Deliverable 2.1: *Existing Sustainable Forest Management Services and Formalization of Functional requirements*

Report

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Lead Author(s):	Andrea Majlingova (TUZVO), Yvonne Brodrechtova (TUZVO), Klára Balikova (TUZVO), Michaela Korena Hillayova (TUZVO)
Reviewers:	MDS, EAI, CTL

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Date	**Due date**	**Responsible Contributor(s)/ Pilot leader**	**Description/Completed on**
	15.04.2022	pbesson@pompiers-urgence.org i.korma@gmail.com France (PUI)	06.05.2022
	15.04.2022	m.spilotros@asset.regione.puglia.it, g.mangialardi@asset.regione.puglia.it Italy (ASSET)	06.05.2022
	15.04.2022	marcello.scipioni@finconsgroup.com, marco.saltarella@finconsgroup.com Italy (FINCONs)	06.05.2022
	15.04.2022	mircea.segarceanu@gmail.com, contact@asfor.ro Office@fundatiapentrusmurd.ro Romania (ASFOR, SMURD)	06.05.2022
	15.04.2022	g.sakkas@kemea-research.gr, cdemest@aua.gr Greece (KEMEA, AUA)	06.05.2022
	15.04.2022	luisa.serra@edp.pt Portugal (EDP)	06.05.2022
	15.04.2022	marek.gasparin@hzsmsk.cz Czech Republic (FRB MSR)	06.05.2022
	15.04.2022	jelena@rinigard.com Croatia (RINI)	06.05.2022
	15.04.2022	majlingova@tuzvo.sk Slovakia (TUZVO)	06.05.2022
	15.04.2022	paulo.borges@data61.csiro.au Australia (CSIRO)	06.05.2022
	15.04.2022	rogerio@ntt.ufrj.br, nelson@ntt.ufrj.br Brazil (UFRJ)	06.05.2022
	15.04.2022	kusrini@amikom.ac.id, arief_s@amikom.ac.id Indonesia (AMIKOM)	06.05.2022

List of Contributors

Partner	Name(s)
TUZVO	Andrea Majlingova, Yvonne Brodrechtova, Klara Balikova, Michaela Korenna Hillayova, Lenka Navrátilová, Ján Tuček, Maroš Sedliak
3MON	Simona Kalinovska, Richard Rehak
ADP	Carlos Brito, Marta Carvalho
AHEPA	Christoforos Kosmidis, Pavlos Zarogoullidis
AMIKOM	Kusrini, Arief Setyanto, Gardyas Bidari Adninda
ASFOR	Mircea Segarceanu, Ciprian Dumitru Musca
ASSET	Mariangela Lupo, Giovanna Mangialardi, Letizia Musaio Somma, Marino Spilotros
ATOS IT	ATOS IT Team
AUA	Konstantinos Demestichas
CERTH	Stelios Andreadis
CMCC F	Monia Santini
CSIRO	Paulo Borges
CTL	CTL Team
DELL	David Bowen
EAI	Vincenzo Masucci, Simone Martin Marotta
EDP	Luisa Serra, Ricardo Lucas, Rafael Oliveira
EXUS	Aris Bonanos
FINC	Marcellp Scipioni, Marco Saltarella
SMURD	Raed Arafat, Daramus Florin, Doina Segarceanu, Ioana Daramus
FRS MB	Marek Gasparin
HB	HB Team
HRT	Iosif Vourvachis, Alexandros Giordanis
HVZ	Željko Cebin, Mario Starčević, Siniša Petkoviček
INTRA	INTRA Team
ITTI	ITTI Team
IST-ID	Vânia Proença
KEMEA	Georgios Sakkas
LETS	Marcello Sacchetti, Gianpiero Lacovara
MD	Lovorko Marić, Anita Jukić
MDS	Natalia Stathakarou
PEGASO	Michele Corleto, Daniela de Gregorio

PLAM	Ján Hanuliak, Elena Kmeťová, Marek Hodálik, Dominik Špilák, Tomáš Gonda, Rastislav Veľas
PNRT	Alessandro Pala, Marianna Mossa
PSTE	PSTE Team
PUI	Iliana Korna, Paul Besson
RINI	Jelena Levak, Zoran Kozačinski
SIMAVI	Bogdan Gornea
SYNC	Panos Kakonitis, Irene Kamba, Evi Demetriou
TP	Ivo Gama, Jorge Palma
TRT	TRT Team
UISAV	Zoltan Balogh, Emil Gatial, Jan Zelenka
VTG	Krishna Chandramouli, Tomas Piatrik
Z&P	Alexandre Lazarou, Domenica Casciano

List of acronyms and abbreviations

ACRONYM	**Description**
CCTV	Closed-circuit television
COP	Provincial Operations Centre
DOS	Directorate of Extinguishing Operations
DSS	Decision Support System
DX.Y	Deliverable X. Y (X refers to the WP and Y to the deliverable in the WP)
EFFIS	European Forest Fire Information System
EU	European Union
FWI	Fire Weather Index
GIS	Geographical Information System
IoT	Internet of Things
IT	Information Technology
LULUCF	Land Use, Land-Use Change and Forestry
N/A	Non-Applicable
UAV	Unmanned Aerial Vehicle
UGV	Unmanned Ground Vehicle
WP	Work Package

List of beneficiaries

No	Partner Name	Short name	Country
1	UNIVERSITA TELEMATICA PEGASO	PEGASO	Italy
2	ZANASI ALESSANDRO SRL	Z&P	Italy
3	INTRASOFT INTERNATIONAL SA	INTRA	Luxembourg
4	THALES	TRT	France
5	FINCONS SPA	FINC	Italy
6	ATOS IT SOLUTIONS AND SERVICES IBERIA SL	ATOS IT	Spain
6.1	ATOS SPAIN SA	ATOS SA	Spain
7	EMC INFORMATION SYSTEMS INTERNATIONAL	DELL	Ireland
8	SOFTWARE IMAGINATION & VISION SRL	SIMAVI	Romania
9	CNET CENTRE FOR NEW ENERGY TECHNOLOGIES SA	EDP	Portugal
10	ADP VALOR SERVICOS AMBIENTAIS SA	ADP	Portugal
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14	SYNTHESIS CENTER FOR RESEARCH AND EDUCATION LIMITED	SYNC	Cyprus
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19	FONDAZIONE CENTRO EURO-MEDITERRANEOSUI CAMBIAMENTI CLIMATICI	CMCC F	Italy
20	EXUS SOFTWARE MONOPROSOPI ETAIRIA PERIORISMENIS EVTHINIS	EXUS	Greece
21	RINIGARD DOO ZA USLUGE	RINI	Croatia
22	Micro Digital d.o.o.	MD	Croatia
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25	GEOPONIKO PANEPISTIMION ATHINON	AUA	Greece
26	ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS	CERTH	Greece
28	ASSOCIACAO DO INSTITUTO SUPERIOR TECNICO PARA A INVESTIGACAO E DESENVOLVIMENTO	IST-ID	Portugal
30	USTAV INFORMATIKY, SLOVENSKA AKADEMIA VIED	UISAV	Slovakia
31	POMPIERS DE L'URGENCE INTERNATIONALE	PUI	France
32	THE MAIN SCHOOL OF FIRE SERVICE	SGPS	Poland

No	Partner Name	Short name	Country
33	ASSET - Agenzia regionale Strategica per lo Sviluppo Ecosostenibile del Territorio	ASSET	Italy
34	LETS ITALIA srls	LETS	Italy
35	Parco Naturale Regionale di Tepilora	PNRT	Italy
36	FUNDATIA PENTRU SMURD	SMURD	Romania
37	Romanian Forestry Association - ASFOR	ASFOR	Romania
38	KENTRO MELETON ASFALEIAS	KEMEA	Greece
39	ELLINIKI OMADA DIASOSIS SOMATEIO	HRT	Greece
40	ARISTOTELIO PANEPISTIMIO THESSALONIKIS	AHEPA	Greece
41	Ospedale Israelitico	OIR	Italy
42	PERIFEREIA STEREAS ELLADAS	PSTE	Greece
43	HASICSKY ZACHRANNY SBOR MORAVSKOSLEZSKEHO KRAJE	FRB MSR	Czechia
44	Hrvatska vatrogasna zajednica	HVZ	Croatia
45	TECHNICKA UNIVERZITA VO ZVOLENE	TUZVO	Slovakia
46	Obcianske zdruzenie Plamen Badin	PLAMEN	Slovakia
47	Universitas Amikom Yogyakarta	AMIKOM	Indonesia
48	COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION	CSIRO	Australia
49	UNIVERSIDADEFEDERAL DO RIO DE JANERIO	UFRJ	Brazil

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Executive Summary

The purpose of the deliverable is to report on the activities being carried out within WP2, which is titled "Environmentally sustainable, resilient forest models and assessment framework" and more specifically to consolidate the outcomes from T2.1(stakeholder consultation through participatory process) and T2.2 (Functional requirements). The outcome of the deliverable will serve as a source of information for the technical partners to consider for the design and development of the SILVANUS platform architecture. Additionally, the information presented in the deliverable will also cater the needs of the demonstration activities to be carried out in WP9. The key insights from the deliverable include detailed description of the Operational Scenarios and a summary of existing sustainable forest management services as undertaken by the pilot owners in the current context. Additionally, the deliverable also elaborates on the key pilot sites and documents the challenges faced by stakeholders in wildfire prevention and preparedness (Phase A); wildfire detection and monitoring (Phase B); forest and soil restoration after the fire and adaptation to climate change (Phase C). After the analysis of the operational scenarios provided by the stakeholders through the participatory approach, functional requirements for the project platform have been developed that captures the needs and requirements of stakeholders, including the functionalities, features of services and technology to be implemented into the SILVANUS platform. This information is a vital input to other WPs as well as for the SILVANUS consortium partners, to be further able to precise their functional and technical requirements regarding the SILVANUS platform and to successfully meet the stakeholder expectation as well the SILVANUS project and the European Green Deal objectives.

The scope of the deliverable is to establish a common approach and understanding among the consortium partners regarding the terminology, data, services, and technology available in the SILVANUS project consortium to be further deployed in the relevant Pilot Site(s) for demonstrations. As envisaged in the project planning, the common framework established in the deliverable through the participatory approach, has enabled discussion among several stakeholders including pilot owners, civil authorities, fire fighters, researchers, industrial members, and SME representatives. Such a large-scale mobilisation of resources and stakeholder discussion is considered crucial for the success of the project implementation.

The deliverable also elaborates on the methodology being adopted to collect a large volume of information sources from several pilot owners and their respective stakeholders. A systematic methodology established in the project adopted the use of online questionnaire completion forms (namely JotForm application), which were completed by the pilot owners based on the guidelines provided developed by TUZVO and shared with the consortium. The information collected through the participatory approach is converted into a database for SILVANUS project partners to further access and clarify any future questions.

1 Introduction

SILVANUS project is envisaged to develop a platform for an environmentally sustainable and climate resilient forest management, based on consultation with relevant internal and external stakeholders. The project presents the need for adopting an interdisciplinary approach which brings together different experts from diverse background such as , like: information technology (IT), Geographical Information System (GIS), climate change researchers, foresters, firefighters, state authorities, municipalities, nature protection authorities and organizations, policy makers, etc.

The first step into developing the data and platform for SILVANUS was the undertake a detailed review of existing information, services, and technologies (including, features and functionalities) currently used across all the 11 Pilots from 11 countries (8 EU countries and 3 outside EU). In addition to the current challenges being faced by the pilot owners, the activities of the project also engaged in collecting and aggregating relevant information, services, and technologies, that are intended to be used within in the context of SILVANUS project in combating wildfires and supporting the sustainability and resilience of forests and soil.

The overall objective of deliverable D2.1 is to provide a summary of information on existing sustainable forest management services (i.e. data, DSS, services and technology currently used) across selected pilot sites. The aggregated knowledge was envisaged to serve the stakeholders to enhance wildfire prevention as well as capabilities of towards preparedness (Phase A), wildfire detection / monitoring and response (Phase B), forest and soil restoration after the fire and adaptation to climate change (Phase C). Additionally, the deliverable also considers functional requirements, including the functionalities and features of technology to be implemented into the SILVANUS platform. To gather this information, the participatory process was established.

The deliverable contains seven (7) main sections completed with Annexes. The first section represents the main body of the deliverable which provides description of the background of the deliverable as well as the SILVANUS project. This section is followed by Section 2, which provides a glossary containing the key terms to be further used by project partners (Table 1). The third section provides a description of the methodology used to establish participatory process and guidelines (Annex 2) which were used to collect the information and knowledge on existing and required data, systems, technology to combat the wildfires. These data were obtained by establishing the participatory process according to the provided methodology. The fourth section provides a description of the pilots, including pilots' summaries, pilot status characteristics, high-level operational scenarios, priorities of the pilots. In the fifth section, feedback collected from the questionnaires – status and functional requirements on SILVANUS platform are introduced. The sixth section provides validation of requirements. In the seventh section, conclusions are described.

The Annexes of the deliverable are represented by: Annex 1 - Summary on completion status of all Questionnaire Tables; Annex 2 - Guidelines for the Preparation and Comparative Analysis of Existing Sustainable Forest Management Services and Formalization of Functional requirements; Annex 3 - JotForm Questionnaire Tables; Annex 4 - Validation of functional requirements on SILVANUS Platform according to the type of external stakeholder.

1.1. Assignment of SILVANUS tasks to the deliverable

This deliverable is a result of an effort from project partners working on two tasks, assigned to stakeholder consultation through participatory process (T2.1) and functional requirements (T2.2).

Task 2.1 - Stakeholder consultation through participatory process [leader: TUZVO].

- The aim of the task was to develop a systematic procedure to engage the stakeholders involved in the forest management operations.

The methodology of this task followed a participatory process including both internal and external stakeholders. This is introduced in the Guidelines attached to this Deliverable.

- The project has adopted a transparent policy for launching consultations and data processing.

The interviewed stakeholders, as well as the Pilot Site leaders, confirmed their consent in the JoTForms[1], directly in the application, before starting to fill the questionnaire table, according to the requirements set by the project Ethics manager.

- The rehabilitation of the forest landscape was analysed through the participatory process methodology established to bring together interdisciplinary expertise.

The procedures used for rehabilitation of forest landscape were analysed through the participatory process- see the relevant tables in the Annex of each Pilot Site.

- The task outlined in detail the process to be adopted in these sessions and will be led by evidence-based data analysis.

The database was created, containing the data collected in interviews in Excel file containing information classified by country and table S (Status), R (Requirements) or D (Description of Operational Scenario). Those data are available to the consortium and can be used for further analyses. Outputs according to the WP requests are going to be generated.

- The process was chaired by the relevant stakeholders responsible for addressing the national priority towards forest rehabilitation and restoration. The process will include external experts invited to share specific knowledge on the process of establishing biodiversity and ecological balance.

Relevant internal and external stakeholders were included to meet this target (see, e.g., Slovak Pilot).

Task 2.2 - Functional requirements [leader: TUZVO]

- The goal of the task is to finalize the functional requirements based on the scenarios identified in T2.1 for the three phases of forest management services to safeguard against wildfires.

Operational scenarios were specified by relevant consortium partners and stakeholders, based on which the information on functional requirement of stakeholders was collected for three phases of combination with wildfires (see relevant R tables in the Annex of each Pilot Site).

- The task aims to review the services supported within the forest management services.

The task collected Information regarding the forest management services current adopted by consortium partners involved in the project. This information is going to be further used in T2.3, where is going to be included in relevant knowledge base to be evaluated by experts in the field to be used for development purposes regarding the SILVANUS platform.

- The functional requirements were validated by the external stakeholders and interdisciplinary experts.

The functional requirements were validated by interdisciplinary experts involved in the project consortium as well as by external stakeholders.

[1] https://www.jotform.com/

- The knowledge generated from this activity (Task 2.1) will result in the drafting of the functional requirements (Task 2.2) for the development of the SILVANUS platform.

The large-scale volume of relevant information collected from the consortium partners and pilot owners have been converted into a database. The information available within the database will be made accessible to the consortium partners in the project lifecycle. The database contains knowledge aggregated from the stakeholders through the participatory approach and will serve as a catalyst to stimulate innovation and bring forward innovative operational scenarios which can be demonstrated within the project demonstration activities.

1.2. SILVANUS project background

It is safe to state that climate change is one of the biggest challenges of mankind. The effects of climate change are already being felt, with the resulting damage having a worldwide impact. Global impacts vary due to multiple factors, with a country's economic power playing one of the biggest roles in preparedness, resulting in vulnerable nations. Decisions must be made to mitigate climate change consequences by increasing preparedness in vulnerable areas against the presumed impacts. Climate change will undoubtedly affect the entire planet and calls for international collective actions.[2]

Most human activities, in particular the combustion of fossil fuels, have accelerated the rise in carbon dioxide emissions and thus the increase in global warming, with tangible impacts on humans, animals, and the ecological balance around the world. The immediate environmental consequence of global warming is the increase in natural hazards that result in disasters, e.g., melting glaciers, more extreme and more frequent floods, wildfires, storms, droughts, and heatwaves. The indirect consequences include threats to human health, and the reduction of biodiversity and habitable areas, leading to migration and deterioration of community, public health, and socioeconomic conditions in most countries of the world.[3] The impacts of climate change will lead to socioeconomic and political instability, which will change the living conditions of many communities.

The reduction of the rate of climate change progress and the mitigation of its consequences requires the creation of a profound scientific basis and the involvement of experts who cover all areas of climate change. These areas range from ecology, life sciences, meteorology, health care, social, and economic sciences, mathematics and computer science to energy, food, and transport. Interdisciplinary approaches deliver huge amounts of data to create reliable future scenarios. They should provide a comprehensive understanding of the problem and possible measures at all levels. All climate change models show significant geographical differences.

Over a period of last few decades, continuous effort has been made by the scientific community to enhance our knowledge of the fundamental mechanisms of the Earth's climate system as well as the implications and impacts of climate change. A portion of this effort has been directed to identifying the new actions for

[2] Klingelhöfer, D., Müller, R., Braun, M. et al. 2020. Climate change: Does international research fulfill global demands and necessities? *Environ Sci Eur* 32**,** 137. https://doi.org/10.1186/s12302-020-00419-.

[3] Watts N. et al. 2019. The 2019 report of The Lancet Countdown on health and climate change: ensuring that the health of a child born today is not defined by a changing climate. *Lancet* 394:1836–1878. https://doi.org/10.1016/S0140-6736(19)32596-6.

mitigating anthropogenic greenhouse gas emission trends. Other efforts have focused on identifying new actions to adapt to the observed and expected changes in climate.[4,5,6.]

Thus, defining and designing salient actions to tackle the negative effects of climate change must be planned at the local scale to guarantee their effectiveness.[7] These actions must be developed in accordance with surrounding landscape structures, socioeconomic and environmental regional characteristics and, finally, in accordance with national and international policies.

Climate change modifies the specific thermo-physical features and frequency of occurrence of climatic events. Therefore, modification of air temperatures, precipitation amounts, air humidity levels, ventilation intensities, and occurrence of extreme events such as floods, drought, cold waves, and heat waves due to climate change produces impacts on the environment, should be studied in detail.

In the last decades, robust scientific knowledge has been produced that provides important information that can be used for studying and further making science-based decisions. However, additional decision-support tools and an understanding of the cognitive processes associated with perceptions of climate change are needed to use this information to make society resilient to climate change and to understand the needs of environmental protection and keeping the general principles of sustainability.

1.2.1 Climate change impacts on European forests

About 182 million hectares (43% of EU land) are covered by forests or other wooded land. Forests also account for half of the Natura 2000 network of nature protection areas, covering 38 million hectares (more than 20% of the EU's Forest area).[8]

Considering the SILVANUS project objectives, the focus is oriented mostly on European forests resilience and adaptation to climate change consequences.

Forests provide multifunctionality (they hold an important role in our economy and society, creating jobs and providing food, medicines, materials, clean water and more), in which there is a space for biodiversity, as well as providing renewable raw materials and many other ecosystem functions. Keeping the sustainability of those services is subject to a range of different forest management practices, land use planning and policymaking regimes in the different Member States.[9]

European forests and the forestry value chain have important strategic roles to play in climate change mitigation and adaptation. However, climate change is putting considerable pressure on them.

The rapid rate of climate change may overcome the natural ability of forest ecosystems to adapt as the frequency and severity of climate and weather extremes are increasing, causing unprecedented events, such as forest fires in the Arctic Circle, severe droughts in the Mediterranean region, unprecedented bark beetle outbreaks in Central and Eastern Europe with devastating effects for European forests. Therefore, the economic viability of forests will be affected, as well as the capacity of forests to provide environmental

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[4] Stocker, T. (ed.). 2014. *Climate change 2013: the physical science basis: Working Group I contribution to the Fifth assessment report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press, 1522 pp. https://doi.org/10.1017/CBO9781107415324.

[5] Field, C. B., Barros, V. R., Mach, K. J. et al. 2014. *Technical summary Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects*. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. (ed. CB Field et al.). Cambridge: Cambridge University Press, 1131 pp. https://doi.org/10.1017/CBO9781107415379.

[6] Pachauri, R. K., Allen, M. R., Barros, V. R. et al. (eds). 2014. *Climate change 2014: synthesis report*. Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change. Switzerland: Geneva, IPCC, 151 pp.

[7] Pascui, M., Di Giuseppe, E. 2019. Climate change, future warming, and adaptation in Europe. *Animal Frontiers* 9(1): 6-11. https://doi.org/10.1093/af/vfy036.

[8] https://climate-adapt.eea.europa.eu/eu-adaptation-policy/sector-policies/forestry

[9] https://eustafor.eu/uploads/EUSTAFOR-booklet_European-forests-Tackling-climate-change-DEF-high.pdf

services (e.g., clean water and air, food and fibre, CO_2 removal, carbon stock, erosion control and provide habitat for forest biodiversity).[10]

Climate change is intensifying the many threats that forests already face but will also have its own impacts on forests.

Increasing global temperatures are expected to support the expansion of tropical forests into areas where temperate forests are now, and the expansion of temperate forests into areas currently inhabited by boreal forests[11]. Boreal forests may be particularly affected by climate change, with mean annual temperature increases of 1.5 °C or more (since pre-industrial era) already being observed over much of the boreal forest biome. Under a global warming scenario of 4 °C by the end of the century, boreal forests could shift to drier regions, with dramatic consequences for CO_2 balance and habitat loss/gain[12].

Changes to climate will also influence the diversity of tree species within existing forests. Modelling of forest composition in Europe under future climate scenarios suggests declines in species richness in lowland forests in the Mediterranean and Central Europe but increasing diversity in elevated forests in Scandinavia and Central Europe[13].

In northern and western Europe, increasing levels of carbon dioxide in the atmosphere and warmer temperatures will likely increase forest growth and wood production in the short term (as is already evident in Finland[14]), but an increasing risk of drought and fire might outweigh any positive effects. The risk is particularly severe in the Mediterranean region, which has limited capacity for adaptation[15].

The drastic changes brought by global warming will occur at rates exceeding the natural adaptive capacity of forest ecosystems, potentially leading to extinctions and loss of vital ecosystem services – including carbon storage.

The total carbon stored in forest ecosystems globally exceeds the carbon in the atmosphere[16]. Any loss of forest brought about by climate change will itself exacerbate climate change, making adaptive forest management approaches essential now. Such approaches should focus on avoiding monoculture plantations dominated by one or few species and fostering biodiverse forests which are likely to be less vulnerable to threats such as fires and pest invasions.

1.2.2 Climate change impact on forest fires

Forest fires are essential for many ecosystems; however, frequent, and large-scale fires are a significant disturbance agent in many forested landscapes. Frequent and large-scale fires have negative impacts on air and water quality, threaten biodiversity, increase the risks of soil erosion, and spoil the aesthetics of a landscape. Forest fires also represent a threat to climate change mitigation, as they release large amounts of greenhouse gases. Furthermore, forest fires can cause large economic damage and the loss of human lives if they affect populated areas. Nevertheless, forest fires play an essential role in the dynamics of many

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[10] https://climate-adapt.eea.europa.eu/eu-adaptation-policy/sector-policies/forestry

[11] Mendelsohn, R., Prentice, I.C., Schmitz, O. et al. 2016. The Ecosystem Impacts of Severe Warming. *American Economic Review* 106(5): 612–614. https://doi.org/10.1257/aer.p20161104.

[12] Gauthier, S., Bernier, P., Kuuluvainen, T. et al. 2015. Boreal forest health and global change. *Science* 49(6250): 819-822. https://doi.org/10.1126/science.aaa9092.

[13] Buras, A., Menzel, A. 2019. Projecting Tree Species Composition Changes of European Forests for 2061–2090 Under RCP 4.5 and RCP 8.5 Scenarios. *Frontiers in Plant Science* 9. https://doi.org/10.3389/fpls.2018.01986.

[14] Henttonen, H.M., Nöjd, P., Mäkinen, H. 2017. Environment-induced growth changes in the Finnish forests during 1971–2010 – An analysis based on National Forest Inventory. *Forest Ecology and Management* 386: 22-36. https://doi.org/10.1016/j.foreco.2016.11.044.

[15] Lindner, M., Maroschek, M., Netherer, S. et al. 2010. Climate change impacts, adaptive capacity, and vulnerability of European forest ecosystems. *Forest Ecology and Management* 259(4): 698–709. https://doi.org/10.1016/j.foreco.2009.09.023.

[16] Pan, Y., Birdsey, R.A., Fang, J. et al. 2011. A Large and Persistent Carbon Sink in the World's Forests. S*cience* 333(6045): 988–993. https://doi.org/10.1126/science.1201609.

ecosystems. They are an essential element of forest renewal, they help control insect and disease damage, and they reduce the build-up of fuel and thus the intensity of future fires.[17]

Climate change is expected to have a strong impact on forest fire risk in Europe, as recognised by the EU strategy on adaptation to climate change[18].

Fire risk depends on many factors such as climatic conditions (e.g., humidity, temperature, and wind), vegetation (e.g., fuel load and condition), topography, forest management practices and socio-economic context. According to the European Environment Agency[17] the large majority of wildfires in Europe are ignited by humans, either accidentally or intentionally. However, climatic factors and the availability of fuel determine the conditions under which fires occur and spread, once ignited. The extreme fire episodes and devastating fire seasons of recent years in Europe were, in most cases, driven by severe fire weather conditions. Thus, climate change is expected to have a strong impact on forest fire regimes in Europe.

The European Forest Fire Information System (EFFIS), managed by the Joint Research Centre (JRC), reports on the number of fires and the burnt area, with data on the latter being considered more robust and policy relevant. The information on burnt area in European countries in period 1980-2020 is introduced in Figure 1.

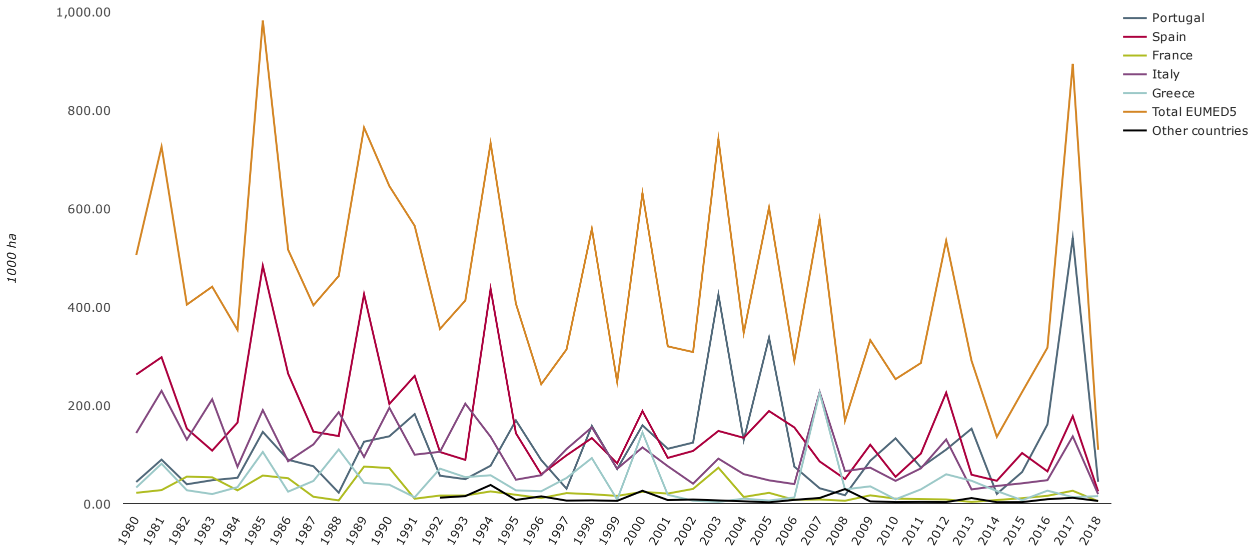

Figure 1 Burnt area in European countries (based on EFFIS data)[19]

Climate change has already increased forest fire risk across Europe. Even so, the burnt area of the Mediterranean region has decreased slightly since 1980, indicating that fire control efforts have been effective (Figure 1). However, in recent years, forest fires coinciding with record droughts and heatwaves have affected regions in central and northern Europe not typically prone to fires. An expansion of fire-prone areas and longer fire seasons are projected in most European regions, for high emissions scenarios, so additional adaptation measures are needed.[20]

Many of the recent extreme fire episodes and devastating fire seasons in Europe were driven by severe weather conditions, with record droughts and heatwaves occurring in the spring and summer of 2017 and

[17] https://www.eea.europa.eu/ims/forest-fires-in-europe

[18] EC, 2021, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions — Forging a climate-resilient Europe — The new EU strategy on adaptation to climate change, COM(2021) 82 final.

[19] EC, 2021, Forest fires in Europe, Middle East and North Africa 2020., Publications Office, Luxembourg.

[20] https://www.eea.europa.eu/ims/forest-fires-in-europe

2018 for instance. The new EU climate adaptation strategy aims to build a climate-resilient Europe by mitigating the negative consequences of climate change, such as the impacts of forest fires, by 2050.[21]

Also, historical fire data series are available in Europe and are regularly updated by EFFIS[22]. EFFIS addresses forest fires in Europe in a comprehensive way, providing EU-level assessments from pre-fire to post-fire phases, thus supporting fire prevention, preparedness, fire-fighting and post-fire evaluations. To complement the data, information from past forest fires is routinely used to rate fire potential due to weather conditions. The Canadian FWI is used by EFFIS to rate daily fire danger conditions in Europe. The Canadian Fire Weather Index (FWI)[23] is used to assess fire risk based on meteorological conditions. From 1980 to 2012, the FWI increased for Europe as a whole, particularly in southern and eastern Europe[24]. The fact that the burnt area of the Mediterranean decreased over the same period suggests that fire management and suppression efforts in this region had some effect[25].

Meteorological fire danger is projected to increase further in most regions, except in parts of north-eastern and northern Europe. This increase is expected to lead to a northward expansion of moderate fire danger zones in western-central Europe, but the countries with the highest absolute fire danger will remain Portugal, Spain, and Turkey[26,27]. Modelling studies indicate that burnt area in European and Mediterranean countries could double under 3 °C global warming, but that adopting additional measures, such as prescribed burning, fire breaks and enhanced fire suppression could substantially limit this increase[28,29].

Wildfires are also becoming an increasing public health issue. Smoke from wildfires is currently estimated to be the direct cause of death of 339,000 people annually[30], and there is a well-documented increase in hospital admissions due to smoke-enhanced cardiovascular and respiratory conditions, amongst others[31].

Forest fires are now an EU-wide concern. In the Mediterranean region, fire is becoming deadlier, while in Central and Northern Europe, unusually dry summers have recently led to forest fires in countries which have historically seen very few. Forest fires not only represent a danger for human beings and rural areas, environment, and biodiversity, but also a serious threat to the climate change mitigation potential of forests.

1.2.3 Information and technology supporting forest fires management

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[21] EC, 2021, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions — Forging a climate-resilient Europe — The new EU strategy on adaptation to climate change, COM(2021) 82 final.

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

[23] Van Wagner, C. E. 1987. Development and structure of the Canadian forest fire weather index system, *Forestry Technical Report* 35, Canadian Forestry Service, Ottawa, Canada.

[24] Venäläinen, A., Korhonen, N., Hyvärinen, O. et al. 2014. Temporal variations and change in forest fire danger in Europe for 1960–2012. *Natural Hazards and Earth System Sciences* 14(6): 1477–1490. https://www.nat-hazards-earth-syst-sci.net/14/1477/2014/.

[25] Turco, M., Bedia, J., Di Liberto, F. et al. 2016. Decreasing fires in Mediterrane*an Europ*e. PLOS One 11(3), e0150663. https://dx.plos.org/10.1371/journal.pone.0150663.

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[27] Costa, H., De Rigo, D., Liberta', G. et al. 2020. European wildfire danger and vulnerability in a changing climate: towards integrating risk dimensions. *Technical Reports EUR 30116 EN*, Publications Office of the European Union, Luxembourg.

[28] Khabarov, N., Krasovskii, A., Obersteiner, M. et al. 2016. Forest fires and adaptation options in Europe. *Regional Environmental Change* 16(1): 21–30. http://link.springer.com/10.1007/s10113-014-0621-0.

[29] Turco, M., Rosa-Cánovas, J. J., Bedia, J. et al. 2018. Exacerbated fires in Mediterranean Europe due to anthropogenic warming projected with non-stationary climate-fire models. *Nature Communications* 9(1): 3821. http://www.nature.com/articles/s41467-018-06358-z.

[30] Johnston, F.H., Henderson, S.B., Chen, Y. et al. 2012. Estimated global mortality attributable to smoke from landscape fires. *Environ. Health Perspect* 120:695–701.

[31] Borchers Arriagada, N., Palmer, A.J., Bowman, D.M. et al. 2020. Unprecedented smoke-related health burden associated with the 2019–20 bushfires in eastern australia. *Med. J. Aust.* 213(6):282-283. https://doi.org/ 10.5694/mja2.50545.

As a result, forest fire sizes and duration are increasing each year and possible impacts, negative outcomes and potential losses are becoming more serious. To keep pace with this situation, new developments are occurring in firefighting equipment, communication equipment, tactical responses, and support capabilities. But information management is an area that can often be overlooked when focusing on operational activities. This area is undergoing such rapid shifts in importance and emerging technology that it cannot be discounted. In fact, information management is quickly affording important and useful opportunities that can benefit and improve wildland fire management in the future.

Growth rate of information is doubling every 18 months, nearly two-thirds of all information users have multiple computing platforms, and most of the organization's data is inefficiently managed.[32] Electronic technology processing speed, viewing size portability and overall utility are improving almost daily. Situational variables such as these, in combination with the need by fire managers to obtain real-time information as fast as possible and make potentially impactful decisions very quickly, are driving a need to improve information management capability.

From a wildland fire management perspective, it must be understood that there is more readily available quality information regarding fire environments and fire situations; faster and more comprehensive computing speed and capability; and better predictive models than ever before. To improve wildland fire management, these capabilities must be capitalized on and incorporated into management activities.

In response to this need, numerous activities are under way to take advantage of new opportunities and technology for wildland fire management. Multiple sources of information exist, and multiple applications are being created to provide quick, efficient ways to obtain these data. Emerging applications are enabling the rapid sharing of information among a variety of systems, but a lack of data standards can affect how well these processes work. Nowadays, the attention should be paid to data standards, data sharing and data management, as well as responding to concerns over exposing data for other than the intended purpose on easily accessible sites. This includes:

- Exploring opportunities to find ways for managers and fire line personnel to use the technology such as tablets and web-enabled smart phones.
- Development of a web-based decision support system that represents a single system for all wildland fires using geospatial data and access to analytical tools that allow better characterize overall risk.
- Creating new fire management information displays to more effectively take advantage of geospatial data that enable users to view multiple information layers during wildfire incidents.
- Developing virtual situation awareness tools to display situation information for decision-makers and planners.

All these tasks involve continuous information management, use of emerging technology, and development of applications facilitating all aspects of wildland fire management.

For some years ago, scientists have been looking into the possibilities that digital technology can bring to predicting and preventing wildfires. The remote capabilities of digital technology solutions seem to be an asset in managing the forest fire risk, starting with fire prevention, preparedness of coping capacities, monitoring, and detection of forest fires and ending in forest fire fighting.

Among these:

[32] https://www.iawfonline.org/article/information-technology-and-the-work-of-managing-fires/

- **Remote sensing technology** employs both satellite[33] and drone[34] technologies to monitor wildfires at an early stage and before they grow out of control. Satellites and bespoke software are used to pinpoint potentially dangerous fires and drones equipped with special infrared cameras are mobilized to track the fire's progress. If it becomes a major threat, the system alerts and dispatches fire tankers and ground firefighters to the fire's location to control it before it spreads. Drones have additional uses in fighting forest fires. They can be fitted with both regular and thermal imaging cameras and can fly into areas that manned aircraft cannot, including at night when winds die down and fires become theoretically easier to control. Drones are primarily used for mapping and hotspot detection. Drones can be used to produce maps overnight which can be used by fire and evacuation crews first thing in the morning and free up aircraft to do other vital work, leading to a decrease in the time needed to have control over the wildfire.
- Another **technological development** that keeps humans out of harm's way are **firefighting robots**[34]. Often wildfires get so hot that firefighters are unable to get close enough to extinguish them. Instead, firefighting robot can approach very close to the fire and suppress the fire besides their capability of transporting firefighting equipment.
- **Virtual reality** (VR)[35] can be applied to train, in a safe environment, firefighters who are responsible for ground operation or parachuting ones into remote areas to fight forest fires. The VR simulators create 3D representations of the fire scenario, with trainers able to change physical characteristics like wind direction and speed, to prepare firefighters for real life engagements in dangerous conditions.
- Low-powered **Internet of Things** (IoT)[36,37] connected sensors are also being used to gather data from remote areas that are potential wildfire hotspots. Sensors can be used to collect the local weather data as well as detect and measure the level of CO and CO_2 and check for unseasonably high temperatures, indicating the possible presence of fires in the area.
- **Early warning and fire detection systems** (e.g., CCTV based smoke detection systems and early-stage alerting systems as ForestWatch®[38] or FireWatch®[39]), remote technologies and digital connectivity are helping to make firefighting a more proactive way, and potentially help to drive down the costs for prevention. This technology has a positive impact in many ways on top of saving lives and protecting property and environment.

1.2.4 Climate change mitigation and adaptation strategies for European forests

The resistance, resilience and biodiversity of Europe's forests are fundamentally linked to the ability to thrive in a changing climate. Any of the enormous benefits of forests to humans – climate buffering, clean air and water, food and medicines, materials, fuel, economic development and jobs, and social and cultural wellbeing – are reliant on the maintenance and restoration of healthy, functioning, diverse, well-connected forest ecosystems. Forest area in the EU has been increasing in recent years. However, the biodiversity and resilience of forests (and their possible adaptation) is under pressure by inadequate management practices and current and future climate changes. The conservation status of protected forest habitats in general has

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[33] Barmpoutis, P.; Papaioannou, P.; Dimitropoulos, K.; Grammalidis, N. A Review on Early Forest Fire Detection Systems Using Optical Remote Sensing. *Sensors* 2020, 20, 6442. https://doi.org/10.3390/s20226442

[34] Roldán-Gómez, J.J.; González-Gironda, E.; Barrientos, A. A Survey on Robotic Technologies for Forest Firefighting: Applying Drone Swarms to Improve Firefighters' Efficiency and Safety. *Appl. Sci.* 2021, 11, 363. https://doi.org/10.3390/app11010363.

[35] https://www.cse.unr.edu/~fredh/papers/conf/054-vaivefwsa/paper.pdf

[36] Novkovic, I.; Markovic, G.B.; Lukic, D.; Dragicevic, S.; Milosevic, M.; Djurdjic, S.; Samardzic, I.; Lezaic, T.; Tadic, M. GIS-Based Forest Fire Susceptibility Zonation with IoT Sensor Network Support, Case Study—Nature Park Golija, Serbia. *Sensors* 2021, 21, 6520. https://doi.org/10.3390/s21196520.

[37] Sahal, R.; Alsamhi, S.H.; Breslin, J.G.; Ali, M.I. Industry 4.0 towards Forestry 4.0: Fire Detection Use Case. Sensors 2021, 21, 694. https://doi.org/10.3390/s21030694.

[38] https://wildfire.fpinnovations.ca/159/Presentations/12_Detection_conference_offsite_monitoring_EVS.pdf

[39] https://www.iq-firewatch.com/references

not improved or, in several cases, has even worsened in the past decades. Therefore, their protection, restoration and adequately adapted management is essential.[40]

The European Union (EU) with the EU Strategy on Adaptation to Climate Change, the EU Biodiversity Strategy for 2030, the proposed EU Forest Strategy for 2030 and the proposed Land Use, Land Use Change and Forestry (LULUCF) regulation has provided several policy frameworks to promote climate change resilient forests able to deliver the many ecosystem services requested by society.

The new EU Strategy on Adaptation to Climate change[41] proposes a coherent and holistic policy framework on European Forests. It aims to accelerate adaptation by developing solutions, moving from planning to implementing adaptation strategies and plans at all levels of governance, also increasing adaptation mainstreaming and a systemic approach for policy development. The new Strategy identifies three cross cutting priorities, which will affect the forestry sector: (1) integrate adaptation into macro-fiscal policy, (2) promote nature-based solutions for adaptation, including sustainable management of forests, with new financial incentives and certification of carbon removals, and (3) stimulate local adaptation actions to improve the science-based knowledge on climate risks, ecosystem restoration, and sustainable management for minimizing risks, improve resilience, and ensure the continued delivery of vital ecosystem services and features. Major emphasis will also be put to encourage collaborative, transnational production, and transfer of high-quality plant reproductive material through active policies and actions to support adaptation in forestry and land ecosystem management.

As part of the European Green Deal[42], and the new EU Biodiversity Strategy to 2030[43], the new proposed Forest Strategy[44] includes measures for strengthening forest protection and restoration, enhancing sustainable forest management, and improving the monitoring and effective decentralised planning on forests in the EU, promoting their multifunctional role and contributing to adaptation requirements by increasing afforestation, forest preservation and restoration.

The LULUCF Regulation sets a binding commitment regarding emission reduction, for the period 2021-2030, for the first time in an EU law. The Regulation extends the accounting of emissions and removals from only forests today to all land uses (including wetlands by 2026). This will support foresters through greater visibility for the climate benefits of wood products, which can store carbon sequestered from the atmosphere and substitute for emission-intensive materials.

Besides the strategies, there are also tactical and mostly operational activities which must be implemented to ensure the sustainability and resilience of forests when facing the climate change impacts. Those activities must be implemented in the framework of the sustainable forest management. Sustainable forest management has evolved as a forest management concept worldwide and is also promoted by European forest policies. The aim of sustainable forest management is to ensure that forests supply goods and services to meet both present-day and future needs and contribute to the sustainable development of communities.[45]

Sustainable forest management lays the foundation for scientifically based, multifunctional and site-adapted management of European forests, balancing various management objectives. With the increased concern for climate change, new concepts such as climate-smart or carbon-conscious forest management

[40] https://ec.europa.eu/environment/integration/research/newsalert/pdf/issue-25-2021-11-european-forests-for-biodiversity-climate-change-mitigation-and-adaptation.pdf

[41] EC, 2021, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions — Forging a climate-resilient Europe — The new EU strategy on adaptation to climate change, COM(2021) 82 final.

[42] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

[43] https://www.eea.europa.eu/policy-documents/eu-biodiversity-strategy-for-2030-1

[44] https://ec.europa.eu/info/sites/default/files/communication-new-eu-forest-strategy-2030_with-annex_en.pdf

[45] https://www.fao.org/sustainable-forests-management/en/

have been proposed, giving more attention to climate change mitigation. However, the fundamentals of sustainable forest management are not in question and will remain, despite the challenges and failures of traditional forest management which was not fully based on the sustainable forest management principles employed today. It is thus more or less a question of how to improve sustainable forest management under a changing global climate, than to come up with a totally new forest management concept.

1.2.5 Climate change mitigation and adaptation challenges concerning forest fires risk

The sustainable forest management practices have an important role to play in improving resilience against forest fires, thus reducing fire's impact on climate change. Managed forests often have lower tree density and a lower accumulation of dead/dry biomass, which makes them less prone to fire than unmanaged forests. Regular thinning is also key for forest fire prevention and can be economically attractive for forest owners and managers, thanks to new developing markets for small dimension roundwood and harvest residues. These practices, in addition to carefully planned and implemented preparedness and prevention measures, contribute to positive long-term impacts on forest resilience, while being adapted to the local conditions of European forest ecosystems.

There is a vast amount of information on wildfires at local, regional, and global levels. However, one major challenge is ensuring that the practice of fire management and its associated governance are making full use of science-based findings and innovations. Specific efforts should be devoted to improving knowledge transfer to and exchange with practitioners and decision-makers.[46]

Forest fire risk is determined by a combination of many factors, including vegetation, climate, forest management practices and other socioeconomic parameters. Management actions and deployment of resources to deter fires are planned based on where and how fires occur. Hence, precise fire mapping and statistics describing how wildfires are changing in time and space are deemed essential for assessing the role of driving factors such as climate, land-based features, fire policies, etc. Policymakers and management agencies require information on wildfire probability, behaviour, and spatial and temporal trends to manage fire prone landscapes and to evaluate the efficacy of prevention plans. Territorial and environmental policies have great potential for addressing the structural causes of fire ignition and propagation in the long term.[47]

Forest planning actions are scheduled with a timescale of a few decades, which requires taking into consideration how the climate will change and its impact on future forest health and fire conditions. Understanding how future climate change will continue to affect forests and their fire proneness in Europe is important in determining fire adaptation and the mitigation potential of forests and natural areas. Furthermore, we need to prepare EU forests and the forest sector to address the nature and magnitude of the challenges posed by climate change. Doing so will depend on the different territorial scenarios existing in Europe on different spatial scales.[47]

Landscapes reflect past uses and land-management actions, in southern Europe where wildfires are frequent events. In a context of changes in wildfire regimes, climate, and vegetation legacies, managing these ecosystems to maintain the services they provide is a challenge. To this end, providing information about how ecosystems respond to fire is most relevant for managing landscapes and planning post-fire recovery.[47]

Advancing our understanding of people's perception of fire management and policies is a prerequisite for their successful implementation.

The depopulation of rural areas and the expansion of urban areas in western Europe has led to the creation of important interfaces between houses (and other built infrastructures) and forests and other vegetation types with accumulated biomass. When burning, such a high fuel load can create very significant threats to

[46] https://ec.europa.eu/info/sites/default/files/181116_booklet-forest-fire-hd.pdf

people and make firefighting and other civil-protection operations much more difficult to coordinate. Limiting the sprawling of wildland-urban interfaces (WUIs) and mitigating the impact of wildfire in these interface areas elicits many social and scientific challenges, such as establishing construction and development standards, defining asset-protection zones with proper fuel management, and predicting fire spread and behaviour in interface areas and making this information available to the public for a better response in case of emergency.[47]

Fires typically occur in certain meteorological conditions. Fire sensitivity to changes in weather varies from place to place. For operational purposes, fire weather indices based on meteorological variables are used for predicting fire ignition and spread potential. A proper understanding of how the meteorological conditions influence fire spread and intensity is imperative for accurate forecasting of fire danger. Improving meteorological diagnostics and fire danger forecasts will lead to a more effective use of fire suppression resources and planning of emergency operations.[37]

Large and very intense forest fires are occurring in many different regions in Europe and the various agencies and communities are generally not prepared to cope with these new challenges. The preparedness of agencies and communities to deal with those events requires adequate evaluation of risk and timely communication through the development of early-warning systems, as well as training of personnel for efficient emergency operations, including evacuation or confinement plans.[47]

The increasing trend in fuel load and continuity in southern Europe can also be attributed to land abandonment, inadequate landscape and forest management, and fire exclusion policies. The projected increase in drought severity and associated increase in fuel flammability due to climate change are further intensifying forest fire risk beyond existing fire prone areas. Hence, there is a need to integrate forest fire prevention principles in land- and forest management strategies.[48]

In extreme weather conditions a fire ignition can rapidly develop into a large and intense wildfire with catastrophic effects. Timely and accurate detection requires the integration of fire behaviour and forest knowledge at strategic and tactical levels. Rapid wildfire detection is therefore fundamental to coordinating and performing a quicker and stronger initial attack.[48]

Increases in fire danger induced by climate change call for a re-evaluation of current approaches for assessing the likelihood of a catastrophic fire. Seasonal changes in wildfire likelihood result from changes in fuel moisture and in fire weather that, when an ignition source is provided, can lead to catastrophic wildfire if fuel build up is large enough[49]. The challenge lies in developing a quantitative and mechanistic understanding of fire danger that is deep enough to allow accurate forecasting, yet simple enough that it can be used for operational purposes.

Traditional approaches for forecasting seasonal changes in fire weather relied on developing fire weather and danger indices that, often, seek to estimate fuel moisture and potential fire spread depending on past meteorological conditions. These indices have shown mixed success in predicting fire danger[50,51], and they have not been exempted from criticism[52]. Those indices represent more prognoses of fire occurrence, i.e.,

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[47] https://ec.europa.eu/info/sites/default/files/181116_booklet-forest-fire-hd.pdf

[48] https://ec.europa.eu/info/sites/default/files/181116_booklet-forest-fire-hd.pdf

[49] Bradstock, R.A. 2010. A biogeographic model of fire regimes in Australia: Current and future implications. *Glob. Ecol. Biogeogr*. 19: 145–158.

[50] Di Giuseppe, F., Vitolo, C., Krzeminski, B. et al. 2020. Fire weather index: The skill provided by the european centre for medium-range weather forecasts ensemble prediction system. *Nat. Hazards Earth Syst. Sci*. 20:2365–2378.

[51] Bedia, J., Herrera, S., Gutiérrez, J.M. et al. 2015. Global patterns in the sensitivity of burned area to fire-weather: Implications for climate change. *Agric. For. Meteorol*. 214-215(7):369-379. https://doi.org/10.1016/j.agrformet.2015.09.002

[52] Ruffault, J., Martin-StPaul, N., Pimont, F. et al. 2018. How well do meteorological drought indices predict live fuel moisture content (lfmc)? An assessment for wildfire research and operations in mediterranean ecosystems. *Agric. For. Meteorol.* 262: 391–401.

calculated probability of specific fire scenario occurrence – the fire risk. However, when talking about fire danger, we are talking about critical conditions which express the actual potential of vegetation (mostly fine fuel) to be ignited by any ignition source according to its moisture content that strongly depends on actual weather situation and soil condition (moisture content). To provide such assessment at regional or local level, microclimate data should be used on input, taken from IoT sensor, and distributed in the territory.

Developing an early warning system for catastrophic fire, which predicts when and where critical wildfires will occur, as well as educating the populace on how to interpret these predictions, has become an increasing necessity[53].

Understanding changes in fire danger requires integration across multiple spatial and temporal scales.

The increasing intensity of wildfires, together with the increased concern about fire safety and costs, requires better strategies and tactics for firefighting. There is a strong need for professional development in firefighting and the promotion of safety practices for firefighters to face extreme wildfire events in Europe. Successful professional development in firefighting depends on the integration of training and education, which are aligned with the principles of integrated fire management. Common Incident Command Systems and common standards on capacity building for emergency training at European level are needed for enhancing international firefighting assistance.[53]

Safety is a key issue for all involved in fire management. Selection of appropriate firefighting protective equipment, but also to the promotion of safety concerns for current and potential vulnerable areas (e.g., in the WUI) and groups such as tourists is a key safety issue. Awareness campaigns focusing on fire safety, but also on the optimisation of operations — such as firefighters' equipment and the use of forest roads for evacuation and for safe firefighting — are all part of the fire safety issue. The major challenges for dealing with this aspect of fire suppression lie in the risk associated with wrong decisions that can expose lives to unnecessary danger. As decision-making relating to safety concerns is delicate and complex, strong cooperation and the exchange of experiences and lessons learned in Europe and worldwide are necessary to be able to recommend new options in this area.[53]

According to the subsidiarity principle at EU level, the formulation of forest policies is the responsibility of the Member States within a clearly defined framework of established ownership rights and national and regional laws and regulations for long-term planning[54].

The EU complements the efforts of its Member States by identifying policy priorities relating to forest fires in the context of sustainable and climate-resilient forest management, providing financial assistance to forest fire-related activities and creating a common European Forest Fire Information System (EFFIS). EFFIS complements national databases and aims to provide EU level assessments of situations before and after fires, to support fire prevention through risk mapping, and to promote preparedness, firefighting, and post-fire evaluations[55]. Nevertheless, the coherence between EU policies' objectives with respect to wildfire risk management should be improved.

It is also necessary to assess the level of complementarity or coincidence between those policies and the national legislative frameworks defining the structural measures and operational activities regarding protecting forests and communities from fire.[56]

At the national and subnational levels, territorial policies have a role to play in solving the wildfire problem at the prevention and propagation stages, but also in raising risk awareness, notably in metropolitan, rural

[53] Boer, M.M., Nolan, R.H., Resco De Dios, V. et al. 2017. Changing weather extremes call for early warning of potential for catastrophic fire. *Earth's Future* 5: 1196–1202.

[54] http://ec.europa.eu/environment/forests/fpolicies.htm

[55] http://effis.jrc.ec.europa.eu/

and wildland-urban interface areas. Significant differences exist between Member States regarding the degree of centralisation of forest fire management and the type of agency to which the various fire management responsibilities are assigned. The influence of the multilevel governance structure is a key issue in wildfire management. Therefore, the involvement of multiple organisations in fire management, from national to local level, requires the clear definition of authority, functions, tasks, and responsibilities, together with the effective coordination of their activities.[56]

Adequate governance mechanisms can facilitate the integration of science into operations. Similarly, transparency and openness in these governance mechanisms can increase citizens' participation and politicians' accountability, opening the way for traditional and local knowledge integration.[56]

Another important policy element relates to the postfire management of burned areas. Whereas in all EU Member States burned areas are protected from land-use changes for several years after a fire, immediate and compulsory reforestation is no longer a self-evident requirement. The traditional approach for the management of burned areas in the Mediterranean region has been based on reforestation with conifers since the 19th century. Nowadays, the range of alternatives is much wider (e.g., natural regeneration or passive restoration; assisted restoration through appropriate silvicultural techniques to support natural regeneration; active restoration through active seeding or plantation; and finally, conversion to other non-forest uses). Yet, the post-fire restoration methods currently implemented in Europe do not always consider the fire ecology of affected forest and vegetation types.[56]

The ecological role of fire and its controlled use to achieve management objectives (e.g., ecological succession, wildlife and livestock pasture improvement, fuel reduction and wildfire suppression) is only reflected to a limited extent in current national policies. For instance, prescribed burning is recognised as an efficient technique of wildfire prevention but is still very controversial in some countries[57]. The legal frameworks for burning in the Mediterranean Basin range from countries that prohibit it (e.g., Greece) to those that have developed regulations and basic criteria and conditions for the use of fire (e.g., France, Portugal and some regions in Spain and Italy). Overall, there is a lack of integration of fire prevention principles in current forest- and land-management practices and policies[58]. Policy instruments creating incentives for forest and landowners to align decisions and management with the sustainable provision of ecosystem services and wildfire prevention objectives are critically needed.

Integrated fire management builds upon a combination of prevention and suppression strategies stemming from social, economic, cultural, and ecological evaluations. It represents a concept for planning and operational systems aiming at minimising the damage from and maximising the benefits of fire. Beyond the sole consideration of fire prevention and fire suppression, integrated fire management links the four steps of emergency crisis management, i.e., mitigation, preparedness, response, and recovery.[59]

Wildfires primarily affect the forestry and ecosystem service sectors, but agricultural and energy production, public health and tourism may also be impacted, causing damage to property and loss of life. The challenge is to develop integrated solutions which take into account the objectives of forestry, urban and rural development, agricultural, climate and energy policies to ensure that wildfires are managed in such a way that the safety of people and housing, economic growth and ecosystem services are maintained or increased inside the forest domain, a multi-risk approach is needed to take into account the interactions and possible amplification processes between fire and other biotic and abiotic threats. Developing more

[56] https://ec.europa.eu/info/sites/default/files/181116_booklet-forest-fire-hd.pdf

[57] Carreiras, M. et al. 2014. Comparative analysis of policies to deal with wildfire risk. *Land Degradation & Development* 25(1): 92-103.

[58] Montiel-Molina, C. 2013. Comparative assessment of wildland fire legislation and policies in the EU: towards a fire framework directive. *Forest Policy and Economics* 29:1-6. https://doi.org/10.1016/j.forpol.2012.11.006.

[59] https://ec.europa.eu/info/sites/default/files/181116_booklet-forest-fire-hd.pdf

efficient and integrated solutions requires better-informed decision-making and more cooperation and coordination is required.[59]

The perception society of the risk of forest fires determines to a large extent people's response in emergency situations. Forest fires are largely perceived by society as a threat. Although awareness campaigns have been effective in reducing the number of fire ignitions and promoting responsible behaviour, they often underestimate the importance of the ecological and environmental functions which fire helps to maintain. Ensuring communities' resilience to the danger of forest fires requires an improvement in the knowledge of actual exposure to the risk and the effective response in the event of an emergency, as well as a better understanding of the differences between the ecological role of fire and the risk-prevention measures associated with catastrophic wildfires.[59]

Prevention, extinction, and post-fire restoration tasks are fundamentally the responsibility of public institutions. The lack of joint responsibility shared by local communities and landowners calls into question inadequate land-use practices and negligent behaviour causing ignition in fire prone areas. In addition to involving local communities in the design and planning of prevention measures, strengthening the forest sector, and promoting bioeconomy and nature-based solutions, as new ways of sustainable consumption and production, can leverage participative governance, self-protection behaviour and a sense of belonging to the area.[59]

The uncertainty associated with the occurrence of extreme wildfire events requires integrated studies to understand the interaction among the main drivers of extreme fires, i.e., weather, climate, landscape structure and connectivity, fuel build-up and continuity, and social issues. This uncertainty limits the scientific community regarding the effective operational translation of scientific results to enhance wildfire management policies and practices. Nevertheless, information about wildfire dynamics and trends should be easily accessible to all bodies involved in the fire management process to improve understanding and decision-making capacities. Finally, ecology, climate change and forest fire management principles, which are often an unfamiliar subject for educators, should be better addressed in curricula.[60]

Addressing these overarching problems, SILVANUS was envisaged to deliver a technology driven intervention services, which can assist the stakeholders such as pilot owners, civil authorities, fire fighters and others to enhance their operational capacity across all three phases of combating the climate impact of wildfires namely prevention and preparedness (Phase A), detection and response (Phase B) and restoration and adaptation (Phase C).

[60] https://ec.europa.eu/info/sites/default/files/181116_booklet-forest-fire-hd.pdf

2 Glossary

In this section, a common vocabulary structure has been established to facilitate communication among the interdisciplinary teams. The key terms (see Table 1) identified in the section will serve as a common reference for the consortium partners to establish communication among the relevant groups of experts.

Table 1 Key terminology to be further used in the project

Term	Synonym	Description
Authentication and authorization infrastructure (AAI)		Service and a procedure that enables members of different institutions to access protected information that is distributed on different web servers.
Activity		An activity is a scheduled phase in a plan with a distinct beginning and end.
Analysis		The process of studying a System by partitioning the system into parts (functions, components, or objects) and determining how the parts relate to each other.
API		An application programming interface (API) is a connection between computers or between computer programs. It is a type of software interface, offering a service to other pieces of software.
Biodiversity Index		A quantitative measure or estimate of biodiversity state in a certain area and time interval, indexes can inform on different dimensions of biodiversity, including taxonomic and functional diversity, or the state of ecosystems and communities, and be used to compare areas, scenarios, and to monitor change.
Cloud	Cloud platform	Cloud (computing) is an on-demand availability of computer system resources, especially data storage (cloud storage) and computing power, without direct active management by the user
Comparative Analysis		Comparing two or more System between each other using multiple criteria to identify differences or similarities.
Data		Information (e.g., facts, observations, measurements, statistics), especially facts or numbers, collected to be examined and considered and used to help decision-making, or information in an electronic form that can be stored and used by a computer.
Decision Support System		A decision support system (DSS) is an interactive software-based system used to support decision making processes in an organization or a business compiling useful information from a combination of raw data, documents, and personal knowledge, or business models to identify and solve problems and make decisions, potentially empowered by Artificial Intelligence techniques.
Demonstration Scenario		A Scenario through which the SILVANUS platform and other interconnected systems capabilities will be demonstrated. Each Pilot can have one or more Demonstration Scenarios.
Demonstration Site (or Scenario		Demonstration Sites are located within the Pilot Site.

Term	Synonym	Description
Area)		
Edge	Edge system, forward command centre, communication	Edge computing is a distributed computing paradigm that brings computation and data storage closer to the sources of data. Far Edge computing infrastructure is deployed in the location farthest from the Cloud infrastructure (especially power efficient devices). Near Edge computing infrastructure is deployed closer to Cloud infrastructure mainly with higher computing power than far edge devices.
Endpoint		An address or connection point to a Web service. It is typically represented by a simple HTTP URL string
Fire environment		The surrounding conditions, influences, and modifying forces of topography, fuel, and weather that determine fire behavior, fire effects and impact.
Fire management	Wildfire management, bush burning management	Fire management is process of planning, preventing, and fighting fires to protect persons, property and the forest resources.
Forest ecosystem services		Forest ecosystem services are the benefits generated by forests to society. These include provisioning services (material goods, namely wood and non-wood products, such as timber and mushrooms), regulating services (non-material benefits, such as regulation of fire spread, control of soil erosion, or carbon sequestration) and cultural services (such as, leisure areas, hunting areas, heritage values).
Forest Management	Forest/landscape management, sustainable forest management, 3D forests landscape management	Forest management is the process of planning and implementing practices for the stewardship and use of forests to meet specific environmental, economic, social and cultural objectives. It deals with the administrative, economic, legal, social, technical and scientific aspects of managing natural and planted forests. Landscape management is a process of managing the use and development of an area of land for: wildfire prevention; conservation, restoration or protection of the environment; commerce; and/or for other reasons. Sustainable forest management, I.e., sustainable forestry, is the practice of regulating forest resources to meet the needs of society and industry while preserving the forest's health. 3D forest, landscape management is process of managing the use and development of an area of land for: wildfire prevention; conservation, restoration or protection of the environment; commerce; and/or for other reasons using the various type on data for decision support which are visualized in 3D space.
Forest models		Environmentally sustainable model is knowledge, methodology, system used for modelling phenomena and processes having impact on forest, its environmental sustainability. Resistant model is a knowledge, methodology, system used for modelling phenomena and processes having impact on forest and its

Term	Synonym	Description
		resistance. Climate resistant model is a knowledge, methodology, system used for modelling phenomena and processes having impact on forest and its resistance considering the various scenarios of climate change progress. Resilient model is a knowledge, methodology, system used for modelling phenomena and processes having impact on forest and its resilience.
Forest monitoring		Forest monitoring is defined by the International Union of Forest Research Organizations (IUFRO) as the regular and periodic measurement of certain parameters of forests (physical, chemical, and biological) to determine baselines to detect and observe changes over time.
Framework	System	Provides ready-made components or solutions that are customized to speed up development/work.
Fuel management		The process of managing fuel or fuel arrangement. The aim of fuel management is usually to create a discontinuity in fuels to achieve fragmentation.
Infrastructure		A set of physical and virtual resources with computing, storage, networking, scheduling, and managements services that support other systems, services, and applications.
Knowledge base		The underlying set of facts, assumptions, and rules which a computer system has available to solve a problem.
Operational Scenario	System Response Scenario, System Response Sequence	A scenario describing how the proposed system should operate and interact with the Stakeholders and external components/systems.
Participation	Participatory processes, semantic framework for stakeholders' involvement	Participation is "a voluntary process in which public can express their views individually or through organized groups, expressing interests that have the potential to influence the decisions or material inputs of the public administration (Food and Agricultural Organization (FAO), 2000)
Pilot (Pilot Site)		Pilot Site means a geographic site carrying out a Pilot. Pilot Site is in the Pilot Provider's territory and selected under the Project for demonstrating the project results. Pilot has typically one Pilot Site, but there can be Pilots with more than one Pilot Site too. We have 11 Pilots in the SILVANUS project.
Pilot Provider		The organization providing the Pilot.
Platform		Option 1) SILVANUS platform consists of all the software and hardware components deployed and used to deliver the SILVANUS functionalities. Thus, SILVANUS is a system of systems. Option 2) SILVANUS platform comprises the software implemented in the Cloud that supports the command centre and the services needed

Term	Synonym	Description
		to support the SILVANUS functionalities. Platform, system, digital services, big-data framework, software-oriented design, ….
Problem Domain		A set of similar problems that occur in an environment and lend themselves to common solutions.
Project Member		A member (organization) of the SILVANUS Project Consortium.
Questionnaire Table		Is a table with questions to be answered by Stakeholders. The Questionnaire Table has a defined structure with defined fields.
Remote Sensing Instrument	Instruments, sensors, cameras	Electronic devices for acquisition of information about an object or phenomenon without making physical contact with the object. The sensor devices are usually installed or focused on the area of sensing and are interconnected with "a remote" processing unit. In current usage, the term "remote sensing" generally refers to the use of satellite or aircraft-based sensor technologies to detect and classify objects on Earth.
Risk	Risk, wildfire risk, fire danger, susceptibility, vulnerability	Risk is a provability of emergency event/phenomena occurrence, which is calculated based on relative frequencies of such an event occurrence in the past. Fire danger is a description of the combination of both constant and variable factors that affect the initiation, spread, and ease of controlling a wildfire on an area. Susceptibility is the probability estimation of fire occurrence in a region. Vulnerability is a characteristic determined by physical, social, economic, and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards (wildfire).
Scenario		A step-by-step description of a series of events that may occur concurrently or sequentially in the Pilot Site (ConOps, 1998).
Solution Domain	Problem Domain	The environment in which a solution or set of solutions resides.
Stakeholders		Stakeholders are any group or individual who can affect or is affected by the achievement of the Pilots objectives. (Freeman, 1984)
System		(A) A collection of interacting components organized to accomplish a specific function or set of functions within a specific environment. (B) A group of people, objects, and procedures constituted to achieve defined objectives of some operational role by performing specified functions. A complete system includes all the associated equipment, facilities, material, computer programs, firmware, technical documentation, services, and personnel required for operations and support to the degree necessary for self-sufficient use in its intended environment.
Use Case		An Operational Scenario can be decomposed into individual steps and subsequently into Use Cases.

Term	Synonym	Description
User		An individual or organization who operates or interacts directly with a software-intensive system - in this case the SILVANUS platform and interconnected components and systems.
User Need/ Requirement		A User requirement for a system that a user believes would solve a problem experienced by the User.
User Products		The software/hardware driven solutions which are accessible to the end-users such as firefighters, civil authorities, and other relevant stakeholders.
Virtual machines		Virtual machine is the virtualization/emulation of a computer system. Virtual machines are based on computer architectures and provide functionality of a physical computer.
Wildfire	Wildfire, wildland fire, bushfire, forest fire	Wildfire is any uncontrolled vegetation fire which requires a decision or action regarding suppression. Wildfires are commonly classified according to size and/or impact upon suppression resources. Wildland fire is an uncontrolled fire in a forest, grassland, brushland, or land sown to crops. Bushfire is an uncontrolled fire in the trees and bushes of scrubland. Forest fire is an uncontrolled fire occurring in vegetation more than 1.8 meters (6 feet) in height.

It is important to note that, as the project platform develops, any new additional vocabulary to the used as a common exchange of medium will be included in the table and a revised version of the table will be included in the WP9 deliverable as a consolidated summary.

3 Participatory Process – Methodology and Guidelines

This section contains the description of methodology used to establish the participatory processes among the SILVANUS stakeholders as well as the guidelines which were used to collect the important information and knowledge on existing data, systems, services, and technology as well as the SILVANUS platform functional requirements specified by stakeholders.

3.1 Participatory process methodology

Within the overall research design of the SILVANUS project, WP2 (T2.1) identifies and suggests ways and means of how to engage all relevant stakeholders. The reasoning behind is to inform and engage the citizen into the project activities, what is one of the scopes of WP3. The citizen engagement programme will engage with diverse communities and evaluate the effectiveness of semantic technologies to facilitate knowledge sharing among stakeholders.

The knowledge developed in SILVANUS project is going to be used to enhance preparedness for combating wildfires, response coordination and rehabilitation activities. To achieve this, **it was necessary to characterize Operational Scenarios and to identify stakeholders within three phases in combating against the spread of wildfires**.

Within SILVANUS project following three phases (A/B/C) in combating against the spread of wildfires are distinguished:

Phase A: Preparedness and Prevention

Specification of significant and vulnerable areas by:

- formalization of environmental biodiversity profile for each geographical region,
- specification of fuel distribution and structure profile for each geographical region,
- self-assessment toolkit for environmental assessment and modelling,
- quantifiable ecological assessment of forest biodiversity.

Improving monitoring and signalling of fire hazards by:

- continuous monitoring of fire danger index against accidental and intentionally set fires and arson using satellite and sensor data (see EFFIS, https://effis.jrc.ec.europa.eu/)
- algorithms to model impacts of wildfires on climate change, environment, and economy,
- enhancement of wildfire prevention and management tactics methodologies and procedures using the progressive ICT tools,
- prophylactic wildfire prevention strategy and on-site management actions, where areas at high risk of wildfire can be treated to reduce wildfire risk and/or protected from ignitions throughout the peak fire season.

Engagement and interconnection of forestry management representatives and public by:

- landscape assessment tools to evaluate wildfire proneness and risk and support management planning
- training handbook for firefighters on the safety regulations for the deployment of technologies,
- upgrade of existing wildfire alerting systems,
- increasing public/citizen awareness – alerting system via a Citizen engagement toolkit (mobile application) for preventive fire monitoring tools.

Phase B: Detection and response

Wildfires early detection and monitoring based on:

- deployment of wireless sensors for early detection of fires,
- deployment of mechanical platform (including Unmanned Aerial Vehicles (UAVs), Unmanned Ground Vehicles (UGVs) for continuous surveillance and early-stage situational awareness,
- wireless communication infrastructure for coordinating first responders,
- aerial platform equipped with innovative multi-spectral sensors and payload capacity for fire site mapping.

UAV-Based Remote Sensing and Remote Operated UGV-Based Methods Application for Wildfire Mapping and Fire behavior Modeling using:

- coordination between UGVs and UAVs to obtain the key information to adjust the parameters used for modelling the fire behavior,
- advanced algorithms to perform onboard stream analytics using edge computation.

Data integration and analytics based on:

- integration of different platforms with existing ICT solutions/platforms in a specific region,
- modelling of granular and incremental weather pattern changes using data analytics.

Decision Support Systems application:

- decision support system for sources and resources deployment and management.

Phase C: Restoration and adaptation

Building knowledge base containing:

- geographical data,
- national forest inventory data,
- fire-fighter`s data scientific knowledge,
- reports on intervention
- scientific knowledge,
- technical reports,
- whitepapers.

Development of the forest and landscape management alternatives for specific regions considering the information on:

- biodiversity index,
- ecological site classification,
- forest growth model,
- climate projections.

Application of Decision Support System (DSS) tool for alternatives assessment and finding the optimal management approach for a specific area considering:

- the stakeholder`s requirements,
- development of fire prevention, impact mitigation and management alternatives for a specific area,
- DSS for assessment of the alternatives,
- soil rehabilitation strategy,
- restoration roadmap of natural resources.

The methodology described here served as a Guide for providing interviews with stakeholders.

The Pilot study coordinators / WP leaders / Task leaders (interviewers) should conduct the interviews based on Questionnaire Tables. Besides defining stakeholders, they also clarified the method (s) of reaching them (e.g., personal interviews, group or focus interviews, mailed questionnaires, telephone interviews, observation). The purpose of the interview or observation was to collect primary data, the original data collected for specific research goal. Secondary data are data that were collected originally for different purpose or research. These data could be reused and collected by Pilot study coordinators / WP leaders / Task leaders (interviewers), as in Hox, Boeije (2005)[61]. The participatory process was composed of following steps:

- Reviewing any existing documentation (e.g., personal sources, journals, newspapers, websites, government records).
- Researching vendor solutions used by stakeholders involved.
- Collecting active user comments and suggestions.

Process of information gathering interview[62,63]:

1. Asking detailed information for the Questionnaire Tables that are related to interviewing stakeholder.
2. The gathered information for one Questionnaire Table should not overlap too much with another Questionnaire Table.
3. Taking through notes to the information does not get missed or forgotten later.
4. Identifying/documenting unanswered items or questions.
5. Noting the open issues which don't match with any Questionnaire Table.
6. Noting if there are any exceptions and errors conditions to consider.

Information gathering interviews (e.g., personal interviews, group or focus interviews, mailed questionnaires, telephone interviews, observation) should be performed by Pilot study coordinators / WP leaders / Task leaders (interviewers):

- Directly interviewing users and other stakeholders.
- Distributing and collecting questionnaires.
- Combination of the above (distribute and collect questionnaires and then interview to clarify any obscure point).

When enacting the interview, the following must be recorded:

- **Interviewer** – person conducting the interview (persons, organization)
    - For persons: Name, position, organization, email, phone
    - For organizations: Full name, Abbreviated name, address, short profile (description)
- **Interview partner** - person with whom is interview conducted (e.g., internal, or external stakeholders)
    - For persons: Name, position, organization, email, phone
    - For organizations: Full name, Abbreviated name, address, short profile (description)
- **Date and Time** – date and time when the interview was accomplished. If multiple sessions, please list all of them.
- **Place** – place where the interview was accomplished (organization, city, country) if in-person meeting. Other types are Phone, Video conferencing, E-mail or other.
- **Recording** (optional, only if available) - if the Responder(s) agree, fill out reference to a meeting recording(s), such as MS Teams call recording, phone call recording or video recording from an in-person meeting. If possible, annotate the recordings with time.

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[61] Hox, J.J., Boeije, H.R. (Data collection2005): Data collection, primary versus secondary. In Kempf-Leonard, K. 2005. *Encyclopaedia of Social Measurement*, p. 593-599.

[62] Kvale, S. 2007. *Doing interviews*. London: SAGE Publications. 157 p. (The SAGE Qualitative Research Kit, Vol. 2).

[63] Creswell, J.W., Guetterman, T.C. 2019. *Educational research: planning, conducting, and evaluating quantitative and qualitative research*. New York, NY: Pearson, pp. 655.

- **Consent** – an agreement of Interview partner to be included/not included in dissemination list of SILVANUS project. The contact details will be not publicly available.

The evaluation of Information gathered by interviews included:

- Review replied to information for accuracy, completeness, and understanding
- Transfer information into data models (database or data tables) and documents (only for face-to-face interviews)
- Data processing (frequency tables, histograms, clusters, stakeholders mapping)
- Based on the open issues, identify if there are any topics that need to be further clarified.

3.2 Guidelines for the Preparation and Comparative Analysis of Existing Sustainable Forest Management Services and Formalization of Functional requirements

This document represents the 'Common Guideline for the Preparation and Comparative Analysis of Existing Sustainable Forest Management Services and Formalization of Functional requirements' of WP2. The purpose of the guideline is to serve as a guide for the SILVANUS project partners who drafted reports concerning tasks T2.1 and T2.2.

This "guideline document" should help SILVANUS partners to understand and guide them on how to describe and provide information concerning existing measures within the above described three phases (A/B/C) in each Operational Scenario. The information provided will be used to design a knowledge platform for the SILVANUS project.

Chosen communication model provides the information needed to create appropriate communication channels and environment for cooperation among individuals within the organizational model while completing specific tasks.

An interview and a questionnaire method were used to obtain information concerning existing measures within the three phases (A/B/C) in each Pilot. For the purposes of planned structured interview (Creswell, Clark 2018), the questionnaire elaborated in English language must be translated by relevant Pilot study coordinator / WP leader / Task leader for each Pilot. The questionnaire will include closed and open questions grouped by specific topic (area) organized in tables, according to Creswell, Clark (2018)[64].

Pilot study coordinator/ WP leader / Task leader should identify in advance relevant stakeholders according to specific nature of analysed phase (A/B/C). The most suitable external stakeholder (e.g., those partners who are geographically close - same country or region or organization, have a close professional relationship with phase A/B/C) for an interview must first receive information about the SILVANUS project and its objectives (e.g., leaflet or other promotional materials of the project). After establishing contact, an appointment for the interview with interested stakeholders must be arranged. The subsequent interview must be based on the Questionnaire Tables provided in this guideline and translated in advance into relevant language. It is necessary to note in which phase (A/B/C) in combating against the spread of wildfires, the given stakeholder is active.

Another objective of the "guideline document" was to standardize and harmonize the process and information asked for in the Questionnaire Tables and provided by the stakeholders to achieve T2.1 and T2.2 goals (Figure 2).

[64] Creswell, J.W., Clark, V.L.P. 2018. *Designing and Conducting Mixed Method Research*.3rd Edition. SAGE Publications, Inc. 520 p.

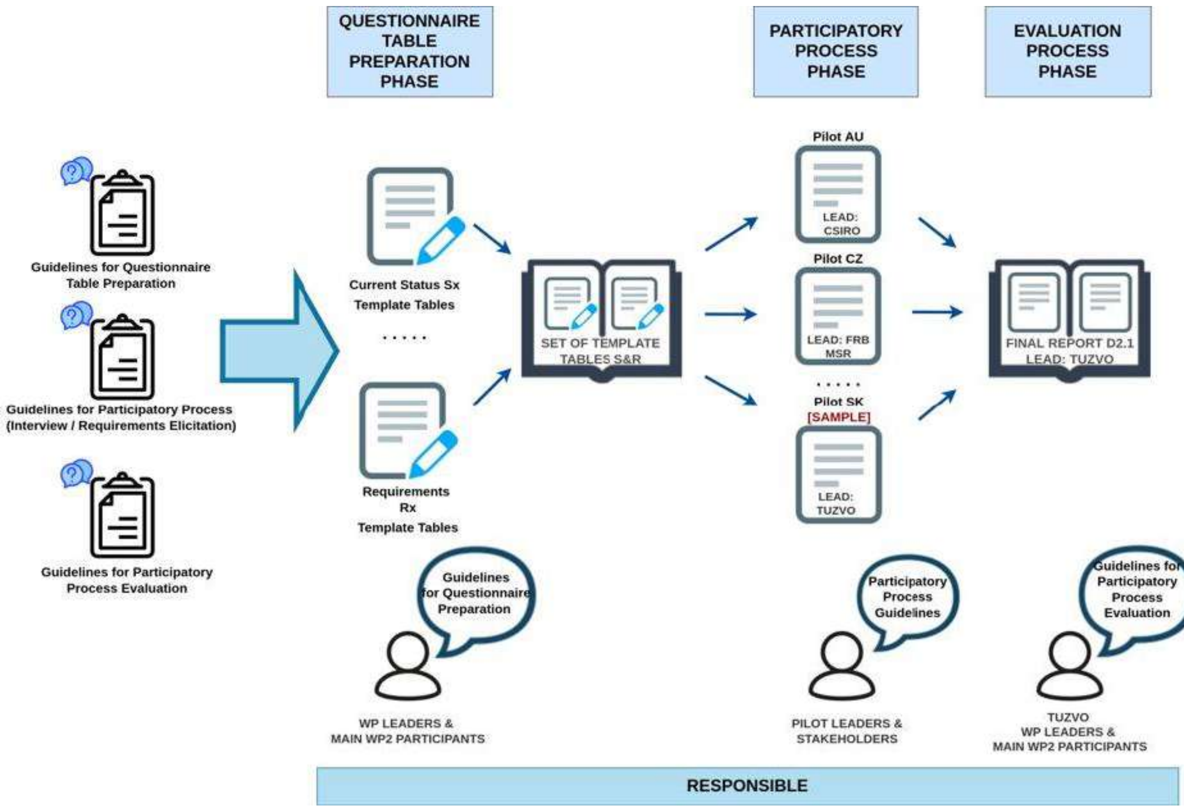


Figure 2 The process of WP2 leading to D2.1

Except the methodology for establishing the participatory processes, another methodology was proposed in these Guidelines, i.e., methodology for questionnaire preparation

3.2.1 Methodology for the Questionnaire Preparation

This methodology is de facto the Guide for the Authors of Questionnaire Tables.

Specifically, this section provides the methodology about how the Questionnaire Tables are designed so the OS coordinators / WP leaders / Task leaders could review and add new questions and/or tables before the consultations (interviews). The questions asked should focus on the status of the methodologies, processes and technologies used in the three phases (A/B/C). The authors of Questionnaire Table (interviewers) must be aware that the answers should help them clarify why the specified functional requirements are necessary and how they enhance the common practice (methodologies, processes, and technologies).

Extending the Questionnaire Table with new questions, please:

- Use the "Revision" Mode in MS Word
- Define the Fields as proposed in the Methodology
- Formulate/reformulate question so it is easily comprehensible by the stakeholders
- Use the terms defined in the Terminology section
- The decision about the final Question formulation is up to the Table Lead

Proposing or reformulating a term in the Terminology table:

- Use the "Revision" Mode in MS Word
- Add a new line or propose a new definition for an existing term

- The decision about the final Question formulation is up to WP2 Task Force

When commenting, please:

1. Select the text you would like to comment
2. Use the "Insert" - "New Comment"
3. The Comment should be resolved by:

- Table Lead – if inside Table
- Guideline Lead (TUZVO, UISAV) – if outside the Table

Proposing a new Table:

- Use the "Revision" Mode in MS Word
- Notify TUZVO about the need to add new table
- Increment Table Number
- Add to the List of Tables
- Create a new Table Template
- Propose individual Table according to instructions in the Guide

Structure of the Questionnaire Tables

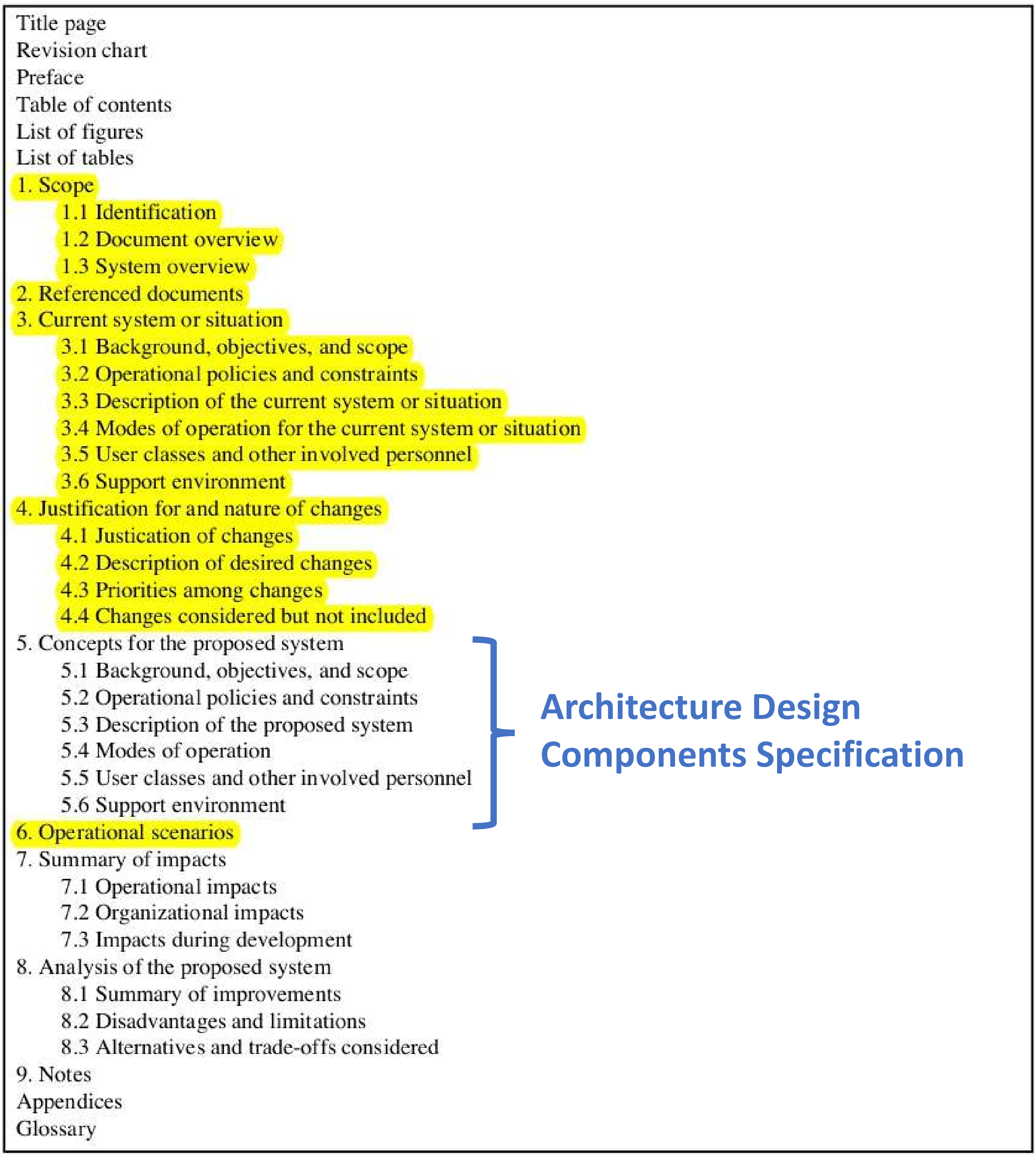
Questionnaire is composed of Tables dedicated to collect information concerning a specific topic (area) either concerning the Current/Existing Status, Functional Requirements and Operational Scenarios. Therefore, the following tables were proposed:

Table 2 The types of Questionnaire Tables

Information Gathered by the Questionnaires	Phase A/B/C Questionnaire Tables
Existing **S**tatus for: • Generic Pilot description • Used Infrastructures and Technologies • Datasets • Stakeholders • Policy Instruments	Table S1 Table S2 Table S3 …
Functional **R**equirements • Challenges • Technologies used to address Challenges	Table R1 Table R2 Table R3 …
Operational Scenarios **D**efinitions • Scenario Definitions • Key parameters of Platform	Table D1 Table D2

The Questionnaire Tables were organized into chapters **loosely following** the ConOps[65] [ConOps98] document structure (Figure 3). Specifically, the highlighted chapters (in the Figure 2) will be generated for each Pilot upon completion of all the Questionnaire Tables. A ConOps is a user-oriented document that describes system characteristics of the to-be-delivered system from the user's viewpoint.

[65] IEEE Std 1362™-1998 (R2007



Title page
Revision chart
Preface
Table of contents
List of figures
List of tables
1. Scope
  1.1 Identification
  1.2 Document overview
  1.3 System overview
2. Referenced documents
3. Current system or situation
  3.1 Background, objectives, and scope
  3.2 Operational policies and constraints
  3.3 Description of the current system or situation
  3.4 Modes of operation for the current system or situation
  3.5 User classes and other involved personnel
  3.6 Support environment
4. Justification for and nature of changes
  4.1 Justication of changes
  4.2 Description of desired changes
  4.3 Priorities among changes
  4.4 Changes considered but not included
5. Concepts for the proposed system
  5.1 Background, objectives, and scope
  5.2 Operational policies and constraints
  5.3 Description of the proposed system
  5.4 Modes of operation
  5.5 User classes and other involved personnel
  5.6 Support environment
6. Operational scenarios
7. Summary of impacts
  7.1 Operational impacts
  7.2 Organizational impacts
  7.3 Impacts during development
8. Analysis of the proposed system
  8.1 Summary of improvements
  8.2 Disadvantages and limitations
  8.3 Alternatives and trade-offs considered
9. Notes
Appendices
Glossary

Figure 3 The generic structure of a ConOps Document

Development of the other chapters of the ConOps document can follow in the tasks (Architecture Design and Component Specification) building on the work delivered in chapters 1-4 and 6 thus forming the chapter 5 of the ConOps.

The Questionnaire Tables were organized according to the above referenced ConOps schema as follows (Figure 4):

SILVANUS Pilot ConOps

Structure

Chapter	Section	Questionnaire Table		Note
1. Scope				
	1.1 Identification			
		S1	Pilot Summary	
	1.2 Document overview			
	1.3 System overview			
		S1.1	Overall Pilot Schema with overview of Technological Components	
2. Referenced documents				
3. Current System Situation				
	3.1 Background, objectives, and scope			
		S2	Key factors to be considered in the demonstration scenario	
	3.2 Policies, constraints and challenges			
		S3	Operational scenarios problems (challenges) to be considered	
		S3.1	Generic Characteristics of Policy	
	3.3 Description of the current system or situation			
		S4	Generic Characteristics of the Pilot Site	
		S5	Use of UAVs (Drones) and UGVs (Robots)	
		S6	Remote sensing technology, Sensors and IoT Tools and Instruments	
		S7	Existing Fire Alerting/Fire Detection Systems	
		S8	Communication Protocols and Data Interchange	
		S9	Big Data Frameworks	
		S10	Cloud usage	
		S11	Social Media Usage	
		S12	Decision Support Systems	
		S13	Available Datasets	
	3.4 Modes of operation for the current system or situation			
		S14	Operational Description (Phase A, B, C)	
	3.5 User classes and other involved personnel			
		S15	Organizational Description, Schema	
		S16	Generic Stakeholder Profile	
4. Justification for and nature of changes				
	4.1 Justication of changes			
		R1	Forest Landscape models	
		R2	Climate sensitive forest management	
		R3	Forest resilience models	
		R4	Forest fire ignition models	
		R5	Prevention methodologies	
		R6	Citizen engagement and awareness programme	
		R7	Tailored weather/climate models for forest fire threat/risk assessment	
		R8	Training Requirements	
	4.2 Description of desired changes/Functional Requirements			
		R9	In-Situ data analytics	
		R10	Social sensing and conceptual extraction	
		R11	UGV monitoring of wildfire behaviour	
		R12	UAVs deployment for remote sensing	
		R13	Earth observation data analytics	
		R14	Situational awareness of fire danger index	
		R15	Real-time monitoring of fire behaviour for response coordination	
		R16	Decision support systems for detecting and preventing forest fires and forest restoration	
	4.3 Priorities among changes			
		R17	Sorted and justified priorities for 4.1 and 4.2	Will be generated. Please do not fill.
	4.4 Changes considered but not included			
		R18	Changes which are wished but not realized in the project	Will be generated. Please do not fill.
6. Operational Scenarios				
		D1	Operational Scenarios - Use Cases	

Figure 4 The SILVANUS Questionnaire Tables organized according to the ConOps structure

Questionnaire Table Design

Each Questionnaire Table has the following **Master Properties**:

- **Table Code** – identifier of the table consisting of a letter representing phase (A/B/C) and a sequence number. For instance, the tables related to phase A will have the following Codes: A1, A2, A3, ...
- **Title** – table title provides description of the topic (area)
- **Lead/Contributors** – who is the lead and who are the contributors to specification of this table (short name of the partners). When updating the field, always the Lead partner should be consulted by the Contributor(s).
- **Output to be used in WP/Tasks** - specifies which WPs and Tasks will mainly use the data gathered by the table. Mainly technical WPs and Tasks are expected to be listed here.

Leading partner was responsible for making sure that the table applies to the guidelines set herein as well as for the content of the table. Each WP/Task Leader must make sure that information required as input for their WP/Task from Stakeholders to be collected!

Each Table has the following columns (**Fields**) which defines the information to be collected:

1. **Id** – unique numerical identification of the item in the table (integer starting from 1)
2. **Item** – a unique item (questionnaire field) name. Please try to describe the item just in few words, use EN letters or numbers with capitalized words, no special characters (e.g., “Fire Type”, or “Communication Protocols”).
3. **Type/**Data Type - what kind of data can best represent the reply to the answer of this item (e.g., Integer/real numbers, List, Image, Schema, Dataset, Text, etc.) by this item. Please refer to all possible data types in **Table 4** below.
4. **Reference** - reference to papers, publications or a relevant web page for further information concerning this field. Full reference should be provided in the last chapter “Reference”. When collecting replies in the table just refer with a reference number from the list.
5. **Unit** (optional) - unit in which the item should be specified (e.g., hectares, EUR, or other).
6. **Questions –** one or several question(s) to be asked. Including hints/notes which might be useful to mention during the consultations.
7. **Response** – if multi-option or single-select, free tech, single number, List with specified fields or other. If schema, request link to its source and request uniform application to be used (e.g., Draw.io or PowerPoint drawing – to have a possibility to make changes to the schema).
8. **Phase A/B/C** (if relevant) -
9. **Comment, Notes or References** (optional) **–** any other comment or note concerning the respective item:
    a. Comments from those answering the questions (Responders) and
    b. Notes from the ones making the interview (Researchers). Can include notes about who specifically has answered the respective item question.

Each field can have some explanatory text to be marked as “**Hint**”.

Each property was mandatory (required) unless specified as optional. The tables should be designed in a way that a database creation is easily feasible when filled out by multiple project partners (internal stakeholders) as well as external stakeholders with further easy data integration, aggregation, and representation. If there were any notes concerning any text in the table, selecting the text and adding comments using MS Word feature was required. If there was already a comment, its attachment as a reply to the respective comment was required.

Table 3 Field/Data Types

Data Type	Description	Example of Use
Text	Multi-Line Text field	“”” Multiline text …”””
String	A short answer where usually a single line string can capture the reply	“Short text answer.”
Integer	Integer Number	10; 5,000.
Real	Real Number	5,000,000.45
Currency	Real Number representing amount of money + currency code, with or without decimal part	4, 500.00 USD 3,567,000 EUR
Date	Format: YYYY-MM-DD	2022-01-23
Time	Format: HH:MM; HH:MM:ss	23:45; 13:54:25
DateTime		2022-01-05 09:16
List	List of several values (numbers or strings) List(string)	(Red) - High Hazard (White) - No Hazard (Green) - Low Hazard
Multi-Choice	Select several choices. Selection	[ ] First Choice [x] Second Choice [x] Third Choice - [ ] First Choice [X] Second Choice [x] Third Choice X – preferred, x – less preferred
Single-Select	Select only out of all selections.	(o) Select One ( ) Select Two ( ) Select Three
Scale <MIN .. MAX)	Select a value on a scale from MIN to MAX.	<10 .. 100) Including value 10, not including value 100.
Drawing	In Diagrams.net or PowerPoint format. Link should be provided to the source, preferably in the MS Teams project repository.	URL to the drawing.
Picture	Photography or image. Link should be provided to the source, preferably in the MS Teams project repository.	URL to the image
Dataset	Any relevant dataset including Link to the data set, License (Terms of Use), short description. How often updated.	URL to the dataset

Video	Link to a video (YouTube preferred) or standard video format (such as MPG, AVI or MKV) or MS Teams telco recording (with a link). Time annotation should be provided	**Video Title:** forest_fire1.mpg **Video Link:** https://.... **Relevant time sequence:** 00:00:45-00:10:00 **Time Annotation:** 00:01:15 – fire is ignited 00:05:23 – firefighting activities starts 00:09:56 – fire is extinguished

For all numerical data types (Integer, Real, Currency) following separators were used:

- Thousand's separator: “,“
- Decimal Separator: “.”

Implementation of the Questionnaire Tables

Survey Tool JotForm was used to Collect the Replies. **Considered Criteria for choosing JotForm were:**

- Enable support of input tables with different fields and formattable paragraph (to enable writing narratives).
- Enable returning to complete the semi-finished survey.
- Export into data format, aggregation, and visualization of results.

Consent from WP/Task Leaders

The information aggregated in the following table (Table 4) have been reviewed and updated by relevant technical partners in the consortium. Additionally, the consolidation of effort required to capture the needs and demands of the end-users have been collected through task leaders and relevant experts from the SILVANUS consortium.

Table 4 WP/Task Leaders’ Consent Table

WP/ Task	Title	Lead	Excerpt from the WP/Task description addressing the need for consultation	Do the formulation of questions in individual questionnaire tables tackle all the inputs and requirements of your WP or Task needed to be addressed during the consultation phase?
WP2	Environmentally sustainable, resilient forest models and assessment framework	TUZVO	The aim of the task is to develop a systematic procedure to engage the stakeholders involved in the forest management operations.	**Consent: YES** **Name:** Andrea Majlingova (TUZVO) **Date:** 2022-01-31 **Note:** -
T2.3	Forest landscape models for wildfire threat assessment	AUA	Models that incorporate other **spatio-temporal processes** such as natural disturbances ... and human influences importance of structurally diverse forests for the conservation of **biodiversity**	**Consent: YES** **Name:** Kostas Demestichas **Date:** 2022-02-02. **Note:** During the course of the project

WP/ Task	Title	Lead	Excerpt from the WP/Task description addressing the need for consultation	Do the formulation of questions in individual questionnaire tables tackle all the inputs and requirements of your WP or Task needed to be addressed during the consultation phase?
			post fire suppression and provision of a wide range of ecosystem services **Fuel management** alternatives for different forest types	implementation, the user requirements analysis will be further refined based on the project outcomes as delivered within the project.
T2.4	Climate sensitive forest models for impacts on forest management	CMCC	The task will apply forest ecosystem models under an ensemble approach to evaluate the future uncertainty in the provision of key forest ecosystem services (climate and water regulation) under alternative climate and management.	**Consent: YES*** **Name:** Monia Santini **Date:** 2022-02-14 **Note:** The development of the climate sensitive forest models will be evaluated for the temporal resolution of the user products delivered for demonstrations.
T2.5	Forest resilience from historical case studies	ASSET	Historical wildfire database, forest resilience assessment based on historical data.	**Consent**: Yes **Name**: Mariangela Lupo **Note**: A broader consolidation of historical case-studies is required to review the global impact of wildfires.
T2.6	Assessment framework	Z&P	The framework will incorporate the stakeholder feedback on the effectiveness of technological intervention delivered by the project	**Consent: YES** **Name:** Alexandre Lazarou **Date:** 2022-02-10 **Note:** Further iterations and refinements are required in consultation with FireLogue and other IA projects.
WP3	Culture of deterrence and prevention against wildfires based on sustainable forest management services	SIMAVI	The outcome of the WP will result in Phase A: Preparedness and prevention solutions developed **through interdisciplinary stakeholder consensus**.	**Consent: YES** **Name:** Gabriela Panzariuc / Mihaela Baciu **Data:** 2022-04-02
T3.1	Sustainable and Resilient Forest Management Knowledge Model (Ontology, Semantic Model)	EAI	… semantic model, based on the biodiversity and fire danger index (T2.3), that seamlessly integrates several **standard vocabularies** for describing **(geographic) knowledge**. … extend the database of 'certainty of knowledge' on the	**Consent: YES** **Name:** Vincenzo Masucci **Date:** 2022-02-22

WP/ Task	Title	Lead	Excerpt from the WP/Task description addressing the need for consultation	Do the formulation of questions in individual questionnaire tables tackle all the inputs and requirements of your WP or Task needed to be addressed during the consultation phase?
			cause of wildfire. … existing datasets need to be ingested and augmented by **project-specific biodiversity data**.	
T3.2	Forest fire ignition models	SIMAVI	The task will include the outcome of T2.4 to include the **historical causes of regional fire** including human negligence, power faults, arson and external weather conditions.	**Consent: YES** **Name:** Razvan Gliga **Data:** 2022-04-02
T3.3	Preparation and pre-planning activities for wildfire response	SBPS	… training methodology will include the **operational knowledge of technologies** developed in WP4 and WP5 …; … task will formalise the **new protocols** developed in the project with the **existing practices adopted by the first responders** across different geographical regions.	**Consent**: Yes **Name**: Pawel Gromek **Date**: 2022-05-04
T3.4	AR/VR content curation for training firefighters	SIMAVI	… o designs the AR/VR interfaces in close consultation with the practitioners to deliver **training for tackling forest fires.**	**Consent: YES** **Name:** Bogdan Gornea **Data:** 2022-04-02
T3.5	Citizen engagement programme for preventing wildfires	HB	These strategies will also consider the **sociocultural framework of the region** and the **characteristics of the local communities** to ensure maximum reach and involvement.	**Consent**: Yes **Name**: Nasrine Olson **Date**: 2022-05-04
T3.6	Mobile application for citizen engagement	MDS	The application will include features such as safety notifications, **regional regulations** across Europe and **global communities for fire prevention** and ability to interface with **wireless communication infrastructure** during the event of a forest fire.	**Consent**: Yes **Name**: Natalia Stathakarou **Date**: 2022-05-04
WP4	Advanced detection capabilities for early-stage detection of wildfires	CMCC	The main aim is to collect, aggregate and pre-process data coming from **heterogeneous sources**, including: **EO satellite data**, outputs from **weather and**	**Consent: YES** **Name:** Marco Mancini (CMCC) **Date:** 2022-02-01

WP/ Task	Title	Lead	Excerpt from the WP/Task description addressing the need for consultation	Do the formulation of questions in individual questionnaire tables tackle all the inputs and requirements of your WP or Task needed to be addressed during the consultation phase?
			climate models, **social media**, in-situ **IoT devices**, **UAVs** and **UGVs**	**Note: -**
T4.1	Data collection, aggregation, and pre-processing of earth observations	DELL	The task will provide relevant IT interfaces for collecting and aggregating earth observation products for subsequent use within the project. The products to be selected from the EO data repository will be identified in collaboration with the pilot parnters.	**Consent**: Yes **Name**: David Bowen **Date**: 2022-05-04
T4.2	Tailored Weather/Climate models output for forest fire threat risk assessment	CMCC	This task will provide high quality and reliable data from **weather forecast models** (ECMWF, COSMO) in the short-term range (up to 72 hours), using statistical analysis tools to remove biases and to perform downscaling. Also, **probabilistic forecasts of fire danger indexes** will be provided based on the ensemble **seasonal forecasts** produced by C3S.	**Consent: YES** **Name:** Paola Mercogliano (CMCC) **Date:** 2022-02-01 **Note: -**
T4.3	Data collection, aggregation and pre-processing of in-situ devices	CTL	The goal of the task is to develop a distributed data architecture, software protocols and services to interface with IoT devices (environmental sensors, CCTV cameras, etc) installed within the forest	**Consent: YES** **Name:** Konstantinos Avgerinakis (CTL) **Date:** 2022-01-31 **Note:** -
T4.4	Social media sensing and concept extraction	CERTH	This task aims at the real-time collection of citizen observations from social media about fire incidents, and the extraction of location-related concepts and visual concepts (e.g., flames, smoke) from social media text and images.	**Consent: YES** **Name:** Stelios Andreadis (CERTH) **Date:** 2022-02-02 **Note: -**
T4.5	UGV–based forest understanding for preventing and mitigating for wildfire	CSIRO	This task will focus on the development of autonomous ground robots to navigate under canopy and extract information from forests (e.g., vegetation density, state, etc) to assist in fire prevention and mitigation	**Consent: YES** **Name:** Paulo Borges (CSIRO) **Date:** 2022-02-03 **Note: -**

WP/ Task	Title	Lead	Excerpt from the WP/Task description addressing the need for consultation	Do the formulation of questions in individual questionnaire tables tackle all the inputs and requirements of your WP or Task needed to be addressed during the consultation phase?
T4.6	UAV deployment for remote sensing and identification of wildfire	TRT	This task aims to develop an autonomous system of UAV to provide monitoring services, so as to minimize human intervention.	**Consent: YES** **Name:** Florence Aligne (THALES) **Date:** 2022-02-04 **Note: -**
WP5	Response coordination to contain the spread of wildfire	DELL	The main aim of the WP is to establish a horizontal activity on setting up the relevant big-data framework and aid in the design and development of wildfire detection and response coordination services.	**Consent**: YES **Name**: David Bowden **Date**: 2022-05-04
T5.2	Semantic framework for information fusion [	CTL	This task aims at delivering a unified, scalable, and holistic semantic framework for information fusion that will generate an RDF-based unified semantic knowledge graph (KG) for decision support from diverse and heterogeneous sources (UAVs, UGVs, cameras, sensors, citizen science, etc.).	**Consent: YES** **Name:** Konstantinos Avgerinakis (CTL) **Date:** 2022-01-31 **Note:** -
T5.3	Real-time monitoring of wildfire behaviour in temporal space for response coordination	CTL	The goal of this task is to develop real-time monitoring dashboard for visualising the spread of wildfires within the landscape models. Additionally, a set of KPIs will be adopted to perform the envisioned monitoring activities for detecting the impact of wildfires on the response teams and citizens in the nearby area.	**Consent: YES** **Name:** Konstantinos Avgerinakis (CTL) **Date:** 2022-01-31 **Note:** -
WP6	Enhanced resilience programme for forest management through restoration and adaptation	AMIKOM	To analyse and promote ecological policies to rehabilitate forests following the neutralisation of wildfires. The rehabilitation strategy will consider the impact of forest fire on the soil, environment, and regional requirements, as well as local communities.	**Consent: YES** **Name:** Kusrini **Date** 2022-02-02 **Note:** need iteration
T6.1	Ecological resilience programme	AMIKOM	To identify the important variables according to previous research	**Consent: YES** **Name:** Kusrini

WP/ Task	Title	Lead	Excerpt from the WP/Task description addressing the need for consultation	Do the formulation of questions in individual questionnaire tables tackle all the inputs and requirements of your WP or Task needed to be addressed during the consultation phase?
			To select and adapt the variables into ecological resilience (ER) framework To adapt and review the ER framework with the pilot area: Gargano park - Italy, Sterea Ellada - Central Greece, Cova da Beira - Portugal, Podpoľanie - Slovakia, Borneo - Indonesia	**Date:** 2022-02-02
T6.2	Models of resilience process adopted towards forest restoration	AMIKOM	To build model of ecological resilience based on variables founded in 6.1 To identify and analyse variable that will be used in forest management strategies To build knowledge forest management strategies	**Consent: YES** **Name:** Kusrini **Date:** 2022-02-02
T6.3	Soil rehabilitation strategy through data analysis	AUA	evaluate the **impact of forest fire on the hydrology and soil physical properties** analysed through chemical process. The analysis will consider the severity of the forest fire, the longevity of the fires and the causes of the fire ignition along with spread of forest fires. These **external factors will be systematically analysed** within the task to develop a systematic **plan for the restoration** activities	**Consent: YES** **Name:** Kostas Demestichas **Date:** 2022-02-02. **Note:** Further iterations and refinements may be needed to address technical details that may depend on questionnaires results
T6.4	Continuous monitoring of rehabilitation strategies	AUA	implement **continuous monitoring systems and self-assessment toolkits** upon inspection to generate an analysis that will quantify the **impact of restoration policies** being adopted. The geographic profile and the **landscape management processes** will be considered	**Consent: YES** **Name:** Kostas Demestichas **Date:** 2022-02-02. **Note:** Further iterations and refinements may be needed to address technical details that may depend on questionnaires results
T6.5	Privacy and societal impact assessment	KEMEA	Implement a privacy by design methodology to protect personal data and examine the impacts on society. Making sure	**Consent: YES** **Name:** Georgios Sakkas **Date:** 2022-02-22

WP/ Task	Title	Lead	Excerpt from the WP/Task description addressing the need for consultation	Do the formulation of questions in individual questionnaire tables tackle all the inputs and requirements of your WP or Task needed to be addressed during the consultation phase?
			the societal acceptance of SILAVNUS for combating wildfires	Note: Task starts M9. T6.5 is more to an overview for the whole project. Some answers will be taken from T1.6 but a dedicated analysis will be conducted.
T6.6	Contribution to EU legal framework for climate - related risks	KEMEA	Contribute/update the Eu framework regarding climate-related risks considering all three phases A, B, C.	**Consent: YES** **Name:** Georgios Sakkas **Date:** 2022-02-22 **Note:** Task starts M9. Partially covered by S3.1. We will discuss this task in detail when it starts. Separate questionnaires maybe distributed.
WP7	Policy recommendations on environmental sustainability and forest restoration	AUA	The objective of the WP is to develop long-term strategic roadmap for governmental agencies, insurance undertakers and other non-technology interventions to support in the rehabilitation and restoration of the forests and natural parks to maintain ecological balance.	**Consent**: YES **Name**: Konstantinos Demestichas **Date**: 2022-05-04
T7.2	Models for the assessment of quantitative and qualitative aspects of forest resilience	AUA	develop and extend models for the assessment of quantitative and qualitative aspects of forest resilience	**Consent: YES** **Name:** Kostas Demestichas **Date:** 2022-02-02. **Note:** Further iterations and refinements may be needed to address technical details that may depend on questionnaires results
T7.3	Governance models for forest restoration	Z&P	Develop governance models which consider the regional requirements	**Consent: YES** **Name:** Alexandre Lazarou **Date:** 2022-02-02. **Note:** Further iterations and refinements may be needed to address technical details that may depend on questionnaires results

WP/ Task	Title	Lead	Excerpt from the WP/Task description addressing the need for consultation	Do the formulation of questions in individual questionnaire tables tackle all the inputs and requirements of your WP or Task needed to be addressed during the consultation phase?
T7.4	Policy recommendations for sustainable and resilient forest management services	KEMEA	Policy recommendations for forging sustainable and resilient forest management services. Economic models will also be considered and innovative forest models.	**Consent: YES** **Name:** Georgios Sakkas **Date:** 2022-02-22. **Note:** table fully updated. Refinements and update will take place at a later stage.
WP8	Platform design specification, interfaces, and integration	INTRA	The objective of the WP is to design and develop integration protocols and deliver the SILVANUS integrated platform for deployment across the pilot owner premises for platform validation	**Consent**: YES **Name**: Nelly Leligou **Date**: 2022-05-04
T8.1	Platform design specification, interfaces, and integration	INTRA	Specifications of platform functionality	**Consent: YES** **Name: Nelly Leligou (INTRA)** **Date:** 2022-01-27 **Note:** WE consider that chapter 5 (if filled in with the currently provided guidelines is sufficient input to task 8.1 from WP2 side.
T8.2	Information sharing protocols across first responders and public	UISAV	The task will identify the **categories of information formats** to be standardised based on the dynamic behaviour of forest fires. … the development of **protocols and services** to engage with external organisations delivering first responder services	**Consent: YES** **Name:** Zoltan Balogh (UISAV) **Date:** 2022-01-31 **Note:**
T8.3	Information sharing between SILVANUS mobile command centres	FINC	Establish secure communication with external installations of SILVANUS platform	**Consent: YES** **Name:** Paolo Scipioni (FINC) **Date:** 2022-01-31 **Note:** Further iterations and refinements may be needed to address technical details that may depend on questionnaires results
T8.4	Integration of data services to environmental impact assessment	FINC	Develop data services to interface with existing	**Consent: YES** **Name:** FINC **Date:** 2022-01-31

WP/ Task	Title	Lead	Excerpt from the WP/Task description addressing the need for consultation	Do the formulation of questions in individual questionnaire tables tackle all the inputs and requirements of your WP or Task needed to be addressed during the consultation phase?
			environmental impact assessment toolkit	**Note:** Further iterations and refinements may be needed to address technical details that may depend on questionnaires results
T8.5	Platform integration	INTRA	The objective of the task is to deliver an integrated platform..	**Consent: YES** **Name: INTRA** **Date:** 2022-01-27 **Note:** WE consider that chapter 5 (if filled in with the currently provided guidelines is sufficient input to task 8.1 from WP2 side.
T8.6	Platform testing and validation	INTRA	Develop procedures and protocols for the platform validation and testing for robust demonstrations.	**Consent: YES** **Name: INTRA** **Date:** 2022-01-27 **Note:** WE consider that chapter 5 (if filled in with the currently provided guidelines is sufficient input to task 8.1 from WP2 side.
WP9	Large-scale demonstration activities of project outcomes	ASFOR	The objective of the WP is to organise and coordinate large-scale pilot demonstrations	**Consent**: YES **Name**: Mircea Segarceanu **Date**: 2022-05-05
T9.4	Phase C – Trials	AUA	Post fire rehabilitation of land will be studied through a systematic setup of respective methodologies. The **impact of restoration and adaptation** will be analysed based on the wildfire severity and duration, as well as the **impact of ecological and biodiversity resilience** in the agricultural sector.	**Consent: YES** **Name:** Kostas Demestichas **Date:** 2022-02-02 **Note:** Further iterations and refinements may be needed to address technical details that may depend on questionnaires results
WP10 T10.4	Dissemination and exploitation Stakeholders' community building and management	MD	The objective of the WP is to coordinate the dissemination, communication, and stakeholder engagement for the project. Additionally, the WP will also undertake activities related to the development of	**Consent: YES** **Name:** Lovorko Maric **Date:** 2022-02-03 **Note:** Further iterations and refinements may be needed to address

WP/ Task	Title	Lead	Excerpt from the WP/Task description addressing the need for consultation	Do the formulation of questions in individual questionnaire tables tackle all the inputs and requirements of your WP or Task needed to be addressed during the consultation phase?
			exploitation roadmap of project outcomes.	communication and dissemination requirements that may depend on questionnaires results

In Table 5, there is introduced the general overview of questionnaire tables used for interviews and collecting the data on current status and functional requirements on SILVANUS platform.

Table 5 Summary List of Questionnaire Tables

Table Code	Questionnaire Table Name
	Current **S**tatus
S1	Pilot Summary
S1.1	Overall Pilot Schema with overview of Technological Components
S2	Key factors to be considered in the Operational Scenario
S3	Operational scenarios problems to be considered
S3.1	Generic Characteristics of Policy
S4	Generic Summary of the Operational Scenario Area
S5	Use of UAVs (Drones) and UGVs (Robots)
S6	Remote sensing technology, Sensors and IoT Tools and Instruments
S7	Existing Fire Alerting/Fire Detection Systems
S8	Communication Protocols and Data Interchange
S9	Big Data Frameworks
S10	Cloud usage
S11	Social Media Usage
S12	Decision Support Systems
S13	Available Datasets
S14	Operational Description (Phase A, B, C)
S15	Organizational Description, Schema
S16	Generic Stakeholder Profile
	Functional **R**equirements
R1	Forest Landscape models
R2	Climate sensitive forest management

Table Code	Questionnaire Table Name
R3	Forest resilience models
R4	Forest fire ignition models
R5	Prevention methodologies
R6	Citizen engagement and awareness programme
R7	Tailored weather/climate models for forest fire threat/risk assessment
R8	In-Situ data analytics
R9	Social sensing and conceptual extraction
R10	UGV monitoring of wildfire behaviour
R11	UAVs deployment for remote sensing
R12	Earth observation data analytics
R13	Situational awareness of fire danger index
R14	Real-time monitoring of fire behaviour for response coordination
R15	Decision support systems for detecting and preventing forest fires and forest restoration
Operational Scenarios **D**escription	
D1	Operational Scenarios (Phase A/B/C)
D2	Key Parameters of the (SILVANUS) Platform

The tables, together with advice and explanations for their use are introduced in Guidelines (Annex 2).

4 Pilots Description

In this section the data on pilot sites, pilot status characteristics, high-level operational scenarios and priorities of individual pilots are provided.

4.1 FRANCE

France is involved in the demonstration of operational scenarios in Phases A (Preparedness and Prevention) and Phase B (Detection and Response).

4.1.1 Pilot Summary

Phase A/B: Forest fire with Industrial accident in highly explosive plant – France (PUI):
The forest fire scenario has three active fronts, moving towards sensitive targets; With a large amount of smoke and a wind exceeding 70km / h, the firefighters urgently need priority information:

- mapping of the area,
- identification of access paths,
- urbanized areas,
- roads and access routes,
- temperature, dehydration of plants,
- speed and direction of the wind,
- anticipation of fire development and development axes.

Partners in charge (stakeholders): Fire service, Prefecture, Municipalities, Agriculture and forest administration, many industries with high risk of human dimensions (for example SEVESO industries) are situated near residential or rural areas.
Managing a major accident in a delicate situation of forest fire is a challenge, and with the production of smoke cloud and explosive.

Figure 5 Operational scenario demonstration situational plan

4.1.2 Pilot Status Characteristics

In this section the existing data, systems, services, and technology used in the Pilot Site is described.

For fire prevention (Phase A) and fire monitoring (Phase B) UAV technology is deployed. See as follows:

- **PHANTOM 4 PRO** (2 devices)
  - Usage: monitoring (phase A/B), active firefighting (phase A/B), communication (phase A/B)
  - Dimensions: 185 x 289 x 289 mm
  - Diagonal length (Propellers excluded): 350mm
  - Weight (Battery & Propellers included): 1,388 g
  - Max speed: 50 km/h (P-mode, without wind)
  - Max flight time: 25 minutes
  - Intelligent Flight Battery 5870mAh, 15,2V, LiPo 4S, 468g
  - Operating Temperature Range: 0° to 40° C (32° to 104° F)
  - Satellite Positioning Systems: GPS/GLONASS
  - Memory Card: microSD /microSDHC/microSDXC
  - Camera: Sensor CMOS 1", Effective pixels 20M, Lens f/2,8-f/11
  - Compression: MPEG4 / H.265
  - Communication frame and data exchange: From: dropdown: Drone (UAV) To: dropdown: C & C Room
  - Communication protocol: TCPIP
  - API: free
  - Datatype: pictures, videos
  - Range 1 km x 1 km
- **MAVIC 2 PRO DUAL ENTERPRISE**
  - Usage: monitoring (phase A/B), active firefighting (phase A/B), communication (phase A/B)
  - Dimensions (unfolded): 322 x 242 x 84 mm
  - Diagonal length: 354 mm
  - Weight (Battery and Propellers included): 1,388 g
  - Max speed: 50 km/h (P-mode, without)
  - Max flight time: 25 minutes
  - Intelligent Flight Battery 3850mAh, 15,4V, LiPo, 297g
  - Operating Temperature Range: 0° to 40° C (32° to 104° F)
  - Satellite Positioning Systems: GPS/GLONASS
  - Memory card: microSD
  - M2ED Visual Camera
  - Sensor: CMOS 1/2.3" 12M Pixels
  - Lens: f/2,8-f/11 Compression MPEG4 / H.264
  - M2ED Thermal Camera
  - Sensor: Uncooled VOx Microbolometer
  - Aperture: f/1.1
  - Sensor Resolution: 160 x 120
  - Spectral Band: 8-14 µm
  - Compression MPEG4 / H.264
  - Scene Range: high range -10° to +140°C, low range -10°C to +400°C
  - Communication frame and data exchange: From: dropdown: Drone (UAV) To: dropdown: Fireman
  - Communication protocol: TCPIP
  - API: free
  - Frequency: internet
  - Datatype: pictures, videos
  - Range 1 km

- Phase A/B: communication from Drone to communication case (computer), streaming to internet, or local network.

No Alerting/Fire Detection Systems are deployed.

Dropbox is used as 3rd party cloud storage system. Encryption is required for this purpose

Cloud platform is not used by stakeholders in the Pilot Site.

For fire situation awareness, social media are used: Facebook, Twitter, WhatsApp, Linkedln. Those are monitored very often. For processing information from social media GIS is used. From social media text (Phase A), image (Phase A/B) and video (Phase A/B) data are gathered.

Decision Support Systems are not used by stakeholders in the Pilot Site.

For the Pilot Sites, only videos from drones are available.

4.1.3 Stakeholders involved

Non-government (NGO) stakeholders were involved in interviews.

4.1.4 High-level Operational Scenario

The forest fire scenario has three active fronts, moving towards sensitive targets; With a large amount of smoke and a wind exceeding 70km / hour, the firefighters urgently need priority information:

- Mapping of the area,
- Identification of access paths,
- Urbanized areas,
- Roads and access routes,
- Temperature, dehydration of plants,
- Speed and direction of the wind,
- Anticipation of fire development and development axes,
- Integration of changing weather conditions.

Fire spread:

The fire spread is dependent on the environmental condition including wind direction with a speed progressing by at least 3% of the speed’s wind. Then, under the influence of the swirling wind, the fire takes different directions producing vortices, while the height of the flames is increasing.

DEFINITION OF PYROTECHNIC ZONES					
	Z1	Z2	Z3	Z4	Z5
DAMAGES FORESEEN TO THE PEOPLE	Fatal injuries in more than 50% cases	Serious injuries that could be fatal	Injuries	Possibles injuries	Very low possibility of minor injuries
	200 mbars	150 mbars	100 mbars	50 mbars	20 mbars
DAMAGES TO THE MATERIALS	Very serious damages	Serious damages	Medium & light damages	Light damages	Very light damages

These zones have been calculated withouth taking into account the leveling of the field

Figure 6 Definition of Pyrotechnic Zones

Aerial views:

As the firefighters are using these tools, they will be able to see the smoke and other potentially toxic plumes. They will also be able to view and anticipate the use of the access tracks. This allows first responders to anticipate access and positioning of response vehicles.

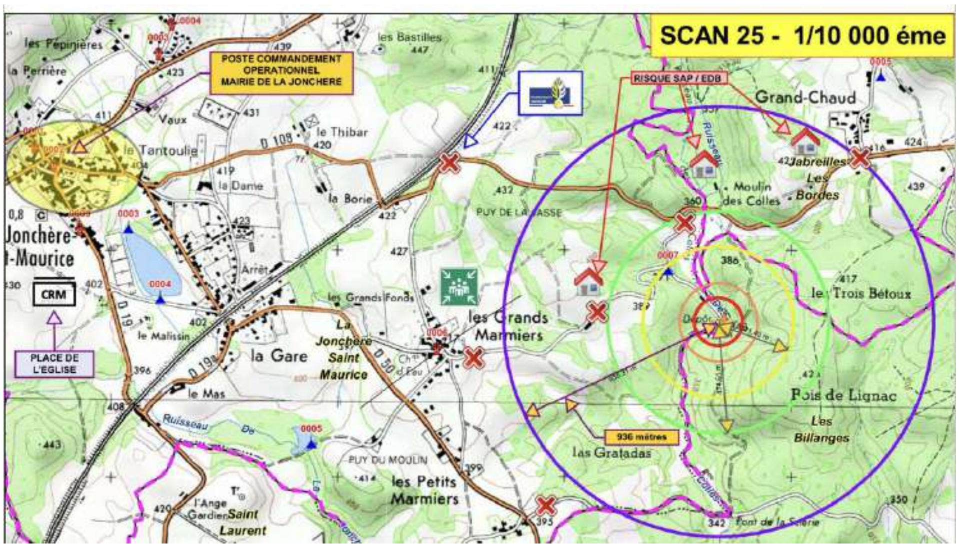


Figure 7 Localisation of demonstration of operational scenario in the Pilot Site

The use of several drones simultaneously will (Figure 8):

- Measure the ground temperature of the flames and fumes, the speed and direction of the wind with different sensors, over the entire intervention area to anticipate the propagation, this information provided continuously will allow the area to be assessed towards which the fire will spread (residences, industries, roads etc. ...).
- Integrate the measurements made by sensors positioned in vulnerable forest areas.
- Drones equipped with gas sensors will make it possible to know the composition of the combustion gases and their dangers for the operators.

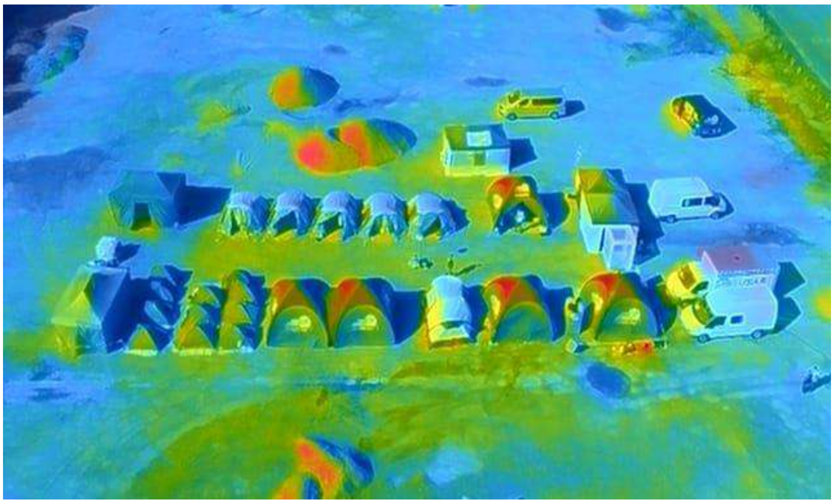


Figure 8 IR image recorded by drone camera

Technological risks considered:

The combination of a forest fire risk and a technological risk is an important issue. The consequences of a site explosion or the threat of a chemical dispersion are dramatic.

Scenario:
Fire start:
An outbreak of fire near a traffic lane is a highly probable assumption in the scenario given the statistics we have in our disposal. The unfavorable meteorological conditions (drought, wind, dehydration of plants, etc.) and the type of plants promote rapid development of the fire.
Fire starts from «Au moulin de Panéche» with a wind in the zone of 146 ° direction of « Puy de la Jasse », for about 2.3 kms. In the main axis of propagation is the TITANOBEL site which is threatened about 1.8 km from the start of the fire.

Depending on the weather conditions (especially the wind) the site is directly threatened for example (Figure 9):

- Wind from 50 km to t + 80mn,
- Wind from 30 km to t+ 120mn.

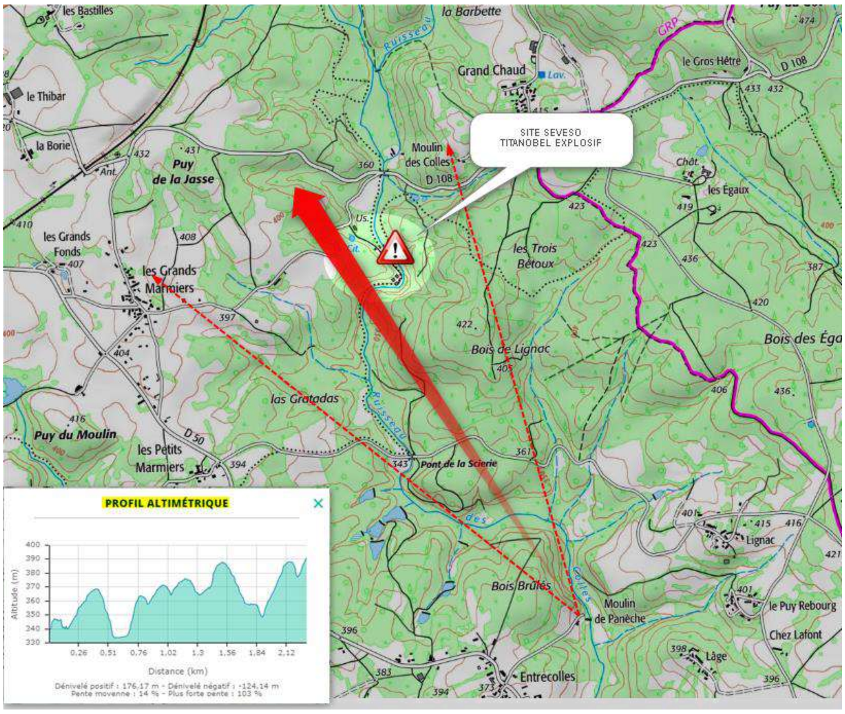


Figure 9 Wind conditions during demonstration

Kinetics and chain of events:

The previous stages of the scenario will permit, by identifying the possible outbreaks of fires, the elements and human actions that may have an impact on the fire, to identify the possible components of the fire scenarios which will lead to a threat for an installation classified as risks.

- o **Fire start**: proximity to a traffic lane, mapping,
- o **Nature of vegetation**: mixture of deciduous and coniferous trees varying the speed of propagation, use of different sensors,
- o **Propagation**: high speed given a strong wind, of the order of 70 to 80 km / hour,
- o **Direction**: the focus is developing towards a production unit for explosive products,
- o **Anticipation**:

- Calculation by the command post of propagation cones, mapping,
- Identification of threatened targets, nature, and quantities,
- Possible chronological sequence, anticipation scenario.

Figure 10 Infrared image of interior

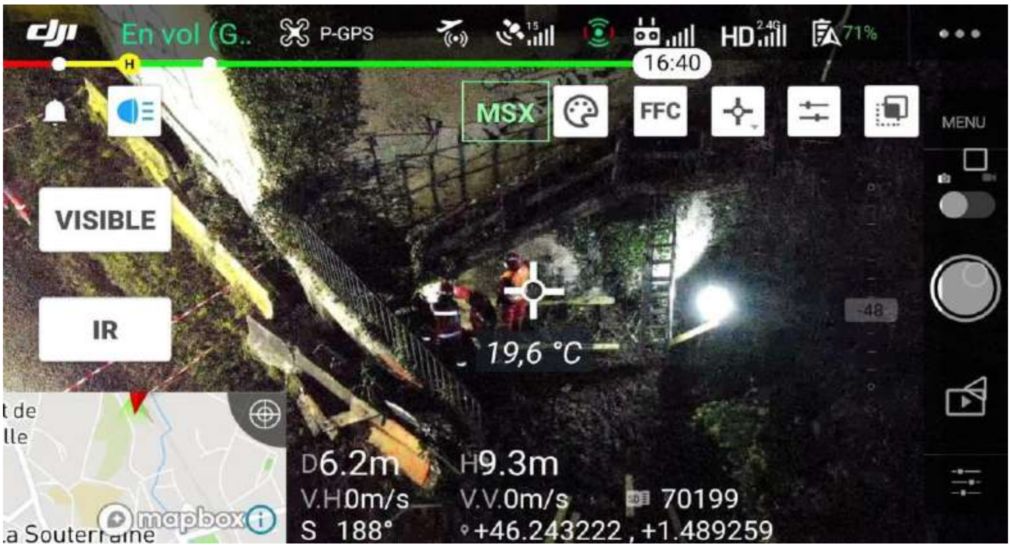


Figure 11 Video in visible mode recorded by drone camera

Figure 12 Intervention site

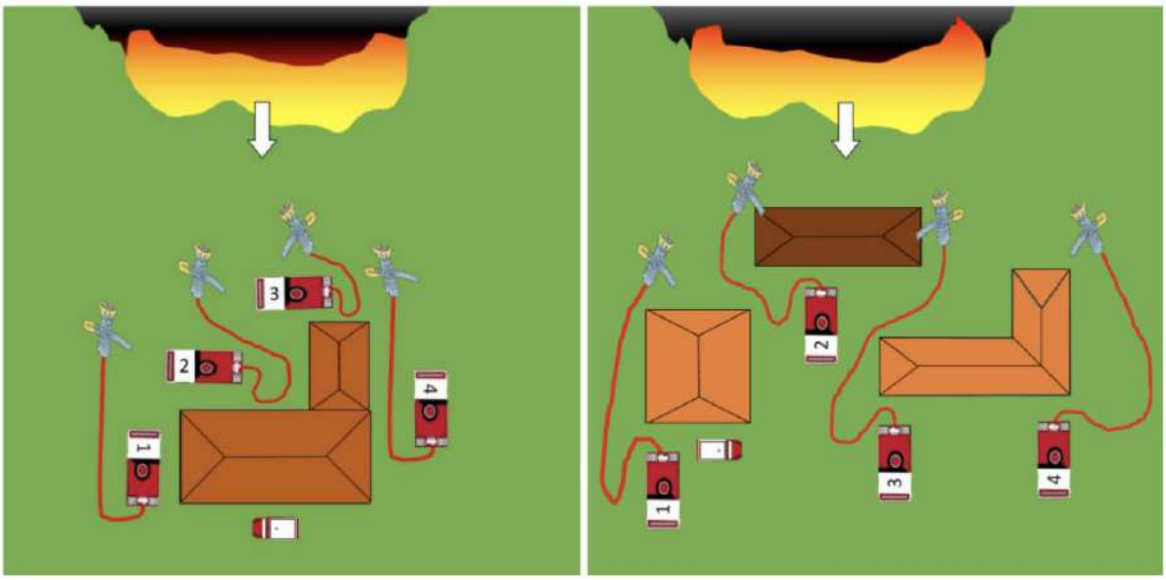


Figure 13 Fire tactics schema

4.1.5 Priorities of the Pilot

Any priorities for pilot were not specified. However, there were specified problems by stakeholders related operational scenarios in all relevant phases, which are introduced.

Phase A (Preparedness and Prevention):

Aerial views: As the firefighters are using these tools, they will be able to see the smoke and other potentially toxic plumes. They will also be able to view and anticipate the use of the access tracks. This allows first responders to anticipate access and positioning of response vehicles.

The use of several drones simultaneously will:

- measure the ground temperature of the flames and fumes, the speed and direction of the wind with different sensors, over the entire intervention area to anticipate the propagation, this information provided continuously will allow the area to be assessed towards which the fire will spread (residences, industries, roads etc.).

Phase B (Detection and Response):

1st event: impact on a technological risk installation

- time to reach the installation at risk, chronology of events,
- implementation of protection or evacuation measures,
- measures to be taken in case of failure of the measures implemented: explosion and spread of fumes.

2nd event: impact on a habitation area

- time to reach the urbanized area, chronology of events,
- implementation of protection or evacuation measures,
- measures to be taken in case of failure of the measures taken.

Phase C (Restoration and Adaptation):

- calculation by the command post of propagation cones, mapping,
- identification of threatened targets, nature, and quantities,
- possible chronological sequence, anticipation scenario.
- no planting any flammable species near dwellings (kermes oak, cypress, mimosa, eucalyptus, thorny plants, and conifers)
- clear the access roads and clear the surroundings of the constructions over a distance of at least 50 m.

4.1.6 Functional requirements on SILVANUS Platform

Functional requirements are introduced on SILVANUS Platform specially for Phase A and Phase B.

Functional requirements on SILVANUS Platform that **must be** included in Phase A:

- visualisation of landscape biodiversity,
- identification of areas/regions of historical significance,
- visualisation and providing information on forest structural diversity,
- providing fire danger index metrics,
- providing information on fuel availability in specific regions of forest,
- simulating spatio-temporal trends of forest changes,
- providing fuel management alternatives for different forest types,
- gathering information on forest landscape using crowd sourcing applications,
- visualision of climate statistics (for historical and future periods; precipitation, temperature, relative humidity etc.),
- providing information on soil types and structure,

- calculating potential greenhouse emissions from fire probability index based on climate conditions and type of vegetation,
- including e.g. AR/VR representation of forest landscape for computing impact of climate change on forest ecosystem services (climate and water cycle regulation),
- providing representation of forest landscape for computing impact different (single or combined) forest managements on ecosystem services (climate and water regulation) under alternative climate scenarios,
- gathering information on fire ignition sources, such as human negligence, arson, environment conditions, climate, and weather conditions (climate change impact including), impact of power grid lines,
- aggregating Copernicus and EO data prior and post fire ignitions,
- quantifying the damage of forest fire and map into ecological assessment (loss of XX cubic tons of oxygen, etc.),
- providing assessment models of forest resilience (e.g., regeneration dynamics),
- providing modelling of human behaviour (and negligence) resulting in forest fire ignition,
- providing simulation of fire ignition scenarios,
- implementing notification protocol for response (first responders) deployment,
- providing AR/VR simulation of combating forest fire,
- allowing weather/environmental data to be processed in emulating forest fire behaviour,
- producing content to engage with citizens on forest fire impact,
- notifying people in the vicinity of forests, on human negligence,
- gathering feedback from citizens on the usefulness of the mobile application,
- allowing people to notify forest management services on human negligence,
- including mobile application which allow people to notify wildfires to the Fire and Rescue Service,
- SILVANUS mobile application must notify people about the fire occurrence in their vicinity,
- SILVANUS mobile application must create user interface for reporting a suspect fire by geo-location, photos, and description,
- SILVANUS mobile application must allow fire management services to contact people in fire vicinity for help by voice call,
- SILVANUS mobile application must allow forest management services to contact people in fire vicinity for help by chat,
- SILVANUS mobile application must allow fire and rescue services to ask people in fire vicinity for help by voice call,
- collect citizen observations from social media,
- providing AI/ML algorithms to detect fire danger,
- providing AI/ML algorithms to detect fire/smoke,
- providing extraction of visual concepts, such as fire or smoke, from social media data sources,
- providing extraction of geoinformation, i.e., mentioned locations, from social media data sources,
- autonomously piloted UAVs must be deployed for remote sensing,
- algorithms to control drone swarms based on e.g., leader-follower configuration must be applied,
- collision avoidance among drones must be implemented,
- drones must be equipped with multi-spectral sensing devices,
- some UAVs must be stationed in particularly critical areas and automatically scan the area if critical conditions arise (e.g., sudden increase in FDI),
- heterogenous data from multi-modal data sources must be integrated,
- data filtering and cleaning process must be providing,
- weather forecasts must be developed,

- AI algorithms should be providing to identify high-risky forest regions according to fire initiation potential,
- distributed storage and repository for heterogenous data sources must be provided,
- training models for AI/ML algorithms must be provided,
- 5V data characteristics must be supported,
- decision support systems for fire detection, fire spread, weather effect on fire intensity must be used,
- cause-and-effect models for the fire ignition must be used,
- simulation of fire ignition and fire spread based on Monte Carlo like models,
- providing visualisation of forest landscape models,
- providing micro-predictive models using AI/ML algorithms for different scenarios specifications,
- providing health impact analysis for fire fighters to model long- and short-term exposure to forest fire,
- considering wearable devices and other medical devices for response coordination,
- providing damage assessment,
- supporting resources deployment,
- allowing to develop evacuation plans,
- supporting coordination of responders,
- providing GIS/GPS visualisation of on-field situation,
- providing visualisation of forest restoration (forest management) alternatives for stakeholder to supporting forest resilience,
- supporting the systematic planning of restoration activities,
- facilitating the selection and configuration of governance models for forest restoration, using criteria such accountability, effectiveness, efficiency, fairness, participation and transparency.

Functional requirements on SILVANUS Platform which **should be** included in Phase A:

- providing AI/ML algorithms trained on historical data sources resulting in forest fire,
- providing probabilistic prediction models for estimating forest fire ignition,
- providing IoT data aggregation from distributed deployment of environmental sensors, CCTV, chemical composition sensors,
- providing Edge based micro-data centres for processing data collected from the field,
- providing data collection for the fire behaviour (spread) modelling,
- supporting the analysis of the impact of forest fires on the hydrology and soil physical properties (using inputs from chemical analysis where applicable),
- supporting continuous monitoring of forest restoration programmes.

Functional requirements on SILVANUS Platform which **must be** included in Phase B:

- providing simulation of fire ignition scenarios,
- notifying people in the vicinity of forests, on human negligence,
- include mobile application which allow people to notify fire to the Fire and Rescue Service,
- SILVANUS mobile application must notify people about the fire occurrence in their vicinity,
- SILVANUS mobile application must allow forest management services to contact people in fire vicinity for help by chat,
- SILVANUS mobile application must allow fire and rescue services to ask people in fire vicinity for help by voice call,
- autonomously piloted UAVs must be deployed for remote sensing,
- algorithms to control drone swarms based on e.g., leader-follower configuration must be applied

- collision avoidance among drones must be implemented,
- drones must be equipped with multi-spectral sensing devices,
- some UAVs must be stationed in particularly critical areas and automatically scan the area if critical conditions arise (e.g., sudden increase in FDI),
- heterogenous data from multi-modal data sources must be integrated,
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- weather forecasts must be developed,
- AI algorithms must be providing to identify high-risky forest regions according to fire initiation potential,
- distributed storage and repository for heterogenous data sources must be provided,
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- providing GIS/GPS visualisation of on-field situation,
- providing visualisation of forest restoration (forest management) alternatives for stakeholder to support forest resilience,
- supporting the systematic planning of restoration activities,
- facilitating the selection and configuration of governance models for forest restoration, using criteria such accountability, effectiveness, efficiency, fairness, participation and transparency.

Functional requirements on SILVANUS Platform which **should be** included in Phase B:

- visualisation of landscape biodiversity,
- identification of areas/regions of historical significance,
- visualisation and providing information on forest structural diversity,
- providing fire danger index metrics,
- providing information on fuel availability in specific regions of forest,
- simulating spatio-temporal trends of forest changes,
- providing fuel management alternatives for different forest types,
- gathering information on forest landscape using crowd sourcing applications,
- visualisation of climate statistics (for historical and future periods; precipitation, temperature, relative humidity etc.),
- providing information on soil types and structure,
- calculating potential greenhouse emissions from fire probability index based on climate conditions and type of vegetation,

- including e.g. AR/VR representation of forest landscape for computing impact of climate change on forest ecosystem services (climate and water cycle regulation),
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- aggregating Copernicus and EO data prior and post fire ignitions,
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- providing probabilistic prediction models for estimating forest fire ignition,
- implement notification protocol for response (first responders) deployment,
- providing AR/VR simulation of combating forest fire,
- allowing weather/environmental data to be processed in the emulating the forest fire behaviour,
- producing content to engage with citizens on forest fire impact,
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- providing AI/ML algorithms to detect fire/smoke,
- providing extraction of visual concepts, such as fire or smoke, from social media data sources,
- providing extraction of geoinformation, i.e., mentioned locations, from social media data sources.

4.2 ITALY

Italy is involved in demonstration of operational scenarios in two pilots. Pilot Site 1 will cope with Phases A (Preparedness and Prevention) and Phase C (Restoration and Adaptation). Pilot Site 2 will deal with Phase A and Phase B.

4.2.1 Pilot Summary

In Italy, there are 2 Pilot sites considered.

The first Pilot Site is Gargano Park. It is a historical and geographical sub-region in the province of Foggia, Apulia, southeast Italy, consisting of a wide isolated mountain massif made of highland and several peaks and forming the backbone of the Gargano Promontory projecting into the Adriatic Sea, the "spur" on the Italian "boot". The highest point is Monte Calvo at 1,065 m (3,494 ft). Most of the upland area, about 1,200 km2 (460 sq mi), is part of the Gargano National Park.

The Gargano National Park is a National Park established in 1991 (according to art. 19 of Law 394/91) and is located on the promontory of the same name, in the province of Foggia, in Apulia. It is managed by the Gargano National Park Authority, established in 1995 (Institutional Decree DPR 05/06/1995), which also manages the Tremiti Islands Marine Nature Reserve, established in 1989 (D.I. 14/07/1989).

The park falls entirely within the province of Foggia, covering nearly the entire promontory and extends over an area of about 120,000 hectares. It includes, totally or partially, 18 municipalities: Apricena, Cagnano Varano, Carpino, Ischitella, Tremiti Islands, Lesina, Manfredonia, Mattinata, Monte Sant'Angelo, Peschici, Rignano Garganico, Rodi Garganico, San Giovanni Rotondo, San Marco in Lamis, San Nicandro Garganico, Serracapriola, Vico del Gargano and Vieste.

The boundaries of the park are jagged and are included within the Fortore river, the Candelaro stream and the coast.

Based on the degree of anthropisation, the Park is divided for internal zoning into two areas, namely:

- Zone 1: of significant naturalistic, landscape and cultural interest with limited or non-existent degree of anthropisation;
- Zone 2: of naturalistic, landscape and cultural value with a greater degree of anthropisation.

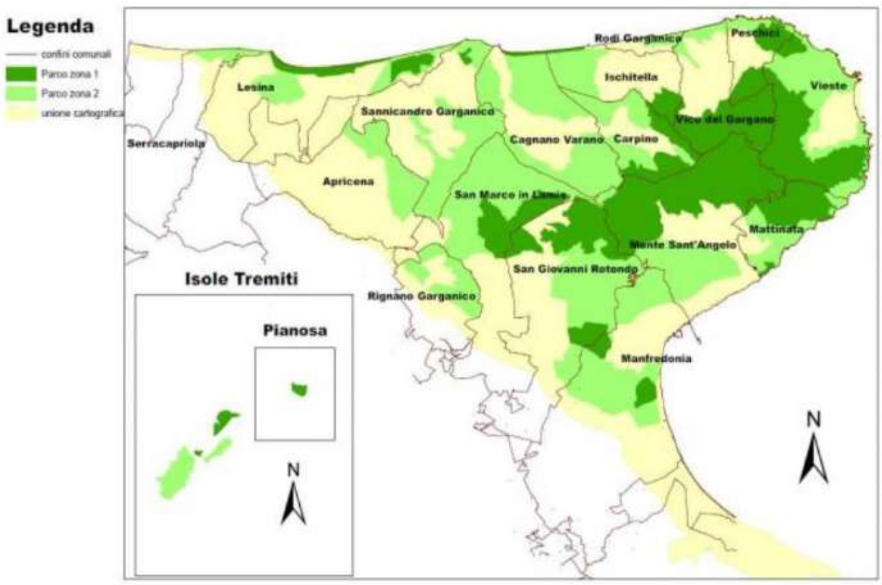

Figure 14 Gargano National Park map

Phase A: Parco del Gargano doesn't work on the prevention and preparedness phases that are under the responsibility of the National Ministry and Regional government. Regarding the prevention phase: every year the Park promotes a sensibilization campaign through mass media (TV and radio advertisement) and diffusion of posters among the municipalities. The aims are:

- to sensibilize the municipalities to implement national fire laws
- to update the Forest Fires Cadastre. Deficiencies may be the territorial size of the park and the absence of fire monitoring technology that may slow down intervention in the event of a fire.

Phase C: The park has historical documents on forest management because it was the object of study of many research works (by universities and research centres). Forest restoration is required by law and must be realised after the fire event by the owners. In the 5 years following the fire event it is not possible to use public funds in the damaged areas for forest restoration. Deficiencies may be the lack of forest growth models for modelling the forest restoration processes; development of forest management alternatives; real time mapping of forest restoration sites.

The second pilot site area is in the territory of the Tepilora Regional Natural Park and includes part of the territory of 4 municipalities: Bitti, Lodè, Torpè and Posada belonging to the province of Nuoro in the Sardinia region, Italy. The resident population in these 4 municipalities is about 10,000 inhabitants (Figure 15).

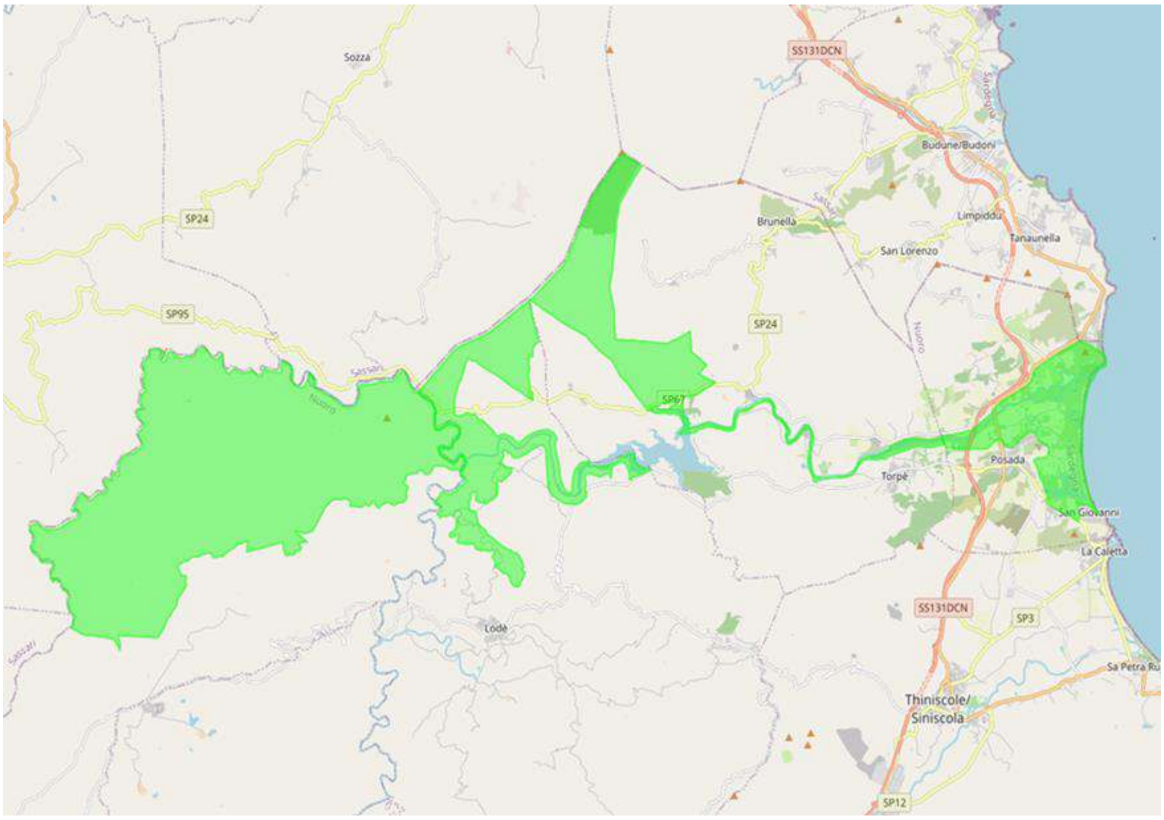

Figure 15 Location of Pilot Italy – Pilot site 2: map of the Regional Natural Park of Tepilora

Located in the north-west of Sardinia, the pilot site includes a vast territory that insists on four municipalities: Torpè, Posada, Lodè and Bitti. The pilot site extends from the Tepilora forest to the mouth of the Rio Posada; its fulcrum is Mount Tepilora (m.528 a.s.l.m.m.), a rocky tip with a triangular profile that stands out in the densely wooded area of Littos and Crastazza and looks towards Lake Posada. Once used for grazing and cutting wood, in the 1980s the area was afforested for 16% of the total and was equipped for hiking and fire protection, becoming a nature reserve.

- In the territory of the municipality of Bitti fall the state forests of Crastazza-Tepilora and Sos Littos-sas tumbas owned by the Autonomous Region of Sardinia and managed by the regional agency FORESTAS.
- In the territory of the municipality of Lodè falls the territory delimited by the forest site of Sant'Anna, owned by the municipality of Lodè and managed by the regional agency FORESTAS.
- In the territory of the municipality of Torpè falls the territory delimited by the usinavà forest yard, owned by the state, and managed by the regional agency FORESTAS.

The area of the pilot site is 60% covered by wooded areas, managed by the Forestas Regional Agency, in the Western part. To the east it is characterized by the presence of the Rio Posada River and other minor waterways that feed the coastal ponds that make up the river delta. The nearest population centres are no less than 10 kilometres away. The Sardinia region is one of the most damaged by fire in Italy. Frequent fires are the most serious risk of forest degradation.

The pilot site 2 is mainly involved in Phase A: prevention and preparedness and in Phase B: detection and response. Basic facts (Figure 1):

Surface (ha): 7,877.00

Country: Italy

Region: Sardinia

Province: Nuoro

Municipalities: Bitti, Lodè, Posada, Torpè

Analysing the fires of the past, we can deduce that fires in the pilot site area and neighbouring areas occur almost exclusively in the summer (in June, July, August, September). Processing the data under consideration in Sardinia, the main cause of fire was found to be 60% of arson, 35% of involuntary origin and 5% of accidental origin. As for fires of unintentional and accidental origin, they are mainly due to cigarette butts, or the removal of plant remains (burning stubble).

4.2.2. Pilot Status Characteristics

Pilot Site 1: Gargano Park, IT

The territory is divided into zone 1 and zone 2; zone 1 is the area of significant natural, landscape and cultural interest with limited or no anthropization. The zone 2 is the area of naturalistic, landscape and cultural value with a greater degree of anthropization. There are 35 land-use classes. In particular, ignoring the case of artificial surfaces (Class 1), which in any case amount to only 1.09% of the surface of the Park (testifying to its high environmental value), it is possible to notice that the used agricultural surfaces (Class 2) are equal to 24.03%, while the % of surface related to wooded and semi-natural areas is the most consistent, being equal to 66.15%. Finally, with very small values (0.87%), the areas invested in wetlands are followed by water bodies amounting to 7.85% of the Park's territory due to the presence of the two large lakes of Lesina and Varano. Concerning the % of homogeneous groups of land use classes, it can be noted that the greater % is the 3.1 Wooded areas with 29.78%, followed by that of 2 Agricultural areas used (24.09%) and 3.2.4 Areas with evolving woody and Areas with evolving woody and shrubby vegetation (15.05%). There is set of wooded areas (code 3.1), areas with evolving woody and shrubby vegetation (code 3.2.4), and areas of Mediterranean scrub (scrubland vegetation). Mediterranean scrub (sclerophyllous vegetation - code 3.2.3) includes a surface area of more than 60,000 hectares, i.e., almost 50% of the Park territory.

No drones, robots, fire detection/alerting systems, remote sensing data, IoT sensors are used in the Pilot Site. No Big Data analytics is provided. No Cloud Services are used. Facebook is used as a social medium for providing mass media and social media campaign related with specific projects. Specialized operators monitored social medias referring to specific projects. No DSS is used for the Pilot Site. Available datasets were not specified.

Pilot site 2: Tepilora Regional Natural Park, IT

General characteristics:

In the hottest time of the year, after a year of low atmospheric precipitation, the risk of fires will be very high. The fire, due largely to human activities (negligence, wilful misconduct), will start mainly from the streets near the forests of the Park. In some cases, however, it could also start from roads inside the Park, in the case of distraction by tourists.

Features of the site:

The area of the Park is covered for 60% by wooded areas, managed by the Fo.Re.S.T.A.S., Regional Agency, in the Western part. To the east it is characterized by the presence of the Rio Posada River and other minor waterways that feed the coastal ponds that make up the river delta. The nearest population centres are no less than 10 kilometres away. On summer days you may find tourists visiting the centre of the Park. The climate of this area is characterized by high spring-summer temperatures and the irregularity of the precipitation, so the conditions are not ideal for a rapid recovery and reinsertion of the tree cover.

Available infrastructure:

For the management of fires, the Tepilora Park follows the indications and uses the infrastructures made available by the Sardinia Region, responsible for the coordination of all the bodies and structures present in the area.

The Region has adopted a Regional Plan for forecasting, prevention and active against wildfires, a three-year plan that is updated annually. The Plan aims to plan and coordinate the fire prevention activities of all the entities in the area and contains the data processed to properly plan the forecasting, prevention, and active control activities. It defines the procedures to be adopted and the roles of all the institutional subjects involved.

As for the Tepilora Park, the wooded area is manned by the lookouts of the Fo.Re.S.T.A.S., Agency, lookout points that carry out daily control over the territory.

An important infrastructure for the communications system is the regional radio network which, due to its specific properties, is the main communication tool for the coordination of activities on the territory. In fact, the radio network that almost entirely covers the regional territory guarantees communications in extra-urban areas not covered by traditional telephone networks.

In addition, unlike mobile phone calls, the radio network allows one-to-many calls (group calls) essential for the coordination of forest fire prevention activities.

Reporting structures

The Sardinia Region has designed a system for the management and analysis of forest fires, called "Fire cloud" that can allow the creation and management of the "fire file". The system manages the information and allows you to share, through a Web portal, the data on residencies within the region, the data on fires in real time, at all levels of the Operational Structure and the command-and-control system.

The system is based on a web-GIS platform and allows, among other things, the positioning of the fire directly on the digital map, and to have all the information on the area in which the event develops including any infrastructure such as roads, power lines, etc.

Phase A: Preparedness and Prevention

The regional fire-fighting activity is regulated in accordance with the provisions of the national framework law on forest fires - Law no. 353 of 21 November 2000 - and the related guidelines issued by the Minister Delegate for the Coordination of Civil Protection (D.M. 20 December 2001), as well as the provisions of Regional Law no. 8 of 27 April 2016. Regional Law no. 8 defines the forecasting and prevention measures, identifies the contents of the Regional Fire Prevention Plan (PRAI), indicates the composition of the regional fire prevention system, and provides guidelines to improve the coordination of firefighting activities

The forecasting activity is the responsibility of the Decentralized Functional Centre (CFD) of the General Directorate of Civil Protection hydro/ground effects area and is carried out, ordinarily from 31 May to 30 October, for the period in which the state of "high danger of forest fires" applies. The CFD evaluates daily the probability that a fire can be ignited and propagated quickly in each territory due to the specific weather conditions derived from the forecast. The forecast is expressed on 26 homogeneous territorial zones (alert zones) and is divided into 4 levels of danger: low, medium, high, and extreme, to which corresponds, in a univocal way, a traffic light colour code: green, yellow, orange and red. The daily danger for each alert zone is summarized through the elaboration of a bulletin, which describes the possible phenomenology expected in case of ignition. The fulfilment of the transmission to the interested parties (institutional authorities, municipalities, and citizens, is carried out through the publication of the daily bulletin on the institutional website of the Regional Civil Protection.

To promote fire prevention activities and the development of an environmental awareness aimed at the conservation of the forest, the Sardinia Region constantly undertakes initiatives that aim to enhance the environmental awareness and to support the education of the population at various levels. At the regional level, the CFVA, Fo.Re.S.T.A.S. and Volunteers carry out educational activities aimed at spreading and growing the culture of civil protection, through the creation of training and information courses in the field of civil protection aimed at schools of all levels.

Also in the preventive field, in accordance with the framework law, the Region approves the Regional Fire Regulations that contain all the measures aimed at countering the actions that can cause the ignition of fires and that regulate the use of fire for the entire calendar year. The dissemination of the contents of the prescriptions takes place through the distribution of leaflets and the posting of posters, at all the Municipalities of Sardinia, Provinces, Schools, Trade Associations, tourist-accommodation facilities, ports, airports, etc.

Among the preventive activities those ordinarily adopted by regional planning are:

- Creation and management of fire protection avenues and strategic bands.
- Network of sighting points.
- Toll-free number 1515 for environmental reports.
- Network of reservoirs and water supply points for the supply of land and air means of struggle.
- Forest roads.

Another preventive activity, although carried out only of an experimental nature, is the "prescribed fire", moreover introduced by the recent DL 120/2021 converted by Law 155/2021.

Finally, all regional personnel, engaged in fire-fighting activities, are constantly subjected and involved in training courses of updating and professional adjustment, both according to the new organizational and operational models in continuous evolution, and to improve knowledge in the field of safety, a particular aspect in the regional control system.

Actions and tools proposed for:

Phase A: Preparedness and Prevention

The Tepilora Regional Natural Park contributes to prevention by offering preventive information to visitors and residents on the danger of forest fires, and on the correct behaviour to be adopted to avoid fires, in particular accidental fires, by preparing a prevention campaign on websites and social networks. These activities aim to reduce the number of fires and promote the growth of ecological awareness in citizens and visitors to the park.

To reduce unintentional fires, it is strictly forbidden to light fires from June 15 to September 15.

A dedicated toll-free telephone number is active for reporting the environmental emergency, which can be used by anyone to alert the operating structures in case of fire.

Phase B: Detection and Response

The alert and detection system foresees in the first place the involvement of the lookout points of the Fo.Re.S.T.A.S., Regional Agency located within the Tepilora Park. The fire will also be observed and reported by the citizens of the Municipalities of the Park and by **any tourists** present, through the toll-free number dedicated to environmental emergencies, active throughout the Sardinia Region.

When an event occurs, the coordination structure is activated following a report. Once learned, the news is verified by the structures at the local level. In relation to the magnitude of the event, all the components of the Management of Extinguishing Operations (DOS) system of the Forestry and Environmental Surveillance Corps of the Sardinia Region are therefore activated, necessary for the rapid suppression of the flames and any subsequent reclamation. The DOS shall carry out the following tasks:

- coordinates on the spot the extinguishing of fires using land and air resources.
- requests from the Provincial Operations Centre (COP) any land and air resources.
- communicates to the COP all the data necessary for the compilation of the fire file on the *Fire Cloud* system including the start time of reclamation, the end of the intervention and a first estimate of the quality and quantity of the surface covered by the fire.
- collaborates, as defined by the collaboration protocol, with the firefighters in the defined interface areas.

For the performance of the fighting activity by direct attack on the ground, the following are used in the regional fire prevention system:

- patrols of the Forest Stations of the Regional Forestry Corps equipped with vehicles for the transport of people and extinguishing liquid.
- teams of the Fo.Re.S.T.A.S., Agency equipped with vehicles for the transport of people and extinguishing liquid.
- teams of voluntary organizations and / or municipal groups, municipalities and barracellari companies (rural public institution typical of Sardinia). equipped with suitable vehicles, and the resources of other competitors to this activity.

In this section the existing data, systems, services, and technology used in the Pilot Site is further described.

The UAV and UGV technology are not deployed. The Remote Sensing Technology, Sensors and IoT Tools and Instruments are not used for combating of wildfire in the Pilot Site. No Alerting/Fire Detection Systems are deployed.

Data are communicated between the individual endpoints were specified as follows:

From: dropdown: C&C Room, Mobile C&C Room, Municipality, Fireman, Forester, Citizens, Wearable Device, Wearable Sensors, Field Sensors, Fire Truck, Helicopter, Airplane, Drone (UAV), Ground Robot (UGV), Social Network, Cloud Service, Volunteer Fire Fighters, Other

To: dropdown: C&C Room, Mobile C&C Room, Municipality, Fireman, Forester, Citizens, Wearable Device, Wearable Sensors, Field Sensors, Fire Truck, Helicopter, Airplane, Drone (UAV), Ground Robot (UGV), Social Network, Cloud Service, Volunteer Fire Fighters, Other

Type of Data: text

Protocol: dropdown: -, TETRA, WiFi, Bluetooth, Zigbee, WiMax, NFC, LoRa, 3G/4G, 5G, UWB, Infrared, RFID, Satellite, Optical Wireless, Radio (PTT), Other

Communication endpoints in Phase A: Forester; Social network.

Communication endpoints in Phase B: Command & Control Room; Municipality; Fireman; Forester; Citizens; Helicopter; Airplane; Volunteer Fire Fighters.

Communication endpoints in Phase C: Forester; Social network.

Communication protocols used in Phase A: 3G/4G.

Communication protocols used in Phase B: TETRA; Radio (PTT).

Communication protocols used in Phase C: TETRA; Radio (PTT).

Italian stakeholders do not use big data, 3rd party cloud storage, social media. There is also no DSS applied in the Pilot Site.

For the Pilot Site, the following data are available:

- GIS layers:

1. vector - geology, hydrography, topography, land use, topography, pedology etc.
2. raster - geology, hydrography, topography, land use, topography, pedology etc.
3. online services - geology, hydrography, topography, land use, topography, pedology etc.

Producer/provider of this data:

- GIS layers:

4. vector – Tepilora regional Natural Park
5. raster - Sardinia region, https://www.sardegnageoportale.it/
6. online services - Sardinia region, https://www.sardegnageoportale.it/

4.2.3. Stakeholders involved

In Pilot Site 1, the Parco Gargano and Protezione Civile were involved in interviews.

The stakeholders who were involved in interviews in Pilot Site 2 were from Government organisation (Public Administration) – Tepilora Regional Natural Park.

Role of stakeholder in Phase A and Phase B:

- protect the environmental heritage of the area,
- promote scientific research, environmental monitoring and training activities aimed at conservation biodiversity and the protection of water and river resources,
- promote an eco-sustainable development model, which does not alter the environment and natural resources, which encourages 1 business and economic requalification.

4.2.4. High-level Operational Scenario

Pilot Site 1: Operational Scenario and Use Cases specified for Phase A (Prevention and Preparedness)

No Operational Scenario and Use Cases specified.

Pilot Site 2: Operational Scenario and Use Cases specified for Phase A (Prevention and Preparedness)

- **Daily map of fire risk**

Availability of the daily map of the fire risk prepared by the Regional Civil Protection and published on the website of the Regional Civil Protection.

- **Public awareness campaign**

Preparation of a public awareness campaign provided to visitors to the Park through social networks, the Park's website and through the use of paper guides in order to adopt measures for the defense of the territory and its natural beauty, through information and education to protect the forests from the danger of fires.

- **Awareness campaign in schools**

Awareness-raising activities to be carried out in schools.

- **Fire hazard/risk map**

Availability of data in the usual GIS formats concerning geology, vegetation, hydrography, settlements, topography, hydrogeological risk, and a base layer related to hazard and fire risk.

- **Orthophotos and satellite images**

The mapping of the site will take place through satellite images and orthophotos.

- **Preventive interventions on the ground**

Implementation of specific interventions in the field of forestry and management of forests and rural areas with a zootechnical vocation to prevent the ignition of fires.

- **Using Surveillance Cameras**

An integrated system of cameras (if available) will be used for video surveillance of the Park.

- **Guidelines and fire prevention plan**

Preparation of guidelines and an internal plan for the Park for fire prevention.

- **IoT sensors**

IoT sensors (if available) will be installed that continuously collect microclimatic data (temperature, precipitation, relative humidity of the air, wind speed, wind direction).

Operational Scenario and Use Cases specified for Phase B (monitoring and detection)

- **Fire sighting**

A regional system of lookouts (survey carried out by staff of the Fo.Re.S.T.A.S. Agency) provides the regional headquarters with timely information on the onset of the fire. This system can be integrated into the park area by the installation of cameras, if available, to constantly monitor the territory and the ignition and spread of a fire.

- **Fire signalizing**

Early warning using social media posts by citizens.

- **Active firefighting**

When an event occurs, the coordination structure is activated following a report. Once learned, the news is verified by the structures at the local level. In relation to the magnitude of the event, all the components of the Directorate of Extinguishing Operations (DOS) system of the Forestry and Environmental Surveillance Corps of the Sardinia Region are therefore activated, necessary for the rapid suppression of the flames and any subsequent reclamation. The DOS shall carry out the following tasks:

  - coordinates on the spot the extinguishing of fires using land and air resources.
  - requests from the Provincial Operations Centre (COP) any land and air resources.
  - collaborates, as defined by the collaboration protocol, with the Fire Brigade in the defined interface areas.

- **Use of regional radio network**

All the subjects involved in the extinguishing operations use the regional radio network which, due to its specific properties, is the main communication tool for the coordination of activities in the area. In fact, the radio network that almost entirely covers the regional territory guarantees communications in extra-urban areas not covered by traditional telephone networks.

- **Evacuation of citizens and tourists**

Citizens and tourists present in the vicinity of the fire will be conveyed to collection points and evacuated.

- **Drone monitoring**

Drones (If available) can be used to monitor the spread and evolution of fire by providing the subjects involved with real-time information.

4.2.5. Priorities of the Pilot

Pilot Site 1:

Any priorities for pilots were not specified. However, there were specified problems by stakeholders related operational scenarios in Phase B.

- predict the fire behaviour parameters (front intensity and propagation speed) as well as the resultant of the propagation factors and their alignment in each part of the fire.
- identification of critical points, where the fire increases intensity and / or speed.
- identification of 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.
- identification of the valid points as areas of control opportunities, also based on the preliminary study of the effectiveness of the various suppression and technical actions.
- identification of meteorological conditions of particular importance for the prediction of complex phenomena (fires with extreme behaviour, with high energy release) and for the definition of extinguishing strategies with greater accuracy and safety.

Pilot Site 2:

Any priorities for pilots were not specified. However, there were specified problems by stakeholders related operational scenarios in all relevant phases.

Phase A: Effective fire-fighting activities cannot be separated from adequate planning of interventions on the territory, in particular forest planning, with specific interventions in the field of forestry and management of forests and rural areas with a zootechnical vocation. Recent regulations allocate many financial resources for extinction and few for prevention, but fire regimes are changing globally and require new ways of managing territories, forests and natural hazards, the regional fighting apparatus, however perfectible, will never be able to get rid of the new generation fires, without effective measures affecting forest planning, the treatment of combustible biomass and the active involvement of the agro-pastoral world.

Phase B: The restoration of the entire regional structure of the original sighting, both in the logistical distribution and in the hourly typology of the service shifts. This is because our sighting system, although archaic, represents the initial cognitive moment of the fire. Its immediacy and the simultaneous alerting of the intervention structures are fundamental for the containment of damage.

Phase C: Forest planning must be increasingly aimed at a correct treatment of combustible biomass to interrupt both horizontal and vertical continuity, with the aim of being able to modify the behaviour of the fire.

4.2.6. Functional Requirements on SILVANUS Platform

The functional requirements on SILVANUS Platform specified for Phase A and Phase B are introduced.

Functional requirements on SILVANUS Platform which **must be** included in Phase A:

- providing fire danger index metrics,
- visualisation of climate statistics (for historical and future periods; precipitation, temperature, relative humidity etc.),
- gathering information on fire ignition sources, such as human negligence, arson, environment conditions, climate, and weather conditions (climate change impact including), impact of power grid lines,
- providing modelling of human behaviour (and negligence) resulting in forest fire ignition,
- providing probabilistic prediction models for estimating forest fire ignition,
- producing content to engage with citizens on forest fire impact,
- including mobile application which allow people to notify fire to the Fire and Rescue Service,
- SILVANUS mobile application must notify people about the fire occurrence in their vicinity.

Functional requirements on SILVANUS Platform which **should be** included in Phase A:

- identifying areas/regions of historical significance,
- providing information forest structural diversity, providing information on soil types and structure,
- providing representation of forest landscape for computing impact different (single or combined) forest managements on ecosystem services (climate and water regulation) under alternative climate scenarios,
- providing AI/ML algorithms trained on historical data sources resulting in forest fire,
- providing simulation of fire ignition scenarios,
- allowing weather/environmental data to be processed in the emulating the forest fire behaviour,
- notifying people in the vicinity of forests, on human negligence,
- allowing people to notify forest management services on human negligence,
- creation of user interface for reporting a suspect fire by geo-location, photos, and description,
- SILVANUS mobile application should allow fire management services to contact people in fire vicinity for help by voice call,
- SILVANUS mobile application should allow forest management services to contact people in fire vicinity for help by chat,

- SILVANUS mobile application should allow fire and rescue services to ask people in fire vicinity for help by voice call,
- providing micro-weather forecasting models (time scale up to 72 hours),
- providing data collection for the fire behaviour (spread) modelling,
- providing AI/ML algorithms to detect fire danger,
- providing AI/ML algorithms to detect fire/smoke,
- UGV should be equipped with LIDAR, visual sensors (cameras), and environmental sensors,
- collision avoidance among drones should be implemented,
- drones should be equipped with multi-spectral sensing devices,
- heterogenous data from multi-modal data sources should be integrated,
- data filtering and cleaning process should be provided,
- weather forecasts should be developed,
- AI algorithms should be provided to identify high-risky forest regions according to fire initiation potential,
- distributed storage and repository for heterogenous data sources should be provided,
- 5V data characteristics should be supported,
- decision support systems for fire detection, fire spread, weather effect on fire intensity should be used,
- cause-and-effect models for the fire ignition should be used,
- simulation of fire ignition and fire spread based on Monte Carlo like models.

Functional requirements on SILVANUS Platform which **could be** included in Phase A:

- providing information on forest structural diversity,
- providing information on fuel availability in specific regions of forest,
- simulation of spatio-temporal trends of forest changes,
- providing fuel management alternatives for different forest types,
- gathering information on forest landscape using crowd sourcing applications,
- calculation of potential greenhouse emissions from fire probability index based on climate conditions and type of vegetation,
- including, e.g., AR/VR representation of forest landscape for computing impact of climate change on forest ecosystem services (climate and water cycle regulation),
- aggregating Copernicus and EO data prior and post fire ignitions,
- quantifying the damage of forest fire and map into ecological assessment (loss of XX cubic tons of oxygen, etc.),
- providing assessment models of forest resilience (e.g., regeneration dynamics),
- implementing notification protocol for response (first responders) deployment,
- providing AR/VR simulation of combating forest fire,
- gathering feedback from citizens on the usefulness of the mobile application,
- providing pilot region specific customisation of AI/ML algorithms for estimating forest fire danger,
- providing prediction models based on seasonal forecasts,
- providing evaluation of forecast models based on observed data,
- providing IoT data aggregation from distributed deployment of environmental sensors, CCTV, chemical composition sensors,
- providing Edge based micro-data centres for processing data collected from the field,
- supporting the analysis of the impact of forest fires on the hydrology and soil physical properties (using inputs from chemical analysis where applicable),
- supporting continuous monitoring of forest restoration programmes,
- collecting citizen observations from social media,
- providing extraction of geoinformation, i.e., mentioned locations, from social media data sources,

- using unmanned and automated ground vehicles (UGV) for monitoring wildfire behaviour,
- Integration of deep learning for the detection of wildfire (using visual concepts such as smoke, fire, etc) could be considered,
- autonomously piloted UAVs could be deployed for remote sensing,
- algorithms to control drone swarms based on e.g., leader-follower configuration could be applied,
- some UAVs should be stationed in particularly critical areas and automatically scan the area if critical conditions arise (e.g., sudden increase in FDI),
- training models for AI/ML algorithms could be provided,
- providing visualisation of forest landscape models,
- providing micro-predictive models using AI/ML algorithms for different scenarios specifications,
- providing health impact analysis for firefighters to model long- and short-term exposure to forest fire,
- considering wearable devices and other medical devices for response coordination.

Functional requirements on SILVANUS Platform which **must be** included in Phase B:

- providing fire danger index metrics,
- visualisation of climate statistics (for historical and future periods; precipitation, temperature, relative humidity etc.),
- gathering information on fire ignition sources, such as human negligence, arson, environment conditions, climate and weather conditions (climate change impact including), impact of power grid lines,
- providing modelling of human behaviour (and negligence) resulting in forest fire ignition,
- providing probabilistic prediction models for estimating forest fire ignition,
- producing content to engage with citizens on forest fire impact,
- including mobile application which allow people to notify fire to the Fire and Rescue Service,
- SILVANUS mobile application must notify people about the fire occurrence in their vicinity.

Functional requirements on SILVANUS Platform which **should be** included in Phase B

- identification of areas/regions of historical significance,
- visualisation of and providing information on forest structural diversity,
- providing information on soil types and structure,
- providing representation of forest landscape for computing impact different (single or combined) forest managements on ecosystem services (climate and water regulation) under alternative climate scenarios,
- providing AI/ML algorithms trained on historical data sources resulting in forest fire,
- providing simulation of fire ignition scenarios,
- allowing weather/environmental data to be processed in the emulating the forest fire behaviour,
- notifying people in the vicinity of forests, on human negligence,
- allowing people to notify forest management services on human negligence,
- creation of user interface for reporting a suspect fire by geo-location, photos, and description,
- allowing fire management services to contact people in fire vicinity for help by voice call,
- allowing forest management services to contact people in fire vicinity for help by chat,
- allowing fire and rescue services to ask people in fire vicinity for help by voice call,
- providing micro-weather forecasting models (time scale up to 72 hours),
- providing data collection for the fire behaviour (spread) modelling,
- providing AI/ML algorithms to detect fire danger,
- providing AI/ML algorithms to detect fire/smoke,
- UGV should be equipped with LIDAR, visual sensors (cameras), and environmental sensors,

- autonomously piloted UAVs should be deployed for remote sensing,
- collision avoidance among drones should be implemented,
- drones should be equipped with multi-spectral sensing devices,
- heterogenous data from multi-modal data sources should be integrated,
- data filtering and cleaning process should be provided,
- weather forecasts should be developed,
- AI algorithms should be provided to identify high-risky forest regions according to fire initiation potential,
- distributed storage and repository for heterogenous data sources should be provided,
- 5V data characteristics should be supported,
- decision support systems for fire detection, fire spread, weather effect on fire intensity should be used.
- cause-and-effect models for the fire ignition should be used,
- simulation of fire ignition and fire spread based on Monte Carlo like models,
- considering wearable devices and other medical devices for response coordination,
- allowing to develop evacuation plans,
- providing GIS/GPS visualisation of on-field situation.

Functional requirements on SILVANUS Platform which **could be** included in Phase B

- visualisation of landscape biodiversity,
- providing information on fuel availability in specific regions of forest,
- simulation of spatio-temporal trends of forest changes,
- providing fuel management alternatives for different forest types,
- gathering information on forest landscape using crowd sourcing applications,
- calculating potential greenhouse emissions from fire probability index based on climate conditions and type of vegetation,
- including e.g., AR/VR representation of forest landscape for computing impact of climate change on forest ecosystem services (climate and water cycle regulation),
- aggregating Copernicus and EO data prior and post fire ignitions,
- quantifying the damage of forest fire and map into ecological assessment (loss of XX cubic tons of oxygen, etc.),
- providing assessment models of forest resilience (e.g., regeneration dynamics),
- implementing notification protocol for response (first responders) deployment,
- providing AR/VR simulation of combating forest fire,
- gathering feedback from citizens on the usefulness of the mobile application,
- providing pilot region specific customisation of AI/ML algorithms for estimating forest fire danger,
- providing prediction models based on seasonal forecasts,
- providing evaluation of forecast models based on observed data,
- providing IoT data aggregation from distributed deployment of environmental sensors, CCTV, chemical composition sensors,
- providing Edge based micro-data centres for processing data collected from the field,
- supporting the analysis of the impact of forest fires on the hydrology and soil physical properties (using inputs from chemical analysis where applicable),
- supporting continuous monitoring of forest restoration programmes,
- collecting citizen observations from social media,
- providing extraction of geoinformation, i.e., mentioned locations, from social media data sources,
- using unmanned and automated ground vehicles (UGV) for monitoring wildfire behaviour,

- integration of deep learning for the detection of wildfire (using visual concepts such as smoke, fire, etc) could be considered,
- algorithms to control drone swarms based on e.g., leader-follower configuration could be applied,
- some UAVs could be stationed in particularly critical areas and automatically scan the area if critical conditions arise (e.g., sudden increase in FDI),
- training models for AI/ML algorithms could be provided,
- providing visualisation of forest landscape models,
- providing micro-predictive models using AI/ML algorithms for different scenarios specifications,
- providing health impact analysis for fire fighters to model long- and short-term exposure to forest fire,
- supporting resources deployment,
- providing damage assessment,
- supporting coordination of responders,
- providing visualisation of forest restoration (forest management) alternatives for stakeholder to support forest resilience,
- supporting the systematic planning of restoration activities,
- facilitating the selection and configuration of governance models for forest restoration, using criteria such accountability, effectiveness, efficiency, fairness, participation, and transparency.

Functional requirements on SILVANUS Platform which **must be** included in Phase C

- providing fire danger index metrics,
- visualisation of climate statistics (for historical and future periods; precipitation, temperature, relative humidity etc.),
- gathering information on fire ignition sources, such as human negligence, arson, environment conditions, climate, and weather conditions (climate change impact including), impact of power grid lines,
- providing modelling of human behaviour (and negligence) resulting in forest fire ignition
- providing probabilistic prediction models for estimating forest fire ignition
- producing content to engage with citizens on forest fire impact,
- including mobile application which allow people to notify fire to the Fire and Rescue Service
- SILVANUS mobile application must notify people about the fire occurrence in their vicinity
- SILVANUS mobile application must create user interface for reporting a suspect fire by geo-location, photos, and description
- SILVANUS mobile application must allow fire management services to contact people in fire vicinity for help by voice call
- SILVANUS mobile application must allow forest management services to contact people in fire vicinity for help by chat
- SILVANUS mobile application must allow fire and rescue services to ask people in fire vicinity for help by voice call.

Functional requirements on SILVANUS Platform which **should be** included in Phase C

- identifying areas/regions of historical significance,
- visualisation and providing information forest structural diversity,
- providing information on soil types and structure,
- providing representation of forest landscape for computing impact different (single or combined) forest managements on ecosystem services (climate and water regulation) under alternative climate scenarios,
- providing AI/ML algorithms trained on historical data sources resulting in forest fire,

- providing simulation of fire ignition scenarios,
- allowing weather/environmental data to be processed in the emulating the forest fire behaviour,
- notifying people in the vicinity of forests, on human negligence,
- SILVANUS mobile application should allow people to notify forest management services on human negligence,
- providing micro-weather forecasting models (time scale up to 72 hours),
- providing data collection for the fire behaviour (spread) modelling,
- providing AI/ML algorithms to detect fire danger,
- providing AI/ML algorithms to detect fire/smoke,
- providing AI/ML algorithms to detect fire danger,
- providing AI/ML algorithms to detect fire/smoke,
- UGV should be equipped with LIDAR, visual sensors (cameras), and environmental sensors
- collision avoidance among drones should be implemented,
- drones should be equipped with multi-spectral sensing devices,
- distributed storage and repository for heterogenous data sources should be provided
- 5V data characteristics should be supported,
- decision support systems for fire detection, fire spread, weather effect on fire intensity should be used,
- cause-and-effect models for the fire ignition should be used,
- simulation of fire ignition and fire spread based on Monte Carlo like models,
- providing micro-predictive models using AI/ML algorithms for different scenarios specifications,
- providing GIS/GPS visualisation of on-field situation.

Functional requirements on SILVANUS Platform which **could be** included in Phase C

- visualisation of landscape biodiversity,
- providing information on fuel availability in specific regions of forest,
- simulation of spatio-temporal trends of forest changes,
- providing fuel management alternatives for different forest types,
- gathering information on forest landscape using crowd sourcing applications,
- calculation of potential greenhouse emissions from fire probability index based on climate conditions and type of vegetation.
- Including, e.g., AR/VR representation of forest landscape for computing impact of climate change on forest ecosystem services (climate and water cycle regulation),
- aggregation of Copernicus and EO data prior and post fire ignitions,
- quantifying the damage of forest fire and map into ecological assessment (loss of XX cubic tons of oxygen, etc.),
- providing assessment models of forest resilience (e.g., regeneration dynamics),
- implementing notification protocol for response (first responders) deployment,
- providing AR/VR simulation of combating forest fire,
- gathering feedback from citizens on the usefulness of the mobile application,
- providing pilot region specific customisation of AI/ML algorithms for estimating forest fire danger,
- providing prediction models based on seasonal forecasts,
- providing evaluation of forecast models based on observed data,
- providing IoT data aggregation from distributed deployment of environmental sensors, CCTV, chemical composition sensors,
- providing Edge based micro-data centres for processing data collected from the field,
- supporting the analysis of the impact of forest fires on the hydrology and soil physical properties (using inputs from chemical analysis where applicable),

- supporting continuous monitoring of forest restoration programmes,
- collecting citizen observations from social media,
- providing extraction of geoinformation, i.e., mentioned locations, from social media data sources,
- collecting citizen observations from social media,
- providing extraction of geoinformation, i.e., mentioned locations, from social media data sources,
- using unmanned and automated ground vehicles (UGV) for monitoring wildfire behaviour,
- Integration of deep learning for the detection of wildfire (using visual concepts such as smoke, fire, etc) could be considered,
- autonomously piloted UAVs could be deployed for remote sensing,
- algorithms to control drone swarms based on e.g., leader-follower configuration could be applied,
- some UAVs could be stationed in particularly critical areas and automatically scan the area if critical conditions arise (e.g., sudden increase in FDI),
- training models for AI/ML algorithms should be provided,
- providing visualisation of forest landscape models,
- providing health impact analysis for fire fighters to model long- and short-term exposure to forest fire,
- considering wearable devices and other medical devices for response coordination,
- providing visualisation of forest restoration (forest management) alternatives for stakeholder to support forest resilience,
- supporting the systematic planning of restoration activities,
- facilitating the selection and configuration of governance models for forest restoration, using criteria such accountability, effectiveness, efficiency, fairness, participation, and transparency.

4.3 ROMANIA

Romania is involved in demonstration of operational scenarios in Phases A (Preparedness and Prevention) and Phase B (Detection and Response).

4.3.1 Pilot Summary

The Romanian use case will develop in “Rodna” Mountains National Park, which is the second largest national park in Romania. The annual average temperature is about 7-8°C downhill and negative (-1.5ºC) uphill. In January, the temperature averages -3ºC downhill and -9ºC uphill respectively. For July, the corresponding figures are 18ºC and 7ºC respectively. Rainfall exceeds 1.200-1.300 mm/year.

Based on a national study, the “Rodna” Mountains National Park Forest area is deemed as a low risk with regards to the probability of forest fires. Nevertheless, national statistics show that 61% of forest fires start by human negligence and 35% are due to unknown causes, most likely also due to human error. Natural causes are responsible for less than 1% of forest fires. One of the main attractions of the pilot area are its offering of hiking trails and camping areas, so human negligence is an important factor to consider in the prevention and mitigation of forest fires.

Most forest fires occur during springtime (March and April), followed by the summer months July and August. These periods also coincide with the increased influx of tourist on the hiking trails and camping sites.

4.3.2 Pilot Status Characteristics

In this section the existing data, systems, services, and technology used in the Pilot Site is described.

No UAVs (Drones) or UGVs (robots) are deployed in the Pilot Site.

No Remote Sensing Technology, Sensors and IoT Tools and Instruments are used for wildfire combating purposes in the Pilot Site.

Data communicated between the individual endpoints:

- From: dropdown: C&C Room, Mobile C&C Room, Municipality, Fireman, Forester, Citizens, Wearable Device, Wearable Sensors, Field Sensors, Fire Truck, Helicopter, Airplane, Drone (UAV), Ground Robot (UGV), Social Network, Cloud Service, Volunteer Fire Fighters, Other.
- To: dropdown: C&C Room, Mobile C&C Room, Municipality, Fireman, Forester, Citizens, Wearable Device, Wearable Sensors, Field Sensors, Fire Truck, Helicopter, Airplane, Drone (UAV), Ground Robot (UGV), Social Network, Cloud Service, Volunteer Fire Fighters, Other.
- Type of Data: text.
- Protocol: dropdown: TETRA, WiFi, Bluetooth, Zigbee, WiMax, NFC, LoRa, 3G/4G, 5G, UWB, Infrared, RFID, Satellite, Optical Wireless, Radio (PTT), Other.

No 3rd party cloud storage usage for storing data by stakeholders operating in the Pilot Site was specified.

No Cloud Platform is used by stakeholders operating in the Pilot Site.

No Social Media are used for purpose of fire situation awareness.

No Decision Support Systems (DSS) are deployed in organisation operating in the Pilot Site.

No available datasets were specified by interviewed stakeholders operating in the Pilot Site.

4.3.3 Stakeholders involved

The stakeholders who were interviewed in the framework of activities related to D2.1 deliverable were:

- ASFOR (forest and/or landowners),

- FptSMURD (firefighting associations),
- SIMAVI (private entity).

4.3.4 High-level Operational Scenario

Operational scenario

Several mountain hikers, who were in the pilot area lit a campfire to prepare their food. During the night, the fire went unattended and spread to the dry vegetation in the area.

The fire was observed in the morning when a hiker in the tent smelled smoke. He found out from the tent that the area was covered in smoke and flames. At that moment, he made a lot of noise and helped some of his colleagues to escape. Several hikers quickly left the area and moved away from the outbreaks. They reported that no other people were in the camp at the time.

There was no GSM signal in the fire site area to announce the event at SNUAU 112 (National Emergency Response number).

Alerted by the SILVANUS monitoring system for fire hazard, the employees of the Forest District, who were patrolling the area, discover a fire of dry vegetation at the forest fund in the pilot area, which quickly spreads to the forest litter, on an area of approx. 500 sqm, with the possibility of spreading to the canopy due to the existence of permanent air currents specific to the area.

The event was detected by the Forest District patrol (following the alert issued by the monitoring system), but calls were also made to 112 by locals in the area, who noticed large smoke emissions in the area. Ocolul Silvic informed the Dispatch Office of the Inspectorate for Emergency Situations of Bistrița County (ISU Bistrita) and sent the approximate coordinates of the event, the latter also having access to the available data collected by the monitoring system.

With support from the SILVANUS monitoring system, ISU Bistrita begins procedures to extinguish the fire in the pilot area.

Phase A operational scenario:

At a certain moment, the temperature sensors detect a sudden increase in temperature compared to normal. In conjunction with other data received from humidity sensors, weather data and mountain tourist flow metering sensors, the monitoring system signals an alert. The biodiversity landscape for the area is already known.

Weather information for the area is extracted from an available database.

The weather situation on <.......> (date), at <.......> (time) is as follows:

- Wind speed: 25 m/s
- Wind direction: from 70°
- Air stability class: D
- Temperature: 30° C
- Precipitation: 7 mm
- Atmospheric pressure: 730 mm col HG
- Information about vegetation in the area
- Information received from the monitoring system (sensors, devices):
- Data on humidity

- Data on meteorological conditions
- Data on the flow of mountain tourists
- Photo data / Images related to the fire burst area from the camera with which the monitoring drone is equipped.

Following the reported event, a drone is sent for monitoring and at the same time the patrol team of the Forest District is alerted, for investigation.

All available information (some gathered on the ground, and some extracted from available databases) is sent to the cloud in the SILVANUS platform to be processed and it issues an alert regarding the fire danger index and necessity of complementary measures for investigation and assessment (e.g., in person, drones, etc.).

Phase B operational scenario:

The mode of operation will be carried out according to the procedures from: The national concept of response in case of forest fires and the Action Plan for forest fires at the level of Bistrița County. These procedures addressing tactical execution and information flow will be detailed further, in the next stage of project implementation.

The firefighters use a sectoral based approach based on genetic tools (shovel, dig, etc.), due to unavailability of access of intervention vehicles.

Activities that may be carried out during intervention phase:

- Cleaning of felling areas, at the same time as making protection strips with the help of screeds, shovels, and where possible, extinguishing with petals of 2-5 liters to hearths
- Transport of water through a human cordon with the help of plastic containers from "hand in hand" to the edge of the outbreaks, based on viable sources of water (near springs)
- Transport of water from the place of establishment of the control point (from tankers - by filling 2–5-liter pots) with 4x4 cars to the affected areas
- 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.

Phase A: Evaluation assessment

- Self-assessment toolkit for environmental modelling.
- Ecological assessment of biodiversity within natural parks.
- Environmental assessment of fire danger index.

Phase B: Continuous monitoring of human behaviour for safety regulations

- Drone inspection of human behaviour for wildfire safety.
- Response actuator system to neutralise early-stage threats.

Involved Romanian partners (stakeholders):

- FptSMURD – will liaise with local firefighters and facilitate the logistical preparedness.
- ASFOR – will provide expertise in research related to the forestry sector (including specific biodiversity and legislation) and facilitate access to the "Rodna" Mountains National Park.
- SIMAVI – will provide AR/VR training to firefighters and support the technical implementation of the pilot.

4.3.5 Priorities of the Pilot

Any priorities for pilots were not specified. However, there were specified problems by stakeholders related operational scenarios in all relevant phases.

Problems to be considered in Phase A:

- identifying relevant areas for mounting temperature, humidity and counting sensors,
- mounting the sensors in the designated areas in accordance with natural park area restrictions,
- identifying relevant location for a forward outpost with access to electricity,
- ensuring uninterrupted connectivity of IoT devices to the internet,
- development of monitoring procedures,
- ensuring connectivity to relevant databases.

Problems to be considered in Phase B:

- analysis of opening-up of territory for purposes of deployment of fire trucks in case of fire,
- mapping of suitable water sources,
- ensuring continuous monitoring activities and uninterrupted flow of data/communication,
- information (image, text, and coordinates of fire site) transfer to Operational Command Centre of Fire and Rescue Service.

4.3.6 Functional requirements on SILVANUS Platform

Preliminary aspects concerning the technical solution were specified in this stage of project implementation, based on technological layers.

- creation of a web interface for data collection,
- gathering of historical data related to forest ignition,
- gathering data based on social media impressions,
- process data based on different data sources – JDBC/REST/SOAP,
- event description and interpretation,
- providing probabilistic or AI/ML algorithms trained on historical data for forest fires,
- providing modelling for human behaviour,
- implementing notification system with alerts,
- providing environmental context,
- creating a mission definition and tactical context,
- creating analysis of the factors that favour the spread of the fire: the season, the degree of humidity of the vegetation and air, the degree of exposure, the speed and direction of the wind,
- visualisation of climate statistics.

4.4 GREECE

Greece is involved in demonstration of operational scenarios in Phase A (Preparedness and Prevention), Phase B (Detection and Response) and Phase C (Restoration and Adaptation).

4.4.1 Pilot Summary

In the Greek pilot, a regional unit of the prefecture of Sterea Ellada (Central Greece, partner: PSTE) will serve as a study area (Figure 16). In particular, the regional units of Evia and Fthiotida have been selected as suitable candidates. Evia will be the pilot site for the SILVANUS project. The exact forest areas will be selected based on their ecological value and fire risk. In the following, a description of Evia regional units is given.

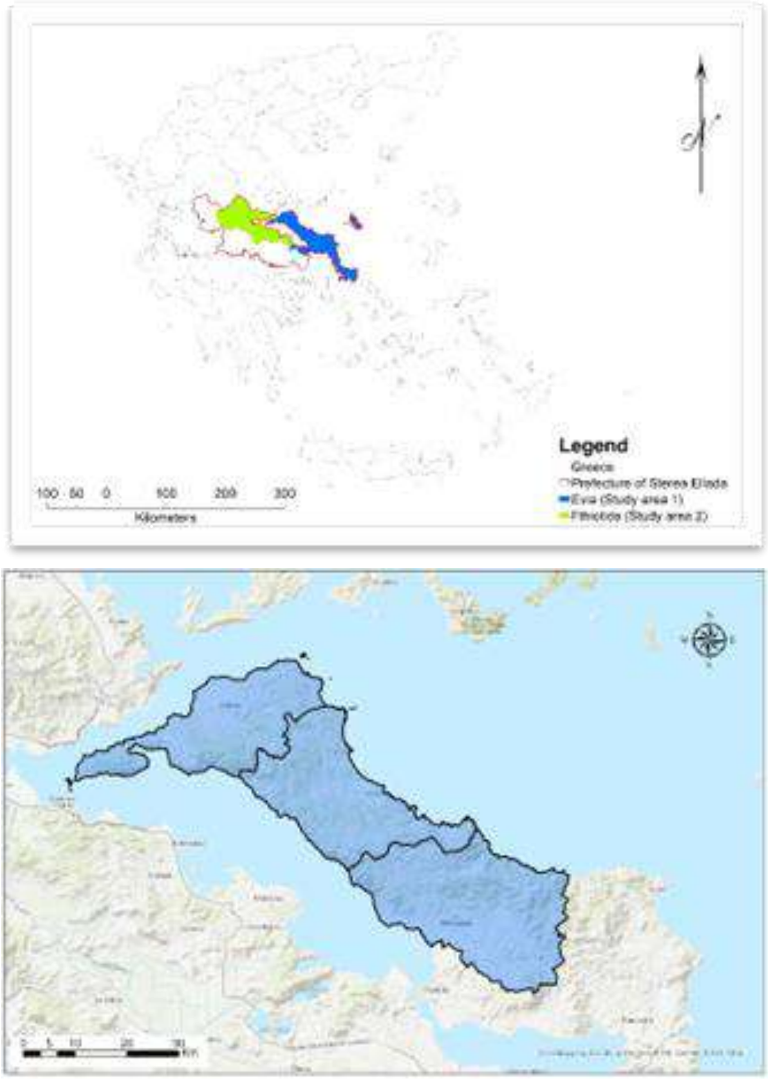

Figure 16 Pilot area map

*****Top: The Region of Sterea Ellada (red line) depicting Evia (main pilot) and Fthiotis (alternative pilot area). Bottom: Focus on the pilot site.

The wildfire occurs on Jul 15, 2023. It is middle of the summer characteristic with a long dry and hot period. Temperature at 37 degrees Celsius. South wind at 7 Beaufort. Air humidity at 65%.

The fire site is composed of dense height-tree forest of Pinus halepensis, with understory of shrubs. Surface fuels thick and very dry. Crown-base height at 3 m. Deep soil covered with needles. Steep terrain.

Small villages with permanent residents and tourists are in danger due to their vicinity. Home properties, churches and summer camps with children could be affected. Agricultural / Cultivated areas are under threat. Power installations (e.g., power transmission lines) can also be damaged. Riparian areas of high value are threatened.

There are reports about possible arson due to the many simultaneous ignition points. Active crown fire with flame length of 25 m. Fire front is estimated at 3 km. Duration: 1 day.

4.4.2 Pilot Status Characteristics

In this section the existing data, systems, services, and technology used in the Pilot Site are described.

Available technology/software/hardware:

- UAVs for monitoring and streaming (KEMEA):
  - various payloads and dimensions
  - various types of cameras
  - Cable for providing continuous power
- Medical equipment (AHEPA):
  - Spirometry measurement for on-site respiratory evaluation
  - Nebulizers and bronchodilators for on-site administration
- GIS software (KEMEA):
  - ESRI ARCGIS Enterprise platform (ArcGIS desktop, ArcGIS Pro, ArcGIS Server, SQL Server RDBMS, etc., full package)
- Coordination Center (KEMEA):
  - GIS based, can be used for incident reporting and visualization of daily risk maps
- Real-time Twitter Crawler (CERTH)
- Monitoring of burn scar using Satellite Data (CERTH)

Cameras used for forest fire monitoring:

- **Zenmuse Z30**
  - Resolution: [x] Full HD (1920×1080), [x] HD (1280×720)
  - Focal length (fixed, min-max in mm): __
  - Maximum aperture size: 1.6
  - Data storage: [x] SD-Card
  - Other parameters: **Used by Drone** (mount on gimbal) Sensor size: CMOS, 1/2.8" 2.3MP Lens: 30x optical zoom, 6x digital zoom FOV: 63.7°(Wide) - 2.3°(Tele) Max. aperture size: 4.7 (Tele)
- **Zenmuse L1**
  - Resolution: 5472x3648
  - Video Coding Standard: [x] H.262
  - Focal length: 8.8
  - Maximum aperture size: 2.8
  - Special Feature: [x] Lidar
  - Data storage: [x] SD-Card
  - Other parameters: **Used by Drone** (mount on gimbal) Livox Lidar + RGB Sensor size: 1" CMOS 20MP Lidar: 240.000 points/sec Lidar Accuracy: 3cm @ 100m
- **Zenmuse X5S**
  - Resolution: 5280×3956
  - Video Coding Standard: [x] H.264, [x] Cinema DNg, H.265

    - Focal length: 15
    - Maximum aperture size: 1.7
    - Data storage: [x] SD-Card, [x] HDD/SSD
    - Other parameters: Used by Drone (mount on gimbal) Sensor size: 4/3" 20.8MP
- **RedEdge MX**
    - Resolution: 1280x960
    - Focal length: 5.4
    - Special Feature: Multispectral (10 bands)
    - Data storage: [x] SD-Card, [x] Optional WiFi
    - Other parameters: **Used by Drone** Field of view: 47.2° HFOV Ground Sample Distance (GSD): 8 cm per pixel (per band) at 120 m
- **Zenmuse H20T**
    - Resolution: 640×512
    - Video Coding Standard: JPEG-R
    - Focal length: 13.5
    - Special Feature: Thermal
    - Maximum Aperture Size: 1.0
    - Data storage: [x] SD-Card
    - Other parameters: **Used by Drone** (mount on gimbal) Scene range: -40°C to 150°C (High Gain), -40°C to 550°C (Low Gain) Digital zoom: 1x, 2x, 4x, 8x
- **Zenmuse XT2**
    - Resolution: UHD (3840×2160)+, Full HD (1920×1080)+
    - Video Coding Standard: H.264 JPEG, MOV, MP4
    - Focal length: 9, 13, 19, 25
    - Special Feature: Thermal, Thermal resolution: 640x512
    - Data storage: [x] SD-Card
    - Other parameters: Used by Drone (mount on gimbal) Sensor: 1/1.7" CMOS (12MP) Digital zoom: 1x, 2x, 4x, 8x Scene range: -40°C to 550°C (low gain), -25°C to 135°C (high gain)

No Alerting/Fire Detection Systems are deployed in the Pilot Sites.

Communication endpoints in Phase A: Municipality, Fireman, Forester, Citizens, Fire Truck, Social Network, Volunteer Fire Fighters.

Communication Protocols used in Phase A: WiFi, 3G/4G, Radio (PTT).

Communication endpoints in Phase A: Command & Control Room, Mobile C&C Room, Municipality, Fireman, Fire Truck, Helicopter, Airplane, Drone (UAV), Volunteer Fire Fighters.

Communication Protocols used in Phase B: WiFi, 3G/4G, Radio (PTT).

Communication endpoints in Phase C: Municipality, Forester, Citizens, Drone (UAV).

Communication Protocols used in Phase C: WiFi, 3G/4G, Satellite.

Data communicated between the individual endpoints:

- From: dropdown: C&C Room, Mobile C&C Room, Municipality, Fireman, Forester, Citizens, Wearable Device, Wearable Sensors, Field Sensors, Fire Truck, Helicopter, Airplane, Drone (UAV), Ground Robot (UGV), Social Network, Cloud Service, Volunteer Fire Fighters, Other
- To: dropdown: C&C Room, Mobile C&C Room, Municipality, Fireman, Forester, Citizens, Wearable Device, Wearable Sensors, Field Sensors, Fire Truck, Helicopter, Airplane, Drone (UAV), Ground Robot (UGV), Social Network, Cloud Service, Volunteer Fire Fighters, Other
- Type of Data: text

- Protocol: dropdown: TETRA, WiFi, Bluetooth, Zigbee, WiMax, NFC, LoRa, 3G/4G, 5G, UWB, Infrared, RFID, Satellite, Optical Wireless, Radio (PTT), Other

Big Data Framework was not specified. No Cloud Platform is used for data storing and management by stakeholders operating in the Pilot Sites. Social Media are not used, too.

No there is not any functional DSS in use. Although there is one developed for research by Agricultural University of Athens. It is designed for forest management planning for wildfire damage reduction. Multiple Criteria Decision Making (MCDM) and Simulation models are included in the DSS. The following methods are included in the models: Multi-Criteria, Decision Making with Rules, Heuristics Fuzzy Logic, Relational Database for Conventional and Spatial Data.

Old (not historical) data that could be used:

- Pictures from drones from past fires.
- Old studies for the forests of the area.
- Satellite images, if any.
- Ktimatologio (land registry) forest maps.
- Corine layers for land use.
- Hellenic statistical Authority data (population, local economy, etc).
- Forest management plans
- Vegetation maps
- Possibly real tweets posted during past fires (if we wish to reenact a past incident)

Data that can be found for the Greek Pilot:

- Topography (1:50,000)
- Weather data (historical data from NOA)
- Real-time: NOA or HNMS. These types of data need extra payment.
- Corine maps.
- Ktimatologio Forest Maps.
- Satellite/aerial imagery free.
- EFFIS burned areas 2021 Euboea, historical data.
- Copernicus emergency mapping service.
- Hellenic Fire service log files.
- Fire propagation based on human forensics (maybe witness statements).
- Real data about fires in Greece or synthetic to follow a specific pilot scenario (volunteers can be engaged to post synthetic tweets).

4.4.3 Stakeholders involved

the following stakeholders are involved in the Operational Scenario.

- **First responders** (Firefighters, police, paramedics, Coast guard).
- **Other Local Civil Protection Authorities** (Municipalities).
- **Regional Civil Protection Authorities** (Prefectures).
- **National Civil Protection Authorities** (General Secretariat of Civil Protection, other Coordination Centres of the Ministry Climate Change & Civil Protection).
- **Forest Offices/Services**.
- **Volunteers Groups** (Firefighting, Cultural & Environmental Associations, etc.).
- **Local Professional Groups** (Resin Producers, Beekeepers, Farmers, etc.).
- **Citizens**.

4.4.4 *High-level Operational Scenario*

Operational Scenario and Use Cases specified for **Phase A** (Prevention and Preparedness):

- Daily fire risk map.
- Fire vulnerability and risk mapping.
- Real-time weather data from the pilot site (under investigation if it will be used).
- Soil moisture (under investigation if it will be used).
- Fire ignition models.
- Training of citizens.
- Exposure of settlements to wildfires.
- Other preparedness (not technological actions) to infrastructures.

Operational Scenario and Use Cases specified for **Phase B** (Detection/Monitoring and Response):

- Early warning through drones.
- Early warning through social media and the use of other mobile applications.
- Decision Support System.
- Mobile Command Centres (if provided for the pilot by any partner).
- Cameras for firefighters (if provided by any partner).
- Citizen engagement: especially evacuation, information for evolution of wildfires.
- Fire propagation models.
- Health metrics.

Operational Scenario and Use Cases specified for **Phase C** (Restoration and Adaptation):

- Soil protection measures with the main goal to protect soil and downstream areas from floods:
    - immediate (short term),
    - long-term measures.
- Soil restoration measures and processes.
- Actions for the protection of remaining forests (also linked to the Preparedness phase).
- Changes in land use (this can be done through satellites as well).
- Forest restoration:
    - Physical resurrection.
    - Human-supported resurrection depending on the type of trees.
- Forest growth models, if any, based on existing studies.
- Socio-cultural and economic issues. Forest in the pilot area supported the local economy through mild agriculture and touristic uses.
- Promote sustainable actions for the forest and its biodiversity.

4.4.5 *Priorities of the Pilot*

Key problems/issues for **Phase A** (Preparedness and Prevention):

- Collection of proper data for fire danger, fire risk and fire vulnerability assessment.
- Preparedness of local settlements, e.g. deforestation and forest cleaning where necessary.
- Preparation of infrastructures for fire season.
- Preparation of settlements with fire safe zones in the perimeter.
- Preparation of the firefighting personnel, continuous training for responding and use of equipment.
- Maintenance of vehicles and resources.
- Mapping and maintenance of water resources.
- Mapping and cleaning of forest roads.
- Emergency planning.

- Training of citizens for risk awareness and self-protection.
- Evacuation planning for various scenarios.

Key problems/issues for **Phase B** (Detection and Response):

- Fast and reliable early warning through various sources, e.g., satellites, drones.
- Use of social sensing algorithms for detection and evolution
- Use of citizens for the demo
- Deployment of resources of various organizations according to emergency planning
- Weather data, vegetation and topography for the fire propagation models
- The platform will make the necessary calculations. Suitable model must be found.

Key problems/issues for **Phase C** (Restoration and Adaptation):

- Identification of the measures for the protection of soils, maybe differentiates for each pilot site.
- Protection of the remaining forests.
- Restoration of burned forests, physical or human supported.
- Analysis of impacts to local economies and societies.
- Training of people to protect the forest and maintain biodiversity. This is linked to phase A as well.
- Promotion for sustainable actions for forest and biodiversity maintenance.

4.4.6 Functional requirements on SILVANUS Platform

Functional requirements on SILVANUS Platform which **must be** included in Phase A:

- Visualisation of landscape biodiversity,
- identifying areas/regions of historical significance,
- visualisation and providing information on forest structural diversity,
- providing fire danger index metrics,
- providing information on fuel availability in specific regions of forest,
- simulation of spatio-temporal trends of forest changes,
- providing fuel management alternatives for different forest types,
- visualisation of climate statistics (for historical and future periods; precipitation, temperature, relative humidity etc.),
- gathering information on fire ignition sources, such as human negligence, arson, environment conditions, climate, and weather conditions (climate change impact including), impact of power grid lines,
- aggregating Copernicus and EO data prior and post fire ignitions,
- providing AI/ML algorithms trained on historical data sources resulting in forest fire,
- providing modelling of human behaviour (and negligence) resulting in forest fire ignition,
- providing probabilistic prediction models for estimating forest fire ignition,
- providing simulation of fire ignition scenarios,
- implementing notification protocol for response (first responders) deployment,
- allowing weather/environmental data to be processed in the emulating the forest fire behaviour
- producing content to engage with citizens on forest fire impact,
- including mobile application which allow people to notify fire to the Fire and Rescue Service,
- SILVANUS mobile application must notify people about the fire occurrence in their vicinity,
- SILVANUS mobile application must create user interface for reporting a suspect fire by geo-location, photos, and description,
- SILVANUS mobile application must allow fire management services to contact people in fire vicinity for help by voice call,

- SILVANUS mobile application must allow forest management services to contact people in fire vicinity for help by chat,
- SILVANUS mobile application must allow fire and rescue services to ask people in fire vicinity for help by voice call,
- providing micro-weather forecasting models (time scale up to 72 hours),
- providing pilot region specific customisation of AI/ML algorithms for estimating forest fire danger,
- predicting models based on seasonal forecasts,
- providing evaluation of forecast models based on observed data,
- providing IoT data aggregation from distributed deployment of environmental sensors, CCTV, chemical composition sensors,
- providing data collection for the fire behaviour (spread) modelling,
- support the analysis of the impact of forest fires on the hydrology and soil physical properties (using inputs from chemical analysis where applicable),
- collecting citizen observations from social media,
- providing AI/ML algorithms to detect fire danger,
- providing extraction of geoinformation, i.e., mentioned locations, from social media data sources,
- UGV must be equipped with LIDAR, visual sensors (cameras), and environmental sensors,
- Integration of deep learning for the detection of wildfire (using visual concepts such as smoke, fire, etc) must be considered,
- collision avoidance among drones must be implemented,
- drones must be equipped with multi-spectral sensing devices,
- heterogenous data from multi-modal data sources must be integrated,
- data filtering and cleaning process must be provided,
- weather forecasts must be developed,
- AI algorithms must be provided to identify high-risky forest regions according to fire initiation potential,
- distributed storage and repository for heterogenous data sources must be provided,
- training models for AI/ML algorithms must be provided,
- 5V data characteristics must be supported,
- decision support systems for fire detection, fire spread, weather effect on fire intensity must be used,
- cause-and-effect models for the fire ignition must be used,
- providing visualisation of forest landscape models,
- providing health impact analysis for fire fighters to model long- and short-term exposure to forest fire,
- providing damage assessment,
- allowing to develop evacuation plans,
- supporting coordination of responders.

Functional requirements on SILVANUS Platform which **should be** included in Phase A:

- providing information on soil types and structure,
- providing AR/VR simulation of combating forest fire,
- SILVANUS mobile application should allow people to notify forest management services on human negligence,
- autonomously piloted UAVs should be deployed for remote sensing,
- algorithms to control drone swarms based on e.g., leader-follower configuration should be applied

- some UAVs should be stationed in particularly critical areas and automatically scan the area if critical conditions arise (e.g., sudden increase in FDI),
- providing micro-predictive models using AI/ML algorithms for different scenarios specifications,
- supporting resources deployment,
- providing visualisation of forest restoration (forest management) alternatives for stakeholder to support forest resilience.

Functional requirements on SILVANUS Platform which **could be** included in Phase A:

- calculating potential greenhouse emissions from fire probability index based on climate conditions and type of vegetation.
- including e.g. AR/VR representation of forest landscape for computing impact of climate change on forest ecosystem services (climate and water cycle regulation),
- providing representation of forest landscape for computing impact different (single or combined) forest managements on ecosystem services (climate and water regulation) under alternative climate scenarios,
- gathering feedback from citizens on the usefulness of the mobile application,
- providing Edge based micro-data centres for processing data collected from the field,
- supporting continuous monitoring of forest restoration programmes,
- providing extraction of visual concepts, such as fire or smoke, from social media data sources,
- simulation of fire ignition and fire spread based on Monte Carlo like models.

Functional requirements on SILVANUS Platform which **must be** included in Phase B:

- visualization of climate statistics (for historical and future periods; precipitation, temperature, relative humidity etc.),
- gathering information on fire ignition sources, such as human negligence, arson, environment conditions, climate and weather conditions (climate change impact including), impact of power grid lines,
- provide simulation of fire ignition scenarios,
- implementation of notification protocol for response (first responders) deployment,
- allowing weather/environmental data to be processed in the emulating the forest fire behaviour,
- including mobile application which allow people to notify fire to the Fire and Rescue Service,
- SILVANUS mobile application must notify people about the fire occurrence in their vicinity,
- SILVANUS mobile application must create user interface for reporting a suspect fire by geo-location, photos, and description,
- SILVANUS mobile application must allow fire management services to contact people in fire vicinity for help by voice call,
- SILVANUS mobile application must allow forest management services to contact people in fire vicinity for help by chat,
- SILVANUS mobile application must allow fire and rescue services to ask people in fire vicinity for help by voice call,
- providing micro-weather forecasting models (time scale up to 72 hours),
- providing pilot region specific customisation of AI/ML algorithms for estimating forest fire danger,
- providing prediction models based on seasonal forecasts,
- providing evaluation of forecast models based on observed data,
- provide IoT data aggregation from distributed deployment of environmental sensors, CCTV, chemical composition sensors,
- providing data collection for the fire behaviour (spread) modelling,

- collecting citizen observations from social media,
- providing AI/ML algorithms to detect fire danger,
- collision of avoidance among drones must be implemented,
- drones must be equipped with multi-spectral sensing devices,
- heterogenous data from multi-modal data sources must be integrated,
- data filtering and cleaning process must be provided,
- weather forecasts must be developed,
- distributed storage and repository for heterogenous data sources must be provided,
- training models for AI/ML algorithms must be provided,
- 5V data characteristics must be supported,
- decision support systems for fire detection, fire spread, weather effect on fire intensity must be used,
- providing visualisation of forest landscape models,
- providing health impact analysis for fire fighters to model long- and short-term exposure to forest fire,
- considering wearable devices and other medical devices for response coordination,
- providing damage assessment,
- supporting resources deployment,
- allowing to develop evacuation plans,
- supporting coordination of responders,
- providing GIS/GPS visualisation of on-field situation.

Functional requirements on SILVANUS Platform which **should be** included in Phase B:

- simulation of spatio-temporal trends of forest changes,
- providing information on soil types and structure,
- providing AR/VR simulation of combating forest fire,
- providing AI/ML algorithms to detect fire/smoke,
- autonomously piloted UAVs should be deployed for remote sensing,
- algorithms to control drone swarms based on e.g., leader-follower configuration should be applied,
- some UAVs should be stationed in particularly critical areas and automatically scan the area if critical conditions arise (e.g., sudden increase in FDI),
- AI algorithms should be provided to identify high-risky forest regions according to fire initiation potential,
- providing micro-predictive models using AI/ML algorithms for different scenarios specifications.

Functional requirements on SILVANUS Platform which **could be** included in Phase B:

- calculating potential greenhouse emissions from fire probability index based on climate conditions and type of vegetation,
- including e.g. AR/VR representation of forest landscape for computing impact of climate change on forest ecosystem services (climate and water cycle regulation),
- providing representation of forest landscape for computing impact different (single or combined) forest managements on ecosystem services (climate and water regulation) under alternative climate scenarios,
- gathering feedback from citizens on the usefulness of the mobile application,
- SILVANUS mobile application could allow people to notify forest management services on human negligence,
- providing Edge based micro-data centres for processing data collected from the field,

- supporting the analysis of the impact of forest fires on the hydrology and soil physical properties (using inputs from chemical analysis where applicable),
- simulation of fire ignition and fire spread based on Monte Carlo like models,
- supporting the systematic planning of restoration activities.

Functional requirements on SILVANUS Platform which **must be** included in Phase C:

- visualisation of landscape biodiversity,
- identification of areas/regions of historical significance,
- visualisation and providing of information forest structural diversity,
- providing fire danger index metrics,
- providing information on fuel availability in specific regions of forest,
- simulation of spatio-temporal trends of forest changes,
- providing fuel management alternatives for different forest types,
- visualisation of climate statistics (for historical and future periods; precipitation, temperature, relative humidity etc.),
- aggregating Copernicus and EO data prior and post fire ignitions,
- supporting the analysis of the impact of forest fires on the hydrology and soil physical properties (using inputs from chemical analysis where applicable),
- supporting continuous monitoring of forest restoration programmes,
- providing AI/ML algorithms to detect fire danger,
- providing AI/ML algorithms to detect fire/smoke,
- data filtering and cleaning process must be provided,
- distributed storage and repository for heterogenous data sources must be provided,
- providing visualisation of forest landscape models,
- providing health impact analysis for fire fighters to model long- and short-term exposure to forest fire,
- providing damage assessment,
- providing visualisation of forest restoration (forest management) alternatives for stakeholder to supporting forest resilience,
- supporting the systematic planning of restoration activities,
- facilitating the selection and configuration of governance models for forest restoration, using criteria such accountability, effectiveness, efficiency, fairness, participation and transparency.

Functional requirements on SILVANUS Platform which **should be** included in Phase C:

- providing e information on soil types and structure,
- quantifying the damage of forest fire and mapping into ecological assessment (loss of XX cubic tons of oxygen, etc.),
- providing assessment models of forest resilience (e.g., regeneration dynamics),
- autonomously piloted UAVs should be deployed for remote sensing,
- heterogenous data from multi-modal data sources should be integrated,
- providing micro-predictive models using AI/ML algorithms for different scenarios specifications.

Functional requirements on SILVANUS Platform which **could be** included in Phase C:

- gathering information on forest landscape using crowd sourcing applications,
- including e.g., AR/VR representation of forest landscape for computing impact of climate change on forest ecosystem services (climate and water cycle regulation),

- providing representation of forest landscape for computing impact different (single or combined) forest managements on ecosystem services (climate and water regulation) under alternative climate scenarios,
- producing content to engage with citizens on forest fire impact,
- gathering feedback from citizens on the usefulness of the mobile application,
- allowing people to notify forest management services on human negligence,
- providing IoT data aggregation from distributed deployment of environmental sensors, CCTV, chemical composition sensors,
- providing data collection for the fire behaviour (spread) modelling,
- collecting citizen observations from social media,
- UGV could be equipped with LIDAR, visual sensors (cameras), and environmental sensors,
- integration of deep learning for the detection of wildfire (using visual concepts such as smoke, fire, etc) could be considered,
- 5V data characteristics could be supported,
- allowing to develop evacuation plans,
- supporting coordination of responders,
- providing GIS/GPS visualisation of on-field situation.

Training requirements: The majority of the training requirements depend on what the platform can/will support. In my opinion training requirements should be based on the following pillars:

- platform modules and services related to first responders (e.g., firefighters) who will use the platform mostly on operational and strategic level.
- platform modules and services related to first responders (e.g., firefighters) who will use the platform mostly on tactical level.
- platform modules and services for civil protection officers.
- citizen engagement.

The requirements should concentrate on the use of simple pdf files as handbooks and on more sophisticated tools such as AR and VR tools.

- Training for the DSS (use of system and evaluation of the results).
- Training for the technologies used and embedded in the platform, e.g. the UGVs or the UAVs.
- Training for the phase C activities which the majority does not cover technologies.
- Training for self-protection measures, especially for the citizens training for risk perception/awareness and risk communication.

4.5 PORTUGAL

Portugal Pilot is involved in demonstration of operational scenarios in Phase A (Preparedness and Preventions) and Phase C (Restoration and Adaptation).

4.5.1 Pilot Summary

The pilot is in Cova da Beira in Portugal, in a farm called Quinta da França. It is dedicated to Phases A and C. Cova da Beira region demo will provide the conditions to demonstrate SILVANUS Phases A and C ambition focus on applied to two essential resources: water and energy, by forest fire prevention and recuperation through the use of integrating ancient agricultural practices with digital technologies focused on remote detection, including satellite imagery and fully-autonomous devices helping to implement all the processes to assure that safety boundaries between Nature and Human critical infrastructure are respected. Some of these fully autonomous devices are drones and robots with recharging bases.

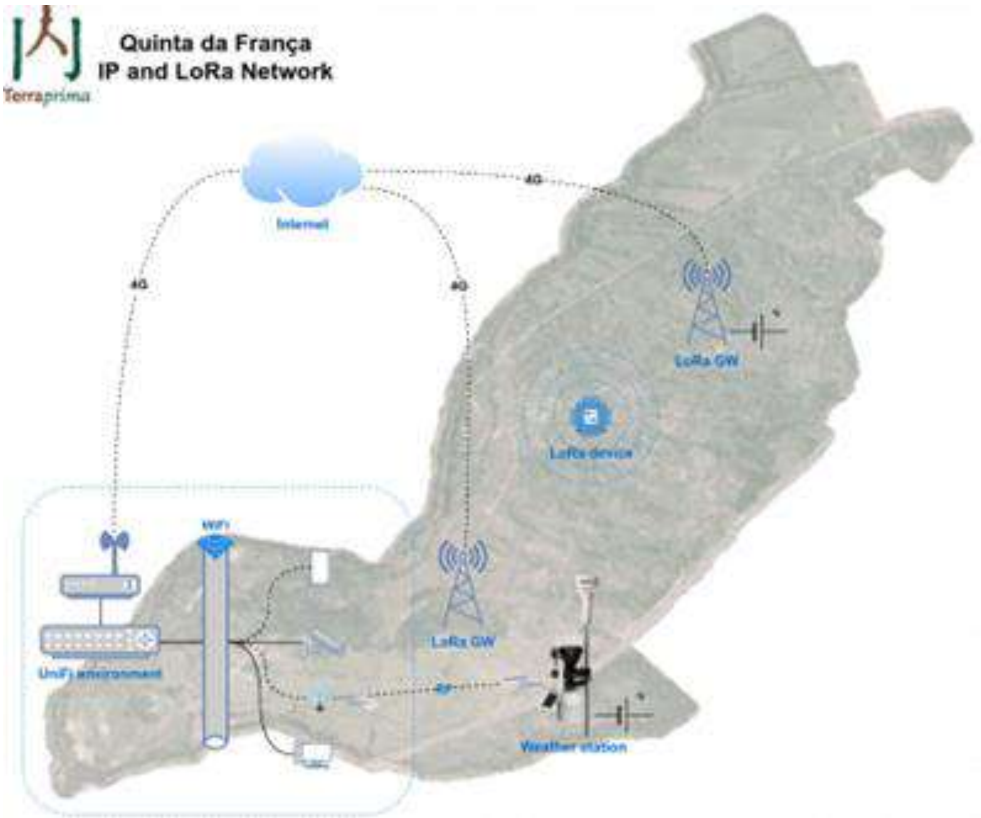

Figure 17 Portugal Pilot schema with a basic overview of Technological Components

Cova da Beira is the region located in Interior-Este part of Portugal. It borders on the North with the subregions of Serra da Estrela and Beira Interior Norte, on the East with Beira Interior Sul, on the South with Beira Interior Sul along with Pinhal Interior Sul and on the West with Pinhal Interior Norte. It comprises 4 counties: Belmonte; Covilhã, Fundão and some parishes of Castelo Branco. It is much known for its top-quality agriculture products. Besides some industry, the region has strong agriculture and forestry activities. Cova da Beira combines a strong implantation of the industry in an area with a strong rural influence, resulting in a rural region of high population density. The asymmetry in land distribution is revealed by the presence of large side-by-side properties with a generalized small holding. The landscape is very diverse, due to the hydrographic network that influences land uses and their distribution. Today most of the agricultural area is occupied with intensive agriculture and fruit farming (apple, peach, cherry). The landscape is strongly compartmentalized, marked by the agricultural land uses and the granitic outcrops with oak woodland patches. This is a region of abundant water resources, characterized by a great interannual irregularity. The watering perimeter of Cova da Beira was implemented to respond to this variability, covering an area of about 14 440 ha. The main water sources are the Sabugal and Meimoa dams. The irrigation blocks of Covilhã, Fundão, Fatela and Capinha, have an equipped surface of 5 695 ha.

4.5.2 Pilot Status Characteristics

In this section the existing data, systems, services, and technology used in the Pilot Site are described.

In the Pilot Site two types of drones are available:

- **Hexacopter frame 680**:
- Multi-rotor with 6 brushless motors and a Pixhawk APM.
- Lion 4S batteries, 6600mAp or 10000mAp, at 14.8v.
- Payload - 2 cameras: VIS and NIR.
- Usage: Monitoring - RGB and VIS orthophoto map mosaic aerial imagery (resolution 4 cm pixel) - Land cover maps (resolution - 20 cm per pixel).
- Degree of autonomy: Level 2 – Partial Automation; Human Dependency: Basic Pilot.

Communication frame and data exchange:

- From: dropdown: C&C Room To: dropdown: C&C Room
- **DJI-M600 PRO:**
- Sensors: RGB: DJI-Z30; DJI-X5S
- IR: DJI-XT2
- LIDAR: VELODYNE-VLP16; STIM-300)
- Usage: Monitoring - RGB and LIDAR areal data collection. Classified 3D point cloud of ground cover.
- Degree of autonomy: Level 2 – Partial Automation; Human Dependency: Basic Pilot.

Communication frame and data exchange:

- From: dropdown: drone (UAV) To: dropdown: Other
- API: licenced
- Frequency: 2.400 GHz to 2.483 GHz
- Range: 2 km
- Legislative conditions: CE Compliant: 2.2 mi (3.5 km)
- Comment: Communication is done between Drone and Pilot Command.
- Drone Control: Communication is ensured by the UAV manufacturer.
- RGB and IR sensor: For controlling communication is ensured by the UAV manufacturer. Data is stored on the equipment.
- LIDAR: No control is needed. Data is stored on the equipment.

For fire prevention purposes remote sensing technology and data are used. Satellite (Sentinel) data and UAV (LIDAR) data are available and used.

Communication endpoints in the Portuguese settings:

- Forester (animal collars used to locate GPS animal position).
- Field Sensors (Wireless Vantage Pro2 Plus weather station. Sensors: Temperature, Relative Humidity, Rain, Pression, Solar Radiation, UV Radiation, Wind speed, Wind Direction).
- Drone (UAV) (Drone with RGB/NIR cameras).
- Video surveillance system (Multiple Ubiquiti cameras).

Data communicated between the individual endpoints:

Table 6 Data communicated between the individual endpoints in Portugal Pilot

From	To	Type of Data	Protocol	Purpose	Frequency
Field sensors	Cloud Service	JSON data	3G/4G	Get weather data	15 min.
Forester	Cloud Service	JSON data	3G/4G	Get animal position	15 min.
Drone (UAV)	Other	Image	3G/4G	N/A	N/A
Other	Cloud Service	Video	3G/4G	Video surveillance	live

3rd party cloud storage system is used: Hybrid cloud: Android, Azzure, Google, Amazon, and OneDrive (applicable in A/C Phase).

There are no Fire Alerting/Fire Detection Systems in place. They would like to develop one within SILVANUS.

Social Media are not used by stakeholders in the Pilot Site for fire prevention purposes.

No Decision Support Systems are used/specified.

For the Pilot Site, the **following data are available**:

- Classified 3D Point Cloud of Overhead Power Lines Corridors,
- HD Classified Land Cover of Quinta da França,
- Classified Land Cover of Quinta da França,
- Drone survey Images of Quinta da França,
- Animal track devices,
- Quinta da França Weather Station (historical data since Dec. 2021),
- Normalized difference vegetation index (NVDI) for Quinta da França Time-series, from Sentinel-2
- Water Infrastructures Locations and Protection Perimeters,
- Classified 3D Point Cloud of Overhead Power Lines Corridors - EDP Labelec.

4.5.3 Stakeholders involved

In the participatory processes as well as demonstration of Pilot Study the following stakeholders are involved:

- Energy and construction industry.
- Infrastructure traffic and road network.
- Research organisations (universities).
- Forest owners and landowners.

The stakeholders that were involved in interviews: edp, AdP, Terraprima and IST-ID.

4.5.4 High-level Operational Scenario

The Operational Scenario in Portugal is focusing power line disruptions resulting in accidental fires.

There are introduced the Use Cases of Operational Scenario for Portuguese Pilot – Phase A.

1) Dynamically evaluate fire risk at regional and plot level

Being plot level the surroundings of critical assets (water treatment plants, electrical lines, electrical transformers)

- **High resolution land cover mapping for wildfire risk assessment at the landscape scale**
- Development of high-resolution maps of fractional land cover for the region and/or selected landscapes.
- Use the high-resolution land cover map developed for the farm where the Portuguese demo is being developed, Quinta da França (200 ha, 20 cm-pixel), to label pixels in the Sentinel grid (10 m – pixel) and train a machine learning model.
- Test indicator value of Sentinel bands and vegetation indexes (and time-series data)
- For model evaluation drone images from Quinta da França in different dates/years and from other areas in Beira Interior can be used.
- Product – High resolution maps of fractional land cover produced from Sentinel imagery.
- **Team:** IST-ID, EDP, TP

2) Remotely sensed vegetation monitoring in critical infrastructures for cost-effective planning of management interventions [two complementary studies]

  - o *<u>Development of monitoring protocols and models to monitor biomass growth using in-situ, (UAV, Lidar) and satellite data</u>*

- Test and develop protocols to monitor the growth of different types of vegetation cover in critical infrastructures.
- Use Quinta da França as a test site, selecting monitoring plots that are representative of the vegetation types and land cover configuration in critical infrastructures (e.g., shrubland, grassland, riparian strips, safety corridors)
- Test new approaches to vegetation monitoring using IoT (cameras, sensors, etc.) – and supported by field measurements – and develop cost-effective monitoring schemes supported by models.
- **Team:** TP, EDP, AdP, IST-ID.

  - o *<u>Development of models, trained with long time-series, to guide the planning of biomass control interventions in critical infrastructures and for early-warning of increased wildfire risk</u>*

- Use long-time- series of satellite data covering critical infrastructures, calibrate an early-warning model [use past-interventions to train the model to identify and signal the need for intervention].
- Apply the models developed in the previous Use Case to areas of critical infrastructures of AdP and EDP [using satellite data].
- Evaluate the models against in-situ data [monitor vegetation in critical infrastructures].
- **Team:** TP, EDP, AdP, IST-ID.

3) Evaluation of preventive measures for the regulation of biomass growth and wildfire prevention

- Comparative assessment of livestock grazing and mechanized shrub control for biomass regulation.
- Biomass growth, vegetation structure and plant composition will be monitored in areas under livestock grazing and in areas after mechanized shrub control.
- Study area: Quinta da França, oak forest. Grazing in south sector since 2018, reference data from 2021 (year 0 of the study, prior to shrub cutting), mechanical control in 2022 (2023?), monitoring in 2023 (2024?) and 2025. **Team:** IST-ID, TP.

4) EU and PT review on regulation on fire prevention, preparedness, detection and response and Restoration and adaptation activities

- Review of the main regulation concerning fires at EU and local level. To be developed by the partners with legal expertise

4.5.5 4.5.5. Priorities of the Pilot

The priorities of the Portugal Pilot in Phase A are:

- Development of high-resolution maps of land cover.
- Regular/continuous monitoring of vegetation growth around critical infrastructures for cost-effective planning of management interventions.
- Evaluation of livestock grazing as preventive measure for the regulation of biomass growth and wildfire prevention at the landscape and local scales.
- Infrastructures Risk Assessment due to wildfire events.
- EU and PT review on regulation on fire prevention, preparedness, detection and response and restoration and adaptation activities.

4.5.6 Functional requirements on SILVANUS Platform

Functional requirements on SILVANUS Platform which **must be** included in Phase A:

- visualisation of landscape biodiversity,
- identifying areas/regions of historical significance,
- visualisation and providing information forest structural diversity,
- providing fire danger index metrics,
- providing fuel management alternatives for different forest types,
- visualisation of climate statistics (for historical and future periods; precipitation, temperature, relative humidity etc.),
- providing information on soil types and structure,
- aggregating Copernicus and EO data prior and post fire ignitions,
- SILVANUS mobile application must notify people about the fire occurrence in their vicinity,
- providing IoT data aggregation from distributed deployment of environmental sensors, CCTV, chemical composition sensors,
- providing Edge based micro-data centres for processing data collected from the field,
- supporting continuous monitoring of forest restoration programmes,
- providing AI/ML algorithms to detect fire danger,
- using unmanned and automated ground vehicles (UGV) for monitoring wildfire behaviour,
- UGV must be equipped with LIDAR, visual sensors (cameras), and environmental sensors,
- autonomously piloted UAVs must be deployed for remote sensing,
- collision avoidance among drones must be implemented,
- heterogenous data from multi-modal data sources must be integrated,
- data filtering and cleaning process must be provided,
- AI algorithms must be provided to identify high-risky forest regions according to fire initiation potential,
- providing visualisation of forest landscape models,
- providing micro-predictive models using AI/ML algorithms for different scenarios specifications.

Functional requirements on SILVANUS Platform which **should be** included in Phase A:

- providing information on fuel availability in specific regions of forest,
- simulation of spatio-temporal trends of forest changes,
- providing representation of forest landscape for computing impact different (single or combined) forest managements on ecosystem services (climate and water regulation) under alternative climate scenarios,
- providing AR/VR simulation of combating forest fire,
- producing content to engage with citizens on forest fire impact,
- notifying people in the vicinity of forests, on human negligence,
- gathering feedback from citizens on the usefulness of the mobile application,

- SILVANUS mobile application should create user interface for reporting a suspect fire by geo-location, photos, and description,
- supporting the analysis of the impact of forest fires on the hydrology and soil physical properties (using inputs from chemical analysis where applicable),
- algorithms to control drone swarms based on e.g., leader-follower configuration should be applied,
- drones should be equipped with multi-spectral sensing devices,
- some UAVs should be stationed in particularly critical areas and automatically scan the area if critical conditions arise (e.g., sudden increase in FDI),
- training models for AI/ML algorithms should be provided,
- decision support systems for fire detection, fire spread, weather effect on fire intensity should be used,
- cause-and-effect models for the fire ignition should be used,
- providing damage assessment,
- providing GIS/GPS visualisation of on-field situation.

Functional requirements on SILVANUS Platform which **could be** included in Phase A:

- including, e.g., AR/VR representation of forest landscape for computing impact of climate change on forest ecosystem services (climate and water cycle regulation),
- quantifying the damage of forest fire and map into ecological assessment (loss of XX cubic tons of oxygen, etc.),
- providing simulation of fire ignition scenarios,
- including mobile application which allow people to notify fire to the Fire and Rescue Service,
- SILVANUS mobile application could allow fire management services to contact people in fire vicinity for help by voice call,
- providing micro-weather forecasting models (time scale up to 72 hours),
- providing pilot region specific customisation of AI/ML algorithms for estimating forest fire danger,
- providing prediction models based on seasonal forecasts,
- providing evaluation of forecast models based on observed data,
- providing data collection for the fire behaviour (spread) modelling,
- collecting citizen observations from social media.

Functional requirements on SILVANUS Platform which **must be** included in Phase C:

- visualisation of landscape biodiversity,
- providing fire danger index metrics,
- providing information on fuel availability in specific regions of forest,
- providing assessment models of forest resilience (e.g., regeneration dynamics),
- SILVANUS mobile application must notify people about the fire occurrence in their vicinity,
- supporting the analysis of the impact of forest fires on the hydrology and soil physical properties (using inputs from chemical analysis where applicable),
- supporting continuous monitoring of forest restoration programmes,
- heterogenous data from multi-modal data sources must be integrated,
- data filtering and cleaning process must be provided,
- AI algorithms must be provided to identify high-risky forest regions according to fire initiation potential,
- providing visualisation of forest landscape models,
- providing micro-predictive models using AI/ML algorithms for different scenarios specifications.

Functional requirements on SILVANUS Platform which **should be** included in Phase C:

- visualisation and provide information on forest structural diversity,
- visualisation of climate statistics (for historical and future periods; precipitation, temperature, relative humidity etc.),
- providing information on soil types and structure,
- providing representation of forest landscape for computing impact different (single or combined) forest managements on ecosystem services (climate and water regulation) under alternative climate scenarios,
- producing content to engage with citizens on forest fire impact,
- notifying people in the vicinity of forests, on human negligence,
- gathering feedback from citizens on the usefulness of the mobile application,
- SILVANUS mobile application should create user interface for reporting a suspect fire by geo-location, photos, and description,
- providing Edge based micro-data centres for processing data collected from the field,
- collision avoidance among drones should be implemented,
- drones should be equipped with multi-spectral sensing devices,
- training models for AI/ML algorithms should be provided,
- decision support systems for fire detection, fire spread, weather effect on fire intensity should be used
- cause-and-effect models for the fire ignition should be used,
- providing damage assessment,
- providing GIS/GPS visualisation of on-field situation,
- providing visualisation of forest restoration (forest management) alternatives for stakeholder to support forest resilience,
- supporting the systematic planning of restoration activities,
- facilitating the selection and configuration of governance models for forest restoration, using criteria such accountability, effectiveness, efficiency, fairness, participation and transparency.

Functional requirements on SILVANUS Platform which **could be** included in Phase C:

- including, e.g., AR/VR representation of forest landscape for computing impact of climate change on forest ecosystem services (climate and water cycle regulation),
- quantifying the damage of forest fire and map into ecological assessment (loss of XX cubic tons of oxygen, etc.),
- including mobile application which allow people to notify fire to the Fire and Rescue Service,
- SILVANUS mobile application could allow fire management services to contact people in fire vicinity for help by voice call,
- providing micro-weather forecasting models (time scale up to 72 hours),
- providing pilot region specific customisation of AI/ML algorithms for estimating forest fire danger,
- providing prediction models based on seasonal forecasts,
- providing evaluation of forecast models based on observed data,
- providing IoT data aggregation from distributed deployment of environmental sensors, CCTV, chemical composition sensors,
- collecting citizen observations from social media,
- providing extraction of geoinformation, i.e., mentioned locations, from social media data sources,
- use unmanned and automated ground vehicles (UGV) for monitoring wildfire behaviour,
- UGV could d be equipped with LIDAR, visual sensors (cameras), and environmental sensors,
- autonomously piloted UAVs could be deployed for remote sensing,
- algorithms to control drone swarms based on e.g., leader-follower configuration could be applied.

4.6 CZECH REPUBLIC

Czech Republic is involved in demonstration of operational scenario in Phase B (Detection and Response).

4.6.1 Pilot Summary

The pilot area is set in the north-east part of the Czech Republic and east part of Moravian-Silesian Region, at the territory of Moravian-Silesian Beskyds Mountains. Beskydy mountains are the northern territory of Protected Landscape Area Beskydy (PLAB). East border of the PLAB is located at national border with Slovak Republic. The territory of PLAB belongs to the most visited tourist resorts in the Czech Republic. The overall area of the Protected Landscape Area Beskydy is 1.160 km2, with the highest mountain, Lysá Hora, with an altitude of 1.323 m. The lowest areas of PLAB have got an altitude of approximately 400 m. The pilot area will be placed at the territory of the Krásná municipality.

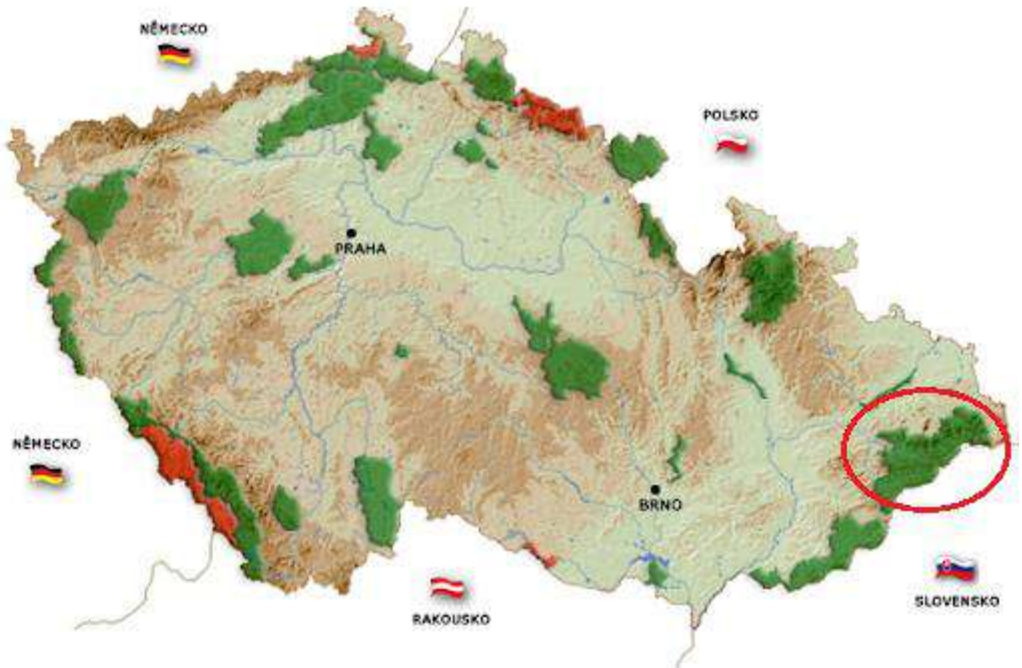

Figure 18 Situation of Czech Pilot Site

Territory of PLAB is frequently affected by wildfires and other nature related emergencies (strong winds, floods, flash floods, landslides). Historical report on wildfires contains overall 146 nature fires in Moravian-Silesian Beskydy Mountain from 2010. These fires caused the direct losses of approximately 200K € and affected territory for about 326 hectares.

There will be a lon high temperature period adjoined by no precipitations in MSBM, which highly increases the risk of wildfires. These unfavourable conditions have caused a wildfire, which occurs at the mountain territory of the Krásná municipality. Because of windy conditions the wildfire extends rapidly in the surrouning forest landscape.

The extending wildfire will be spotted by several persons situated at the territory of Krásná municipality. Wildfires will be announced at public safety answering point (emergency lines 112 and 150) operated by Fire Rescue Brigade of Moravian-Silesian Region (FRB MSR). Advanced Mobile Location technology will be used to localize the place of emergency calls at the Control Room of FRB MSR. Control Room will handle emergency calls and deploy firefighting units to treat the emergency.

4.6.2 Pilot Status Characteristics

In this section the existing data, systems, services, and technology used in the Pilot Site are described.

In the Pilot Site one drone (UAV) - **multirotor4**, provided by the Fire Rescue Brigade of Moravian-Silesian Region (FRB MSR), is used for monitoring (via camera and infra red camera) purposes.

Drone degree of autonomy: Level 0 – No Automation; Human Dependency: Trained & Skilled Pilot.

Drone is equipped with basic meteorological sensors – temperature, wind velocity, altitude (plus GPS coordinates).

Communication frame and data exchange:

- From: Mobile C&C Room,
- To: dropdown: Mobile C&C Room,
- Communication protocol: HDMI cable.
- Comment: Video from UAV can be shared via cable to mobile C&C Room.

Communication endpoints in Czech settings:

- Command & Control Room.
- Mobile C&C Room.
- Municipality.
- Fireman.

Communication protocols used:

- 3G/4G,
- 5G,
- Radio (PTT),
- Cable Fixed,
- TETRAPOL

*Note: the voice communication only, statuses/codes can be used between infield terminals (portable and car terminals) and Command and Control Room radio-terminal, GIS application data transfer between mobile devices.

Data communicated between the individual endpoints:

- From: C&C Room To: Mobile C&C Room

Type of Data: various data sources, including GIS application.

Protocol: 3G/4G.

Purpose: operational management.

Frequency: continuous.

- From: C&C Room To: Fireman

Type of Data: voice communication, codes.

Protocol: other.

Purpose: operational management.

Frequency: continuous.

- From: Fireman To: Volunteer Firefighters

Type of Data: voice communication.

Protocol: Other.

Purpose: operational management.

Frequency: continuous.

- From: C&C Room
- To: Fire Truck

Type of Data: voice communication.

Protocol: 3G/4G.

Purpose: operational management.

Frequency: continuous.

*Note: Wildfire emergencies are very varied and there are many options of communication frameworks and communication flows. All this depends on how many first responders, emergency services and stakeholders are involved in emergency. Prevailing communication tool is voice communication through radios or mobile phones. Officer in charge of the emergency can deploy its own communication structures to manage the wildfire.

Fire Alerting/Fire Detection Systems in the Pilot Site are not deployed.

3rd party cloud storage is not used.

No Cloud Platform is used for storing data.

No social media is used.

No DSS is used in Pilot Sire, only GIS application.

Data available for the Pilot Site:

- GIS layers:
- Vector (Base map, vector layers in SHP or FGDB formats).
- Raster (Orthophoto maps).

GIS application can be used at C&C Room and Mobile C&C Room.

Producer/provider of the data: GIS layers can be - self-created or provided by the 3rd party.

4.6.3 Stakeholders involved

In the interviews, the stakeholders from the Fire Rescue Brigade of Moravian-Silesian Region (FRB MSR) - emergency response organization, organizational state body, were involved.

4.6.4 High-level Operational Scenario

Scenario description: There will be a long high temperature period adjoined by no precipitation in MSBM, which highly increases the risk of wildfires. These unfavourable conditions have caused a wildfire, which occurs at the mountain territory of the Krásná municipality. Because of windy conditions the wildfire extends rapidly in neighbouring forest landscape. Crowdsourcing application will be used by some persons to announce the wildfire at the Control Room of FRB MSR.

Use Cases considered in the Operational Scenario (Phase B):

- **Crowdsourcing application**

The extending wildfire will be spotted by several persons situated at the territory of Krásná municipality. Wildfires will be announced at public safety answering point (emergency lines 112 and 115) operated by Fire Rescue Brigade of Moravian-Silesian Region (FRB MSR). Advanced Mobile Location technology will be used to localize the place of emergency calls at the Control Room of FRB MSR. Control Room will handle emergency calls and deploy firefighting units to treat the emergency. Crowdsourcing application will be used by some persons to announce the wildfire at the Control Room of FRB MSR.

- **Navigation to fire site**

Deployed professional and volunteer firefighting unit will be navigated at the scene of emergency by navigation technology facilitated on fire appliances. The navigation technology will be utilized by Control Room for monitoring of deployment of assigned firefighting units.

- **Decision support for emergency management**

The officer in charge at the scene of wildfire will manage all activities related to treating of wildfire, will be responsible for continuous assessment, real-time monitoring and evaluation, deployment of firefighting units, equipment, and appliances and for cooperation with the emergency services, municipality, and all stakeholders. Decision support system will be utilized for wildfire emergency management.

- **Mapping firefighters' position in the field**

Application for positioning of deployed firefighters will be used to manage the wildfire.

- **UAV technology deployment**

UAV appliance will be used for aerial monitoring and assessment of real-time situation. UAV appliance will be facilitated by the camera and the infra-red thermal camera for detection of fire affected areas. The video signal from UAV will be transmitted to the emergency service command post.

- **UGV technology deployment**

UGV appliance will be used for ground monitoring and assessment. This appliance will be used for transport and firefighting purposes too. The video signal from UAV will be transmitted to the emergency service command post.

- **Lessons learned**

The lesson learned session after the wildfire will be held, good and bad practise will be shared through all stakeholders, deployed technologies will be evaluated.

4.6.5 Priorities of the Pilot

Key parameters that should be considered in the SILVANUS platform (Phase B):

- **Overall benefits for first responders**

SILVANUS Platform key functionalities, operational availability, customization, accuracy of modelling, visualization, accessibility, robustness, resource requirements, visualization platforms, real-time awareness, prediction, data accuracy, etc.

4.6.6 Functional requirements on SILVANUS Platform

Functional requirements on SILVANUS Platform which **must be** included in Phase B:

- providing representation of forest landscape for computing impact different (single or combined) forest managements on ecosystem services (climate and water regulation) under alternative climate scenarios,
- gathering information on fire ignition sources, such as human negligence, arson, environment conditions, climate and weather conditions (climate change impact including), impact of power grid lines,
- providing AI/ML algorithms trained on historical data sources resulting in forest fire,

- providing simulation of fire ignition scenarios,
- implementing notification protocol for response (first responders) deployment,
- notifying people in the vicinity of forests, on human negligence,
- SILVANUS mobile application must notify people about the fire occurrence in their vicinity,
- SILVANUS mobile application must create user interface for reporting a suspect fire by geo-location, photos, and description,
- providing micro-weather forecasting models (time scale up to 72 hours),
- providing prediction models based on seasonal forecasts,
- providing evaluation of forecast models based on observed data,
- providing data collection for the fire behaviour (spread) modelling,
- UGV must be equipped with LIDAR, visual sensors (cameras), and environmental sensors,
- integration of deep learning for the detection of wildfire (using visual concepts such as smoke, fire, etc) must be considered,
- collision avoidance among drones must be implemented,
- data filtering and cleaning process must be provided,
- weather forecasts must be developed,
- AI algorithms must be provided to identify high-risky forest regions according to fire initiation potential,
- training models for AI/ML algorithms must be provided,
- decision support systems for fire detection, fire spread, weather effect on fire intensity must be used,
- providing visualisation of forest landscape models,
- providing micro-predictive models using AI/ML algorithms for different scenarios specifications,
- providing damage assessment,
- supporting resources deployment,
- allowing to develop evacuation plans,
- supporting coordination of responders,
- providing GIS/GPS visualisation of on-field situation.

Functional requirements on SILVANUS Platform which **should be** included in Phase B:

- visualisation of landscape biodiversity,
- visualisation and providing information forest structural diversity,
- providing fire danger index metrics,
- providing information on fuel availability in specific regions of forest,
- simulation of spatio-temporal trends of forest changes,
- visualisation of climate statistics (for historical and future periods; precipitation, temperature, relative humidity etc.),
- providing information on soil types and structure,
- including e.g., AR/VR representation of forest landscape for computing impact of climate change on forest ecosystem services (climate and water cycle regulation),
- aggregating Copernicus and EO data prior and post fire ignitions,
- providing assessment models of forest resilience (e.g., regeneration dynamics),
- providing modelling of human behaviour (and negligence) resulting in forest fire ignition,
- providing probabilistic prediction models for estimating forest fire ignition,
- providing AR/VR simulation of combating forest fire,
- allowing weather/environmental data to be processed in the emulating the forest fire behaviour,
- producing content to engage with citizens on forest fire impact,

- including mobile application which allow people to notify fire to the Fire and Rescue Service,
- SILVANUS mobile application should allow fire management services to contact people in fire vicinity for help by voice call,
- providing pilot region specific customisation of AI/ML algorithms for estimating forest fire danger,
- providing IoT data aggregation from distributed deployment of environmental sensors, CCTV, chemical composition sensors,
- providing Edge based micro-data centres for processing data collected from the field,
- providing AI/ML algorithms to detect fire danger,
- providing AI/ML algorithms to detect fire/smoke,
- using unmanned and automated ground vehicles (UGV) for monitoring wildfire behaviour,
- autonomously piloted UAVs should be deployed for remote sensing,
- drones should be equipped with multi-spectral sensing devices,
- Some UAVs should be stationed in particularly critical areas and automatically scan the area if critical conditions arise (e.g., sudden increase in FDI),
- heterogenous data from multi-modal data sources should be integrated,
- considering wearable devices and other medical devices for response coordination.

Functional requirements on SILVANUS Platform which **could be** included in Phase B:

- identification of areas/regions of historical significance,
- providing fuel management alternatives for different forest types,
- gathering information on forest landscape using crowd sourcing applications,
- quantifying the damage of forest fire and map into ecological assessment (loss of XX cubic tons of oxygen, etc.),
- feedback from citizens on the usefulness of the mobile application,
- SILVANUS mobile application could allow people to notify forest management services on human negligence,
- allowing forest management services to contact people in fire vicinity for help by chat,
- supporting the analysis of the impact of forest fires on the hydrology and soil physical properties (using inputs from chemical analysis where applicable),
- supporting continuous monitoring of forest restoration programmes,
- collecting citizen observations from social media,
- providing extraction of visual concepts, such as fire or smoke, from social media data sources,
- providing extraction of geoinformation, i.e., mentioned locations, from social media data sources,
- algorithms to control drone swarms based on e.g., leader-follower configuration could be applied,
- distributed storage and repository for heterogenous data sources could be provided,
- 5V data characteristics could be supported,
- cause-and-effect models for the fire ignition could be used,
- simulation of fire ignition and fire spread based on Monte Carlo like models,
- providing health impact analysis for fire fighters to model long- and short-term exposure to forest fire,
- providing visualisation of forest restoration (forest management) alternatives for stakeholder to support forest resilience,
- supporting the systematic planning of restoration activities,
- facilitating the selection and configuration of governance models for forest restoration, using criteria such accountability, effectiveness, efficiency, fairness, participation, and transparency.

Training requirements

Training could contain the educational and in-field activities. The training scenarios should reflect real emergencies. It would be convenient to involve more stakeholders to training activities. Lesson learned activities should be involved.

4.7 CROATIA

Croatia Pilot is involved in demonstration of operational scenarios in Phase A (Preparedness and Prevention) and Phase B (Detection and Response).

4.7.1 Pilot Summary

The Pilot Site is situated in Liburnija, Primorsko-goranska county. The estimated total area is 30,800 ha, of which about 50% is overgrown forest land and forests, forests themselves occupy 12,410 ha (40%). Part of the uncultivated areas, earlier pastures, and meadows due to non-use are overgrown with autochthonous vegetation of honeysuckle, black hornbeam, and black pine. Forests and forest land are mostly managed by the Public Company Croatian Forests, and about 30 percent of the area belongs to private forests of forest owners. Forests stretch from the sea to 1400-meter above sea. A significant part of the area is occupied by the public institution Učka Nature Park, which manages the Park on a total of 160 km2 (part in Liburnija, and part of the Istria County). In the area of Liburnija, approximately 10,176 ha of land is used as agricultural land, entirely in the form of gardens or in the immediate vicinity of residential areas, and some pastures are in the edge zone.

In the Operational Scenario, a wildfire occurring in spring is considered. There will be a longer period without precipitations (January, February, March), before plants start to green. The fine fuel moisture content will reach the critical moisture content values with very high risk of wildfire.

The fire will start in a rural inaccessible area and under influence of wind and spread towards training facilities on pilot site Šapjane, where critical infrastructure will be endangered, also endangered local inhabitants and workers at Šapjane facilities.

The fire initiator will be human activity (negligence during prescribed burning) – the fire will start in a rural inaccessible area and under influence of wind and spread towards training facilities.

4.7.2 Pilot Status Characteristics

In this section the existing data, systems, services, and technology used in the Pilot Site are described.

In the Pilot Site, there are several UGV, and UAV types deployed:

- **UGV** – Tracked firefighting robot **Rhyno** (two robots).
- Equipped with water cannon, cameras, possibly other equipment (meteo station, ...).
- Usage: monitoring, active firefighting. Robot could be used for assessment for the incident commander, or for the firefighters using the cameras that are on the robot. It could be used to transport equipment up to 200 kg or it could be used for firefighting by using the nozzle with water flow up to 1000 l/min.
- Degree of autonomy: Level 0 – No Automation; Human Dependency: Trained & Skilled Pilot. The robot will be used by firefighters for their support. In normal version the robot can operate by the pilot up to 500 m from the pilot.

Communication frame and data exchange:

- From: dropdown: Ground Robot (UGV)
- To: dropdown: Fireman
- API: free
- Frequency: 433 & 870 MHz
- Datatype: video, telemetry, data
- Range: 500 m

- **UAV - DJI Phantom 4 PRO**
    - 4K camera 1 inch sensor: 20MP

- Operating frequencies: 2,4 GHZ / 5,8Ghz
- Max range control: 6km
- Flight time: up to 30 min / per battery – 3 available
- Weight: (battery & propellers included) 1,388 g
- Max wind resistance speed: 10m/s
- Usage: monitoring. Able to live stream to YouTube, Facebook. Monitoring live view quality 720P @ 30fps, mapping.
- Degree of autonomy: Level 0 – No Automation; Human Dependency: Trained & Skilled Pilot; Level 1 – Controller Assisted; Human Dependency: Trained Pilot; Level 2 – Partial Automation; Human Dependency: Basic Pilot; Level 3 – Conditional Automation; Human Dependency: Operator Monitoring Onsite.

Communication frame and data exchange:

- From: dropdown: C&C Room
- To: dropdown: C&C Room

*Note: Phase A: Live stream max 720P @ 30fps – 4G teleoperator connection required, file made after end of transmit, MPEG 4 format, no public share due to law restrictions without prior inspection from authority, internal use approved.

Phase B: Live stream max 720P @ 30fps – 4G teleoperator connection required, file made after end of transmit, MPEG 4 format, public share and afterwards within 8 days submission to the authority for footage inspection due to law.

- **UAV – DJI Phantom 4 PRO Obsidian edition**
  - 4K camera 1 inch sensor 20MP
  - 5-Direction obstacle sensing and 4 direction obstacle avoidance
  - Operating frequencies 2,4 GHZ / 5,8Ghz
  - Max range control 7km
  - Flight time up to 30 min / per battery – 5 available
  - Weight (battery & propellers included) 1388g
  - Max wind resistance speed 10m/s
  - Micro HDMI output option
  - Usage: monitoring. Able to live stream to YouTube, Facebook. Monitoring live view quality 720P @ 30fps, mapping.
  - Degree of autonomy: Level 0 – No Automation; Human Dependency: Trained & Skilled Pilot; Level 1 – Controller Assisted; Human Dependency: Trained Pilot; Level 2 – Partial Automation; Human Dependency: Basic Pilot; Level 3 – Conditional Automation; Human Dependency: Operator Monitoring Onsite.

Communication frame and data exchange:

- From: dropdown: C&C Room
- To: dropdown: C&C Room

- From: dropdown: Field Sensors
- To: dropdown: C&C Room
- API: not available
- Frequency: 2,4 GHz
- Datatype: video
- Range: 2km
- Legislative conditions: NO

* Note: Phase A: Live stream max 720P @ 30fps – 4G teleoperator connection required, file made after end of transmit, MPEG 4 format, no public share due to law restrictions without prior inspection from authority, internal use approved.

- **Software Defined Radio** - video format, type of transfer - bi-directional, transmission rate 3-5Mbps, transmitting power: 100mW.

Phase B: Live stream max 720P @ 30fps – 4G teleoperator connection required, file made after end of transmit, MPEG 4 format, public share and afterwards within 8 days submission to the authority for footage inspection due to law.

SDR - video format, type of transfer - bi-directional, transmission rate 3-5Mbps, transmitting power: 100mW.

Remote Sensing Technology and data currently used:

- Satellite data (GIS cloud, GINA)
- Aerial data and technology (Ministry of Defence)
- UAV
- Mesh in the sky
- UGV
- Camera devices: name not available, resolution Full HD (1920×1080).

There is deployed a Fire Alerting/Fire Detection System called "Firefighting alarm", produced by Rinelsd.o.

The system was created as a web application that HVZ provides free of charge for all firefighting organizations in the Republic of Croatia. The application is intended to alert firefighters to firefighting interventions via voice calls and/or SMS messages. The alarm centre and the competent fire commanders receive feedback on.

Among the capabilities of this system belongs:

- No cost for fire-fighting organizations (maintenance, 40 SIP trunk lines and telephone turnover totally covered by HVZ for whole Croatia).
- Ease of use – only a computer and internet connection are enough to use the system, and it is also possible to start by alarming directly by mobile telephone.
- The ability to choose whether the alert goes by voice message, text message or both.
- Voice and SMS messages can be predefined or arbitrary.
- The alarm centre has immediate feedback on the response of firefighters and the number of responded drivers.
- Higher fire commanders have immediate information about the alerts initiated.
- Ability to analyse activated alerts at al authorized levels.
- Integration with the Firefighting Management system (FMC-UVI), which speeds up the start of alarms by the command centres.
- Integration with the database of HVZ (VATROnet), which allows fire-fighting units to create alert groups independently and arbitrarily.

In Figure 19, there is introduced the architecture of this system.

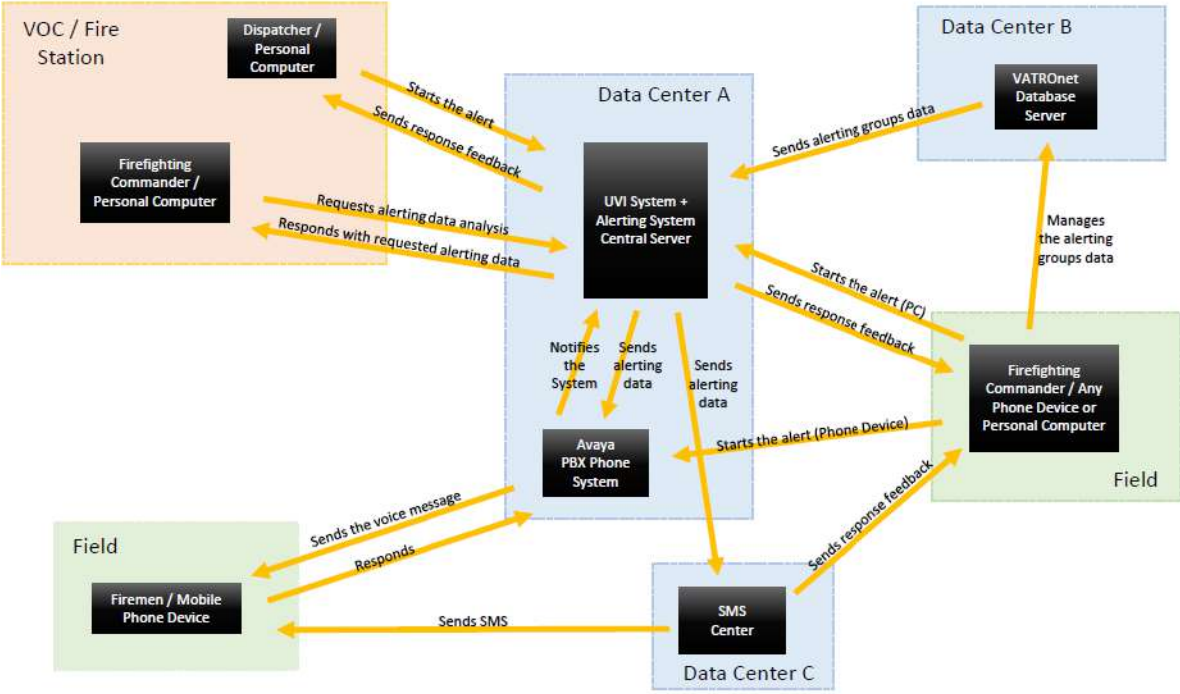

Figure 19 Architecture of alerting system

Communication endpoints in Croatian settings: Command & Control Room. In case of emergency in the endangered (affected) area, a mobile C&C room can be used.

Data are communicated between the individual endpoints:

- From: dropdown: C&C Room, Mobile C&C Room, Municipality, Fireman, Forester, Citizens, Wearable Device, Wearable Sensors, Field Sensors, Fire Truck, Helicopter, Airplane, Drone (UAV), Ground Robot (UGV), Social Network, Cloud Service, Volunteer Fire Fighters, Other.
- To: dropdown: C&C Room, Mobile C&C Room, Municipality, Fireman, Forester, Citizens, Wearable Device, Wearable Sensors, Field Sensors, Fire Truck, Helicopter, Airplane, Drone (UAV), Ground Robot (UGV), Social Network, Cloud Service, Volunteer Fire Fighters, Other
- Type of Data: text
- Protocol: dropdown: -, TETRA, WiFi, Bluetooth, Zigbee, WiMax, NFC, LoRa, 3G/4G, 5G, UWB, Infrared, RFID, Satellite, Optical Wireless, Radio (PTT), Other.

3rd party cloud storage systems are used:

- Google Drive/Drive Enterprise (Google Workspace Business Starter).
- Centar dijeljenih usluga - government cloud infrastructure for some of our applications and services.
- Proaxis - private business cloud infrastructure for some of our applications and services.

Cloud platform used: Google Cloud, Google Workspace, Business Starter.

There is a DSS used in the Pilot Site - **Fire Management System** (FMC Croatian name is Upravljanje Vatrogasnim Intervencijama (UVI). Manufacturer: Rinels d.o.o.

The application is an operational tool and as such is used primarily to support work processes that take place before, during and after a firefighting incident. Prior to the incident, it allows the definition of operational areas, engagement plan, alert and exit plan, operational database, and daily orders. During the intervention, it enables receiving a notification, alerting, sending the location to vehicles, entering, and exchanging information on the situation on the ground with all levels of management, sending requests for additional forces to the Firefighting operational command centre.

After the intervention, it allows commanders to enter intervention reports and generate predefined reports and advanced analysis of all interventions.

Important capabilities:

- enables the definition of operational areas of fire brigades and the plan for alerting units and engaging firefighting vehicles depending on the intensity and type of intervention, which is used by the Firefighting operational command centre during the management of firefighting interventions.
- allows the definition and easy access to a database of operational data containing various information and contact information on stakeholders of interest during the management of firefighting interventions.
- enables the definition of daily orders that contain information on the current state of personnel and equipment of firefighting units.
- enables the receipt and entry of data on alerts via telephone lines by citizens or fire alarm facilities
- enables alerting units to firefighting interventions and sending locations to GPS devices in firefighting vehicles.
- enables the entry and exchange of information on the situation on the ground with all levels of command.
- Allows you to send requests for additional forces to the Firefighting operational command centre.
- Allows commanders to fill in reports that already contain information in advance about the alert and the course of the intervention entered by the competent Firefighting operational command centre.
- allows the generation of various reports and analysis of firefighting interventions for a period or area of operation.
- integrated with the main database of units, firefighters, equipment, and vehicles to be filled by fire brigades.

Technical parameters:

- Dispatcher, commanders, operators using the system: Windows 10 64-bit Personal Computer with internet Access. Java Runtime Environment and FMC Desktop Application installations are required
- FMC System Server: Linux Server

Available Data:

- Data type: numerical, text, GIS layers (vector, raster), audio/video
- Producer/provider of the data:
  - Numerical - HVZ
  - Text - HVZ
  - Vector GIS layers – HVZ, other government institutions.
  - Raster GIS layers – HVZ, other government institutions.
  - Audio/Video – HVZ, other government institutions.

*Note: Some GIS data which HVZ has right to use, we are not freely allowed to share publicly.

4.7.3 Stakeholders involved

There are introduced the stakeholders to be considered in the Operational Scenario:

- Firefighting associations.
- Public administration.
- Forest governance associations.
- IT business.
- IT/ software and technology developers on wildfire prevention.

In thew interviews following stakeholders were involved:

- Odašiljači iveze d.o.o., Vatrogasna Zajednica Primorskogoranske Županij (government organisation),
- HVZ (government organisation).

4.7.4 High-level Operational Scenario

There are introduced the Use Cases specified for Operational Scenario in Phase A and Phase B.

Use cases for Phase A:

- **Seasonal integrated public awareness campaign**

Seasonal integrated public awareness campaign will be provided to citizens and possible tourists through TV and radio spots, billboards, leaflets, exhibition of burnt areas.

- **Susceptibility of territory to wildfire**

Susceptibility of territory to wildfire assessment will be provided from risk assessment plan provided by Croatian Forestry Service using data on terrain (elevation, terrain slope, aspect), fuel (vegetation type, quantity, and quality). Additional data from GIS-CLOUD from HVZ will be provided like public utilities (power lines, hydrant network and fire brakes).

- **Prevention, education, and suppression activities**

Prevention, education, and suppression activities will be based on the National Program of Activities in the implementation of special fire protection measures of interest to the Republic of Croatia for 2023.

- **County Fire-fighting plan**

County Fire-fighting plan will be prepared on an HVZ platform as a base of engagement of firefighting forces and communication with other stakeholders.

- **Mapping of site**

Mapping of Pilot Site will be done through orthophotos, satellite images and images collected by cameras from UAV (drone).

- **Fire danger assessment using information on fine fuel moisture**

The moisture content of fine fuel will be calculated and compared with moisture content critical value (moisture of extinction) under which limit any of fire initiators is capable to start the fire. The output of comparing the actual and critical fine fuel moisture content values will be assignment of an area (forest stand) to one of 4 degrees of fire danger. This will be provided on daily basis. Maps of fire danger are published at the public portal of Croatian Forrest. Information (map) is sent to involved stakeholders daily.

- **Robotic systems deployment**

Robotic systems are constantly in the state of preparedness in county Civil Protection facilities, provided by HVZ, 3MON and DOK-ING.

- **An integrated national surveillance system of cameras deployment**

An integrated national surveillance system of cameras will be used for video surveillance of site.

- **IoT sensors deployment**

There will be installed IoT sensors (distributed on the vehicles) continuously gathering the microclimate data (temperature, precipitations, relative air humidity, wind speed, wind direction). The data from IoT will be collected, stored, and processed by 3MON and sent to GIS cloud.

Use cases for Phase B:

- **Integrated national video-surveillance system of cameras deployment**

An integrated national video-surveillance system of cameras provides the county and national firefighting headquarter with information from all parts of the country. Automatic alerts will be provided for fire and smoke detection. Additionally, if fire (smoke) will be detected by cameras on site, national firefighting headquarters will automatically collect information from other 96 cameras (image, coordinates, and distance of fire source) deployed on national level for immediate risk assessment and redeployment of firefighting forces.

- **Citizen's engagement**

The fire will also be observed by citizens and tourists by calling the fire-fighting alert number 193. This information will be used by firefighters to precise the position of fire site.

- **Integrated Fire-fighting Management System deployment**

An integrated national Fire-fighting Management System (GIS cloud based HVZ system) will provide alarming of fire-fighting forces, navigating them to the site, additional mapping of suitable water sources for extinguishing activities, critical infrastructure on sites, tracking and recording of firefighting events. Basically, it will provide overall situation of the scene. Additionally, we will in parallel deploy tracking devices, mobiles with command aps and GINA central system as a different tool to manage the resources on the ground, or in the air provided by 3MON.

- **Involvement of Volunteer Fire Brigades**

After arrival of first fire brigade to fire site, the fire will be fully developed, and deployment of further fire-fighting forces and resources will be needed. Except professional firefighters from Rijeka and Opatija, 10 volunteer Fire Brigades will be deployed. Mapping of position of fire fighters in terrain is ensured by GIS cloud. In parallel, GINA system from 3MON will also be used for sharing communication and images/videos from GINA users on the fire line to the command post.

- **Fire Behaviour Modelling**

For modelling wildfire behaviour on site GIS based FESB wildland fire spreading simulator using data on terrain (elevation, terrain slope, aspect), fuel (vegetation type, quantity, and quality) and estimation of wind will be used.

- **Incident Management and Coordination supported with GINA mobile apps**

A mobile fire-fighting Operational Centre will be used to monitor and lead all activities on the endangered site, estimating possibility of coordination of several mobile fire-fighting operational centres and separate command post of HVZ with the county and national operative centres. Alternative communication means (5G etc.) will be used. The mobile unit will be provided by the Firefighting Association of Primorsko-goranska County. In parallel, the GINA central will be in mobile operational centre or near it. Depending on the space of the operational centre, the GINA central can communicate with another mobile apps GINA. Tracking system will be used with the trackers that will be deployed before the scenario on chosen assets (planes, helicopters, fire engines, individuals...)

- **Aerial Forces deployment**

Aerial forces of MORH will be included in monitoring and fire extinguishing activities, providing terrain pictures that will be transferred to the mobile fire-fighting command centre. Additionally, fire site area will be monitored (image, coordinates, and distance of fire source) with the UAV (drones) providing data that will be transferred to the mobile fire-fighting command centre. We will try to install small tracking device on a firefighting helicopter or the firefighting plane so we can see the position of the aerial assets in real time on the GINA central and onto the mobile apps GINA. Also, GINA drone will communicate with the GINA software and can create a real time map of the fire.

- **Mesh in the Sky system deployment**

A RINI Mesh in the Sky system will be used for transferring monitored data from the sensors deployed on drones if all other communication systems fail.

- **IoT sensors deployment to gather data on microclimate**

IoT sensor will be used for monitoring the microclimate situation and getting information for real time modelling of fire behaviour.

- **UGV (robots) deployment**

For ground monitoring of the fire site area UGV (robots) will be used. Those will be used for fire monitoring, transport of firefighting resources and fire extinguishing purposes. Data from UGVs will be transmitted to the mobile fire-fighting Operational Centre.

- **Education programs elaboration**

Advanced education programs will be elaborated for fighting wildfires, using the technology deployed in the pilot.

- **Guidelines for conducting training of firefighters**

New guidelines for conducting training of firefighters and use of new technologies in coping with wildfires will be elaborated. After the demonstration, there will be organized debriefing with different stakeholders. The pros and cons of applied procedures, technology deployed, fire tactics used, will be discussed.

There is also introduced a schema/current operational flow Phase A (Figure 20) and Phase B (Figure 21).

Figure 20 Operational Schema for Phase A

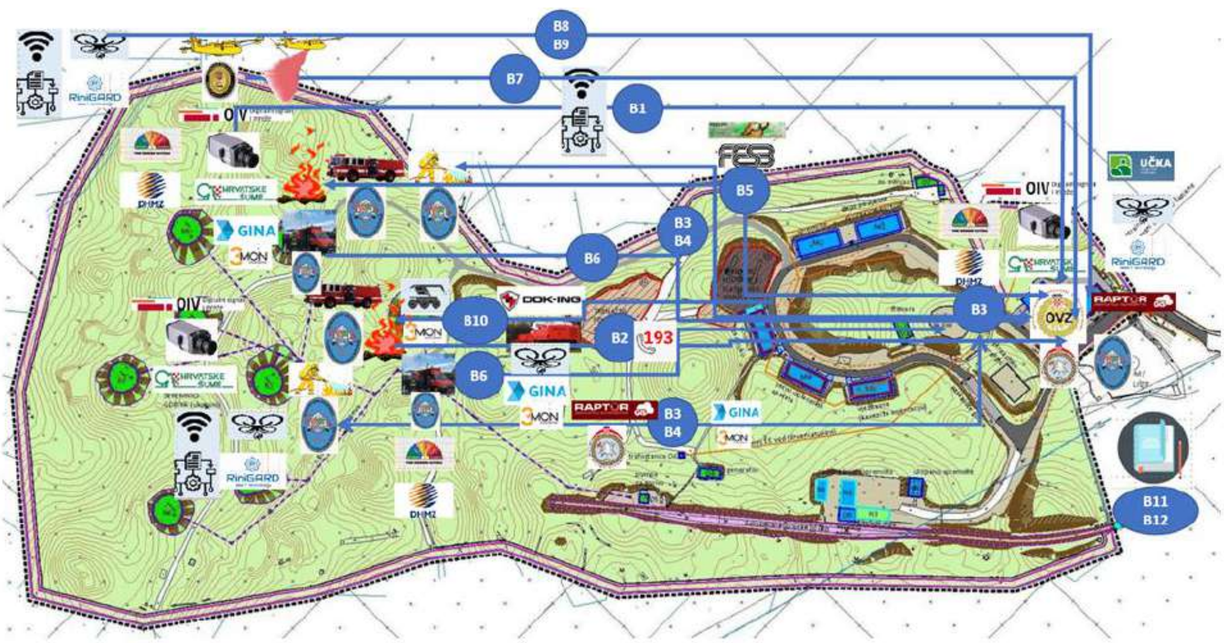

Figure 21 Operational Schema for Phase B

4.7.5 Priorities of the Pilot

There were specified following key parameters that should be considered:

- the accuracy of the platform to predict the shape of the wildfire,
- the time difference between the time estimated by the platform for first responders to reach the place of action in the event of a wildfire and the real time.

4.7.6 Functional requirements on SILVANUS Platform

Functional requirements on SILVANUS Platform which **must be** included in Phase A:

- providing fire danger index metrics,
- providing information on fuel availability in specific regions of forest,

- providing representation of forest landscape for computing impact different (single or combined) forest managements on ecosystem services (climate and water regulation) under alternative climate scenarios,
- gathering information on fire ignition sources, such as human negligence, arson, environment conditions, climate and weather conditions (climate change impact including), impact of power grid lines,
- providing modelling of human behaviour (and negligence) resulting in forest fire ignition,
- providing probabilistic prediction models for estimating forest fire ignition,
- providing simulation of fire ignition scenarios,
- implementing notification protocol for response (first responders) deployment,
- allowing weather/environmental data to be processed in the emulating the forest fire behaviour,
- including mobile application which allow people to notify fire to the Fire and Rescue Service,
- SILVANUS mobile application must notify people about the fire occurrence in their vicinity,
- SILVANUS mobile application must create user interface for reporting a suspect fire by geo-location, photos, and description,
- SILVANUS mobile application must allow fire and rescue services to ask people in fire vicinity for help by voice call,
- providing damage assessment,
- supporting resources deployment,
- supporting coordination of responders,
- providing GIS/GPS visualisation of on-field situation.

Functional requirements on SILVANUS Platform which **should be** included in Phase A:

- visualisation of landscape biodiversity,
- visualisation of and provide information forest structural diversity,
- providing fuel management alternatives for different forest types,
- visualise climate statistics (for historical and future periods; precipitation, temperature, relative humidity etc.),
- providing information on soil types and structure,
- aggregating Copernicus and EO data prior and post fire ignitions,
- quantifying the damage of forest fire and map into ecological assessment (loss of XX cubic tons of oxygen, etc.),
- providing AR/VR simulation of combating forest fire,
- notifying people in the vicinity of forests, on human negligence,
- SILVANUS mobile application should allow fire management services to contact people in fire vicinity for help by voice call,
- SILVANUS mobile application should allow forest management services to contact people in fire vicinity for help by chat,
- providing micro-weather forecasting models (time scale up to 72 hours),
- providing pilot region specific customisation of AI/ML algorithms for estimating forest fire danger,
- providing prediction models based on seasonal forecasts,
- providing evaluation of forecast models based on observed data,
- providing IoT data aggregation from distributed deployment of environmental sensors, CCTV, chemical composition sensors,
- providing data collection for the fire behaviour (spread) modelling,
- providing AI/ML algorithms to detect fire danger,
- providing AI/ML algorithms to detect fire/smoke,
- providing extraction of geoinformation, i.e., mentioned locations, from social media data sources,

- autonomously piloted UAVs should be deployed for remote sensing,
- drones should be equipped with multi-spectral sensing devices,
- providing visualisation of forest landscape models,
- providing health impact analysis for fire fighters to model long- and short-term exposure to forest fire,
- allowing to develop evacuation plans,
- facilitating the selection and configuration of governance models for forest restoration, using criteria such accountability, effectiveness, efficiency, fairness, participation and transparency.

Functional requirements on SILVANUS Platform which **could be** included in Phase A:

- identifying areas/regions of historical significance,
- simulation of spatio-temporal trends of forest changes,
- gathering information on forest landscape using crowd sourcing applications,
- calculating potential greenhouse emissions from fire probability index based on climate conditions and type of vegetation,
- providing assessment models of forest resilience (e.g., regeneration dynamics),
- providing AI/ML algorithms trained on historical data sources resulting in forest fire,
- producing content to engage with citizens on forest fire impact,
- providing Edge based micro-data centres for processing data collected from the field,
- supporting the analysis of the impact of forest fires on the hydrology and soil physical properties (using inputs from chemical analysis where applicable),
- supporting continuous monitoring of forest restoration programmes,
- collecting citizen observations from social media,
- providing extraction of visual concepts, such as fire or smoke, from social media data sources,
- some UAVs could be stationed in particularly critical areas and automatically scan the area if critical conditions arise (e.g., sudden increase in FDI),
- collision avoidance among drones could be implemented,
- heterogenous data from multi-modal data sources could be integrated,
- data filtering and cleaning process could be provided,
- weather forecasts could be developed,
- AI algorithms could be provided to identify high-risky forest regions according to fire initiation potential,
- distributed storage and repository for heterogenous data sources could be provided,
- training models for AI/ML algorithms could be provided,
- 5V data characteristics could be supported,
- decision support systems for fire detection, fire spread, weather effect on fire intensity could be used,
- cause-and-effect models for the fire ignition could be used,
- simulation of fire ignition and fire spread based on Monte Carlo like models,
- providing micro-predictive models using AI/ML algorithms for different scenarios specifications,
- considering wearable devices and other medical devices for response coordination,
- providing visualisation of forest restoration (forest management) alternatives for stakeholder to support forest resilience,
- supporting the systematic planning of restoration activities.

Functional requirements on SILVANUS Platform which **must be** included in Phase B:

- providing fire danger index metrics,
- providing information on fuel availability in specific regions of forest,

- providing representation of forest landscape for computing impact different (single or combined) forest managements on ecosystem services (climate and water regulation) under alternative climate scenarios,
- gathering information on fire ignition sources, such as human negligence, arson, environment conditions, climate and weather conditions (climate change impact including), impact of power grid lines,
- providing modelling of human behaviour (and negligence) resulting in forest fire ignition,
- providing probabilistic prediction models for estimating forest fire ignition,
- providing simulation of fire ignition scenarios,
- implementing notification protocol for response (first responders) deployment,
- allow weather/environmental data to be processed in the emulating the forest fire behaviour,
- SILVANUS mobile application should allow people to notify forest management services on human negligence,
- including mobile application which allow people to notify fire to the Fire and Rescue Service,
- SILVANUS mobile application must notify people about the fire occurrence in their vicinity,
- SILVANUS mobile application must create user interface for reporting a suspect fire by geo-location, photos, and description,
- SILVANUS mobile application must allow fire and rescue services to ask people in fire vicinity for help by voice call,
- providing damage assessment,
- supporting resources deployment,
- supporting coordination of responders,
- providing GIS/GPS visualisation of on-field situation.

Functional requirements on SILVANUS Platform which **should be** included in Phase B:

- visualisation of landscape biodiversity,
- visualisation and providing information forest structural diversity,
- providing fuel management alternatives for different forest types,
- visualisation of climate statistics (for historical and future periods; precipitation, temperature, relative humidity etc.),
- providing information on soil types and structure,
- aggregating Copernicus and EO data prior and post fire ignitions,
- quantifying the damage of forest fire and map into ecological assessment (loss of XX cubic tons of oxygen, etc.),
- providing AR/VR simulation of combating forest fire,
- notifying people in the vicinity of forests, on human negligence,
- SILVANUS mobile application should allow fire management services to contact people in fire vicinity for help by voice call,
- SILVANUS mobile application should allow forest management services to contact people in fire vicinity for help by chat,
- providing micro-weather forecasting models (time scale up to 72 hours),
- providing pilot region specific customisation of AI/ML algorithms for estimating forest fire danger,
- providing prediction models based on seasonal forecasts,
- providing evaluation of forecast models based on observed data,
- providing IoT data aggregation from distributed deployment of environmental sensors, CCTV, chemical composition sensors,
- providing data collection for the fire behaviour (spread) modelling,
- providing AI/ML algorithms to detect fire danger,

- providing AI/ML algorithms to detect fire/smoke,
- providing extraction of geoinformation, i.e., mentioned locations, from social media data sources,
- use unmanned and automated ground vehicles (UGV) for monitoring wildfire behaviour,
- UGV should be equipped with LIDAR, visual sensors (cameras), and environmental sensors,
- autonomously piloted UAVs should be deployed for remote sensing,
- drones should be equipped with multi-spectral sensing devices,
- providing visualisation of forest landscape models,
- providing health impact analysis for fire fighters to model long- and short-term exposure to forest fire,
- allowing to develop evacuation plans,
- facilitating the selection and configuration of governance models for forest restoration, using criteria such accountability, effectiveness, efficiency, fairness, participation and transparency.

Functional requirements on SILVANUS Platform which **could be** included in Phase B:

- identifying areas/regions of historical significance,
- simulation of spatio-temporal trends of forest changes,
- gathering information on forest landscape using crowd sourcing applications,
- calculating potential greenhouse emissions from fire probability index based on climate conditions and type of vegetation,
- providing assessment models of forest resilience (e.g., regeneration dynamics),
- providing AI/ML algorithms trained on historical data sources resulting in forest fire,
- producing content to engage with citizens on forest fire impact,
- providing Edge based micro-data centres for processing data collected from the field,
- supporting the analysis of the impact of forest fires on the hydrology and soil physical properties (using inputs from chemical analysis where applicable),
- supporting continuous monitoring of forest restoration programmes,
- collecting citizen observations from social media,
- providing extraction of visual concepts, such as fire or smoke, from social media data sources,
- integration of deep learning for the detection of wildfire (using visual concepts such as smoke, fire, etc) could be considered,
- collision avoidance among drones could be implemented,
- some UAVs could be stationed in particularly critical areas and automatically scan the area if critical conditions arise (e.g., sudden increase in FDI),
- heterogenous data from multi-modal data sources could be integrated,
- data filtering and cleaning process could be provided,
- weather forecasts could be developed,
- AI algorithms could be provided to identify high-risky forest regions according to fire initiation potential,
- distributed storage and repository for heterogenous data sources could be provided,
- training models for AI/ML algorithms could be provided,
- 5V data characteristics could be supported,
- decision support systems for fire detection, fire spread, weather effect on fire intensity could be used,
- cause-and-effect models for the fire ignition could be used,
- simulation of fire ignition
- providing micro-predictive models using AI/ML algorithms for different scenarios specifications,
- considering wearable devices and other medical devices for response coordination,
- providing visualisation of forest restoration (forest management) alternatives for stakeholder to support forest resilience,

- supporting the systematic planning of restoration activities.

Training requirements:

There are going to be elaborated:

- Advanced education programs for fighting wildfires, using the technology deployed in the pilot.
- New guidelines for conducting training of firefighters and use of new technologies in coping with wildfires.

4.8 SLOVAKIA

Slovakia is involved in demonstration of operational scenarios in all phases: Phases A (Preparedness and Prevention), Phase B (Detection and Response) and Phase C (Restoration and Adaptation).

4.8.1 Pilot Summary

Slovak Pilot Site is localized in the Central part of Slovakia. This region is called Podpolanie (Figure 22).

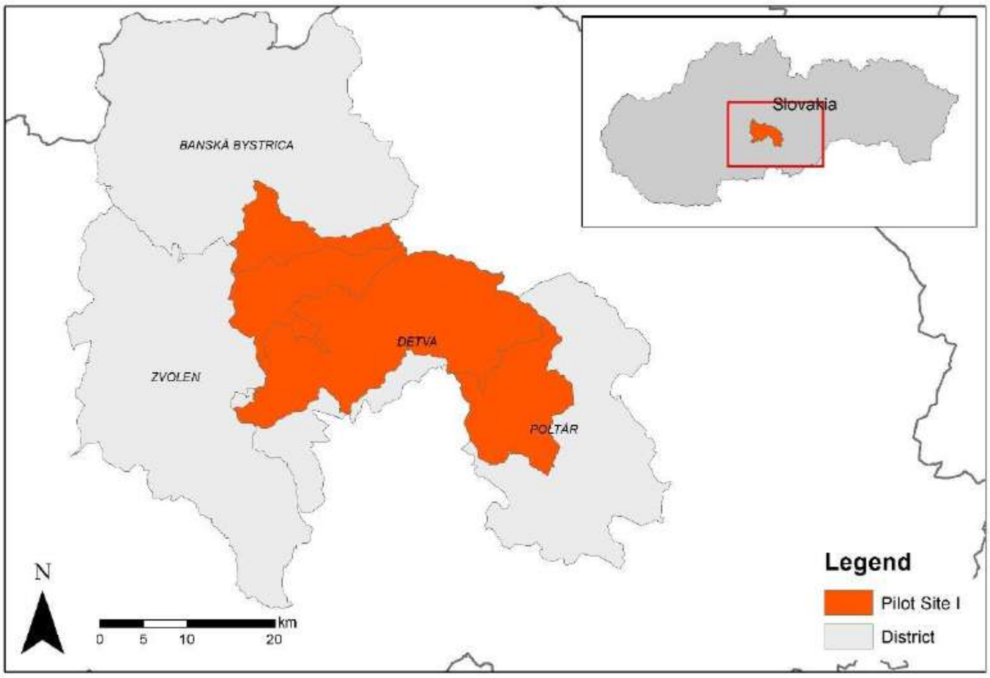

Figure 22 Location of Pilot Site Slovakia

The territory is represented by a mosaic of different types of land use: forests, grasslands, agricultural land. The forest belongs under the administration of different stakeholders: state, municipal, association of foresters, church, private. This region is well known because of wildfires which are often deliberately ignited due to the intended burning of dry crop and grasses in the spring and in autumn. Some of those fires were further spread to the surrounding forests and caused damages resulting not only to the wood but also to the surrounding biota. In this area only surface fires are considered. In the demonstration, all three phases solved in the project will be included.

In the Phase A, GIS technology is going to be used for GIS data processing and landscape and biodiversity visualisation as well as for providing the geospatial analyses focusing the area opening-up analysis and deployment of fire trucks, fire susceptibility and fire danger analysis. Drones are going to be deployed for monitoring the area from the fire prevention point of view. Regarding fire danger index calculation, data on current local weather situation coming from IoT sensors distributed in the area are going to be used. GIS data coming from the Pilot Study area are available and can be stored in the project database. Training materials for professional and volunteer firefighters are going to be developed.

In the Phase B, GINA technical solution is going to be deployed and will be used for communication of firefighters with the Integrated Rescue System Coordination Centre as well as for spatial decision support for the firefighters when navigating to the incident site (also personal trackers for localisation of firefighters in the field) and for incident commanders when looking for the best tactics to fight the wildfire. For monitoring the fire site area above the tree crown close to the fire, as well as for mobile GSM network creation, drones are going to be used. For monitoring the fire site area under the tree crown close to the fire, as well as for the transportation of firefighting material over long distances, UGV / robots are going to be deployed. Fire predictions according to the results of wildfire behaviour modelling, are going to be used too. Those will be used for the modification of chosen fire tactics, when necessary. Crowdsourcing is going to be used for wildfire announcement. For automated smoke detection and firefighters alerting, the ForestWatch early-stage fire warning system is going to be used.

In the Phase C, forest management alternatives for forest stands affected by fire are going to be developed. The visualisation of growth modelling results (model Sibyla) in the Virtual 3D cave is going to be provided.

The demonstration will take place in April/May 2023, considering the summer weather situation (July). In the demonstration, professional fire fighters, 6 volunteer fire brigades, foresters and municipality authorities are going to participate.

In the demonstration TUZVO (leader), UISAV, 3MON and Plamen are involved.

GINA technology and software, UAV and UGV are going to be provided by 3MON. GIS and geospatial analyses as well as fire behaviour modelling are going to be provided by TUZVO. UISAV will provide drones and crowdsourcing application. Plamen will be involved in intervention activities and will be responsible for finding the best tactics to fight the fire and deploy the sources and resources. TUZVO will also be responsible for tree growth modelling and for the identification of the forest management strategies as well as for providing the participatory processes with stakeholders.

4.8.2 Pilot Status Characteristics

In this section the existing data, systems, services, and technology used in the Pilot Site are described.

Phase A

Prevention

Currently, the fire monitoring is provided by field patrols, especially during the declared time of increased fire risk. However, there was installed also CCTV based smoke detection and early fire alerting system ForestWatch, which can monitor majority of the territory.

The ForestWatch® is a powerful smoke detection and early warning system. ForestWatch® is a range-aware vision system, that uses maps and other GIS (Geographical Information System) layers specific to your area (e.g., elevations, property borders). This means that when an operator clicks on an event on the screen, co-ordinates are immediately generated for that exact location in reality. With immediate accurate information, resources – such as firefighting aircraft – can be dispatched quickly and efficiently. While some automated detection systems use only black and white imagery, ForestWatch® uses the full colour spectrum. Full colour makes the system more sensitive to subtle scene changes, resulting in more accurate detection and a lower rate of false alarms. ForestWatch® has the ability to integrate with the existing communications infrastructure in the area. This allows for the creation of a link to fire departments and the police, allowing for the sharing of information and an improved coordinated response during emergencies. Communications integration can also be used to immediately alert decision makers to an event, and allow them to monitor it in real-time via the password protected ForestWatch Online web application. In ideal conditions, ForestWatch® can detect events over distances of up to 40km. However, the greater the range, the longer the cameras take to automatically scan and analyse the landscape. Although, there are ways to combat this slower lap time, the recommended optimal surveillance distance is therefore 8-16 km per tower. ForestWatch® is working with powerful cameras, high-definition digital imagery and other advanced sensors, ForestWatch® has been programmed in such a way that it actually learns its environment over time so that it can distinguish between smoke and other harmless occurrences (e.g., vehicle lights). Instead of constantly relaying video and imagery back to the operations centre for optimisation and analysis, the ForestWatch® system uses less bandwidth. This method of relaying information avoids transmission delays.

The architecture of the system is introduced in Figure 23.

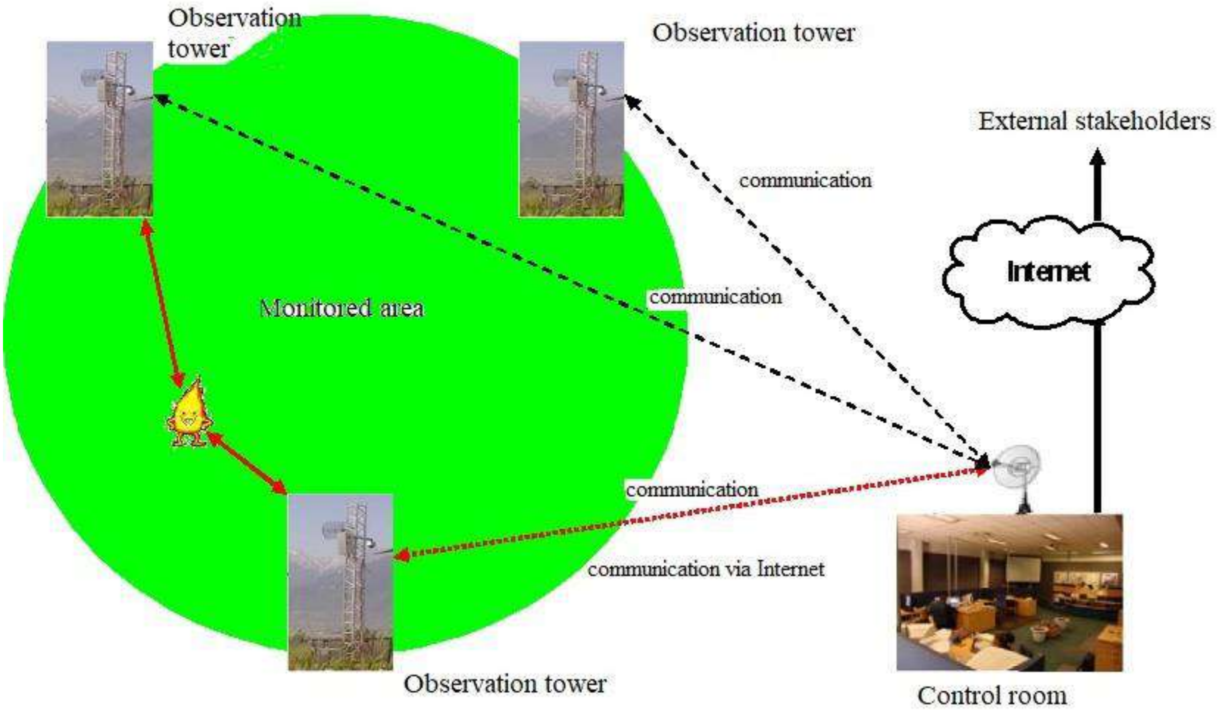

Figure 23 Architecture of ForestWatch system deployed in the Pilot Site

The fire danger assessment is not provided on local or regional level but only at national level. For this purpose, the meteorological fire danger index is used, which is calculated based on Baumgartner formula. Drones, robots, IoT and satellite data are not used for prevention purposes.

Forests of the Slovak Republic, S.E. provides a KML file with all the forest objects (Figure 24) important for firefighting purposes: firefighting tool warehouses, water tanks and watercourses suitable for pumping water by fire trucks, helicopter landing places, etc.

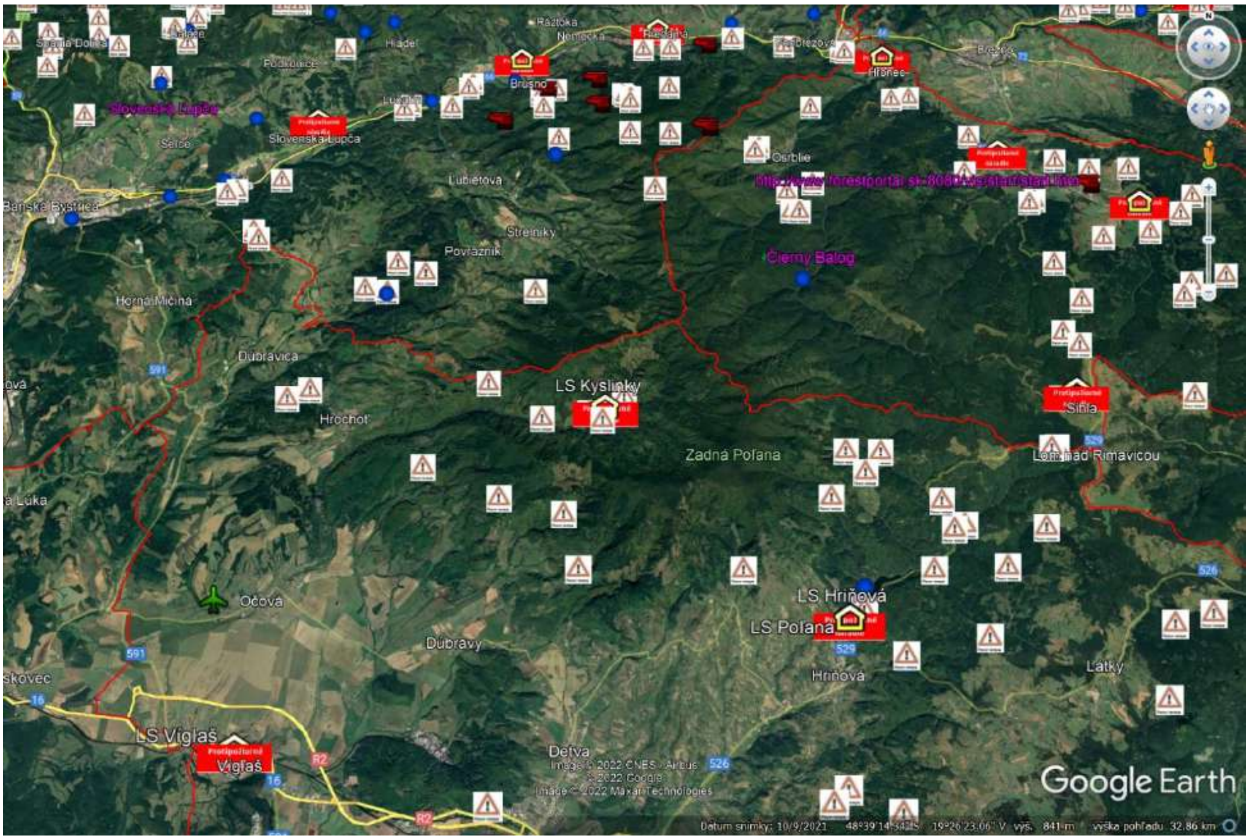

Figure 24 Forest objects important for firefighting purposes – file provided by the Forests of the Slovak Republic, S.E.

GIS layers are available: vector (stand outlines + forestry database, roads, watercourses and reservoirs, forest types, soil types) and raster (DTM, orthophotos) are available, too.

Vector GIS layers: Forest stand outlines, water bodies, roads, contour lines, protected areas polygons, soil type, forest type, touristic and cycling routes, buildings

Raster layers: Digital terrain model (spatial resolution of 10 m), ortho photos (spatial resolution of 0.5 m), Corine Land Cover data.

Numerical data: Database containing detailed description (numerical and text) of individual forest stands (can be joined with forest stand outlines vector layer).

Online Map services - Available data sources – open access:

- Data sources for digital elevation model (DTM, DSM…):
- DMR05 (derivate from Lidar mapping) https://data.gov.sk/dataset/digitalnyvyskovy-referencny-model-dvrm05
- DMR 3.5 (photogrammetry based) https://data.gov.sk/dataset/digitalny-modelreliefu-dmr3-5
- LAS/LAZ from project area (10 ground return points per sq meter minimum) Free of charge but must be requested from authority if needed.
- Data sources for land cover development:
- Orthophotomaps 2020-2022 https://data.gov.sk/dataset/ortofotomozaik a#
- Orthophotomaps 2017-2019 https://data.gov.sk/dataset/ortofotomozaik a#
- Topographic maps (vectorized from ortho/digita photogrammetry): https://data.gov.sk/dataset/topografickeudaje-zbgis-zobrazovacie-sluzby-wms
- Agriculture field (Hranice užívania), yearly updated https://data.gov.sk/dataset/hranice-uzivani
- Land Parcel Information System (could be used for grasslands identification) - https://data.gov.sk/dataset/systemidentifikacie-polnohospodarskychpozemkov-lpis

- Forest information data sources:
- Forest typology units https://data.gov.sk/dataset/lesnetypologicke-jednotky#
- Forest management units (Lesné hospodárske celky) https://data.gov.sk/dataset/lesnehospodarske-celky#
- Forest soil units/types https://data.gov.sk/dataset/lesne-podnejednotky# Forest management records (Lesná hospodárska evidencia) https://data.gov.sk/dataset/lesnahospodarska-evidencia
- Register of forest spatial distribution units (Register jednotiek priestorového rozdelenia lesa) https://data.gov.sk/dataset/register-jprl
- Forest stands (Lesné porasty) 3 https://data.gov.sk/dataset/lesne-porastyplan
- Information system on Forest management: https://gis.nlcsk.org/islhp/#lesnictvo

No crowdsourcing application (social media) is used for fire announcement and monitoring purposes. Citizens have information only on announced period with high fire danger – information comes officially from district fire directorate to all relevant municipalities in paper and electronic form.

Preparedness

There is a forest fire prevention legislation which requires the forest users/owners to have available: maps of the territory, identified suitable places for pumping the water for firefighting in the territory, for landing helicopters, fire extinguishing tools placement (defined specific numbers depending on the extent of the territory)

Firefighters uses and train (tactical exercises concerning fighting forest fires) the fire tactics procedures according to the training documentation (should be updated). Slovak firefighters have suitable fire trucks (also special vehicles for forest fires) to fight the forest fires.

Phase B

For fire monitoring, only field patrols (foresters) are used now. There is also provided a monitoring service by aero planes and helicopters flying over the territory of the Slovak Republic, which when they notice a fire, report it to the air tower and they contact the firefighters. ForestWatch smoke detection and alerting system is not used (will be operating during demonstration). No drones are used for this purpose by foresters.

When there is a large fire, the firefighters use their own drones (3 drones in the entire Fire and Rescue Service – professional firefighters) for monitoring the situation when intervening and not deploying the helicopters to localize the fire. For navigation to fire site and as a spatial (map) support they use system GINA installed in tablet.

Phase C

There is no DSS available for development and assessment of forest management alternatives in Slovakia. For Central European conditions a tree growth simulation model called Sibyla was developed at the Technical University in Zvolen. For visualization of simulation results a 3D virtual cave is used.at the Technical University in Zvolen. For communication with stakeholders' participatory processes are established.

Sybila - tree growth simulator Models available: http://etools.tuzvo.sk/sibyla/english/

The simulator of forest biodynamics (SIBYLA) belongs to the category of tree growth simulators (hereinafter called as a growth simulator). It is a simulator that strives to imitate the behaviour of trees in the context of forest ecosystems. It consists of the set of mathematical models and algorithms that are transformed into an integrated software package SIBYLA Suite. The difference between the growth simulator SIBYLA and a classical forest model (e.g., forest yield tables) can be defined as follows:

A growth simulator is a system, that strives to imitate forest behaviour using the principles of ecosystem and cybernetical modelling. It utilizes a very wide range of input conditions and parameters. It simulates different initial forest stand structures starting from even-aged homogeneous stands (pure plantations) of the type of age classes, through differentiated multi-storeyed forest, mixed stands and shelterwood systems, up to selection forests. It can simulate a wide range of natural conditions defined by ecological (site) classifications in the form of climate, air, and soil characteristics. In addition, it also offers a quite large operating space to make the interventions of a forest manager in the form of various thinning and felling regimes. And besides, a specific economic environment is accounted for inclusive of applied technological techniques. At the same time, growth simulator provides a user with a great variety of output data. Apart from classical production data it also deals with ecological information, such as biodiversity, biomass, fixation of nutrient elements in trees, oxygen production and carbon dioxide consumption. It also covers an economic aspect in the form of assortment structure of produced wood, forest revenues and management costs. To imitate the real forest as faithfully as possible, stochastic principles are applied, i.e., every time the simulation is repeated, the model produces slightly different results. The behaviour of randomness follows the probability principles and functions derived from real forest ecosystems. Thanks to the randomness, the component of theoretical model error can be obtained, and statistical tests of the differences between various scenarios can be performed. The nature of the system is complex, since it utilises a set of various linked models and algorithms of a different nature: allometric equations, regressions, growth curves, mensuration relationships, physical and chemical relationships, production rules, Boolean and fuzzy logic, heuristics, planar and spatial geometry, two- and multi-dimensional probability models, etc. Due to this complexity, it is undoubtedly required that the system exists in the form of a computer program. Since the system is characterised by several input parameters and a variety of possibilities to define different variants and scenarios, its application is more challenging. Primarily, it is suitable for scientific and educational purposes.

Yield tables represent a mathematical model, which today describes forest development by the system of mathematical equations. It simulates the development of even-aged homogeneous forest stands (pure plantations) at full density and 100% proportion of a particular tree species in relation to age and site. The site is defined by stand class, or also by stand volume level. Yield tables are restricted to only one thinning regime, or eventually to a set of pre-defined variant regimes with no possibility to modify them. The outputs are primarily oriented at production aspect of a forest, while usually they are presented in tabular form. Thanks to the model simplicity and to the restricted range of possible variants of a forest, the model does not have to exist as a computer program. It is mainly composed of simple growth curves, or eventually of other mensuration relationships. The model is strictly deterministic, and hence, its character is often normative. Due to the facts that this model does not require many input parameters and is simply applicable, it is primarily used in the forestry practice.

For adaptation to climate change several strategies were developed at European and at national level, which are further incorporated to forest management plans, however those are not binding for forest owners and forest users.

4.8.3 Stakeholders involved

In the interviews, the following stakeholders were involved:

- 3MON (SME),
- PLAMEN (non-government organisation – Civic Association)
- Regional Directorate of Fire and Rescue Service in Banska Bystrica (government organisation)
- State owned forest enterprise Forests SR – headquaters in Banska Bystrica (government organisation),

- Association of community and private forest owners in Banska Bystrica region (non-government organisation),
- State owned forest enterprise Forests SR – Branch POLANA (government organisation),
- Nature protection administration of Slovak Republic – Protected Landscape Area Poľana (government, State Nature state Preservation, public administration),
- National Forest Centre in Zvolen (government organisation).

4.8.4 High-level Operational Scenario

There are introduced the Use Cases specified for Operational Scenario in Phase A, Phase B and Phase C.

Use cases for Phase A:

- **Assessment of susceptibility of the territory to wildfire**

There will be produced a GIS based assessment of the susceptibility of the territory to wildfire using data on terrain (elevation, terrain slope, aspect), fuel (vegetation type, quantity, and quality) and potential occurrence of human in forest (using forestry data on timber logging and forest cultivation activities – planned for each stand for period of 10 years, also considering the distance from nearest road or settlement in form of buffer zone).

- **Microclimate data gathering via IoT sensors**

There will be installed IoT sensors (distributed in the territory) continuously gathering the microclimate data (temperature, precipitations, relative air humidity, wind speed, wind direction). The data from IoT will be collected, stored, and processed by TUZVO.

- **Fire danger assessment**

The moisture content of fine fuel will be calculated and compared with moisture content critical value (moisture of extinction) under which limit any of fire initiators is capable to start the fire. The output of comparing the actual and critical fine fuel moisture content values will be assignment of an area (forest stand) to one of 5 degrees of fire danger. This will be provided on daily basis. Maps of fire danger are published at the TUZVO website. Information (map) is sent to involved stakeholders daily.

- **Territory opening-up analysis (using GIS) to deploy the fire trucks**

For purposes of deployment of fire trucks in case of fire an analysis of opening-up of territory will be provided in GIS.

- **Suitable water sources to be used for extinguishing activities**

Mapping of suitable water sources for extinguishing activities will be provided (in GIS and in the field).

- **Mapping of sites to be used as heliports**

Mapping of sites to be used as heliports will be provided in GIS. Helicopters are used for firefighting purposes in Slovakia.

- **Monitoring the forested area by CCTV**

The area is under the fire monitoring using the CCTV fire detection system (ForestWatch). The cameras are operated by a person in Operational Centre. Automatic alerts are provided when smoke detected. Totally 3 cameras are deployed.

- **Monitoring the forested area by UAV**

UAV will be used by foresters to monitor the forested area in days (time during the day will be specified) with high fire danger degree in the field. The drone operators communicate with ForestWatch Operational Centre.

Use cases for Phase B:

- **Fire detection by ForestWatch**

Fire (smoke) will be detected by the ForestWatch system and information (image, text, and coordinates of fire site) will be sent from ForestWatch Operational Centre to the Coordination Center of the Integrated Rescue System and will be registered as an emergency in the CoordCom SW used for management of sources and resources of the Fire and Rescue Service.

- **Crowdsourcing application**

Fire will also be observed by tourists and announced via crowdsourcing application send to social networks. Fire site coordinates will be sent, too. This information will be used by firefighters to precise the position of fire site.

- **Navigation to fire site**

Gina application will be used for navigation of professional fire brigade (first responder) to the fire site and for support of spatial decision-making process (GIS layers, CoordCom SW) of incident commander as well as Command Staff.

- **Decision support for incident management**

After arrival of first fire brigade to fire site, the fire will be fully developed, and deployment of further forces and resources will be needed. Except professional firefighters from Zvolen and Detva and Banska Bystrica Fire Stations, also 6 Volunteer Fire Brigades will be deployed and military fire brigade from Sliac airport. Forest workers will be involved in firefighting activities, too. For better coordination of those forces and resources a Command Staff (at incident area) will be established, which will coordinated by the director of the Regional Directorate of the Fire and Rescue Service in Banska Bystrica. The incident commanders of the deployed fire services and representative of forest administration body will be involved in the Command Staff. As a SDSS tool they will use the maps included in GINA application and real time data from UAV and UGV.

- **Fire behaviour modelling**

For modelling wildfire behaviour FARSITE environment will be applied. TUZVO will provide in its specialized workplace and online provide to Command Staff.

- **Input information to modelling gathering**

IoT sensor will be used for monitoring the microclimate situation and getting information for real time modelling of fire behaviour.

- **Mapping firefighters' position in the field and health state**

To map the position of fire fighters in terrain and their health will be used. Output will be visualized in GINA which will be used by Command Staff.

- **UAV technology deployment**

For aerial monitoring of the fire site area the UAV technology will be used. Information from UAV will be transmitted to the Command Staff.

- **UGV technology deployment**

For ground monitoring of the fire site area UGV (robots) will be used. Those will be used for fire monitoring, transport of firefighting resources and fire extinguishing purposes, too. Information (video) from UGV will be transmitted to the Command Staff.

- **Helicopters deployment**

Helicopters will be deployed for fire localisation and extinguishing purposes.

- **New tactical procedures to fight the wildfire**

There will be elaborated methodological guideline for fighting the wildfires using the technology deployed in the pilot.

- **Training and training manuals for firefighters**

New guidelines for conducting training of firefighters in coping with wildfires will be elaborated.

Use cases for Phase C:

- **Forest growth models implementation**

There will be provided modelling using the Sibyla forest growth simulator for the forest stands effected by wildfire.

- **Forest management alternatives development**

Forest management alternative will be provided for the stakeholders to choose among different ecosystem services and their combinations to increase the resilience of forest to wildfires

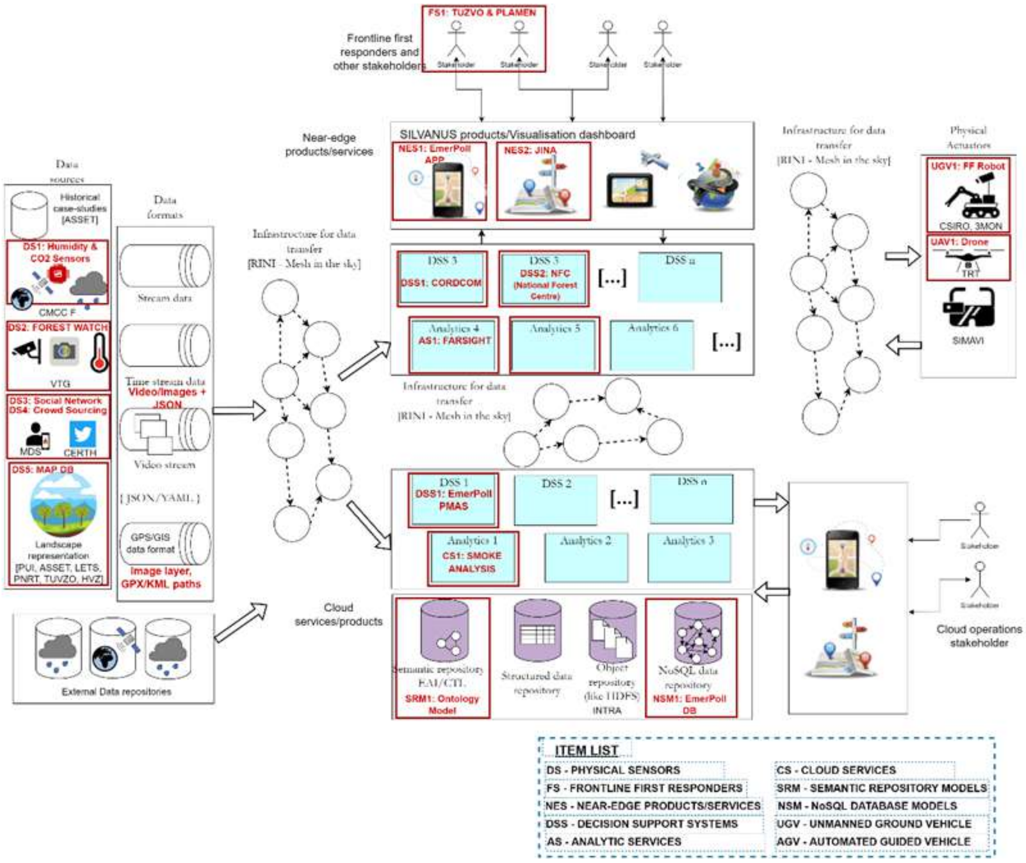

Figure 25 **Overall Pilot Slovakia Schema with overview of Technological Components**

There is further introduced schema/current operation flow concerning current work/current system used in Slovakia in Phase B in Figure 25.

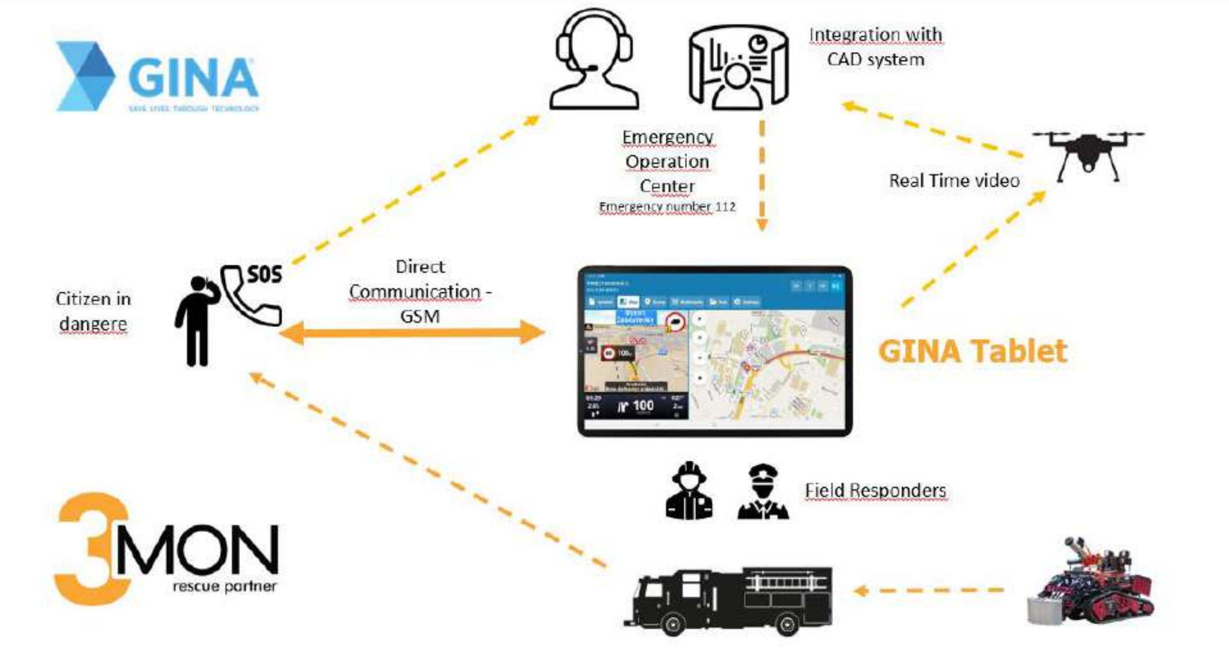

Figure 26 Schema/current operation flow concerning current work/current system used in Slovakia in Phase B

Communication endpoints to be used in Operational Scenario – Phase A: Municipality, Forester, Citizens, Field Sensors, Airplane, Drone (UAV), SHMU (Slovak Hydrometeorological Institute), web: https://www.shmu.sk/; Ministry of Economy.

*Notes: Communication Endpoints involved in Phase A:

SHMU - Fire Danger Warnings - they declare warning levels (5 categories) - Degree of fire danger (SK: Stupeň požiarneho nebezpečenstva) - Map of Slovakia with Warning Levels: https://www.shmu.sk/sk/?page=1608 - Methodology: https://www.shmu.sk/sk/?page=70 - The warning is currently very inaccurate, because the warning is declared for a large area (district, in SK: district) - If there are fires 2 days in a row, the third day is the warning declared - SK: if it could be transferred according to the fuel model (flammability test), then for 280 ha the risk can be declared.

Ministry of Economy - Planes - Sometimes order monitoring by small planes (aero-clubs or agricultural planes) - If the plane spots smoke or fire they can deploy some fire extinguisher (max. 1200-3000 liters of water maximum)

Foresters - Monitoring of the Forests in person and by drones 1 Field Sensors - humidity, temperature (limited number of sensors) – previous collaboration of ARDACO and TUZVO.

Communication endpoints to be used in Operational Scenario – Phase B: Command & Control Room, Mobile C&C Room, Municipality, Forester, Citizens, Fireman, Fire Truck, Helicopter, Volunteer Fire Fighters, Drone (UAV).

Notes: Communication Endpoints involved in Phase B:

Helicopters - MI17 is equipped with a radio, BlackHawks are not. Collaboration between Police and Fire Fighters (source: https://www.minv.sk/?elektronicke-sluzbyinformacnych-systemov-mv-sr-na-useku-policajneho-zboru-2-faza&subor=263545, slide: 19): Integration of the SITNO network and IRS operational centers - Call groups - Individual calls - SMS, Codes of typical activities - Open channel - Dispatching call -

Emergency communication - Quiet eavesdropping Data record exchange and cooperation between the police force and the Fire and Rescue Service - Life-saving events, rescuing people and directing traffic.

Communication endpoints to be used in Operational Scenario – Phase C: Forester, Citizens, Fireman, Field Sensors, Volunteer Fire Fighters.

Communication protocols used in Slovak settings – Phase A: TETRA

Communication protocols used in Slovak settings – Phase B: TETRA, WiFi, 3G/4G, 5G, Satellite, Radio (PTT), Web (SHMU)

Communication protocols used in Slovak settings – Phase C: TETRA, WiFi, 3G/4G, 5G, Satellite, Radio (PTT), MATRA

Data communicated between the individual endpoints in Operational Scenario are introduced in Table 7.

Table 7 Data communicated between the individual endpoints in Operational Scenario

Phase	From	To	Type of Data	Protocol	Purpose	Frequency
A	Drone (UAV)	Forester	Video, photos	WiFi	Monitoring	When on-site, streaming, during forest inspection
A	Airplane	C&C Room	Phone Call	Other	Warning	Anytime a smoke or fire is spoted by a dedicated airplane
A	Forester	C&C Room	Phone Call		Warning	
B	Fireman	Mobile C&C Room	Voice	TETRA	Operational Communication	During the Intervention
B	Fireman	Drone (UAV)	Video, Photos	WiFi	Monitor the Fire	During the Intervention
B	Fire Truck	C&C Room	Voice	3G/4G	Operational Communication	If Radio signal is lost
A	Other	Citizens	From: SHMU, Degree of fire danger		Warning	Daily
B	Citizens	C&C Room	Voice, SMS (limited)	3G/4G	Emergency Event Notification	In case of an Event
B	C&C Room	Fire Truck	GINA Tablet (Map, Navigation, etc.)	3G/4G	Coordination	During the Deployment and Intervention
A	Field Sensors	C&C Room	Humidity, Temperature	3G/4G	Monitoring	Continuous
B	Helicopter	C&C Room	Voice	TETRA	Coordination	During the Intervention

In the Phase B, UAVs and UGVs are going to be deployed for fire monitoring purposes:

- **UGV – Tracked firefighting robot Colossus**
  - Usage: monitoring, active firefighting.

Robot is very universal, could be used for assessment of the situation with cameras (thermal/RGB), could be used to measure telemetry around, could be used for firefighting, could be used for transporting equipment, or injured.

- Level of autonomy: Level 0 – No Automation; Human Dependency: Trained & Skilled Pilot; Level 1 – Controller Assisted; Human Dependency: Trained Pilot

Communication frame and data exchange:

- From: Ground Robot (UGV)
- To: Fireman
- API: free
- Frequency: 433 & 870 MHz
- Datatype: video, telemetry, data
- Range: 500 m
- Comment: The robot will be used by firefighters for their support

- **UAV - multirotor DJI Mavic 2 Enterprise** (2 drones)
  - Usage: monitoring (RGB land map with resolution 30m/pix, thermal map)
  - Level of autonomy: Level 0 – No Automation; Human Dependency: Trained & Skilled Pilot; Level 1 – Controller Assisted; Human Dependency: Trained Pilot; Level 2 – Partial Automation; Human Dependency: Basic Pilot

Communication frame and data exchange.

- From: Drone (UAV)
- To: C&C Room
- API: free
- Frequency: 2.4 GHz and 5.8 GHz
- Datatype: video
- Range: 10
- Comment: There will be a connection between drone and the C&C software GINA

- From: Drone (UAV)
- To: Other
- From: C&C Room
- To: C&C Room
- API: free
- Frequency: 2.4 GHz and 5.8 GHz
- Datatype: video
- Range: 10 km
- Comment: the DJI Smart Controller supports automatic switching between 2.4 GHz and 5.8 GHz, reducing the influence of environmental interference on drone operation and image quality. This also ensures reliable long-range transmission at distances of up to 10 km. (https://www.dji.com/sk/mavic-2- enterprise)

IoT Tools and Instruments are going to be deployed in Phase A and Phase B for gathering the microclimate data.

4.8.5 Priorities of the Pilot

Key parameters to be considered in Phase A:

- Fire danger assessment.

- Fire susceptibility assessment.
- Road network survey.
- Opening-up of territory analysis in GIS for fire truck and helicopters purposes.
- Preventive monitoring of the area with drones when high fire danger index.
- Building network of IoT sensors to get microclimate data online.

Key parameters to be considered in Phase B:

- Fire detection based on automatic smoke detection – ForestWatch.
- Fire spread prognosis – fire behaviour modelling.
- Using local microclimate data from IoT sensors as an input to fire modelling.
- Using drones for monitoring the area above crown closure during the fire.
- Using UGV for fire monitoring under crown closure and transport of firefighting material.
- Crowdsourcing application for fire announcement by civil persons.
- Using GINA application for navigation and spatial decision support of incident commander.
- Using personal trackers for firefighters to monitor their position in fire site area.
- Using drones swarm for fire monitoring purposes.
- Using drone to establish local GSM network.
- Using GIS layers for spatial decision support of management staff.

Key parameters to be considered in Phase C:

- Using Sibyla tree growth simulator for modelling and visualisation of fire affected forest stands after restoration.
- Development of forest management alternatives and their rating based on various forest ecosystem services prioritization.

4.8.6 Functional requirements on SILVANUS Platform

Functional requirements on SILVANUS Platform which **must be** included in Phase A:

- visualisation of landscape biodiversity,
- visualisation and providing information on forest structural diversity,
- providing fire danger index metrics,
- providing information on fuel availability in specific regions of forest,
- gathering information on fire ignition sources, such as human negligence, arson, environment conditions, climate and weather conditions (climate change impact including), impact of power grid lines,
- providing probabilistic prediction models for estimating forest fire ignition,
- allow weather/environmental data to be processed in the emulating the forest fire behaviour,
- producing content to engage with citizens on forest fire impact,
- notifying people in the vicinity of forests, on human negligence,
- SILVANUS mobile application must allow people to notify forest management services on human negligence,
- SILVANUS mobile application must create user interface for reporting a suspect fire by geo-location, photos, and description,
- providing micro-weather forecasting models (time scale up to 72 hours),
- providing pilot region specific customisation of AI/ML algorithms for estimating forest fire danger,
- providing IoT data aggregation from distributed deployment of environmental sensors, CCTV, chemical composition sensors,
- collect citizen observations from social media,
- providing AI/ML algorithms to detect fire danger,

- provide AI/ML algorithms to detect fire/smoke,
- providing extraction of geoinformation, i.e., mentioned locations, from social media data sources,
- autonomously piloted UAVs must be deployed for remote sensing,
- collision avoidance among drones must be implemented,
- drones must be equipped with multi-spectral sensing devices,
- heterogenous data from multi-modal data sources must be integrated,
- data filtering and cleaning process should be provided,
- weather forecasts must be developed,
- AI algorithms must be provided to identify high-risky forest regions according to fire initiation potential,
- providing visualisation of forest landscape models.

Functional requirements on SILVANUS Platform which **should be** included in Phase A:

- simulation of spatio-temporal trends of forest changes,
- providing fuel management alternatives for different forest types,
- providing modelling of human behaviour (and negligence) resulting in forest fire ignition,
- providing simulation of fire ignition scenarios,
- SILVANUS platform should gather feedback from citizens on the usefulness of the mobile application,
- including mobile application which allow people to notify fire to the Fire and Rescue Service,
- SILVANUS mobile application should notify people about the fire occurrence in their vicinity,
- providing evaluation of forecast models based on observed data,
- providing Edge based micro-data centres for processing data collected from the field,
- some UAVs should be stationed in particularly critical areas and automatically scan the area if critical conditions arise (e.g., sudden increase in FDI),
- distributed storage and repository for heterogenous data sources should be provided,
- training models for AI/ML algorithms should be provided,
- 5V data characteristics should be supported,
- decision support systems for fire detection, fire spread, weather effect on fire intensity should be used,
- allowing to develop evacuation plans,
- supporting coordination of responders,
- providing GIS/GPS visualisation of on-field situation.

Functional requirements on SILVANUS Platform which **could be** included in Phase A:

- identifying areas/regions of historical significance,
- gathering information on forest landscape using crowd sourcing applications,
- visualization of climate statistics (for historical and future periods; precipitation, temperature, relative humidity etc.),
- providing information on soil types and structure,
- calculation of potential greenhouse emissions from fire probability index based on climate conditions and type of vegetation,
- including e.g. AR/VR representation of forest landscape for computing impact of climate change on forest ecosystem services (climate and water cycle regulation),
- providing representation of forest landscape for computing impact different (single or combined) forest managements on ecosystem services (climate and water regulation) under alternative climate scenarios,
- aggregation of Copernicus and EO data prior and post fire ignitions,

- providing AI/ML algorithms trained on historical data sources resulting in forest fire,
- providing AR/VR simulation of combating forest fire,
- SILVANUS mobile application could allow fire management services to contact people in fire vicinity for help by voice call,
- SILVANUS mobile application could allow forest management services to contact people in fire vicinity for help by chat,
- allowing fire and rescue services to ask people in fire vicinity for help by voice call,
- providing prediction models based on seasonal forecasts,
- providing extraction of visual concepts, such as fire or smoke, from social media data sources,
- using unmanned and automated ground vehicles (UGV) for monitoring wildfire behaviour,
- UGV could be equipped with LIDAR, visual sensors (cameras), and environmental sensors,
- integration of deep learning for the detection of wildfire (using visual concepts such as smoke, fire, etc) could be considered,
- algorithms to control drone swarms based on e.g., leader-follower configuration could be applied,
- cause-and-effect models for the fire ignition could be used,
- simulation of fire ignition and fire spread based on Monte Carlo like models,
- provide micro-predictive models using AI/ML algorithms for different scenarios specifications.

Functional requirements on SILVANUS Platform which **must be** included in Phase B:

- visualisation of landscape biodiversity,
- visualisation and providing information on forest structural diversity,
- providing information on fuel availability in specific regions of forest,
- providing simulation of fire ignition scenarios,
- allowing weather/environmental data to be processed in the emulating the forest fire behaviour,
- SILVANUS mobile application must notify people about the fire occurrence in their vicinity,
- SILVANUS mobile application must create user interface for reporting a suspect fire by geo-location, photos, and description,
- providing micro-weather forecasting models (time scale up to 72 hours),
- providing IoT data aggregation from distributed deployment of environmental sensors, CCTV, chemical composition sensors,
- providing data collection for the fire behaviour (spread) modelling,
- collecting citizen observations from social media,
- providing AI/ML algorithms to detect fire danger,
- providing AI/ML algorithms to detect fire/smoke,
- providing extraction of geoinformation, i.e., mentioned locations, from social media data sources,
- using unmanned and automated ground vehicles (UGV) for monitoring wildfire behaviour,
- collision avoidance among drones must be implemented,
- drones must be equipped with multi-spectral sensing devices,
- heterogenous data from multi-modal data sources must be integrated,
- data filtering and cleaning process should be provided,
- weather forecasts must be developed,
- AI algorithms must be provided to identify high-risky forest regions according to fire initiation potential,
- providing visualisation of forest landscape models,
- providing micro-predictive models using AI/ML algorithms for different scenarios specifications,
- supporting resources deployment,
- supporting coordination of responders,
- providing GIS/GPS visualisation of on-field situation.

Functional requirements on SILVANUS Platform which **should be** included in Phase B:

- identifying areas/regions of historical significance,
- simulation of spatio-temporal trends of forest changes,
- providing information on soil types and structure,
- aggregating Copernicus and EO data prior and post fire ignitions,
- producing content to engage with citizens on forest fire impact,
- gathering feedback from citizens on the usefulness of the mobile application,
- SILVANUS mobile application should allow people to notify forest management services on human negligence,
- including mobile application which allow people to notify fire to the Fire and Rescue Service,
- SILVANUS mobile application should allow fire management services to contact people in fire vicinity for help by voice call,
- SILVANUS mobile application should allow forest management services to contact people in fire vicinity for help by chat,
- providing pilot region specific customisation of AI/ML algorithms for estimating forest fire danger,
- providing evaluation of forecast models based on observed data,
- providing Edge based micro-data centres for processing data collected from the field,
- some UAVs should be stationed in particularly critical areas and automatically scan the area if critical conditions arise (e.g., sudden increase in FDI),
- distributed storage and repository for heterogenous data sources should be provided,
- training models for AI/ML algorithms should be provided,
- 5V data characteristics should be supported,
- decision support systems for fire detection, fire spread, weather effect on fire intensity should be used,
- considering wearable devices and other medical devices for response coordination,
- providing damage assessment,
- allowing to develop evacuation plans.

Functional requirements on SILVANUS Platform which **could be** included in Phase B:

- providing fire danger index metrics,
- providing fuel management alternatives for different forest types,
- gathering information on forest landscape using crowd sourcing applications,
- visualisation of climate statistics (for historical and future periods; precipitation, temperature, relative humidity etc.),
- calculation of potential greenhouse emissions from fire probability index based on climate conditions and type of vegetation,
- including, e.g., AR/VR representation of forest landscape for computing impact of climate change on forest ecosystem services (climate and water cycle regulation),
- providing representation of forest landscape for computing impact different (single or combined) forest managements on ecosystem services (climate and water regulation) under alternative climate scenarios,
- gathering information on fire ignition sources, such as human negligence, arson, environment conditions, climate and weather conditions (climate change impact including), impact of power grid lines,
- quantifying the damage of forest fire and map into ecological assessment (loss of XX cubic tons of oxygen, etc.),
- implementing notification protocol for response (first responders) deployment,
- notifying people in the vicinity of forests, on human negligence,

- SILVANUS mobile application could allow fire and rescue services to ask people in fire vicinity for help by voice call,
- providing prediction models based on seasonal forecasts,
- providing extraction of visual concepts, such as fire or smoke, from social media data sources,
- UGV could be equipped with LIDAR, visual sensors (cameras), and environmental sensors,
- integration of deep learning for the detection of wildfire (using visual concepts such as smoke, fire, etc) could be considered,
- autonomously piloted UAVs could be deployed for remote sensing,
- algorithms to control drone swarms based on e.g., leader-follower configuration could be applied
- cause-and-effect models for the fire ignition should be used,
- simulation of fire ignition and fire spread based on Monte Carlo like models,
- providing health impact analysis for fire fighters to model long- and short-term exposure to forest fire.

Functional requirements on SILVANUS Platform which **must be** included in Phase C:

- Visualization of landscape biodiversity,
- visualisation and providing information on forest structural diversity,
- simulation of spatio-temporal trends of forest changes,
- providing representation of forest landscape for computing impact different (single or combined) forest managements on ecosystem services (climate and water regulation) under alternative climate scenarios,
- quantifying the damage of forest fire and map into ecological assessment (loss of XX cubic tons of oxygen, etc.),
- providing assessment models of forest resilience (e.g., regeneration dynamics),
- supporting continuous monitoring of forest restoration programmes,
- collecting citizen observations from social media,
- providing AI/ML algorithms to detect fire danger,
- providing AI/ML algorithms to detect fire/smoke,
- providing extraction of geoinformation, i.e., mentioned locations, from social media data sources,
- collision avoidance among drones must be implemented,
- drones must be equipped with multi-spectral sensing devices,
- heterogenous data from multi-modal data sources must be integrated,
- data filtering and cleaning process must be provided,
- providing visualisation of forest landscape models,
- providing micro-predictive models using AI/ML algorithms for different scenarios specifications,
- providing visualisation of forest restoration (forest management) alternatives for stakeholder to support forest resilience.

Functional requirements on SILVANUS Platform which **should be** included in Phase C:

- providing information on fuel availability in specific regions of forest,
- visualisation of climate statistics (for historical and future periods; precipitation, temperature, relative humidity etc.),
- providing information on soil types and structure,
- calculation of potential greenhouse emissions from fire probability index based on climate conditions and type of vegetation,
- providing evaluation of forecast models based on observed data,
- providing Edge based micro-data centres for processing data collected from the field,

- supporting the analysis of the impact of forest fires on the hydrology and soil physical properties (using inputs from chemical analysis where applicable),
- some UAVs should be stationed in particularly critical areas and automatically scan the area if critical conditions arise (e.g., sudden increase in FDI),
- distributed storage and repository for heterogenous data sources should be provided,
- training models for AI/ML algorithms should be provided,
- 5V data characteristics should be supported,
- decision support systems for fire detection, fire spread, weather effect on fire intensity should be used,
- supporting the systematic planning of restoration activities,
- facilitating the selection and configuration of governance models for forest restoration, using criteria such accountability, effectiveness, efficiency, fairness, participation, and transparency.

Functional requirements on SILVANUS Platform which **could be** included in Phase C:

- identifying areas/regions of historical significance,
- providing fire danger index metrics,
- providing fuel management alternatives for different forest types,
- gathering information on forest landscape using crowd sourcing applications,
- including, e.g. AR/VR representation of forest landscape for computing impact of climate change on forest ecosystem services (climate and water cycle regulation),
- aggregating Copernicus and EO data prior and post fire ignitions,
- producing content to engage with citizens on forest fire impact,
- gathering feedback from citizens on the usefulness of the mobile application,
- SILVANUS mobile application could allow people to notify forest management services on human negligence,
- including mobile application which allow people to notify fire to the Fire and Rescue Service,
- SILVANUS mobile application could notify people about the fire occurrence in their vicinity,
- SILVANUS mobile application could create user interface for reporting a suspect fire by geo-location, photos, and description,
- SILVANUS mobile application could allow fire management services to contact people in fire vicinity for help by voice call,
- providing micro-weather forecasting models (time scale up to 72 hours),
- providing pilot region specific customisation of AI/ML algorithms for estimating forest fire danger,
- providing prediction models based on seasonal forecasts,
- providing extraction of visual concepts, such as fire or smoke, from social media data sources,
- autonomously piloted UAVs could be deployed for remote sensing,
- algorithms to control drone swarms based on e.g., leader-follower configuration could be applied.

Training requirements

- Phase A:

Firefighter`s (professional as well as volunteer) preparedness - training should be focused on using VR/AR to solve model situations (using fire behaviour modelling) in different conditions to find the optimal fire tactics; training focused on UAV/UGV operation, handling.

Citizens: events focused on education of children, adults and seniors: fire prevention

- Phase B:

Firefighters: trainings of incident commanders to use and understand fire behaviour modelling results, procedures how to cope with the emergency, effective deployment of sources and resources. GIS, image sources from UAV/UGV, fire behaviour modelling results, VR/AR technology can be used for this purpose.

- Phase C:

Forest users/ forest owners (land users / land owners): climate change scenarios, consequences in the region, regional environmental changes resulting from climate change, potential forest management alternatives (pros and cons of each).

4.9 Australia

Australia is involved in demonstration of operational scenarios in Phase B (Detection and Response).

4.9.1 Pilot Summary

The Australian Pilot Site is the Queensland Centre for Advanced Technologies (QCAT) which is in the southeaster part of the state of Queensland in Australia. A significant part of the site is composed of bushland. Apart from a large, vegetated area, QCAT hosts CSIRO's research facilities and administration buildings. More precisely, QCAT sits approximately 20 km west of the Brisbane city centre in the suburb of Pullenvale at a latitude of approximately 27 degrees south. With a subtropical climate, the area is diverse with sparse and dense forests, including hilly and flat terrain, wetlands, and a creek, covering about 300.000 square meters. The site is an excellent representation of the general Australian bushland, serving as an ideal site for testing and illustrating the capability of ground robots in the prevention and mitigation of fire. A large proportion of Australia's bushfires occur in areas very similar to our pilot site.

The area was severely damaged by the Australian Wildfires of 2019-20. The area highlighted in red is CSIRO test site, shown in detail in Figure 27. A satellite image of the site is shown in Figure 28 below, on the left. On the right, there is shown a 3D mapped version of the site using CSIRO's 3D mapping technology using a mobile robotic platform. Being able to create such maps is essential for efficient and real-time operations. The locally acquired 3D map serves as the basis for local robotic navigation, including localisation, obstacle detection, terrain analysis and path planning. This site forms a perfect testing ground for the technology proposed and UGV development.

Figure 27 Map of Southeast Queensland with the test area highlighted in red

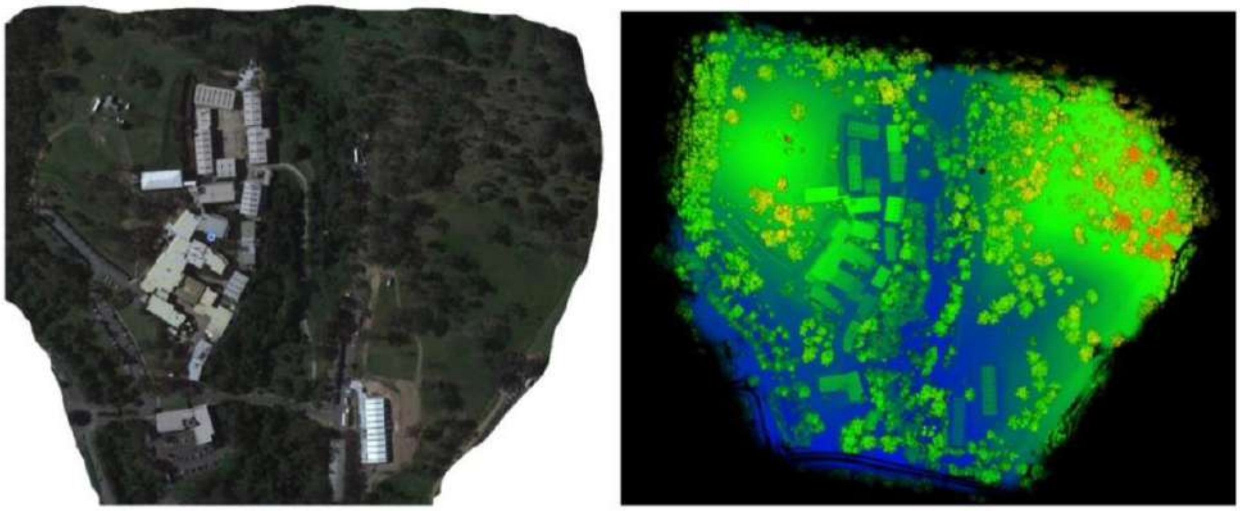

Figure 28 Test site for UGV operations (left). 3D mapped version of the site using Lidar and a mobile robot (right).

4.9.2 Pilot Status Characteristics

In this section the existing data, systems, services, and technology used in the Pilot Site is described.

In the Australia Pilot Site UGV technology is deployed:

- **Tracked Titan BIA5** UGV (https://bia5.com/)
- Total Weight: 120 kg
- Payload capacity: 140 kg
- Operation Time: 6 hours
- Usage: monitoring (forest density under canopy monitoring for fire risk estimation); active firefighting (forest density under canopy monitoring for fire risk estimation); communication (forest density under canopy monitoring for fire risk estimation and possibly reaching the fire front for firefighting).
- Level of Autonomy: Level 2 – Partial Automation; Human Dependency: Basic Pilot; Level 3 – Conditional Automation; Human Dependency: Operator Monitoring Onsite; Level 4 – High Automation; Human Dependency: Remote Operator Monitoring.

Communication frame and data exchange:

- From: Ground Robot (UGV)
- To: dropdown: Mobile C&C Room, Municipality
- Communication protocol: unknown
- API: licenced
- Frequency: 24 GHz
- Datatype: Lidar, Images, text
- Range: 3 km

Legislative conditions: Allowed Use of UGVs (robots).

4.9.3 Stakeholders involved

In the interviews only CSIRO was involved.

4.9.4 High-level Operational Scenario

Operational Scenario and Use Cases were not specified.

4.9.5 Priorities of the Pilot

Priorities of the Pilot, key parameters to be considered in the Operational Scenario:

1. 3D mapping using CSIRO's 3D mapping technology using a mobile robotic platform. 3D maps are essential for efficient and real-time operations. The locally acquired 3D map serves as the basis for local robotic navigation, including localisation, obstacle detection, terrain analysis and path planning.

4.9.6 Functional requirements on SILVANUS Platform

No functional requirements for SILVANUS platform were specified.

4.10 Brazil

Brazil is involved in demonstration of operational scenarios in two phases: Phases A (Preparedness and Prevention) and Phase C (Restoration and Adaptation).

The Pantanal is about 140,000–160,000 km^2 (54,000–62,000 sq mi), gently-sloped basin that receives runoff from the upland areas (the Planalto highlands) and slowly releases the water through the Paraguay River and tributaries. The formation is a result of the large, concave pre-Andean depression of the earth's crust, related to the Andean orogeny of the Tertiary. It constitutes an enormous internal river delta, in which several rivers flowing from the surrounding plateau merge, depositing their sediments and erosion residues, which have been filling, throughout the years, the large depression area of the Pantanal. This area is also one of the distinct physiographic provinces of the larger Parana-Paraguay Plain area, which encompasses a total of 1.5 million square kilometres (580,000 square miles).

The Pantanal is bounded by the Chiquitano dry forests to the west and northwest, by the Arid Chaco dry forests to the southwest, and the Humid Chaco to the south. The Cerrado savannas lie to the north, east and southeast. The Pantanal is a tropical wet and dry region with an average annual temperate of 21.5 °C (70.7 °F) and rainfall at 1,320 mm (52 in) a year.[9] Throughout the year, temperature varies about 6.0 °C (10.8 °F) with the warmest month being November (with an average temperature of 26 °C or 79 °F) and the coldest month being June (with an average temperature of 20 °C or 68 °F). Its wettest month is January (with an average of 340 mm or 13 in) and its driest is June (with an average of 3 mm or 0.12 in).

- Wildfires erupting in August have ravaged much of Brazil's Pantanal Matogrossense National Park, which is a part of the Pantanal region, the world's largest tropical wetland.
- Fires have so far consumed nearly 4.5 million hectares across the Pantanal, totaling about 30% of the biome and nearly 22 times the area lost between 2000 and 2018.

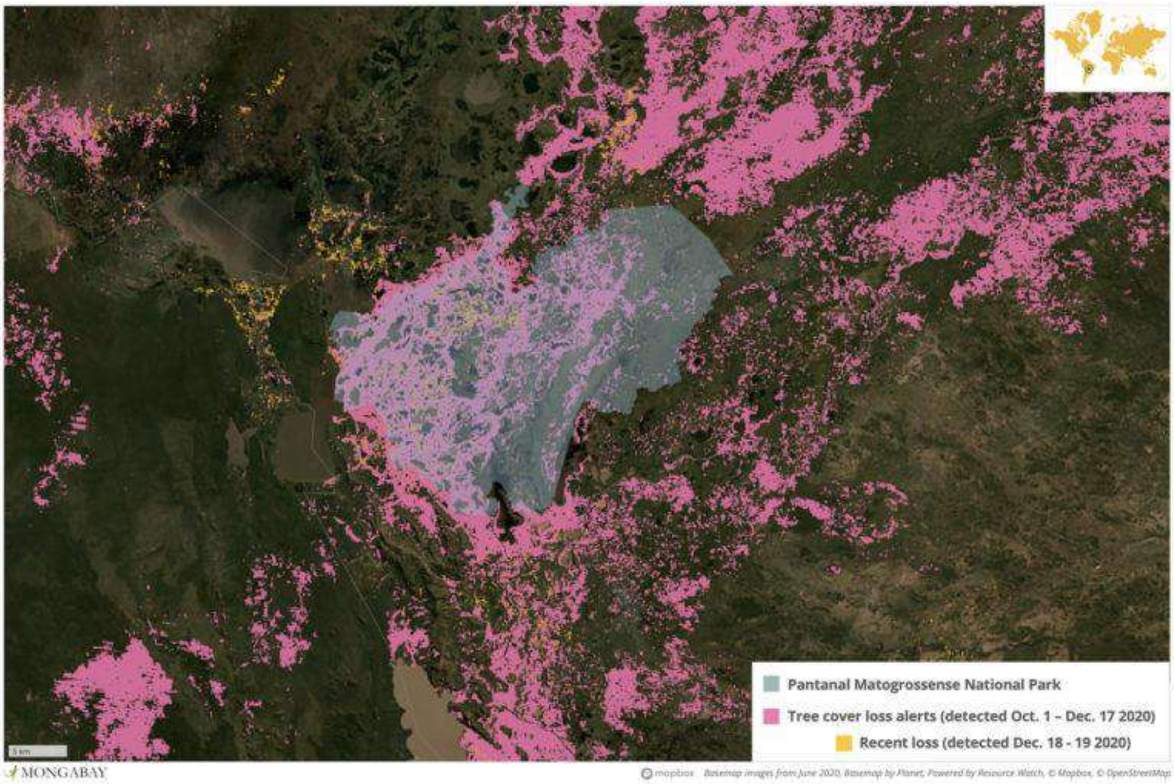

Figure 29 - Satellite data of areas of tree cover of Pantanal Matogrossense National Park following the latest spate of wide-ranging, out of control wildfires

The pilot will demonstrate Phase A and C activities within the region.

4.11 Indonesia

Indonesia is involved in demonstration of operational scenarios in Phase C (Restoration and Adaptation).

4.11.1 Pilot Summary

Indonesia's size, tropical climate, and archipelagic geography support one of the world's highest levels of biodiversity, and it is among the 17 megadiverse countries identified by Conservation International. Over 25 thousand flowering plants comprise 10 percent of the world's flowering plant species. Five hundred mammalian species, 600 reptilian species, some 1,500 species of birds, some 270 species of amphibians, and over 2,500 species of fish, constituting 45 percent of the world's fish species. Indonesia is second only to Australia in terms of total endemic species, with 36% of its1,531 species of bird and 39% of its 515 species of mammal being endemic.

Based on data from the Directorate General of Forestry Planning and Environmental Management (Planologi Kehutanan dan Tata Lingkungan), Ministry of Environment and Forestry (Kementerian Lingkungan Hidup dan Kehutanan), Indonesia has 94.1 million hectares of forested land area (50.1 percent of the entire mainland). Indonesia is the second-largest country in the world with the largest peat area after Brazil, with 22.5 million hectares (https://www2.cifor.org/global-wetlands/), making Indonesia a country capable of absorbing 30% of the world's carbon.

Indonesia has 34 provinces, one of them being Central Kalimantan Province. This province is located on Borneo Island. The capital city is Kota Palangka Raya. According to Central Bureau of Statistics of Central Kalimantan, in 2021 the cover area of Central Kalimantan is 15,356,450 ha. Central Bureau of Statistics of Central Kalimantan also shows the population of this province in 2020 is 2,670,000 (1,385,700 men and 1,284,300 women).

Central Kalimantan has extensive forests. The forest area in Central Kalimantan is 12,561,867.57 ha. It is the second largest in Indonesia after Papua Province. According to the website https://inarisk.bnpb.go.id/, Central Kalimantan is one area that has a high potential for forest fires. The incidence of forest fires in the Central Kalimantan Province recorded at https://sipongi.menlhk.go.id/ from 2017 to 2021 are as follows 1,744; 47,433; 317,749; 7,681; and 3,653 Ha. The incidence of major fires occurred in 2019 and declined sharply in 2020 and 2021.

To preserve tropical peat forests, the Minister of Forestry of the Republic of Indonesia, through Minister of Forestry Decree No. 423/Menhut-II/2004, designates the Sebangau area in Central Kalimantan Province as a National Park with an area of 568,700 hectares. Sebangau National Park is the largest tropical peat forest conservation area in Indonesia, with variations in peat depth between 1 meter to 12 meters and up to 14 meters at some points.

Sebangau National Park is geographically located at 1° 55' 14.80" - 3° 02' 32.71" South Latitude and 113° 18' 22.71" - 114° 04' 36.58" East Longitude. Administratively it is in Katingan Regency, Pulang Pisau Regency, and Kota Palangka Raya in Central Kalimantan Province. Sebangau National Park (Taman Nasional Sebangau) is the only national park in Indonesia where more than 90% of its area is a peat ecosystem. This national park management office is located on Jalan Mahir Mahar KM. 1.2, Paduran Sabangau, Sebangau Kuala, Paduran Sabangau, Kec. Sebangau Kuala, Palangka Raya, Central Kalimantan 74874. Complete information about the Sebangau National Park can be accessed at tnsebangau.com.

From July to September 2019, there were 125 hectares of fire in the Sebangau National Park area. During these three months, 141 hotspots were monitored. This burned land is not a stretch, but only on a small scale. However, as a result, many trees fall. The fire also threatens the life of endangered animals in the forest, such as gibbons, orangutans, macaques, pangolins, thongs, and more. So, Sebangau National Park needs to pay attention.

Indonesia's pilot area is involved in phase C, without the phase A and B demonstration. Therefore, we aim to observe the effect of certain rehabilitation program and strategy in pilot area. Moreover, we heavily rely on historical data on the pilot location. We aim to analyse the forest biodiversity over time based on current observation as well as societal engagement observation on pilot site and its impact to the prevention of fire. We also work based on the historical data such as the forest fire incident, forest fire mitigation, rehabilitation policy and action. The impact of those combination towards the restoration of the forest will be measured based on available data on biodiversity model. To do that we will need technology to support our observation.

4.11.2 Pilot Status Characteristics

In this section the existing data, systems, services, and technology used in the Pilot Site are described.

Datasets will be available:

- Policy dataset.
- Forest fire incident.
- Rehabilitation program and progress.
- Annotated Leaf Dataset (to be collected and annotated.)

Indonesia pilot is involved on phase C, without the demonstration on phase A and B. Therefore, it will heavily rely on historical data on the pilot location. The requirement regarding to the pilot site is to gather the historical data. The aim is to analyse the forest growth based on the historical data such as the forest fire incident, forest fire mitigation, rehabilitation policy and action. The impact of those combination towards the restoration of the forest will be measured by the size of vegetation cover after the forest fire. The possible technology involved in the Indonesian pilot is to utilize and analyse multispectral data images in time series. To collect the periodical vegetation, cover historical data against other data such as the rehabilitation programs, rainfall, and other related climate data. The problem with historical time series is that multispectral image might be the biggest challenge to collect.

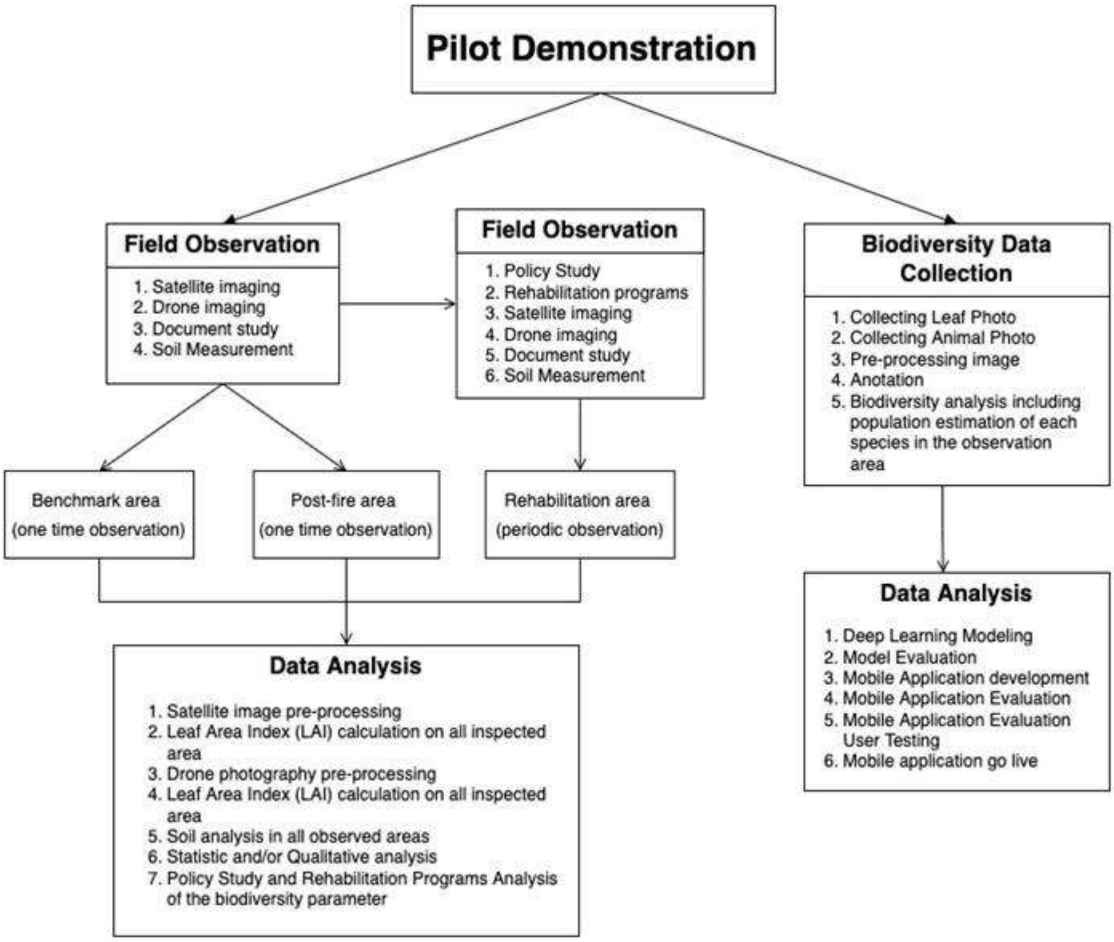

Figure 30 Methodology of data review

The stakeholder uses private cloud for data storing.

To maintain the security and confidentiality of data and the purpose for which the data is used, access to a specific user and agreement is required.

The data obtained are in the form of spatial data and numerical data, so it is necessary to carry out a data join stage to obtain more complete data information.

Data types available for the Pilot Site: GIS layers, online services (https://www.arcgis.com/home/item.html?id=dece90af1a0242dcbf0ca36d30276aa3)

This layer presents detectable thermal activity from VIIRS satellites for the last 7 days. VIIRS Thermal Hotspots and Fire Activity is a product of NASA's Land, Atmosphere Near real-time Capability for EOS (LANCE) Earth Observation Data, part of NASA's Earth Science Data.

No DSS, social media are used in the Pilot Site.

4.11.3 Stakeholders involved

In the interviews, the Universitas Amikom Yogyakarta was involved.

There are also external stakeholders to be considered in the Operational Scenario:

- Environmental bureau of Central Borneo (DLH Provinsi Kalimantan Tengah).
- Taman Nasional (National Park) Sebangau (TNS).
- Ministry of Environmental and Forestry Republic Indonesia (Kementrian Lingkungan Hidup dan Kehutanan Republik Indonesia).

4.11.4 High-level Operational Scenario

In the Phase C, in the Operational Scenario, the following issues are going to be included:

1. Forest Fire Incident

There will be provided: date of past fire incident, affected area, duration, and all incident data available

2. Forest Fire Treatment

There will be provided the historical data of fire forest treatment caried out by the local government just after the incident.

3. Forest Rehabilitation Strategy

There will be provided the historical data of fire rehabilitation caried out by the local government including but not limited to the programs, society engagement, budget, and technology.

4. Forest Rehabilitation Impact historical data

There will be provided the historical data recovery between the incident and current condition. Whatever possible, the numerical data resulting from processing gathered from the local government and ministry of forest and environmental affair, more analysis can be carried out from the multispectral satellite images in time series.

Use Cases to be considered in the Operational Scenario for Phase C:

- Take aerial images of well condition forest as benchmark.
- Collect/access multispectral satellite images of well condition forest as benchmark.
- Measure soil parameters in well condition forest.
- Interviews to stakeholders and identify past forest fire incident data collecting in the pilot location.
- Take post fire condition images through aerial photo and multispectral satellite imaging.
- Measure soil parameters in post fire forest (if available based on interviews and historical data).
- Interviews to stakeholder and identify rehabilitation programs and location.
- Take forest rehabilitation condition multispectral images through aerial photo and satellite imaging periodically.
- Community engagement program by installing mobile apps for surrounding forest community to provides crowd sourcing trees and animal diversity.

Technology support:

- To measure the soil parameters during rehabilitation and adaptation, we need to install some instruments with IoT Support.
- To measure the vegetation cover over time we need a support of satellite multispectral image with minimum 15m resolution periodically , aerial imaging captured periodically (monthly).
- To estimate the Leaf Area Index (LAI) we need A software to estimate LAI based on satellite images.
- To estimate the LAI we need A software to estimate LAI based on aerial imaging.
- To Estimate the animal diversity, we need a machine learning system to recognize animal diversity through visual or bioacoustics.
- To collect the tree and animal diversity through crowdsourcing platform we need a mobile application to improve community engagement in forest.

4.11.5 Priorities of the Pilot

There are introduced the key parameters of the SILVANUS Platform to be applicable in Operational Scenario.

The impact on biodiversity caused by a wildfire after 1 year rehabilitation for parameters:

- soil,
- animal,
- tree,
- community.

4.11.6 Functional requirements on SILVANUS Platform

Functional requirements on SILVANUS Platform which **must be** included in Phase C:

- visualisation and providing information on forest structural diversity,
- simulation of spatio-temporal trends of forest changes,
- visualisation of climate statistics (for historical and future periods; precipitation, temperature, relative humidity etc.),
- providing information on soil types and structure,
- providing representation of forest landscape for computing impact different (single or combined) forest managements on ecosystem services (climate and water regulation) under alternative climate scenarios,
- quantifying the damage of forest fire and map into ecological assessment (loss of XX cubic tons of oxygen, etc.),
- providing assessment models of forest resilience (e.g., regeneration dynamics),
- implement notification protocol for response (first responders) deployment,
- allowing weather/environmental data to be processed in the emulating the forest fire behaviour,
- producing content to engage with citizens on forest fire impact,
- notifying people in the vicinity of forests, on human negligence,
- supporting continuous monitoring of forest restoration programmes,
- collecting citizen observations from social media,
- providing extraction of geoinformation, i.e., mentioned locations, from social media data sources,
- heterogenous data from multi-modal data sources must be integrated,
- data filtering and cleaning process must be provided,
- distributed storage and repository for heterogenous data sources should be provided,
- training models for AI/ML algorithms must be provided,
- providing visualisation of forest restoration (forest management) alternatives for stakeholder to support forest resilience,
- supporting the systematic planning of restoration activities,
- facilitating the selection and configuration of governance models for forest restoration, using criteria such accountability, effectiveness, efficiency, fairness, participation and transparency.
- providing visualisation of forest landscape models,

Functional requirements on SILVANUS Platform which **should be** included in Phase C:

- including, e.g., AR/VR representation of forest landscape for computing impact of climate change on forest ecosystem services (climate and water cycle regulation),
- aggregating Copernicus and EO data prior and post fire ignitions,
- gathering feedback from citizens on the usefulness of the mobile application,
- providing AI/ML algorithms trained on historical data sources resulting in forest fire,
- SILVANUS mobile application should create user interface for reporting a suspect fire by geo-location, photos, and description,
- providing prediction models based on seasonal forecasts,
- providing evaluation of forecast models based on observed data,

- supporting the analysis of the impact of forest fires on the hydrology and soil physical properties (using inputs from chemical analysis where applicable),
- 5V data characteristics should be supported,
- providing damage assessment,
- supporting resources deployment.

Functional requirements on SILVANUS Platform which **could be** included in Phase C:

- providing extraction of visual concepts, such as fire or smoke, from social media data sources,
- algorithms to control drone swarms based on e.g., leader-follower configuration should be applied,
- providing micro-predictive models using AI/ML algorithms for different scenarios specifications,
- providing GIS/GPS visualisation of on-field situation.
- SILVANUS mobile application must allow fire and rescue services to ask people in fire vicinity for help by voice call,
- providing IoT data aggregation from distributed deployment of environmental sensors, CCTV, chemical composition sensors,
- UGV must be equipped with LIDAR, visual sensors (cameras), and environmental sensors,
- autonomously piloted UAVs must be deployed for remote sensing,
- drones must be equipped with multi-spectral sensing devices,
- providing Edge based micro-data centres for processing data collected from the field.

Training requirements

In general, forest fires in Indonesia are caused by extreme heat in the dry season (from March to September) on peatlands rich in carbon content, making them easily combustible. Furthermore, human factors that change peatlands into the agricultural, plantation, or industrial land affect the balance of the peatland ecosystem. The parties directly involved in efforts to extinguish forest fires in Indonesia are firefighters and the community. It is necessary to develop community skills training in utilizing peat forest land that does not damage its ecosystem. Meanwhile, firefighters need the training to use an integrated information system, especially at hotspot locations.

5 Synthesis of Feedback Collected from Questionnaires

5.1 Requirements Analysis - Aggregated Tables for All Phases

There were evaluated the functional requirements for SILVANUS Platform (for each phase A/B/C) by internal and external stakeholders. The classification of those requirements (must /should /could) was introduced in the sections related to each Pilot Site.

In the following sections, there are introduced the aggregated tables for all the phases (A/B/C) including their cross validation.

Please note that only requirements from pilots which have provided their inputs could be considered. Therefore, the statistics is not a representative statistic of all the SILVANUS pilots.

5.1.1 Table R1: Forest Landscape models

The information on the biodiversity richness available within the forest is an important factor. Despite the significance, there is a clear lack of existing tools and techniques that can be used as a baseline for the stakeholders to provide relevant requirements for the application.

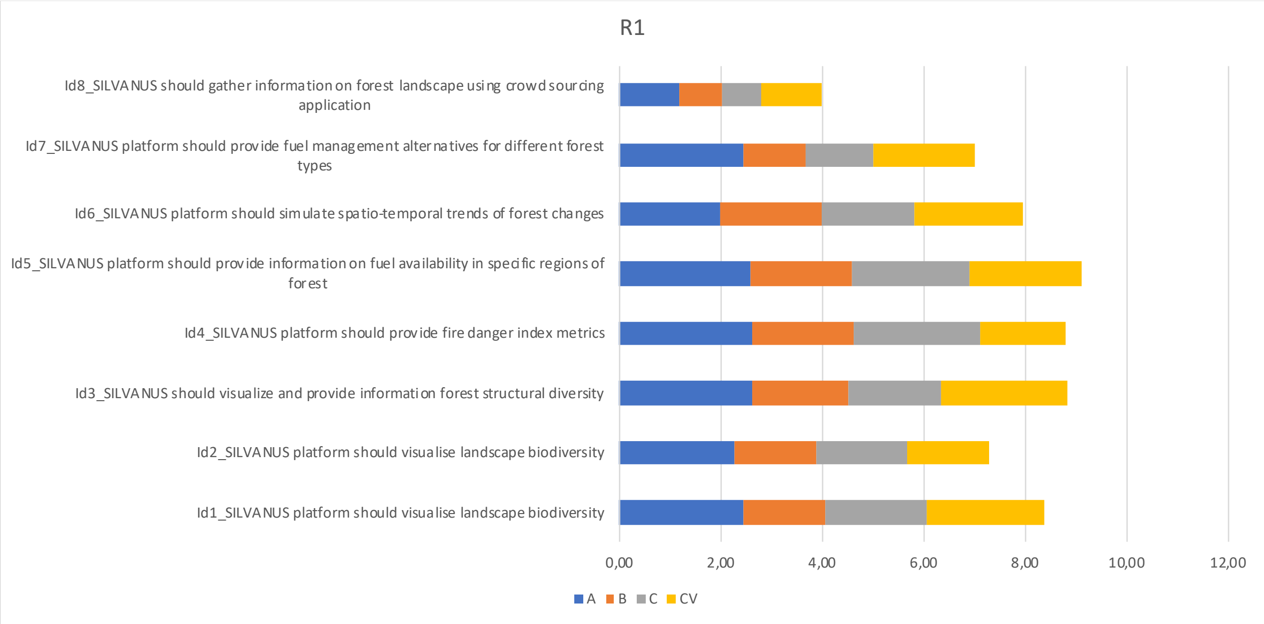

Figure 31 Table R1: Forest Landscape models

5.1.2 Table R2: Climate sensitive forest management

Following interactions with stakeholders and external project representatives (such as Firelinks, Fire-RES, FIREURISK and FireLogue), it is widely acknowledged that, there is a direct correlation between the impact of climate sensitivity on the forest management. The impact of environmental factors such as wind could play a key role in strategically designing how and where the first line of defence could be established that could prevent and/or mitigate the spread of fire. The knowledge that can be gained from using such insights have been accepted to play a key role in effectively combating against wildfires.

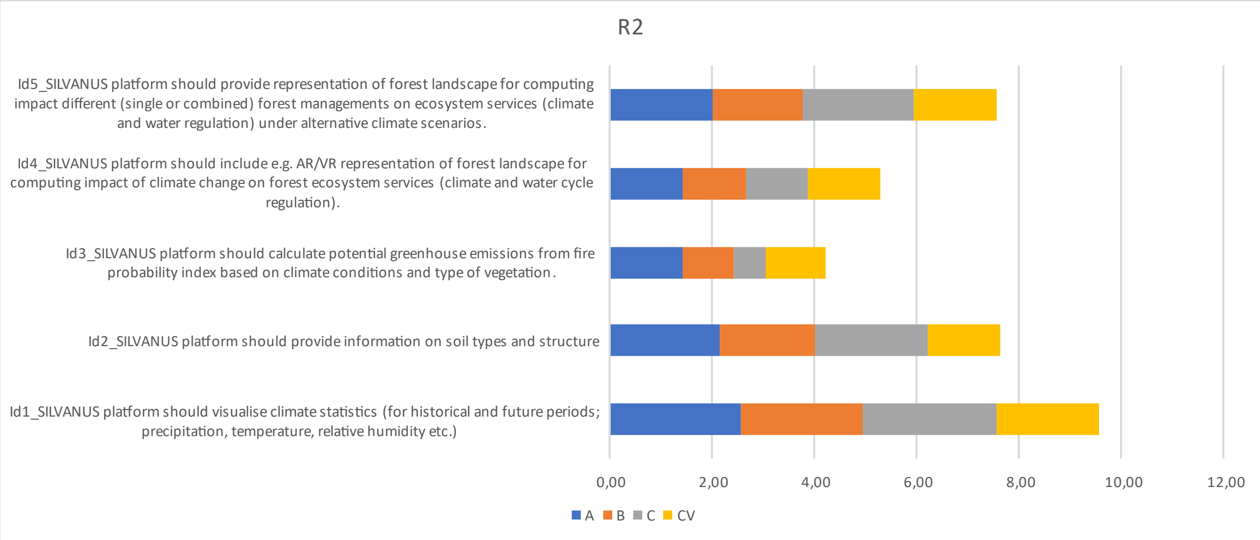

Figure 32 Table R2: Climate sensitive forest management

5.1.3 Table R3: Forest resilience models

Forest resilience against wildfires is an important research topic which has come under severe scrutiny among the conversationists in recent years. The definition of forest resilience is still under debate among the experts and one such interpretation includes the consumption rate of forest biomass fuel and the rate of combustion of different forest species. To effectively capture such information, it is important to model the biodiversity of the forest species, which extends beyond the natural growth of forest to include insect's species and other supported livelihood.

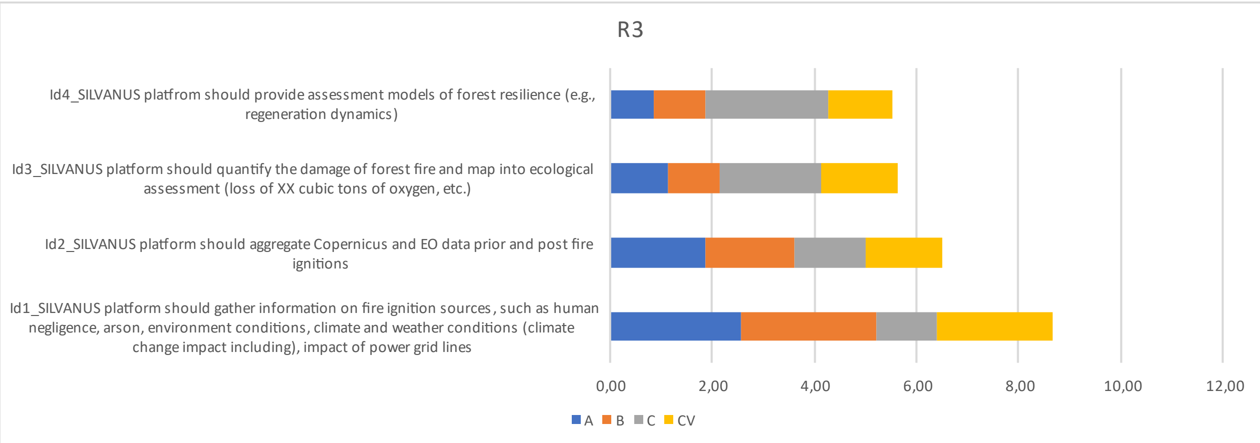

Figure 33 Table R3: Forest resilience models

5.1.4 Table R4: Forest fire ignition models

Fire ignition models have been studied in the literature based on historical case-studies. The six (6) causes of fire ignition cited by a white paper includes human negligence, natural causes, and others. Therefore, for each of these scenarios, it is important to develop representative models that would enable the determination of fire spread. It is widely acknowledged that the motivation of the fire ignition plays a significant role in the amount of fuel that would be used to cause the fire. As an example, the instance of human negligence would disproportionately include the fuel which is a result of an arson. Similarly, the strength and magnitude of fire caused by natural sources will also depend on the relevant causes.

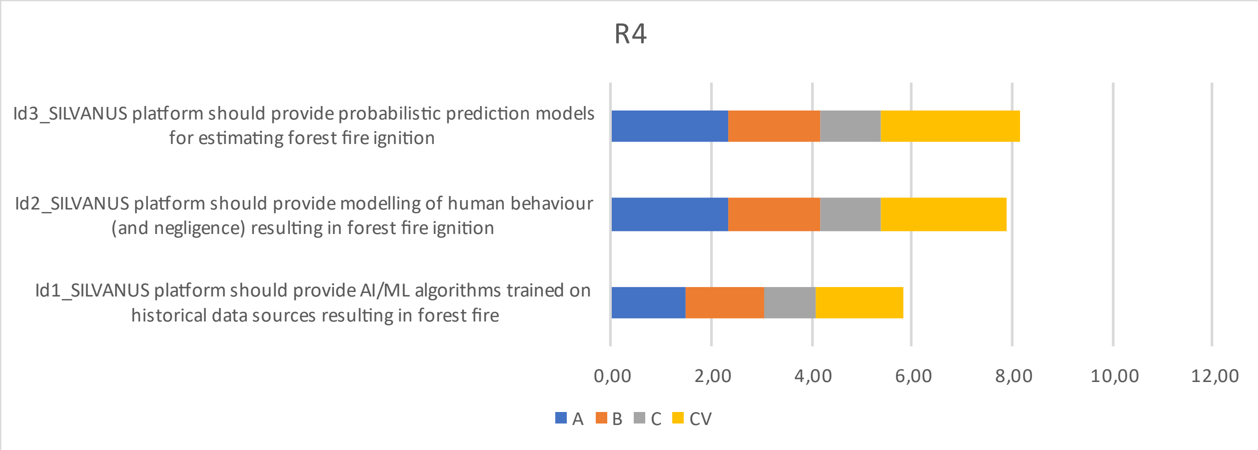

Figure 34 Table R4: Forest fire ignition models

5.1.5 *Table R5: Prevention methodologies*

Across the global community, it is widely acknowledged that prevention is better than post fire detection and mitigation. While several methodologies have been identified and reported in the literature, there still does not exist a unified methodology that brings tools and other services to promote fire safety among wider public and deliver intelligent training to the fire-fighters. Additionally, there still lacks systematic tools in implementing these methodologies. The scope of SILVANUS includes gathering requirements for addressing such shortcomings.

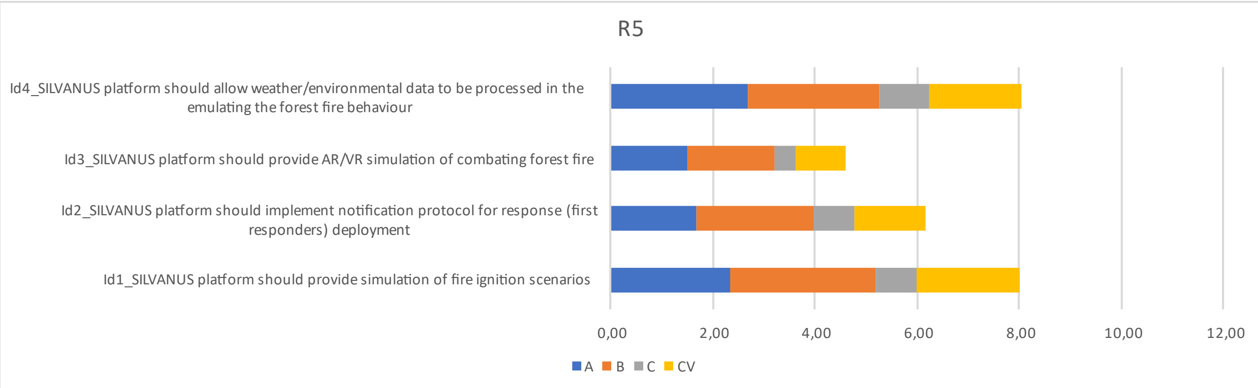

Figure 35 Table R5: Prevention methodologies

5.1.6 *Table R6: Citizen engagement and awareness programme*

As cited earlier, human negligence is often cited as a source of forest fire, which are ignited in regions of low probability and low levels of preparedness. Therefore, to mitigate against such threats, the citizen engagement programme within the project aims to develop a systematic approach in which specific methodologies and relevant tools would be developed that address the challenges of communicating fire safety to a wide group of European and Global citizens. The requirements identified for addressing citizen engagement aims to encompass a holistic overview of the various needs and requirements including culture, geographical area and other parameters.

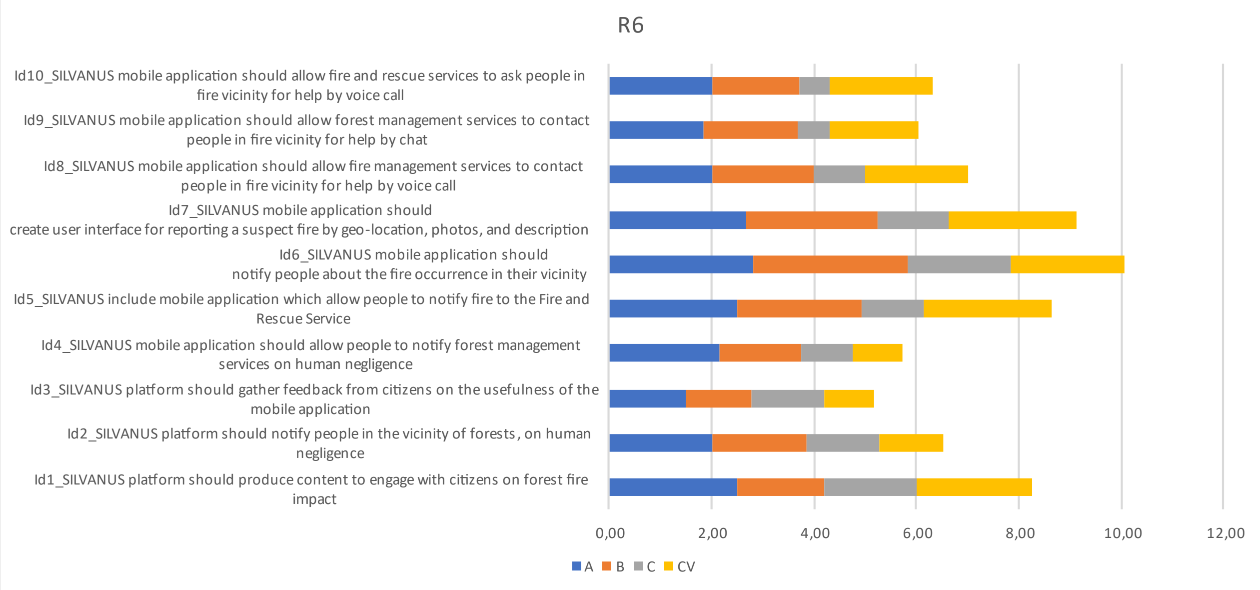

Figure 36 Table R6: Citizen engagement and awareness programme

5.1.7 Table R7: Tailored weather/climate models for forest fire threat/risk assessment

The threat of wildfire can be attributed to a wide range of parameters which are often complex and needs to be modelled using advanced ML and AI algorithms. As noted earlier, the impact of climate and weather data plays a crucial role in the ability of observe the threat level across a geographic region. To this end, the SILVANUS project has gathered relevant requirement on the overall modelling of the intelligent systems that could accurately predict the threat of wildfire and offer stakeholders an advance warning system towards improved forest maintenance.

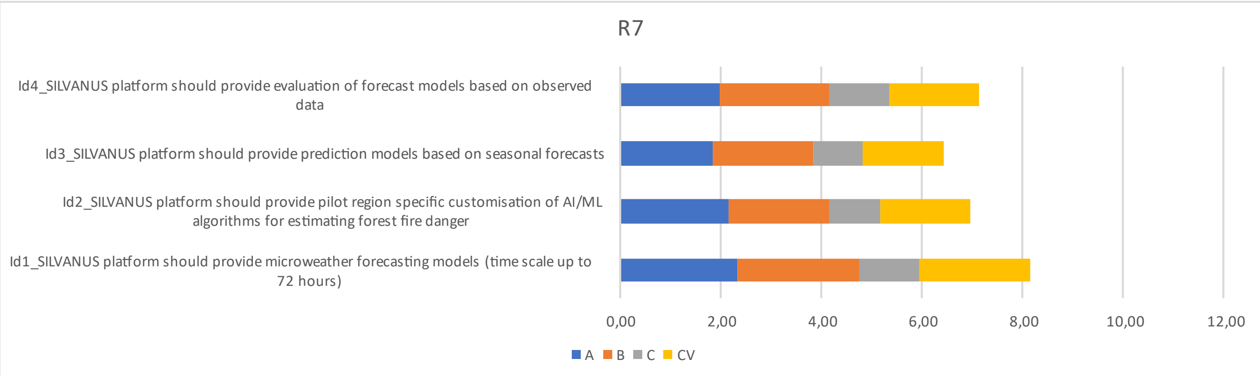

Figure 37 Table R7: Tailored weather/climate models for forest fire threat/risk assessment

5.1.8 Table R9: In-Situ data analytics

Following the user requirements aggregation process being completed it was observed that there is a critical lack of in-situ devices which are already installed and are available to collect relevant data from the field. In discussion with the stakeholders, it was identified that one of the biggest limitations of installing in-situ devices on the field relates to the lack of power supplies, upon which a large proportion of digital devices depend upon. Therefore, there is a general lack of awareness and ability to install and collect relevant data sources. Subsequently, it was agreed that within the scope of the project, appropriate field visits will be carried out to further enhance and enrich the knowledge on in-situ device installation capacity and bring forward relevant devices.

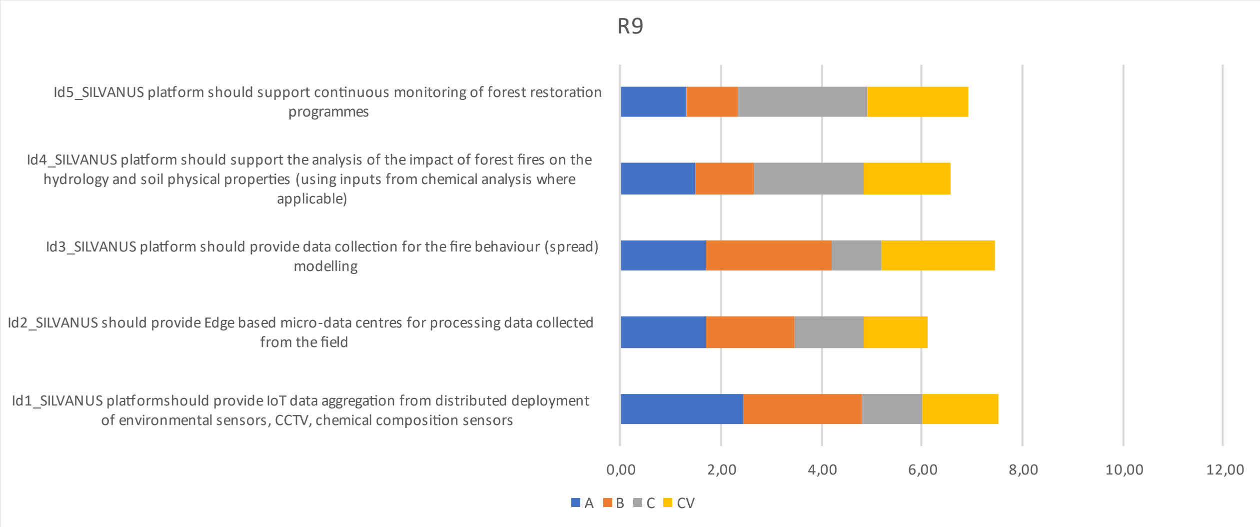

Figure 38 Table R9: In-Situ data analytics

5.1.9 *Table R10: Social sensing and conceptual extraction*

Social media has become a big part of our day-to-day life and visits to forest offers a great opportunity for the public to share and promote awareness on climate change, ecological balance, and biodiversity among relevant social groups. Therefore, if there is a fire being cited, crawling social media for such citing offers a unique advantage to the relevant firefighters and stakeholders to engage citizens as a first line of defence. To this end, the requirements collected within SILVANUS offers such a unique capability to detect such citing gathered from social media.

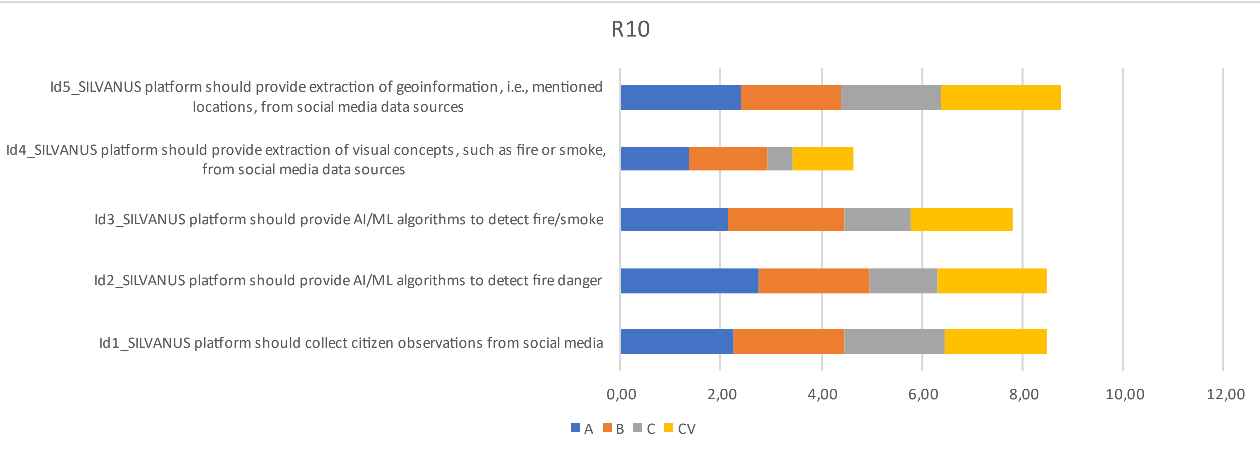

Figure 39 Table R10: Social sensing and conceptual extraction

5.1.10 *Table R11: UGV monitoring of wildfire behaviour*

The advancement in the field of robots and aerial vehicles have offered a unique opportunity to deploy these systems either autonomously or through pilots to be able to gather vital information from the wildfire front lines. To this end, UGVs and UAVs will be deployed to undertake surveillance and aid in the knowledge aggregation process to suitably supplement the relevant information which could be obtained from in-situ devices. Requirements from the stakeholders provides support to enhance the ability of data processing onboard.

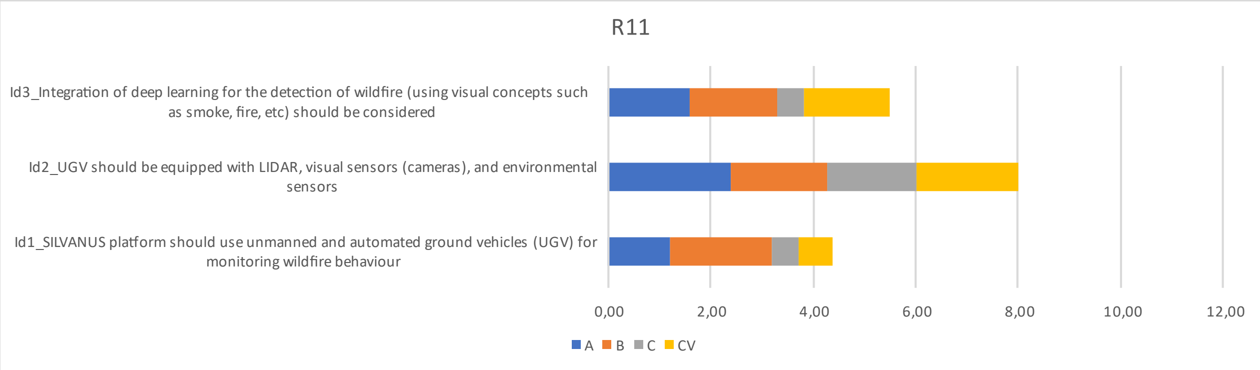

Figure 40 Table R11: UGV monitoring of wildfire behaviour

5.1.11 Table R12: UAVs deployment for remote sensing

UAVs offer the capacity to be deployed for conducting a large-scale aerial surveillance for detecting the boundaries of the wildfire, but also to detect any personnel and/or any manmade structures, which could be vulnerable to the spread of wildfire.

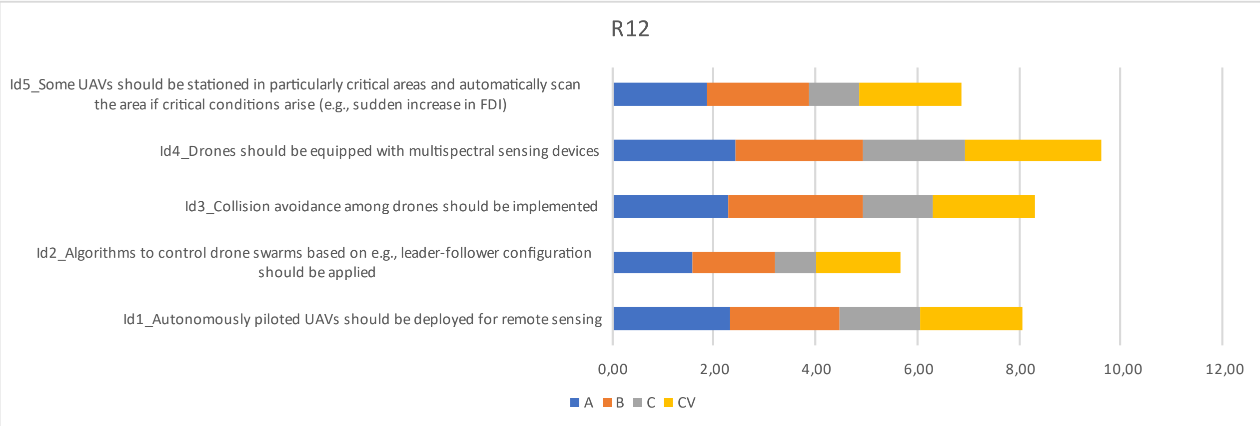

Figure 41 Table R12: UAVs deployment for remote sensing

5.1.12 Table R13: Earth observation data analytics

For gathering information on the overall state of forest at a macro scale, earth observation repositories provide a reliable source of information.

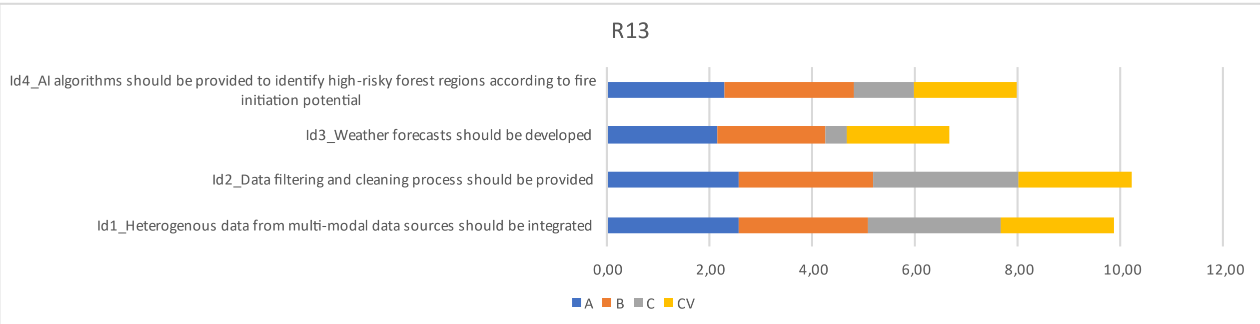

Figure 42 Table R13: Earth observation data analytics

5.1.13 Table R14: Situational awareness of fire danger index

Upon the detection of a fire ignition, the situational awareness of fire danger index should integrate relevant AI/ML algorithms that can demonstrate the potential fire spread across geographical regions. Such predictions should be evolved in time to aid in the process of accurate modelling across temporal scale, against the on-field data being collected.

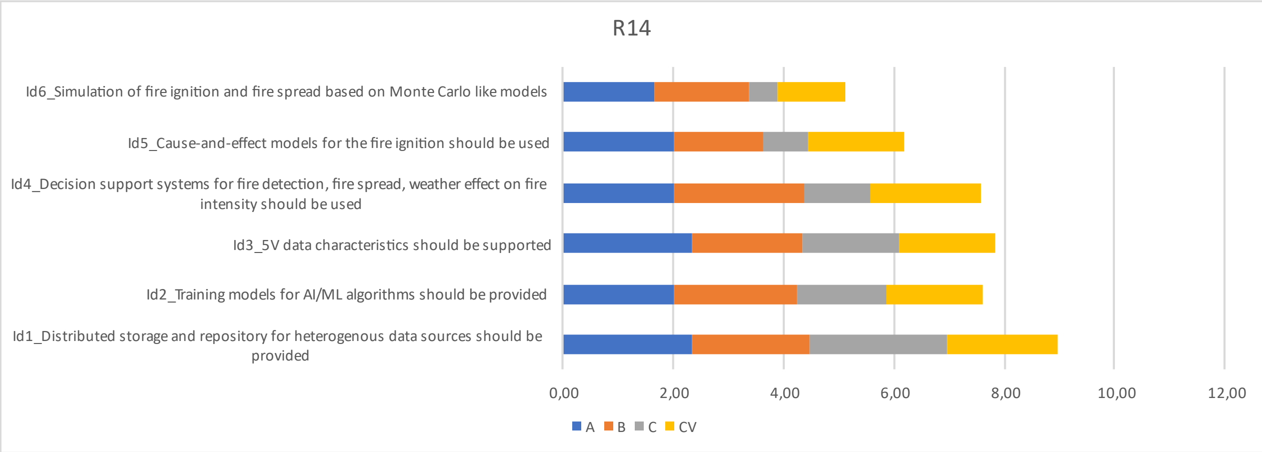

Figure 43 Table R14: Situational awareness of fire danger index

5.1.14 Table R15: Real-time monitoring of fire behaviour for response coordination

Monitoring of real-time spread of wildfire plays a crucial role in the determination of the fire spread. The use of cause-and-effects models and monte-carlo simulation on the fire datasets would be further evaluated in the scope of the project.

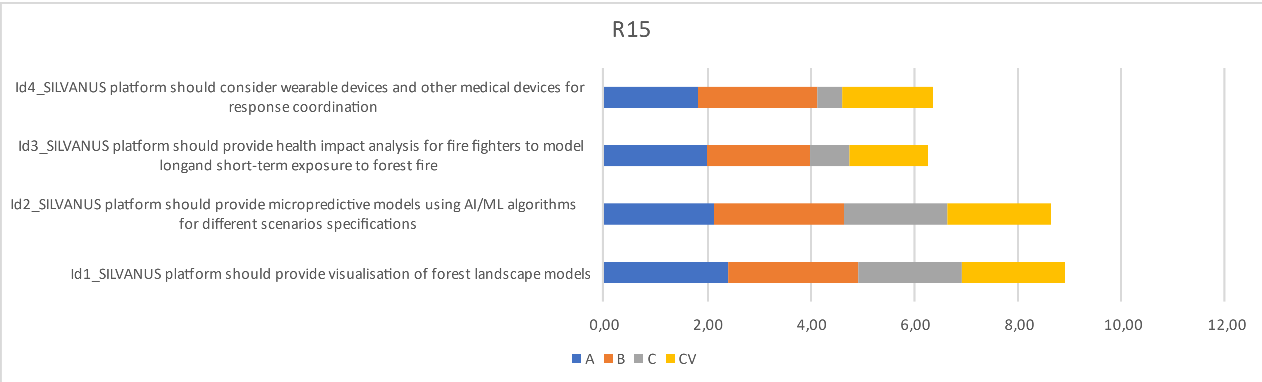

Figure 44 Table R15: Real-time monitoring of fire behaviour for response coordination

5.1.15 Table R16: Decision support systems for detecting and preventing forest fires and forest restoration

The outcome from the SILVANUS platform implementation is the decision support system for detecting and preventing forest fires. The requirements gathered will emulate real-world scenarios from the historical case-studies to demonstrate the effectiveness of the SILVANUS technological intervention.

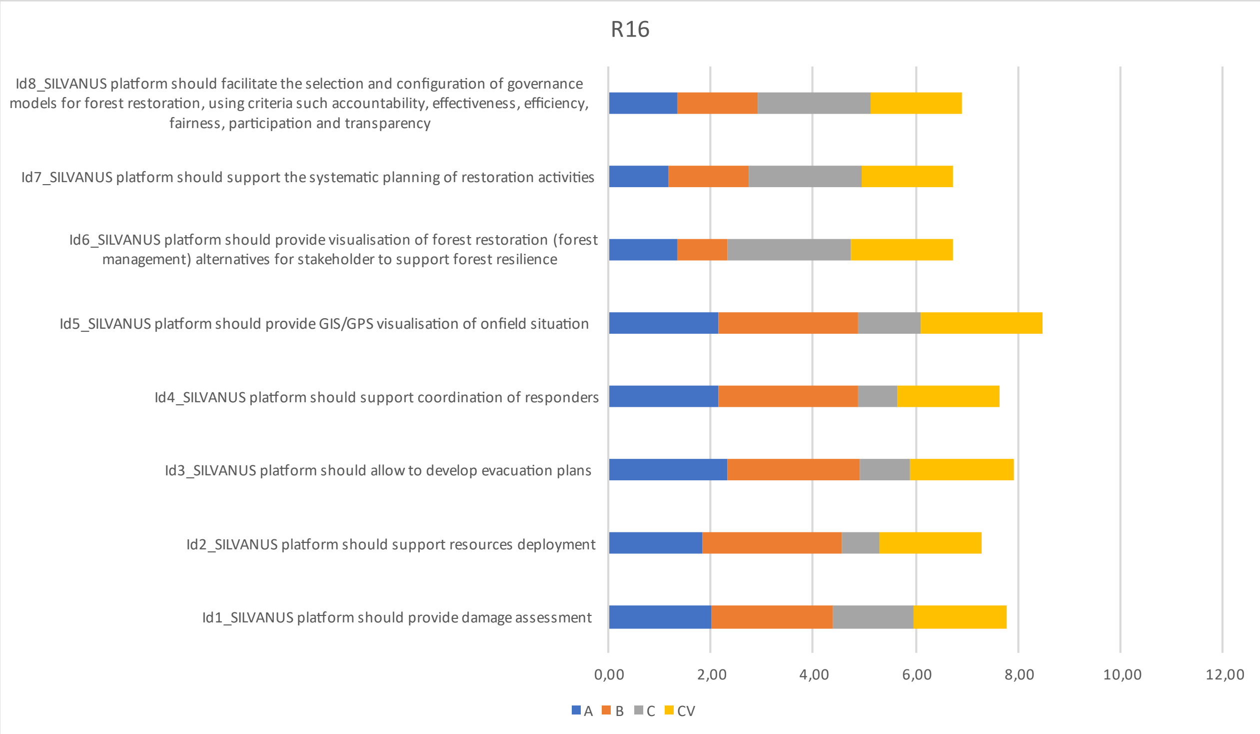

Figure 45 Table R16: Decision support systems for detecting and preventing forest fires and forest restoration

5.2 Requirements Analysis – Classification of Functional Requirements

There is further also introduced the functional requirements classification arising from their overall evaluation by stakeholders (altogether).

Functional requirements on SILVANUS Platform which **must be** included in **Phase A**:

- visualisation of landscape biodiversity,
- visualisation and providing information on forest structural diversity,
- providing fire danger index metrics,
- providing information on fuel availability in specific regions of forest,
- providing fuel management alternatives for different forest types,
- visualisation of climate statistics (for historical and future periods; precipitation, temperature, relative humidity etc.),
- gathering information on fire ignition sources, such as human negligence, arson, environment conditions, climate, and weather conditions (climate change impact including), impact of power grid lines,
- providing modelling of human behaviour (and negligence) resulting in forest fire ignition,
- providing probabilistic prediction models for estimating forest fire ignition,
- providing simulation of fire ignition scenarios,
- allowing weather/environmental data to be processed in the emulating the forest fire behaviour,
- producing content to engage with citizens on forest fire impact,
- including mobile application which allow people to notify fire to the Fire and Rescue Service,
- SILVANUS mobile application must notify people about the fire occurrence in their vicinity,
- SILVANUS mobile application must create user interface for reporting a suspect fire by geo-location, photos, and description,
- providing IoT data aggregation from distributed deployment of environmental sensors, CCTV, chemical composition sensors,
- providing AI/ML algorithms to detect fire danger,
- providing AI/ML algorithms to detect fire/smoke,

- providing extraction of geoinformation, i.e., mentioned locations, from social media data sources,
- UGV must be equipped with LIDAR, visual sensors (cameras), and environmental sensors,
- autonomously piloted UAVs must be deployed for remote sensing,
- collision avoidance among drones must be implemented,
- heterogenous data from multi-modal data sources must be integrated,
- data filtering and cleaning process must be provided,
- AI algorithms must be provided to identify high-risky forest regions according to fire initiation potential,
- distributed storage and repository for heterogenous data sources must be provided,
- 5V data characteristics must be supported,
- providing visualisation of forest landscape models,
- allowing to develop evacuation plans.

Functional requirements on SILVANUS Platform which **should be** included in **Phase A**:

- identifying areas/regions of historical significance,
- simulation of spatio-temporal trends of forest changes,
- providing information on soil types and structure,
- providing representation of forest landscape for computing impact different (single or combined) forest managements on ecosystem services (climate and water regulation) under alternative climate scenarios,
- aggregating Copernicus and EO data prior and post fire ignitions,
- providing AI/ML algorithms trained on historical data sources resulting in forest fire,
- implementing notification protocol for response (first responders) deployment,
- providing AR/VR simulation of combating forest fire,
- notifying people in the vicinity of forests, on human negligence,
- gathering feedback from citizens on the usefulness of the mobile application,
- allowing people to notify forest management services on human negligence,
- allowing fire management services to contact people in fire vicinity for help by voice call,
- SILVANUS mobile application should allow forest management services to contact people in fire vicinity for help by chat,
- SILVANUS mobile application should allow fire and rescue services to ask people in fire vicinity for help by voice call,
- providing micro-weather forecasting models (time scale up to 72 hours),
- providing pilot region specific customisation of AI/ML algorithms for estimating forest fire danger,
- providing prediction models based on seasonal forecasts,
- providing evaluation of forecast models based on observed data,
- providing Edge based micro-data centres for processing data collected from the field,
- providing data collection for the fire behaviour (spread) modelling,
- supporting the analysis of the impact of forest fires on the hydrology and soil physical properties (using inputs from chemical analysis where applicable),
- collecting citizen observations from social media,
- integration of deep learning for the detection of wildfire (using visual concepts such as smoke, fire, etc) should be considered,
- algorithms to control drone swarms based on e.g., leader-follower configuration should be applied
- some UAVs should be stationed in particularly critical areas and automatically scan the area if critical conditions arise (e.g., sudden increase in FDI),
- weather forecasts should be developed,
- training models for AI/ML algorithms should be provided,

- decision support systems for fire detection, fire spread, weather effect on fire intensity should be used,
- cause-and-effect models for the fire ignition should be used,
- simulation of fire ignition and fire spread based on Monte Carlo like models,
- providing micro-predictive models using AI/ML algorithms for different scenarios specifications,
- providing health impact analysis for fire fighters to model long- and short-term exposure to forest fire,
- providing damage assessment,
- supporting resources deployment,
- supporting coordination of responders,
- providing GIS/GPS visualisation of on-field situation.

Functional requirements on SILVANUS Platform which **could be** included in **Phase A**:

- gathering information on forest landscape using crowd sourcing applications,
- calculation of potential greenhouse emissions from fire probability index based on climate conditions and type of vegetation.
- including, e.g. AR/VR representation of forest landscape for computing impact of climate change on forest ecosystem services (climate and water cycle regulation),
- quantifying the damage of forest fire and map into ecological assessment (loss of XX cubic tons of oxygen, etc.),
- providing assessment models of forest resilience (e.g., regeneration dynamics),
- supporting continuous monitoring of forest restoration programmes,
- providing extraction of visual concepts, such as fire or smoke, from social media data sources,
- using unmanned and automated ground vehicles (UGV) for monitoring wildfire behaviour,
- considering wearable devices and other medical devices for response coordination,
- providing visualisation of forest restoration (forest management) alternatives for stakeholder to support forest resilience,
- supporting the systematic planning of restoration activities,
- facilitating the selection and configuration of governance models for forest restoration, using criteria such accountability, effectiveness, efficiency, fairness, participation, and transparency.

Functional requirements on SILVANUS Platform which **must be** included in **Phase B**:

- visualisation of climate statistics (for historical and future periods; precipitation, temperature, relative humidity etc.),
- gathering information on fire ignition sources, such as human negligence, arson, environment conditions, climate, and weather conditions (climate change impact including), impact of power grid lines,
- providing simulation of fire ignition scenarios,
- implementing notification protocol for response (first responders) deployment,
- allowing weather/environmental data to be processed in the emulating the forest fire behaviour,
- including mobile application which allow people to notify fire to the Fire and Rescue Service,
- SILVANUS mobile application must notify people about the fire occurrence in their vicinity,
- SILVANUS mobile application must create user interface for reporting a suspect fire by geo-location, photos, and description,
- providing micro-weather forecasting models (time scale up to 72 hours),
- providing evaluation of forecast models based on observed data,
- providing IoT data aggregation from distributed deployment of environmental sensors, CCTV, chemical composition sensors,

- providing data collection for the fire behaviour (spread) modelling,
- providing AI/ML algorithms to detect fire danger,
- providing AI/ML algorithms to detect fire/smoke,
- collision avoidance among drones must be implemented,
- drones must be equipped with multi-spectral sensing devices,
- heterogenous data from multi-modal data sources must be integrated,
- data filtering and cleaning process must be provided,
- AI algorithms must be provided to identify high-risky forest regions according to fire initiation potential,
- training models for AI/ML algorithms must be provided,
- decision support systems for fire detection, fire spread, weather effect on fire intensity must be used,
- providing visualisation of forest landscape models,
- providing micro-predictive models using AI/ML algorithms for different scenarios specifications,
- providing health impact analysis for fire fighters to model long- and short-term exposure to forest fire,
- considering wearable devices and other medical devices for response coordination,
- providing damage assessment,
- supporting resources deployment,
- allowing to develop evacuation plans,
- supporting coordination of responders,
- providing GIS/GPS visualisation of on-field situation.

Functional requirements on SILVANUS Platform which **should be** included in **Phase B**:

- visualisation landscape biodiversity,
- visualisation and provide information forest structural diversity,
- providing fire danger index metrics,
- providing information on fuel availability in specific regions of forest,
- simulation of spatio-temporal trends of forest changes,
- providing information on soil types and structure,
- providing representation of forest landscape for computing impact different (single or combined) forest managements on ecosystem services (climate and water regulation) under alternative climate scenarios,
- aggregation of Copernicus and EO data prior and post fire ignitions,
- providing AI/ML algorithms trained on historical data sources resulting in forest fire,
- providing modelling of human behaviour (and negligence) resulting in forest fire ignition,
- providing probabilistic prediction models for estimating forest fire ignition,
- providing AR/VR simulation of combating forest fire,
- producing content to engage with citizens on forest fire impact,
- notifying people in the vicinity of forests, on human negligence,
- SILVANUS mobile application should allow people to notify forest management services on human negligence,
- SILVANUS mobile application should allow fire management services to contact people in fire vicinity for help by voice call,
- SILVANUS mobile application should allow forest management services to contact people in fire vicinity for help by chat,

- SILVANUS mobile application should allow fire and rescue services to ask people in fire vicinity for help by voice call,
- providing e pilot region specific customisation of AI/ML algorithms for estimating forest fire danger,
- providing prediction models based on seasonal forecasts,
- providing Edge based micro-data centres for processing data collected from the field,
- collecting citizen observations from social media,
- providing extraction of visual concepts, such as fire or smoke, from social media data sources,
- providing extraction of geoinformation, i.e., mentioned locations, from social media data sources,
- using unmanned and automated ground vehicles (UGV) for monitoring wildfire behaviour,
- UGV should be equipped with LIDAR, visual sensors (cameras), and environmental sensors,
- integration of deep learning for the detection of wildfire (using visual concepts such as smoke, fire, etc) should be considered,
- autonomously piloted UAVs should be deployed for remote sensing,
- algorithms to control drone swarms based on e.g., leader-follower configuration should be applied,
- some UAVs should be stationed in particularly critical areas and automatically scan the area if critical conditions arise (e.g., sudden increase in FDI),
- weather forecasts should be developed,
- distributed storage and repository for heterogenous data sources should be provided,
- 5V data characteristics should be supported,
- cause-and-effect models for the fire ignition should be used,
- simulation of fire ignition and fire spread based on Monte Carlo like models,
- providing health impact analysis for fire fighters to model long- and short-term exposure to forest fire.

Functional requirements on SILVANUS Platform which **could be** included in **Phase B**:

- identifying areas/regions of historical significance,
- providing fuel management alternatives for different forest types,
- gathering information on forest landscape using crowd sourcing applications,
- calculation of potential greenhouse emissions from fire probability index based on climate conditions and type of vegetation,
- including, e.g. AR/VR representation of forest landscape for computing impact of climate change on forest ecosystem services (climate and water cycle regulation),
- quantifying the damage of forest fire and map into ecological assessment (loss of XX cubic tons of oxygen, etc.),
- providing assessment models of forest resilience (e.g., regeneration dynamics),
- gathering feedback from citizens on the usefulness of the mobile application,
- supporting the analysis of the impact of forest fires on the hydrology and soil physical properties (using inputs from chemical analysis where applicable),
- supporting continuous monitoring of forest restoration programmes,
- providing visualisation of forest restoration (forest management) alternatives for stakeholder to supporting forest resilience,
- supporting the systematic planning of restoration activities,
- facilitating the selection and configuration of governance models for forest restoration, using criteria such accountability, effectiveness, efficiency, fairness, participation and transparency.

Functional requirements on SILVANUS Platform which **must be** included in **Phase C**:

- visualisation of landscape biodiversity,
- visualisation and providing information on forest structural diversity,

- providing information on fuel availability in specific regions of forest,
- visualisation of climate statistics (for historical and future periods; precipitation, temperature, relative humidity etc.),
- providing assessment models of forest resilience (e.g., regeneration dynamics),
- supporting continuous monitoring of forest restoration programmes,
- heterogenous data from multi-modal data sources must be integrated,
- data filtering and cleaning process must be provided,
- providing visualisation of forest landscape models,
- providing visualisation of forest restoration (forest management) alternatives for stakeholder to support forest resilience.

Functional requirements on SILVANUS Platform which **should be** included in **Phase C**:

- identifying areas/regions of historical significance,
- providing fire danger index metrics,
- simulation of spatio-temporal trends of forest changes,
- providing information on soil types and structure,
- providing representation of forest landscape for computing impact different (single or combined) forest managements on ecosystem services (climate and water regulation) under alternative climate scenarios,
- quantifying the damage of forest fire and map into ecological assessment (loss of XX cubic tons of oxygen, etc.),
- producing content to engage with citizens on forest fire impact,
- including mobile application which allow people to notify fire to the Fire and Rescue Service,
- SILVANUS mobile application should notify people about the fire occurrence in their vicinity,
- supporting the analysis of the impact of forest fires on the hydrology and soil physical properties (using inputs from chemical analysis where applicable),
- collect citizen observations from social media,
- providing AI/ML algorithms to detect fire danger,
- providing AI/ML algorithms to detect fire/smoke,
- providing extraction of geoinformation, i.e., mentioned locations, from social media data sources,
- UGV should be equipped with LIDAR, visual sensors (cameras), and environmental sensors,
- autonomously piloted UAVs should be deployed for remote sensing,
- drones should be equipped with multi-spectral sensing devices,
- distributed storage and repository for heterogenous data sources should be provided,
- training models for AI/ML algorithms should be provided,
- 5V data characteristics should be supported,
- providing micro-predictive models using AI/ML algorithms for different scenarios specifications,
- providing damage assessment,
- supporting the systematic planning of restoration activities,
- facilitating the selection and configuration of governance models for forest restoration, using criteria such accountability, effectiveness, efficiency, fairness, participation and transparency.

Functional requirements on SILVANUS Platform which **could be** included in **Phase C**:

- providing fuel management alternatives for different forest types,
- gathering information on forest landscape using crowd sourcing applications,
- including, e.g. AR/VR representation of forest landscape for computing impact of climate change on forest ecosystem services (climate and water cycle regulation),

- gathering information on fire ignition sources, such as human negligence, arson, environment conditions, climate and weather conditions (climate change impact including), impact of power grid lines,
- aggregation of Copernicus and EO data prior and post fire ignitions,
- providing AI/ML algorithms trained on historical data sources resulting in forest fire,
- providing modelling of human behaviour (and negligence) resulting in forest fire ignition,
- providing probabilistic prediction models for estimating forest fire ignition,
- SILVANUS platform could provide simulation of fire ignition scenarios,
- implementing notification protocol for response (first responders) deployment,
- allowing weather/environmental data to be processed in the emulating the forest fire behaviour,
- notifying people in the vicinity of forests, on human negligence,
- gathering feedback from citizens on the usefulness of the mobile application,
- SILVANUS mobile application could allow people to notify forest management services on human negligence,
- SILVANUS mobile application could create user interface for reporting a suspect fire by geo-location, photos, and description,
- SILVANUS mobile application could allow fire management services to contact people in fire vicinity for help by voice call,
- SILVANUS mobile application could allow forest management services to contact people in fire vicinity for help by chat,
- SILVANUS mobile application could allow fire and rescue services to ask people in fire vicinity for help by voice call,
- providing micro-weather forecasting models (time scale up to 72 hours),
- providing pilot region specific customisation of AI/ML algorithms for estimating forest fire danger,
- providing prediction models based on seasonal forecasts,
- providing evaluation of forecast models based on observed data,
- providing IoT data aggregation from distributed deployment of environmental sensors, CCTV, chemical composition sensors,
- providing Edge based micro-data centres for processing data collected from the field,
- providing data collection for the fire behaviour (spread) modelling,
- algorithms to control drone swarms based on e.g., leader-follower configuration could be applied,
- collision avoidance among drones could be implemented,
- some UAVs could be stationed in particularly critical areas and automatically scan the area if critical conditions arise (e.g., sudden increase in FDI),
- AI algorithms could be provided to identify high-risky forest regions according to fire initiation potential,
- decision support systems for fire detection, fire spread, weather effect on fire intensity could be used,
- cause-and-effect models for the fire ignition could be used,
- providing health impact analysis for fire fighters to model long- and short-term exposure to forest fire,
- supporting resources deployment,
- allowing to develop evacuation plans,
- supporting coordination of responders,
- providing GIS/GPS visualisation of on-field situation.

6 Validation of requirements

The functional requirements were validated by the external stakeholders and interdisciplinary experts.

Validation of functional requirements was provided by 6 validators, stakeholders representing foresters (2), firefighters and fire engineering experts (3) and civil protection experts (2) - totally 7 persons.

For validation the same R Tables were used to be filled and used for validation of functional requirements evaluated by the internal and external stakeholders within the Task 2.1 and T 2.2.

There are introduced the results of validation providing summarized information for each R Table.

6.1 Validation of functional requirements on SILVANUS Platform according to validators decision

There are introduced results of validation of a group of validators for each R Table in graphical form.

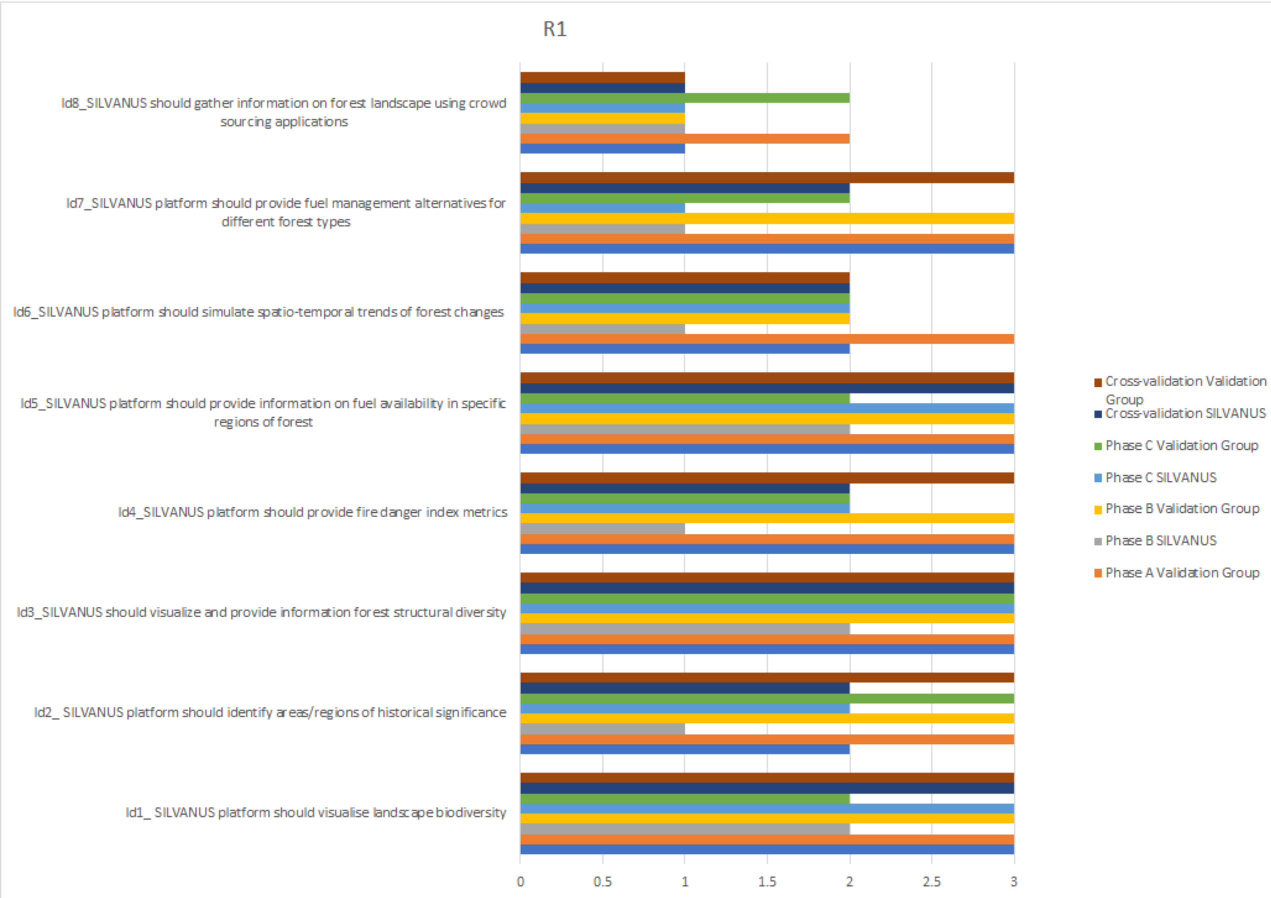

Figure 46 Table R1 Forest Landscape models - validation

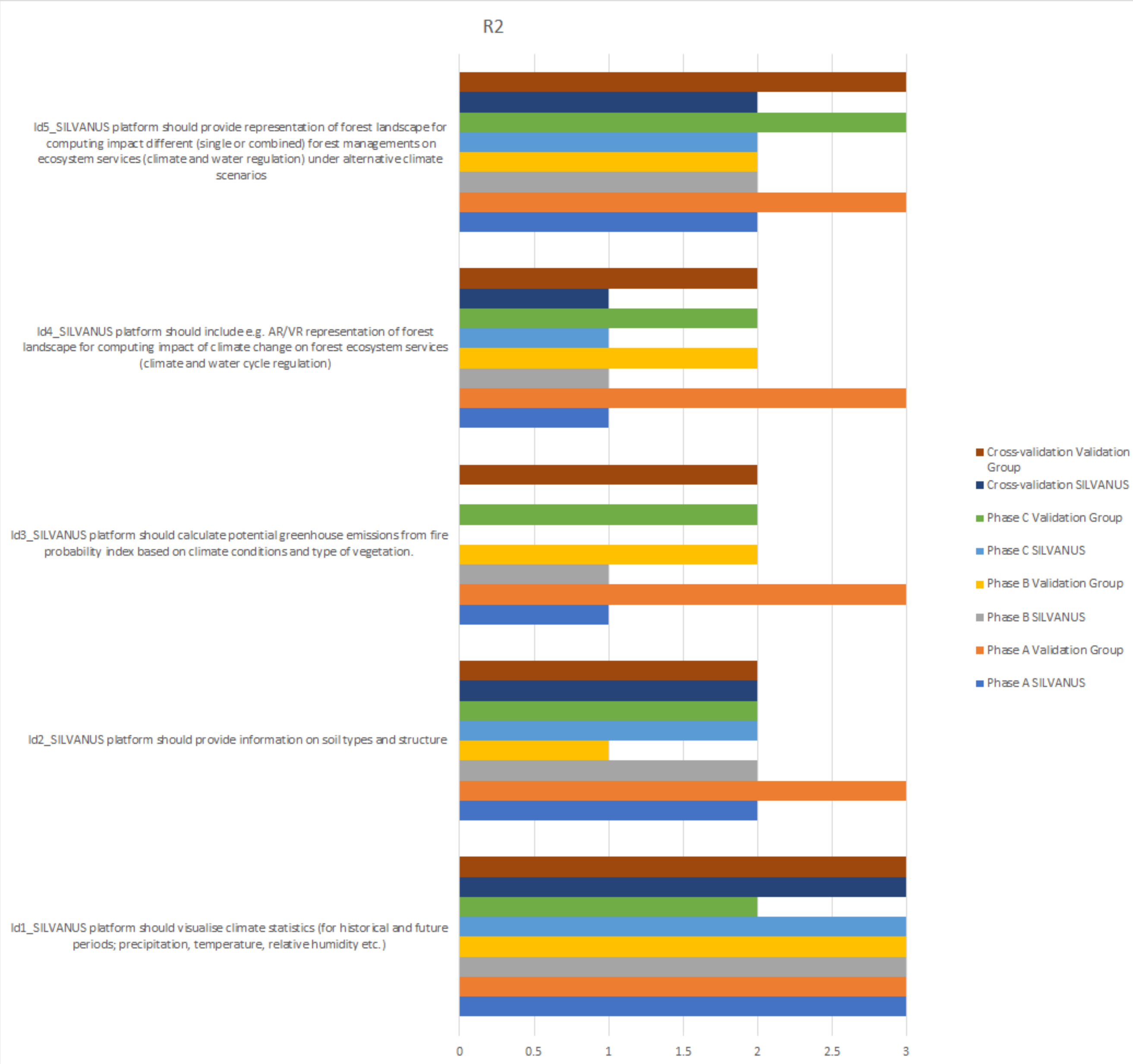

Figure 47 Table R2 Climate sensitive forest management - validation

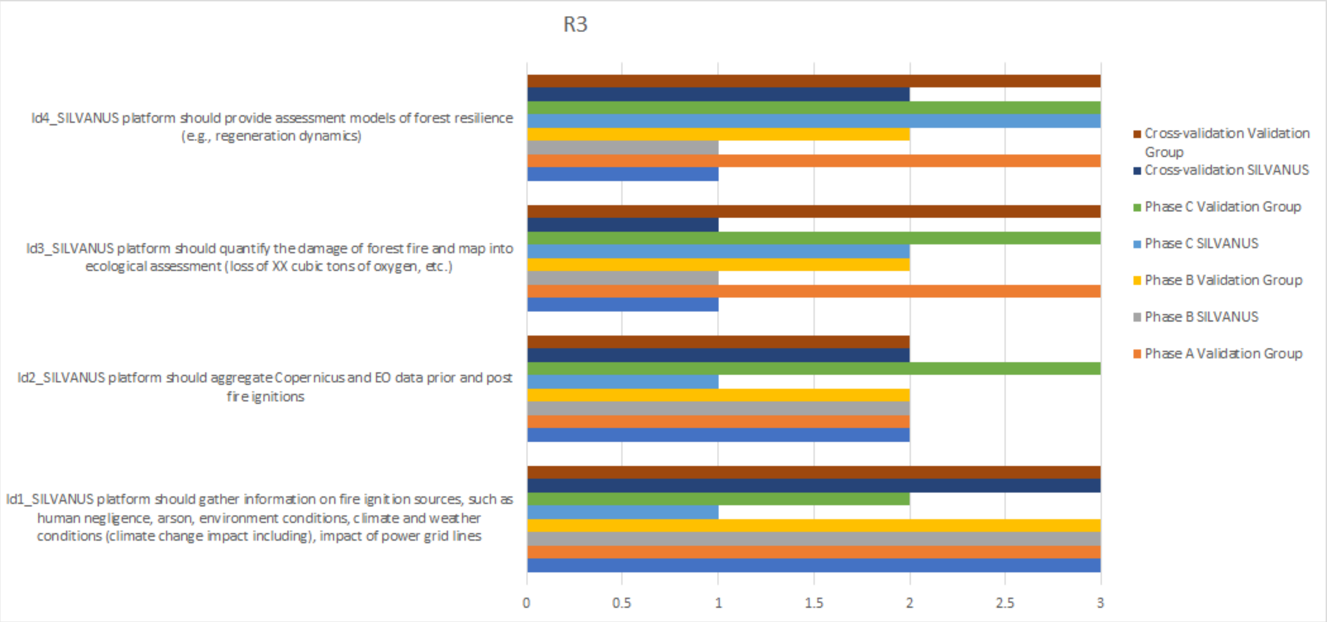

Figure 48 Table R3 Forest resilience models - validation

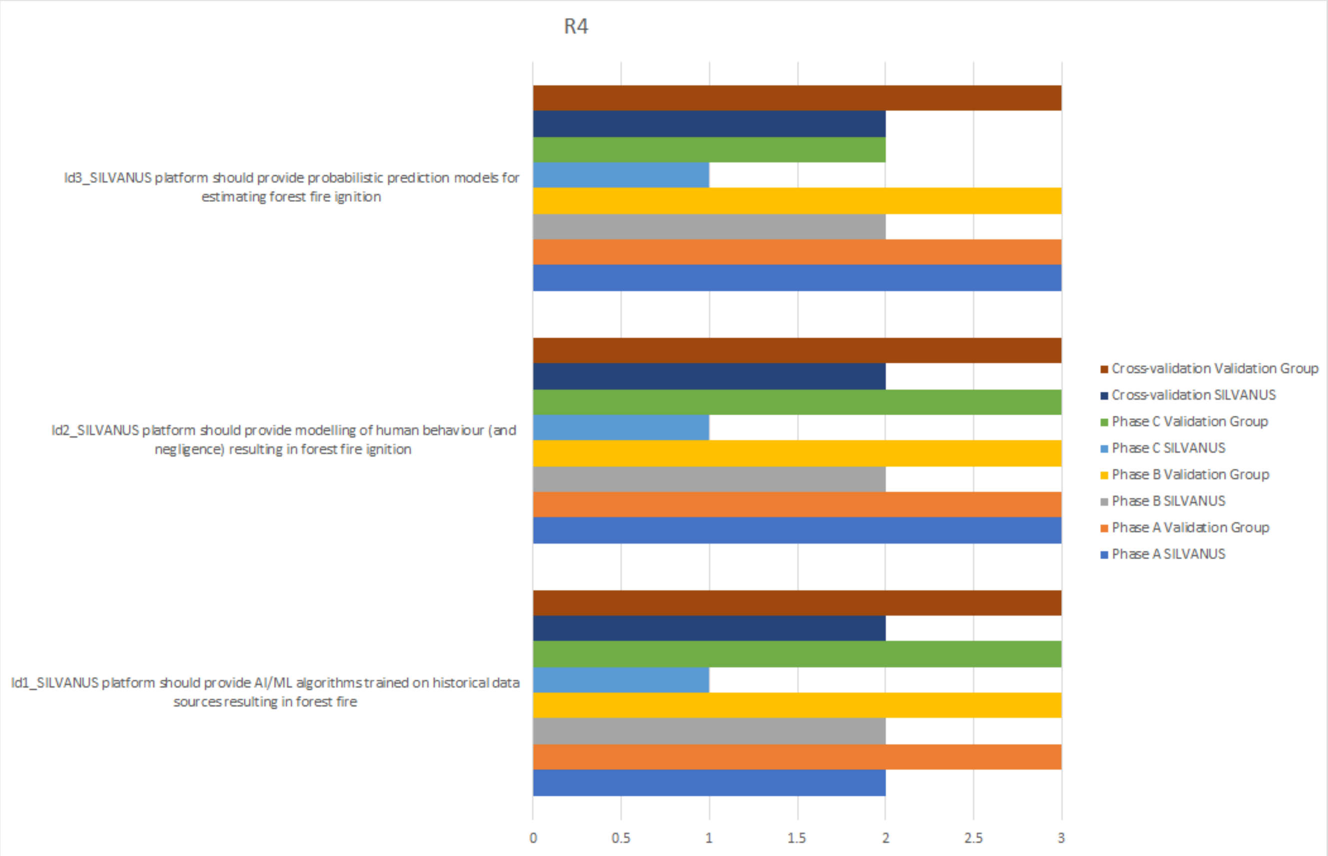

Figure 49 Table R4 Forest fire ignition models - validation

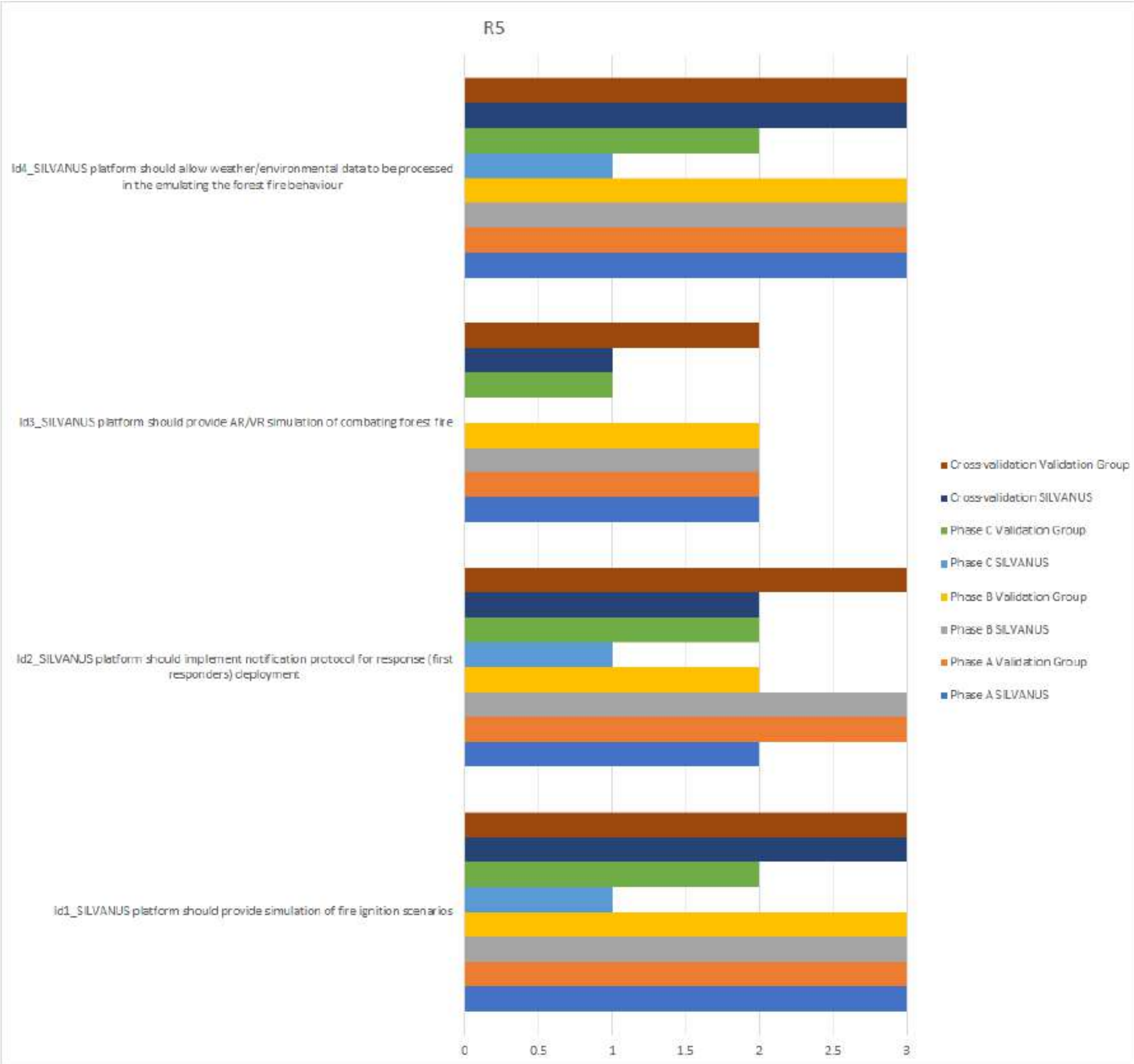

Figure 50 Table R5 Prevention methodologies - validation

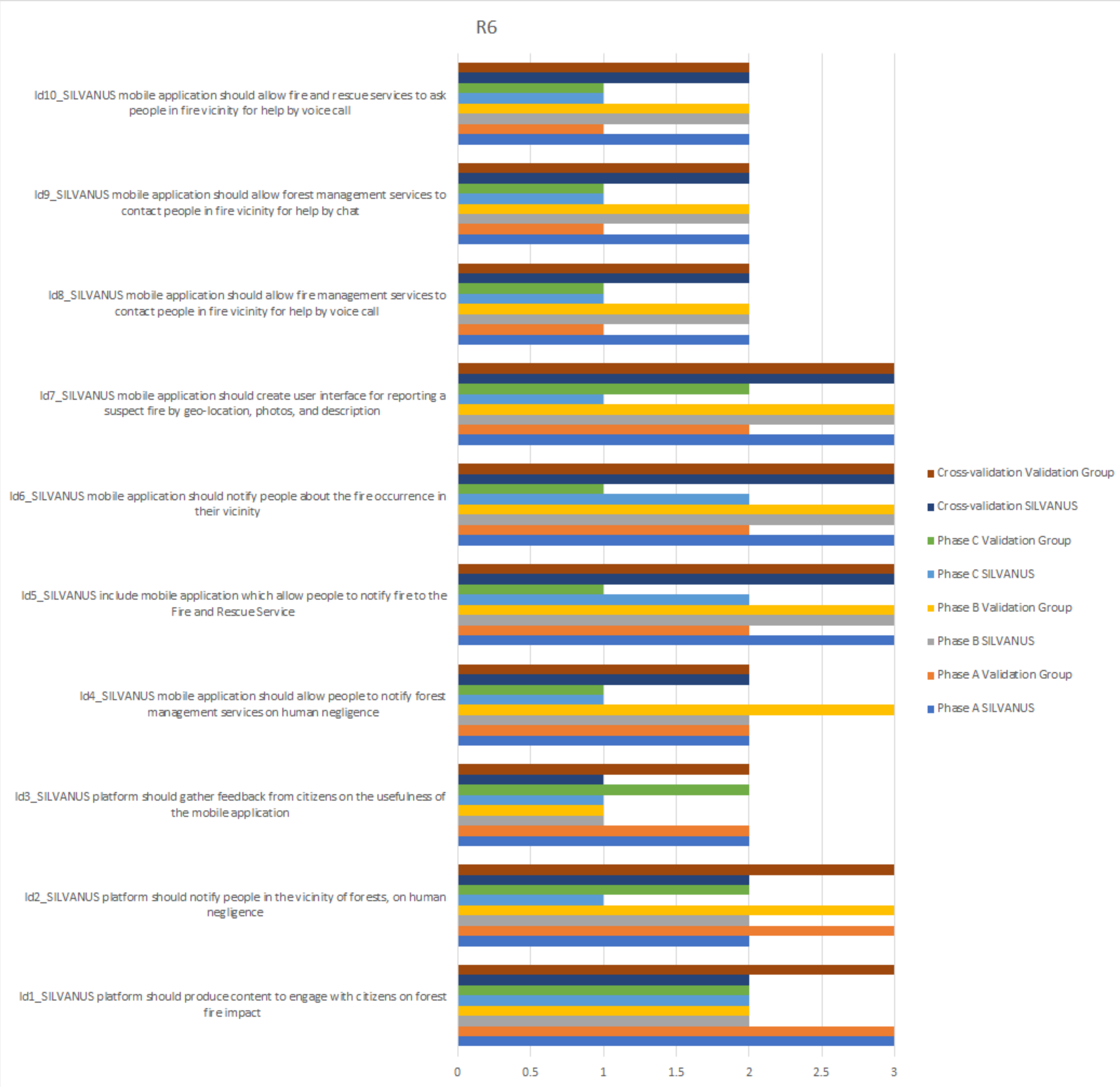

Figure 51 Table R6 Citizen engagement and awareness programme - validation

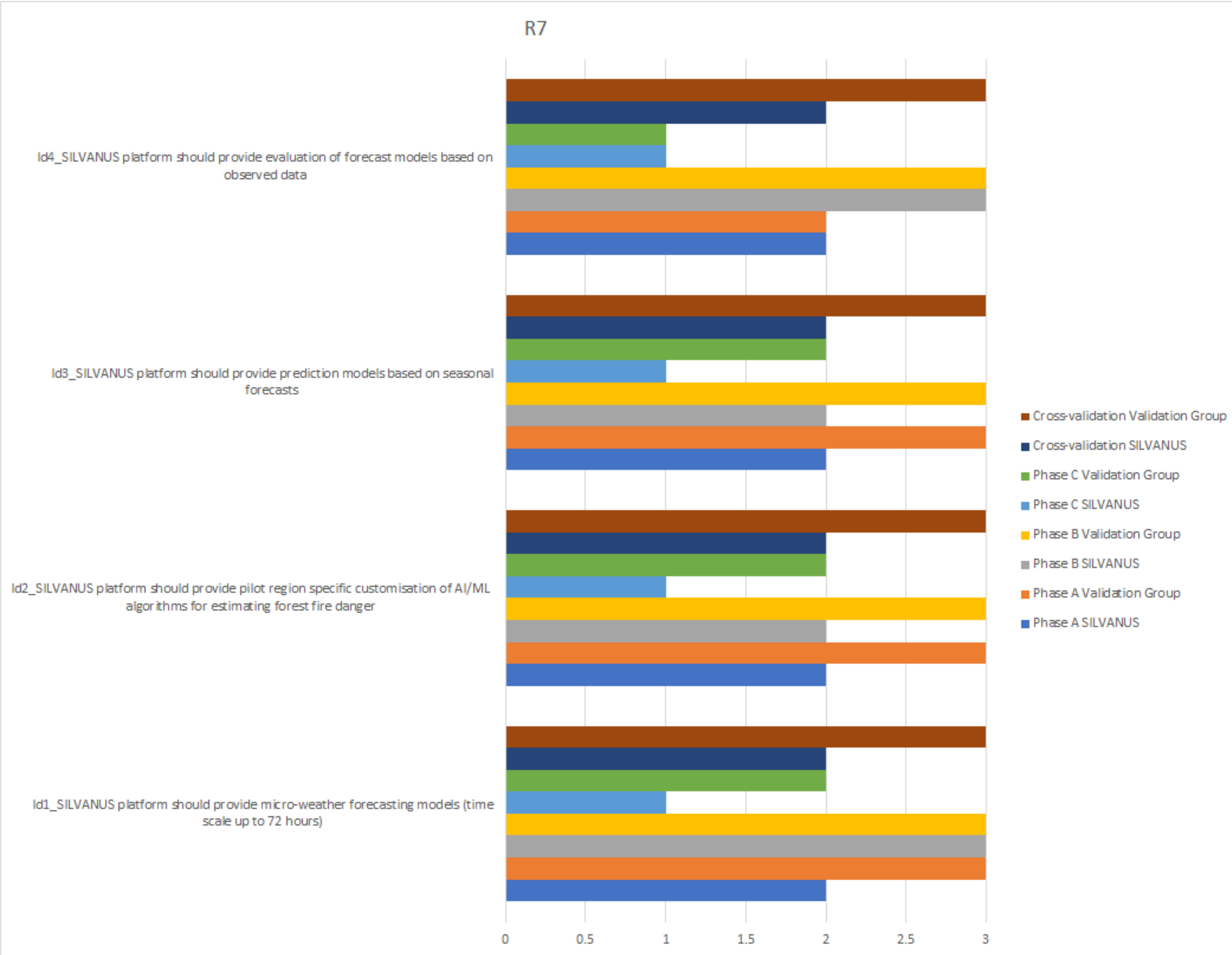

Figure 52 Table R7 Tailored weather/climate models for forest fire threat/risk assessment - validation

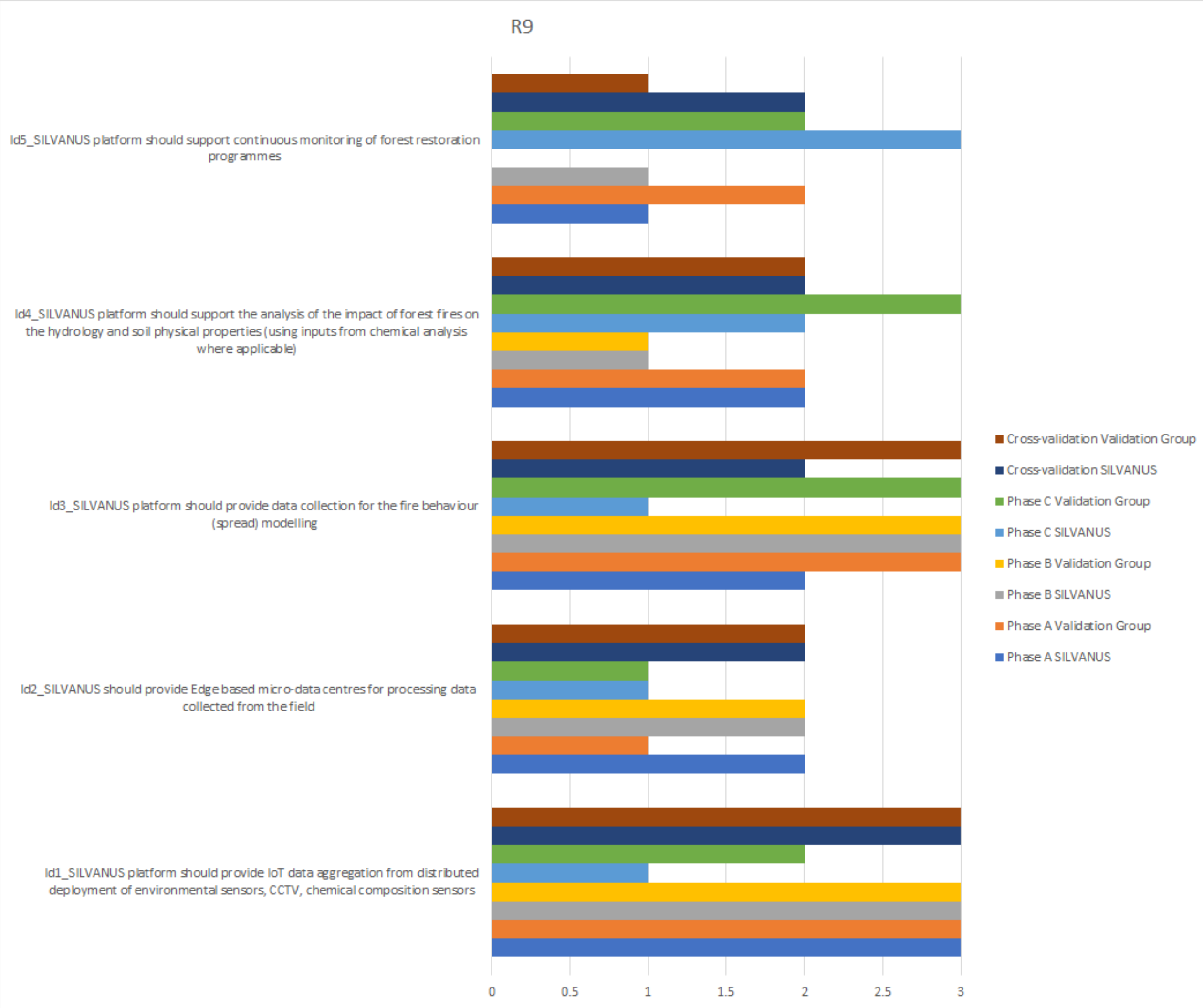

Figure 53 Table R9 Social sensing and conceptual extraction - validation

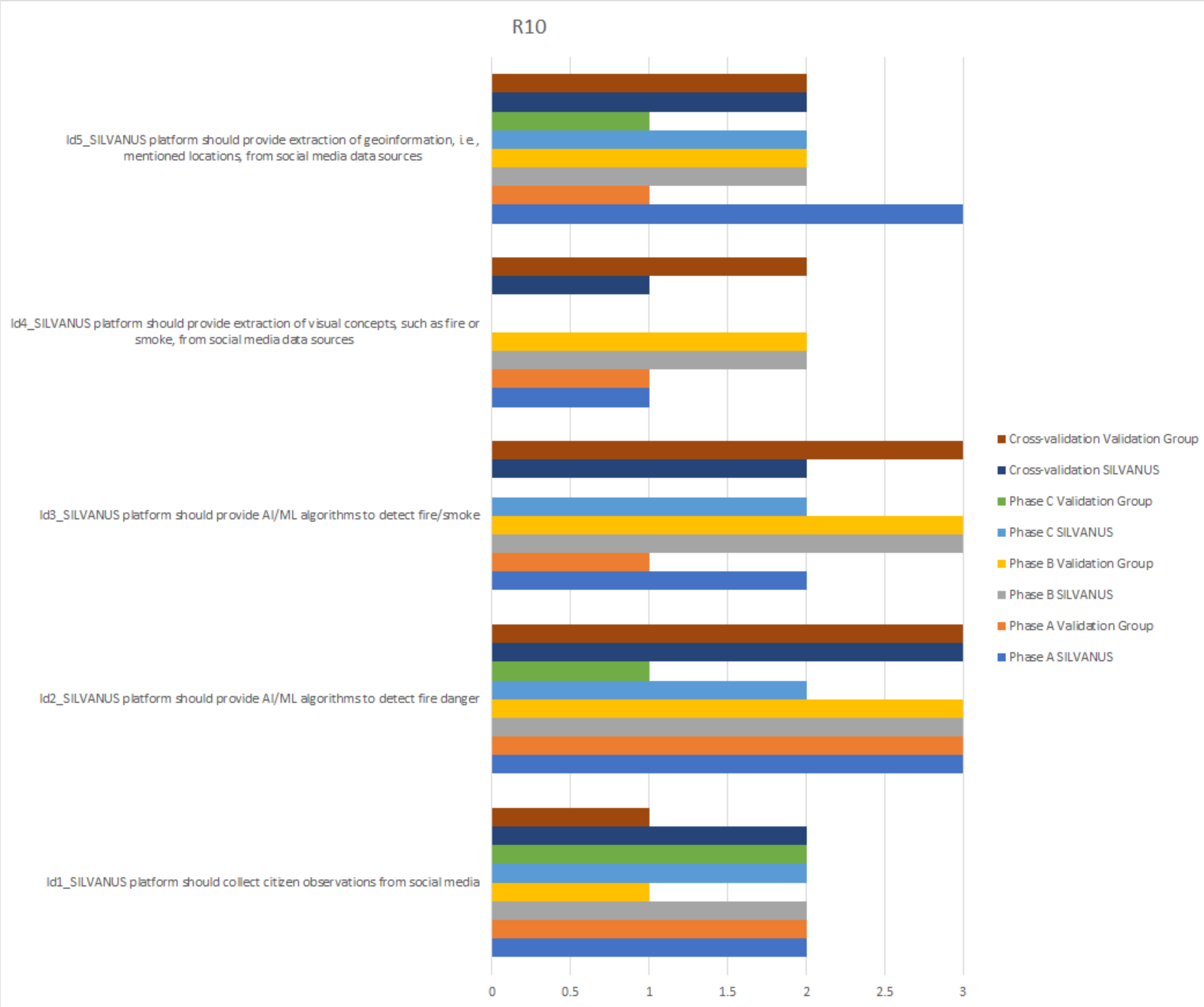

Figure 54 Table R10 UGV monitoring of wildfire behaviour - validation

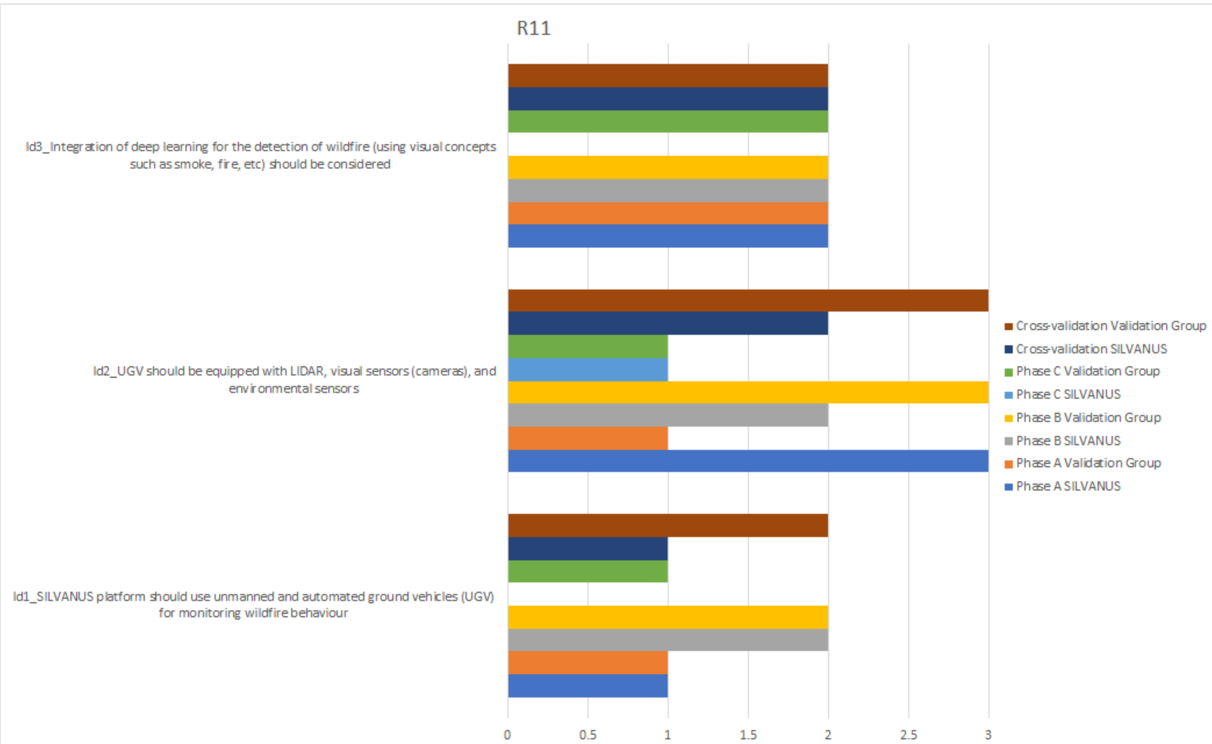

Figure 55 Table R11 UAVs deployment for remote sensing - validation

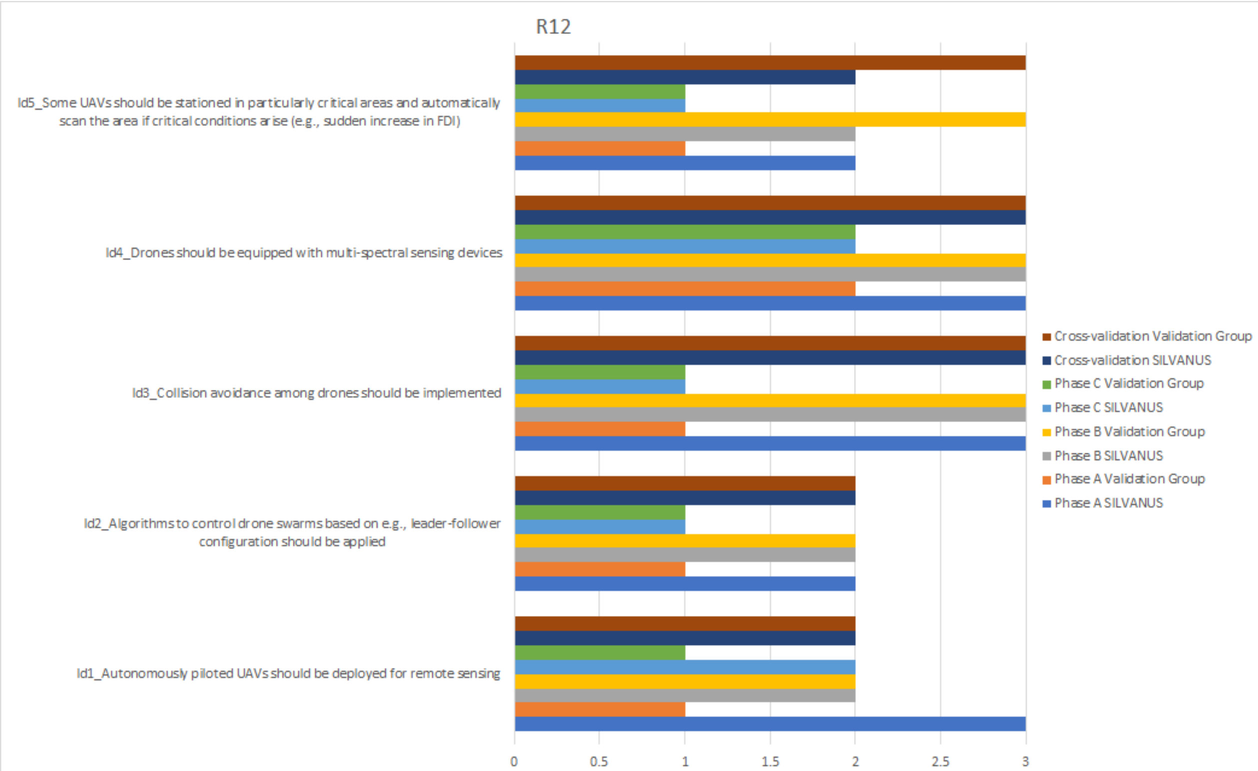

Figure 56 Table R12 Earth observation data analytics - validation

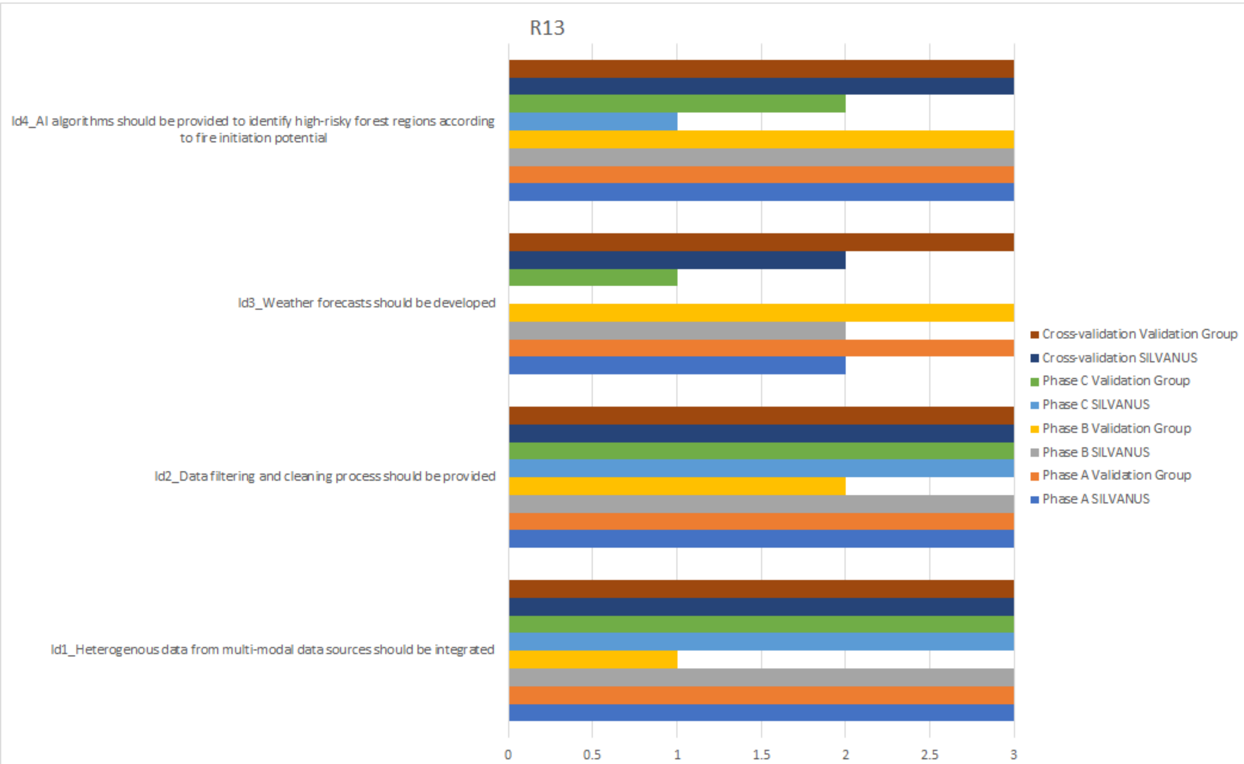

Figure 57 Table R13 Situational awareness of fire danger index - validation

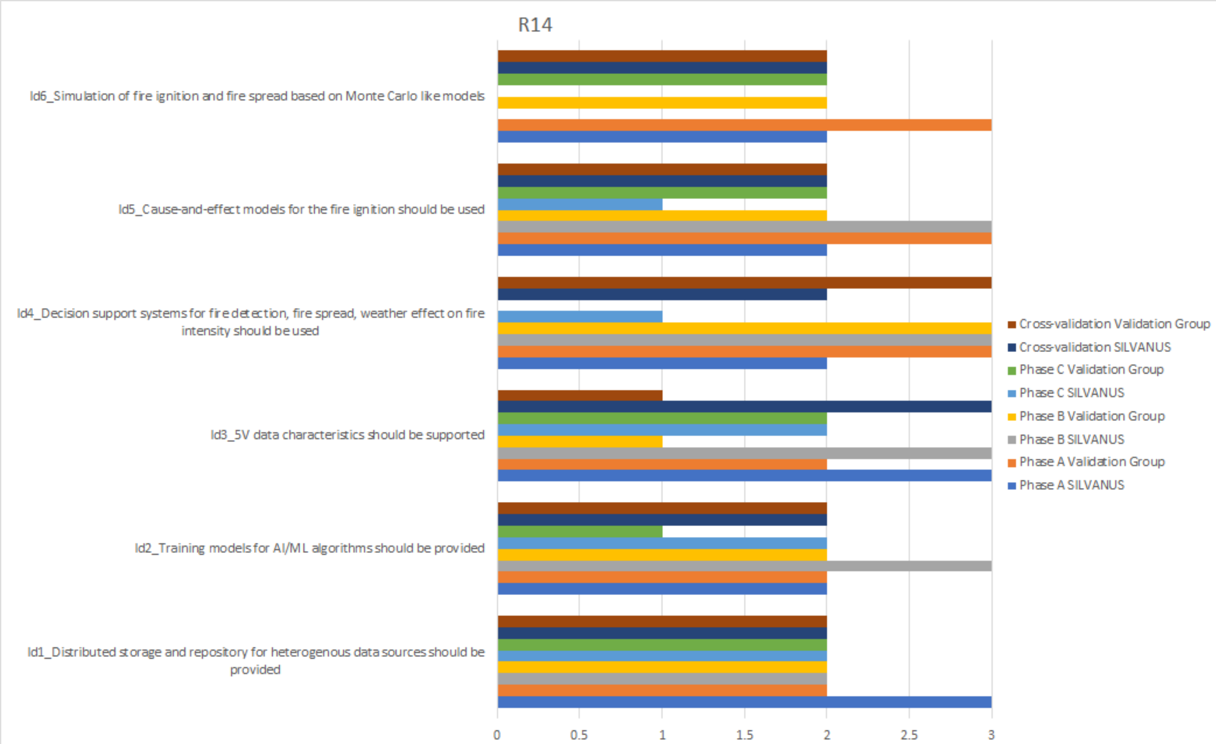

Figure 58 Table R14 Real-time monitoring of fire behaviour for response coordination - validation

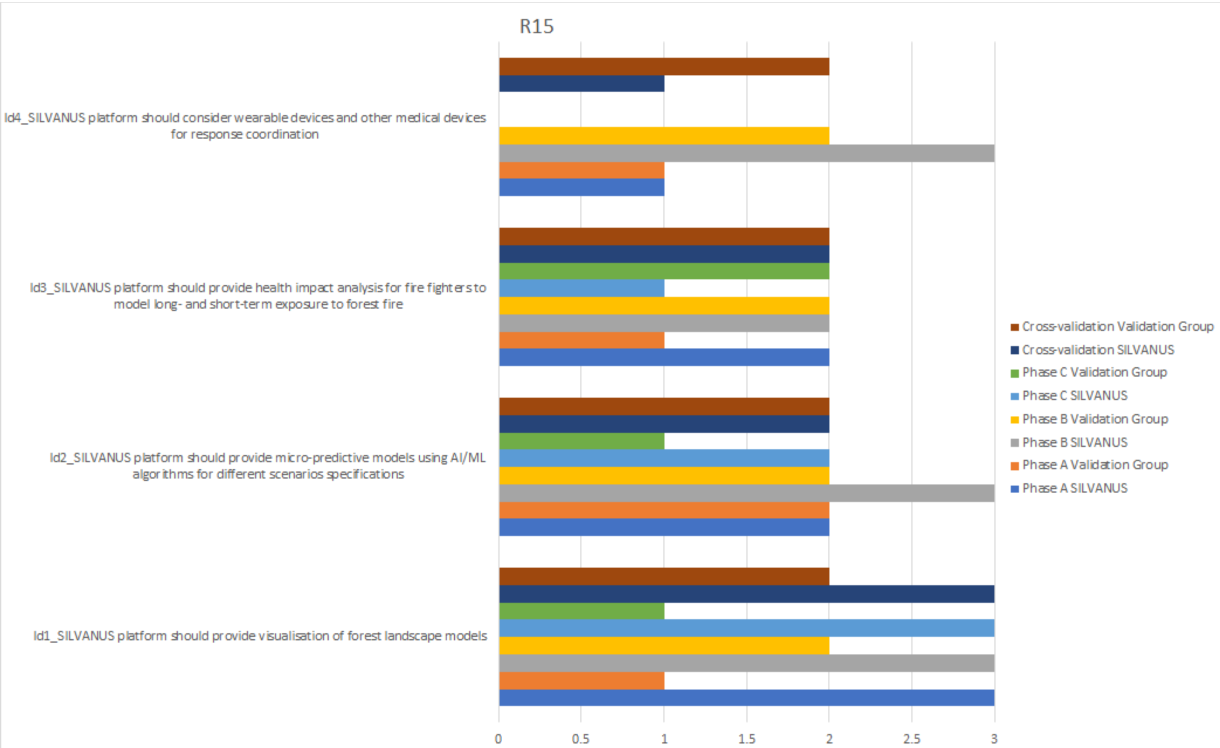

Figure 59 Table R15 Decision support systems for detecting and preventing forest fires and forest restoration - validation

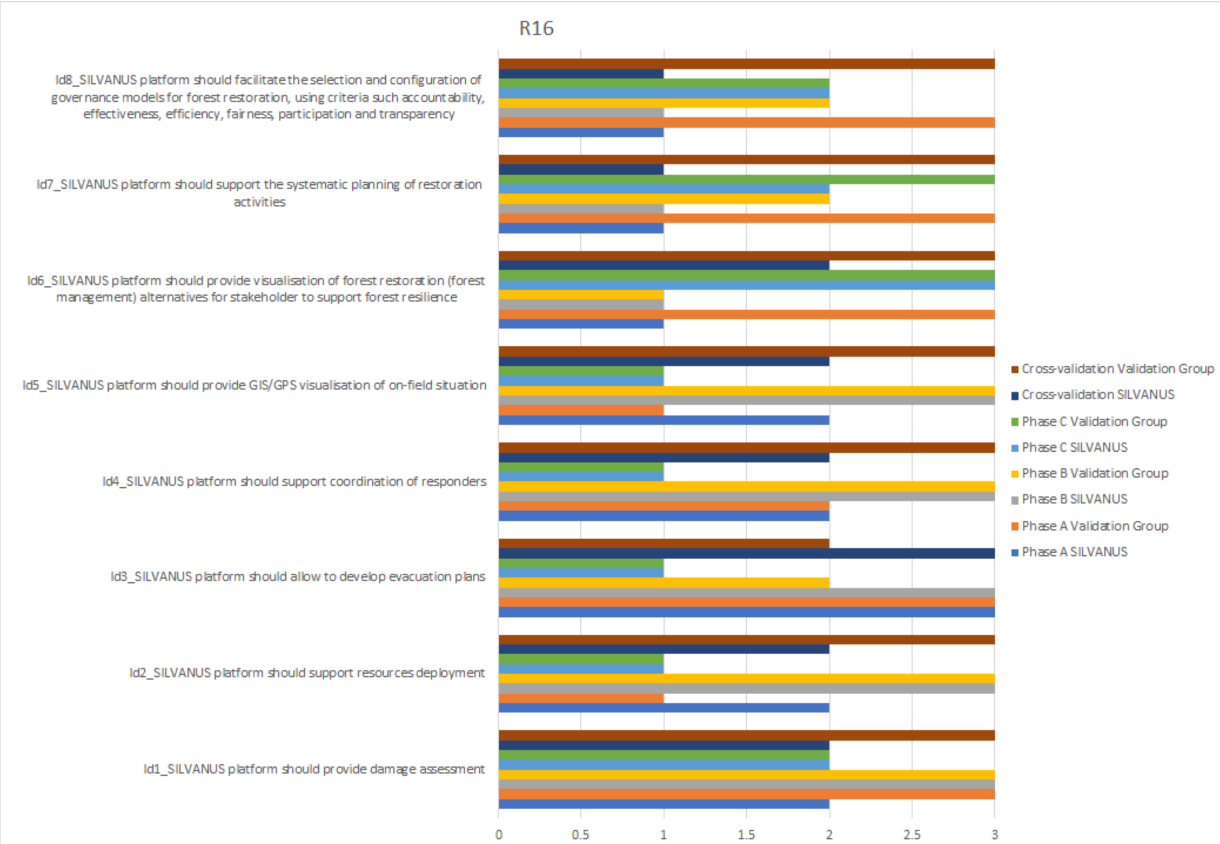

Figure 60 Table R16 Decision support systems for detecting and preventing forest fires and forest restoration - validation

In Table 8, there is shown the match and differences in responses of SILVANUS stakeholders and Validation Group members.

Table 8 Matches and differences in responses of SILVANUS stakeholders and Validation Group members

Table	Statement	Phase A	Phase B	Phase C	Cross-validation
R1	Id1_ SILVANUS platform should visualise landscape biodiversity	Match	Difference	Difference	Match
	Id2_ SILVANUS platform should identify areas/regions of historical significance	Difference	Difference	Difference	Difference
	Id3_SILVANUS should visualize and provide information forest structural diversity	Match	Difference	Match	Match
	Id4_SILVANUS platform should provide fire danger index metrics	Match	Difference	Match	Difference
	Id5_SILVANUS platform should provide information on fuel availability in specific regions of forest	Match	Difference	Difference	Match
	Id6_SILVANUS platform should simulate spatio-temporal trends of forest changes	Difference	Difference	Match	Match
	Id7_SILVANUS platform should provide fuel management alternatives for different forest types	Match	Difference	Difference	Difference

Table	Statement	Phase A	Phase B	Phase C	Cross-validation
	Id8_SILVANUS should gather information on forest landscape using crowd sourcing applications	Difference	Match	Difference	Match
R2	Id1_SILVANUS platform should visualise climate statistics (for historical and future periods; precipitation, temperature, relative humidity etc.)	Match	Match	Difference	Match
	Id2_SILVANUS platform should provide information on soil types and structure	Difference	Difference	Match	Match
	Id3_SILVANUS platform should calculate potential greenhouse emissions from fire probability index based on climate conditions and type of vegetation.	Difference	Difference	Difference	Difference
	Id4_SILVANUS platform should include e.g. AR/VR representation of forest landscape for computing impact of climate change on forest ecosystem services (climate and water cycle regulation)	Difference	Difference	Difference	Difference
	Id5_SILVANUS platform should provide representation of forest landscape for computing impact different (single or combined) forest managements on ecosystem services (climate and water regulation) under alternative climate scenarios	Difference	Match	Difference	Difference
R3	Id1_SILVANUS platform should gather information on fire ignition sources, such as human negligence, arson, environment conditions, climate and weather conditions (climate change impact including), impact of power grid lines	Match	Match	Difference	Match
	Id2_SILVANUS platform should aggregate Copernicus and EO data prior and post fire ignitions	Match	Match	Difference	Match
	Id3_SILVANUS platform should quantify the damage of forest fire and map into ecological assessment (loss of XX cubic tons of oxygen, etc.)	Difference	Difference	Difference	Difference
	Id4_SILVANUS platform should provide assessment models of forest resilience (e.g., regeneration dynamics)	Difference	Difference	Match	Difference
R4	Id1_SILVANUS platform should provide AI/ML algorithms trained on historical data sources resulting in forest fire	Difference	Difference	Difference	Difference
	Id2_SILVANUS platform should provide modelling of human behaviour (and negligence) resulting in forest fire ignition	Match	Difference	Difference	Difference
	Id3_SILVANUS platform should provide probabilistic prediction models for estimating forest fire ignition	Match	Difference	Difference	Difference
R5	Id1_SILVANUS platform should provide simulation of fire ignition scenarios	Match	Match	Difference	Match
	Id2_SILVANUS platform should implement notification protocol for response (first responders) deployment	Difference	Difference	Difference	Difference

Table	Statement	Phase A	Phase B	Phase C	Cross-validation
	Id3_SILVANUS platform should provide AR/VR simulation of combating forest fire	Match	Match	Difference	Difference
	Id4_SILVANUS platform should allow weather/environmental data to be processed in the emulating the forest fire behaviour	Match	Match	Difference	Match
R6	Id1_SILVANUS platform should produce content to engage with citizens on forest fire impact	Match	Match	Match	
	Id2_SILVANUS platform should notify people in the vicinity of forests, on human negligence	Difference	Difference	Difference	Difference
	Id3_SILVANUS platform should gather feedback from citizens on the usefulness of the mobile application	Match	Match	Difference	Difference
	Id4_SILVANUS mobile application should allow people to notify forest management services on human negligence	Match	Difference	Match	Match
	Id5_SILVANUS include mobile application which allow people to notify fire to the Fire and Rescue Service	Difference	Match	Difference	Match
	Id6_SILVANUS mobile application should notify people about the fire occurrence in their vicinity	Difference	Match	Difference	Match
	Id7_SILVANUS mobile application should create user interface for reporting a suspect fire by geo-location, photos, and description	Difference	Match	Difference	Match
	Id8_SILVANUS mobile application should allow fire management services to contact people in fire vicinity for help by voice call	Difference	Match	Match	Match
	Id9_SILVANUS mobile application should allow forest management services to contact people in fire vicinity for help by chat	Difference	Match	Match	Match
	Id10_SILVANUS mobile application should allow fire and rescue services to ask people in fire vicinity for help by voice call	Difference	Match	Match	Match
R7	Id1_SILVANUS platform should provide micro-weather forecasting models (time scale up to 72 hours)	Difference	Match	Difference	Difference
	Id2_SILVANUS platform should provide pilot region specific customisation of AI/ML algorithms for estimating forest fire danger	Difference	Difference	Difference	Difference
	Id3_SILVANUS platform should provide prediction models based on seasonal forecasts	Difference	Difference	Difference	Difference
	Id4_SILVANUS platform should provide evaluation of forecast models based on observed data	Match	Difference	Difference	Difference

Table	Statement	Phase A	Phase B	Phase C	Cross-validation
R9	Id1_SILVANUS platform should provide IoT data aggregation from distributed deployment of environmental sensors, CCTV, chemical composition sensors	Match	Difference	Difference	Match
	Id2_SILVANUS should provide Edge based micro-data centres for processing data collected from the field	Difference	Match	Match	Match
	Id3_SILVANUS platform should provide data collection for the fire behaviour (spread) modelling	Difference	Match	Difference	Difference
	Id4_SILVANUS platform should support the analysis of the impact of forest fires on the hydrology and soil physical properties (using inputs from chemical analysis where applicable)	Match	Match	Difference	Match
	Id5_SILVANUS platform should support continuous monitoring of forest restoration programmes	Difference	Difference	Difference	Difference
R10	Id1_SILVANUS platform should collect citizen observations from social media	Match	Difference	Match	Difference
	Id2_SILVANUS platform should provide AI/ML algorithms to detect fire danger	Match	Match	Difference	Match
	Id3_SILVANUS platform should provide AI/ML algorithms to detect fire/smoke	Difference	Match	Difference	Difference
	Id4_SILVANUS platform should provide extraction of visual concepts, such as fire or smoke, from social media data sources	Match	Match	Match	Difference
	Id5_SILVANUS platform should provide extraction of geoinformation, i.e., mentioned locations, from social media data sources	Difference	Match	Difference	Match
R11	Id1_SILVANUS platform should use unmanned and automated ground vehicles (UGV) for monitoring wildfire behaviour	Match	Match	Difference	Difference
	Id2_UGV should be equipped with LIDAR, visual sensors (cameras), and environmental sensors	Difference	Difference	Match	Difference
	Id3_Integration of deep learning for the detection of wildfire (using visual concepts such as smoke, fire, etc) should be considered	Match	Match	Difference	Match
R12	Id1_Autonomously piloted UAVs should be deployed for remote sensing	Difference	Match	Difference	Match
	Id2_Algorithms to control drone swarms based on e.g., leader-follower configuration should be applied	Difference	Match	Match	Match

Table	Statement	Phase A	Phase B	Phase C	Cross-validation
	Id3_Collision avoidance among drones should be implemented	Difference	Match	Match	Match
	Id4_Drones should be equipped with multi-spectral sensing devices	Difference	Match	Match	Match
	Id5_Some UAVs should be stationed in particularly critical areas and automatically scan the area if critical conditions arise (e.g., sudden increase in FDI)	Difference	Difference	Match	Difference
R13	Id1_Heterogenous data from multi-modal data sources should be integrated	Match	Difference	Match	Match
	Id2_Data filtering and cleaning process should be provided	Match	Difference	Match	Match
	Id3_Weather forecasts should be developed	Difference	Difference	Difference	Difference
	Id4_AI algorithms should be provided to identify high-risky forest regions according to fire initiation potential	Match	Match	Difference	Match
R14	Id1_Distributed storage and repository for heterogenous data sources should be provided	Difference	Difference	Match	Match
	Id2_Training models for AI/ML algorithms should be provided	Match	Difference	Difference	Match
	Id3_5V data characteristics should be supported	Difference	Difference	Match	Difference
	Id4_Decision support systems for fire detection, fire spread, weather effect on fire intensity should be used	Difference	Match	Difference	Difference
	Id5_Cause-and-effect models for the fire ignition should be used	Difference	Difference	Difference	Match
	Id6_Simulation of fire ignition and fire spread based on Monte Carlo like models	Difference	Difference	Difference	Match
R15	Id1_SILVANUS platform should provide visualisation of forest landscape models	Difference	Difference	Difference	Difference
	Id2_SILVANUS platform should provide micro-predictive models using AI/ML algorithms for different scenarios specifications	Match	Difference	Difference	Match
	Id3_SILVANUS platform should provide health impact analysis for fire fighters to model long- and short-term exposure to forest fire	Difference	Match	Difference	Match
	Id4_SILVANUS platform should consider wearable devices and other medical devices for response coordination	Match	Difference	Match	Difference
R16	Id1_SILVANUS platform should provide damage assessment	Difference	Match	Match	Difference
	Id2_SILVANUS platform should support resources deployment	Difference	Match	Match	Difference
	Id3_SILVANUS platform should allow to develop evacuation plans	Match	Difference	Match	Difference

Table	Statement	Phase A	Phase B	Phase C	Cross-validation
	Id4_SILVANUS platform should support coordination of responders	Match	Match	Match	Difference
	Id5_SILVANUS platform should provide GIS/GPS visualisation of on-field situation	Difference	Match	Match	Difference
	Id6_SILVANUS platform should provide visualisation of forest restoration (forest management) alternatives for stakeholder to support forest resilience	Difference	Match	Match	Difference
	Id7_SILVANUS platform should support the systematic planning of restoration activities	Difference	Difference	Difference	Difference
	Id8_SILVANUS platform should facilitate the selection and configuration of governance models for forest restoration, using criteria such accountability, effectiveness, efficiency, fairness, participation, and transparency	Difference	Difference	Match	Difference

Validation results showed the consensus was found at level of 40% when considering the Phase A, 53% for Phase B, 40% for Phase C and 46% for cross-validation values. The reason is the high level of subjectivity which is given to the question asked. The aim of this survey was to identify the priority given by stakeholders to the provided options which are considered important by SILVANUS Consortium.

6.2 Validation of functional requirements on SILVANUS Platform according to the type of external stakeholder

As mentioned above, in the validation, the three types of external stakeholders were involved: foresters, firefighters and civil protection experts.

In Annex 4, there are introduced the results of validation according to those three groups of stakeholders in graphical form.

Results of validation provided by foresters showed the consensus was found at level of 50% when considering the Phase A, 31% for Phase B, 31% for Phase C and 58% for cross-validation values. The reason is the high level of subjectivity which is given to the question asked. The aim of this survey was to identify the priority given by stakeholders to the provided options which are considered important by SILVANUS Consortium.

Results of validation provided by firefighters showed the consensus was found at level of 36% when considering the Phase A, 46% for Phase B, 28% for Phase C and 39% for cross-validation values. The reason is the high level of subjectivity which is given to the question asked. The aim of this survey was to identify the priority given by stakeholders to the provided options which are considered important by SILVANUS Consortium.

Results of validation provided by civil protection experts showed the consensus was found at level of 40% when considering the Phase A, 33% for Phase B, 24% for Phase C and 36% for cross-validation values. The reason is the high level of subjectivity which is given to the question asked. The aim of this survey was to identify the priority given by stakeholders to the provided options which are considered important by SILVANUS Consortium.

7 Summary

The aim of this deliverable was to gather and collect information on existing data, system, services, and technology used in the Pilot Sites for combating the wildfires in the framework of 3 phases: Phase A (Preparedness and Prevention), Phase B (Detection and Response) and Phase C (Restoration and Adaptation).

Another task was to gather and collect information about functional requirements on the SILVANUS Platform being built in the framework of SILVANUS project.

To gather this information, participatory processes must be established, both between internal and external stakeholders. For establishment of participatory processes, a methodology was developed (see section 3), to be further used when involving stakeholders to activities related to the other SILVANUS WPs (WP3, WP5, WP8, WP9, WP10) and their tasks.

According to time schedule introduced in the Guidelines (Annex 2), there was implemented the process of stakeholders interviewing and filling the proposed questionnaire tables/forms in JotForm (see Annex 3).

Information was collected from totally 10 Pilot Sites. Information about the Brazilian Pilot Site, operational scenarios and functional requirements will be later supplemented and stored in the SILVANUS database being built as a part of SILVANUS Knowledge Base.

Operational Scenarios are going to be demonstrated for all three phases included in the SILVANUS project.

Phase A: 8 demonstrations (France, Italy, Romania, Greece, Croatia, Portugal, Slovakia, Brazil).

Phase B: 8 demonstrations (France, Italy, Romania, Greece, Croatia, Czech Republic, Slovakia, Australia).

Phase C: 6 demonstrations (Italy (PS1), Greece, Portugal, Slovakia, Brazil, Indonesia).

The (current) status related to the data, systems, services, and technology used for combating the wildfires was summarized in this document in section 4. This information is also processed and stored in the SILVANUS database which is going to be available for all the consortium partners to be a source of data to be further used in the WPs/tasks to achieve their goals. This database is going to be further updated and supplemented by all relevant project partners according to the information gathered from the external stakeholders.

In Table 9 is introduced summarized information on existing technology and services used for combating the wildfires in the Pilot Sites.

Table 9 Summarized information on existing technology and services

Technology/Service	Country
UGV	Croatia, Slovakia, Australia
UAV	France, Portugal, Czech Republic, Croatia, Slovakia
IoT	Slovakia
Fire Alerting/Detection System (e.g., CCTV)	Croatia, Slovakia, Indonesia
Cameras	Greece
GIS	Greece, Slovakia
DSS	Greece, Croatia
Big Data	France, Portugal, Croatia, Indonesia
Cloud Services	Portugal, Croatia
Social Media	France

Tables 10, 11, 12 provide summarized information of intended uses cases (also requirements on SILVANUS platform) to be demonstrated at Pilot Sites in relevant countries.

Table 10 Uses Cases in Phase A

	Phase	Use Case/Country	Country
1	**A**	Mapping of the Pilot Site Area (roads, sites to be used as heliports)	France, Italy, Greece, Croatia, Slovakia
2		Territory opening-up analysis (using GIS) to deploy the fire trucks	Slovakia
3		Identifying relevant areas for mounting temperature, humidity and counting sensors	Romania
4		Self-assessment toolkit for environmental modelling	Romania
5		Ecological assessment of biodiversity within natural parks	Romania
6		Public awareness campaign	Italy, Greece, Croatia
7		Fire hazard/ danger/susceptibility/vulnerability/risk map	Italy, Romania, Greece, Portugal, Croatia, Slovakia
8		Preventive interventions on the ground	Italy
9		Using Surveillance Cameras – preventive monitoring	Italy, Croatia, Slovakia
10		Guidelines and fire prevention and firefighting plan	Italy, Croatia
11		IoT sensors	France, Romania, Greece, Croatia, Slovakia
12		Other preparedness (not technological actions) to infrastructures	Greece
13		Preparation of the firefighting personnel, continuous training for responding and use of equipment	Greece
14		Evacuation planning for various scenarios	Greece
15		Development of high-resolution maps of land cover	Portugal
16		Regular/continuous monitoring of vegetation growth around critical infrastructures for cost-effective planning of management interventions.	Portugal
17		Evaluation of livestock grazing as preventive measure for the regulation of biomass growth and wildfire prevention at the landscape and local scales.	Portugal
18		EU and PT review on regulation on fire prevention, preparedness, detection and response and restoration and adaptation activities	Portugal
19		Robotic systems deployment	Croatia
20		Monitoring the forested area by UAV (preventive)	Slovakia

Table 11 Uses Cases in Phase B

No.	Phase	Use Case/Country	Country
1	**B**	Using drones (drone swarm) to measure the ground temperature of the flames and fumes, the speed and direction of the wind with different sensors; equipped with gas sensors will make it possible to know the composition of the combustion gases and their dangers for the operators; monitoring the fire spread; inspection of human behaviour for wildfire safety	France, Italy, Romania, Czech Republic, Slovakia
2		Implementation of protection or evacuation measures	France, Italy
3		Fire sighting (patrols)	Italy
4		Fire signalizing via social media	Italy
5		Active firefighting	Italy, Slovakia
6		Use of regional radio network	Italy
7		Response actuator system to neutralise early-stage threats	Romania
8		Analysis of opening-up of territory for purposes of deployment of fire trucks in case of fire	Romania
9		Mapping of suitable water sources	Romania, Greece, Slovakia
10		Information (image, text, and coordinates of fire site) transfer to Operational Command Centre of Fire and Rescue Service	Romania,
11		Early warning through social media and the use of other mobile applications	Greece
12		Decision Support System for Emergency Management	Greece, Czech Republic, Croatia
13		Mobile Command Centres	Greece, Slovakia
14		Cameras for firefighters	Greece
15		Citizen engagement: especially evacuation, information for evolution of wildfires	Greece, Croatia
16		Fire propagation models	Greece, Croatia, Slovakia
17		Preparation of the firefighting personnel, continuous training for responding and use of equipment	Greece, Croatia
18		Fast and reliable early warning through various sources, e.g., satellites, drones, CCTV	Greece, Croatia, Slovakia
19		Use of social sensing algorithms for detection and evolution	Greece
20		Deployment of resources of various organizations according to emergency planning	Greece, Slovakia

No.	Phase	Use Case/Country	Country
21		Weather data, vegetation and topography for the fire propagation models	Greece, Slovakia
22		Crowdsourcing application	Czech Republic, Slovakia
23		Navigation to fire site	Czech Republic, Slovakia
24		Mapping firefighters' position in the field	Czech Republic, Slovakia
25		UGV appliance will be used for ground monitoring and assessment. This appliance will be used for transport and firefighting purposes.	Czech Republic, Croatia, Slovakia
26		Involvement of Volunteer Fire Brigades	
27		Incident Management and Coordination supported with GINA mobile apps	Czech Republic, Croatia, Slovakia
28		Aerial Forces deployment	Croatia, Slovakia
29		Mesh in the Sky system deployment	Croatia, Slovakia
30		IoT sensors deployment to gather data on microclimate	Croatia, Slovakia
31		Education programs, Guidelines for conducting training of firefighters	Croatia, Slovakia
32		Firefighters' health state monitoring in the field	Greece, Slovakia
33		3D mapping using CSIRO's 3D mapping technology using a mobile robotic platform	Australia

Table 12 Uses Cases in Phase C

No.	Phase	Use Case/Country	Country
1	**C**	Calculation by the command post of propagation cones, mapping	France
2		Silvicultural procedures optimisation	Italy, Greece
3		Forest fire prevention measures	Italy
4		Sustainable forest management (forest silviculture, management, restoration)	Italy, Greece, Slovakia
5		Soil protection (including the monitoring soil condition)	Greece, Indonesia
6		Soil restoration	Greece
7		Land use changes, land, burnt area mapping (aerial and satellite data)	Greece, Indonesia
8		Socio-cultural and economic issues	
9		Citizen's engagement	Greece, Indonesia
10		Forest growth models	Greece, Slovakia
11		Forest management alternatives development	Slovakia

No.	Phase	Use Case/Country	Country
12		Building database on historical fires in the Pilot Site	Indonesia
13		IoT sensor deployment to measure soil parameters	Indonesia
14		Community engagement program by installing **mobile apps** for surrounding forest community to provides **crowd sourcing** trees and animal diversity	Indonesia
15		Install CCTV on sample of pilot area to provides time series images to observe biodiversity through image	Indonesia

The functional requirements on SILVANUS Platform were further evaluated (for each phase) by internal and external stakeholders. The classification of those requirements (must/should/could) was introduced in the section 5.

The data gathered and collected in the database also represents a key input for other WPs (see Figure 61) and their tasks.

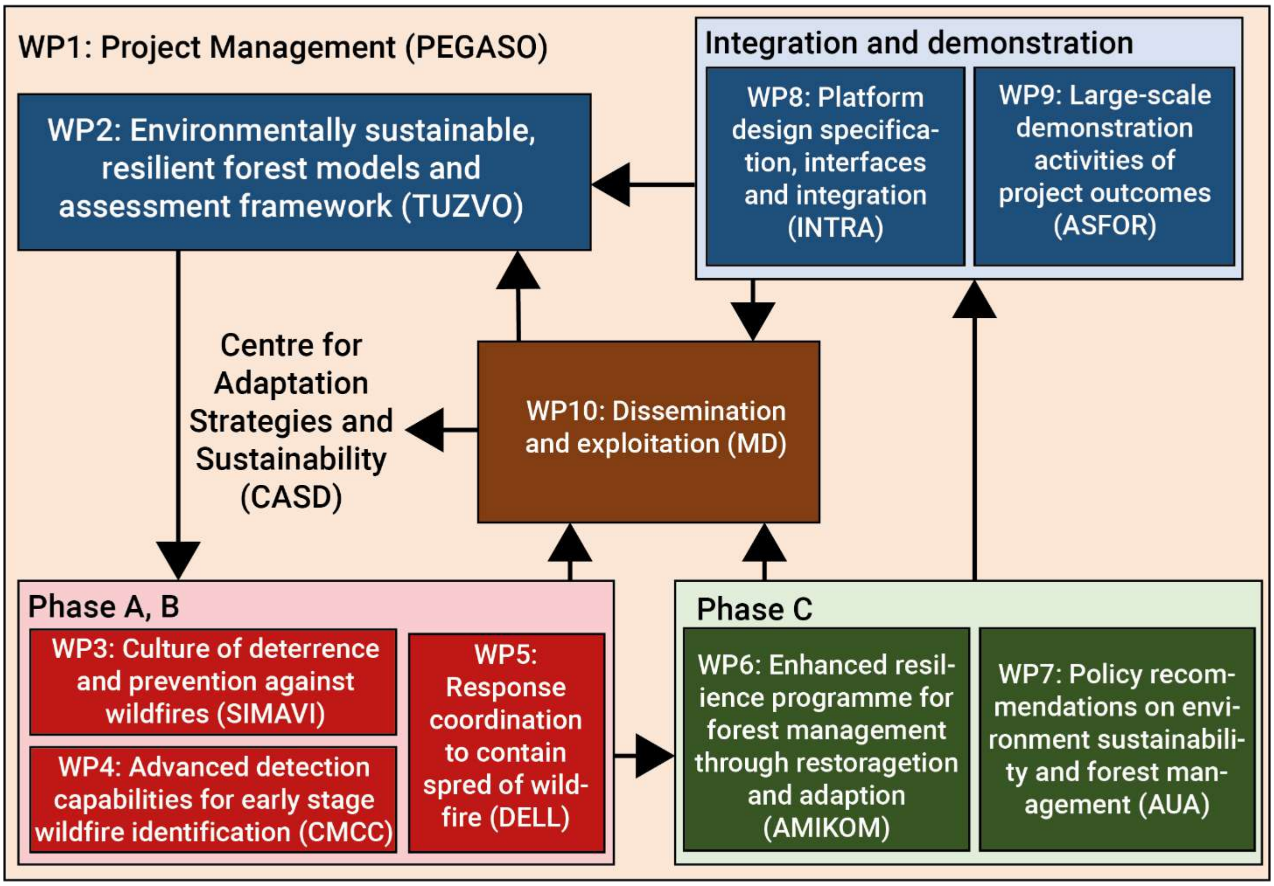

Figure 61 Linkage of D2.1/WP2 outputs with other WPs

Information collected in the Framework of T2.1 and T2.2 (also D2.1) is going to be further used in comparative analyses, too. Those are going to be published in separate scientific publications (papers, monographs).