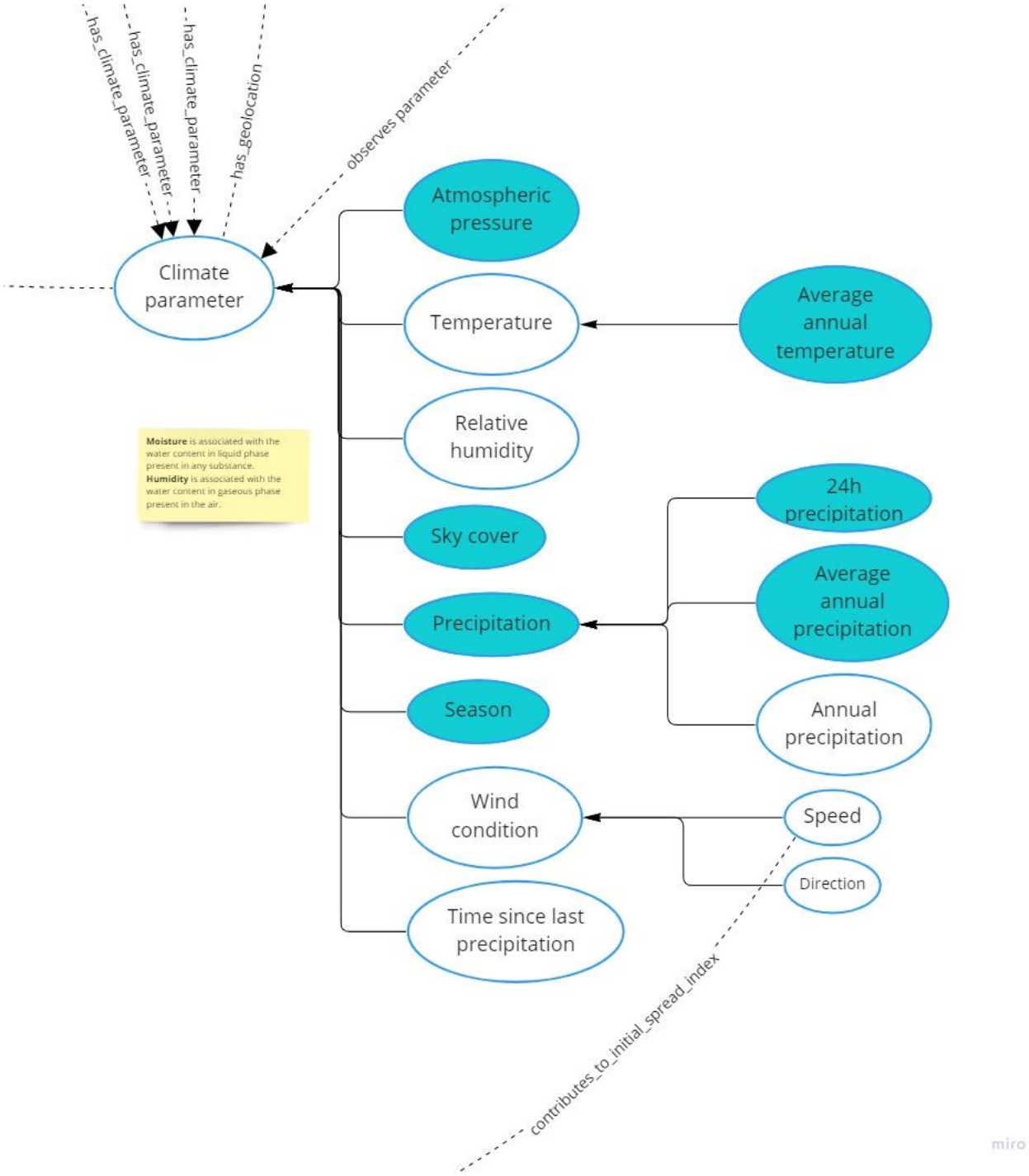


Figure 52 Climate ontology macro-area

The main classes in this area are "Precipitation", "Atmospheric pressure", "Temperature", "Humidity", "Season", "Sky Cover", "Time since last precipitation", "Wind condition", “Drought”.

- "Precipitation" class contains "Annual precipitation", "Average annual precipitation", "24h precipitation". Any product of the condensation of atmospheric water vapour that falls under gravity from clouds. The main forms of precipitation include drizzle, rain, sleet, snow, ice pellets, graupel and hail.
- "Temperature" class contains "Average annual temperature". Temperature in a given area at a given time.

- "Wind condition" class contains "Wind speed", "Wind direction", "Average wind speed", "Average, wind direction", “Beaufort wind sale”. The perceptible natural movement of the air, especially in the form of a current of air blowing from a particular direction.
- "Humidity" class contains “Absolute humidity”, “Relative humidity”.

Regarding properties, those that affect this macro-area are the following:

- Property "affects fire characteristic" links class "Climate parameter" to class "Fire characteristic".
- Property "has climate parameter" links class "Area burned", "Incident", "Monitored area" to class "Climate parameter".
- Property "has geolocation" links class "Animal", "Area burned", "Climate parameter", "Fire", "Incident", "Media item", "Monitored area", "Responder", "Response resource", "Sensor", "Vulnerable object" to class "Location".
- Property "observes parameter" links class "Sensor" to class "Climate parameter".

5.1.5.9 Monitored Area

The Monitored area-related area of the SILVANUS ontology is meant to represent concepts and relationships related to Monitored area. The following figure 52 is an ensemble view of the area.

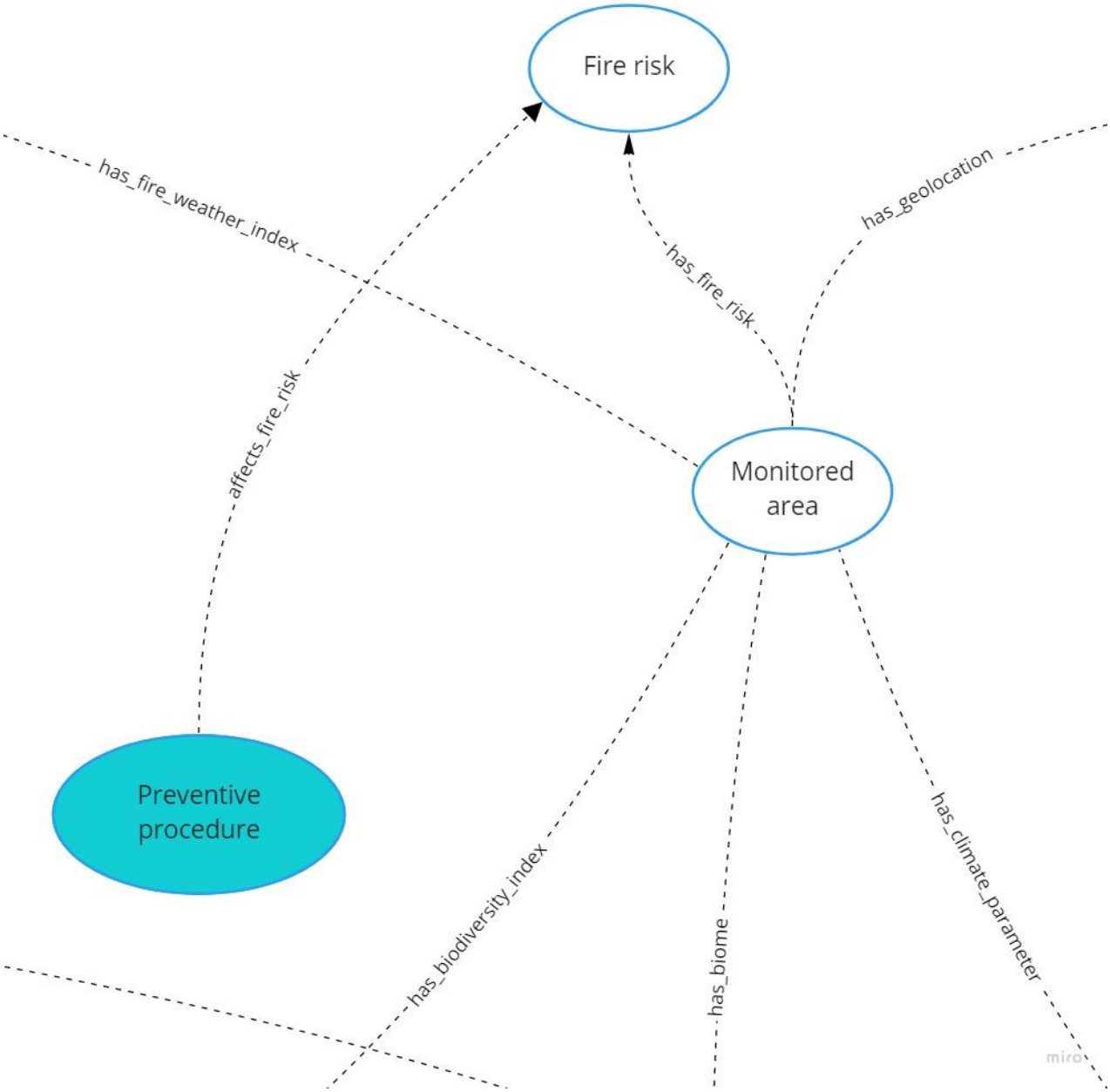


Figure 53 Monitored area ontology macro-area

The main class in this area is "Area burned" and “Fire Hazardous Area”.
Regarding properties, those that affect this macro-area are the following:

- Property "has biodiversity index" links class "Area burned", "Monitored area", "Vegetated area" to class "Biodiversity index".
- Property "has biome" links class "Area burned", "Location", "Monitored area" to class "Biome".
- Property "has climate parameter" links class "Area burned", "Incident", "Monitored area" to class "Climate parameter".
- Property "has fire regime condition class" links class "Monitored area" to class "Fire regime condition class".
- Property "has fire risk" links class "Monitored area" to class "Fire risk".
- Property "has fire weather index" links class "Monitored area" to class "Fire weather index".

- Property "has geolocation" links class "Animal", "Area burned", "Climate parameter", "Fire", "Incident", "Media item", "Monitored area", "Responder", "Response resource", "Sensor", "Vulnerable object" to class "Location".

5.2 Metadata index

5.2.1 SILVANUS Big-Data Framework

In this section we outline the Metadata Index component of the SILVANUS Big-data Framework, specifically the ontology that will serve to catalogue and provide an expressive search interface to SILVANUS data objects. Combined with the SILVANUS KB Semantic Model, these components will work in synchronise promoting an expansive, semantically linked view of the forest, from high level concepts and observations to the data objects and lineage that provide these insights.
To provide the context in which the Metadata Index will function as well as requirements, we first introduce the SILVANUS Big-data Framework (BDF) component. The BDF is responsible for the storage and analysis of heterogeneous data ingested from various sources throughout the SILVANUS platform. The goal of this Framework to provide inferences via deployed machine learnings models, e.g. fire spread and fire danger indices. Each model deployed will require varying input datasets, dependant on different requirements such as spatial & temporal attributes or device and ingestion mechanism features. It is the objective of the Metadata Index to provide an expressive search mechanism / catalog over these data objects ingested and that are accessible to the ML models deployed within SILVANUS.
Key features that will define the Metadata Index semantic model:

- Geospatial and temporal description
- Cross-referencing (External KB, Event link)
- Extensible model
- Internal & External data object references
- Access policies

5.2.2 Component Overview

The main purpose of the Metadata Index is to serve as a searchable catalog of data objects held both internally within the SILVANUS Big-data Framework storage solution, as well as references to data objects contained within external repositories (e.g. Earth Observation datasets). Through an expressive semantic model we aim to provide rich search / query functionality (e.g. return object(s) by geospatial coordinates + event + time). A key objective of this component includes the integration with the SILVANUS Knowledge Base model allowing for cross-referenceable events, objects etc., further promoting an expansive search mechanism. The Metadata Index semantic model will also support us in implementing data lifecycle management and data privacy/access control via object linked policy information, for use specifically within the Big-data Framework.
The Metadata Index is a sub-component of the Storage Abstraction Layer and is responsible for cataloguing all data objects cached in the SILVANUS object store, as well as certain external datasets available from third-party data hubs such a Copernicus. Via APIs exposed by the Storage Abstraction Layer SILVANUS services can search the Metadata Index for data objects they require to perform their analysis or display the previous results to end users. In addition, the Metadata Index manages the access control and lifecycle of all objects in the object store, such deleting objects that have passed the expiration data or issuing event messages when an object has been manipulated.
Unlike many conventional catalogues or metadata indexes, which use based on relational databases, the SILVANUS Metadata Index is implemented as an RDF semantic graph, similar to the SILVANUS Knowledge Base. Whereas the domain of interest for the Knowledge Base is forests

and wildfires, the domain of interest for the Metadata Index is the structured and unstructured data objects used by services in the SILVANUS system. So, to maintain a separation of concerns the Knowledge Base and Metadata Index are stored in separate semantic graphs; however, as they are based on the same technology that supports SPARQL queries, a single SPARQL query can run across both semantic graphs. The Metadata Index will be implemented using the opensource Jena application encapsulated as a service, however it is fully encapsulated by the Storage Abstraction Layer and only exposed by APIs in the Storage Abstraction Layer. As with the Knowledge Base, and RDF semantic graph is used because it can model the domain data in a more flexible and expressive way. For example, new attributes, classes and relationships can be added dynamically without having to generate a new data access schema; in fact, RDF can support multiple data access schemas at the same time.

In addition to the cached data objects and the external data object references, the Metadata Index also models specific domain concepts that are utilized by the queries, such as a geospatial bounding box around each SILVANUS pilot site. As most data objects will have a geospatial context, it is possible to ascertain if a specific object is contained or intersects with a pilot site. This information is used in pre-processing the data, such as cropping the data to the pilot's bounding box or determining into which S3 bucket an object will be placed; if a data object has no geospatial context, it is placed in the General S3 bucket.

The types of metadata stored in the Metadata Index is quite diverse and may include information about an object's a) content and format; b) provenance or remote reference; c) geospatial and temporal context; d) access rights and lifecycle; e) relationship to other objects; and f) attributes and annotations specific to the object and its source. For example, a UGV might capture an image of a fire in the forest. The location of the UGV and time the image was taken defines its geospatial and temporal context, but additionally, the compass direction of the camera and its depth of view provide supplementary information that can help contextualise where the fire is. The core entity of the Metadata Index is the data object, which has a globally unique identifier (GUID/UUID), generated by the Storage Abstraction Layer. Table 44 Metadata Index initial datapoint requirements contains the initial set of metadata types associated to the data object under the classifications listed above. Additional fields and relationships may be added in the future as required.

5.2.3 Data Sources

In this section we detail each of the required data sources, formats and key metadata features for use within the SILVANUS platform, this analysis presents some unique characteristics and drives the investigation and decisions made for the Metadata Index ontology.

5.2.3.1 Earth Observation

Earth observation datasets are one of the more varied data sources that will be leveraged within the SILVANUS Big data/analytic solution, these datasets vary in size, format and metadata specification. Due to these data characteristics, we will detail each input dataset individually, and formalize the datasets providing based on the following attributes:

1. *Data source*
2. *Data format*
3. *Ingestion Frequency*
4. *Description*

These attributes are important considerations to how the Metadata Index model is constructed to appropriately accommodate an expressive, semantically linked model for the cataloguing of earth observation datasets. This model should also accommodate the description and indexing of datasets which are not currently stored within the SILVANUS Storage solution, this promotes a resource efficient method of retrieving datasets on-demand where possible. Data provenance / lineage is also

a key modelling attribute related to the Earth Observation Product lifecycle within SILVANUS, which will describe the intermediary processing and relation to raw data assets while the dataset is present within the SILVANUS Big-data framework.

Sentinel Products

Data Source: Copernicus Open API Hub

Data Format: Compressed .SAFE – Image .JPG – Metadata .XML/JSON

Ingestion Frequency: Dynamic

Description: This is a dynamic category of products offered through the ESA's Copernicus Satellite missions. This product can be viewed as a 'top-level' view of Sentinel services, specific datasets in this category can vary depending on the processing requirement. Different types of data can be retrieved, from specific image frequency bands, terrain and height maps to weather and climate related data. Product metadata retrieved in JSON format via a REST API request containing Product ID. This retrieved metadata contains a range of useful indexing variables, of note are spatial footprints / bounding box coordinate values, temporal and sensor values.

Digital Elevation Model

Data Source: Copernicus Land Services

Data Format: Compressed .ZIP – Image .TIFF – Metadata .XML

Ingestion Frequency: Static

Description: This is a static dataset provided by Copernicus land services, describing the height / elevation for a region within Europe. Products split into tiles, which are 'sections' of land covered by the DEM. Each tile has a metadata descriptor attached, which describes the region / spatial context, as well as other relevant indexing datapoints.

Normalized Difference Vegetation Index

Data Source: Copernicus Land Services

Data Format: Compressed .ZIP – Image .TIFF – Metadata .XML

Ingestion Frequency: Dynamic – weekly

Description: This product provides an indication of the "greenness" of a region, generally used for monitoring ecosystems. This product is computed via a simple formula to measure the spectral reflectance from near infrared and red wavebands from a base level product, generally publicly available datasets are derived from a sentinel-3 product.

Land Surface Temperature

Data Source: Copernicus Land Services

Data Format: Compressed .ZIP – NetCDF .nc

Ingestion Frequency: Dynamic – hourly

Description: This product gives an estimated surface and air temperature based on remote sensor readings from a number of geostationary satellites. These readings are subject to relatively rapid change based on several ground conditions, therefor this is one of the Products requiring higher dynamic ingestion frequencies.

Burnt Area

Data Source: Copernicus Land Services

Data Format: Compressed .ZIP – Image .TIFF – Metadata .XML

Ingestion Frequency: Dynamic – monthly

Description: This product provides burn scar/burn area indicators, areas which have been affected by wildfires and have seen a significant change in the vegetation cover. These computed products are derived from Sentinel-3 and PROBA-V Products.

Weather

Data Source: EUMETSAT (via CMCC system)

Data Format: Variable by Product / Processing Level (NetCDF, BUFR, PNG)

Ingestion Frequency: Dynamic

Description: This ingestion source covers a range of products offered by the EUMETSAT platform, these datasets provide access to a range of earth observation related datasets, including climate,

weather, atmosphere and ocean products. Specifically relevant to the Metadata Index we will catalogue weather & climate data, some of which may undergo some pre-processing within a partner deployed weather cataloguing and analytics platform.

5.2.3.2 In-situ Devices

For the in-situ data collection devices, we consider two distinct ingestion modes which influence the base Metadata Index model.

IoT Environmental Sensors

These devices collect environmental data such as temperature and gas readings, these datasets are relevantly lightweight data sources. Contextual metadata (e.g., spatial, temporal data from the sensor) will also be provided and ingested through the Storage Abstraction Layer. The Metadata Index model is responsible for providing a semantically link via metadata related to this device for indexing and later retrieval. For consideration in relation to the metadata index

IoT Camera Sensors

Camera sensors data source formats and ingestion frequency will likely differ from the Storage Abstraction Layer and ingestion perspective, in terms of frequency of ingestion (I.e. event or stream based ingestion), another feature will be the data format, whereby data can be ingested as single images, a collection of images and finally a video file. With respect to the Metadata Index semantic model, we only consider the cataloguing and object series link requirements to data objects produced by these devices. In this case we only need to consider the key modelling attributes such as the spatial, temporal, object link and other key features that may be indexed for later retrieval.

5.2.3.3 Weather & Climate

Weather and Climate datasets for use within the SILVANUS Big-data framework are another key source of input for some deployed ML models. These datasets vary widely in temporal resolution and datapoints produced, based on location and availability of sensors. Generally, datasets in this source category are formatted in NetCDF, HDF and GRIB. These are self-contained, portable files which also describe contextual metadata such as source location, date/time and a range of weather sensor readings. Weather and Climate based datasets produced at round weather stations will serve as an auxiliary input into the SILAVNUS Big-data framework, with EUMETSTAT Products primarily providing coverage for most required datapoints and regions.

5.2.3.4 Arial & Ground

This category of data source encompasses ingestion and description of data from drones and ground robots deployed to some pilot sites. Datasets catalogued from this source will fall into a similar descriptive category to those described above. Specific data sources from the sensor devices deployed to these platforms include environmental data collected through sensors and visual data collected from cameras. It is therefore envisaged that within the semantic model, minimal additional features are needed. One key point for this category is the focus on a spatial-temporal linked data series, allowing for the description and indexing of a datapoint based on a mission. This allows for datapoints collected via to a specific drone flight or robot deployment are semantically linked, and there for the data produced can be indexed and later retrieved.

An important aspect for consideration with respect to the above input data sources, is the level of granularity provided within the Metadata Index semantic model. This governs how expansive the indexing / search process will be, e.g. will the model accommodate specific dataset values (temperature), approximations (avg. temperature) or only a high level view of data objects linked by spatial and temporal properties. This aspect will be detailed in the next section.

5.2.4 Indexing Requirements & Terms

In this section we detail an initial draft of the metadata key points produced from an analysis of each data source category. We will use this as a set of baseline features that will be targeted within the Metadata Index semantic model. The below table 44 formalizes this vocabulary analysis into four points:

- **Classification**: Category of the metadata term
- **Name**: Metadata term or concept
- **Mandatory or Optional:** Distinguishes required datapoints
- **Description:** A term summary

Table 44 Metadata Index initial datapoint requirements

Classification	Name	Mandatory or Optional	Description
Content and format			
	Object class	M	The type of the object, e.g. SAFE file, Tiff file, JPEG Image, etc. The values of the class are the enumerated classification of the types of data objects supported by the SILVANUS system, defined by a terminological ontology. Each type of data objects will have a defined set of metadata attributes that are relevant to it.
	Format	M	
	CRC	O	The Cyclic Redundancy Check of the data object.
Provenance or remote reference			
	Origin	O	The URL of the original data object ingested into the SILVANUS system.
	Original ID	O	ID of the original object. UUIDs from original object IDs should not be used as the SILVANUS object UUID.
	Origin Certificate	O	Certificate details of source, if available
	Creation Date	O	Date data object was ingested or created into SILVANUS system.
	Service	O	The SILVANUS service that generated the results (internally generated data object)
	Derived from	O	Where the data object was internally generated, a set of data objects it was computed from.
Geospatial and temporal context			
	Geospatial context	O	The geospatial context of the data object, e.g. a point or bounding box. Polygons and multi-polygons should be avoided unless absolutely necessary, as they greatly increase the complexity of intersection queries.

	Temporal context	O	The temporal context of the data object. This will typically be a date and time, but in certain cases could be a date range.
	Geospatial resolution	O	Many data objects are formatted as a 2D matrix over a geospatial area, where each cell maps to a square of a given size on the ground in metres, e.g. 10m, 25m, 1000m.
Access rights and lifecycle			
	Access control	M	Fields should be defined by the W3C ODRL specification
	Expiration date	O	The date after which the data object should be deleted. This is useful when discarding ingested data objects, after a subset of the data has been extracted and stored as separate data object(s), e.g. cropped images from a SAFE file.
	Emit Event	O	Cause the Storage Abstraction Layer to emit an event based on a specific event type, e.g. emit event 2 days before data object deletion or emit event if metadata update.
Relationship to other objects			
	Part of dataset	O	This is a loose grouping of data objects that are all peer related to each other, e.g. a mosaic of overlapping images from a UAV flight path. It requires a dataset subject to be first created.
	Tag	O	A free format tag that is associated to the data object

5.2.5 Metadata Index Ontology

5.2.5.1 DCAT – Data Catalog Vocabulary

Data Catalog Vocabulary (DCAT) is an ontology that is prominent in the use case of representing metadata related to multiple datasets and data service providers, promoting interoperability and discoverability of data within a centralized metadata catalogue. Figure 52 shows an overview of DCAT model. This model provides three key attributes that are well suited to the use case of the Metadata Index supporting the implementation of an aggregated data catalogue of:

1. Aggregated data catalogue of data objects - With reference to an object access point within an external object store.
2. Description of a datasets metadata properties - Supporting geospatial and temporal referencing, tagging and semantically linked data series
3. Description of external data service providers – Expressive model for the description of service providers, including provider descriptions, access URLs and API parameters

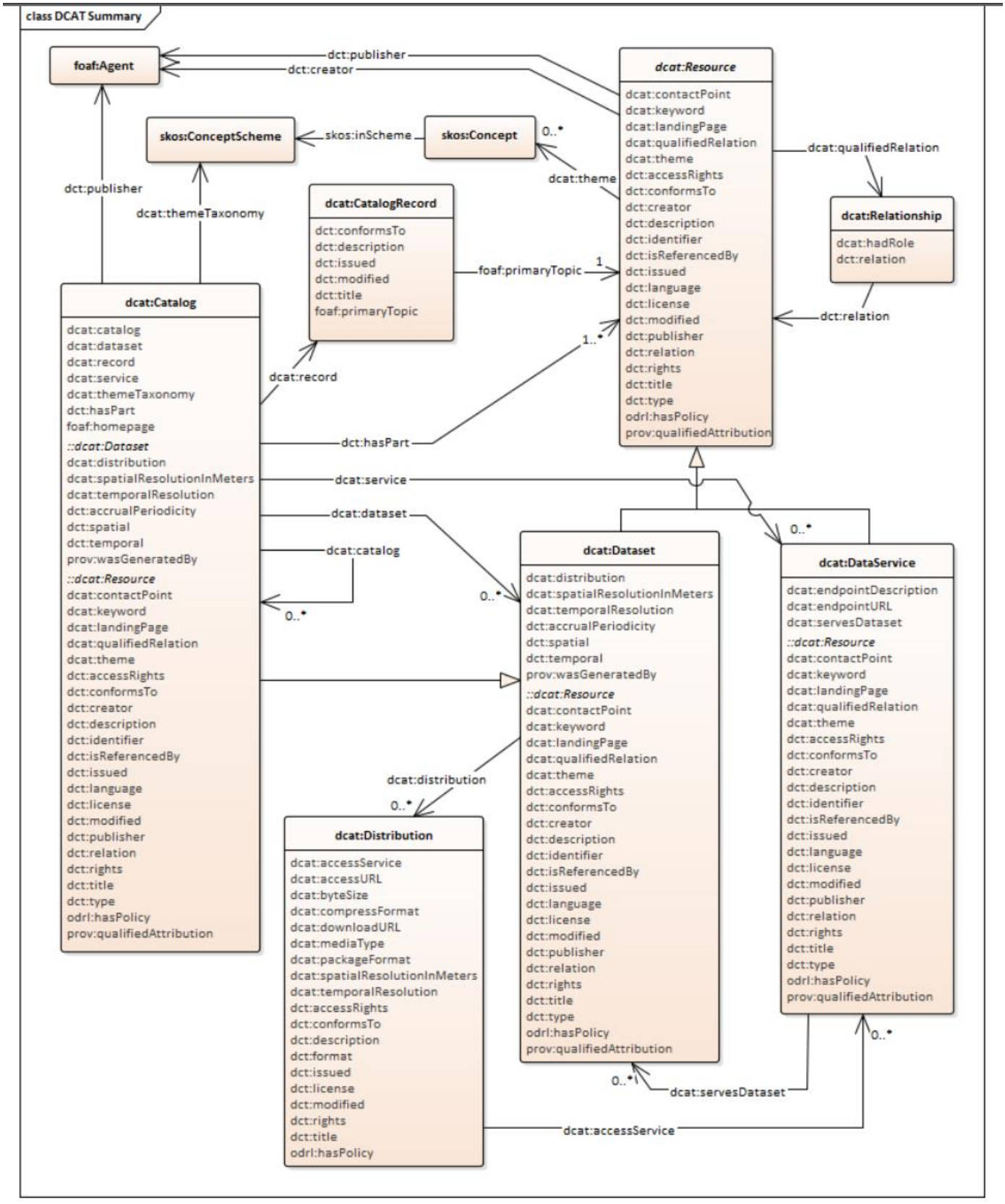


Figure 54 Overview of DCAT model, showing the classes of resources that can be members of a Catalog, and the relationships between them [30]

[30] "Data Catalog Vocabulary (DCAT) - version 2," W3C. [Online]. Available: https://www.w3.org/TR/vocab-dcat-2/. [Accessed: 29-Sep-2022].

The DCAT specification also defines the implementation and extension of the vocabulary with the use of key vocabularies for a more expressive and specialized catalogue of datasets. These vocabulary extensions are outlined in two specific categories, Normative vocabularies are included as part of the standard DCAT model, while Non-normative vocabularies are only provided as a guideline for more specialized use cases and modelling requirements. Of interest to the Metadata Index semantic model within these two categories are:

- *Normative: ODRL, OWL, DC PROV, RDF, RDFS, SKOS, TIME*
- *Non-normative: w3cgeo, earl, geosparql,*

The above vocabularies allow for an extensible model for a variety of features required in the Metadata Index semantic model. These normative vocabularies are widely used in a variety of model use cases and will be useful in further expanding the scope of DCAT where applicable. The following outlines the key vocabularies implemented within the DCAT ontology and their application to the Metadata Index key features of interest.

Content description:

DC/DCT – Many of the base properties within the DCAT vocabulary reference The Dublin Core Metadata Initiative (DCMI) ontology, a base vocabulary for describing resources. Dublin Core Terms is an extension of the DC vocabulary which further models the entity relationships between resources.

Data provenance & Lineage:

PROV-O – PROV-0 is an ontology implementation of the PROV Data Model, a model for the description of data movement including, data origin, data transformation / processes and related entities.

Policy & Access Control:

ODRL: Open Digital Rights Language is a vocabulary which models the access rights and usage of entities. In our use case specifically this will allow for the definition of rule based data object access control.

Temporal modelling

DCAT, DCT: DCAT Implements five properties for temporal data modelling, each varying on specific data model features. The most basic properties of temporal data describe the date of creation (dcterms:issued), date of modification (dcterms:modified) and update frequency (dcterms:accrualPeriodicity). We may also model the temporal separation (dcat:temporalResolution) as well as the temporal range (dcterms:temporal) of a dataset. Table 45 shows a code sample of temporal data modelling.

Temporal Range RDF

Table 45 Code Sample: DCAT Temporal Range[31]

```
dcterms:temporal [ a dcterms:PeriodOfTime , time:ProperInterval ;
    time:hasBeginning [ a time:Instant ;
      time:inXSDDate "2016-03-04"^^xsd:date ;
    ] ;
    time:hasEnd [ a time:Instant ;
      time:inXSDDate "2018-08-05"^^xsd:date ;
    ] ;
```

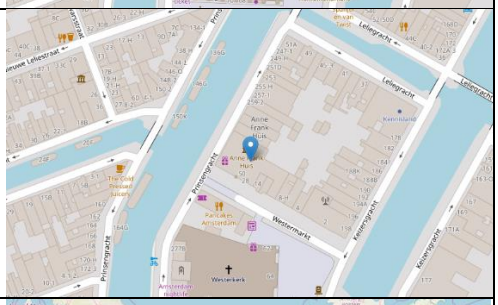
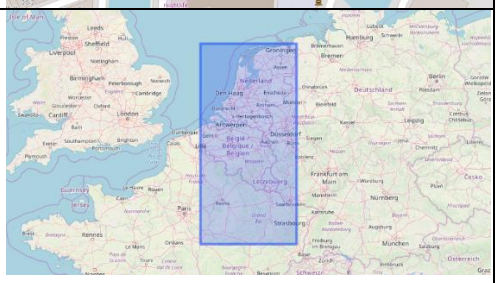
[31] "Data Catalog Vocabulary (DCAT) - version 3," W3C. [Online]. Available: https://www.w3.org/TR/vocab-dcat-3/#temporal-properties. [Accessed: 29-Sep-2022].

```
                    ] .
```

Geospatial modelling

DCAT, DCT, locn: DCAT defines top level Location class based on a the Dublin Core dcterm:location. The vocabulary and format for description of geospatial data within DCAT conforms the Spatial Data on the Web Best Practices and in particular the GeoSPARQL Specification. GeoSPARQL provides a standardizes representation of geospatial data within RDF as well as querying best practices. One key attribute to for consideration in GeoSPARQL and geospatial data modelling is the Coordinate Reference System (CRS) definition. CRSs are used to flatten/project 3D point data onto a 2D grid representation. It is important for required data points within a single related domain refer to the same CRS, this ensures that all modelled points are accurately located. Within the Metadata Index this allows for all modelled points to refer to the same base coordinate system, many of these systems currently exist and are widely in mapping applications (e.g. EPSG. Implemented within DCAT are three distinct properties for the representation of geospatial data in relation to a dataset). Table 46 shows a code sample of geospatial data modelling.

Table 46 Code Sample: DCAT Geospatial data[32]

Geometry	*locn:geometry* *"""<http://www.opengis.net/def/crs/EPSG/0/28992> POLYGON ((* *120749.725 487589.422 ,* *120752.55 487594.375 ,* *<<…>>* *120749.725 487589.422* *))"""^^geosparql:wktLiteral ;* *] .*	
Centroid	<AnneFrank_2> a dcat:Dataset ; dcterms:spatial [a dcterms:Location ; dcat:centroid "POINT(4.88412 52.37509)"^^geosparql:wktLiteral ;] .	
Bounding Box	dcterms:spatial [a dcterms:Location ; dcat:bbox """POLYGON((3.053 47.975 , 7.24 47.975 , 7.24 53.504 , 3.053 53.504 , 3.053 47.975))"""^^geosparql:wktLiteral ;] .	

5.2.5.2 SSN - Semantic Sensor Network Ontology

The Semantic Sensor Network ontology further extends the modelling capabilities offered within the Metadata Index, this modular ontology aims to provide an expressive model to represent sensor data at a series of defined granularity levels. This model defines a series cross-referenceable / linked

[32] "Data Catalog Vocabulary (DCAT) - version 3," W3C. [Online]. Available: https://www.w3.org/TR/vocab-dcat-3/#spatial-properties. [Accessed: 29-Sep-2022].

description levels, from low level sensor observations and features to systems and deployment platforms.
If necessary, the level of granularity provided by the SSN ontology will further expand the scope of the Metadata Index, allowing for a much greater range of datapoints by which a data object may be retrieved. These expanded modelling classes could prove extremely beneficial to the description of data sources such as Arial and Ground observations as well as Earth Observation datasets, by classifying specific sensor models and capabilities to platforms and robotic deployments. Figure 53 and 54 provide an overview of the Semantic Sensor Network ontology modules, classes and properties.

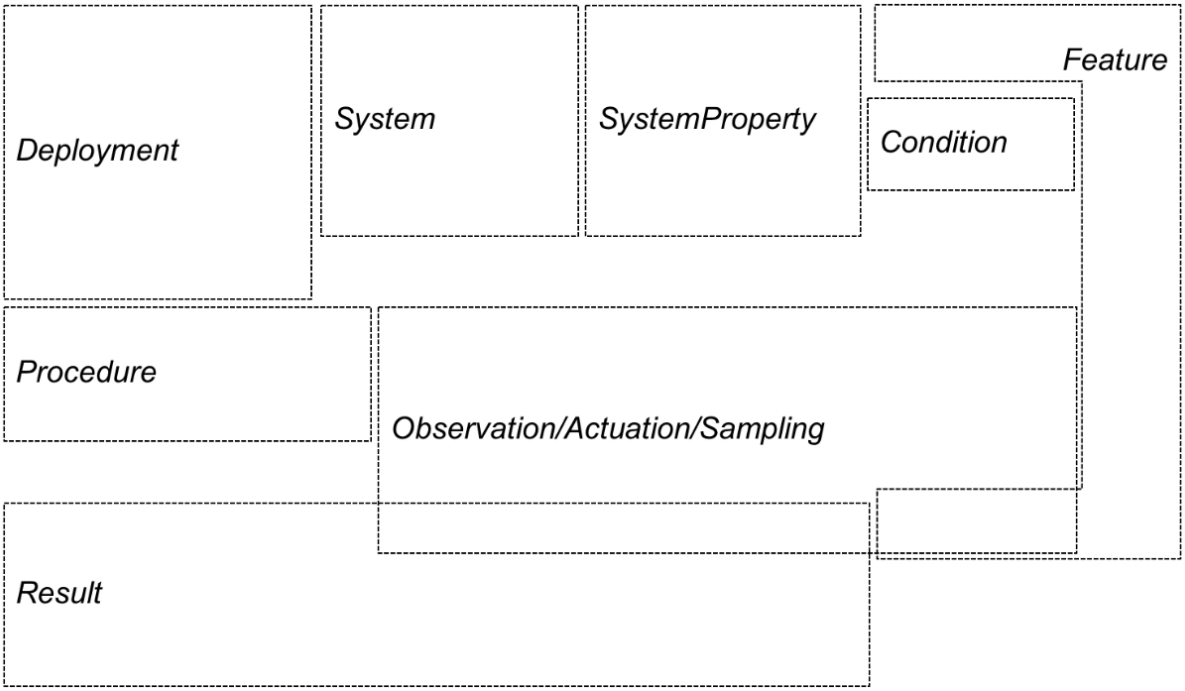


Figure 55 Overview of the SSN ontology modules[33]

[33] "Semantic Sensor Network Ontology," W3C. [Online]. Available: https://www.w3.org/TR/vocab-ssn/. [Accessed: 29-Sep-2022].

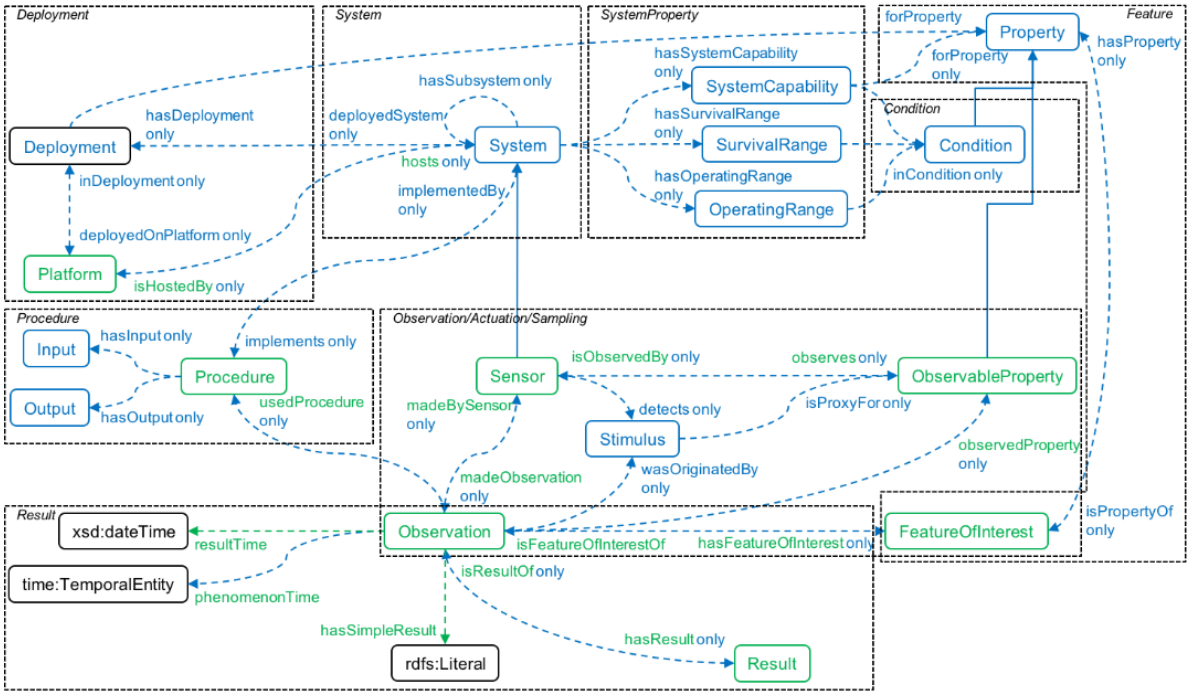


Figure 56 Overview of the SSN classes and properties

The below table 47 summarizes the initial version Metadata Index ontology requirements mapped to classes and properties provided in the above vocabularies

Table 47 Metadata Index vocabulary analysis

Classification	Name	Mandatory or Optional	Class/Property
Content and format			
	Object class	M	dct:Type
	Format	M	dct:conformsTo, :mediaType, :packageFormat
	CRC	O	dct:checksum
Provenance or remote reference			
	Origin	O	Prov:hadPrimarySource
	Original ID	O	
	Origin Certificate	O	
	Creation Date	O	prov:generatedAtTime
	Service	O	dcat:DataService
	Derived from	O	prov:wasDerivedFrom
Geospatial and temporal context			
	Geospatial context	O	dcterms:location, dcterms:spatial
	Temporal context	O	dcat:temporalResolution, dcterms:temporal, dcterms:peroidOfTime

	Geospatial resolution	O	dcat:spatialResolution
Access rights and lifecycle			
	Access control	M	ODRL:Policy
	Expiration data	O	
	Emit Event	O	
Relationship to other objects			
	Part of dataset	O	dcat:DatasetSeries, dcat:inSeries, dcat:next, dcat:prev, dcat:first, dcat:last
	Tag	O	dcat:theme, foaf:primiaryTopic, dcterms:type

5.2.6 Interoperability - SILVANUS Semantic Model

This section outlines the integration and interoperability designed to provide expanded query potential between both the Metadata Index and Knowledge base semantic models. The objective of this model integration is primarily to enhance the complimentary aspects, between the Knowledge Base model which represents the forest characteristics combined with the Metadata Index, which describes and indexes the data objects contained within the forest.
A key feature gained through semantically linking these two distinct data model ontologies is the ability to provide a link between forest model facts contained within the Knowledge Base with data object metadata and data access information. As an example of the functionality semantic linking between KB facts and data objects is the ability to link a fire detection event within the Knowledge Base to a) all related data objects for a specified geospatial region, b) a data object attributed to a fire detection event.

In order to facilitate the above objective, through an analysis of semantic models to determine an appropriate cross-referencing mechanism, we have outlined preliminary class definition within the context of the Knowledge Base Sensor ontology. This class, Metadata Index Reference (MDI_REF) is related to the Dataset class within the Sensor ontology, each Dataset will have the ability to additionally accommodate a semantic link between the Knowledge Base and Metadata Index through this 'MDI_REF' relationship. This class relationship will provide a link to the Metadata Index, the semantic link to the Metadata Index is implemented via a universally unique identifier (UUID) described by the MDI_REF. This UUID refers to each individual data object entity within the Metadata Index ontology. Figure 55 shows an initial design for the KB and MDI model integration.

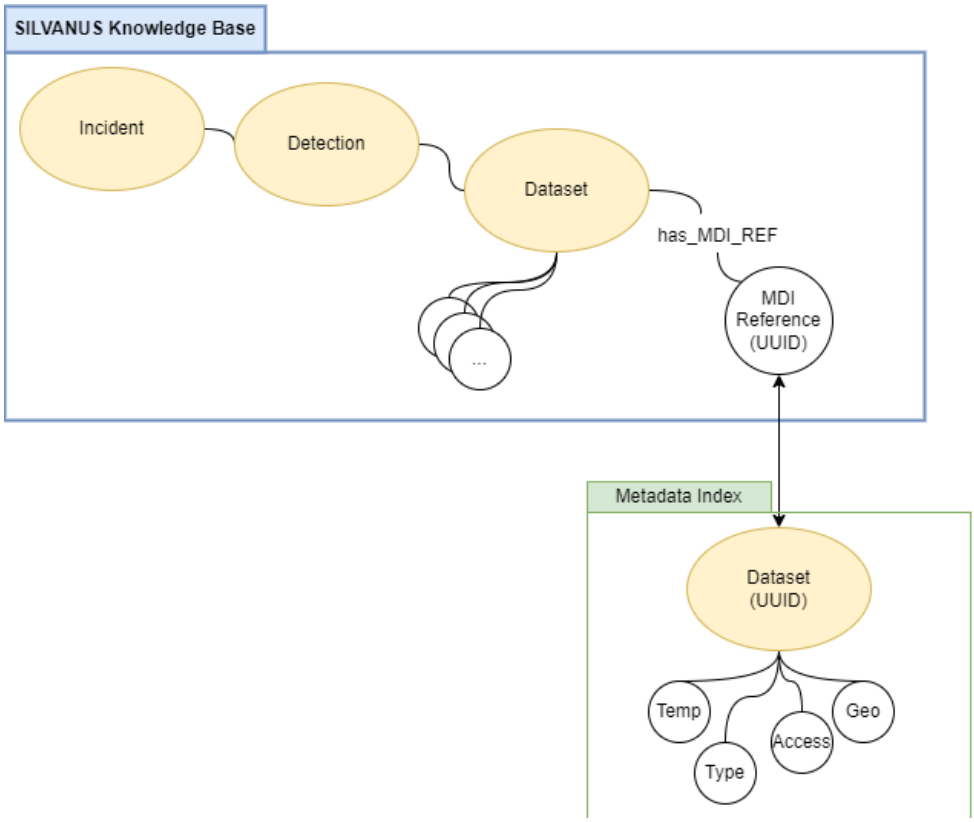


Figure 57 Initial design for KB & MDI model integration

In a future technical deployment of these both models, we will leverage the properties of semantic knowledge representation and query language support to execute queries across both model implementations. Providing this link between two semantic models will enable enhanced, extensive query capabilities within the future technical implementation of these models

6 Conclusion

Deliverable 3.1 represents the outcome of the SILVANUS ontology design effort, which was the result of a critical analysis of both existing technologies and a bottom-up listening methodology that allowed for the identification of SILVANUS-specific ontology classes.
At the time of submission of Deliverable 3.1, an initial version of the SILVANUS ontology has been designed, with the aim of collecting all concepts relevant to the SILVANUS project and uniquely describing their meaning (semantics) and the relationships between these concepts.
The paper walks through the various stages of the process that led to the design of the ontology. A first phase involved the collection and objective description of all the material reported in literature in terms of ontologies and taxonomies related to the topic of forest fires. This was followed by the collection of relevant information extracted from the analysis of internal project material, pilot descriptions, and deliverables written by partners in the early stages of the project.
In the second phase of the deliverable, all the material described in the previous point is analyzed for the purposes of the SILVANUS project, is categorized according to a methodology described in detail, and choices are made according to widely described criteria with the aim of harmonizing the collected knowledge.
Finally, we detail the Metadata Index ontology with reference to the model interoperability and integration design carried out between the SILVANUS Knowledge Base and Metadata Index semantic models. This work aims to support the semantic capabilities offered by the SILVANUS platform, through the offering of a fact-based model representation of the forest environment supported by a semantic link to the data objects that underpin these observations.
The resulting ontology is described so that it can be a reference for all project partners. Everyone will be able to consult the ontology in the way that suits them best. Just to simplify the consultation of the ontology, three different representations have been proposed:

- a graphical representation for non-expert users, which allows quick visualization of concepts and relationships
- a tabular representation for users who are interested in details
- an automatic representation provided by the ontology representation tool most widely used by ontology representation experts, Protégé.

It should be noted that to enable semantic interoperability, all SILVANUS project partners will need to consult and adhere to the proposed ontology by appropriately using the concepts and relationships it contains, both during the design and development phases of the tools and models created during the project. The risk is that semantic references may be lost, and knowledge disharmonized.
This ontology will be made public for the European union by the end of the project. Meanwhile, the latest version can be downloaded on the Silvanus website resources section.
As the SILVANUS project and its products evolve in the months to come, the SILVANUS ontology will evolve naturally along them. It will be updated, tweaked, and enhanced up until the end of Task 3.1 in 2024 both concepts-wise and relations-wise, most notably following the near-future collaboration with Catalink for Task 5.2 – Semantic fusion, as well as following adaptations and adjustments as required by project partners.

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8 Appendix A – Ontology tabular representation

The followind tables list the ontology classes and properties in a tabular format. They offer greater detail regarding classes and properties of the SILVANUS ontology, reporting a description of each elements, parents and children of classes and the source from which they were reused (if any).

Classes

Table 48 Tabular ontology classes representation

Class name	Climate_parameter
Class description	Parameters based on the Canadian Fire Weather Index System https://www.nwcg.gov/publications/pms437/cffdrs/fire-weather-index-system
Class parents	Thing
Subclasses	Wind_condition, Precipitation, Atmospheric_pressure, Temperature, Humidity, Relative_humidity, Season, Sky_Cover, Time_since_last_precipitation
Sources	http://www.semanticweb.org/smarotta/ontologies/2022/4/silvanusOntology#ClimateParameter
Class name	Fire_characteristic
Class description	Represents parameters used to describe the characteristics or behavior of a fire event.
Class parents	Thing
Subclasses	Area_burned, Active_fronts_number, Extreme_fire_behavior, Fire_Frequency, Fire_access_path, Fire_critical_point, Fire_distance, Fire_intensity, Fire_prediction, Fire_severity, Fire_spread_rate, Fire_spread_direction, Flame_ground_temperature, Flame_height, Rreaction_intensity, Smoke_amount, Total_heat_release
Sources	http://cerrado.linkeddata.es/ecology/fire#FireCharacteristic
Class name	Preventive_procedure
Class description	Preventive interventions on the ground
Class parents	Thing
Subclasses	
Sources	Italian pilot
Class name	Fire_risk
Class description	"Map of fire hazard risk at the landscape and farm/local scale (resolution to be adapted to scale requirements). Relevant to identify priority areas for preventive biomass management (portugese fire hazard risk reference - https://florestas.pt/sfirefightinga-mais/como-se-calcula-o-indice-de-risco-de-incendio-florestal/)"
Class parents	Thing
Subclasses	
Sources	Portuguese pilot, http://cerrado.linkeddata.es/ecology/fire#FireRisk
Class name	Impact

Class description	Injuries, damage to properties etc.
Class parents	Thing
Subclasses	
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Impact
Class name	Vulnerable_object
Class description	Any living being or object that needs to be protected from hazards.
Class parents	Thing
Subclasses	Living_being, Asset
Sources	http://www.semanticweb.org/earthquake#Loss, https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#VulnerableObject
Class name	Cause
Class description	Cause that started the fire
Class parents	Thing
Subclasses	Accident, Negligence, Deliberate, Natural, Rekindle, Unknown
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	Fire
Class description	It's the rapid oxidation of a material in the exothermic chemical process of combustion, releasing heat, light, and various reaction products.
Class parents	Thing
Subclasses	Crown_fire, Controlled_fire, Brush_fire, Uncontrolled_fire, Forest_fire, Ground_fire, Scrub_fire
Sources	http://cerrado.linkeddata.es/ecology/fire#Fire
Class name	Ignition_probability_factor
Class description	Represents the factors that together affect the likelihood of a certain are to burn or to start a fire event.
Class parents	Thing
Subclasses	
Sources	http://cerrado.linkeddata.es/ecology/fire#IgnitionProbabilityFactor
Class name	Incident
Class description	Any collateral incident that can be caused by a fire damaging infrastructures and that affects vulnerable objects
Class parents	Thing
Subclasses	
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Incident
Class name	Dataset

Class description	Represents the dataset produced by a silvanus module.
Class parents	Thing
Subclasses	
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Dataset
Class name	Detection
Class description	Represents detections in a dataset.
Class parents	Thing
Subclasses	
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Detection
Class name	Drought_fuel_moisture
Class description	The Drought Code (DC) is a numeric rating of the average moisture content of deep, compact organic layers. This code is a useful indicator of seasonal drought effects on forest fuels and the amount of smoldering in deep duff layers and large logs.
Class parents	Moisture
Subclasses	
Sources	https://cwfis.cfs.nrcan.gc.ca/background/summary/fwi
Class name	Duff_fuel_moisture
Class description	The moisture in the 2.8-inch-deep (7 cm) layer below the fine fuel layer, assumed to be a layer of loosely compacted organic material. The duff moisture code has a time lag of approximately 12 days. It is an indicator for the fire consumption of a moderate duff layer or medium-diameter woody debris. The duff moisture code is always positive, but has no maximum, and high values indicate drier litter and higher fire spread/danger than low values. The Duff Moisture Code (DMC) is a numeric rating of the average moisture content of loosely compacted organic layers of moderate depth. This code gives an indication of fuel consumption in moderate duff layers and medium-size woody material.
Class parents	Moisture
Subclasses	
Sources	https://cwfis.cfs.nrcan.gc.ca/background/summary/fwi, https://www.fs.fed.us/database/feis/glossary2.html
Class name	Buildup_index
Class description	The Buildup Index (BUI) is a numeric rating of the total amount of fuel available for combustion. It is based on the DMC and the DC. The BUI is generally less than twice the DMC value, and moisture in the DMC layer is expected to help prevent burning in material deeper down in the available fuel.
Class parents	Fire_weather_index
Subclasses	
Sources	https://cwfis.cfs.nrcan.gc.ca/background/summary/fwi

Class name	Initial_spread_index
Class description	The Initial Spread Index (ISI) is a numeric rating of the expected rate of fire spread. It is based on wind speed and FFMC. Like the rest of the FWI system components, ISI does not take fuel type into account. Actual spread rates vary between fuel types at the same ISI.
Class parents	Fire_weather_index
Subclasses	
Sources	https://cwfis.cfs.nrcan.gc.ca/background/summary/fwi
Class name	Fire_weather_index
Class description	The Fire Weather Index (FWI) is a numeric rating of fire intensity. It is based on the ISI and the BUI, and is used as a general index of fire danger throughout the forested areas of Canada.
Class parents	Thing
Subclasses	Buildup_index, Initial_spread_index
Sources	https://cwfis.cfs.nrcan.gc.ca/background/summary/fwi
Class name	Wind_speed
Class description	Wind speed
Class parents	Wind_condition
Subclasses	
Sources	https://cwfis.cfs.nrcan.gc.ca/background/summary/fwi
Class name	Human
Class description	Represents human beings in danger.
Class parents	Living_being
Subclasses	
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Human
Class name	Age_group
Class description	a number of people or things classed together as being of similar age.
Class parents	Thing
Subclasses	Adolescent, Adult, Child, Elder, Infant
Sources	https://w3id.org/empathi/Age_Group
Class name	Community
Class description	The people with common interests living in a particular area
Class parents	Asset
Subclasses	
Sources	Indonesian pilot
Class name	Area_under_pressure
Class description	Areas under pressure, meaning with negative impacts on biodiversity, due to human causes

Class parents	Thing
Subclasses	
Sources	
Class name	Mission
Class description	Represents a mission assigned to a rescue unit during a crisis.
Class parents	Thing
Subclasses	
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Mission
Class name	Responder
Class description	Represents a first responder unit.
Class parents	Response_resource
Subclasses	CommunicationLeader, Firefighting_unit, IncidentCommander, LogisticChief, MedicalPlanningLeader, MedicalStaff, OperationChief, Patrol, PlanningChief, PublicInfoOfficer, ResourceUnitLeader, SafetyOfficer, SupplyLeader, TaskForceSectorLeader
Sources	http://www.semanticweb.org/earthquake#FirstResponder, https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Responder
Class name	Area_burned
Class description	It's the total area affected by fire in a burn event.
Class parents	Fire_characteristic, Monitored_area
Subclasses	
Sources	http://cerrado.linkeddata.es/ecology/fire#AreaBurned
Class name	Monitored_area
Class description	Area that is being monitored because is potentially susceptible to wildfires
Class parents	Thing
Subclasses	Area_burned
Sources	
Class name	Vegetated_area
Class description	A vegetated area is a geographic feature which has ground cover dominated by plant communities.
Class parents	Thing
Subclasses	Area_Of_Cropland, Forest, Area_Of_Lichen-dominated_Vegetation, Area_Of_Moss-dominated_Vegetation, Area_Of_Sedge-_And_Forb-dominated_Herbaceous_Vegetation, Area_Of_Tundra, Area_Of_Woody_Wetland, Bush_Area, Flower_Strip, Grassland, Grassland_Area, Heath, Oasis, Savanna, Scrubland_Area, Shrubland, Wetland_Area, Wooded_shrubland, Woodland, Woodland_Area
Sources	http://purl.obolibrary.org/obo/ENVO_01001305

Class name	Biodiversity_index
Class description	Scientists use a formula called the biodiversity index to describe the amount of species diversity in a given area. A simple biodiversity index is calculated as follows: number of species in the area ÷ total number of individuals in the area = biodiversity index
Class parents	Thing
Subclasses	Biome, Fire_regime_condition_class, Fuel, Fuel_class, Fuel_continuity, Fuel_loading, Animal, Canopy_cover, Damage_quantification, Diametric_class, Dominant_formation, Evnironment_index, Erosion, Vegetation_type, Geology, Grazing_activity, Hydrography, Land_use, MeasureInUnities, Population_index, Species_richness, Thickness_of_Dead_Layer, Topography, Vegetation_growth, Vegetation_index, Vegetation_quantity, Vegetation_vertical_structure
Sources	
Class name	Location
Class description	Represents a location (point or area), indicated by latitude, longitude, and radius.
Class parents	Thing
Subclasses	
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Location
Class name	Biome
Class description	A biome is an ecosystem to which resident ecological communities have evolved adaptations.
Class parents	Biodiversity_index
Subclasses	Alpine_Biome, Terrestrial_Biome, Aquatic_Biome, Arid_Biome, Mediterranean_Biome, Montane_Biome, Ocean_Biome, Polar_Biome, Subalpine_Biome, Subpolar_Biome, Subtropical_Biome, Temperate_Biome, Tropical_Biome
Sources	http://purl.obolibrary.org/obo/ENVO_00000428
Class name	Structure
Class description	Represents various structures and buildings.
Class parents	Asset
Subclasses	Building, Constructed_barrier, Bridge, Collection_point, Leevee, Monument, Square, Wall
Sources	http://purl.obolibrary.org/obo/ENVO_00000070, https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Structure
Class name	Construction_material
Class description	Construction materials of a building
Class parents	Thing
Subclasses	

Sources	Portuguese pilot
Class name	Fire_regime_condition_class
Class description	A standardized, interagency index to measure the departure of current conditions from reference or historical conditions [74]. The fire regime condition classes are [9]:
Class parents	Biodiversity_index
Subclasses	FRCC1, FRCC2, FRCC3
Sources	https://www.fs.fed.us/database/feis/glossary2.html
Class name	Fuel
Class description	Fuel is comprised of living and dead vegetation that can be ignited. It is often classified as dead or alive and as natural fuels or those from logging operations. Fuel components refer to such items as downed dead woody material in various size classes, litter, duff, herbaceous vegetation, live foliage, etc. [20].
Class parents	Biodiversity_index
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html#fuel
Class name	Fuel_class
Class description	A set of fuels with similar traits. Fuels are categorized as herbaceous or woody and live or dead. Dead fuels are classed as 1-, 10-, 100-, or 1,000-hour timelag fuels, based on the time needed for fuel moisture to come into equilibrium with the environment [92]:
Class parents	Biodiversity_index
Subclasses	1-hour_timelag_fuels, 10-hour_timelag_fuels, 100-hour_timelag_fuels, 1000-hour_timelag_fuels
Sources	https://www.fs.fed.us/database/feis/glossary2.html#FuelClass
Class name	Fuel_continuity
Class description	A qualitative description of the distribution of fuels both horizontally and vertically. Continuous fuels readily support fire spread. The larger the fuel discontinuity, the greater the fire intensity required for fire spread [20].
Class parents	Biodiversity_index
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html#FuelContinuity
Class name	Fuel_loading
Class description	The weight per unit area of fuel, often expressed in tons/acre or tonnes/hectare. Dead woody fuel loadings are commonly described for small material in diameter classes of 0 to 1/4, 1/4 to 1, and 1 to 3 inches and for large material in one class greater than 3 inches [20].
Class parents	Biodiversity_index
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html#FuelLoading
Class name	Animal

Class description	List and map of wildlife known to be present in the area of interest
Class parents	Biodiversity_index, Living_being
Subclasses	
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Animal
Class name	Media_item
Class description	Represents a generic media item. Subclasses include specific types of media items.
Class parents	Thing
Subclasses	Audio_item, Image_item, Text_item, Video_item
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#MediaItem
Class name	Response_resource
Class description	Assets for fighting the fire
Class parents	Thing
Subclasses	Responder, Response_vehicle, Item, Response_procedure, CommunicationChannel, Firebreak, FoodAndShelter, Water_source, Medical_equipment, Power_line, RescueTeam
Sources	http://www.semanticweb.org/earthquake#Resources
Class name	Sensor
Class description	A Sensor is an instrument that observes a property or phenomenon with the goal of producing an estimate of the value of a parameter.
Class parents	Thing
Subclasses	IoT_sensor, Biodiversity_sensor, Camera, Chemical_sensor, Health_sensor, Satellite, Tourist_flow_sensor, Weather_station
Sources	http://www.semanticweb.org/earthquake#Instruments, http://www.w3.org/ns/sosa/Sensor, https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Sensor
Class name	Government_policy
Class description	Policy adopted by the local government
Class parents	Thing
Subclasses	
Sources	Indonesian pilot
Class name	High_priority_area
Class description	Area with high prority of intervention
Class parents	Thing
Subclasses	
Sources	Greek pilot

Class name	Infrastructure_development
Class description	
Class parents	Thing
Subclasses	
Sources	Development of infrastructures in a community, Indonesian pilot
Class name	Living_being_stat
Class description	Statistics related to living beings
Class parents	Thing
Subclasses	Density, Dominant_species, Mortality_rate, Population
Sources	Indonesian pilot
Class name	Moisture
Class description	Moisture is associated with the water content in liquid phase present in any substance. Aquic: A reducing regime in which the soil is nearly free of dissolved oxygen due to saturation by groundwater during periods when the soil temperature at 20 inches (50 cm) is >41 °F (5 °C). Udic: Soil is neither dry for as long as 90 cumulative days nor for as long as 60 consecutive days in the 90 days following summer solstice at periods when the soil temperature at 20 inches (50 cm) is >41 °F (5 °C). Ustic: A limited amount of water is available for plants but occurs at times when the soil temperature is optimum for plant growth. Xeric: A limited amount of water is present but does not occur at optimum periods for plant growth; common in mediterranean climates with moist, cool winters and warm, dry summers. Aridic: No water is available for plants for more than half the cumulative time that the soil temperature at 20 inches (50 cm) is >41 °F (5 °C), and no period as long as 90 consecutive days when water is available for plants while soil temperature is continuously >46 °F (8 °C) [125,134].
Class parents	Vegetation_stat
Subclasses	Drought_fuel_moisture, Duff_fuel_moisture, Fine_fuel_moisture
Sources	https://www.fs.fed.us/database/feis/glossary2.html
Class name	Vegetation_stat
Class description	Statistics related to vegetation
Class parents	Thing
Subclasses	Moisture, Fire_strategy, Mean_height
Sources	Indonesian pilot
Class name	Measure
Class description	The measured value made over a property. It is also linked to the unit of measure in which the value is expressed and to the timestamp of the measurement.
Class parents	Thing
Subclasses	Basal_Area, Volume_with_bark, Measure_In_Centimeters, Measure_In_Decimeters, Measure_In_Degrees, Measure_In_Gradians, Measure_In_Hectares, Measure_In_Meters, Measure_In_Millimeters,

	Measure_In_Percentage, Measure_In_SquareMeters, Measure_In_Unities, Measure_In_Years
Sources	http://crossforest.eu/measures/ontology/Measure, https://saref.etsi.org/core/Measurement
Class name	Reliability
Class description	Reliability of the measurement
Class parents	Thing
Subclasses	
Sources	http://crossforest.eu/measures/ontology/Reliability
Class name	Incident_report
Class description	Represents an incident report submitted to the Public Safety Answering Points (PSAP).
Class parents	Thing
Subclasses	
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#IncidentReport
Class name	Spatial_entity
Class description	It's the entity used to describe the spatial reations between entities or other elements.
Class parents	Thing
Subclasses	Position, Altitude, NUTS_unit, City, Coordinate, Country, Direction, Distance, District, Ending_point, Extension, Hectares, LeftBound, LowerBound, RightBound, Starting_point, UpperBound
Sources	http://ecoinformatics.org/oboe/oboe.1.0/oboe-spatial.owl#SpatialEntity, http://www.w3.org/2003/01/geo/wgs84_pos#SpatialThing
Class name	Temporal_entity
Class description	It's the entity used to describe the temporal relationships between entities or other elements.
Class parents	Thing
Subclasses	Duration, Ending_time, Fire_interval, Starting_time
Sources	http://ecoinformatics.org/oboe/oboe.1.0/oboe-temporal.owl#TemporalEntity
Class name	Unit
Class description	Unit in which a measure is taken
Class parents	Thing
Subclasses	
Sources	http://crossforest.eu/measures/ontology/Unit, https://w3id.org/saref#UnitOfMeasure
Class name	Silvanus_UP
Class description	A task that has to do with analyzing or processing items.
Class parents	Thing

Subclasses	Data_analysis
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Task
Class name	Wind_condition
Class description	The perceptible natural movement of the air, especially in the form of a current of air blowing from a particular direction.
Class parents	Climate_parameter
Subclasses	Wind_speed, Wind_direction
Sources	https://cwfis.cfs.nrcan.gc.ca/background/summary/fwi, https://bimerr.iot.linkeddata.es/def/weather#Wind
Class name	Living_being
Class description	Any living being that is in danger during a natural disaster.
Class parents	Vulnerable_object
Subclasses	Human, Animal
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#LivingBeing
Class name	Asset
Class description	Any non-living item of interest.
Class parents	Vulnerable_object
Subclasses	Community, Structure, Ecological_asset, Infrastructure, Property
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Asset
Class name	Accident
Class description	Wildfire unintentionally and indirectly caused by human without use of fire, connected neither to will nor to negligence rather to fatality.
Class parents	Cause
Subclasses	Electrical_power, Other_accident, Railroads, Self-ignition, Vehicles, Weapons, Works
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	Accomodation
Class description	Settlement
Class parents	Building
Subclasses	
Sources	http://www.semanticweb.org/earthquake#Accomodation
Class name	Building
Class description	An Artifact that is designed as a building or campus dedicated to some specific purpose.
Class parents	Structure

Subclasses	Accomodation, Transportation_Facility, Church, CommunicationFacility, Industrial_building, EducationFacility, Public_Safety_Facility, Medical_Facility, Military_Facility, Rail_Facility, Summer_camp, WaterFacility, university_campus, water_intake
Sources	http://www.ontologylibrary.mil/CommonCore/Mid/ArtifactOntology#Facility, http://www.semanticweb.org/earthquake#Building, https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Building
Class name	Active_crown_fire
Class description	A crown fire in which the entire fuel complex is involved in flame, but the crowning phase remains dependent on heat released from surface fuel for continued spread. An active crown fire may also be also called a running crown fire or continuous crown fire. An active crown fire presents a solid wall of flame from the surface through the canopy fuel layers. Flames appear to emanate from the canopy as a whole rather than from individual trees within the canopy. Active crown fire is one of several types of crown fire and is contrasted with passive crown fires which are less vigorous types of crown fire that do not emit continuous, solid flames from the canopy
Class parents	Crown_fire
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html
Class name	Crown_fire
Class description	Fire that burns in the crowns of trees and shrubs. Usually ignited by a surface fire. Crown fires are common in coniferous forests and chaparral-type shrublands [20]. Also see active crown fire and passive crown fire.
Class parents	Fire
Subclasses	Active_crown_fire, Passive_crown_fire
Sources	https://www.fs.fed.us/database/feis/glossary2.html#CrownFire
Class name	Active_fronts_number
Class description	Number of active fire fronts
Class parents	Fire_characteristic
Subclasses	
Sources	French pilot
Class name	Adolescent
Class description	An adolescent is a person aged 10 to 19 years inclusive
Class parents	Age_group
Subclasses	
Sources	https://w3id.org/empathi/adolescent
Class name	Adult
Class description	An adult is a person older than 19 years of age unless national law defines a person as being an adult at an earlier age
Class parents	Age_group

Subclasses	
Sources	https://w3id.org/empathi/adult
Class name	Agricultural_management
Class description	Wildfire caused by all types of agricultural burnings (stubble burnings, etc.).
Class parents	Use_of_fire
Subclasses	
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	Use_of_fire
Class description	Wildfire unintentionally set by people making fire especially for cleaning or recreation. The difference between “deliberate” and this category is that the fire is initially voluntarily set for a specific purpose and not in order to destroy the natural area. To be classified in this category, the fire has to escape and get out of control.
Class parents	Negligence
Subclasses	Agricultural_management, Other_negligent_use_of_fire, Recreation, Vegetation_management, Waste_management
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	Negligence
Class description	Wildfire unintentionally caused by human using fire or glowing object, not connected to fatality
Class parents	Cause
Subclasses	Use_of_fire, Use_of_glowing_objects
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	Use_of_glowing_objects
Class description	Wildfire unintentionally set by people using glowing objects such as (i) fireworks, (ii) cigarettes, (iii) hot ash handling by residents or (iv) during working activities such as apiculture, fumigation or disinfection or when expulsion of firebrands out of chimney.
Class parents	Negligence
Subclasses	Cigarettes, Hot_ashes, Other_use_of_glowing_objects, Fireworks,_firecrackers,_distress_flares
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	Agriculture
Class description	Agricultural used spaces.
Class parents	Ecological_asset
Subclasses	
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Agriculture

Class name	Ecological_asset
Class description	Ecological assets of various types.
Class parents	Asset
Subclasses	Agriculture, Dunes, Natural_habitat, Plant, River
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#EcologicalAsset
Class name	Aircraft
Class description	Aircraft
Class parents	Response_vehicle
Subclasses	
Sources	http://www.ontologylibrary.mil/CommonCore/Mid/ArtifactOntology#Aircraft
Class name	Response_vehicle
Class description	Vehicle for emergency response
Class parents	Response_resource
Subclasses	Aircraft, Ground_Vehicle, Watercraft
Sources	
Class name	Airport
Class description	A Transportation Facility that is designed for launching, receiving, and housing Aircraft.
Class parents	Transportation_Facility
Subclasses	Heliport
Sources	http://www.ontologylibrary.mil/CommonCore/Mid/ArtifactOntology#Airport, http://www.semanticweb.org/earthquake#AirportLoss
Class name	Transportation_Facility
Class description	A Facility that is designed for commencing or concluding the transportation of transportation artifacts, or for housing transportation artifacts.
Class parents	Building
Subclasses	Airport, Pier, Port
Sources	http://www.ontologylibrary.mil/CommonCore/Mid/ArtifactOntology#TransportationFacility
Class name	All_season_road
Class description	A road which is usable across all seasons.
Class parents	Street
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000771
Class name	Street
Class description	Represents the road network infrastructure.

Class parents	Transportation
Subclasses	All_season_road, Asphalt_road, Concrete_road, Driveway, Public_street, Track
Sources	http://purl.obolibrary.org/obo/ENVO_00000064, http://www.semanticweb.org/earthquake#RoadLoss, https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Street
Class name	Transportation
Class description	Represents transportation services and infrastructure.
Class parents	Infrastructure
Subclasses	Street, Bridge, Causeway, Cycling_route, Public_transport, Touristic_route, ford, lock, pier, railway
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Transportation
Class name	Allocentric_Position
Class description	Position from a set of points
Class parents	Position
Subclasses	
Sources	http://crossforest.eu/position/ontology/AllocentricPosition
Class name	Position
Class description	Position where a spatial entity can be located
Class parents	Spatial_entity
Subclasses	Allocentric_Position, Egocentric_Position, Geocentric_Position, Polygon, Reference_Position
Sources	http://crossforest.eu/position/ontology/Position
Class name	Alpine_Biome
Class description	A biome which is subject to alpine altitudinal conditions.
Class parents	Biome
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01001835
Class name	Altitude
Class description	Altitude from sea level
Class parents	Spatial_entity
Subclasses	
Sources	http://crossforest.eu/ifi/ontology/Altitude
Class name	Anemometer
Class description	An anemometer is a device that measures wind speed and direction. It is a common weather station instrument.

Class parents	IoT_sensor
Subclasses	
Sources	Most pilots
Class name	IoT_sensor
Class description	IoT devices are the nonstandard computing devices that connect wirelessly to a network and have the ability to transmit data, such as the many devices on the internet of things
Class parents	Sensor
Subclasses	Anemometer, Humidity_sensor, Moisture_sensor, Thermometer, UAV, UGV
Sources	Most pilots
Class name	Animal_tracker
Class description	Device for tracking animal position
Class parents	Biodiversity_sensor
Subclasses	
Sources	Portuguese pilot
Class name	Biodiversity_sensor
Class description	Sensor for detecting biodiversity features
Class parents	Sensor
Subclasses	Animal_tracker
Sources	Portugues pilot
Class name	Annual_precipitation
Class description	Precipitations in the span of 1 year
Class parents	Precipitation
Subclasses	
Sources	Brazilian pilot
Class name	Precipitation
Class description	Any product of the condensation of atmospheric water vapour that falls under gravity from clouds. The main forms of precipitation include drizzle, rain, sleet, snow, ice pellets, graupel and hail.
Class parents	Climate_parameter
Subclasses	Annual_precipitation, Average_annual_precipitation, 24h_precipitation
Sources	https://bimerr.iot.linkeddata.es/def/weather#Precipitation
Class name	Anthropogenic_Terrestrial_Biome
Class description	An anthropogenic terrestrial biome is a terrestrial biome which has community structures determined by human activity.
Class parents	Terrestrial_Biome
Subclasses	Dense_Settlement_Biome, Rangeland_Biome, Village_Biome
Sources	http://purl.obolibrary.org/obo/ENVO_01000219

Class name	Terrestrial_Biome
Class description	A biome which is primarily or completely situated on a landmass.
Class parents	Biome
Subclasses	Anthropogenic_Terrestrial_Biome, Mangrove_Biome, Shrubland_Biome, Tundra_Biome, Woodland_Biome
Sources	http://purl.obolibrary.org/obo/ENVO_00000446
Class name	Aquatic_Biome
Class description	A biome which is determined by a water body and which has ecological climax communities adapted to life in or on water.
Class parents	Biome
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_00002030
Class name	Area_Of_Cropland
Class description	An area of a planet's surface which is partly covered either by annual crops and perennial woody crops or by actively tilled land. This area is in contact with an atmospheric column extending from the planetary boundary layer to the planet's exosphere with little to no physical obstruction.
Class parents	Vegetated_area
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000892
Class name	Area_Of_Evergreen_Forest
Class description	An area of a planet's surface which is primarily covered by a forest in which the majority of trees maintain their foliage despite seasonal change. The surfaces of this area (including the surface of the forest canopy) are in contact with an atmospheric column extending from the planetary boundary layer to the planet's exosphere with little to no physical obstruction.
Class parents	Forest
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000843
Class name	Forest
Class description	A formation dominated by trees, in which the canopy is more closed than open [112]. Generally, overstory trees are >16 feet (5 m) tall and have 60% to 100% cover [75]. When describing forests, use of a dash indicates an overstory/understory relationship (e.g., northern red oak/America witch-hazel forest). Compare with grassland, shrubland, wooded shrubland, woodland, savanna.
Class parents	Vegetated_area
Subclasses	Area_Of_Evergreen_Forest, Area_Of_Mixed_Forest
Sources	https://www.fs.fed.us/database/feis/glossary2.html
Class name	Area_Of_Lichen-dominated_Vegetation
Class description	An area of a planet's surface which is primarily covered by fruticose or foliose lichens and which is in contact with an atmospheric column extending from

	the planetary boundary layer to the planet's exosphere with little to no physical obstruction.
Class parents	Vegetated_area
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000889
Class name	Area_Of_Mixed_Forest
Class description	An area of a planet's surface which is primarily covered by a forest in which the trees are a mixture between those that lose and retain their foliage despite seasonal change. The surfaces of this area (including the surface of the forest canopy) are in contact with an atmospheric column extending from the planetary boundary layer to the planet's exosphere with little to no physical obstruction.
Class parents	Forest
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000855
Class name	Area_Of_Moss-dominated_Vegetation
Class description	An area of a planet's surface which is primarily covered by mosses and which is in contact with an atmospheric column extending from the planetary boundary layer to the planet's exosphere with little to no physical obstruction.
Class parents	Vegetated_area
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000890
Class name	Area_Of_Sedge-_And_Forb-dominated_Herbaceous_Vegetation
Class description	An area of a planet's surface which is primarily covered by sedges or forbs, possibly interpersed with grasses or grass-like plants. This area is in contact with an atmospheric column extending from the planetary boundary layer to the planet's exosphere with little to no physical obstruction.
Class parents	Vegetated_area
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000887
Class name	Area_Of_Tundra
Class description	A vegetated area which is part of a tundra ecosystem.
Class parents	Vegetated_area
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_00000112
Class name	Area_Of_Woody_Wetland
Class description	An area of a planet's surface which is partly covered by forest or shrubland vegetation and where the underlying soil or substrate is periodically saturated with or covered by water. This area is in contact with an atmospheric column extending from the planetary boundary layer to the planet's exosphere with little to no physical obstruction.
Class parents	Vegetated_area
Subclasses	

Sources	http://purl.obolibrary.org/obo/ENVO_01000893
Class name	Arid_Biome
Class description	A biome which is subject to arid environmental conditions.
Class parents	Biome
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01001838
Class name	Armored_Personnel_Carrier
Class description	An armoured personnel carrier (APC) is a broad type of armoured military vehicle designed to transport personnel and equipment in combat zones.
Class parents	Ground_Motor_Vehicle
Subclasses	
Sources	http://www.ontologylibrary.mil/CommonCore/Mid/ArtifactOntology#ArmoredPersonnelCarrier
Class name	Ground_Motor_Vehicle
Class description	A land-based motorized vehicle that traveled on the ground/land
Class parents	Ground_Vehicle
Subclasses	Armored_Personnel_Carrier, Automobile, Bus, Infantry_Fighting_Vehicle, Motorcycle, Tank, Truck
Sources	http://www.ontologylibrary.mil/CommonCore/Mid/ArtifactOntology#GroundMotorVehicle
Class name	Ground_Vehicle
Class description	A land-based vehicle that traveled on the ground/land
Class parents	Response_vehicle
Subclasses	Ground_Motor_Vehicle, Bicycle, Rail_Transport_Vehicle
Sources	http://www.ontologylibrary.mil/CommonCore/Mid/ArtifactOntology#GroundVehicle
Class name	Asphalt_road
Class description	A road which is primarily composed of asphalt.
Class parents	Street
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01001277
Class name	Atmospheric_pressure
Class description	The force exerted over a given area or object, either because of gravity pulling on it or other motion the object has. Molecules in the air produce pressure through both their weight and movement, and this pressure is connected to other properties of the atmosphere.
Class parents	Climate_parameter
Subclasses	
Sources	Romanian pilot, https://bimerr.iot.linkeddata.es/def/weather#Pressure

Class name	Audio_item
Class description	Represents an audio item
Class parents	Media_item
Subclasses	
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#AudioItem
Class name	Automobile
Class description	A four-wheeled road vehicle that is powered by an engine and is able to carry a small number of people
Class parents	Ground_Motor_Vehicle
Subclasses	
Sources	http://www.ontologylibrary.mil/CommonCore/Mid/ArtifactOntology#Automobile
Class name	Average_annual_precipitation
Class description	Average annual precipitation for a given area
Class parents	Precipitation
Subclasses	
Sources	Brazilian pilot
Class name	Average_annual_temperature
Class description	Average annual temperature for a given area
Class parents	Temperature
Subclasses	
Sources	Brazilian pilot
Class name	Temperature
Class description	Temperature in a given area at a given time
Class parents	Climate_parameter
Subclasses	Average_annual_temperature
Sources	https://cwfis.cfs.nrcan.gc.ca/background/summary/fwi, https://bimerr.iot.linkeddata.es/def/weather#Temperature
Class name	Backfire
Class description	A fire set along the inner edge of a fireline to consume the fuel in the path of a fire or to change the fire's convection column [92]. Backfires are often set during the course of wildland firefighting, with the prescribed fire advancing aginast the wind [79].
Class parents	Controlled_fire
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html
Class name	Controlled_fire

Class description	Any fire intentionally ignited by management in accordance with applicable laws, policies, and regulations to meet specific objectives. Also called a controlled burn or prescribed burn [91,147]. An escaped prescribed fire is considered a wildfire [91]. A fire set under controlled and planned situation.
Class parents	Fire
Subclasses	Backfire, Hazard-reduction_fire
Sources	https://www.fs.fed.us/database/feis/glossary2.html#PrescribedFire, http://cerrado.linkeddata.es/ecology/fire#PrescriptionFire
Class name	Basal_Area
Class description	Sum of the sectional areas of the trees at 1.30 m from the ground.
Class parents	Measure
Subclasses	
Sources	http://crossforest.eu/ifi/ontology/BasalArea
Class name	Volume_with_bark
Class description	Volume of the tree including the bark
Class parents	Measure
Subclasses	
Sources	http://crossforest.eu/ifi/ontology/VolumeWithBark
Class name	Basic_region_for_the_application_of_regional_policies
Class description	NUTS 2: basic regions for the application of regional policies
Class parents	NUTS_unit
Subclasses	
Sources	http://crossforest.eu/ifi/ontology/NUTS2
Class name	NUTS_unit
Class description	The NUTS (Nomenclature of Territorial Units for Statistics) is a classification defined by the Eurostat office of the European Union.
Class parents	Spatial_entity
Subclasses	Basic_region_for_the_application_of_regional_policies, Major_socio-economic_region, Small_region_for_specific_diagnoses
Sources	http://crossforest.eu/ifi/ontology/NUTSUnit
Class name	Bicycle
Class description	A vehicle consisting of two wheels held in a frame one behind the other, propelled by pedals and steered with handlebars attached to the front wheel.
Class parents	Ground_Vehicle
Subclasses	
Sources	http://www.ontologylibrary.mil/CommonCore/Mid/ArtifactOntology#Bicycle
Class name	Boundary_wall
Class description	A boundary wall is a constructed barrier which is usually opaque, constructed from masonry, and of greater structural strength than a fence.
Class parents	Constructed_barrier

Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000466
Class name	Constructed_barrier
Class description	A constructed barrier is a freestanding wall, berm, or fence built to limit movement of entities across a boundary.
Class parents	Structure
Subclasses	Boundary_wall, Dam, Fence
Sources	http://purl.obolibrary.org/obo/ENVO_01000467
Class name	Bridge
Class description	Represents subway infrastructure.
Class parents	Structure, Transportation
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_00000075, http://www.semanticweb.org/earthquake#BridgeLoss, https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Bridge
Class name	Infrastructure
Class description	Represents critical infrastructure that is in danger during a natural disaster.
Class parents	Asset
Subclasses	Transportation, Communication, Critical_infrastructure, Pipeline_network, Water_supply, Educational_facility, Energy, Fire_department, Garbage_collection, Hospital, Irrigation, Police, Sewer
Sources	http://www.semanticweb.org/earthquake#InfrastructureLoss, https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Infrastructure
Class name	Bronchodilator
Class description	Bronchodilators are a type of medication that make breathing easier by relaxing the muscles in the lungs and widening the airways
Class parents	MedicalItem
Subclasses	
Sources	Greek pilot
Class name	MedicalItem
Class description	Drug or other medical items
Class parents	Item
Subclasses	Bronchodilator
Sources	http://www.semanticweb.org/earthquake#MedicalItem
Class name	Item
Class description	
Class parents	Response_resource

Subclasses	MedicalItem, ReliefItem, SupplyGood
Sources	http://www.semanticweb.org/earthquake#Item
Class name	Brush_fire
Class description	A fire in low-growing and brush
Class parents	Fire
Subclasses	
Sources	http://cerrado.linkeddata.es/ecology/fire#BrushFire
Class name	Bus
Class description	A large motor vehicle, having a long body, equipped with seats or benches for passengers, usually operating as part of a scheduled service
Class parents	Ground_Motor_Vehicle
Subclasses	
Sources	http://www.ontologylibrary.mil/CommonCore/Mid/ArtifactOntology#Bus
Class name	Bush_Area
Class description	A vegetated area which has not been cleared or is sparsely settled, usually scrub-covered or forested
Class parents	Vegetated_area
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01001293
Class name	CCTV
Class description	CCTV stands for closed-circuit television and is commonly known as video surveillance. “Closed-circuit” means broadcasts are usually transmitted to a limited (closed) number of monitors, unlike “regular” TV, which is broadcast to the public at large. CCTV networks are commonly used to detect and deter criminal activities, and record traffic infractions, but they have other uses.
Class parents	Camera
Subclasses	
Sources	Slovak pilot
Class name	Camera
Class description	Device for capturing images
Class parents	Sensor
Subclasses	CCTV, Infrared_camera, Static_camera
Sources	Croatian pilot, Czech pilot, Italian pilot, Portuguese pilot, Romanian pilot
Class name	Canopy_cover
Class description	Forest canopy cover, also known as canopy coverage or crown cover, is defined as the proportion of the forest covered by the vertical projection of the tree crowns
Class parents	Biodiversity_index
Subclasses	
Sources	http://crossforest.eu/ilu/ontology/CanopyCover

Class name	Car
Class description	Represents any type of car.
Class parents	Vehicle
Subclasses	
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Car
Class name	Vehicle
Class description	Represents any type of vehicle.
Class parents	Property
Subclasses	Car
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Vehicle
Class name	Property
Class description	Represents any type of private property.
Class parents	Asset
Subclasses	Vehicle
Sources	http://www.semanticweb.org/earthquake#PropertyLoss, https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Property
Class name	Causeway
Class description	Represents subway infrastructure.
Class parents	Transportation
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_00000158
Class name	Chemical_composition_sensor
Class description	Sensor to elicit the composition of the combustion gases
Class parents	Chemical_sensor
Subclasses	
Sources	French pilot
Class name	Chemical_sensor
Class description	A chemical sensor is a device that converts a property (physical or chemical) of a particular analyte into a measurable signal that is proportional to the analyte concentration. It recognizes the analyte molecule in a selective way by transforming the response into an analytical electrical signal.
Class parents	Sensor
Subclasses	Chemical_composition_sensor, Gas_sensor, Smoke_detector
Sources	French pilot

Class name	Child
Class description	A child is a person 19 years or younger unless national law defines a person to be an adult at an earlier age
Class parents	Age_group
Subclasses	
Sources	https://w3id.org/empathi/child
Class name	Children
Class description	Wildfire set by children (under legal age) for game or entertainment.
Class parents	Irresponsible
Subclasses	
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	Irresponsible
Class description	Wildfire caused by people not responsible for their actions because under legal age or mentally ill.
Class parents	Deliberate
Subclasses	Children, Mental_illness
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	Mental_illness
Class description	Wildfire caused by people in case of pyromania or other mental illnesses.
Class parents	Irresponsible
Subclasses	
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	Deliberate
Class description	Wildfire intentionally caused by human with the use of fire.
Class parents	Cause
Subclasses	Irresponsible, Responsible
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	Responsible
Class description	Wildfire wilfully ignited by people over the legal age, which burns or spreads to vegetation or property without consent of the owner.
Class parents	Deliberate
Subclasses	Conflict, Crime_concealment, Excitement, Extremist, Interest, Vandalism
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	Church

Class description	Represents any type of religious building
Class parents	Building
Subclasses	
Sources	Greek pilot
Class name	Cigarettes
Class description	Wildfire caused by cigarettes and tobacco pipe regardless of the activity or the location of the smoker. It includes the fires set by the match used for lighting the cigarette and negligently thrown away by the smoker, but not cases where a cigarette or matches have been used to set an arson fire.
Class parents	Use_of_glowing_objects
Subclasses	
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	City
Class description	A city is a large human settlement. A city is distinguished from other human settlements by its relatively great size, but also by its functions and its special symbolic status, which may be conferred by a central authority.
Class parents	Spatial_entity
Subclasses	
Sources	https://w3id.org/def/saref4city#City
Class name	ClarificationOfSituation
Class description	Clarification of the situation
Class parents	Response_procedure
Subclasses	
Sources	http://www.semanticweb.org/earthquake#ClarificationOfSituation
Class name	Response_procedure
Class description	Response procedure
Class parents	Response_resource
Subclasses	ClarificationOfSituation, ClearingWork, Containment, EnlightenmentOfPopulation, Evacuation, HumanitarianAssistance, MedicalSupport, RehabilitationAndRecovery, SearchAndRescue, SupplyGoodSupport
Sources	http://www.semanticweb.org/earthquake#Emergency_Response
Class name	ClearingWork
Class description	Clearing of rubble and obstacles
Class parents	Response_procedure
Subclasses	
Sources	http://www.semanticweb.org/earthquake#ClearingWork
Class name	Clothing

Class description	Clothing items
Class parents	ReliefItem
Subclasses	
Sources	http://www.semanticweb.org/earthquake#Clothing
Class name	ReliefItem
Class description	Relief items for people affected by fire
Class parents	Item
Subclasses	Clothing, DryFood, First_Aid_Kit, HousingEquipment, SanitaryEquipment
Sources	http://www.semanticweb.org/earthquake#ReliefItem
Class name	Collection_point
Class description	A geographically defined place where people meet in case of emergency.
Class parents	Structure
Subclasses	
Sources	Italian piliot
Class name	Communication
Class description	Represents any type of (tele)communication infrastructure.
Class parents	Infrastructure
Subclasses	Communication_tower
Sources	http://www.semanticweb.org/earthquake#Communication, https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Communication
Class name	CommunicationChannel
Class description	Transmission medium
Class parents	Response_resource
Subclasses	
Sources	http://www.semanticweb.org/earthquake#CommunicationChannel
Class name	CommunicationFacility
Class description	Any and all public and private instrumentalities used or useful in the transmission of writing, signs, signals, pictures, or sounds of all kinds and includes mail, telephone, wire, radio, and all other means of communication.
Class parents	Building
Subclasses	
Sources	http://www.semanticweb.org/earthquake#CommunicationFacility, https://w3id.org/empathi/Communication
Class name	CommunicationLeader
Class description	Person in charge of the communication
Class parents	Responder

Subclasses	
Sources	http://www.semanticweb.org/earthquake#CommunicationLeader
Class name	Communication_tower
Class description	Telecommunications tower, a mast or tower built primarily to hold telecommunications antennas
Class parents	Communication
Subclasses	
Sources	Italian pilot
Class name	Concrete_road
Class description	A road which is primarily composed of concrete.
Class parents	Street
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01001278
Class name	Conflict
Class description	Wildfire set in retaliation for real or perceived injustice or wrong: - Personal revenge: (to retaliate for a one-to one or personal grievance, argument, fight, personal affront or any of infinite arrays of events perceived by the offender to warrant retaliation). - Societal retaliation: (in revenge against the society that the author perceives has wronged him). - Institutional: (fire against institutions or use of fire to settle grievances with the institution and to intimidate those associated with the institution). - Group retaliation: (fire as expression of anger towards the group or its members rather than anger at a specific individual within the group). - Intimidation.
Class parents	Responsible
Subclasses	
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	Containment
Class description	Containment of the interested area
Class parents	Response_procedure
Subclasses	
Sources	http://www.semanticweb.org/earthquake#Containment
Class name	Cool-season_fire
Class description	It's a fire set during the cool season, to avoid the fire to achieve very high temperatures or to make it easy to stop it.
Class parents	Hazard-reduction_fire
Subclasses	
Sources	http://cerrado.linkeddata.es/ecology/fire#CoolSeasonFire
Class name	Hazard-reduction_fire
Class description	It's a fire set in order to prevent large and severe events of burning.

Class parents	Controlled_fire
Subclasses	Cool-season_fire, High-intensity_fire
Sources	http://cerrado.linkeddata.es/ecology/fire#HarzardReductionFire
Class name	Coordinate
Class description	Any of a set of numbers used in specifying the location of a point on a line, on a surface, or in space
Class parents	Spatial_entity
Subclasses	
Sources	http://crossforest.eu/position/ontology/Coordinate, http://www.w3.org/2003/01/geo/wgs84_pos#Point
Class name	Country
Class description	A country is a region that is identified as a distinct national entity in political geography.
Class parents	Spatial_entity
Subclasses	
Sources	http://crossforest.eu/ifi/ontology/Country, https://w3id.org/def/saref4city#Country
Class name	Crime_concealment
Class description	Wildfire set to hide or conceal the primary crime activity: murder, suicide, breaking and entering, embezzlement, larceny, destroying records. Fires set as diversionary tactic fall into this category.
Class parents	Responsible
Subclasses	
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	Critical_infrastructure
Class description	Areas around critical infrastructure need to be kept clear of combustible biomass. Identification and monitoring of these areas is therefore necessary. They are defined by a perimeter around the critical infrastructure.
Class parents	Infrastructure
Subclasses	
Sources	Portuguese pilot
Class name	Crown_class
Class description	Measure of stand structure classifying trees within a stand as dominant (crowns rise through or above general canopy and receive full light from above and partial light from the sides), codominant (crowns in upper canopy but are blocked from receiving light from the sides by neighboring crowns), emergent (crowns completely above main canopy), intermediate (crowns receive little light from above and none from the side), overtopped or suppressed (one or more neighboring trees completely overtop crowns), and seedlings
Class parents	Thing
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html

Class name	Cycling_route
Class description	A cycling route is a bikeway separated from motorized traffic and dedicated to cycling or shared with pedestrians or other non-motorized users.
Class parents	Transportation
Subclasses	
Sources	Slovak pilot
Class name	Dairy
Class description	A dairy is a building in which animal milk is harvested and, optionally, processed for human consumption
Class parents	Industrial_building
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_00003862
Class name	Industrial_building
Class description	An industrial building is a building within which goods are produced and, optionally, stored or within which services are rendered.
Class parents	Building
Subclasses	Dairy, Waste_treatment_plant, Factory, Power_plant, Sawmill, food_processing_building
Sources	http://purl.obolibrary.org/obo/ENVO_00003861
Class name	Dam
Class description	A barrier constructed across a watercourse to control the flow or raise the level of water.
Class parents	Constructed_barrier
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_00000074
Class name	Damage_quantification
Class description	Quantifying the damage of forest fire (loss of XX cubic tons of oxygen, etc.)
Class parents	Biodiversity_index
Subclasses	
Sources	French pilot
Class name	Data_analysis
Class description	A type of task carried out by a silvanus module involving data analysis.
Class parents	Silvanus_UP
Subclasses	Image_analysis, Text_analysis, Video_analysis
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#DataAnalysis
Class name	Dense_Settlement_Biome
Class description	A dense settlement biome is an anthropogenic terrestrial biome which is primarily used for human habitation, recreation, and industry within built structures with little other land use.

Class parents	Anthropogenic_Terrestrial_Biome
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000248
Class name	Density
Class description	1) In plant ecology, density = (Total number of individuals)/(total number of quadrats)[45]. Sometimes called abundance [87], a term usually not used in FEIS because of its ambiguity. 2) In range and wildlife ecology, the number of animals per unit area at a given time; stocking [43]
Class parents	Living_being_stat
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html
Class name	Diametric_class
Class description	Set of trees in a given forest having a diameter at the height of human breast between the two extremes of the class, e.g. class 41 to 45 cm
Class parents	Biodiversity_index
Subclasses	
Sources	http://crossforest.eu/ifi/ontology/DiametricClass
Class name	Direction
Class description	A course along which someone or something moves.
Class parents	Spatial_entity
Subclasses	
Sources	http://crossforest.eu/position/ontology/Direction
Class name	Distance
Class description	The length of the space between two points.
Class parents	Spatial_entity
Subclasses	
Sources	http://crossforest.eu/position/ontology/Distance
Class name	District
Class description	A district is a type of administrative division that, in some countries, is managed by local government. Across the world, areas known as "districts" vary greatly in size, spanning regions or counties, several municipalities, subdivisions of municipalities, school district, or political district.
Class parents	Spatial_entity
Subclasses	
Sources	https://saref.etsi.org/saref4city/District
Class name	Dominant_formation
Class description	The extent to which a given species predominates in a community because of its size, abundance, or coverage [78].
Class parents	Biodiversity_index
Subclasses	

Sources	https://www.fs.fed.us/database/feis/glossary2.html#dominance, http://crossforest.eu/ifi/ontology/DominantFormation
Class name	Dominant_species
Class description	The dominant species in a community based on its size, abundance, or coverage
Class parents	Living_being_stat
Subclasses	
Sources	Indonesian pilot, https://www.fs.fed.us/database/feis/glossary2.html#dominance
Class name	Drinking_water_pipeline_network
Class description	A pipeline network which is used to transport drinking water to consumers.
Class parents	Pipeline_network
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_03600012
Class name	Pipeline_network
Class description	A human construction which is used to transport a material which is primarily composed of liquid or gas through a system of pipes.
Class parents	Infrastructure
Subclasses	Drinking_water_pipeline_network, Oil_pipeline_network
Sources	http://purl.obolibrary.org/obo/ENVO_03600014
Class name	Transmission_pipeline
Class description	A human construction which is used to transport a material which is primarily composed of liquid or gas through a system of pipes.
Class parents	Water_supply
Subclasses	
Sources	Portuguese pilot, http://purl.obolibrary.org/obo/ENVO_03600014
Class name	Drinking_water_treatment_plant
Class description	An industrial building in which water undergoes a purification process to make it fit for human consumption.
Class parents	Waste_treatment_plant, Water_supply
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_03600004
Class name	Waste_treatment_plant
Class description	Building for waste treatment
Class parents	Industrial_building
Subclasses	Drinking_water_treatment_plant
Sources	http://purl.obolibrary.org/obo/ENVO_00002272
Class name	Water_supply
Class description	Water Infrastructures typology displayed on map

Class parents	Infrastructure
Subclasses	Transmission_pipeline, Drinking_water_treatment_plant, Pumping_station, Reservoir
Sources	http://www.semanticweb.org/earthquake#WaterSupply, https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#WaterSupply
Class name	Driveway
Class description	A road which is used for local access to one or more structures, and is privately owned and maintained by an individual or group.
Class parents	Street
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01001280
Class name	DryFood
Class description	Dryfood items
Class parents	ReliefItem
Subclasses	
Sources	http://www.semanticweb.org/earthquake#DryFood
Class name	Duff
Class description	Partially decomposed organic matter lying beneath the litter layer and above the mineral soil. Includes the fermentation and humus layers of the forest floor (Oa and Oe soil horizons) [20,125]. Also see litter.
Class parents	Evnironment_index
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html
Class name	Evnironment_index
Class description	
Class parents	Biodiversity_index
Subclasses	Duff, Soil, Soil_pH, Soil_structure, Soil_type
Sources	
Class name	Dunes
Class description	Represents dunes.
Class parents	Ecological_asset
Subclasses	
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Dunes
Class name	Duration
Class description	The length of time that combustion occurs at a given point [83]. Fire duration relates closely to downward heating and fire effects below the fuel surface as well as heating of tree boles above the surface.
Class parents	Temporal_entity

Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.htmlhttp://cerrado.linkeddata.es/ecology/fire#Duration, http://cerrado.linkeddata.es/ecology/fire#Duration
Class name	EducationFacility
Class description	Represents any type of educational facility.
Class parents	Building
Subclasses	
Sources	http://www.semanticweb.org/earthquake#EducationalInstitute, https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#EducationalFacility, https://w3id.org/empathi/#Education_Resource
Class name	Educational_facility
Class description	Represents any type of educational facility.
Class parents	Infrastructure
Subclasses	
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#EducationalFacility
Class name	Egocentric_Position
Class description	Position from a point of reference
Class parents	Position
Subclasses	
Sources	http://crossforest.eu/position/ontology/EgocentricPosition
Class name	Elder
Class description	An adult is a person older than 60 years of age
Class parents	Age_group
Subclasses	
Sources	
Class name	Electric_energy_supply
Class description	Represents electric energy supply infrastructure.
Class parents	Energy
Subclasses	
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#ElectricEnergySupply
Class name	Energy
Class description	Represents any type of energy-generating infrastructure.
Class parents	Infrastructure
Subclasses	Electric_energy_supply, Overhead_lines, Substation, Transmission_tower

Sources	Portuguese pilot, http://www.semanticweb.org/earthquake#Electricity, https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Energy
Class name	Electrical_infrastructure_criticallity
Class description	Criticallity, based on grid redundancy and voltage characteristics.
Class parents	Thing
Subclasses	
Sources	Portuguese pilot
Class name	Electrical_power
Class description	Wildfire caused by sparks due to failure of electric lines or other electric wirings: short-circuits due to contact between two lines or between line and vegetation or bird, fall of the line, etc.
Class parents	Accident
Subclasses	
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	Ending_point
Class description	Ending point of a space
Class parents	Spatial_entity
Subclasses	
Sources	http://cerrado.linkeddata.es/ecology/fire#EndingPoint
Class name	Ending_time
Class description	Ending timestamp of an event
Class parents	Temporal_entity
Subclasses	
Sources	http://cerrado.linkeddata.es/ecology/fire#EndingTime
Class name	EnlightenmentOfPopulation
Class description	Updating the communities on the state of the incident
Class parents	Response_procedure
Subclasses	
Sources	http://www.semanticweb.org/earthquake#EnlightenmentOfPopulation
Class name	Erosion
Class description	Erosion is the geological process in which earthen materials are worn away and transported by natural forces such as wind or water.
Class parents	Biodiversity_index
Subclasses	
Sources	http://crossforest.eu/ifi/ontology/Erosion
Class name	Escaped_prescribed_fire

Class description	Prescribed fire that has exceeded prescription or is expected to exceed prescription or, for some other reason, meets criteria for conversion to wildfire. An escaped prescribed fire is considered a wildfire [91].
Class parents	Uncontrolled_fire
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html
Class name	Uncontrolled_fire
Class description	Fires that were not planned, but were started by arson, accident or lightning and burn out-of-control.
Class parents	Fire
Subclasses	Escaped_prescribed_fire, High-severity_fire, Low-severity_fire, Moderate-severity_fire, Replacement-severity_fire, Wildfire
Sources	http://cerrado.linkeddata.es/ecology/fire#UncontrolledFire
Class name	Evacuation
Class description	Evacuation of the interested area
Class parents	Response_procedure
Subclasses	
Sources	http://www.semanticweb.org/earthquake#Evacuation
Class name	Excitement
Class description	Wildfires set to gain attention and to meet the needs of being important. Seeking of thrill, attention, recognition, relief of boredom. Includes fires lit in order to admire the spectacle of extinguishing means.
Class parents	Responsible
Subclasses	
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	Extension
Class description	Extension in space
Class parents	Spatial_entity
Subclasses	
Sources	http://cerrado.linkeddata.es/ecology/fire#Extension
Class name	Extreme_fire_behavior
Class description	Fire behavior characteristics that ordinarily preclude methods of direct control action. One or more of the following is usually involved: high rate of spread, prolific crowning and/or spotting, presence of fire whirls, strong convection column. Characteristics of such fires may change rapidly and dangerously. Terms used to describe extreme fire behavior include "blowup", "flare-up", and "fire storm" [92].
Class parents	Fire_characteristic
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html

Class name	Extremist
Class description	Wildfire set to further social, political or religious causes: terrorism, discrimination, riots/civil disturbance.
Class parents	Responsible
Subclasses	
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	FRCC1
Class description	ecosystems with high (>66%) departure from reference conditions
Class parents	Fire_regime_condition_class
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html
Class name	FRCC2
Class description	ecosystems with moderate (33%-66%) departure
Class parents	Fire_regime_condition_class
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html
Class name	FRCC3
Class description	ecosystems with low (<33%) departure from a defined reference period; i.e., landscapes still within the natural or historical range of variation
Class parents	Fire_regime_condition_class
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html
Class name	Factory
Class description	A factory (previously manufactory) or manufacturing plant is an industrial site, usually consisting of buildings and machinery, or more commonly a complex having several buildings, where workers manufacture goods or operate machines processing one product into another.
Class parents	Industrial_building
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000536
Class name	Feaure_of_Interest
Class description	A feature of interest represents any real world entity from which a property is measured. It is linked to the different properties it has and to its measurements.
Class parents	Thing
Subclasses	
Sources	https://saref.etsi.org/core/FeatureOfInterest
Class name	Fence
Class description	A fence is a constructed barrier which is generally of lighter construction than a wall and used to provide visual sectioning of spaces.
Class parents	Constructed_barrier

Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000468
Class name	Fine_fuel_moisture
Class description	The Fine Fuel Moisture Code (FFMC) is a numeric rating of the moisture content of litter and other cured fine fuels. This code is an indicator of the relative ease of ignition and the flammability of fine fuel.
Class parents	Moisture
Subclasses	
Sources	https://cwfis.cfs.nrcan.gc.ca/background/summary/fwi
Class name	Fire-prone_invasive_species
Class description	Location of patches or individuals of fire-prone invasive species; their presence in the landscape aggravates the potential ecological and socio-economic effects of wildfires, thus requiring preventive measures to remove or control their expansion.
Class parents	Vegetation_type
Subclasses	
Sources	Portuguese pilot
Class name	Vegetation_type
Class description	Type of vegetation
Class parents	Biodiversity_index
Subclasses	Fire-prone_invasive_species, Fire-resistant_species, Fire-sensitive_species, Forest_type, Plant_type, Tree_type
Sources	Croatian pilot
Class name	Fire-resistant_species
Class description	Species with morphological characteristics that give it a lower probability of being injured or killed by fire than a fire-sensitive species
Class parents	Vegetation_type
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html
Class name	Fire-sensitive_species
Class description	A species with a "relatively high" probability of being injured or killed by fire [83]. Compare with fire-resistant species
Class parents	Vegetation_type
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html
Class name	Fire_Frequency
Class description	The average time interval between successive fires or the number of fires within a specific period of time.
Class parents	Fire_characteristic
Subclasses	
Sources	http://cerrado.linkeddata.es/ecology/fire#FireFrequency

Class name	Fire_Station
Class description	A Public Safety Facility that is designed for the storage of firefighting apparatus.
Class parents	Public_Safety_Facility
Subclasses	
Sources	http://www.ontologylibrary.mil/CommonCore/Mid/ArtifactOntology#FireStation
Class name	Public_Safety_Facility
Class description	A Facility that is designed for the prevention of and protection from events that could endanger, injure, or damage the general public.
Class parents	Building
Subclasses	Fire_Station, Police_Station
Sources	http://www.ontologylibrary.mil/CommonCore/Mid/ArtifactOntology#PublicSafetyFacility
Class name	Police_Station
Class description	A Public Safety Facility that is designed for the professional and clerical processes of a local police force.
Class parents	Public_Safety_Facility
Subclasses	
Sources	http://www.ontologylibrary.mil/CommonCore/Mid/ArtifactOntology#PoliceStation
Class name	Fire_access_path
Class description	Identification of fire access paths for fireghting apparatus
Class parents	Fire_characteristic
Subclasses	
Sources	French pilot
Class name	Fire_critical_point
Class description	The point where the fire increases intensity and / or speed
Class parents	Fire_characteristic
Subclasses	
Sources	Italian pilot
Class name	Fire_department
Class description	Represents fire departments.
Class parents	Infrastructure
Subclasses	
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#FireDepartment
Class name	Fire_distance
Class description	Distance of fire front from an individual

Class parents	Fire_characteristic
Subclasses	
Sources	Greek pilot
Class name	Fire_intensity
Class description	A general term relating to the heat energy released in a fire [63,83]. Wherever possible, FEIS uses more specific terms to describe rate of heat release. See fireline intensity below. Energy output from fire.
Class parents	Fire_characteristic
Subclasses	Fireline_intensity
Sources	https://www.fs.fed.us/database/feis/glossary2.html#FireIntensity, http://cerrado.linkeddata.es/ecology/fire#FireIntensity
Class name	Fire_interval
Class description	Number of years between two successive fires in a specified area. The size of the area must be clearly specified [83,91]. Often used to designate an average of intervals (i.e., mean fire interval).
Class parents	Temporal_entity
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html
Class name	Fire_prediction
Class description	Anticipation of fire development and development axes
Class parents	Fire_characteristic
Subclasses	
Sources	French pilot
Class name	Fire_severity
Class description	Fire severity generally indicates the degree of environmental change caused by fire [92,118]. The FRCC guidebook classifies levels of fire severity as low, mixed, and replacement.
Class parents	Fire_characteristic
Subclasses	Low, Mixed, No_fire_effects, Replacement
Sources	https://www.fs.fed.us/database/feis/glossary2.html, http://cerrado.linkeddata.es/ecology/fire#FireSeverity
Class name	Fire_spread_rate
Class description	it's the average speed of the fire front.
Class parents	Fire_characteristic
Subclasses	
Sources	http://cerrado.linkeddata.es/ecology/fire#FireSpeed
Class name	Fire_spread_direction
Class description	It's how the fire event is spreading, the directions.
Class parents	Fire_characteristic
Subclasses	

Sources	http://cerrado.linkeddata.es/ecology/fire#FireSpread
Class name	Fire_strategy
Class description	Plant species and populations have different strategies of responding to fires. Some species can survive fires (resprouters), disperse their seeds in the soil before fires (geosporous), others die (non-sprouters) or disperse seeds postfires (serotinous).
Class parents	Vegetation_stat
Subclasses	Geosporous, Non-resprouter, Resprouer, Serotinous
Sources	https://botany.one/2020/10/four-plant-strategies-to-deal-with-fire/
Class name	Firebreak
Class description	An obstacle to the spread of fire, such as a strip of open space in a forest. .The location of firebreaks (natural and man-made) is important for the modelling of the fire spread behaviour, as well as for monitoring the state of the firebreak and if it needs clearing.
Class parents	Response_resource
Subclasses	
Sources	
Class name	Firefighting_unit
Class description	Individual firefighter
Class parents	Responder
Subclasses	Professional_unit, Volunteer_unit
Sources	http://www.semanticweb.org/earthquake#FireBrigade
Class name	Fireline_intensity
Class description	The rate of heat release per unit time per unit length of fire front. Numerically, the product of the heat of combustion, quantity of fuel consumed per unit area in the fire front, and the rate of spread of a fire, expressed in kW/m [83]. Not synonymous with fire severity, which refers to the degree of environmental change caused by fire.
Class parents	Fire_intensity
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html#FirelineIntensity
Class name	First_Aid_Kit
Class description	First-aid kit items
Class parents	ReliefItem
Subclasses	
Sources	http://www.semanticweb.org/earthquake#First_Aid_Kit
Class name	Flame_ground_temperature
Class description	Ground temperature of the flames
Class parents	Fire_characteristic
Subclasses	

Sources	French pilot
Class name	Flame_height
Class description	The length of flames in a fire front measured along the slant of the flame, from the midpoint of its base to its tip. Flame length is mathematically related to fireline intensity and tree crown scorch height. Its the maximum height a flame achieve in a fire event.
Class parents	Fire_characteristic
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html, http://cerrado.linkeddata.es/ecology/fire#FlameHeight
Class name	Flower_Strip
Class description	A vegetated area which includes a community of flowering plants that provide food for local pollinators.
Class parents	Vegetated_area
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000848
Class name	FoodAndShelter
Class description	Sustainment for those affected by a fire
Class parents	Response_resource
Subclasses	
Sources	http://www.semanticweb.org/earthquake#FoodAndShelter
Class name	Forest_fire
Class description	A fire that occurs in a wooded area.
Class parents	Fire
Subclasses	
Sources	http://cerrado.linkeddata.es/ecology/fire#ForestFire
Class name	Forest_type
Class description	Type of Forest
Class parents	Vegetation_type
Subclasses	
Sources	http://crossforest.eu/ilu/ontology/ForestType
Class name	Garbage_collection
Class description	Represents garbage collection infrastructure and services.
Class parents	Infrastructure
Subclasses	
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#GarbageCollection
Class name	Gas_emission

Class description	Wildfire caused by natural emissions of gas (e.g. coming from peat bog) that can
Class parents	Natural
Subclasses	
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	Natural
Class description	Any wildfire caused by natural origin, with no human involvement in any way
Class parents	Cause
Subclasses	Gas_emission, Lightning, Volcanism
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	Gas_sensor
Class description	Gas sensors are devices that can detect the presence and concentration of various hazardous gases and vapors, such as toxic or explosive gases, volatile organic compounds (VOCs), humidity, and odors
Class parents	Chemical_sensor
Subclasses	
Sources	French pilot
Class name	Geocentric_Position
Class description	Position that uses a geodetic coordinate reference system
Class parents	Position
Subclasses	
Sources	http://crossforest.eu/position/ontology/GeocentricPosition
Class name	Geology
Class description	Geology describes the structure of the Earth on and beneath its surface, and the processes that have shaped that structure.
Class parents	Biodiversity_index
Subclasses	
Sources	Italian pilot
Class name	Geosporous
Class description	Species disperse their seeds in the soil before fires
Class parents	Fire_strategy
Subclasses	
Sources	https://botany.one/2020/10/four-plant-strategies-to-deal-with-fire/
Class name	Grassland
Class description	A formation dominated by grasses (>25% cover), with shrubs and trees constituting <25% of total cover [75]. Compare with shrubland, woodland, wooded shrubland, savanna, forest.
Class parents	Vegetated_area

Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html#grassland
Class name	Grassland_Area
Class description	An area in which grasses (Graminae) are a significant component of the vegetation.
Class parents	Vegetated_area
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_00000106
Class name	Grazing_activity
Class description	Report on grazing activity - areas of higher activity; daily, monthly and annual patterns of habitat selection and dominant behaviour per area (resting, grazing, moving/walking)
Class parents	Biodiversity_index
Subclasses	
Sources	Portuguese pilot
Class name	Ground_fire
Class description	Fire that burns in the organic material below the litter layer, mostly by smoldering combustion. Fires in duff, peat, dry or dead moss and lichens, and/or punky wood are typically ground fires [20].
Class parents	Fire
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html#GroundFire
Class name	Health_sensor
Class description	A sensor capable of collecting health-related parameters
Class parents	Sensor
Subclasses	Heart_rate_monitor, Spirometer
Sources	Greek pilot, Slovak pilot
Class name	Heart_rate_monitor
Class description	A heart rate monitor (HRM) is a personal monitoring device that allows one to measure/display heart rate in real time or record the heart rate for later study.
Class parents	Health_sensor
Subclasses	
Sources	AHEPA
Class name	Heath
Class description	An upland moor or sandy area dominated by low shrubby vegetation including heather.
Class parents	Vegetated_area
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_00000107
Class name	Hectares

Class description	The hectare is a non-SI metric unit of area equal to a square with 100-metre sides (1 hm2), or 10,000 m2, and is primarily used in the measurement of land.
Class parents	Spatial_entity
Subclasses	
Sources	http://crossforest.eu/measures/ontology/Hectares
Class name	Heliport
Class description	An Airport that is designed for launching, receiving, and housing Rotorcraft.
Class parents	Airport
Subclasses	
Sources	http://www.ontologylibrary.mil/CommonCore/Mid/ArtifactOntology#Heliport
Class name	High-intensity_fire
Class description	The high-intensity fires are set in order to clear a certain area, that is, to remove all fuel material.
Class parents	Hazard-reduction_fire
Subclasses	
Sources	http://cerrado.linkeddata.es/ecology/fire#HighIntensityFire
Class name	High-severity_fire
Class description	May refer to either high soil burn severity, high vegetation burn severity, or replacement-severity fire. As used in LANDFIRE, refers only to replacement-severity fires, which kill or top-kill more than 75% of the upper canopy layer [9]. Also see discussion of fire severity.
Class parents	Uncontrolled_fire
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html
Class name	Hospital
Class description	Represents hospitals.
Class parents	Infrastructure, Medical_Facility
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_00002173, https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Hospital
Class name	Medical_Facility
Class description	A place where sick or injured people are given care or treatment (as a hospital, urgent care center, or a clinic).
Class parents	Building
Subclasses	Hospital
Sources	http://www.ontologylibrary.mil/CommonCore/Mid/ArtifactOntology#HealthcareFacility, http://www.semanticweb.org/earthquake#HospitalLoss
Class name	Hot_ashes

Class description	Wildfire caused by hot ash handling by people after a barbecue or a fire. This class is related to recreational activities. Hot ashes related to work are classified in the following class.
Class parents	Use_of_glowing_objects
Subclasses	
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	HousingEquipment
Class description	Housing equipment items
Class parents	ReliefItem
Subclasses	
Sources	http://www.semanticweb.org/earthquake#HousingEquipment
Class name	HumanitarianAssistance
Class description	Humanitarian assistance
Class parents	Response_procedure
Subclasses	
Sources	http://www.semanticweb.org/earthquake#HumanitarianAssistance
Class name	Humidity
Class description	Measure of the amount of moisture in the air. It tells you how comfortable it is to be outside, and if there is enough moisture to create clouds and rain. Humidity may be absolute or relative. Absolute humidity is the amount of water vapor in a unit volume of air which is expressed in kilograms per cubic meter. It does not change according to the temperature of the air. When there is a high amount of water vapor in the air, absolute humidity will also be high.
Class parents	Climate_parameter
Subclasses	
Sources	https://bimerr.iot.linkeddata.es/def/weather#Humidity
Class name	Humidity_sensor
Class description	A humidity sensor is a device that detects and measures water vapor.
Class parents	IoT_sensor
Subclasses	
Sources	Most pilots
Class name	Hydrant
Class description	A fitting in a street or other public place with a nozzle by which a hose may be attached to a water main.
Class parents	Water_source
Subclasses	
Sources	Croatian pilot
Class name	Water_source

Class description	Refers to bodies of water (such as rivers, streams, lakes, reservoirs, springs, and ground water) that provide water to public drinking-water supplies and private wells. Water sources can include: Surface water (for example, a lake, river, or reservoir) Ground water (for example, an aquifer
Class parents	Response_resource
Subclasses	Hydrant
Sources	Portuguese pilot
Class name	Hydrography
Class description	Description of the physical features of oceans, seas, coastal areas, lakes and rivers, as well as with the prediction of their change over time
Class parents	Biodiversity_index
Subclasses	
Sources	Italian pilot
Class name	Image_analysis
Class description	Analysis of an image
Class parents	Data_analysis
Subclasses	
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#ImageAnalysis
Class name	Image_item
Class description	Represents an image item
Class parents	Media_item
Subclasses	
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#ImageItem
Class name	IncidentCommander
Class description	The incident commander is the person responsible for all aspects of an emergency response; including quickly developing incident objectives, managing all incident operations, application of resources as well as responsibility for all persons involved. The incident commander sets priorities and defines the organization of the incident response teams and the overall incident action plan.
Class parents	Responder
Subclasses	
Sources	http://www.semanticweb.org/earthquake#IncidentCommander
Class name	Infant
Class description	An infant is a child younger than one year of age
Class parents	Age_group
Subclasses	
Sources	https://w3id.org/empathi/Infant

Class name	Infantry_Fighting_Vehicle
Class description	An infantry fighting vehicle is a type of armoured fighting vehicle used to carry infantry into battle and provide direct-fire support
Class parents	Ground_Motor_Vehicle
Subclasses	
Sources	http://www.ontologylibrary.mil/CommonCore/Mid/ArtifactOntology#Infantry FightingVehicle
Class name	Infrared_camera
Class description	A device that creates an image using infrared (IR) radiation, similar to a normal camera that forms an image using visible light.
Class parents	Camera
Subclasses	
Sources	Czech pilot
Class name	Interest
Class description	Wildfire set for profit, either directly for monetary gain or from a goal other than money: fraud, insurance, liquidate property, dissolve business, inventory, employment, parcel clearance, competition for agricultural, forestry, hunting and pastoral purposes to frighten wildlife, to get a job in the fire fighting area, to change land-uses or to get a better salary as fire-fighter, etc.
Class parents	Responsible
Subclasses	
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	Irrigation
Class description	Represents irrigation systems
Class parents	Infrastructure
Subclasses	
Sources	http://www.semanticweb.org/earthquake#Irrigation
Class name	Land_use
Class description	Use and occupation of the land
Class parents	Biodiversity_index
Subclasses	
Sources	http://crossforest.eu/ilu/ontology/LandUse
Class name	Leevee
Class description	An embankment for preventing flooding.
Class parents	Structure
Subclasses	
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Levee
Class name	LeftBound

Class description	Left boundary of an area
Class parents	Spatial_entity
Subclasses	
Sources	http://crossforest.eu/position/ontology/LeftBound
Class name	Lightning
Class description	Wildfire caused directly or indirectly by lightning.
Class parents	Natural
Subclasses	
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	Locomotive
Class description	A self-propelled vehicle that runs on rails and is used for moving railroad cars
Class parents	Rail_Transport_Vehicle
Subclasses	
Sources	http://www.ontologylibrary.mil/CommonCore/Mid/ArtifactOntology#Locomotive
Class name	Rail_Transport_Vehicle
Class description	A vehicle used for the carrying of cargo or passengers on a rail transport system (a railroad/railway). Such cars, when coupled together and hauled by one or more locomotives, form a train.
Class parents	Ground_Vehicle
Subclasses	Locomotive, Train
Sources	http://www.ontologylibrary.mil/CommonCore/Mid/ArtifactOntology#RailTransportVehicle
Class name	Train
Class description	A connected line of railroad cars with or without a locomotive
Class parents	Rail_Transport_Vehicle
Subclasses	
Sources	http://www.ontologylibrary.mil/CommonCore/Mid/ArtifactOntology#Train
Class name	LogisticChief
Class description	The Logistics Section Chief Type 1 (LSC1) is responsible for managing, organizing, and supervising the Logistics section on wildland fire incidents and serves as a member of the Command and General Staff (C&G) for the Incident Management Team (IMT). The LSC1 supervises the Service (Communications, Medical, and Food) (SVBD) and Support (Supply, Facilities, and Ground Support) Branch Directors (SUBD) of the Logistics functional area and reports to the Incident Commander (IC). The LSC1 works in the Logistics functional area.
Class parents	Responder
Subclasses	

Sources	http://www.semanticweb.org/earthquake#LogisticChief
Class name	Low
Class description	A fire that has little effect on soil heating or on vegetation, especially the overstory vegetation
Class parents	Fire_severity
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html#LowSeverityFire
Class name	Low-severity_fire
Class description	A fire that has little effect on soil heating or on vegetation, especially the overstory vegetation [121]. As used in LANDFIRE, a low-severity fire is a surface fire that replaces less than 26% of the upper canopy layer, thus maintaining the site in a given successional stage [9]. Similar to understory fire, but can refer to grasslands and shrublands as well as forests and woodlands. See discussion of fire severity.
Class parents	Uncontrolled_fire
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html
Class name	LowerBound
Class description	Lower boundary of an area
Class parents	Spatial_entity
Subclasses	
Sources	http://crossforest.eu/position/ontology/LowerBound
Class name	Major_socio-economic_region
Class description	NUTS 1: major socio-economic regions
Class parents	NUTS_unit
Subclasses	
Sources	http://crossforest.eu/ifi/ontology/NUTS1
Class name	Mangrove_Biome
Class description	A mangrove biome is a terrestrial biome which includes, across its spatial extent, mangrove plants (Rhizophoraceae). Mangrove plants are able to withstand high levels of salinity as well as regions of anoxia and frequent tidal inundation. Mangrove biomes often occur near tropical and sub-tropical estuaries and depositional marine coastal environments where fine sediments (often with high organic content) collect in areas protected from high energy wave action.
Class parents	Terrestrial_Biome
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000181
Class name	Mean_height
Class description	Mean height of the vegetation

Class parents	Vegetation_stat
Subclasses	
Sources	
Class name	Measurable_Entity
Class description	Entity from which a measure or a number of measures is taken
Class parents	Thing
Subclasses	Measurable_Entity_in_Centimeters, Measurable_Entity_in_Decimeters, Measurable_Entity_in_Degrees, Measurable_Entity_in_Gradians, Measurable_Entity_in_Hectares, Measurable_Entity_in_Meters, Measurable_Entity_in_Millimeters, Measurable_Entity_in_Square_Meters, Measurable_Entity_in_Years
Sources	http://crossforest.eu/measures/ontology/MeasurableEntity
Class name	Measurable_Entity_in_Centimeters
Class description	
Class parents	Measurable_Entity
Subclasses	
Sources	http://crossforest.eu/measures/ontology/MeasurableEntityInCentimeters
Class name	Measurable_Entity_in_Decimeters
Class description	
Class parents	Measurable_Entity
Subclasses	
Sources	http://crossforest.eu/measures/ontology/MeasurableEntityInDecimeters
Class name	Measurable_Entity_in_Degrees
Class description	
Class parents	Measurable_Entity
Subclasses	
Sources	http://crossforest.eu/measures/ontology/MeasurableEntityInDegrees
Class name	Measurable_Entity_in_Gradians
Class description	
Class parents	Measurable_Entity
Subclasses	
Sources	http://crossforest.eu/measures/ontology/MeasurableEntityInGradians
Class name	Measurable_Entity_in_Hectares
Class description	
Class parents	Measurable_Entity
Subclasses	
Sources	http://crossforest.eu/measures/ontology/MeasurableEntityInHectares

Class name	Measurable_Entity_in_Meters
Class description	
Class parents	Measurable_Entity
Subclasses	
Sources	http://crossforest.eu/measures/ontology/MeasurableEntityInMeters
Class name	Measurable_Entity_in_Millimeters
Class description	
Class parents	Measurable_Entity
Subclasses	
Sources	http://crossforest.eu/measures/ontology/MeasurableEntityInMillimeters
Class name	Measurable_Entity_in_Square_Meters
Class description	
Class parents	Measurable_Entity
Subclasses	
Sources	http://crossforest.eu/measures/ontology/MeasurableEntityInSquareMeters
Class name	Measurable_Entity_in_Years
Class description	
Class parents	Measurable_Entity
Subclasses	
Sources	http://crossforest.eu/measures/ontology/MeasurableEntityInYears
Class name	MeasureInUnities
Class description	
Class parents	Biodiversity_index
Subclasses	Number_of_trees
Sources	http://crossforest.eu/measures/ontology/MeasureInUnities
Class name	Measure_In_Centimeters
Class description	
Class parents	Measure
Subclasses	
Sources	http://crossforest.eu/measures/ontology/MeasureInCentimeters
Class name	Measure_In_Decimeters
Class description	
Class parents	Measure
Subclasses	

Sources	http://crossforest.eu/measures/ontology/MeasureInDecimeters
Class name	Measure_In_Degrees
Class description	
Class parents	Measure
Subclasses	
Sources	http://crossforest.eu/measures/ontology/MeasureInDegrees
Class name	Measure_In_Gradians
Class description	
Class parents	Measure
Subclasses	
Sources	http://crossforest.eu/measures/ontology/MeasureInGradians
Class name	Measure_In_Hectares
Class description	
Class parents	Measure
Subclasses	
Sources	http://crossforest.eu/measures/ontology/MeasureInHectares
Class name	Measure_In_Meters
Class description	
Class parents	Measure
Subclasses	
Sources	http://crossforest.eu/measures/ontology/MeasureInMeters
Class name	Measure_In_Millimeters
Class description	
Class parents	Measure
Subclasses	
Sources	http://crossforest.eu/measures/ontology/MeasureInMillimeters
Class name	Measure_In_Percentage
Class description	
Class parents	Measure
Subclasses	
Sources	http://crossforest.eu/measures/ontology/MeasureInPercentage
Class name	Measure_In_SquareMeters
Class description	
Class parents	Measure

Subclasses	
Sources	http://crossforest.eu/measures/ontology/MeasureInSquareMeters
Class name	Measure_In_Unities
Class description	
Class parents	Measure
Subclasses	
Sources	http://crossforest.eu/measures/ontology/MeasureInUnities
Class name	Measure_In_Years
Class description	
Class parents	Measure
Subclasses	
Sources	http://crossforest.eu/measures/ontology/MeasureInYears
Class name	Years
Class description	Time measured in years
Class parents	Thing
Subclasses	
Sources	http://crossforest.eu/measures/ontology/Years
Class name	MedicalPlanningLeader
Class description	Person in charge of the medical planning
Class parents	Responder
Subclasses	
Sources	http://www.semanticweb.org/earthquake#MedicalPlanningLeader
Class name	MedicalStaff
Class description	Medical staff
Class parents	Responder
Subclasses	
Sources	http://www.semanticweb.org/earthquake#MedicalStaff
Class name	MedicalSupport
Class description	Medical support
Class parents	Response_procedure
Subclasses	
Sources	http://www.semanticweb.org/earthquake#MedicalSupport
Class name	Medical_equipment
Class description	Medical equipment to be used on the field

Class parents	Response_resource
Subclasses	Nebulizer
Sources	Greek pilot
Class name	Mediterranean_Biome
Class description	A biome which is subject to mediterranean climatic conditions.
Class parents	Biome
Subclasses	Mediterranean_Savanna_Biome, Mediterranean_Sea_Biome, Mediterranean_Shrubland_Biome, Mediterranean_Woodland_Biome
Sources	http://purl.obolibrary.org/obo/ENVO_01001833
Class name	Mediterranean_Savanna_Biome
Class description	A savanna biome which is subject to mediterranean climate patterns.
Class parents	Mediterranean_Biome
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000229
Class name	Mediterranean_Sea_Biome
Class description	The mediterranean sea biome comprises mostly enclosed seas that have limited exchange of deep water with outer oceans and where the water circulation is dominated by salinity and temperature differences rather than winds.
Class parents	Mediterranean_Biome
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000047
Class name	Mediterranean_Shrubland_Biome
Class description	A mediterranean shrubland biome is a subtropical shrubland biome which includes communities adapted to hot to warm, dry summers, mild to cold, rainy winters, and the influence of large, usually marine, bodies of water.
Class parents	Mediterranean_Biome
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000217
Class name	Mediterranean_Woodland_Biome
Class description	A subtropical woodland biome which includes communities adapted to hot to warm, dry summers, mild to cold, rainy winters, and the influence of large, usually marine, bodies of water.
Class parents	Mediterranean_Biome
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000208
Class name	Military_Facility
Class description	A Facility that is designed to support forces that are authorized to use deadly force and weapons to support the interests of the state and some or all of its citizens.
Class parents	Building

Subclasses	
Sources	http://www.ontologylibrary.mil/CommonCore/Mid/ArtifactOntology#Military Facility
Class name	Mixed
Class description	A fire that exhibits a wide range of fire severity as a result of surface fire in some patches, burning others with stand-replacement severity, and thinning the overstory in other patches. An equal proportion of low-, moderate-, and high-severity burning clearly fits into the mixed-severity fire class, but there is currently no standard by which to define what mix of fire severities should be classified as a mixed-severity fire
Class parents	Fire_severity
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html#MixedSeverityFire
Class name	Moderate-severity_fire
Class description	Fire that causes moderate soil heating. Occurs where litter is consumed and duff is charred or consumed, but the underlying mineral soil is not visibly altered [92,148]. Although thresholds are subjective, fire that kills from 30% to 70% of the upper canopy layer is generally considered moderate severity [121].
Class parents	Uncontrolled_fire
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html
Class name	Moisture_sensor
Class description	A moisture sensor is a device that detects and measures water vapor.
Class parents	IoT_sensor
Subclasses	
Sources	Most pilots
Class name	Montane_Biome
Class description	A biome which is subject to montane altitudinal conditions.
Class parents	Biome
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01001836
Class name	Montane_Shrubland_Biome
Class description	A montane shrubland biome is a shrubland biome which occurs in regions elevated above sea level and which has community structure determined by elevation-dependent environmental conditions.
Class parents	Shrubland_Biome
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000216
Class name	Shrubland_Biome

Class description	A shrubland biome is a terrestrial biome which includes, across its entire spatial extent, dense groups of shrubs.
Class parents	Terrestrial_Biome
Subclasses	Montane_Shrubland_Biome, Subtropical_Shrubland_Biome, Temperate_Shrubland_Biome, Tidal_Mangrove_Shrubland, Tropical_Shrubland_Biome, Xeric_Shrubland_Biome
Sources	http://purl.obolibrary.org/obo/ENVO_01000176
Class name	Monument
Class description	A structure or building that is built to honour a special person or event.
Class parents	Structure
Subclasses	
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Monument
Class name	Mortality_rate
Class description	Mortality rate of a species
Class parents	Living_being_stat
Subclasses	
Sources	Indonesian pilot
Class name	Motorcycle
Class description	A two-wheeled vehicle that is powered by a motor and has no pedals
Class parents	Ground_Motor_Vehicle
Subclasses	
Sources	http://www.ontologylibrary.mil/CommonCore/Mid/ArtifactOntology#Motorcycle
Class name	Natural_habitat
Class description	Represents natural habitats.
Class parents	Ecological_asset
Subclasses	
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#NaturalHabitat
Class name	Nebulizer
Class description	A nebulizer changes medication from a liquid to a mist so you can inhale it into your lungs.
Class parents	Medical_equipment
Subclasses	
Sources	Greek pilot
Class name	No_fire_effects
Class description	A fire that has no effect on soil heating or on vegetation, especially the overstory vegetation

Class parents	Fire_severity
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html#FireSeverity
Class name	Non-resprouter
Class description	Species die following a fire
Class parents	Fire_strategy
Subclasses	
Sources	https://botany.one/2020/10/four-plant-strategies-to-deal-with-fire/
Class name	Number_of_trees
Class description	Number of trees in an area
Class parents	MeasureInUnities
Subclasses	
Sources	http://crossforest.eu/ifi/ontology/NumberOfTrees
Class name	Oasis
Class description	An oasis is a vegetated area located in a desert, supplied with water from a water source which it surrounds, and surrounded by arid soil, sand, or rock.
Class parents	Vegetated_area
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01001304
Class name	Ocean_Biome
Class description	A marine biome which is determined by an ocean.
Class parents	Biome
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000048
Class name	Oil_pipeline_network
Class description	A pipeline network which is used to transport oil to consumers.
Class parents	Pipeline_network
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_03600003
Class name	OperationChief
Class description	The Operations Chief: Is responsible to the Incident Commander for the direct management of all incident-related operational activities Establishes tactical objectives for each operational period Has direct involvement in the preparation of the Incident Action Plan The Operations Section Chief may have one or more Deputies assigned. The assignment of Deputies from other agencies may be advantageous in the case of multijurisdictional incidents.
Class parents	Responder
Subclasses	

Sources	http://www.semanticweb.org/earthquake#OperationChief
Class name	Other_accident
Class description	Wildfire caused by other accidental cause (Other technical incidents) than those previously defined. In this class are coded the wildfires due to “Sun” because the sun alone does not allow the ignition but needs an object like a piece of glass. Also included are causes such as “Glass”, “Friction energy”, “thermal reaction of chemicals” or “Self-ignition of coal”.
Class parents	Accident
Subclasses	
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	Other_negligent_use_of_fire
Class description	Wildfire caused by other use of fire than those previously defined. In this class are coded the wildfires due to “bonfires at work” “facility fires” and “Candles”.
Class parents	Use_of_fire
Subclasses	
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	Other_use_of_glowing_objects
Class description	Wildfire caused by other use of glowing object than those previously defined. In this class are coded wildfires due to working activities such as apiculture, fumigation or disinfection or due to glowing firebrands expulsed out of chimneys regardless of the building.
Class parents	Use_of_glowing_objects
Subclasses	
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	Overhead_lines
Class description	An overhead power line is a structure used in electric power transmission and distribution to transmit electrical energy across large distances. It consists of one or more uninsulated electrical cables (commonly multiples of three for three-phase power) suspended by towers or poles.
Class parents	Energy
Subclasses	
Sources	Portuguese pilot
Class name	Substation
Class description	A substation is a part of an electrical generation, transmission, and distribution system. Substations transform voltage from high to low, or the reverse, or perform any of several other important functions. Between the generating station and consumer, electric power may flow through several substations at different voltage levels. A substation may include transformers to change voltage levels between high transmission voltages and lower distribution voltages, or at the interconnection of two different transmission voltages.

Class parents	Energy
Subclasses	
Sources	Portuguese pilot
Class name	Passive_crown_fire
Class description	A type of crown fire in which the crowns of individual trees or small groups of trees burn, but solid flaming in the canopy cannot be maintained except for short periods. Passive crown fire encompasses a wide range of crown fire behavior, from occasional torching of isolated trees to nearly active crown fire. Passive crown fire is also called torching or candling. A fire in the crowns of the trees in which trees or groups of trees torch, ignited by the passing front of the fire. The torching trees reinforce the spread rate, but these fires are not basically different from surface fires
Class parents	Crown_fire
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html
Class name	Patrol
Class description	An expedition to keep watch over an area, especially by guards or police walking or driving around at regular intervals.
Class parents	Responder
Subclasses	
Sources	Italian pilot
Class name	Pier
Class description	A Transportation Facility that is designed to partially enclose a harbor and form a landing place for Watercraft.
Class parents	Transportation_Facility
Subclasses	
Sources	http://www.ontologylibrary.mil/CommonCore/Mid/ArtifactOntology#Pier
Class name	PlanningChief
Class description	The Planning Section Chief oversees incident-related data gathering and analysis regarding incident operations and assigned resources, facilitates incident action planning meetings and prepares the Incident Action Plan (IAP) for each operational period
Class parents	Responder
Subclasses	
Sources	http://www.semanticweb.org/earthquake#PlanningChief
Class name	Plant
Class description	Represents the fauna.
Class parents	Ecological_asset
Subclasses	
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Plant
Class name	Plant_type

Class description	Type of plant
Class parents	Vegetation_type
Subclasses	
Sources	
Class name	Polar_Biome
Class description	A biome which is subject to polar climatic conditions.
Class parents	Biome
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000339
Class name	Police
Class description	Represents law enforcement infrastructure and services.
Class parents	Infrastructure
Subclasses	
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Police
Class name	Polygon
Class description	A plane figure with at least three straight sides and angles, and typically five or more.
Class parents	Position
Subclasses	
Sources	http://crossforest.eu/position/ontology/Polygon
Class name	Population
Class description	Population rate of a species
Class parents	Living_being_stat
Subclasses	
Sources	Indonesian pilot
Class name	Population_index
Class description	Any indicator of the size of a population (e.g., mountain bluebird nests/km2) [43].
Class parents	Biodiversity_index
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html#PopulationIndex
Class name	Port
Class description	A Transportation Facility that is designed to contain harbors for docking Watercraft and for transfering people or cargo to and from land.
Class parents	Transportation_Facility
Subclasses	
Sources	http://www.ontologylibrary.mil/CommonCore/Mid/ArtifactOntology#Port, http://www.semanticweb.org/earthquake#PortLoss

Class name	Power_line
Class description	Power line to use for equipment
Class parents	Response_resource
Subclasses	
Sources	Italian pilot
Class name	Power_plant
Class description	A power plant is a building which contains one or more generators which convert mechanical energy into electrical energy through the relative motion between a magnetic field and a conductor. The energy source harnessed to turn the generator varies widely.
Class parents	Industrial_building
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_00002214, http://www.semanticweb.org/earthquake#ElectricFacility, https://w3id.org/empathi/Electricity
Class name	Professional_unit
Class description	Professional firefighter
Class parents	Firefighting_unit
Subclasses	
Sources	Czech pilot
Class name	PublicInfoOfficer
Class description	The PIO is the individual responsible for communicating with the public, media, and/or coordinating with other agencies, as necessary, with incident related information requirements.
Class parents	Responder
Subclasses	
Sources	http://www.semanticweb.org/earthquake#PublicInfoOfficer
Class name	Public_street
Class description	A road which is publically accessible.
Class parents	Street
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000780
Class name	Public_transport
Class description	Represents public transportation services and infrastructure.
Class parents	Transportation
Subclasses	
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#PublicTransportation

Class name	Pumping_station
Class description	Facilities containing pumps and equipment for pumping fluids from one place to another. They are used for a variety of infrastructure systems, such as the supply of water to canals, the drainage of low-lying land, and the removal of sewage to processing sites.
Class parents	Water_supply
Subclasses	
Sources	Portuguese pilot
Class name	Rail_Facility
Class description	A Transportation Facility that is designed for transferring people or cargo to and from Trains.
Class parents	Building
Subclasses	
Sources	http://www.ontologylibrary.mil/CommonCore/Mid/ArtifactOntology#RailFacility, http://www.semanticweb.org/earthquake#RailwayLoss
Class name	Railroads
Class description	Wildfire caused by sparks emitted by train brakes or fall of catenaries. It has to be linked with the operation of trains. Fires lit intentionally or not by passengers or railway employees (by smoking, managing vegetation, etc.) are not classified in this category and must be classified in the category corresponding to “what these persons did” to set the fire (and not to “where they were”).
Class parents	Accident
Subclasses	
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	Rangeland_Biome
Class description	A rangeland biome is an anthropogenic terrestrial biome which is primarily used for the rearing and grazing of livestock.
Class parents	Anthropogenic_Terrestrial_Biome
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000247
Class name	Recreation
Class description	Wildfire caused by people engaged in a recreational activity (vacationing, fishing, picnicking, non-commercial berry picking, hiking, and hunting) setting barbecues, bonfires and campfires of any kind (for cooking, heating, etc).
Class parents	Use_of_fire
Subclasses	
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	Reference_Position
Class description	Position taken as reference for the position of other spatial entities

Class parents	Position
Subclasses	
Sources	http://crossforest.eu/position/ontology/ReferencePosition
Class name	RehabilitationAndRecovery
Class description	Restoration of the environment
Class parents	Response_procedure
Subclasses	
Sources	http://www.semanticweb.org/earthquake#RehabilitationAndRecovery
Class name	Rekindle
Class description	Wildfire caused by re-ignition of a previous fire, due to latent heat or embers.
Class parents	Cause
Subclasses	
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	Relative_humidity
Class description	Humidity is associated with the water content in gaseous phase present in the air.Relative humidity is the percentage or ratio of the amount of water vapor in a volume of air at a given temperature and the amount that it can hold at that given temperature. An amount of water vapor in warm air will result to a lower relative humidity than in cool air.
Class parents	Climate_parameter
Subclasses	
Sources	"https://cwfis.cfs.nrcan.gc.ca/background/summary/fwi
Class name	Replacement
Class description	A fire that causes >75% kill or top-kill of the upper canopy layer (>80%, according to Smith's [122] definition of stand-replacing fire), reverting vegetation to an earlier successional stage. Can be applied to all vegetation formations (forests, woodlands, shrublands, and grasslands). Replacement-severity fire may kill or only top-kill the plants in the upper canopy layer. LANDFIRE documentation states explicitly that replacement of the upper canopy can occur in any vegetation formation: "replacement fire in grassland removes the leaves, but leaves sprout from the basal crown, whereas replacement fire in most conifers causes mortality of the plant"
Class parents	Fire_severity
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html#ReplacementSeverityFire
Class name	Replacement-severity_fire
Class description	A fire that causes >75% kill or top-kill of the upper canopy layer (>80%, according to Smith's [122] definition of stand-replacing fire), reverting vegetation to an earlier successional stage. Can be applied to all vegetation formations (forests, woodlands, shrublands, and grasslands). Replacement-severity fire may kill or only top-kill the plants in the upper canopy layer.

	LANDFIRE documentation states explicitly that replacement of the upper canopy can occur in any vegetation formation: "replacement fire in grassland removes the leaves, but leaves sprout from the basal crown, whereas replacement fire in most conifers causes mortality of the plant" [9]. See stand-replacement fire and fire severity.
Class parents	Uncontrolled_fire
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html
Class name	RescueTeam
Class description	Rescue team
Class parents	Response_resource
Subclasses	
Sources	http://www.semanticweb.org/earthquake#RescueTeam
Class name	Reservoir
Class description	Water reservoirs locations for airborne firefighting water tanks refilling. Include only the possible locations.
Class parents	Water_supply
Subclasses	
Sources	Portuguese pilot
Class name	ResourceUnitLeader
Class description	The Resources Unit Leader (RESL) establishes all incident check-in activities including preparing and processing resource status information and maintaining a master list of resources assigned to the incident and their assignment at the incident. The RESL supervises the Status/Check-in Recorder (SCKN) and reports to the Planning Section Chief (PSC). The RESL works in the Planning functional area.
Class parents	Responder
Subclasses	
Sources	http://www.semanticweb.org/earthquake#ResourceUnitLeader
Class name	Resprouer
Class description	Species can survive fires and resprout
Class parents	Fire_strategy
Subclasses	
Sources	https://botany.one/2020/10/four-plant-strategies-to-deal-with-fire/
Class name	Serotinous
Class description	Species disperse seeds postfires
Class parents	Fire_strategy
Subclasses	
Sources	https://botany.one/2020/10/four-plant-strategies-to-deal-with-fire/
Class name	RightBound

Class description	Right boundary of an area
Class parents	Spatial_entity
Subclasses	
Sources	http://crossforest.eu/position/ontology/RightBound
Class name	River
Class description	Represents rivers.
Class parents	Ecological_asset
Subclasses	
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#River
Class name	Rreaction_intensity
Class description	The energy release rate of the fire front. The energy is released when burning gases are released from combustable organic matter in fuels; therefore, fuel parameters including particle size, bulk density, moisture, and chemical composition are factors determining reation intensity. Expressed as the amount of heat released/unit area2 [115].
Class parents	Fire_characteristic
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html#ReactionIntensity
Class name	SafetyOfficer
Class description	Safety officers will be responsible for the following: Identifying safety issues Starting corrective action Maintaining safe systems of work; Ensuring people are wearing appropriate personal protection equipment Observing the working environment Monitoring physical condition of crews Regular reviews Recording an analytical risk assessment Updating the incident commander when circumstances change This is not an exhaustive list.
Class parents	Responder
Subclasses	
Sources	http://www.semanticweb.org/earthquake#SafetyOfficer
Class name	SanitaryEquipment
Class description	Sanitary equipment items
Class parents	ReliefItem
Subclasses	
Sources	http://www.semanticweb.org/earthquake#SanitaryEquipment
Class name	Satellite
Class description	An artificial body placed in orbit round the earth or moon or another planet in order to collect information or for communication.
Class parents	Sensor
Subclasses	
Sources	Most pilots

Class name	Savanna
Class description	A formation in which the overstory is dominated by woody vegetation growing as scattered individuals or clusters. The dominant life form may be trees (i.e., tree savanna; dominants are >6.5 feet (2 m) tall) or shrubs (i.e., shrub savanna; dominants are ≤6.5 feet (2 m) tall) [112]. The understory is composed of grass; shrubs are sparse to absent [113,120]. When describing savannas, use of a hyphen indicates about equal cover of dominant overstory and understory species (e.g., Oregon white oak-California brome savanna). Compare with grassland, shrubland woodland, wooded shrubland, forest.
Class parents	Vegetated_area
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html#savanna
Class name	Sawmill
Class description	A building within which logs are cut into lumber products.
Class parents	Industrial_building
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_00004638
Class name	Scrub_fire
Class description	A fire in scrubby trees.
Class parents	Fire
Subclasses	
Sources	http://cerrado.linkeddata.es/ecology/fire#ScrubFire
Class name	Scrubland_Area
Class description	Area covered with low-growing or stunted perennial vegetation and usually not mixed with trees.
Class parents	Vegetated_area
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_00000300
Class name	SearchAndRescue
Class description	Search and rescue operations
Class parents	Response_procedure
Subclasses	
Sources	http://www.semanticweb.org/earthquake#SearchAndRescue
Class name	Season
Class description	Season of the year
Class parents	Climate_parameter
Subclasses	
Sources	https://bimerr.iot.linkeddata.es/def/weather#Season
Class name	Self-ignition

Class description	Wildfire caused by self-ignition of vegetation wastes and other products left in piles.
Class parents	Accident
Subclasses	
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	Sewer
Class description	Represents sewage infrastructure.
Class parents	Infrastructure
Subclasses	
Sources	http://www.semanticweb.org/earthquake#SewageSystem, https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Sewer
Class name	Shrubland
Class description	A formation in which the overstory is dominated by shrubs 1.6 to 16 feet (0.5-5 m) tall, and trees have <5% total cover [75]. Compare with grassland, woodland, wooded shrubland, savanna, forest.
Class parents	Vegetated_area
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html#shrubland
Class name	Sky_Cover
Class description	The extent to which the sky is obscured by clouds.
Class parents	Climate_parameter
Subclasses	
Sources	https://bimerr.iot.linkeddata.es/def/weather#SkyCover
Class name	Small_region_for_specific_diagnoses
Class description	NUTS 3: as small regions for specific diagnoses
Class parents	NUTS_unit
Subclasses	
Sources	http://crossforest.eu/ifi/ontology/NUTS3
Class name	Smoke_amount
Class description	Amount of smoke in the air
Class parents	Fire_characteristic
Subclasses	
Sources	French pilot
Class name	Smoke_detector
Class description	A smoke detector is a device that senses smoke, typically as an indicator of fire.
Class parents	Chemical_sensor

Subclasses	
Sources	French pilot
Class name	Soil
Class description	Ground properties where the measures are made.
Class parents	Evnironment_index
Subclasses	
Sources	https://bimerr.iot.linkeddata.es/def/weather#Ground
Class name	Soil_pH
Class description	Soil pH is a measure of the acidity or basicity (alkalinity) of a soil. Soil pH is a key characteristic that can be used to make informative analysis both qualitative and quantitatively regarding soil characteristics.
Class parents	Evnironment_index
Subclasses	
Sources	Indonesian pilot
Class name	Soil_structure
Class description	Soil structure describes the arrangement of the solid parts of the soil and of the pore spaces located between them (Marshall & Holmes, 1979).
Class parents	Evnironment_index
Subclasses	
Sources	Indonesian pilot
Class name	Soil_type
Class description	A soil type is a taxonomic unit in soil science. All soils that share a certain set of well-defined properties form a distinctive soil type.[1] Soil type is a technical term of soil classification, the science that deals with the systematic categorization of soils. Every soil of the world belongs to a certain soil type. Soil type is an abstract term. In nature, you will not find soil types. You will find soils that belong to a certain soil type.
Class parents	Evnironment_index
Subclasses	
Sources	Indonesian pilot
Class name	Species_richness
Class description	The number of different species represented in an ecological community, landscape or region [26].
Class parents	Biodiversity_index
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html
Class name	Spirometer
Class description	A spirometer is an apparatus for measuring the volume of air inspired and expired by the lungs. A spirometer measures ventilation, the movement of air into and out of the lungs. The spirogram will identify two different types of abnormal ventilation patterns, obstructive and restrictive.
Class parents	Health_sensor

Subclasses	
Sources	AHEPA
Class name	Square
Class description	Represents squares in danger during an environmental crisis.
Class parents	Structure
Subclasses	
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Square
Class name	Starting_point
Class description	Starting point of a space
Class parents	Spatial_entity
Subclasses	
Sources	http://cerrado.linkeddata.es/ecology/fire#StartingPoint
Class name	Starting_time
Class description	Starting timestamp of an event
Class parents	Temporal_entity
Subclasses	
Sources	http://cerrado.linkeddata.es/ecology/fire#StartingTime
Class name	Static_camera
Class description	Static Camera means a Body type or Non-PTZ camera installed in a fixed position at a fixed field of view. Static Cameras may have variable zoom capabilities.
Class parents	Camera
Subclasses	
Sources	Italian pilot
Class name	Subalpine_Biome
Class description	A biome which is subject to subapline altitudinal conditions.
Class parents	Biome
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01001837
Class name	Subpolar_Biome
Class description	A biome which is subject to subpolar climatic conditions.
Class parents	Biome
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01001834
Class name	Subtropical_Biome

Class description	A biome which is subject to subtropical climatic conditions.
Class parents	Biome
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01001832
Class name	Subtropical_Shrubland_Biome
Class description	A shrubland biome which is subject to subtropical climate patterns.
Class parents	Shrubland_Biome
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000213
Class name	Summer_camp
Class description	A camp providing recreational and sporting facilities for children during the summer holiday period.
Class parents	Building
Subclasses	
Sources	
Class name	SupplyGood
Class description	Materials
Class parents	Item
Subclasses	
Sources	http://www.semanticweb.org/earthquake#SupplyGood
Class name	SupplyGoodSupport
Class description	Support to the supply of goods
Class parents	Response_procedure
Subclasses	
Sources	http://www.semanticweb.org/earthquake#SupplyGoodSupport
Class name	SupplyLeader
Class description	The Supply Leader (SPUL) is primarily responsible for ordering personnel, equipment, and supplies for wildland fire incidents. The SPUL is responsible for overseeing and supervising the ordering and receiving process and determining the right size inventory for the incident.
Class parents	Responder
Subclasses	
Sources	http://www.semanticweb.org/earthquake#SupplyLeader
Class name	Tank
Class description	An enclosed heavily armed and armored combat vehicle that moves on tracks
Class parents	Ground_Motor_Vehicle
Subclasses	

Sources	http://www.ontologylibrary.mil/CommonCore/Mid/ArtifactOntology#Tank
Class name	TaskForceSectorLeader
Class description	The Task Force Leader (TFLD) directs any combination of personnel, crews and different types of Incident Command System (ICS) equipment in performing tactical missions on a division or segment of a division, on wildland fire incidents. The TFLD reports to a Division/Group Supervisor (DIVS), Incident Commander (IC), or other assigned supervisor. The TFLD works in the Operations functional area.
Class parents	Responder
Subclasses	
Sources	http://www.semanticweb.org/earthquake#TaskForceSectorLeader
Class name	Temperate_Biome
Class description	A biome which is subject to temperate climatic conditions.
Class parents	Biome
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01001831
Class name	Temperate_Shrubland_Biome
Class description	A shrubland biome which is subject to temperate climate patterns.
Class parents	Shrubland_Biome
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000215
Class name	Text_analysis
Class description	Analysis of a text
Class parents	Data_analysis
Subclasses	
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#TextAnalysis
Class name	Text_item
Class description	Represents a text item
Class parents	Media_item
Subclasses	
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#TextItem
Class name	Thermometer
Class description	An instrument for measuring and indicating temperature
Class parents	IoT_sensor
Subclasses	
Sources	Most pilots

Class name	Thickness_of_Dead_Layer
Class description	Thickness of Dead Layer
Class parents	Biodiversity_index
Subclasses	
Sources	http://crossforest.eu/ifi/ontology/DeadLayer
Class name	Tidal_Mangrove_Shrubland
Class description	A shrubland biome which is densely vegetated by dwarf or short mangroves (and associates) that are generally less than 6 meters in height, is tidally influenced, is located in tropical or subtropical areas.
Class parents	Shrubland_Biome
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01001369
Class name	Time_since_last_precipitation
Class description	Period without precipitations in a given area
Class parents	Climate_parameter
Subclasses	
Sources	Croatian pilot
Class name	Topography
Class description	Topography of the terrain, as it is important for the modelling of the fire spread behaviour, as well as for the coordination of firefighting crews.
Class parents	Biodiversity_index
Subclasses	
Sources	Italian pilot, Portuguese pilot
Class name	Total_heat_release
Class description	The heat released by combustion during burnout of all fuels, expressed in BTU/foot2 or Kcal/meter2 [20].
Class parents	Fire_characteristic
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html
Class name	Tourist_flow_sensor
Class description	A people counter is an electronic device that is used to measure the number of people traversing a certain passage or entrance. Examples include simple manual clickers, smart-flooring technologies, infrared beams, thermal imaging systems, WiFi trackers and video counters using advanced machine learning algorithms.
Class parents	Sensor
Subclasses	
Sources	Romanian pilot
Class name	Touristic_route

Class description	An established or selected course for travel consisting, typically, of secondary roads with significant scenic, cultural, historic, geological or natural features and including vistas, rest areas, and interpretive sites matching the scenic characteristics of the course.
Class parents	Transportation
Subclasses	
Sources	Slovak pilot
Class name	Track
Class description	A small road, generally not paved.
Class parents	Street
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_00000122
Class name	Transmission_tower
Class description	A transmission tower is a tall structure, usually a steel lattice tower, used to support an overhead power line.
Class parents	Energy
Subclasses	
Sources	Portuguese pilot
Class name	Tree_type
Class description	Type of tree
Class parents	Vegetation_type
Subclasses	
Sources	
Class name	Tropical_Biome
Class description	A biome which is subject to tropical climatic conditions.
Class parents	Biome
Subclasses	Tropical_Marginal_Sea_Biome, Tropical_Marine_Coral_Reef_Biome, Tropical_Marine_Upwelling_Biome, Tropical_Savanna_Biome, Tropical_Shrubland_Biome, Tropical_Woodland_Biome
Sources	http://purl.obolibrary.org/obo/ENVO_01001830
Class name	Tropical_Marginal_Sea_Biome
Class description	A marginal sea biome which is located in a region with a tropical climate.
Class parents	Tropical_Biome
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01001230
Class name	Tropical_Marine_Coral_Reef_Biome
Class description	A marine coral reef biome which is located in a region with a tropical climate.
Class parents	Tropical_Biome

Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000854
Class name	Tropical_Marine_Upwelling_Biome
Class description	A marine upwelling biome which is subject to tropical climate patterns.
Class parents	Tropical_Biome
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000859
Class name	Tropical_Savanna_Biome
Class description	A savanna biome which is located in a region with a tropical climate.
Class parents	Tropical_Biome
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000188
Class name	Tropical_Shrubland_Biome
Class description	A shrubland biome which is subject to tropical climate patterns.
Class parents	Shrubland_Biome, Tropical_Biome
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000214
Class name	Tropical_Woodland_Biome
Class description	A woodland biome which is located in a region with a tropical climate.
Class parents	Tropical_Biome
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000220
Class name	Truck
Class description	A wheeled vehicle for moving heavy articles
Class parents	Ground_Motor_Vehicle
Subclasses	
Sources	http://www.ontologylibrary.mil/CommonCore/Mid/ArtifactOntology#Truck
Class name	Tundra_Biome
Class description	A terrestrial biome which comprises a tundra ecosystem that has reached its climax community.
Class parents	Terrestrial_Biome
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000180
Class name	UAV
Class description	An unmanned aerial vehicle (UAV), commonly known as a drone, is an aircraft without any human pilot, crew, or passengers on board.

Class parents	IoT_sensor
Subclasses	
Sources	Most pilots
Class name	UGV
Class description	An unmanned ground vehicle (UGV) is a vehicle that operates while in contact with the ground and without an onboard human presence.
Class parents	IoT_sensor
Subclasses	
Sources	Most pilots
Class name	Unknown
Class description	Wildfire with no cause found
Class parents	Cause
Subclasses	
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	UpperBound
Class description	Upper boundary of an area
Class parents	Spatial_entity
Subclasses	
Sources	http://crossforest.eu/position/ontology/UpperBound
Class name	Vandalism
Class description	Malicious or mischievous fire setting that results in damage to property: wilful and malicious mischief or peer group pressure
Class parents	Responsible
Subclasses	
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	Vegetation_growth
Class description	Estimation in the temporal dimension of when the vegetation or biomass, will reach a predetermined size or density, through the development of a vegetation growth rate. This will optimize the clearing interventions.
Class parents	Biodiversity_index
Subclasses	
Sources	Portuguese pilot
Class name	Vegetation_index
Class description	
Class parents	Biodiversity_index
Subclasses	
Sources	Portugues pilot

Class name	Vegetation_management
Class description	Wildfire caused by any kind of vegetation burnings for private, forestry, pastoral (pasture regeneration) purposes including prescribed burnings, burning of slashes or of piles of vegetal waste but except for agricultural purposes.
Class parents	Use_of_fire
Subclasses	
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	Vegetation_quantity
Class description	Quantity of vegetation
Class parents	Biodiversity_index
Subclasses	
Sources	Croatian pilot
Class name	Vegetation_vertical_structure
Class description	Forest understory growth can greatly contribute to the spread and to severe canopy forest fires. Vegetation management may be required, including the use of livestock grazing coupled (or not) with mechanized interventions. Identification of areas with dense and continuous undergrowth is needed to guide management and plan interventions.
Class parents	Biodiversity_index
Subclasses	
Sources	Portugues pilot
Class name	Vehicles
Class description	Wildfire caused by exhausts (expulsion of glowing carbon deposits, hot catalytic converter) and brakes of vehicles travelling along the road, or by road incidents (Burning motor for example) or traffic accidents
Class parents	Accident
Subclasses	
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	Video_analysis
Class description	Analysis of a video
Class parents	Data_analysis
Subclasses	
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#VideoAnalysis
Class name	Video_item
Class description	Represents a video item
Class parents	Media_item
Subclasses	

Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#VideoItem
Class name	Village_Biome
Class description	A village biome is an anthropogenic terrestrial biome which contains settlements such as villages, towns, and/or small cities and which is primarily used for agricultural activity.
Class parents	Anthropogenic_Terrestrial_Biome
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000246
Class name	Volcanism
Class description	Wildfire caused by volcanism.
Class parents	Natural
Subclasses	
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	Volunteer_unit
Class description	Volunteer firefighter
Class parents	Firefighting_unit
Subclasses	
Sources	Czech pilot, http://www.semanticweb.org/earthquake#Volunteer
Class name	Wall
Class description	A vertical structure often made of stone or brick that divides or surrounds something.
Class parents	Structure
Subclasses	
Sources	https://raw.githubusercontent.com/beAWARE-project/ontology/master/beAWARE_ontology#Wall
Class name	Waste_management
Class description	Wildfire caused by garbage burnings in official or illegal dumps (dunghill) including
Class parents	Use_of_fire
Subclasses	
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	WaterFacility
Class description	Any plants, structures and other real and personal property acquired, rehabilitated or constructed or planned for the purpose of accumulating, supplying, transmitting, treating or distributing water, including but not limited to surface or groundwater reservoirs, basins, dams, canals, aqueducts, aqueduct taps, standpipes, conduits, pipelines, mains, pumping stations,

	pumps, water distribution systems, compensating reservoirs, intake stations, waterworks or sources of water supply, wells and purification.
Class parents	Building
Subclasses	
Sources	http://www.semanticweb.org/earthquake#WaterFacility, https://w3id.org/empathi/Water
Class name	Water_infrastructures_criticality
Class description	Criticallity, based on the design flow and system´s redundancy characteristics
Class parents	Thing
Subclasses	
Sources	Portuguese pilot
Class name	Watercraft
Class description	Craft for water transport
Class parents	Response_vehicle
Subclasses	
Sources	http://www.ontologylibrary.mil/CommonCore/Mid/ArtifactOntology#Watercraft
Class name	Weapons
Class description	Wildfire caused either by military exercises (firing, explosions) or by citizens using firearms (in hunting activities for instance) or explosion due to explosives during works. This class takes also into account the fires set after explosions due to ammunitions from I and II World Wars buried underground.
Class parents	Accident
Subclasses	
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	Weather_station
Class description	A weather station is a facility, either on land or sea, with instruments and equipment for measuring atmospheric conditions to provide information for weather forecasts and to study the weather and climate. The measurements taken include temperature, atmospheric pressure, humidity, wind speed, wind direction, and precipitation amounts.
Class parents	Sensor
Subclasses	
Sources	
Class name	Wetland_Area
Class description	A vegetated area which overlaps a wetland ecosystem.
Class parents	Vegetated_area
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_00000043

Class name	Wildfire
Class description	A fire burning in wildland fuel.
Class parents	Uncontrolled_fire
Subclasses	
Sources	http://cerrado.linkeddata.es/ecology/fire#Wildfire, http://www.semanticweb.org/earthquake#WildFire
Class name	Wind_direction
Class description	Wind direction
Class parents	Wind_condition
Subclasses	
Sources	https://cwfis.cfs.nrcan.gc.ca/background/summary/fwi
Class name	Wooded_shrubland
Class description	A formation dominated by woody species, in which the proportion of shrubs is generally greater than the proportion of trees [112]. Grass and bare ground are usually present but not required for defining this formation. Compare with grassland, shrubland, wooded shrubland, savanna, forest.
Class parents	Vegetated_area
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html#WoodedShrubland
Class name	Woodland
Class description	A formation in which tree cover is greater than shrub cover, but the canopy is not closed [112]. Generally, overstory trees are >16 feet (5 m) tall and have 25% to 60% cover [75]. When describing woodlands, use of a dash indicates an overstory/understory relationship (e.g., bur oak/big bluestem woodland). Compare with grassland, shrubland, wooded shrubland, savanna, forest.
Class parents	Vegetated_area
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html#woodland
Class name	Woodland_Area
Class description	Land having a cover of trees, shrubs, or both.
Class parents	Vegetated_area
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_00000109
Class name	Woodland_Biome
Class description	A woodland biome is a terrestrial biome which includes, across its entire spatial extent, woody plants spaced sufficiently far apart to allow light penetration to support communities of herbaceous plants or shrubs living closer to the woodland floor.
Class parents	Terrestrial_Biome
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000175

Class name	Works
Class description	Wildfire caused by sparks emitted by engines and machinery (such as chainsaw) in industry, forestry and agriculture or people at work (explosions, welding, grinding, smoldering) or by ignition of flammables and vapors during works in industrial activities.
Class parents	Accident
Subclasses	
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)
Class name	Xeric_Shrubland_Biome
Class description	A shrubland biome which is subject to xeric climate patterns.
Class parents	Shrubland_Biome
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000218
Class name	food_processing_building
Class description	A food processing building is a building in which materials that contain or consist of essential body nutrients - such as carbohydrates, fats, proteins, vitamins, or minerals - and may be ingested and assimilated by an organism to produce energy, stimulate growth, and maintain life are converted alternative forms.
Class parents	Industrial_building
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_00003863
Class name	ford
Class description	The shallow part of a stream which can be easily crossed.
Class parents	Transportation
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_00000411
Class name	lock
Class description	A device for raising and lowering boats between stretches of water of different levels on river and canal waterways.
Class parents	Transportation
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_00000357
Class name	pier
Class description	A raised walkway over water, supported by piles or pillars.
Class parents	Transportation
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_00000563

Class name	railway
Class description	A permanent way having one or more rails which provides a track for cars.
Class parents	Transportation
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_00000065
Class name	university_campus
Class description	An area of land on which a college or university and related institutional buildings are situated.
Class parents	Building
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_00000467
Class name	water_intake
Class description	A hydraulic-engineering installation which transports water - in specified amounts, of a specified quality, and in accordance with a water-consumption plan - from a source of supply into a conduit.
Class parents	Building
Subclasses	
Sources	http://purl.obolibrary.org/obo/ENVO_01000968
Class name	1-hour_timelag_fuels
Class description	1-hour timelag fuels: Dead fuels comprised of herbaceous plants or woody plants less than about 0.25 inch (6.4 mm) in diameter and the surface layer of litter on the forest floor.
Class parents	Fuel_class
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html#FuelClass
Class name	10-hour_timelag_fuels
Class description	10-hour timelag fuels: Dead fuels comprised of wood from 0.25 to 1 inch (0.6-2.5 cm) in diameter and the litter from just beneath the surface to around 0.75 inch (1.9 cm) below ground.
Class parents	Fuel_class
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html#FuelClass
Class name	100-hour_timelag_fuels
Class description	100-hour timelag fuels: Dead fuels comprised of wood from 1 to 3 inches (2.5-7.6 cm) in diameter and litter from around 0.75 to about 4 inches (1.9-10 cm) below ground.
Class parents	Fuel_class
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html#FuelClass
Class name	1000-hour_timelag_fuels

Class description	1,000-hour timelag fuels: Dead fuels comprised of wood from 3 to 8 inches (7.6-20.3) in diameter and the forest floor layer >4 inches (10 cm) below ground.
Class parents	Fuel_class
Subclasses	
Sources	https://www.fs.fed.us/database/feis/glossary2.html#FuelClass
Class name	24h_precipitation
Class description	Precipitations in the last 24h
Class parents	Precipitation
Subclasses	
Sources	https://cwfis.cfs.nrcan.gc.ca/background/summary/fwi
Class name	Fireworks,_firecrackers,_distress_flares
Class description	Wildfire caused by fireworks with or without preventive measures, by firecrackers and by distress flares regardless of who lit it.
Class parents	Use_of_glowing_objects
Subclasses	
Sources	https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/effis/reports-and-publications/effis-related-publications/lb-na-25-923-en-n.pdf (page 10)

Properties

Table 49 Tabular ontology properties representation

Property name	affects_fire_characteristic
Property description	Indicates entities that affect a fire characteristic
Property domain	Climate_parameter
Property range	Fire_characteristic
Property name	affects_fire_risk
Property description	Indicates entities that affect a fire risk
Property domain	Preventive_procedure
Property range	Fire_risk
Property name	affects_vulnerable_object
Property description	Links an affected object to an impact.
Property domain	Impact
Property range	Vulnerable_object
Property name	causes_fire
Property description	Links a cause to a fire
Property domain	Cause, Fire, Ignition_probability_factor
Property range	Fire
Property name	causes_incident
Property description	Links a fire to an incident
Property domain	Fire
Property range	Incident

Property name	contains_detection
Property description	Indicates detections contained in a dataset
Property domain	Dataset
Property range	Detection
Property name	contributes_to_buildup_index
Property description	Indicated what entity contributes to buildup index
Property domain	Drought_fuel_moisture, Duff_fuel_moisture
Property range	Buildup_index
Property name	contributes_to_fire_weather_index
Property description	Indicated what entity contributes to fire weather index
Property domain	Buildup_index, Initial_spread_index
Property range	Fire_weather_index
Property name	contributes_to_initial_spread_index
Property description	Indicated what entity contributes to initial spread index
Property domain	Wind_speed
Property range	Initial_spread_index
Property name	detects_incident
Property description	Links a detection to an incident
Property domain	Detection
Property range	Incident
Property name	detects_vulnerable_objects
Property description	Links Detection to Vulnerable object
Property domain	Detection
Property range	Vulnerable_object
Property name	has_age_group
Property description	Links Human to Age group
Property domain	Human
Property range	Age_group
Property name	has_area_under_pressure
Property description	Links Community to Area under pressure
Property domain	Community
Property range	Area_under_pressure
Property name	has_assigned_responder
Property description	Links Mission to Responder
Property domain	Mission
Property range	Responder
Property name	has_biodiversity_index
Property description	Links some entites to Biodiversity index

Property domain	Area_burned, Monitored_area, Vegetated_area
Property range	Biodiversity_index
Property name	has_biome
Property description	Links some entites to Biome
Property domain	Area_burned, Location, Monitored_area
Property range	Biome
Property name	has_climate_parameter
Property description	Links a climate parameter measurement to an entity.
Property domain	Area_burned, Incident, Monitored_area
Property range	Climate_parameter
Property name	has_construction_material
Property description	Links Structure to Construction material
Property domain	Structure
Property range	Construction_material
Property name	has_fire_characteristic
Property description	Links Fire to Fire characteristic
Property domain	Fire
Property range	Fire_characteristic
Property name	has_fire_regime_condition_class
Property description	Links Monitored area to Fire regime condition class
Property domain	Monitored_area
Property range	Fire_regime_condition_class
Property name	has_fire_risk
Property description	Links Monitored area to Fire risk
Property domain	Monitored_area
Property range	Fire_risk
Property name	has_fire_weather_index
Property description	Links Monitored area to Fire weather index
Property domain	Monitored_area
Property range	Fire_weather_index
Property name	has_fuel_class
Property description	Links Fuel to Fuel class
Property domain	Fuel
Property range	Fuel_class
Property name	has_fuel_continuity
Property description	Links Fuel to Fuel continuity
Property domain	Fuel
Property range	Fuel_continuity

Property name	has_fuel_loading
Property description	Links Fuel to Fuel loading
Property domain	Fuel
Property range	Fuel_loading
Property name	has_geolocation
Property description	Links some entites to Location
Property domain	Animal, Area_burned, Climate_parameter, Fire, Incident, Media_item, Monitored_area, Responder, Response_resource, Sensor, Vulnerable_object
Property range	Location
Property name	has_government_policy
Property description	Links Community to Government policy
Property domain	Community
Property range	Government_policy
Property name	has_high_priority_area
Property description	Links Community to High priority area
Property domain	Community
Property range	High_priority_area
Property name	has_impact
Property description	Links an impact to an incident.
Property domain	Fire, Incident
Property range	Impact
Property name	has_infrastructure_development
Property description	Links Community to Infrastructure development
Property domain	Community
Property range	Infrastructure_development
Property name	has_living_being_stats
Property description	Links Animal to Living being stat
Property domain	Animal
Property range	Living_being_stat
Property name	has_moisture
Property description	Links Fuel to Moisture
Property domain	Fuel
Property range	Moisture
Property name	has_vegetation_stat
Property description	Links some entites to Vegetation stat
Property domain	Biome, Fuel, Vegetated_area
Property range	Vegetation_stat
Property name	has_reliability

Property description	Links Measure to Reliability
Property domain	Measure
Property range	Reliability
Property name	has_report
Property description	Links Incident to Incident report
Property domain	Incident
Property range	Incident_report
Property name	has_response_resource
Property description	Links Location to Response resource
Property domain	Location
Property range	Response_resource
Property name	has_spatial_entity
Property description	Links Fire to Spatial entity
Property domain	Fire
Property range	Spatial_entity
Property name	has_temporal_entity
Property description	Links Fire to Temporal entity
Property domain	Fire
Property range	Temporal_entity
Property name	has_unit
Property description	Links Measure to Unit
Property domain	Measure
Property range	Unit
Property name	involves_vulnerable_object
Property description	Indicates the incident a vulnerable object is involved in.
Property domain	Incident
Property range	Vulnerable_object
Property name	observes_parameter
Property description	Indicates which parameter is observed by a sensor
Property domain	Sensor
Property range	Climate_parameter
Property name	produces_dataset
Property description	Indicates what entites produce what dataset
Property domain	Sensor, Silvanus_UP
Property range	Dataset
Property name	relates_to_mission
Property description	Links Incident to Mission
Property domain	Incident
Property range	Mission

Property name	relates_to_silvanus_UP
Property description	Links Media item to Silvanus UP
Property domain	Media_item
Property range	Silvanus_UP

9 Appendix B – Ontology Protégé representation

The followind pictures list the ontology classes in OWL Viz format. OWL Viz is a visualization plugin for Protégé that automatically generates visualization for the current ontology. It is a good tool to visualize parents / children relationships but it does not visualize other type of relationships. Because of the difficulties of displaying such a large image in Word while keeping it readable, the representation is available at the following link:

Full resolution image

While unreadable, the full image is available on the next page as well.