# FIREURISK - DEVELOPING A HOLISTIC, RISK-WISE STRATEGY FOR EUROPEAN WILDFIRE MANAGEMENT

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# D5.6 – Report of FirEUrisk Pilot Site 1 Demonstration

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# Executive Summary

The FirEUrisk project, which brings together a very large consortium involving 38 institutions from 17 countries, is an ambitious project addressing the problem of integrated forest fire management, particularly those occurring under extreme conditions that endanger human lives and expose assets to risk. Key demonstration events bringing together all relevant stakeholders are organized with the aim of presenting, co-developing, and refining improved solutions and methodologies.

The project's fourth Pilot Site Demonstration Event was organized by RISE and took place in Stockholm, Sweden, on May 7th, 2024. The demonstration comprised of a small physical meeting of RISE and stakeholders from two organisations (MSB - The Swedish Civil Contingencies Agency as well as Skogforsk – The Swedish Forestry Research Institute) as well as online attendees numbering in total 83 during the whole day. These represented County boards, researchers, rescue services, the Kalmar Region Forest Agency, municipal representatives and forestry industry.

The Region of Kalmar in Sweden was selected for this pilot site. The region is one of the driest in Sweden and is the region where changes in climate is expected to yield the largest increase in fire danger towards the end of the century. However, most product were valid or had been implemented on a national scale. The event agenda was developed considering the focus of the North European pilot – future challenges. Thus, the number of presentations were kept short and mostly aimed towards this focus.

During and after the event, attendees provided suggestions and feedback on the work and how that could be utilised in their day-to-day work.

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# Table of Contents


1 Introduction ..... 7

1.1 The FirEUrisk project and objectives ..... 7
1.2 Pilot site – Sweden and Kalmar County ..... 8
1.3 Purpose and structure of the document ..... 9

2 Implementation of the PS1 Demonstration Event ..... 10

2.1 Registration and agenda ..... 10
2.2 Attendance characterization ..... 11

3 Products Description ..... 12

3.1 09:15 - Integrated wildfire risk ..... 12
3.2 09:45 - Review of past European fire seasons ..... 12
3.3 10:10 - Modern fire regime in Sweden ..... 13
3.4 10:30 - Structure damages from wildfires in North Europe ..... 14
3.5 11:10 - Fires in humid temperate regions ..... 14
3.6 11:30 - Grassland fire danger ..... 14
3.7 13:00 - The Wildland Urban Interface in Kalmar County ..... 15
3.8 13:30 - Expected future Forest Fire Danger in Sweden – its relevance for fire occurrence ..... 16
3.9 14:00 - A shiny app for forest fire danger projections ..... 17
3.10 14:15 - Future fire regimes under climate and land-use change ..... 18
3.11 15:00 - Emissions from Wildfires – Example from Sweden ..... 21
3.12 15:20 - Intermittent behaviour of mega fires ..... 22

4 Validation ..... 23

4.1 Results of the immediate feedback ..... 23
4.2 Post-event validation ..... 27

4.2.1 Reflections on the different parts of the demonstration ..... 27
4.2.2 Other reflections on the project ..... 30

5 Conclusions and Lessons Learnt from the Demonstration Event ..... 30
6 References ..... 31
Annex A: Mentimeter questionnaire ..... 32

Presentation and introduction ..... 32
Evaluation and validation of products on risk assessment, reduction and adaptation. Part 1. ..... 35
Evaluation and validation of products on risk assessment, reduction and adaptation. Part 2. ..... 39

Annex B: PS3 demonstration event presentations ..... 45

# List of Figures

Figure 1. FirEURisk's integrated strategy to calculate wildfire risk. Source: (Chuvieco et al., 2023). ..... 7
Figure 2. Kalmar county from satellite imagery (Left, source: Lantmäteriet) and the WUI-map of the county (Right, source: Avi Bar-Masada, presentation during the event). ..... 9
Figure 3. The agenda of the event. ..... 10
Figure 4. Distribution of participants by country of origin. ..... 11
Figure 5. Distribution of external participants by country of origin. ..... 11
Figure 6. Distribution of external participants by organization type (several individuals were present in each of the three connected rescue services). ..... 12
Figure 7. Population density in Sweden, Forest fire occurrence (1996 - 2020) burning >1 ha and 100 ha. From Ref [11]. ..... 13
Figure 8. Buildings, vegetation and WUI in Kalmar county. ..... 16
Figure 9. 95$^{th}$ percentile (over the full year) of FWI over Europe based on seven individual model assuming SSP5-8.5 (continued reliance on fossil fuels). ..... 17
Figure 10. Estimated change in forest fire occurrence of different burn sizes in Kalmar County only due to expected change in forest fire danger towards the end of the 21$^{st}$ century. ..... 17
Figure 11. Screenshot from the app showing projected 95$^{th}$ percentile (over the full year) of FWI over Sweden for two future pathways with a lever scanning the years. ..... 18
Figure 12. Screenshot from the app showing expected change on a selected region. ..... 18
Figure 13. Comparison of changes in land cover in SSP 1 & 3 between 2015 and 2050. Brown represents shrubland cover, light green represents grassland cover, and dark green represents forest cover. ..... 19
Figure 14. Model overview from Climate and land-use scenarios to changes in burnt area [15] ..... 20
Figure 15. Model overview and the algorithm principal scheme ..... 21

# 1 Introduction

The demonstration event agenda was created based on the needs of end-users identified beforehand (FirEURisk_D34_D5.1_User requirements database and report_v1.0.pdf). The products were selected to enhance integration among the identified needs and topics, as well as to facilitate their future use. It is important to emphasize that the FirEURisk project aims to strengthen solutions during the prevention phase, and better organizing and coordinating responses to wildfires, considering the foreseeable need to adapt fire management due to changes in climate, land use, demographics, suppression resources and organisation among other factors affecting the wildfire statistic trends. The integrated strategy of FirEURisk serve as the foundation for product development, as these products are integrated into components used to calculate wildfire risk [1] as shown below.

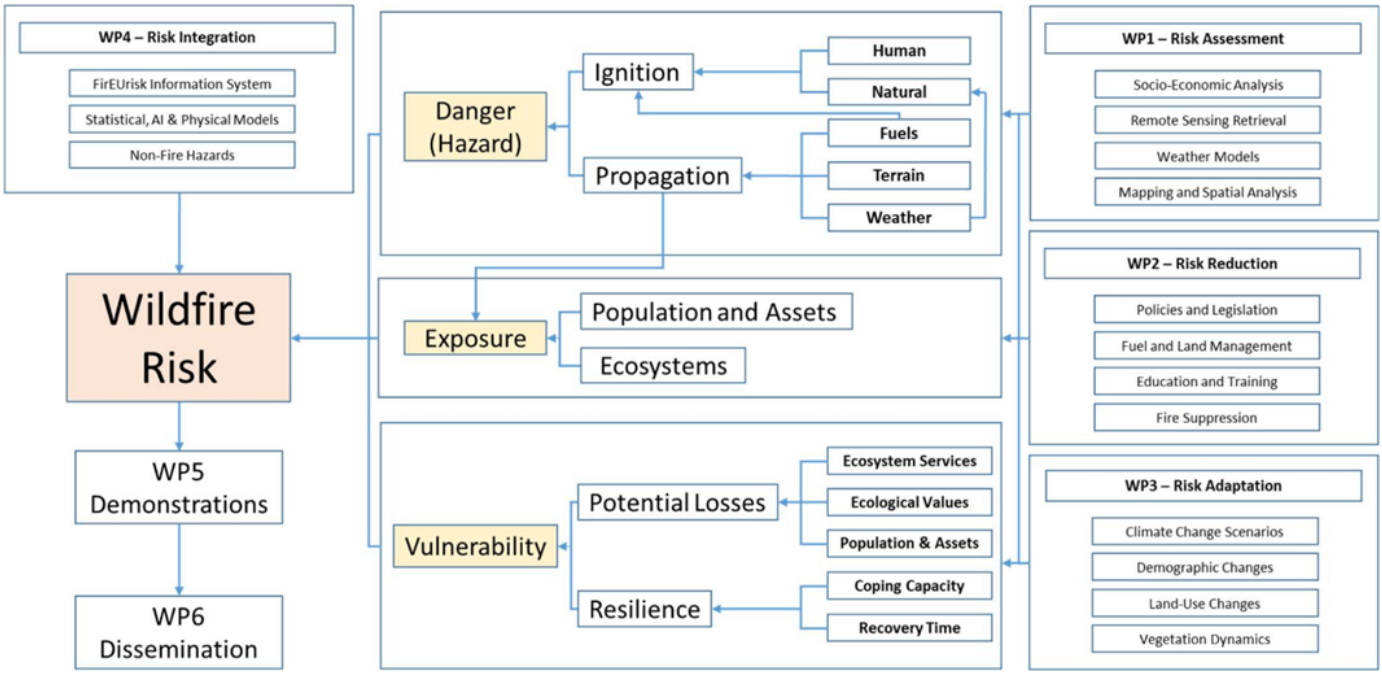



*Figure 1. FirEURisk's integrated strategy to calculate wildfire risk. Source: (Chuvieco et al., 2023).*

## 1.1 The FirEURisk project and objectives

The FirEURisk Project seeks to enhance and standardize current European strategies for wildfire mitigation by integrating factors ranging from socioeconomic to climate modelling. Danger, exposure and vulnerability to wildfire all entail a broad spectrum of factors that are difficult to combine. The knowledge, tools, recommendations, models and maps that the project produces are all different products that can fit different actors working with wildfire risk in Europe and elsewhere.

The FirEURisk project encompasses six pilot sites – PS1: North Europe (Southeast Sweden), PS2: Southern Brandenburg and eastern Saxony (Germany), PS3: Central Region of Portugal, PS4: Barcelona Province (Spain), PS5: Attica Region (Greece), and PS6: European Territory.

This report describes the demonstration event of PS1, focusing on Sweden in general and the on the County of Kalmar in southeast Sweden in particular, as a model for north European wildfire risks. The pilot site is focused on future wildfire danger and therefore selects products more related to estimating and mitigating future risks. During the event, a handful of selected products was chosen for this specific implementation. Previous reports on pilot site demonstration event held in Catalunya, Central Portugal and Central Europe can be found on the project website ( https://fireurisk.eu/).

This document aims to comprehensively report relevant aspects associated with the demonstration event for North Europe. It also shows all presentations in the appendices and a link to the presentation video. The document describes the event and the feedback received by the participants to be used in further developments of the products. Chapter 2 details the outline of the day and the participants. Chapter 3 has a short overview of the presentations and products. The response from the Mentimeter questions after the sessions are presented in chapter 4, followed by a summary of the responses received from selected participant a week after the event itself in chapter 5. Conclusions are wrapped up in chapter 6. All Mentimeter results are shown in Appendix A and the thumbnails of the presentations in Appendix B.

## 1.2 Pilot site – Sweden and Kalmar County

Most of the research products presented were implemented on a national scale whereas some were concentrated to Kalmar, one of Sweden's 21 counties situated in the southeast bordering the Baltic Sea.

Sweden was one of the earliest boreal regions exploited for industrial forestry. The early adaptation to industrial forestry came with high incentives for fire suppression and a dramatic drop in burned area already in the late 1800s and early 1900s [2,3], down from levels on par with other parts of the boreal. Annual burned area is today less than 1% of that in the mid-1800s, in contrast to the increasing fire activity in Mediterranean Europe [4], Siberia or the North American boreal region [5]. More than 95% of the Swedish forest is managed for wood production, currently supplying 9% of the world's sawn wood export [6]. This requires effective fire protection, also to secure the building stock in rural areas that is vulnerable to wildfire [7].

Despite the overall low fire frequency, Sweden has recently experienced several high-intensity wildfires. Examples include the Västmanland fire in central Sweden, burning ~13,000 ha, 2/3 of it in crown fire during a single afternoon in 2014 [8], and the simultaneous fires overwhelming the suppression resources and burned approximately 25,000 ha in 2018 [9]. These incidents exposed a limit of wildfire suppression resources in extreme fire-weather situations. Further, climate projections show longer fire seasons and more severe fire-weather scenarios, especially in the south-east and along the eastern Baltic coastline [10].

Sweden extends 1500 km in N–S direction and 300 km in E-W, with substantial variation in both temperature and precipitation [11]. Ignitions are well correlated to population density whereas the expected fire area is equally anti-correlated to population density [12]. The main reason for the larger areas in sparsely populated areas is a longer response time due to increased times for detection and resource gathering, exacerbated by rural depopulation during last decades [12].

Kalmar county is not the most rural areas in Sweden but it has a lower population density than the rest of the south edge. Instead, it has the highest summer temperatures and the lowest summer precipitations [11]. It comprises 12 municipalities, and 246,346 inhabitants over 11,171 km² of land (Figure 2). It is also (as seen in the following presentations) the region which expects the largest increase in forest fire danger during the rest of the century. The region is highly susceptible to ignitions and wildfires have been shown to be an integral part of the communities living there. At the same time, the actual knowledge of working with fires and understanding of the potential hazard has decreased significantly during the last few decades. The experience of many, but mostly well-managed fires (by the municipal rescue services), have ensured residents that fires are not a large concern, and they therefore do not take strong mitigating actions to reduce potential losses from fires. Instead, they rely on the rescue service to efficiently supress fires before large damages. While this is highly reasonable from the developments in the last few decades, the large changes in fire danger expected within the rest of this century could unveil large vulnerabilities for incidents where fires may overtake suppression capacities.

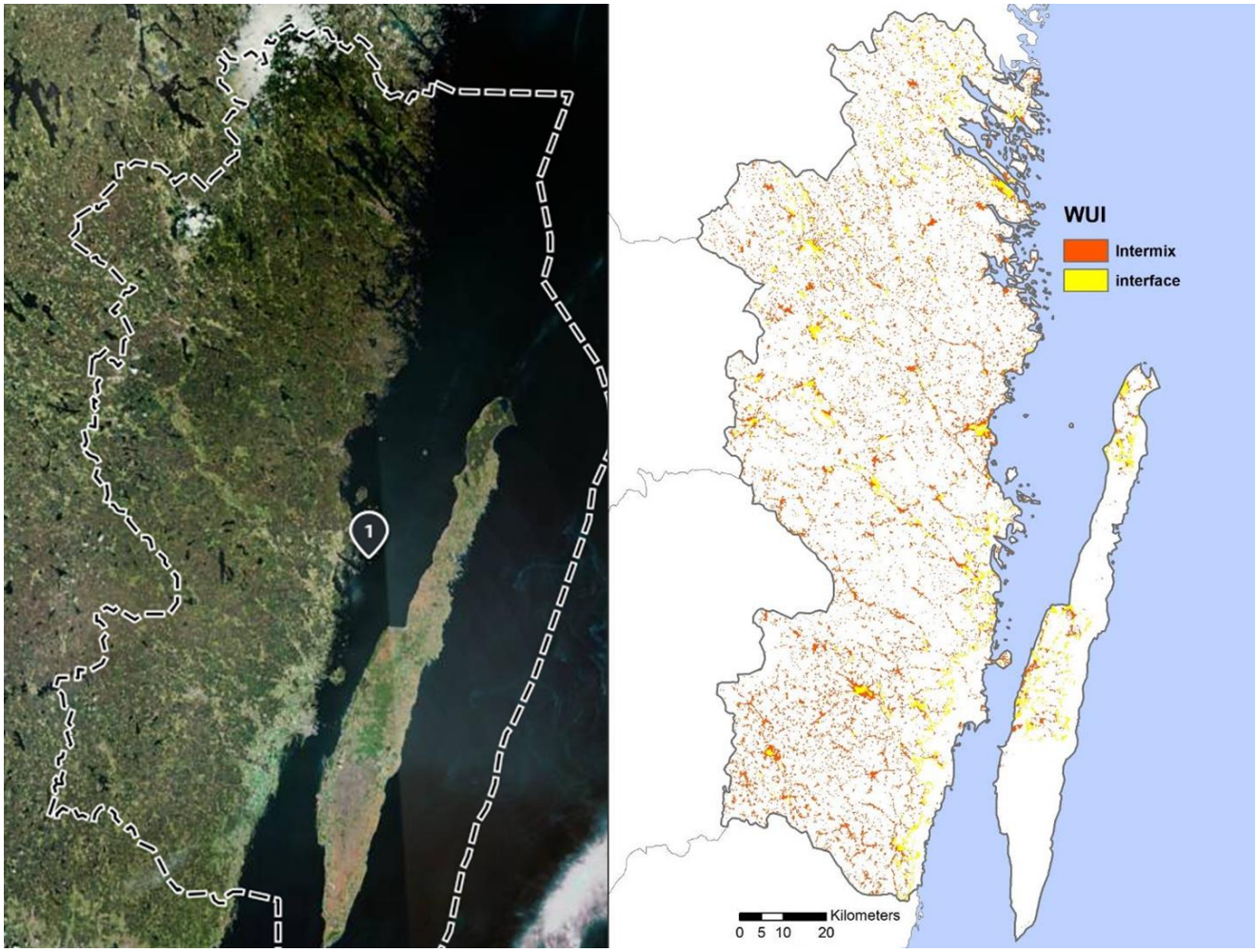



*Figure 2. Kalmar county from satellite imagery (Left, source: Lantmäteriet) and the WUI-map of the county (Right, source: Avi Bar-Masada, presentation during the event).*

# 2 Implementation of the PS1 Demonstration Event

## 2.1 Registration, materials and agenda

The registration of the event was through a Google form which was distributed through the FirEURisk website, e-mail contacts as well as through LinkedIn. The presentations were all in English.
The recording of the Demonstration Event is available on FirEURisk YouTube channel (Link), with a link from the FirEURisk website (Link). The PowerPoint slides are available in Appendix B. The agenda was available on the event website prior to the event (Figure 3). Evaluation using Mentimeter questions by GMV was performed on two occasions, one just before lunch for the morning sessions and one at the end of the day for the afternoon sessions.




**FIREURISK – DEVELOPING A HOLISTIC, RISK-WISE STRATEGY FOR EUROPEAN WILDFIRE**
Grant Agreement number: 101003890
Styrelserummet, Drottning Kristinas Väg 61, Stockholm

**North European Pilot Site Demonstration Event, Tuesday 7th May, 2024**

**08:40** Registration and coffee for in-person attendees

**09:00** **Welcome to the FirEURisk project**
Emilio Chuvieco, Johan Sjöström; University of Alcalá, RISE research institutes of Sweden

**09:15** **Integrated wildfire risk**
Emilio Chuvieco, University of Alcalá

**09:45** **Review of past European fire seasons**
Miguel Almeida, University of Coimbra - ADAI

**10:10** **Modern fire regime in Sweden**
Johan Sjöström, RISE research institutes of Sweden

**10:30** **Structure damages from wildfires in North Europe**
Frida Vermina Plathner, RISE research institutes of Sweden

**10:50** **COFFEE BREAK**

**11:10** **Fires in humid temperate regions**
Tadas Nikonovas, Swansea University

**11:30** **Grassland fire danger**
Johan Sjöström, RISE research institutes of Sweden

**11:45** **Evaluation and Q&A**
Julia Yagüe, GMV Aerospace and Defence SAU

**12:00** **LUNCH**

**13:00** **The Wildland Urban Interface in Kalmar County**
Avi Bar-Massada, University of Haifa

**13:30** **Expected future Forest Fire Danger in Sweden – Its relevance for fire occurrence**
Jessica Hetzer, Senckenberg Research Institute

**14:00** **A shiny app for forest fire danger projections**
Jessica Hetzer, Senckenberg Research Institute

**14:15** **Future fire regimes under climate and land-use change**
Kirsten Thonicke / Alex Neidermeier
Potsdam Institute for Climate Impact Research / Vrije Universiteit Amsterdam

**14:45** **LEG-STRETCHER AND COFFEE**

**15:00** **Emissions from Wildfires – Example from Sweden**
Tobias Oswald, University of Aveiro

**15:20** **Intermittent behaviour of mega fires**
Carlos Ribeiro, University of Coimbra - ADAI

**15:40** **Wrap-up and outlook**
Johan Sjöström, RISE research institutes of Sweden

**16:00** **Evaluation**
Julia Yagüe, GMV Aerospace and Defence SAU

**16:20** **Closure and final remarks**
Johan Sjöström, RISE research institutes of Sweden

*Figure 3. The agenda of the event.*

## 2.2 Attendance characterization

The event was predominantly online with only representatives from Swedish authorities (MSB), industry (Skogforsk) (6 representatives) and FirEURisk partner RISE present in the venue. In total, more than 83 participants joined, from 19 different countries (Figure 4).

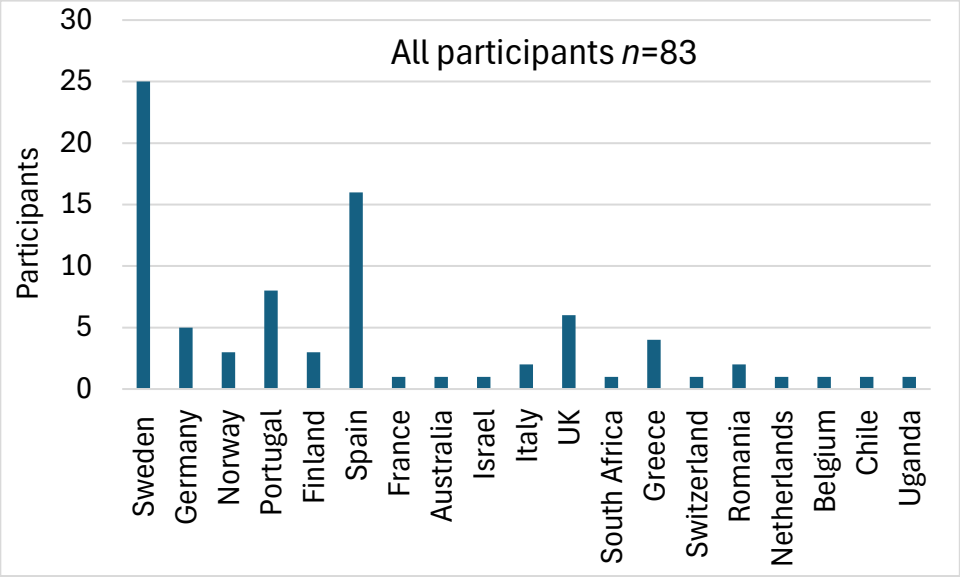



*Figure 4. Distribution of participants by country of origin.*

Excluding the participants that are part of the FirEURisk project there were more than 46 external participants from 14 countries and 4 continents. Most of these were online for more than 6 hours (Figure 5). Some of these attendees used just one link to join online while they comprised a group of several individuals from the same organisation but they could not be accounted individually. This mostly applied to the rescue service organisations.

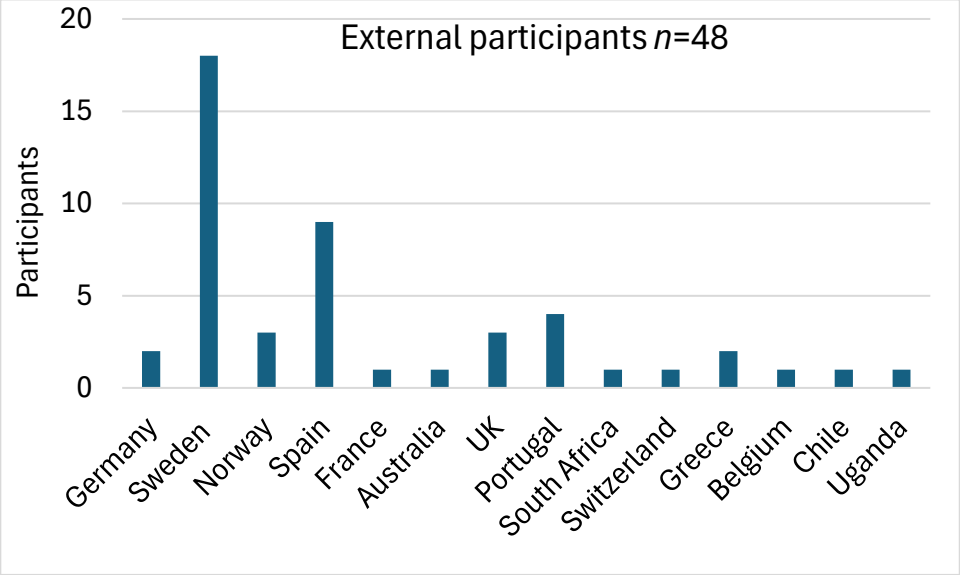



*Figure 5. Distribution of external participants by country of origin.*

The external participants were gathered into six different groups: Research (*n*=24 participants), Authorities (*n*=10), Industry (*n*=7), Rescue services (*n*=3), Other governmental institutions (*n*=3) and Testing (*n*=1) (Figure 6). The authorities held different professional positions, from the Swedish civil contingencies agency and the Forest agency. Industry was mostly providers of remote sensing data or solutions for suppression and the rescue services (which each had several participants) were from Kalmar County, South Älvsborg's rescue union and Jämtland's county's rescue services. The other governmental institutions representatives dealt with matters of forestry and climate change adaptation.

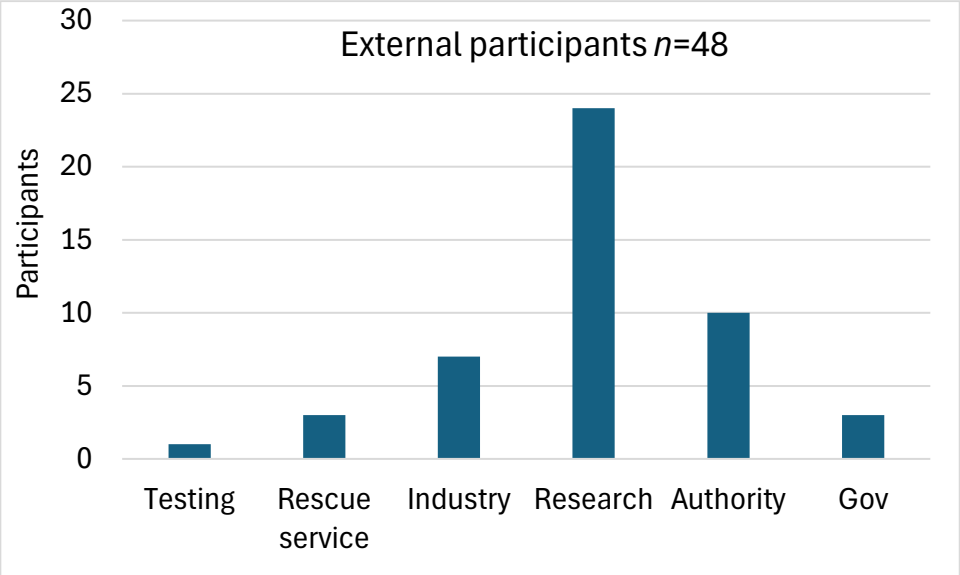



*Figure 6. Distribution of external participants by organization type (several individuals were present in each of the three connected rescue services).*

# 3 Products Description

In this chapter, we present a description of the products showcased at the demonstration event. The description includes the presenter's name and data from either the product cards or from the publication where it is disseminated.

## 3.1 09:15 - Integrated wildfire risk

Emilio Chuvieco describes the FirEURisk project and the integrated strategy to calculate wildfire risk (Figure 1). The risk is a product of three factors: Danger, Exposure and Vulnerability. Each of these is driven by factors within work on Assessment, Reduction and Adaptation in an integrated scheme described in Chuvieco et al. (2023). This scheme is what coordinates and guides the work within the FirEURisk project.

## 3.2 09:45 - Review of past European fire seasons

Miguel Almeida describes the work done of characterising the fire seasons of 2021 and 2022. These reports describe a selected number of fires on the European territory based on those have significantly (1) large burnt area, (2) large

impact to people or properties or (3) difficulties in suppression such as unusual events or transboundary fires. The main conclusions from the studies are that:

- There is a need for better capacity to predict periods and locations associated with particularly high risks such that restrictions on ignition prone activities are more effective and not over conservative.
- Evaluation of fire patterns at smaller scales (e.g. parish level) should be executed already during the fire season and not after the season, as currently practiced.
- There is a need to enhance self-protection capacity of citizens and private entities.
- European wildfire risk information and empowerment need harmonization of data, response capacity and formation of joint multinational forces. The current state of only sending aerial means should be expanded.

The report from the FirEURisk project for 2021 is published by JRC: https://publications.jrc.ec.europa.eu/repository/handle/JRC133972 . The report for the 2022 season is under editorial review and will be available at JRC shortly.

## 3.3 10:10 - Modern fire regime in Sweden

Johan Sjöström presents the overview of the modern fire regime in Sweden finished within the FirEURisk project. The previous fire interval of about 100 years have decreased dramatically since the onset of industrial forestry to less than 1 % of the previous burnt area. Today, an annual mean of 3,500 ha burns and the large areas are associated to sparsely populated areas while the ignitions are directly proportional to population density. The key driver is the time to detect and reach the fires which is strongly related to rural development. Clear declines of ignitions related to traditional use of fire as well as ignitions from children playing with fire have been observed [11].

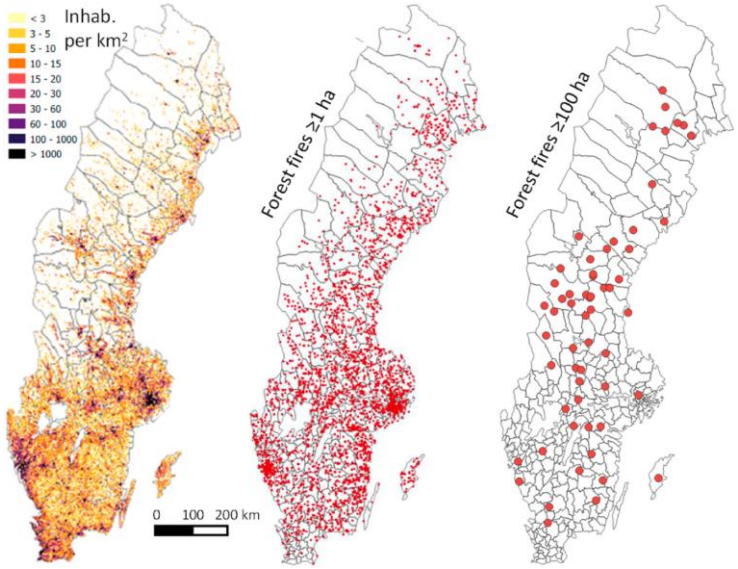



*Figure 7. Population density in Sweden, Forest fire occurrence (1996 - 2020) burning >1 ha and 100 ha. From Ref [11].*

The study can be found here: https://www.sciencedirect.com/science/article/pii/S0379711223000115.

## 3.4 10:30 - Structure damages from wildfires in North Europe

Frida Vermina Plathner presents key factors for building fires in Sweden based on field studies of buildings within large forest fires as well as studies of incident reports of all identified buildings threatened by wildfires in all of Sweden during 25 years. Survival to large fires depends on three major factors, all of which relate to the characteristics of the garden:

- A mowed lawn around the building
- Little artificial fuels or vegetation (Cedar, Cupressus, Spruce or Juniper) directly at the façade
- Inclusion of deciduous trees around the garden

Most buildings ignited by wildfires are actually not affected in large summer forest fires but in predominantly small (<1000 $m^2$) fires starting in or just outside of garden perimeters. These fires mostly occur during spring and utilises the light dead fuel from last season, becoming flammable only after one afternoon of dry and sunny weather.

25 buildings burn in Sweden annually and just less than one person die in fires in or around gardens since the 90s. More information can be found in this study [7]: https://doi.org/10.1016/j.ssci.2022.105928.

## 3.5 11:10 - Fires in humid temperate regions

Tadas Nikonovas from Swansea University showed a study were fire in UK, as a representative region for humid temperate regions, are assessed in relation to season, phenology and weather. Key outcomes are:

- Fuel load is a poor predictor for wildfire risk for dormant fuels, except in severe droughts.
- Phenology is instead the key driver of fire occurrence and including phenological states could greatly improve risk predictions.
- However, fire-suppression based on 'phenology barrier' can break during extreme summer droughts, which are expected to increase in frequency and severity under climate change.

The study is under per review and will be openly available once accepted.

## 3.6 11:30 - Grassland fire danger

Johan Sjöström from RISE presented the fire danger model for spring grassland fires in the north. The model aims to describe the fire danger in light herbaceous fuels that have undergone senescence during the cold winter and now remain as fine dead and very airy fuel after snowmelt. In the north, afternoon relative humidities are the lowest throughout the year, and the fuel becomes flammable after only a few hours of sunny, dry and windy weather. As the new green vegetation grows, it intermixes with the litter and gradually transforms the fuel bed from highly flammable to a very poor conveyer of flames within just 4-6 weeks. The model accounts for the different aspects of grass fire danger including meteorology affecting the dead fuel moisture, wind affecting the rate of spread and season affecting the dampening effect of seasonal growth.

Unlike forest fire danger for which fireline intensity is the usual danger metric, the danger levels are determined based on the rate of spread, the most challenging part of grassland fires. The model is now used in the Swedish national wildfire danger system, updated hourly by the meteorological institute.

| Characteristics | Description |
|---|---|
| Type of products: | Geospatial product / model |
| Units: | Categorical : fire danger classes |
| Update Frequency: | Hourly |
| Accuracy: | not applicable |
| Output Format: | .tiff |
| Fire risk component (accordingly to the Integrated Scheme of the FirEUrisk project): | Propagation - Weather |
| Temporal coverage: | Forecast for five days. Model based on 1996-2021 |
| Spatial resolution: | 2.5 km |
| Availability on FirEUrisk platform: | https://www.smhi.se/vader/prognoser/brandrisk |

The danger model, with algorithms, is presented here *A phenology-driven fire danger index for northern grasslands* (2023), International Journal of Wildland Fire, https://doi.org/10.1071/WF23013.

Link to the hourly updated maps: https://www.smhi.se/vader/varningar-och-brandrisk/brandrisk.

## 3.7 13:00 - The Wildland Urban Interface in Kalmar County

This product identifies the locations of wildland - urban interfaces (WUI) of two types, interface (where human settlements adjoin flammable vegetation) and intermix (where human settlements are interspersed with a matrix of flammable vegetation). Developer: HU. The product developed within the Activity "A1.2.2 Societal vulnerability and resilience assessment ".

### *Technical components*

| Characteristics | Description |
|---|---|
| Type of products: | Geospatial product |
| Units: | Categorical: 0 - non WUI, 1 - intermix WUI, 2 - interface WUI |
| Update Frequency: | Static layer |
| Accuracy: | 80-90% |
| Output Format: | .tiff |
| Fire risk component: | Exposure/vulnerability (Population-Assets) |
| Temporal coverage: | 2020 |
| Spatial resolution: | > 1 ha (10m) |
| Availability on FirEUrisk platform: | https://fireurisk.satways.net/collection/62bab3dee4b0b33bb116f8ea |

### *Methodology*

The mapping method builds upon the approach of Bar-Massada et al. (2012). This is a point-based (i.e., buildings) approach, which was converted here to a raster approach due to data availability on settlements. For WUI mapping

purposes, only two classes of this dataset were considered: forests and shrublands. Detailed description of algorithm of calculation and data sources are available here:
https://www.sciencedirect.com/science/article/pii/S0169204623000786

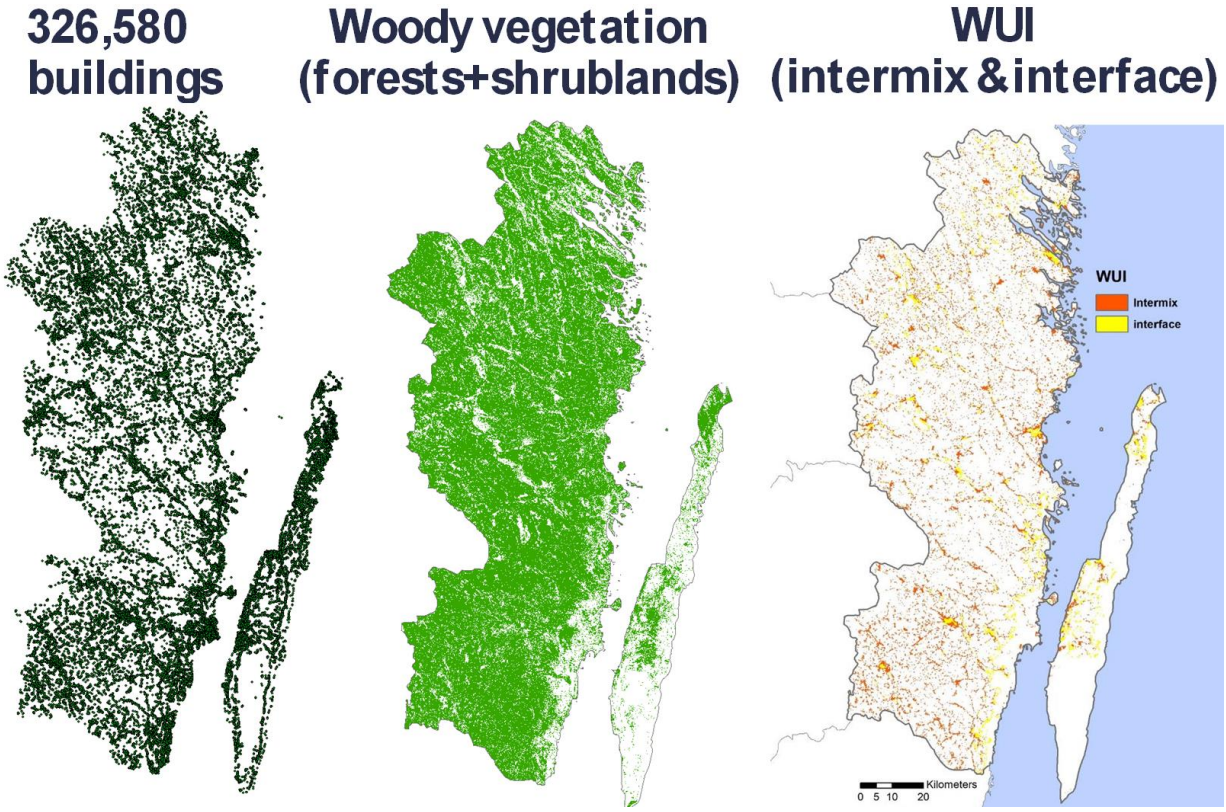



*Figure 8. Buildings, vegetation and WUI in Kalmar county.*

## 3.8 13:30 - Expected future Forest Fire Danger in Sweden – its relevance for fire occurrence

Jessica Hetzer shows the data set of calculated forest fire danger over Europe in general and Sweden in particular over the remaining of the 21st century. The data set, using the Canadian forest Fire Weather Information System (FWI), shows, in line with other studies, an increased frequency of high-danger days in south-eastern Sweden as well as along the eastern Baltic coastline (Figure 9).

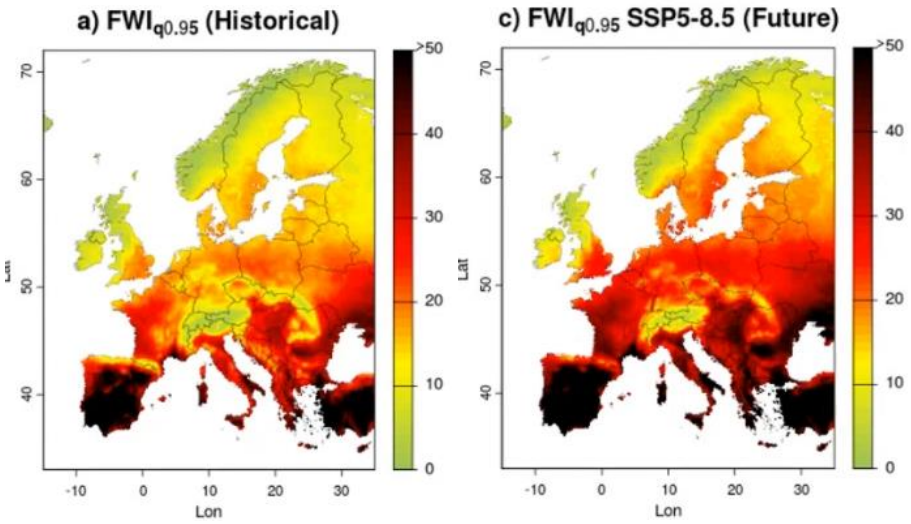



*Figure 9. 95th percentile (over the full year) of FWI over Europe based on seven individual model assuming SSP 5-8.5 (continued reliance on fossil fuels).*

Next, Johan Sjöström exemplifies how such changes in fire danger would play out in terms of number of large forest fires, given 25 years of FWI-correlated forest fire incidents over the country. Everything else (suppression resources, human caused ignition patterns and land-use) equal, the expected change in fire outcome (just due to changes in fire danger) can be estimated. Comparing future Shared Socioeconomic Pathways of strong decrease in global warming emissions (SSP2-4.5) with one in which the emissions continue to a high degree (SSP5-8.5) the number of small fires is expected to increase by ~10 and ~30 %, respectively. The number of large fires is likewise expected to increase by 10-20 and 35-55 %, respectively (Figure 10).

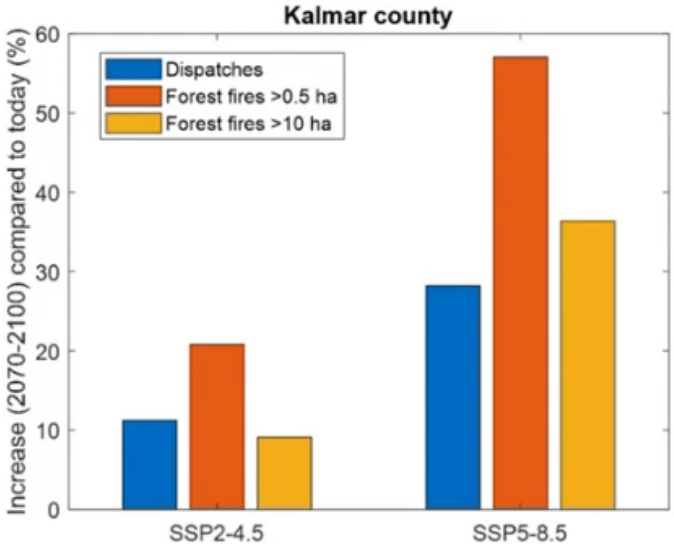



*Figure 10. Estimated change in forest fire occurrence of different burn sizes in Kalmar County only due to expected change in forest fire danger towards the end of the 21st century.*

## 3.9 14:00 - A shiny app for forest fire danger projections

Jessica Hetzer shows the app where the future forest fire danger displays over Sweden. The app can be found here: https://hetzerj.shinyapp.io/Sweden_demo/. Within the app you can drag along different years to see changes in the

FWI (Figure 11) and also click on certain points on the map to extract the full period of changes under different future pathways, from 1950 to 2100 (Figure 12).

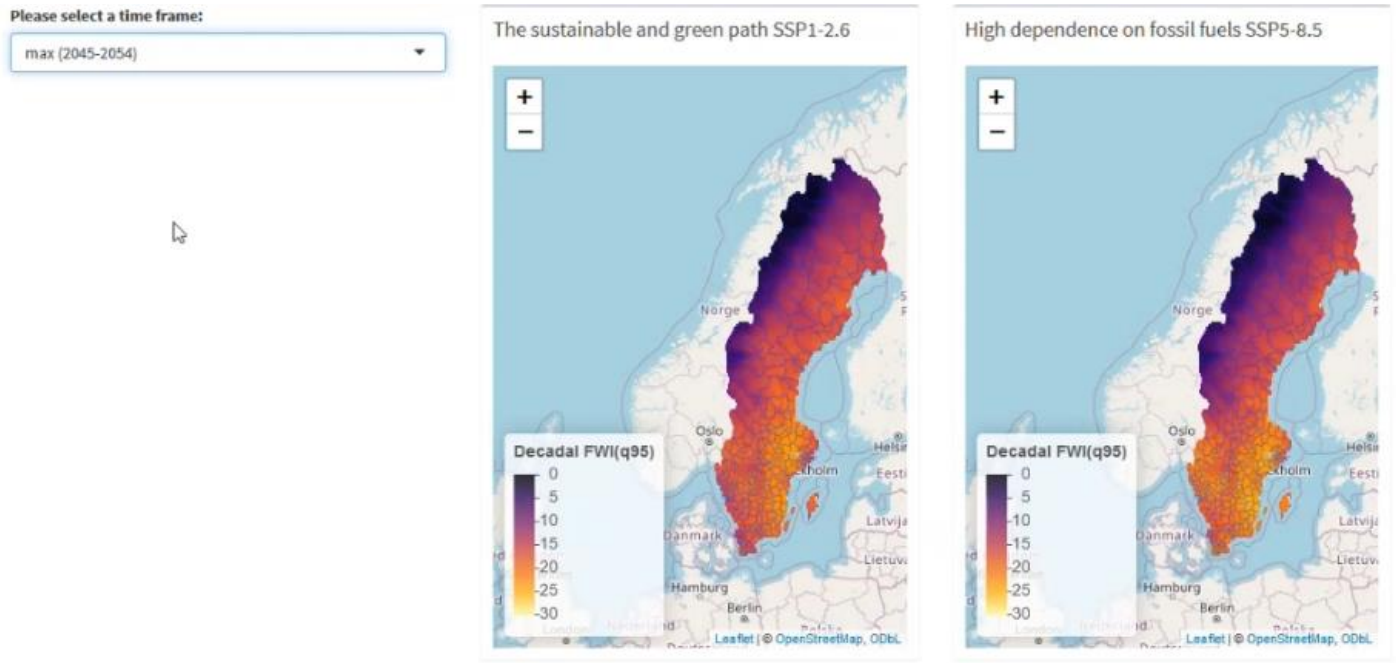



*Figure 11. Screenshot from the app showing projected 95$^{th}$ percentile (over the full year) of FWI over Sweden for two future pathways with a lever scanning the years.*

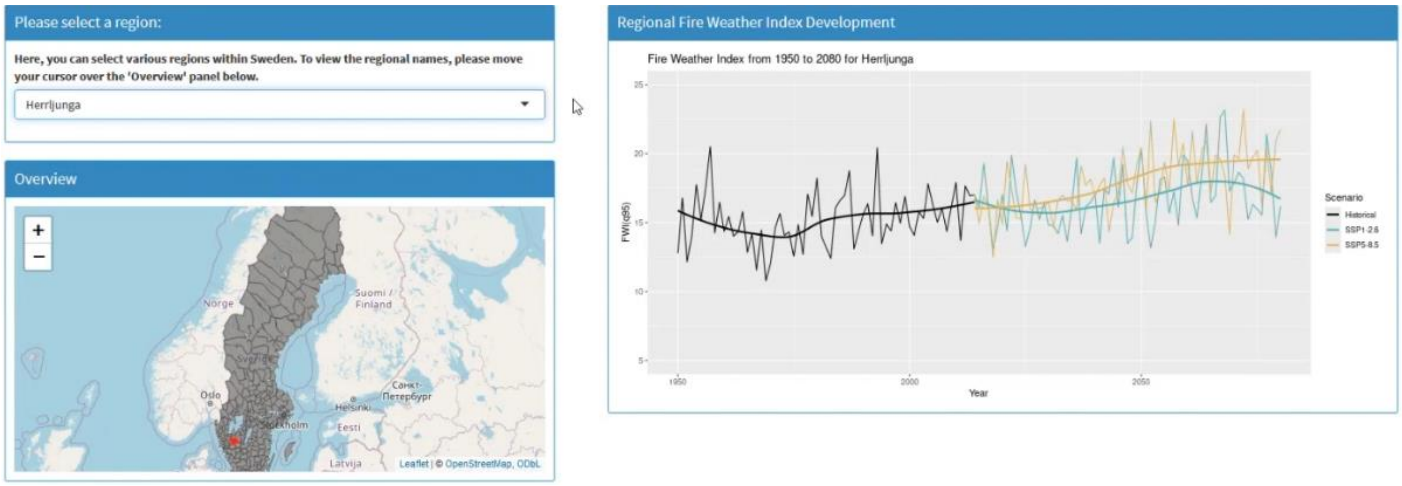



*Figure 12. Screenshot from the app showing expected change on a selected region.*

## 3.10 14:15 - Future fire regimes under climate and land-use change

Alex Neidermeyer presents land-use scenarios and stylised fuel management scenarios, which have been applied to the European territory. The scenarios assess fuels generated by Dynamics Global Vegetation Models (DGVM) which uses historical data from 1960 to 2010 from the HILDA+ dataset [13], which combines several open data streams (remote sensing, reconstructions and statistics) to estimate land use change. The future land use scenarios were simulated using CLUMondo, a spatially explicit and dynamic land system change model [14]. The future land use scenarios were simulated using CLUMondo, a spatially explicit and dynamic land system change model [14]. We

adopted Shared Socioeconomic Pathways (SSP) 1 ("Sustainability") and SSP3 ("Regional rivalry") to explore the effects on land use of divergent developmental paths for Europe. While the time series is based on a 1-km resolution, we made a conversion in aggregating the data to a 9-km resolution and an aggregated land cover class legend to match that used natively in the DGVMs. These scenarios can be used as examples of what type of futures that should be prepared for in terms of fuel, fuel management and vegetation.

| Characteristics | Description |
|---|---|
| Type of products: | Geospatial |
| Units: | Land cover classes |
| Update Frequency: | Static |
| Accuracy: | N/A |
| Output Format: | .tiff |
| Fire risk component (accordingly to the Integrated Scheme of the FirEUrisk project): | Risk Adaptation |
| Temporal coverage: | 1960-2050 (decadal) |
| Spatial resolution: | 9 $km^2$ |
| Availability on FirEUrisk platform: | All data can be found on: DataverseNL |
| Key contact for questions | Alex Neidermeier a.neidermeier@vu.nl |

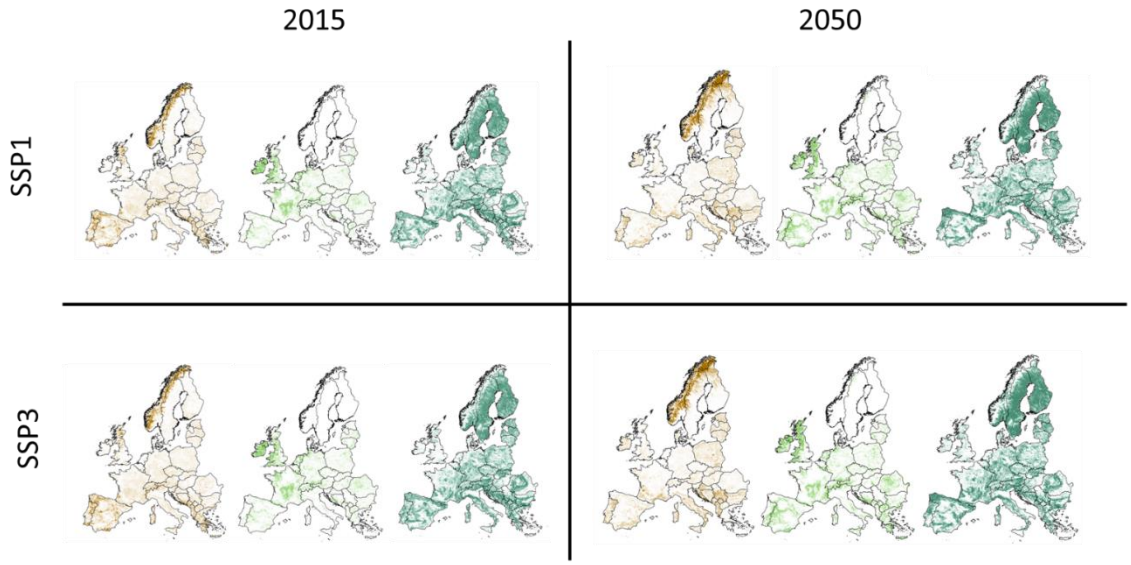



*Figure 13. Comparison of changes in land cover in SSP 1 & 3 between 2015 and 2050. Brown represents shrubland cover, light green represents grassland cover, and dark green represents forest cover.*

The scenarios were followed by a presentation from Kirsten Thonicke on trying to extend the future land-use, the future climate to predict future fire regimes under these different scenarios. The method uses the SPITFIRE model [15].

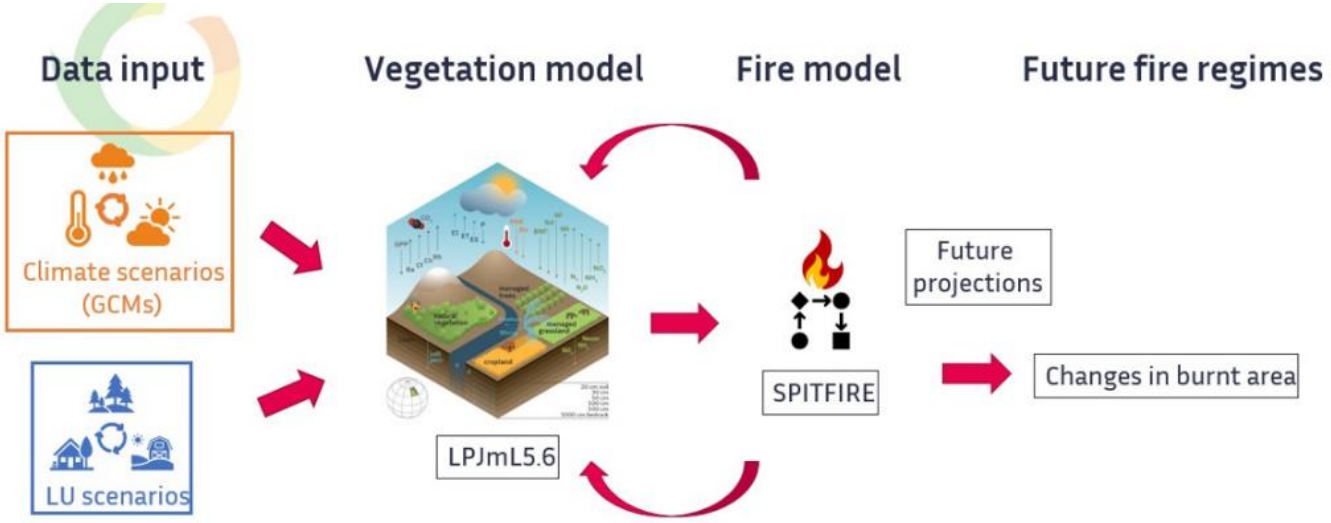



*Figure 14. Model overview from Climate and land-use scenarios to changes in burnt area [15].*

Technical specs of the model are found below.

| Characteristics | Description |
|---|---|
| Type of products: | Geospatial product |
| Units: | Not applicable |
| Update Frequency: | Not applicable |
| Accuracy: | Not applicable |
| Output Format: | .netcdf |
| Availability | See https://egusphere.copernicus.org/preprints/2024/egusphere-2024-1914/egusphere-2024-1914.pdf |
| Fire risk component (accordingly to the Integrated Scheme of the FirEUrisk project): | Ignition / Propagation |
| Temporal coverage: | 2020-2100 |
| Spatial resolution: | > 1 km (9 km) |

## 3.11 15:00 - Emissions from Wildfires – Example from Sweden

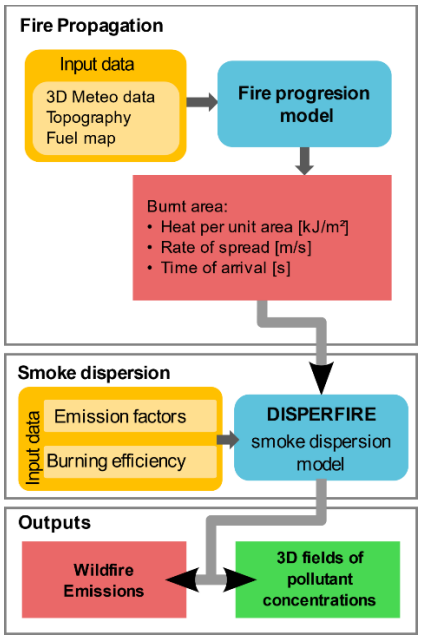



*Figure 15. Model overview and the algorithm principal scheme*

Tobias Oswald presented the Chimere-Apiflame model which can be used to analyse impacts of wildfires to air-quality in Sweden. Tobias used the latest model version to look at the Västmanland fire burning ten years ago (2014). The results show that accumulation of smoke was found in close vicinity of the Fire on the 5$^{th}$ day of burning. Improvements on the model was discussed and the specification of the model from the product card can be found below:

| Characteristics | Description |
|---|---|
| Type of products: | Geospatial |
| Units: | µg.m-3 |
| Update Frequency: | Near-real time after wildfire ignition |
| Accuracy: | Uncertainty: 50% to 100% |
| Output Format: | .shp, .tif |
| Fire risk component: | Exposure |
| Temporal coverage: | Fire duration (see Methodology) |
| Spatial resolution: | <1 km |
| Availability on FirEUrisk platform: | Under development |

The model implemented to the 2021 Attica fires can be found here: https://www.publish.csiro.au/WF/pdf/WF22148 and the slides from the Västmanland application are displayed in Appendix B.

## 3.12 15:20 - Intermittent behaviour of mega fires

Carlos Ribeiro presented a series of work related to very large fires and their intermittent behaviour. Thus, their rate of spread is not just a function of slope, fuel, moisture content and wind but also has an implicit variation once the fire grow very large.

A summary of the work can be found here: https://www.publish.csiro.au/wf/pdf/WF21098 and a short description follows below:

- **Session:** Fire spread and smoke modelling. Domingos Viegas, ADAI (Portugal) and Ana Miranda, UAVR (Portugal).
- **Developer:** Domingos Viegas, ADAI (Portugal).
- **Activity:** "A2.3.1 Extreme Fire Behavior Modelling".
- **Product description:** The product allows to estimate the ROS of the head fire in some situations of Extreme Fire Behaviour, associated to the interaction between the atmosphere and the burning fire that induce a dynamic change of the ROS which is not considered in current fire behaviour simulators.
- **Methodology:** The product proposes a semiempirical method to estimate the dynamic behavior of a fire considering the interaction between the fire and the atmosphere that consists usually in a fire acceleration and deceleration, that may have one or more cycles, leading to the achievement of very high values of the ROS and time dependent fire spread properties that may have important implications in fire suppression and fire safety.
  The model is based on extensive analytical research supported by laboratory and field experiments, analysis of past fires and has a semi-empirical nature, with a set of differential equations to evaluate the positive or negative acceleration of the head fire as a function of parameters that are set or can be determined for common fuels and for a wide set of operational conditions.
  The model can be applied to three situations of dynamic fire behaviour that have been studied so far: (A) eruptive fires, (B) junction fires and (C) accelerating and decelerating fires.
  At present there are publications supporting Models A and B. Model C is being developed and has been tested in some cases in Portugal but must be extended to other cases.
  Detailed description of the Extreme Fire Behaviour Modelling available here: Deliverable D2.5 (M36).
- **FirEUrisk component of the integrated strategy:** Propagation
- **https://fireurisk.satways.net/collection/**
- **Technical characteristics:**

| Characteristics | Description |
|---|---|
| Type of products: | Mathematical Model |
| Units: | m/s |
| Update Frequency: | Depends on the situation being modelled |
| Accuracy: | 20 to 30% |
| Output Format: | Report/program |
| Fire risk component (according to the Integrated Scheme of the FirEUrisk project): | Fire propagation |
| Temporal coverage: | Duration of fire spread (1 to 10 hours) |
| Spatial resolution: | 10m |
| Availability on FirEUrisk platform: | Draft version of D2.5 |

# 4 Validation

One of the main objectives of the event was presenting FirEUrisk's products and gather feedback for further improvement when possible. To facilitate this, using the Mentimeter tool (https://www.mentimeter.com), interactive surveys were introduced during the event to capture individual perspectives on attendance and each product. However, recognizing the limitations of the approach using the Mentimeter tool, post-event assessment was made with four selected participants from civil protection, rescue services, forestry and research organizations, respectively. During these sessions each presentation was discussed again and suggestions for improvements as well as usability in the participant's day-to-day activities was put forward. Last, some expectations on the rest of the whole project were discussed.

## 4.1 Results of the immediate feedback

In this section, we present the responses to the questionnaires collected during the event. As noticed in previous events, for online sessions the participation rate in answering the Mentimeter questions is very low. Thus, these evaluations were supplemented by a post-event assessment with a few chosen end-users.

### Mentimeter Answers:

2. What aspect of wildfire risk assessment is most important in your activity? (*n*=17)

| Aspect | Share |
|---|---|
| Ignition causes (natural/human) | 16 % |
| Fire propagation (fuels, terrain, weather) | 30 % |
| Population | 21 % |
| Ecosystem exposure | 0 % |
| Potential losses (ecological/socio-economic assets) | 14 % |
| Resistance and response capacity | 19 % |
| Other | 0 % |

3. What other fire risk components do you deal with in your activity? (e.g., land management plans, fighter's training, residents' education) (*n*=24)

| Fire risk components identified | | |
|---|---|---|
| Detection | Prevention before and after forest machine work | Combustion of peat |
| Forest machine design | Climate change | Weather conditions |
| High vulnerability of structures | Practices of land management | Detect faster the ignition |
| The work (Forestry) and tourism in the forest. Also the railways ignition of vegetation | Biomass load | traditional uses of land and forest abandonment |
| Low risk perception | Identify prescribed vs wild forest fires | Situational awareness in forest fires |

| Fire risk components identified | | |
|---|---|---|
| Accessibility info to fight fire for fire fighters | Fire danger or fire weather | Operational response |
| Seasonal monitoring | Public awareness | Prescribed fire implementation |
| Public education | Lightning | Sustainable forest fuel management programs |

## Products assessment:

1. Has the explanation of the fire risk assessment products sufficient? (*n*=18)

| Choices | Votes (0-5) |
|---|---|
| Structure damages from wildfires in North Europe – factors for building survivability | 4.5 |
| Fires in humid temperate regions | 4.4 |
| Grassland fire danger | 4.7 |
| Wildland urban interface in Kalmar County | 4.0 |
| Expected future forest fire danger in Sweden – it's relevance for fire occurrence | 3.6 |
| A shiny app for forest fire danger projections | 3.9 |
| Future fire regimes under climate and land-use changes | 3.9 |
| Emissions potential from wildfires – Example from Sweden | 4.3 |
| Intermittent behaviour of mega fires | 4.4 |

2. How suitable are these risk assessment products for your territory (*n*=15)

| Choices | Votes (0-5) |
|---|---|
| Structure damages from wildfires in North Europe – factors for building survivability | 3.7 |
| Fires in humid temperate regions | 3.5 |
| Grassland fire danger | 4.1 |
| Wildland urban interface in Kalmar County | 3.7 |
| Expected future forest fire danger in Sweden – it's relevance for fire occurrence | 3.6 |
| A shiny app for forest fire danger projections | 3.7 |
| Future fire regimes under climate and land-use changes | 4.1 |
| Emissions potential from wildfires – Example from Sweden | 4.0 |
| Intermittent behaviour of mega fires | 4.0 |

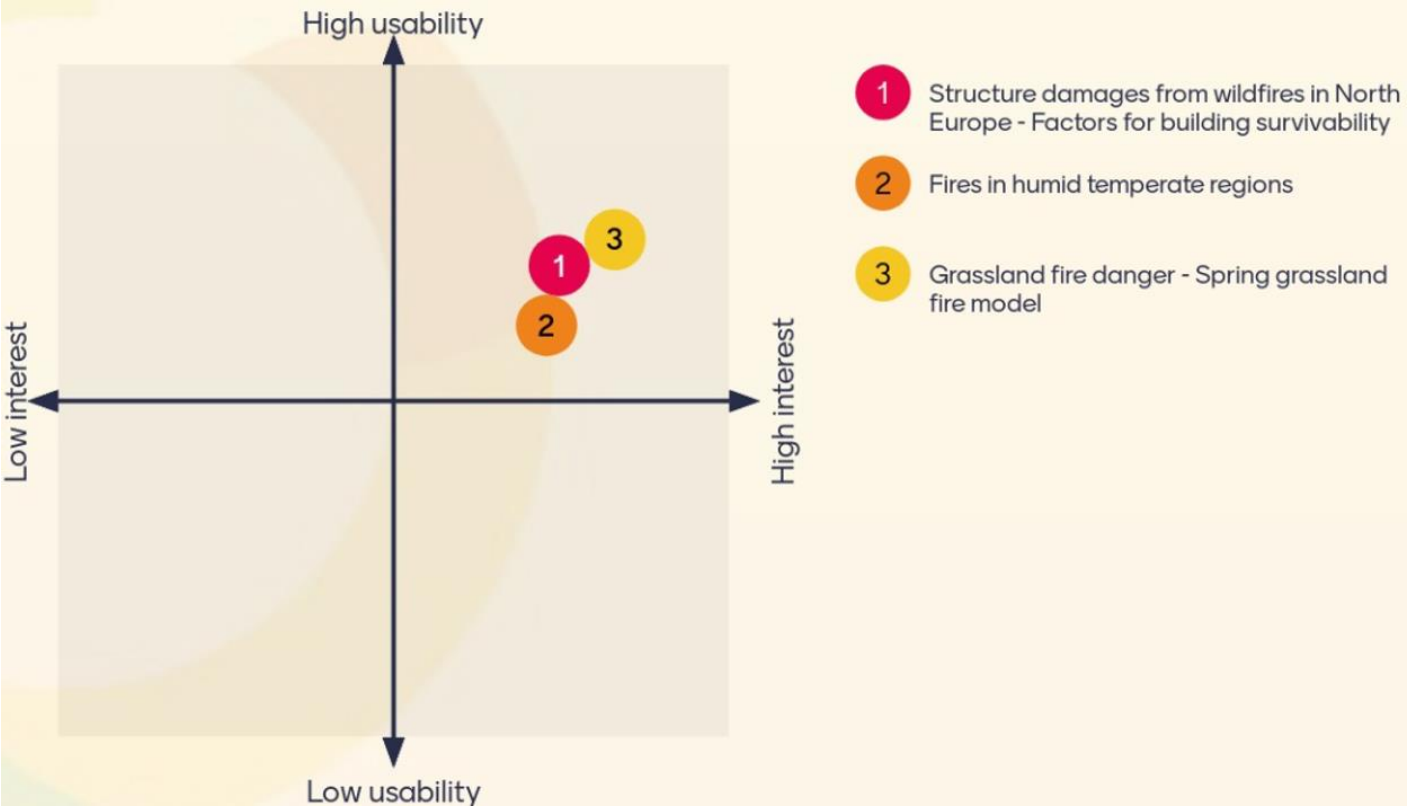
3. What other information for fire risk assessment would you need? (*n*=25)

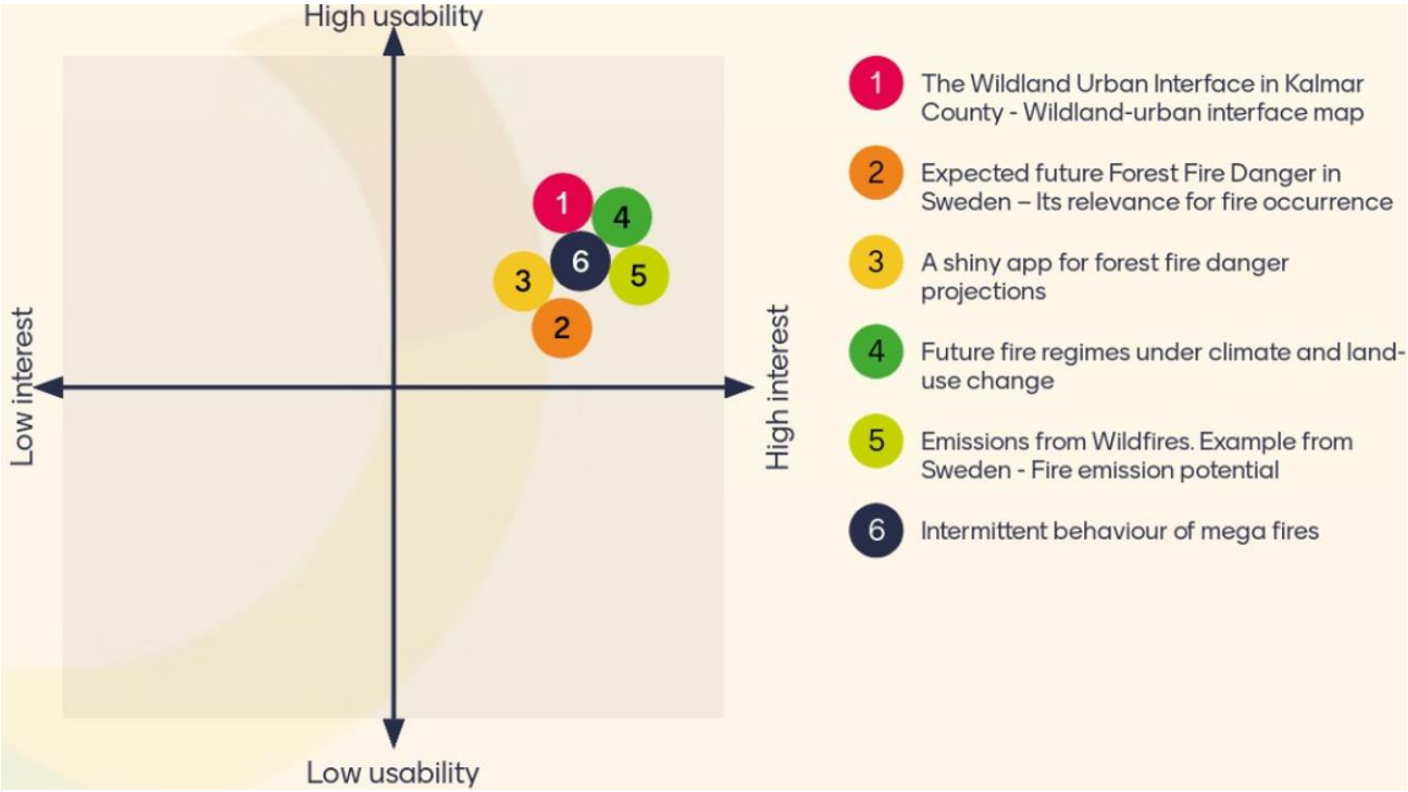
| Additional fire risk assessment information required | | |
|---|---|---|
| More frequent satellite data over northern parts of Scandinavia | Forest practices for modifying fire potential | Quick evaluation of conditions in early spring |
| Really high-resolution fire risk estimation is difficult, but still on the wish-list for forestry | Fuel models based on Lidar | Daily forecasted custom info. |
| Risk reduction culture development | Wildfire behaviour analyst role inside F&R services for operational purposes | Increased knowledge of what burns easiest |
| Lower satellite data latency | When does thunderstorms and strikes start fires and which factors does it depend on? | Using Lidar to measure and predict fuel models |
| High-resolution (local) free weather data | Scenarios of climate change impact to forest and grass fire risk | General guidance (rule book) for tourists in the remote areas |
| Interpretation of fire risk data | Worst case for some days FWI-model | Free weather forecasts |
| High resolution satellite images | Mapping products on storms | Cause of fire in relation to FWI |
| Integration of all products | More about the consequences for the society | The integrations to predict the fire behaviour |
| More about efficiency and effectiveness of the assessments | | |

4. Is the approach to fire risk assessment products comprehensive? (*n*=8)

| Choices | Votes (0-5) |
|---|---|
| Structure damages from wildfires in North Europe – factors for building survivability | 4.3 |
| Fires in humid temperate regions | 4.2 |
| Grassland fire danger | 4.5 |
| Wildland urban interface in Kalmar County | 4.2 |
| Expected future forest fire danger in Sweden – it's relevance for fire occurrence | 4.4 |
| A shiny app for forest fire danger projections | 4.3 |
| Future fire regimes under climate and land-use changes | 4.1 |
| Emissions potential from wildfires – Example from Sweden | 4.0 |
| Intermittent behaviour of mega fires | 4.3 |

5. How interesting are these products? Would you use them in your activities? (*n*=16)



## Evaluation of the whole event:

1. To what extent do you agree with the following statements? (*n*=10)

| Choices | Votes |
|---|---|
| Was FirEUrisk project well presented at the start of the demonstration? | 3.0 |
| Were products described in sufficient detail for your needs? | 3.2 |
| Did you understand the use of the products? | 3.5 |
| Did you understand the questions about the product(s)? | 3.1 |
| Were questions answered satisfactorily? | 3.4 |
| The on-line experience was sufficient to validate the product | 3.8 |

## 4.2 Post-event validation

Four end-users were selected for further assessment a few weeks after the event. During these sessions the end-users were allowed to speak freely on needs and how they relate to the usability of the products. The end-users were associated to (1) forestry industry organization, (2) civil protection, (3) rescue service organization and (4) scientific research. All presentations were discussed focusing on development and improvements as well as their usability for the specific end-user. The individual validation sessions were held between May 20th and June 10th.

### 4.2.1 Reflections on the different parts of the demonstration

***09:15 - Integrated wildfire risk***

All end-users described the concept as interesting but not very useful in every-day practices. The most valuable part of the structure is to make sure that no aspects are forgotten when rescue services or civil protection organizations conduct risk- and vulnerability studies. The research organization also pointed out that clear definitions that came with the presentation are very handy such as to avoid confusion in communication.

One suggestion was to add the chart to the webpage and add clickable boxes with more info (definitions, links, references and practical examples) within each factor.

***09:45 - Review of past European fire seasons***

This session was much appreciated by all attendees but as with previous part, not much applicable to every-day tasks. However, an overview and deeper knowledge about the rest of Europe is important to tackle all questions arising from the public, which is mostly triggered by news media in which the different aspects sometimes are poorly reflected and can be leaned against dramatic and spectacular descriptions. All end-users looked forward to the report.

***10:10 - Modern fire regime in Sweden***

This was very useful to the participants as a reminder of the special conditions for northern Europe compared to other parts of the continent. The product is a knowledge-increasing action, which is appreciated. A short popular science summary of it was sought and such publication has just been released to which the participants were given the link.

Further development on studies within the same topic was suggested. These were to assess ignition causes in relation to weather, how it changes and how authorities could alter their communication with the seasons. Also, to correlate the occurrence to the present knowledge we have on soil moisture, fuel maps etc.

***10:30 - Structure damages from wildfires in North Europe***

To the four participants, much of the knowledge presented in the presentation was new. They were looking forward to seeing the second part published for them to utilise in rescue service communication and plans for civil protection. The most important part was the number of buildings, quantifying the problem as well as the characteristics which, despite general belief, only weakly correlated to rural areas. The non-researchers in the group were also asking for short summaries in Swedish for easy dissemination throughout the municipalities.

The civil protection organisation asked for shorter guidelines and input of how to change the dispatch report, in order to catch information on this in the future.

***11:10 - Fires in humid temperate regions***

This was all very interesting to the participants as it is rare to see anything other than fire weather as a danger indicator. The rescue service participant said that this is often known among the fire fighters, but it is rarely communicated out and not used so much for authorisation of burn bans and warnings. Since the new grassland fire model was introduced, this is however partly covered. The researcher was specifically asking how the team was utilising this data to formulate a fire danger model. That would make a big difference in the region and could possibly inspire homogenisation of the Swedish grassland fire danger and other European models for fire danger driven by both weather and phenology.

***11:30 - Grassland fire danger***

Much related to the discussion above. The product is highly utilised by both the rescue service and the civil contingency agency. The forest industry does not use it very much as most of their decision on works are based on the forest fire danger. The researcher and civil protection stressed a gain in utilisation if phenology was either validated in other winter-cold parts of Europe or if it could be assessed by remote sensing. If so, the same model could be used in larger areas and possibly communicated by EFFIS (European Forest Fire Information Service).

***13:00 - The Wildland Urban Interface in Kalmar County***

This presentation was considered very interesting, and the rescue service organisation stated that such maps, if available also for other regions, would be much help in preparedness for the municipal rescue services. For forestry the utilisation of WUI is not emphasised as any house adjacent to their lands are always part of the assessment. The civil contingency agency and the researchers all stated that the value of it would increase a lot if it was made public on the web platform and not needing a GIS program on the PC to investigate.

All participants also highlighted that the presentation itself was good in that it reflected over what the WUI was and what its purpose is.

***13:30 - Expected future Forest Fire Danger in Sweden – Its relevance for fire occurrence***

This was all very interesting. The civil protection organisation appreciated it since a similar study was just released focusing on only Sweden. Clear comparison between these two studies was asked for. The transformation of changes in fire danger to changes in wildfire outcome was all very appreciated and all participants asked for more maps that

could describe this change in more detail. The forestry organization also asked for a connection to the differences in fire danger and their relation to differences seen for e.g. tree species composition or resource availability from national resources. As for what can be done within the project, the participants asked for maps showing changes in fire outcome and that these could be assessed in the project viewer.

***14:00 - A shiny app for forest fire danger projections***

This was one of the most interesting parts for all participants. The forestry organisation already had future projections for other aspects of forestry but civil protection, the rescue service and the researcher all highlighted that this would be a good source for planning, for education and for referencing changes in certain areas. They all asked for the app to be continuously updated and that perhaps it could also describe the above-mentioned changes in fire outcome in similar clickable maps.

A special request from the research organization was the downloadable option from the map to ascii or similar.

***14:15 - Future fire regimes under climate and land-use change***

This was one of the more difficult topics for the participants to grasp. The forestry organisation asked for info on how the changes would impact forestry operations and also asked if the changes could be compared to known changes in e.g. tree species composition, something which today is highly managed by the landowners. More maps on how deciduous tree inclusion would change fire activity was the most wanted improvement that the participants would appreciate. All participant highly appreciated the approach to describe possible scenarios, rather than stating probabilistic futures. This makes it easier to take in and can be utilised in planning for e.g. the rescue service (even though it would have minor impact on day-to-day activities) and the civil protection organisation (for which long term planning is a mandate and these type of scenarios more useful). The civil protection organisation asked for publication or material which was not specifically an article in a scientific journal.

***15:00 - Emissions from Wildfires: Example from Sweden***

The potential emissions presentation was interesting from a civil protection perspective as it could help in risk- and vulnerability assessment that municipalities guided by the authority. The rescue service organisation stated that if such info could be readily available in a web interface and applied without much prior knowledge the product would be very useful in daily operational work. Presently, the method of identifying residential areas in the downwind and projected downwind direction is sufficient but for larger incidents (like the one applied to in the presentation) deeper analysis would be very helpful. However, this required it being packaged in a user-friendly interface without the need for additional software.

The forestry organisation expressed low usability in their present work but thought it would be appropriate in the national wildfire system as a general info, both for their personnel and the public.

***15:20 - Intermittent behaviour of mega fires***

The rescue service organisation noticed that such intermittent behaviour was observed in the periods of highest intensity the summer of 2018. The selected participants thought the idea and the results were very interesting and that it could be important to emphasise in fire-fighting training that the linear behaviour might not be expected for very large and rare incidents. However, all participants asked how applicable the modelling was to boreal conditions for which the moderator (RISE) had no answers. They also noted that it was difficult to follow all of the rationale and that dissemination on the project webpage could possibly be organised in a more user-friendly manner.

### 4.2.2 Other reflections on the project

The participants were keen on seeing the viewer. All of them were asking for a one stop place here all information they needed was gathered and where data was available for them. It had to be highly user-friendly. The rescue service organization described previous project where they had expected similar, but which was just full of files which were difficult to understand, difficult to process and difficult to use. Easy solutions like the shiny app were much appreciated but it would be good if it was concentrated to the webpage of the project.
The civil protection organization emphasized that detection and localization was important for the North European perspective and that there was little of such in the program. It also highlighted the interplay between fire danger and the fuel and that this would be good to have combined in an easy web application. However, they stressed that the models could not be FlamMap or similar used further south but something which is realistic for the surface fuels that are abundant in Scandinavia.

In terms of integration, both the research organization and the rescue services emphasized that integration of all aspects of wildfire risk such that it converged into one scalar risk number was not important for successful utilization. Instead, the integration should focus on if improvements in one end would be unfavorable in other ends. How the different aspects interplays qualitatively are more important than their interaction in quantitative manners?

# 5 Conclusions and Lessons Learnt from the Demonstration Event

This report summarises the knowledge and tools (products) developed within the FirEUrisk project which can have a support function on wildfire risk mitigation in the European boreal region. The assessment of the products was done both by direct Mentimeter questions, during the event itself, and a deeper discussion with four individual institutions a few weeks after the event.

Overall, the products were positively received. In particular, products showing real outcomes that could be compared to present day problems were appreciated, as most projections towards future scenarios can be complex and difficult to penetrate. End-users considered it vital that products that result in tools had a clear focus on user-friendliness and products that were more oriented towards knowledge and awareness were also published in short notes using non-scientific jargon to increase uptake. Many opinions of how to relate the products to current forestry practises were also raised. While this is a difficult task due to the high landowner autonomy and together with complex regulations from both the national and the European perspective, this is something that the project needs to carry along to the final year of dissemination.

Another important take-home message is that evaluation via mobile phones receives less participants for online events compared to if they are done during an in-person event. Therefore, extended and in-depth evaluations from a selected number of participants are useful for a better understanding of how the products were received and assessed.

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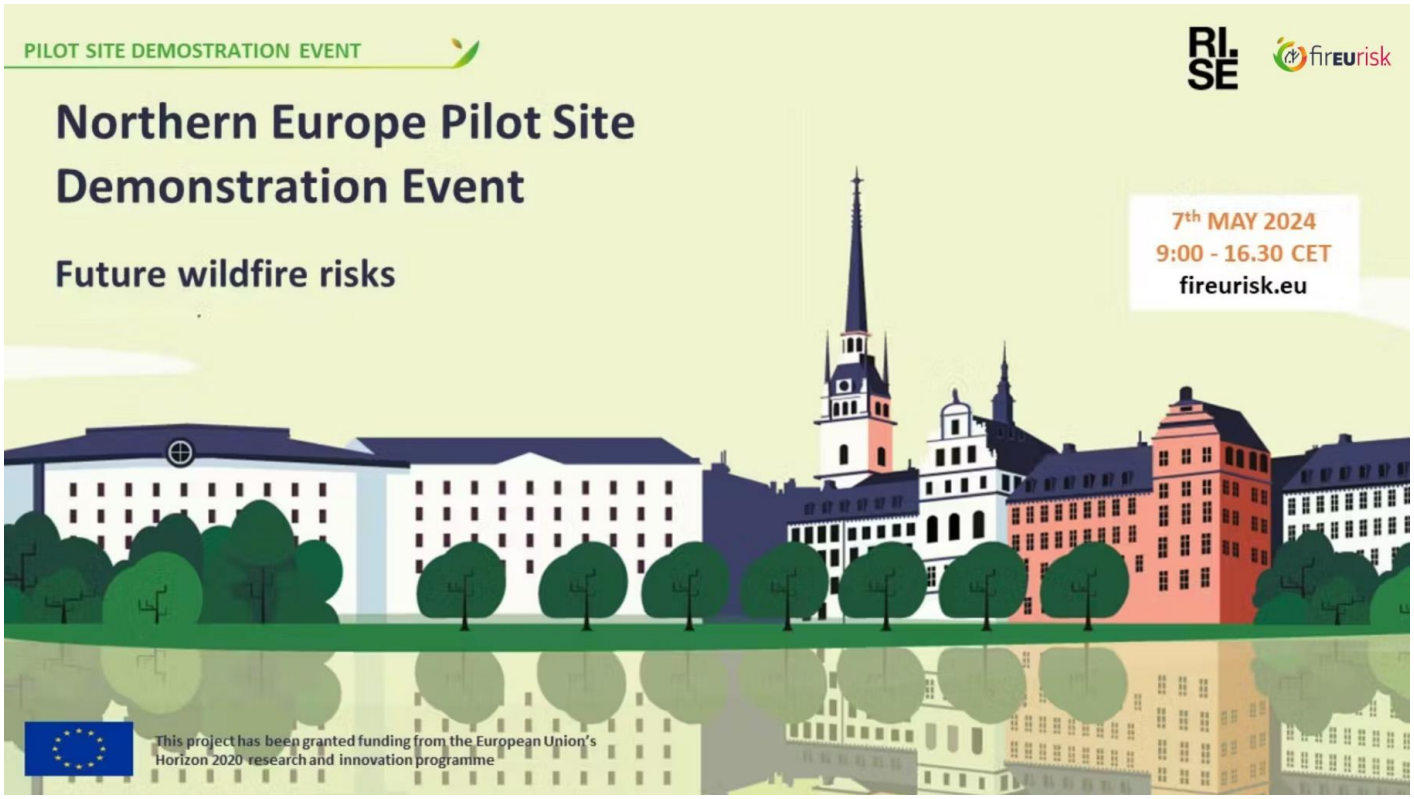
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## Annex A: Mentimeter questionnaire

### Presentation and introduction

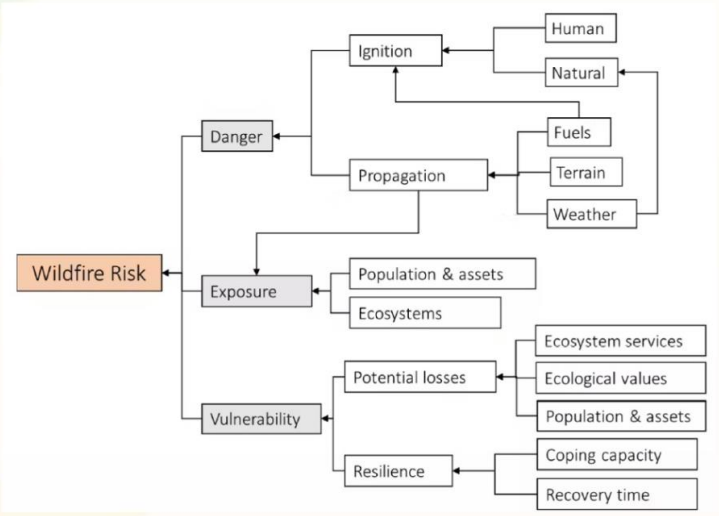





# 1. What is your organization's name?

19 responses

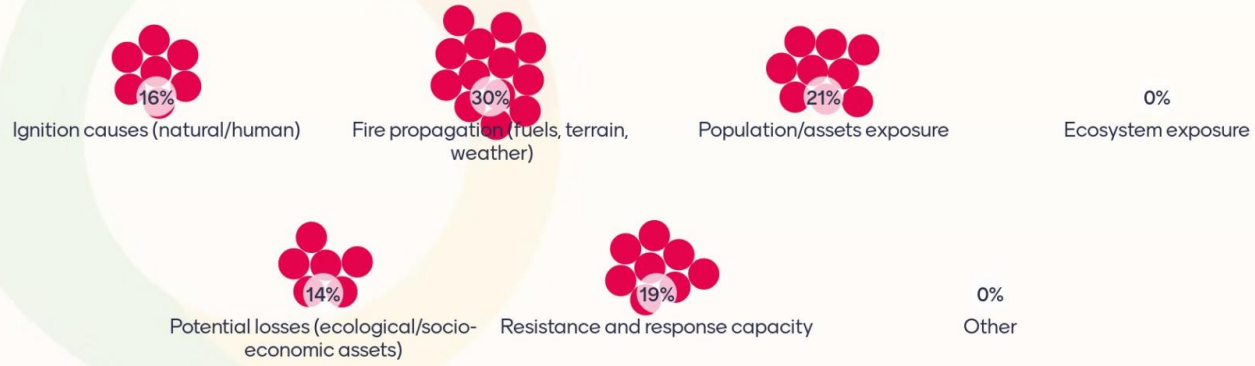



These are the integrated components to assess wildfire risk

SELECT UP TO 3 OPTIONS

## 2. What component of wildfire risk is most important in your activity?

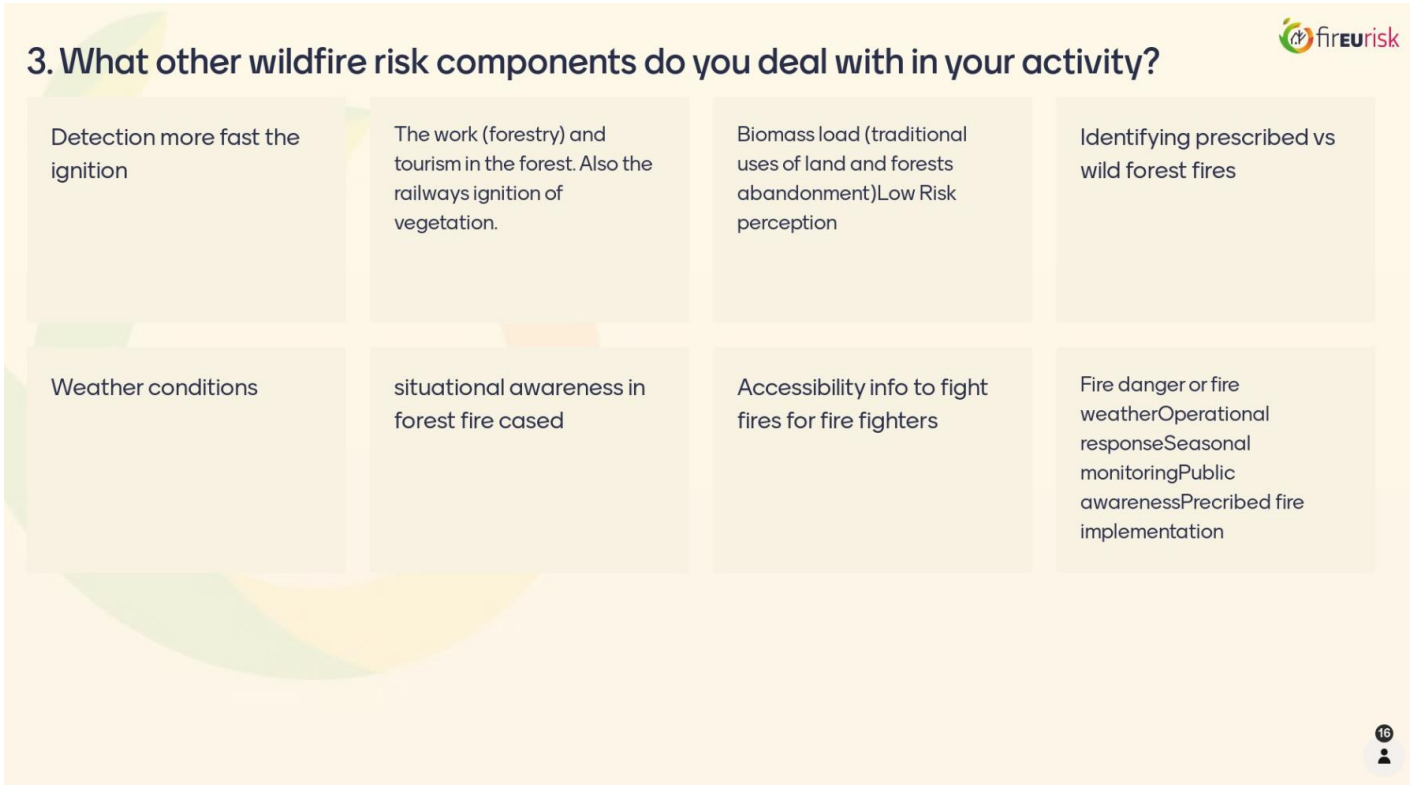



17

## 3. What other wildfire risk components do you deal with in your activity?

| | | | |
|---|---|---|---|
| Detection | Prevention before/during forest machine work | Combustion of peat | Forest machine design |
| global/climate change | Weather conditions | Weather | Practices of land management |

16







**Evaluation and validation of products on risk assessment, reduction and adaptation. Part 1.**

# FirEUrisk products on risk assessment, reduction, and adaptation

Part 1

## 1. Was the explanation of the fire risk products sufficient?



## 2.How suitable are these fire risk products for your territory?




15

## 3. What other information about fire risk (assessment, reduction, and adaptation) would you need?

| | | | |
|---|---|---|---|
| More frequent satellite data over the northern parts of Scandinavia | Forestry practices for modifying fire potential | Quick evaluation of conditions in early spring | Really high-resolution fire risk estimation is difficult, but still on the wishlist for forestry... |
| fuel models based on lidar | Daily forecasted custom info. Risk reduction culture devepment. Wildfire behavior analyst role inside F&R services for operational porpouses | Increased knowledge of what burns easiest | Lower satillite data latency |

12

## 3. What other information about fire risk (assessment, reduction, and adaptation) would you need?

When start thunderstoms and strikes a fire and which factors is it depends on.

Using LIDAR to measure and predict the fuel models

High-resolution (local) free weather data

Scenarios of climate change impact to forest and grass fire risk

General guidance/rule book for tourists in the remote area

Interpretation of fire risk data

Worts case for some days FWI-model

Free weather forecasts

12

## 3. What other information about fire risk (assessment, reduction, and adaptation) would you need?

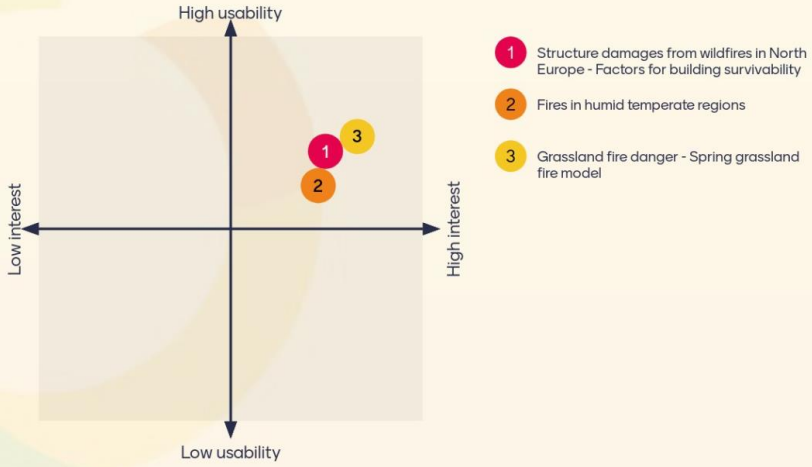
High resolution satélite imagesMapping products on storms

12

## 4. Is the approach of fire risk prevention products comprehensive?



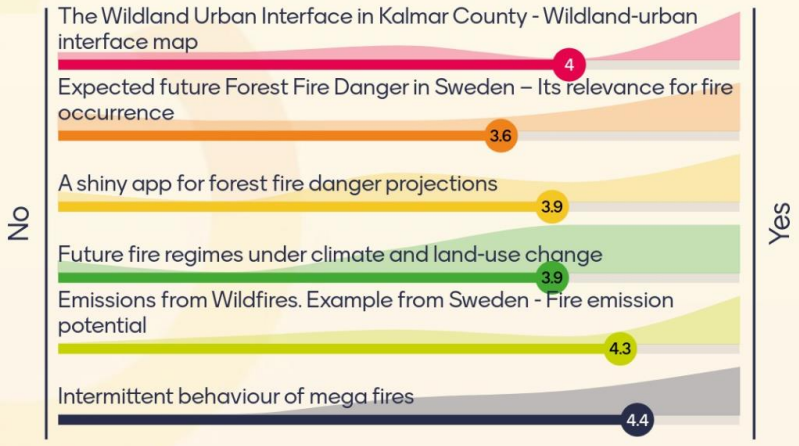

## 5. How interesting and usable are these products?



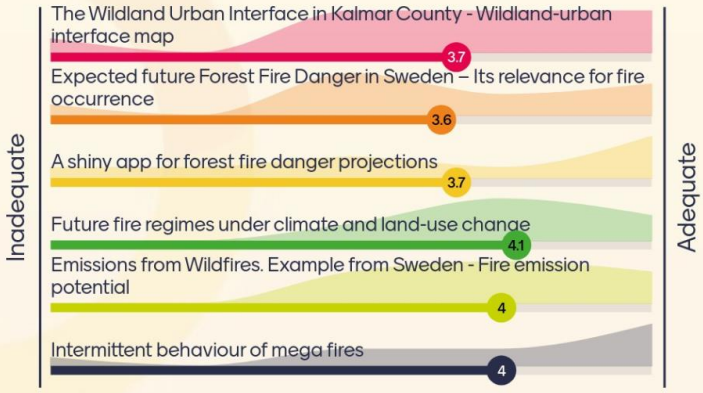
# FirEUrisk products on risk assessment, reduction, and adaptation

Part 2

## 1. Was the explanation of the fire risk products sufficient?



## 2.How suitable are these fire risk products for your territory?



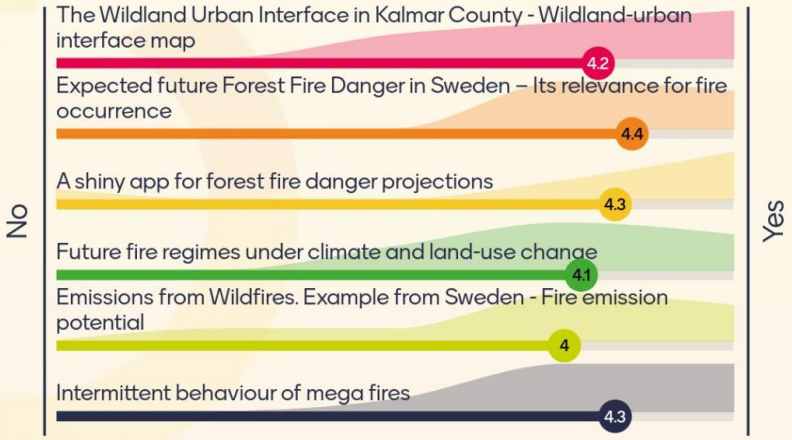

11

## 3. What other information for fire risk (assessment, reduction, and adaptation) would you need?

- Same as the answers from this morning
- Causes of fire in relation to FWI
- Integration of all products
- More about consequences for the society
- The integration to predict the fire behaviour
- More about efficiency and effectiveness of the assessments

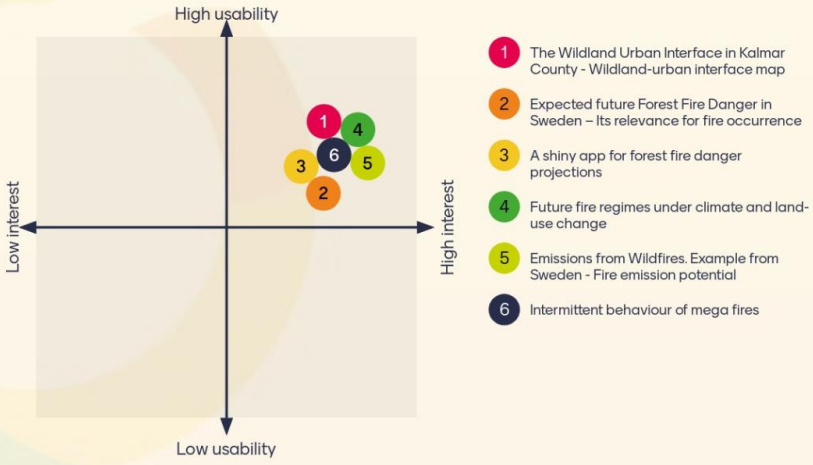
6

# 4. Is the approach to fire risk products comprehensive?




9

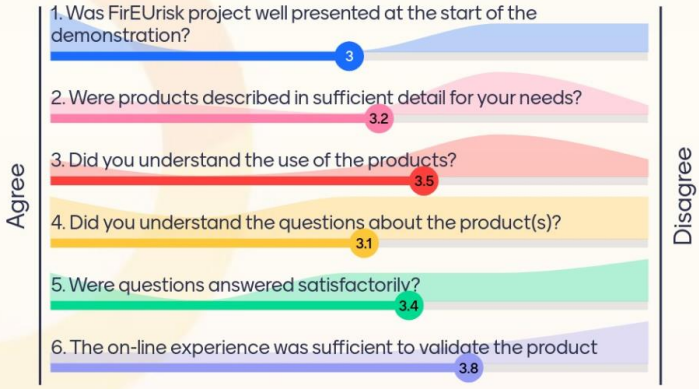
# 5. How interesting and usable are these products?




10

# FirEUrisk display platform and FirEUrisk Northern Europe Pilot Site Demostration Event.

## 2. To what extent do you agree with the following questions?



## 3. Please let us know items to improve or any question to be answered

Too late in the afternoon. Head is full

Let us know the link to the platfom when opened to the public

Note that the last question had agree and disagree in the opposite order than the other wuestions. That might have infleuenced the results

How well will it work on Nordic condition & how difficult will it be to adjust for example the last model for Swedish conditions?

4



This project has been granted funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement no. 101003890

# Annex B: PS3 demonstration event presentations

## Integrated wildfire risk


North European Pilot Site Demonstration Event, Tuesday 7th May, 2024
Integrated wildfire risk
FirEURisk project
Emilio Chuvieco (Universidad de Alcalá, Spain)
Science leader, on behalf of the FirEURisk consortium
emilio.chuvieco@uah.es

1


FirEURisk project objectives
1.Expand the capabilities of existing wildfire risk assessment systems.
2.Use risk-assessment to drive wildfire management and reduce current fire risk conditions.
3. Adapt fire management strategies to expected future climate and socio-economic changes.
4. Integrate all fire management phases and activities.
firEURisk

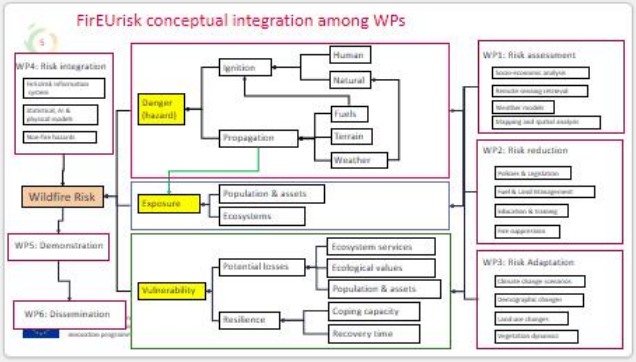
2


firEURisk

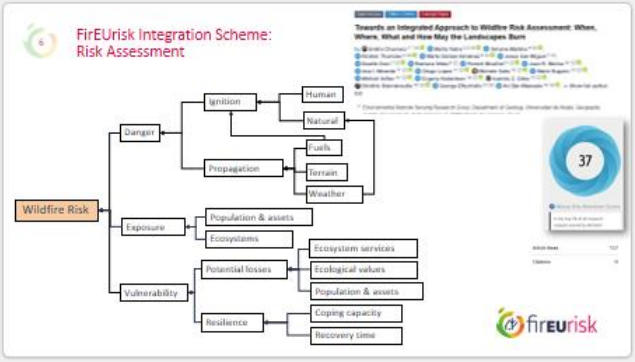
3


Project partners
firEURisk

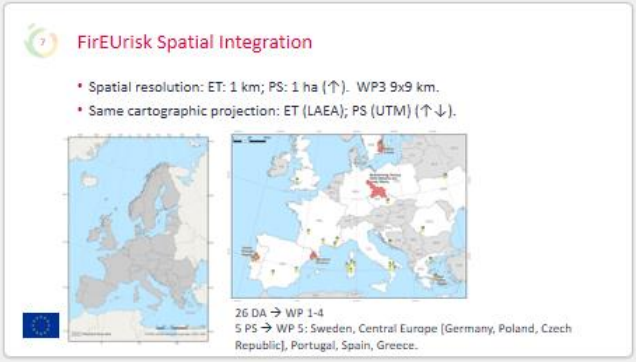
4


FirEURisk conceptual integration among WPs
WP4: Risk integration
Wildfire Risk
WP5: Demonstration
WP6: Dissemination
Danger (hazard)
Ignition
Human
Natural
Propagation
Fuels
Terrain
Weather
Exposure
Population & assets
Ecosystems
Vulnerability
Potential losses
Ecosystem services
Ecological values
Population & assets
Resilience
Coping capacity
Recovery time
WP1: Risk assessment
WP2: Risk reduction
WP3: Risk Adaptation

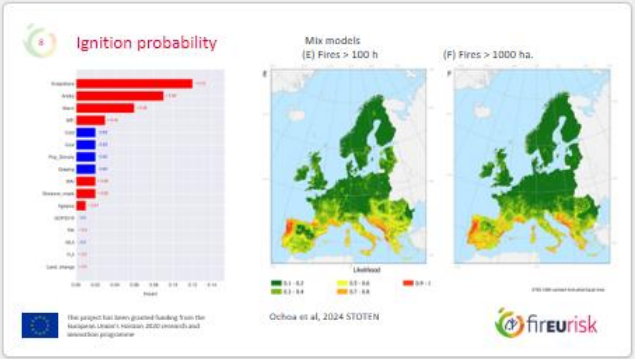
5


FirEURisk Integration Scheme:
Risk Assessment
Wildfire Risk
Danger
Ignition
Human
Natural
Propagation
Fuels
Terrain
Weather
Exposure
Population & assets
Ecosystems
Vulnerability
Potential losses
Ecosystem services
Ecological values
Population & assets
Resilience
Coping capacity
Recovery time
37
firEURisk

6


FirEURisk Spatial Integration
• Spatial resolution: ET: 1 km; PS: 1 ha (↑). WP3 9x9 km.
• Same cartographic projection: ET (LAEA); PS (UTM) (↑↓).
26 DA → WP 1-4
5 PS → WP 5: Sweden, Central Europe [Germany, Poland, Czech Republic], Portugal, Spain, Greece.

7


Ignition probability
Mix models
(E) Fires > 100 h
(F) Fires > 1000 ha.
Likelihood
Ochoa et al, 2024 STOTEN
firEURisk

8

## European fuel mapping

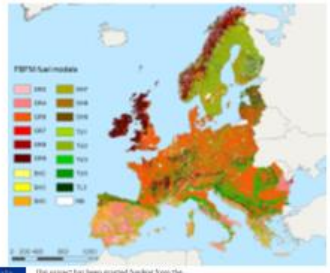
| Main fuel type | Leaf type/ Type | Phenology | Fractional cover (%) |
|---|---|---|---|
| 1. Forest | 11. Broadleaf | 111. Evergreen | 1111. Open (15-70%) |
| | | | 1112. Closed (70-100%) |
| | | 112. Deciduous | 1121. Open (15-70%) |
| | | | 1122. Closed (70-100%) |
| | 12. Needleleaf | 121. Evergreen | 1211. Open (15-70%) |
| | | | 1212. Closed (70-100%) |
| | | 122. Deciduous | 1221. Open (15-70%) |
| | | | 1222. Closed (70-100%) |
| | 13. Mixed | | 1301. Open (15-70%) |
| | | | 1302. Closed (70-100%) |
| | Fuel depth | | |
| 2. Shrubland | 21. Low (0-0.5m) | | |
| | 22. Medium (0.5-1.5m) | | |
| | 23. High (≥ 1.5m) | | |
| 3. Grassland | 31. Low (0-0.3m) | | |
| | 32. Medium (0.3-0.7m) | | |
| | 33. High (≥ 0.7m) | | |
| | Type | | |
| 4. Cropland | 41. Herbaceous | | |
| | 42. Woody (shrub-tree) | | |
| 5. Wet and peat/ semi-peat land | 51. Trees | | |
| | 52. Shrubland | | |
| | 53. Grassland | | |
| 6. Urban | 61. Continuous fabric: urban fabric (≥ 80%) | | |
| | 62. Discontinuous fabric: vegetation and urban fabric (15-80%) | | |
| 7. Nonfuel | | | |



Aragoneses et al. 2023 ESSD

9

## European fuel mapping



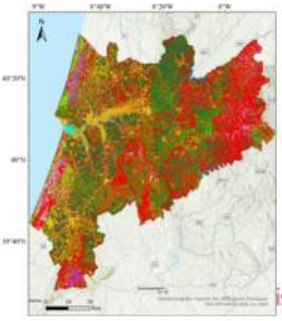


Aragoneses et al. 2023 ESSD

10

## Fuel type from S-2: Portugal

- Low shrubland (0-0.5 m)
- Medium shrubland (0.5-1.5 m)
- High shrubland (> 1.5 m)
- Low grassland (0-0.3 m)
- Medium grassland (0.3-0.7 m)
- High grassland (> 0.7 m)
- Herbaceous cropland
- Woody cropland
- Shrubland wet and peat/semi-peat land
- Grassland wet and peat/semi-peat land
- Urban continuous fabric
- Urban discontinuous fabric
- Nonfuel
- Open broadleaf evergreen forest
- Closed broadleaf evergreen forest
- Open broadleaf deciduous forest
- Closed broadleaf deciduous forest
- Open needleleaf evergreen forest
- Closed needleleaf evergreen forest



11

## Estimation of fuel parameters from GEDI / ML

Forest inventory data and input airborne LiDAR (ALS)

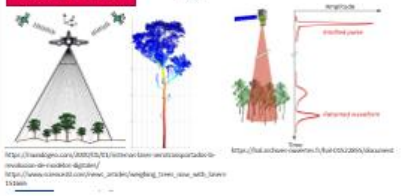
Spain -> 4 areas
Germany -> 2 areas
Slovenia -> 1 area

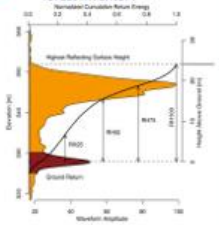
Clip by forest plots

Simulate satellite GEDI-like waveforms

Simulation -> Extract metrics

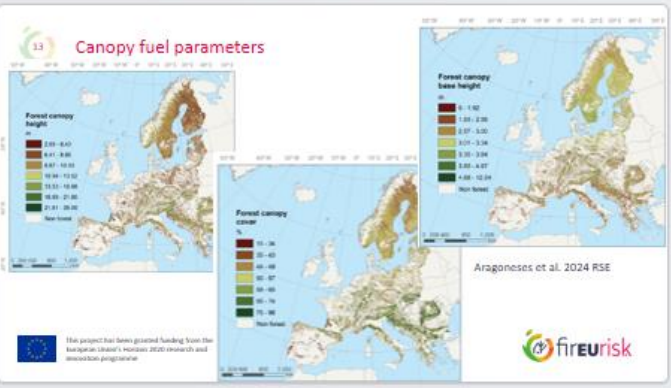
GEDI-based model using reference data from ALS and forest inventory





12

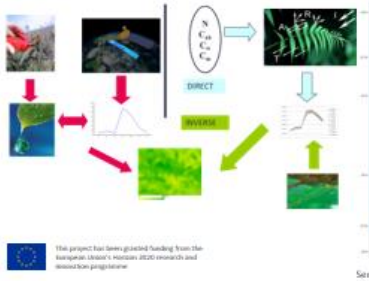
## Canopy fuel parameters

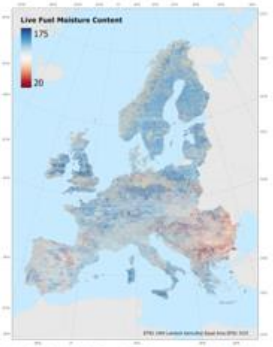


Aragoneses et al. 2024 RSE

13

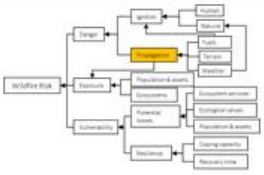
## Live Fuel moisture content




Sentinel-3 based LFMC in the ET: Pampanoni, et al. 2023

14



- Extreme fire weather scenario:
  - 95% weather conditions for days when any fire > 1000 ha occurred in Europe.
- Rothermel's model surface fires:
  - Flammap implementation in progress



15

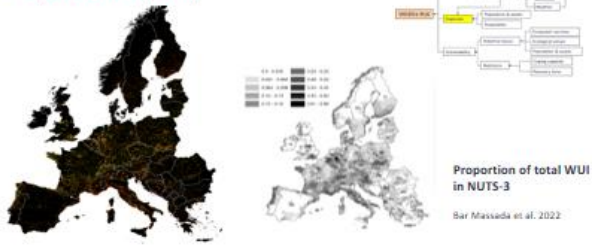
## Propagation potential: results for Barcelona PS



Fireline intensity | Flame length | Crown fire activity | Rate of spread

16

## Exposure: WUI (2020)




17

## Vulnerability components (Ecosystem services)

- Timber.
- Grazing.
- Mushrooms
- Recreational
- Soil erosion
- Carbon stocks



18

## Vulnerability components (Ecological values)

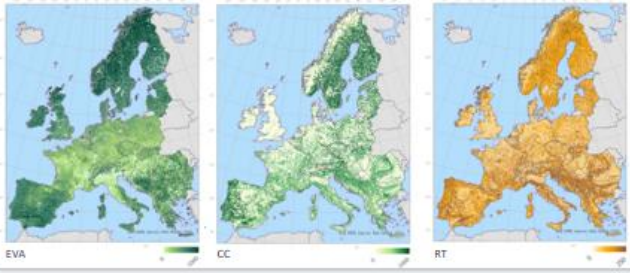
- Biological distinctiveness:
  - Species richness.
  - Abundance.
  - Forest productivity.
  - Key biodiversity areas,
- Conservation status:
  - Exceptional forest.
  - Special conservation areas.
  - Human pressures.
  - Forest loss
  - Unique habitats.
- Integration using PCA.



19

## Ecological vulnerability

$$EVW = (EVA * (1 - CC)) \times \frac{1 - (1 + r)^{-\ln RT}}{r}$$




20

## Reducing citizen-driven fire ignitions

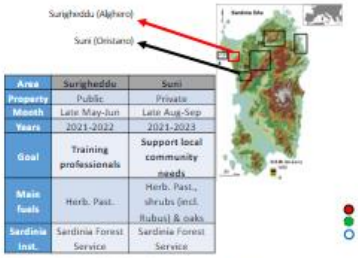
Prescribed burnings and trainings (Sardinia)

- ✓ FirEURisk meeting "Fire risk mitigation by prescribed fire and preventive silviculture" (June 2023)
- ✓ Annual program of prescribed fires (100 ha treated, Suni, September-October 2023)
- ✓ Forest Service training (Alghero, October 2023)



21

## Reducing citizen-driven fire ignitions




| Area | Surigheddu | Suni |
|---|---|---|
| Property | Public | Private |
| Month | Late May-Jun | Late Aug-Sep |
| Years | 2021-2022 | 2021-2023 |
| Goal | Training professionals | Support local community needs |
| Main fuels | Herb. Past. | Herb. Past., shrubs (incl. Rubus) & oaks |
| Sardinia Inst. | Sardinia Forest Service | Sardinia Forest Service |



Professional teams applying prescribed burnings and pastoral uses of fire

Professional teams
Pastoral use
Losses in the traditional use of fire; difficulty to support restoration

(CNR – Bachisio Arca)

22

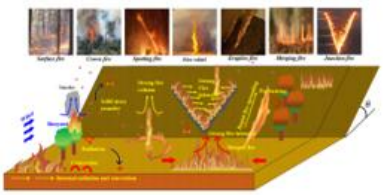
## Analyses of extreme fires




23

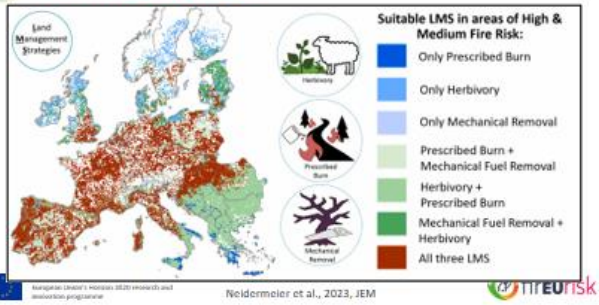
## Extreme fire behaviours (ADAI, UNSW)

- Spot
- Crown
- Eruptive
- Junction
- Conflagrations
- Whirls
- Blow-up



24

## Fuel Management Strategies




Neidermeier et al., 2023, JEM

25

## Future fire conditions: Climate scenarios

2nd round of data: projections at the European scale, daily/annual, 9 km

Variables

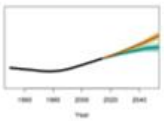
- CMIP6 climate (D3.1)
- Land-use projections (D3.2)
- Fire weather index projections (D3.4, manuscript in review)
- Vegetation projections (D3.4, manuscript in prep.)
- Burned area projections (D3.4, two manuscripts in prep.)

Scenarios

*Local rivalry*, SSP3-7.0, +4.0°-6.0°

*The green way*, SSP1-2.6, +1.5°-2.0°

Fire weather index projections



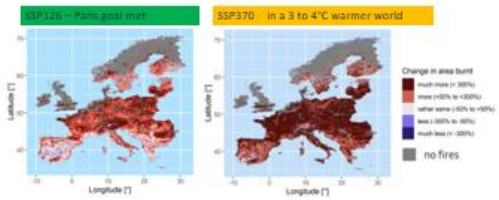
5-7/03/2024 | 7th Plenary Meeting

26

## Future Fire Occurrence Predictions

Relative change in area burnt (2000 – 2030 to 2070 – 2100)

- Be prepared in central and northern EU!
- More Fires in Southern EU under SSP370.




27

## Future fire conditions: LPJmL-SPITFIRE

1. Future land systems projections from CLUMondo
2. Fuel Management Scenarios
3. LMS Fuel Reduction Rules

SSP3: "Regional"

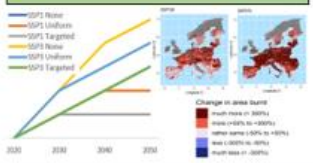
SSP1:

Baseline

1000-hour

4. Dynamic Global Vegetation Model (DGVM) + Fire Propagation

5. Six stylized fuel management scenario outcomes



LPJmL-SPITFIRE

28

## Integration activities in FirEUrisk

- Integration within each WP:
  - Danger, Exposure, Vulnerability.
- Integration within the Project:
  - Assessment, Reduction, Adaptation.
- Integration at EC level:
  - With external platforms and legacy systems (EFFIS, DRMC, etc.)
  - With other EU Fire-initiatives through Firelogue.
  - With other natural hazards: cascading Effects.



29

## Process Integration

- Danger:
  - Ignition: human and natural probabilities. PI = (PHI + PNI – PHI*PNI) * 1000
  - Fire propagation (FI, FL) potential. PP (f, FI).
  - Integrated Danger (D) = 0.33*PI + 0.66* PP
- Vulnerability:
  - Socio-economic & Ecological dimensions.
  - Calculate pre-fire values.
  - Calculate reduction of values as a result of fire
  - Calculate integrated losses throughout the absence.
  - Integrated vulnerability: V = 0.6*HV+0.4*EV
- Exposure (E) was measured in 3 categories: not burnable, burnable and WUI, which they are recoded to 0, 0.8 and 1, respectively.
- Integrated risk index (IRI):
  - IRI = (0.6*D + 0.4*V)*E

30

## Dissemination




31

## https://fireurisk.eu/project/




emilio.chuvieco@uah.es

32

## Review of past European fire seasons

# Review of past European fire seasons

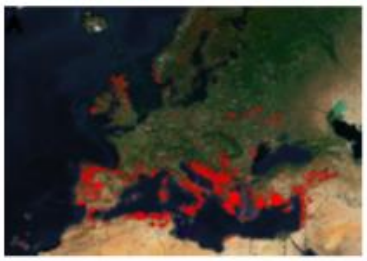
Miguel Almeida [Miguelalmeida@adai.pt]

03/11/2023 | Demonstration Event (PSI.North Europe)

This project has been granted funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement no. 101003890

1

## Analysis on critical wildfire events






2

## Analysis on critical wildfire events



2021 Fires Report



2022 Fires Report

3

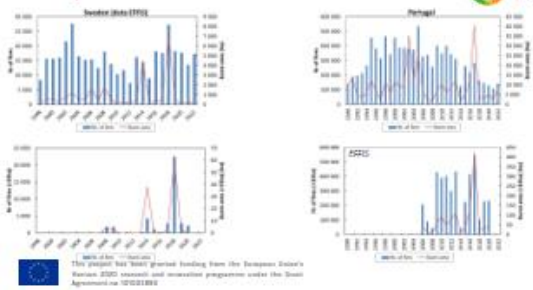
## Selection of the fire events to report

- Dimensions of wildfire events
- Impacts of wildfire events
- International dimension of the events
- Emerging wildfire countries



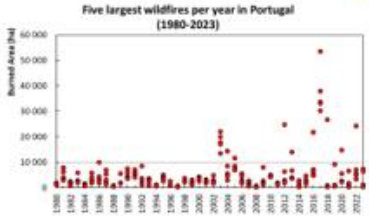
4

## European fires trends



5

## European fires trends




6

## Description of each fire event

- General description of the fire





Casto Marim (Portugal), 2021

7

## Description of each fire event

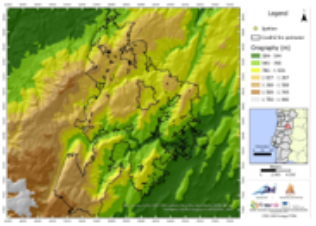
- General description of the fire
- Description of the region affected by the fire
  - Demography

| Municipality | Residents (Var. 2011-2021) | Residents /km2* | Age > 65yrs | University education |
|---|---|---|---|---|
| Covilhã | 46 521 (-10,1% ) | 83,0 | 29,0% | 16,9% |
| Guarda | 40 173 (-5,7%) | 56,5 | 25,2% | 7,5 % |
| Manteigas | 2 909 (-15,2%) | 24,3 | 37,4% | – |
| Gouveia | 12 222 (-13,0% ) | 40,0 | 30,2% | – |
| Celorico da Beira | 6 503 (-14,4%) | 26,7 | 34,9% | – |
| Belmonte | 6 205 (-9,5%) | 52,1 | 31,0% | – |
| Portugal | 10 343 066 (-2,1%) | 112,2 | 23,4% | 19,0% |

8

## Description of each fire event

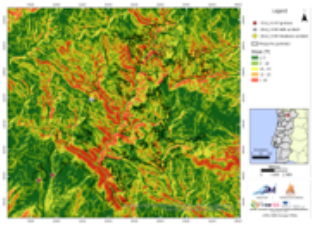
- General description of the fire
- Description of the region affected by the fire
  - Demography
  - Orography



9

## Description of each fire event

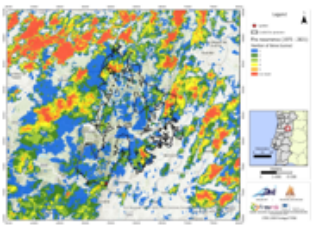
- General description of the fire
- Description of the region affected by the fire
  - Demography
  - Orography
  - Slope



10

## Description of each fire event

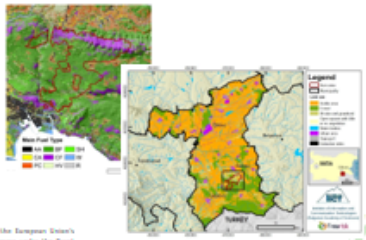
- General description of the fire
- Description of the region affected by the fire
  - Demography
  - Orography
  - Slope
  - Fire recurrence



11

## Description of each fire event

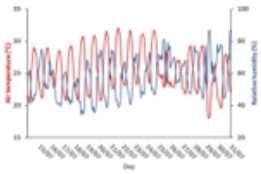
- General description of the fire
- Description of the region affected by the fire
  - Demography
  - Orography
  - Slope
  - Fire recurrence
  - Land use

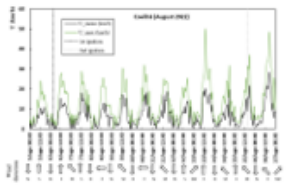


12

## Description of each fire event

- General description of the fire
- Description of the region affected by the fire
- Fire conditions
  - Meteorology

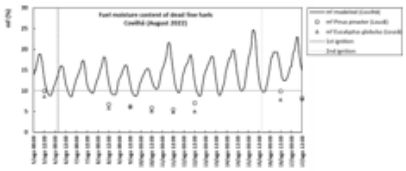




13

## Description of each fire event

- General description of the fire
- Description of the region affected by the fire
- Fire conditions
  - Meteorology
  - Fuel moisture content



14

## Description of each fire event

- General description of the fire
- Description of the region affected by the fire
- Fire conditions
  - Meteorology
  - Fuel moisture content
  - Fire danger indexes

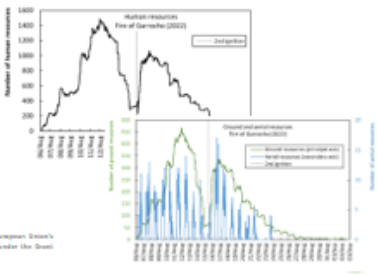
| Day | Aug. 5th | Aug. 6th | Aug. 7th |
|---|---|---|---|
| ISI | 16.2 | 18.2 | 13.8 |
| BUI | 240.2 | 243.9 | 267.7 |
| FWI | 53.7 | 57.7 | 48.7 |

| Level | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| ISI | 2.0 | 4.0 | 8.0 | 12.0 | 17.0 | 23.0 | 30.0 | >30 |
| BUI | 50.0 | 100.0 | 150.0 | 200.0 | 250.0 | 325.0 | >325 |
| FWI | 8.5 | 17.2 | 24.4 | 33.2 | 50.1 | 64.0 | >64 |

15

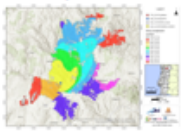
## Description of each fire event

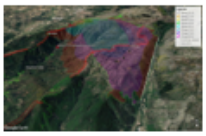
- General description of the fire
- Description of the region affected by the fire
- Fire conditions
  - Meteorology
  - Fuel moisture content
  - Fire danger
  - Resources allocated

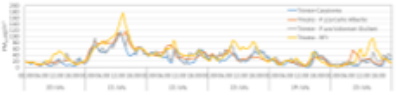


## Description of each fire event

- General description of the fire
- Description of the region affected by the fire
- Fire conditions
- Fire evolution and smoke









17 ★

## Description of each fire event

- General description of the fire
- Description of the region affected by the fire
- Fire conditions
- Fire evolution and smoke
- Fire management at WUI







18

## Description of each fire event

- General description of the fire
- Description of the region affected by the fire
- Fire conditions
- Fire evolution
- Fire impacts
- Post fires (cascading effects)







19 ★

## Description of each fire event

Alla ändringar har sparats

- General description of the fire
- Description of the region affected by the fire
- Fire conditions
- Fire evolution
- Fire impacts
- Post fires (cascading effects)
- Lessons learned



20

## Main lessons learned

- Increased prediction capacity for days and locations with higher fire danger classes



21

## Main lessons learned

- Increased prediction capacity for days and locations with higher fire danger classes
- Evaluation of fire patterns at smaller scales than currently (e.g., parish level) during the peak fire period



22

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- Enhancing self-protection capacity of citizens and private entities



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- Harmonization of wildfire risk information and empowerment of cooperation between countries – European Firefighting Common Force

## Main lessons learned

- Increased prediction capacity for days and locations with higher fire danger classes
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- Enhancing self-protection capacity of citizens and private entities
- Harmonization of wildfire risk information and empowerment of cooperation between countries – European Firefighting Common Force
- Analysis of wildfires and wildfire episodes to extract lessons that can enhance firefighting management capabilities

This project has been granted funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement no. 101003890



25

## Protocol for wildfire events analysis

1. Local data survey and intervenient interviews
   - 1.1 Data survey during the fire event
   - 1.2 Aftermath data survey:
2. Complementary data survey
   - 2.1 Orography
   - 2.2 Meteorological data
   - 2.3 Environmental data
   - 2.4 Infrastructure characterization data
   - 2.5 Earth observation imagery and derived products
3. Data mining, process and analysis
   - 3.1 Useful tools
   - 3.2 Reconstruction of events

This project has been granted funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement no. 101003890



26

Miguel Almeida
(miguelalmeida@adai.pt)

This project has been granted funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement no. 101003890

27

## Modern fire regime in Sweden

# Overview of the Swedish wildfire regime

Johan Sjöström, RISE Research institutes of Sweden

07/05/2024 | N European pilot site implementation

This project has been granted funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement no. 101003890

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## Wildfire is both a natural and a cultural phenomenon

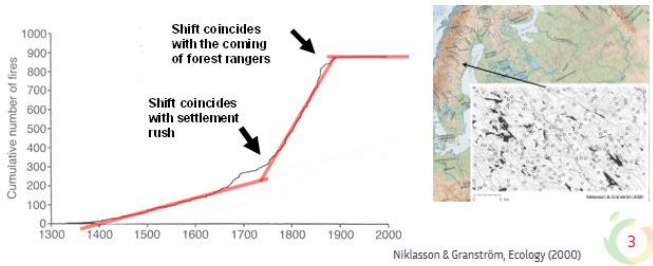






2

## Number of fires
## Example area in north Sweden

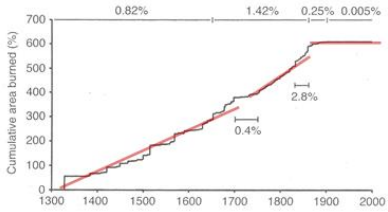





Niklasson & Granström, Ecology (2000)

3

## Cumulative area burnt
## (portion of area burnt per year)




4

## From a situation similar to Canada to a >99% reduction in burnt area. How?



- Burning stopped
- Incitements for protecting the timber and infrastructure
- Wildfire vigorously attacked using "Standard measures"
- Good general knowledge of fire behaviour and fuel status
- Benign fire climate / favourable landscape structure
- Growing network of forestry roads

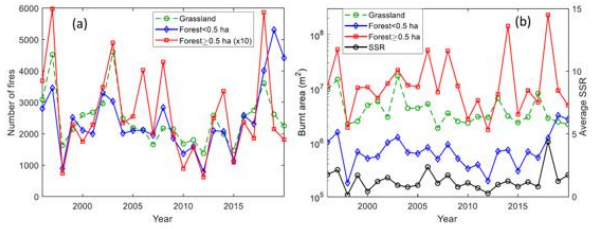
07/05/2024 | N Eur pilot site implementation

This project has been granted funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement no. 101003890

5

## Present day situation

Sjöström & Granström, Fire Safety Journal (2023)




6

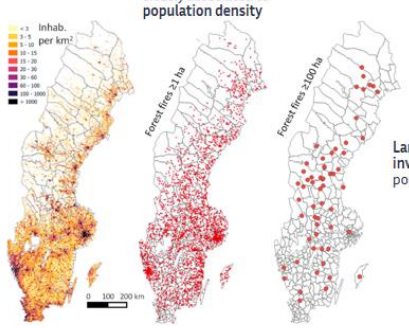
## What determines the outcome of wildfire occurrence and burnt area?

- Ignitions
- Fuel – (land use)
- Weather
- Response / detection / surveillance

This project has been granted funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement no. 101003890

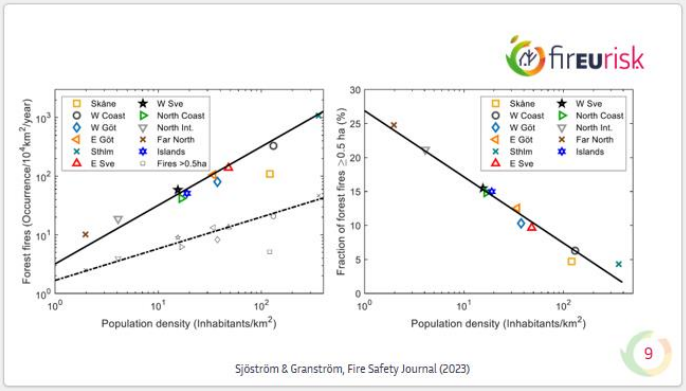
7

## Forest fire **occurrence** is closely associated to **population density**




**Large fire** occurrence is **inversely** related to population density

8



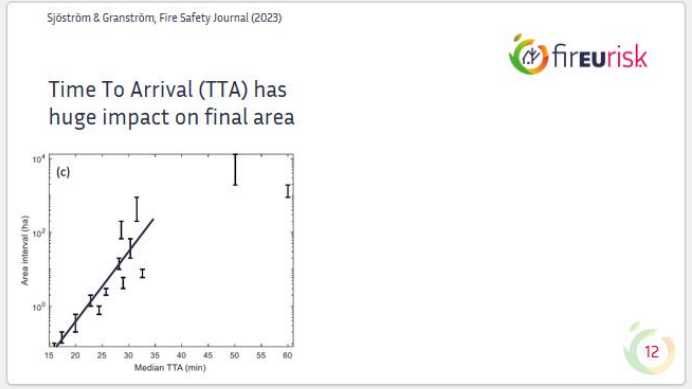

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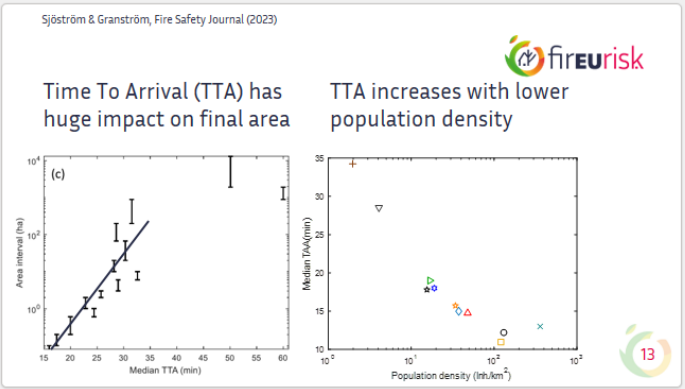

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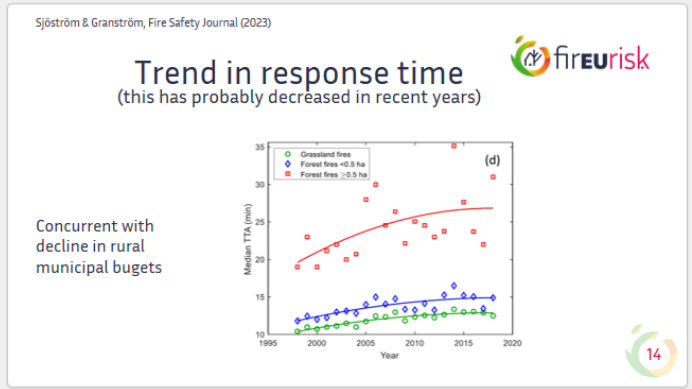

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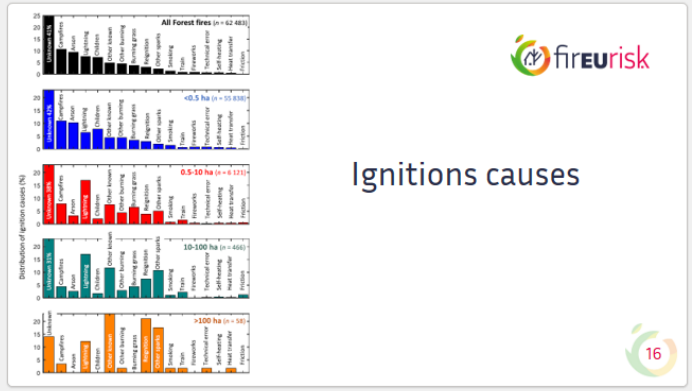

13



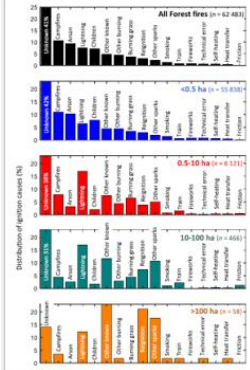

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16




Granström (2020) MSB1496

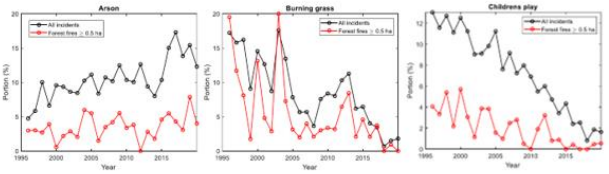
Ignition cause of the 12 largest fires in 2018

| Location | Ares (ha) | Ignition cause |
|---|---|---|
| Enskogen | 4326 | Lightning / Re-ignition |
| Fågelsjö | 3921 | Lightning / Re-ignition |
| Ängra | 3797 | Lightning |
| Trängslet | 3468 | Lightning / Re-ignition |
| Storbrättan | 944 | Lightning/ Re-ignition |
| Nötberget | 872 | Lightning / Re-ignition |
| Lima | 501 | Lightning / Re-ignition |
| Brattsjö | 468 | Tree against powerline / Re-ignition |
| Grötingen | 423 | Lightning |
| Sierre | 353 | Lightning / Re-ignition |
| Tovåsen | 344 | Lightning / Re-ignition |
| Pålgård | 221 | Lightning |

17

17

## Trends in ignitions




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18

18

## Trends in land-use with decade long legacies

19

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## 3 main native species

3 main native species *Pinus sylvestris*, *Picea abies* and *Betula* spp.

- Coniferous stands usually constitute good fuel



20

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## Trends in land-use with decade long legacies

- Pre-commercial thinning has become highly aggressive



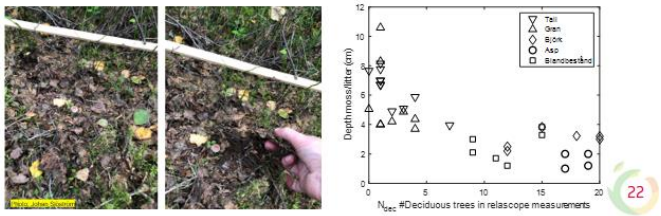
21

21

## Trends in land-use with decade long legacies

Even small inclusion (5-15%) of deciduous trees have a huge impact on forest floor fuels.

Leaving a larger portion can significantly decrease potential for rapid spread and high intensities




22

22

## Trends in land-use with decade long legacies

Drainage of wetlands

- ~2-3×$10^6$ ha of forest land and mire have been drained in Sweden.
- Peaked in 1980s.



23

23

## Trends in land-use

3 main native species *Pinus sylvestris*, *Picea abies* and *Betula* spp.

- The newly introduced *Pinus contorta* makes very flammable fuel bed




24

24

## Summary

- Wildfires in Scandinavia are driven by choices made by people
- High potential to reach fires early after ignition. Key to success compared to other parts of the boreal region. Also, missing key to the few cases of very large fires.
- Densely distributed resources, centralized aerial firefighting and proper mop-up safeguards against large-consequence fires
- Land-use choices will control the flammability of the forests for decades to come
  - Pre-commercial thinning of deciduous trees
  - Maintaining drained land vs restoration of wetlands
  - *P contorta*
- Future fire regimes seems to be in our own hands

This project has been granted funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement no.101003890



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26

Thank you for listening

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27

## Structure damages from wildfires in North Europe


Factors for building survival in north-European wildfires
Frida Vermina Plathner – RISE Research Institutes of Sweden

1


fireurisk

2


3
BACKGROUND
The determining features for building loss in wildfire vary across ecoregions
Fuel type
Land use
Fire behavior
Garden vegetation
Non-veg. combustibles in gardens
fireurisk

3


4
BACKGROUND
... and across settlement types
Building materials
Settlement patterns
Intermix or interface
Road network
Resources
fireurisk

4


5
HOME IGNITION ZONE (HIZ)
The immediate zone
(0-1.5 m)
The building and its closest vicinity
The intermediate zone
(1.5-10 m)
The garden
The extended zone
(10-30 m)
The surrounding forest
fireurisk

5


6
Physical features
fireurisk

6


7
Upper part of tree crowns heatscorched by the convection stream. The ground beneath is unburnt due to nonflammable fuelbed
Intact lawn
Spotfires
Heatscorched lawn
Burnt ground
Destroyed building
Burnt conifer forest
Wind

7


8
Tree crowns heat-scorched by the convection stream. The ground beneath is unburnt
Heat-scorched trees
Burnt ground

8

## 9 Significant factors for building survival in large forest fires

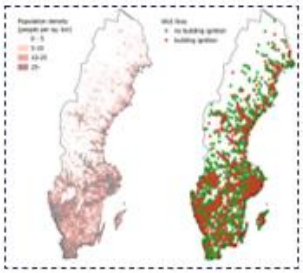



fireurisk

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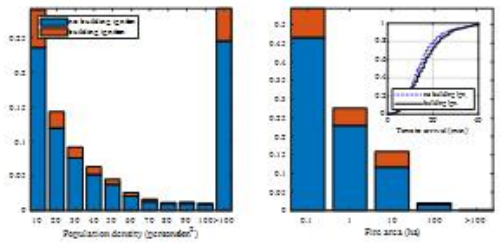
## 10 BUT! Most buildings are ignited in small fires

- ~125 fires threaten or ignite buildings annually
- ~30 building ignitions and 1 fatality per year from wildfires
- WUI fires = vegetation fires that ignite or threaten buildings



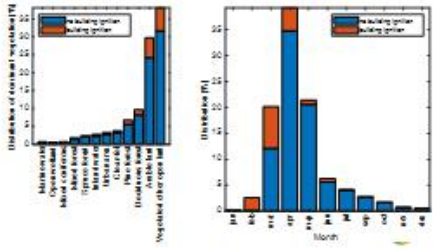
10

## 11 WUI fires are generally small



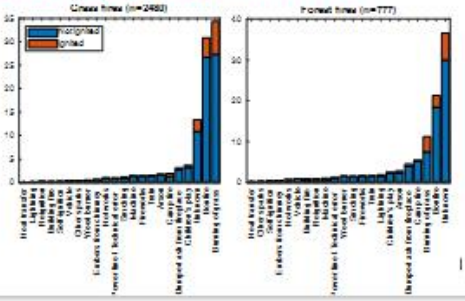

11

## 12 ... and occur in meadows during spring



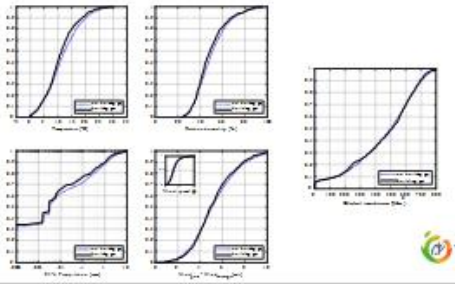

12

## 13 ...caused by traditional fire use




13

## 14 Building ignition (or not) in a WUI fire is only weakly related to weather



fireurisk

14







URBAN VEGETATION FIRE
"The spruce hedge was burning furiously upon our arrival, with 6-7m flames. In the middle of the hedge was a small house with burning eaves, and a workshop in the end of the hedge was just about to ignite. Cause of ignition: a weed burner"

17


SUMMER FIRE

18


fireurisk
Frida Vermina Plathner
Research Institutes of Sweden
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19

## Fires in humid temperate regions

## Spatio-temporal patterns of fire in humid-Atlantic Europe: is vegetation phenology rather than fire weather the key driver?

Tadas Nikonovas[1], Stefan Doerr[1], Cristina Santin[1,2], Gareth Clay[3], Claire Belcher[4], Nicholas Kettridge[5], and Thomas Smith[6]

[1]Centre for Wildfire Research, Swansea University, UK
[2]IMIB – CSIC, University of Oviedo, Spain
[3]University of Manchester, UK
[4]Exeter University, UK
[5]Birmingham University, UK
[6]London School of Economics, UK

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fireurisk



Grant Reference: NE/T003103/1

1

## Fire weather indices and UK fire regime

Fire weather indices (FWI) used widely to predict landscape fire potential



EFFIS/Copernicus FWI 19 July 2022



>30,000 vegetation fires in England each year alone, but UK fire fighters often busier with flood rescue than fire

2

## Fire weather indices and UK fire regime

Fire weather indices (FWI) used widely to predict landscape fire potential



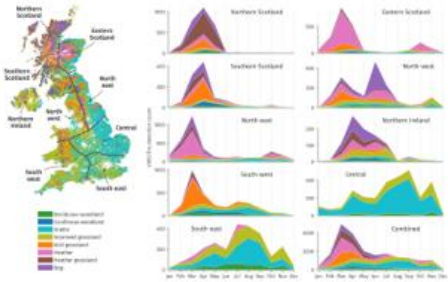
EFFIS/Copernicus FWI 19 July 2022



Record FWI during heatwave with record building loss from wildfire 19 July 2022

3

## UK land cover, climatology and fire for 2012-2023

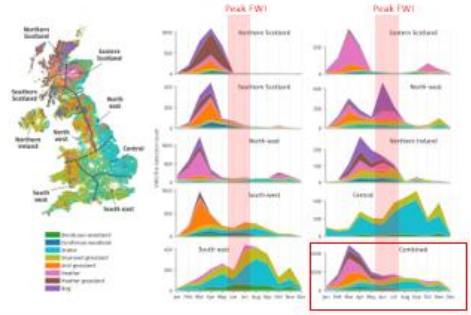


Monthly VIIRS active fire detection counts for different UK climatic regions and key (CEH) vegetation covers 2012-2023

Figure: Nikonovas et al. (in revision). *Int. J. Wildland Fire*

4

## UK land cover, climatology and fire for 2012-2023



Monthly VIIRS active fire detection counts for different UK climatic regions and key (CEH) vegetation covers 2012-2023

Figure: Nikonovas et al. (in revision). *Int. J. Wildland Fire*

5

## UK and comparable European humid-Atlantic regions

- **Semi-natural grass and shrub-land dominates** fire occurrence across UK
- Fire occurrence out of phase with FWI components
- Is vegetation phenology* the key driver for fire occurrence here?

**phenology: seasonal vegetation change from dormancy – growth – senescence - dormancy*





Example fuels: Molina grass (*Molinia caerulea*) and heather shrubs (*Calluna vulgaris*)

6

## UK and comparable European humid-Atlantic regions

- Semi-natural grass and shrub-land dominates fire occurrence across UK
- Fire occurrence out of phase with FWI components
- **Is vegetation phenology* the key driver for fire occurrence here?**

**phenology: seasonal vegetation change from dormancy – growth – senescence - dormancy*



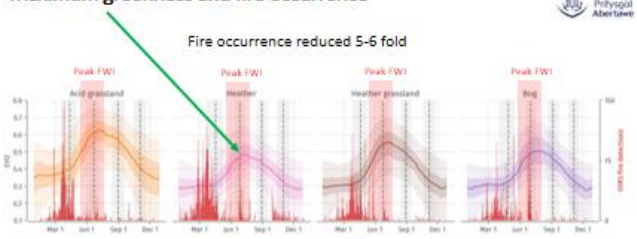




Example South Wales: bracken fern – a common fuel on formally grazed areas

7

## Maximum greenness and fire occurrence




Vegetation greenness (EVI2) 2012-2022. Red bars: VIIRS fire detections

Figure: Nikonovas et al. (in revision). *Int. J. Wildland Fire*

8

## BUT *phenology barrier* can break during extreme drought

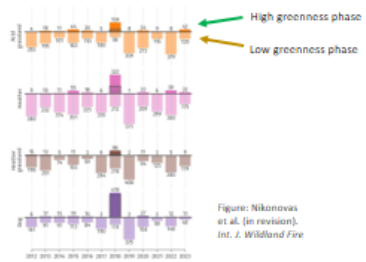
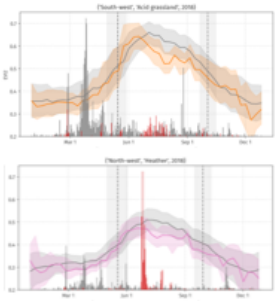



Figure: Nikonovas et al. (in revision). *Int. J. Wildland Fire*

Fire detections for high and low greenness phases
Hatched areas: Saddleworth Moor and Winter Hill wildfires

9

## Using phenology to predict extreme summer fire risk ?



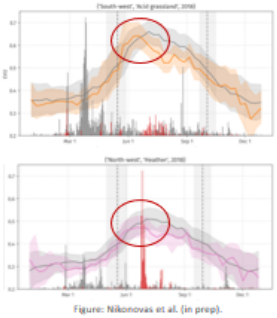
Median EVI2 (greenness) during years with **droughts (colour) vs other years (grey)**

Red bars: VIIRS fire detections during the extreme weather year, grey bars show fire detections during other years

Figure: Nikonovas et al. (in prep).

10

## Using phenology to predict extreme summer fire risk ?



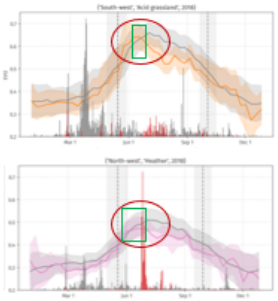
Median EVI2 (greenness) during years with **droughts (colour) vs other years (grey)**

Red bars: VIIRS fire detections during the extreme weather year, grey bars show fire detections during other years

Figure: Nikonovas et al. (in prep).

11

## Using phenology to predict extreme summer fire risk ?



Early deviation from greenness trend as indicator for fire risk (breaking of phenology barrier)?




Figure: Nikonovas et al. (in prep).

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## Weekly NDVI anomaly during the high greenness phase vs DC and DMC

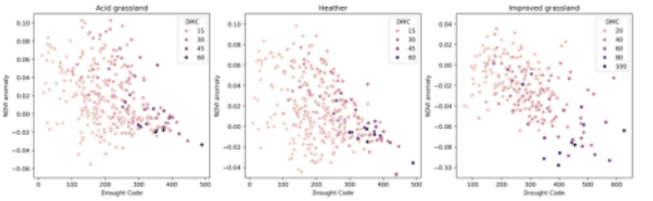



Figure: Nikonovas et al. (in prep).

13

## Key outcomes

- FWI poor predictor for wildfire risk for dominant fuels here except in severe droughts
- Incorporating phenology could improve fire risk predictions
- Fire-suppressing 'phenology barrier' can break during extreme summer droughts
- These are expected to increase in frequency and severity under changing climate



14

## Thank you



Contact:
Tadas.Nikonovas@swan.ac.uk

15

# Grassland fire danger



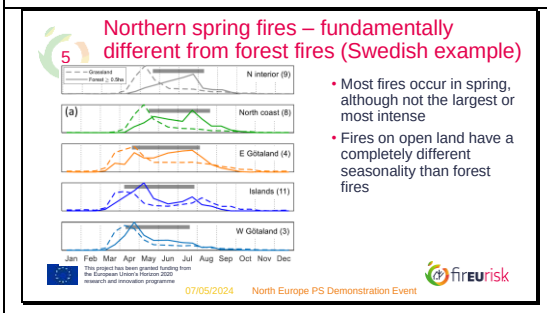














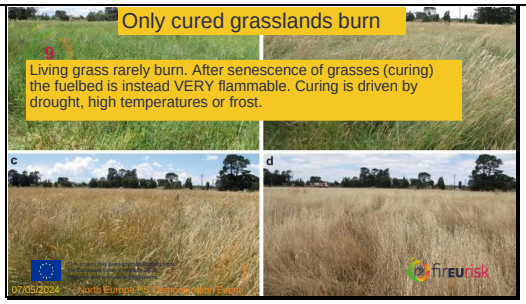







## Only cured grasslands burn

Living grass rarely burn. After senescence of grasses (curing) the fuelbed is instead VERY flammable. Curing is driven by drought, high temperatures or frost.






## 10 Evolution of a grassland in Northern Europe with mild winters (occational snow)

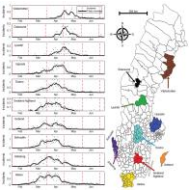



After winter, the fuel bed is completely cured, followed by 'reversed curing' as green grass emerges



## 11 Evolution of a grassland in Northern Europe with harsh winters

The grassfire season shifts to later in the season and gets shorter for higher latitudes








## 12 Constructing a fire danger model for northern grasslands

The danger index for grasslands is based on *Rate of spread* as opposed to *fireline intensity* for forest fires

Important factors for spread rate

- Fuel height (but fuel load is less significant)
- Fuel moisture content
- Wind speed
- Curing degree

**We use a model system 7-13 cm compressed with occasional standing grass. (300 g/m² – drymass)**



## 13 Constructing a fire danger model for northern grasslands

The danger index for grasslands is based on *Rate of spread* as opposed to *fireline intensity* for forest fires

Important factors for spread rate

- Fuel height (but fuel load is less significant)
- Fuel moisture content
- Wind speed
- Curing degree

**Accounts for**

- **Rain**
- **Temperature**
- **Sun irradiation**
- **Wind speed**
- **Relative humidity**

**De have defined new equilibrium moisture contents for colder temperatures**



## 14 Constructing a fire danger model for northern grasslands

The danger index for grasslands is based on *Rate of spread* as opposed to *fireline intensity* for forest fires

Important factors for spread rate

- Fuel height (but fuel load is less significant)
- Fuel moisture content
- Wind speed
- Curing degree

**Known from many experiments in Australia and North America**



## 15 Constructing a fire danger model for northern grasslands

The danger index for grasslands is based on *Rate of spread* as opposed to *fireline intensity* for forest fires

Important factors for spread rate

- Fuel height (but fuel load is less significant)
- Fuel moisture content
- Wind speed
- Curing degree

**Determined from 25 years of incident statistics in Sweden together with burn series following full seasons.**



## 16 Constructing a fire danger model for northern grasslands

The danger index for grasslands is based on *Rate of spread* as opposed to *fireline intensity* for forest fires

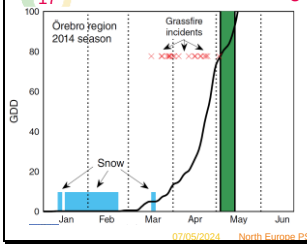
$$ROS = R_W \emptyset_{mc} \emptyset_c$$

**Spread rate in completely cured and completely dry grasslands**

**Reduction due to moisture content**

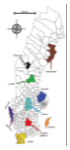
**Reduction due to decreasing curing as green grass grows**

## 17 Grassfire season is defined from 25 years of fires in ten different regions



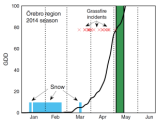

GDD = Growing Day Degrees

GDD = 0 – grasslands completely cured
GDD = 100 – fuel can hardly support spread





## 18 Grassfire season is defined from 25 years of fires in ten different regions



$$\mathrm{GDD}(d) = \tfrac{1}{4}\Sigma_{i=1}^{d}(T_i - 2) \times \left[1 + \mathrm{erf}\left(\tfrac{i-80}{60}\right)\right]$$

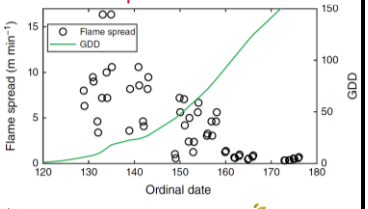
$$T_i = \left(\Sigma_{j=i-3}^{i} T_{\mathrm{corr},j}\right)/4, \quad \mathrm{Limited by} T_i \geq 2$$

$$T_{\mathrm{corr}} = \begin{cases} 0 & \text{(if snow)} \\ 0.1 \times T_{\mathrm{air}} & \text{(if no snow \& } T_{\mathrm{air}} < 0\text{)} \\ T_{\mathrm{air}} & \text{(else)} \end{cases}$$



## 19 Grassfire season's effect on spread rate is defined from burn experiments

Large fluctuations due to different moisture and wind conditions between the days

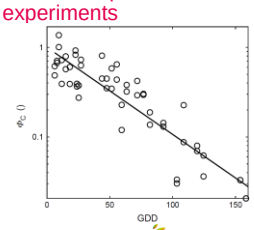





## 20 Grassfire season's effect on spread rate is defined from burn experiments

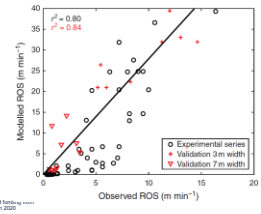
Correct for the mc and wind.
Only the seasonality remains

$$\Phi_C = e^{-0.0224 \times \mathrm{GDD}}$$



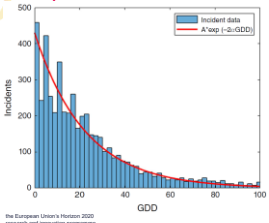



## 21 The model is complete and we compare it to fires with known spread rates






## 22 The model for curing agrees well with dispatch occurrence over 25 years




Exactly 2 times the exponent for rate of spread. Account for that also the likelihood of ignition varies with the same dependence as ROS.



## 23 (1) Caluclate season's length Average daily temperatures and snow cover

$$\mathrm{GDD}(d) = \tfrac{1}{4}\Sigma_{i=1}^{d}(T_i - 2) \times \left[1 + \mathrm{erf}\left(\tfrac{i-80}{60}\right)\right]$$

$$T_i = \left(\Sigma_{j=i-3}^{i} T_{\mathrm{corr},j}\right)/4, \quad \mathrm{Limited by} T_i \geq 2$$

$$T_{\mathrm{corr}} = \begin{cases} 0 & \text{(if snow)} \\ 0.1 \times T_{\mathrm{air}} & \text{(if no snow \& } T_{air} < 0\text{)} \\ T_{\mathrm{air}} & \text{(else)} \end{cases}$$



## 24 (2) For each hour, calculate Equilibrium moisture content Temp, RH, wind, solar radiation

$$T_E = T + 35.07 \times I \times e^{-0.2237 \times W}$$

$$\mathrm{RH}_E = \mathrm{RH} \times 10^{2\left(\frac{T}{237+T} - \frac{T_E}{237+T_E}\right)}$$

$$\mathrm{EMC}_D = 2.21 \times \mathrm{RH}_E^{0.46} + 13.7 \times e^{\frac{\mathrm{RH}_E - 100}{13}} + 0.08 \times (26.67 - T_E)$$

$$\mathrm{EMC}_W = 2.00 \times \mathrm{RH}_E^{0.44} + 12.0 \times e^{\frac{\mathrm{RH}_E - 100}{18}} + 0.08 \times (26.67 - T_E)$$



## 25 (3) For each hour, calculate fuel moisture content Temp, RH, wind, solar radiation

$$\Delta mc = 100 \times (P/0.3)$$

$$mc_0 = mc(t-\delta) + \Delta mc, \ (mc_0 \leq 400\%)$$

$$R = \begin{cases} \mathrm{RH}_E/100 \text{ (fordrying)} \\ 1 - \mathrm{RH}_E/100 \text{ (forwetting)} \end{cases}$$

$$k\,[h^{-1}] = 0.897 \times e^{0.0365 \times T_E} \times [0.424 \times (1 - R^{1.7}) + 0.1317 \times \sqrt{W} \times (1 - R^8)]$$

$$mc(t) = \mathrm{EMC} + [mc_0 - \mathrm{EMC}] \times e^{-k \times \delta}$$



## 26 (4) Calculate Rate Of Spread

$$\Phi_{mc} = \begin{cases} \exp(-0.108 \cdot mc), & (mc \leq 12\,\%) \\ 0.684 - 0.0342 \cdot mc, & (mc > 12\,\% \ W < 3\ \mathrm{m\ s^{-1}}) \\ 0.547 - 0.0228 \cdot mc, & (mc > 12\,\% \ W > 3\ \mathrm{m\ s^{-1}}) \end{cases}$$

$$\Phi_C = e^{-0.0224 \cdot GDD}$$

$$ROS = \begin{cases} [0.9 + 16.13 \cdot W]\Phi_{mc}\Phi_C, & (\text{for } W < 1.4\ \mathrm{m\ s^{-1}}) \\ [23.33 + 41.18 \cdot (W - 1.3889)^{0.844}]\Phi_{mc}\Phi_C, & (\text{for } W \geq 1.4\ \mathrm{m\ s^{-1}}) \end{cases}$$

27

## (5) Set a danger class

| Danger level | ROS (m min$^{-1}$) |
|---|---|
| Low | ROS $\leq$ 5 |
| Moderate | 5 $<$ ROS $\leq$ 15 |
| High | 15 $<$ ROS $\leq$ 25 |
| Very high | ROS $\geq$ 25 |

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28

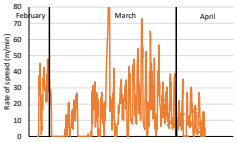
## Example from the Swedish warning system

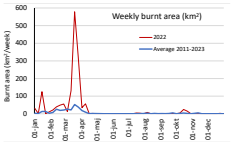





29

## A look at Romania 2022




See: Report on the large wildfires of 2022 in Europe



30

## Future developments

- Applying the model to more regions (FirEUrisk)
- Evaluating satellite evaluation of seasonal progression (MSB)
- Extending satellite evaluation to other regions (FirEUrisk)



31

## Read more

https://www.publish.csiro.au/wf/pdf/WF23013





32

## Thank you



# The Wildland Urban Interface in Kalmar County

## The Wildland Urban Interface in Kalmar County

Avi Bar-Massada

7/5/2024 | PS1 Demonstration Event

This project has been granted funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement no. 101003890

1

## The WUI: a formal[ish] definition

**Where settlements are adjacent to or interspersed with wildland vegetation**

This project has been granted funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement no. 101003890

2

2

## Why are we so worried about the WUI?



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3

3

## Why are we so worried about the WUI?




*Figure 2. The biotic and abiotic processes associated with human settlements in the wildland–urban interface.*

Bar-Massada et al. (2014)

This project has been granted funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement no. 101003890

4

4

## How much WUI?

**~5% of the global land surface**

**~12% of Europe's land area. Or ~7.5%. Or maybe ~10%. Depends on who you ask. And on their definition of "Europe". And on their definition of "WUI". And other stuff**

**There are many ways to map the WUI! We will mostly focus on one of them**

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5

## WUI definition: the integral components

**Where settlements are adjacent to or interspersed with wildland vegetation**

WUI Geometry | Building type and density | How far? From what? | How much fuel is around? | Landscape context | Fuel type

Spatial relationship between built-up areas and fuels

Characteristics of wildland fuels

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6

6

## So many choices! But do they matter?

"WUI maps have proliferated in recent years, and different WUI patterns on these maps have caused confusion among land managers. The underlying cause for these differences, though, are the different purposes for which the maps were developed; such as focusing on vegetation versus focusing on housing or mapping for local planning purposes versus national policy-making.

The solution is not to declare a single map best or, conversely, to tell managers not to use a given map because it is wrong, but rather to consider the purpose for which each map was developed and critically evaluate the quality of the data and analysis on which it is based."

Stewart et al. (2009)



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## WUI definition: the integral components

**Where settlements are adjacent to or interspersed with wildland vegetation**

WUI Geometry

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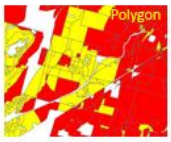
8

## The geometry of the WUI



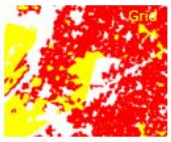

Pereira et al. (2018)

What is the length of the WUI?
How many houses are near it?




Radeloff et al. (2005, 2018)

What is the area of the WUI?
How many houses are in it?




Bar-Massada et al. (2013)

What is the area of the WUI?
How many houses are in it?

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9

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## WUI definition: the integral components

Where settlements are adjacent to or interspersed with wildland vegetation

Building type and density

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10

10

## What constitutes a settlement?

Any building type or just houses?

Can a settlement comprise a single building?

Yes

The WUI can [potentially] be everywhere there's a building **(FirEURisk)**

No

How many buildings comprise a settlement?

The WUI can be where building density is above a threshold **(US approach)**

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11

11

## WUI definition: the integral components

Where settlements are adjacent to or interspersed with wildland vegetation

Spatial relationship between built-up areas and fuels







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12

12

## Interface vs. intermix WUI

Intermix WUI: settlements are within vegetation



Interface WUI: settlements adjoin vegetation



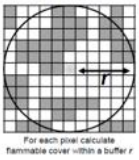
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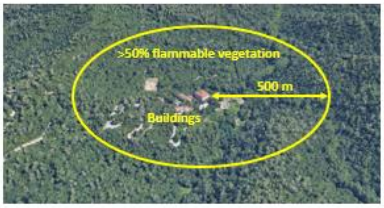
13

## Identifying intermix WUI

Flammable vegetation raster




For each pixel calculate flammable cover within a buffer *r*



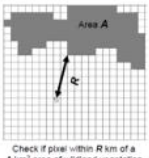

This project has been granted funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement no. 101003890

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14

## Identifying interface WUI

Flammable vegetation raster




Check if pixel within *R* km of a *A* km² area of wildland vegetation




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15

15

## WUI definition: the integral components

Where settlements are adjacent to or interspersed with wildland vegetation

Landscape context

Fuel type

Characteristics of wildland fuels

This project has been granted funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement no. 101003890

16

16

## Wildland vegetation – landscape context

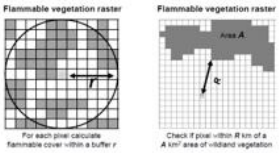


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17

## Wildland vegetation – landscape context






Larger *r*, *R*, and *A* values can reduce the role of isolated woody patches in driving WUI formation in cities, in and around urban parks

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18

18

## Wildland vegetation – fuel type

- In WUI mapping, we assume that ***wildland vegetation = flammable vegetation***
- Vegetation types differ in flammability and associated hazard
- Veg. types that are mostly inflammable now might become flammable under severe draught
- Basic WUI maps assume a binary veg. classification: wildland (flammable) vs. other (non-flammable)
- Another distinction is possible between multiple vegetation types (e.g., *grassland* and *woody*)
- Also, distinction between different levels of flammability

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19

19

## Implications of WUI fuel choices

ESA landcover | Wildland veg. (no grassland) | Wildland veg. (with grassland)



Globally, 2/3 of the WUI is forest/shrublands/wetlands vs. 1/3 grasslands (Schug et al. 2023)

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20

20

## Implications of WUI fuel choices

Tradeoff: size of exposed area vs. actual likelihood of exposure

| Strategy | Approach | Example | Subsequent WUI size |
|---|---|---|---|
| Permissive (to be on the safe side, minimize omission errors) | Include all fuel types regardless of hazard potential | Trees, shrubs, and grasslands, regardless of species identity | Largest |
| In-between, focus on veg. type with high fuel / area ratio | Focus on woody fuels | Trees and shrubs, regardless of species identity | Intermediate |
| Restrictive, focus on high hazard areas (minimize commission errors) | Focus on highly flammable tree species | *Pinus* species | Smallest |

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21

21

## Summary: so many choices...

**Where settlements are adjacent to or interspersed with wildland vegetation**

- Line, polygon, or grid?
- Houses vs. all buildings
- Use a density threshold?
- Distance *R*...
- ...to Wildland patch of size *A*
- %wildland vegetation > *P*
- Within a buffer distance *r*
- Include urban forests/parks?
- Wildlands = all vegetative fuels or just some?

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22

22

## FirEUrisk choices

**Where settlements are adjacent to or interspersed with wildland vegetation**

- Grid with 10m square cells
- Use all building types<br>No min. building density threshold<br>100m buffer
- Distance < 600m to wildland veg. patches > 5km²
- %wildland vegetation > 50<br>Within a buffer distance of 500m
- Avoid urban forests/parks if possible (*r* set accordingly)
- Wildlands = only woody fuels (forests + shrublands)

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23

23

## Application: WUI mapping in Kalmar County

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24

24

## Inputs (10m spatial resolution)

**326,580 Individual buildings**



**Woody vegetation (forests+shrublands)**



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25

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## How much WUI?

118,666 ha, or ~**10.2%** of the region

88,287 ha (74.4%) intermix WUI
30,379 ha (25.6%) interface WUI



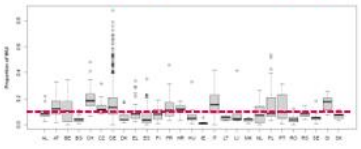

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## European context

WUI covers 7.4% of the European territory,
[Kalmar County 10.2%]

46.6% intermix [74.4%], 53.4% interface [25.6%]





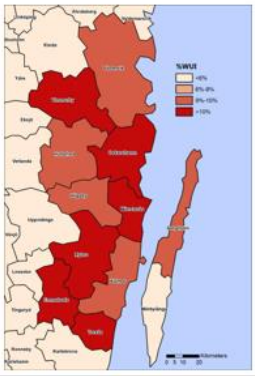

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27

## How much WUI area? (municipality level)

There's little variation in WUI percent among municipalities (except one)

WUI ranges from 5.1% to 12.2%




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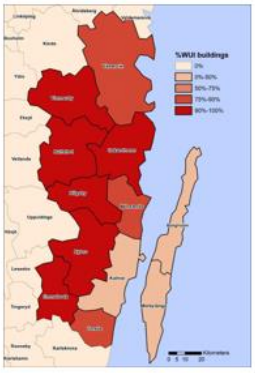
28

## Buildings in the WUI

There are **236,136** buildings in the WUI, which represent **72.3%** of the buildings in Kalmar County

**150,518** WUI buildings (**63.7%**) are inside intermix WUI (higher exposure category)

**Six** municipalities have more than **90%** of their buildings in the WUI




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29

## Insights

By European standards, Kalmar County has a relatively high level of wildfire exposure to human settlements

Possibly, this is due to predominantly scattered settlement patterns coupled with significant forest cover

It is likely that our estimates of exposure are conservative, as they disregard herbaceous fuels (a problem during spring) and assume a short travel distance of flaming embers

At the same time, there's some over-estimation of exposure due to disregard of differences in flammability among tree species

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30

30

## Thank you!

The WUI map is available via the FirEURisk viewer

Feel free to contact me at: avi-b@sci.haifa.ac.il

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31

31

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JS

# What does the increased forest fire danger imply?

Johan Sjöström, RISE Research institutes of Sweden
Frida Vermina Plathner
Jessica Hetzer (Senckenberg)

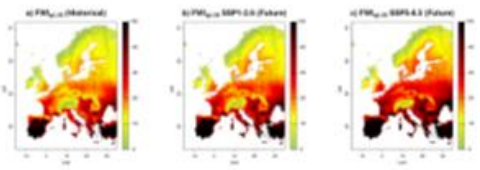
07/05/2024 | N European pilot site implementation

1



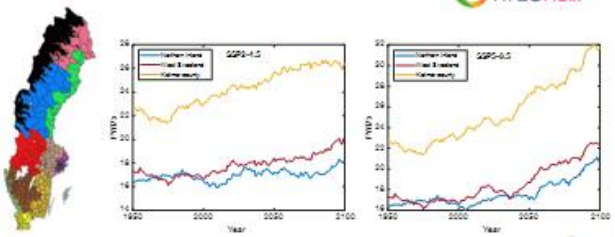

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## Remember Jessica's future projections?



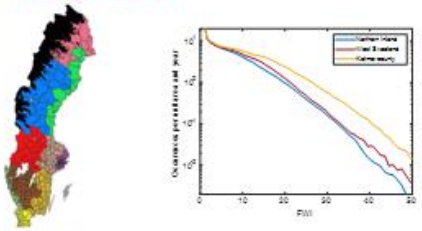
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## Using another metric – FWI7x



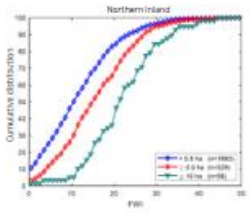

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## But there is a distribution of fire danger during a season



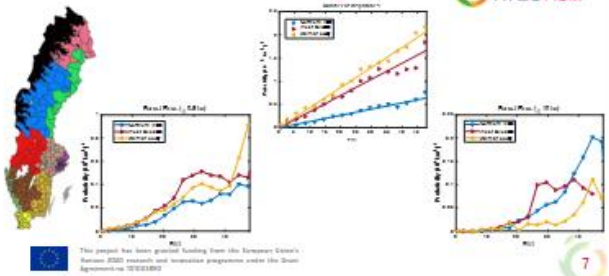
5

## And a distribution of fire danger when fires occur




6

## Finding the probability of fire occurrence of different sizes for different fire danger



7

## Comparing the outcome of the last 25 years to the outcome for 2070 - 2100

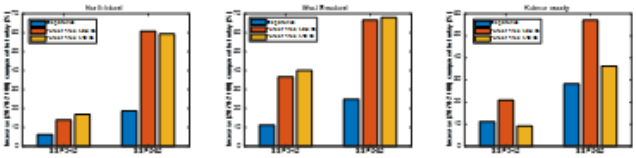
Assuming all other factors (fuel, resources, ignitions, ...) are the same

Calculate the shift in dispatches, forest fires >0.5 ha, and forest fires >10 ha for each region

Assess difference in scenario SSP2-4.5 and SSP5-8.5

8

## Comparing the outcome of the last 25 years to the outcome for 2070 - 2100



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9

9

## Summary

- With only a change in fire danger, dispatches are expected to increase 10-20 % by the end of the century for SSP2 and 20-30% for SSP5.
- The same increase for larger fires is projected to 15-35 % for SSP2 and 35-65 for SSP5.
- We know that the huge impact of suppression efforts as well as fuel management can encompass larger differences than that of the projected change in fire danger.
- The reduction due to suppression efforts and fuel management is only possible if the wildfire issue will continue to be
  - Of high priority for rescue services
  - Not forgotten after a decade of few fires with large implications
  - Important for fire fighting training
- Future fire regimes seems to be in our own hands

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Thank you for listening

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11

## A shiny app for forest fire danger projections

# Imagining the Future

Using scenarios to envision European land use with CLUMondo

Presenting:
Alex Neidermeier
a.Neidermeier@vu.nl



May 7th, 2024 | Demonstration Event, Stockholm

This project has been granted funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement no. 101036690

1

## Presentation goals:

- Consider the role of land management in fire dynamics
- Understand how we can use scenarios to probe the future
- Understand how the scenarios are turned into a spatial product through CLUMondo
- Look at the scenario design and land use results for northern Europe

2

## How are fuelscapes changing in Europe?




Climate change

*Land abandonment*

Changes in the WI

From Moreira et al. 2011

| Drivers | Landscape patterns | Fire hazard |
|---|---|---|
| Decrease of farming activities | Forests ↑<br>Shrublands ↑<br>Agricultural areas ↓ | ↑ |
| Decrease of pastoral activities | Forests ↑<br>Shrublands ↑<br>Grasslands and pastures ↓ | ↑ |
| Population ageing and decline/ Emigration | Forests ↑<br>Shrublands ↑<br>Agricultural areas ↓ | ↑ |
| Afforestation/reforestation | Forests ↑ | ↑ |
| Decreased exploitation of timber and wood resources | Forests ↑<br>Shrublands ↑ | ↑ |

3

## How can we use what we know about land management to help us prepare for the future?





4

## Imagining the future: Shared Socioeconomic Pathways

**SSP1: Sustainability Taking the Green Road**

**Associated climate pathway: Representative Concentration Pathway (RCP) 2.6**, which assumes a high effort to reduce emissions and increase renewable energy and emissions capture

SSP2: Middle of the Road

**SSP3: Regional Rivalry *A Rocky Road***

**Associated climate pathway: RCP7.0**, which indicates mixed renewable and fossil fuel energy generation, limited public transportation options, and an overall low effort to curb emissions.

SSP 4: Inequality *A Road Divided*

SSP5: Fossil-Fueled Development *Taking the Highway*




5

## SSP1: Sustainability. Taking the Green Road.

Economic development ↑

Environmental standards ↑

Governance ↑

Technology ↑

Health & education ↑

BETTER LAND MANGEMENT

*But*

MORE BIOMASS



6

## SSP3: Regional Rivalry. A Rocky Road.

Economic development —

Environmental standards ↓

Governance ↓

Technology ↓

Health & education ↓

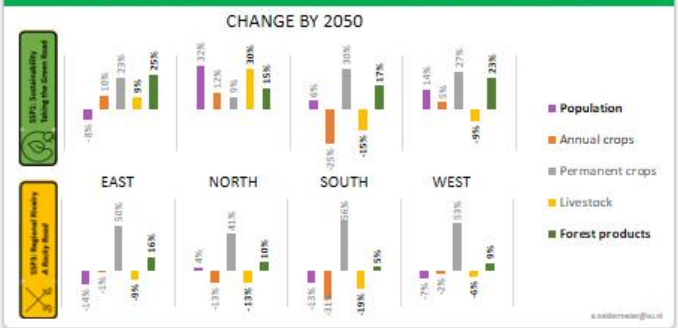
FRACTURED LAND MANAGEMENT =
MORE FIRE





7

## Imagining the future: SSP interpretations for Future Land Use




8

## CLUMondo: A spatially explicit land use model



- Area restrictions
- Conversion restrictions
- Competitive advantage
- Local suitability
- Neighborhood influence
- Conversion resistance



Pics of timber, grain, etc. from settlers, livestock

9

## Sample results: Northern Europe Urban (9k)



2050 (CLUMondo SSP1)



2050 (CLUMondo SSP3)

10

## Sample results: Northern Europe Forest (9k)



2050 (CLUMondo SSP1)



2050 (CLUMondo SSP3)

11

## Sample results: Northern Europe Shrublands (9k)



2050 (CLUMondo SSP1)



2050 (CLUMondo SSP3)

12

## Thank you!


**Presenting:**
**Alex Neidermeier**
Vrije Universiteit
Amsterdam
a.Neidermeier@vu.nl


VU Vrije Universiteit Amsterdam

fireurisk

13

## Emissions from Wildfires – Example from Sweden

fireurisk

# Emissions from wildfires
## Impact of 2014 Västmanland wildfire on air quality

**Tobias Osswald**, Carla Gama, Ana Miranda
University of Aveiro, Portugal

1

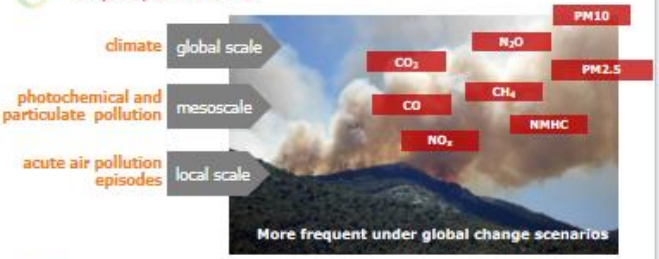
## Air quality and wildfires






2

## Air quality and wildfires



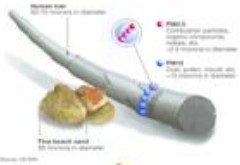



3

## Air quality and wildfires



Wildfire smoke is dangerous on:
- Population (increased short- and long-term hospital admissions)
- Firefighters (intoxication, deterioration of health indicators)



EU air quality standards – limit values

| Pollutant | Concentration | Averaging period |
|---|---|---|
| Fine particles ($PM_{2.5}$) | 20 µg/m³ | 1 year |
| Particulate matter ($PM_{10}$) | 50 µg/m³<br>40 µg/m³ | 24 hours<br>1 year |
| Carbon monoxide (CO) | 10 mg/m³ | Maximum daily 8 hour mean |
| Ozone | 120 µg/m³ | Maximum daily 8 hour mean |



4

## Västmanland wildfire

**August 2014 Sweden**

- **Heat wave** during end of July
- **Started July 31st**
  - Due to a spark from a forestry vehicle
- On August 4th rapid growth
  - 9.000 ha
  - Reached 5km/h progression
- **Extinguished September 11th**
- Largest forest fire in Europe in 2014 (**12.800 ha**)
- Largest recorded in Sweden
- Thousands had to be evacuated

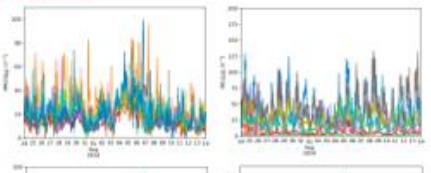





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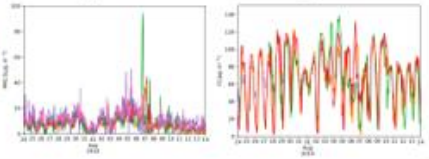
## Observed impact on air quality

**August 2014 Sweden**



Air quality monitoring network





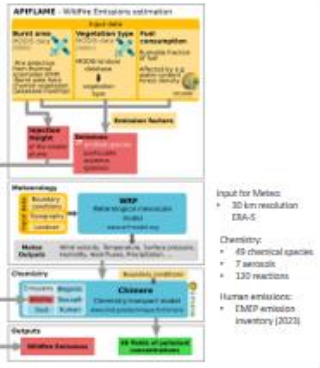


6

## Modelling methodology

**Estimating smoke levels in the air we breathe**

- Modeling system to estimate air-pollutant **concentrations** (CHIMERE-APIFLAME)
- **Weather** is calculated by **WRF**
- **Emissions** are calculated or obtained from **databases**
- Wildfire **smoke emissions** are calculated with **APIFLAME**
- Chose 5 km **resolution**




Input for Meteo:
- 10 km resolution ERA-5

Chemistry:
- 49 chemical species
- 7 aerosols
- 130 reactions

Human emissions:
- EMEP emission inventory (2023)



7

## Satellite wildfire detections

**Fire Radiative Power**

- Wildfires have a strong **thermal signal**. Hotspots
- **MODIS** Terra and Aqua satellites provide **Fire Radiative Power** daily (MOD14A1 and MYD14A1)
- This can be used to detect the **time** and **location** of wildfires as well as **intensity**
- Wildfire west of stockholm (**Västmanland**)
  - 31/07 first detection
  - 05/08 strongest signal
  - 06/08 no more signal



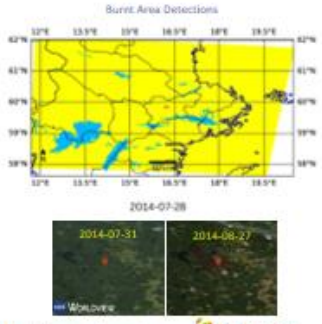



8

## Satellite wildfire detections

**Burnt Area**

- Wildfires leave a charred black landscape detectable by satellites (**burn scars**)
- Merge this information with wildfire infrared **hotspots**
- **MODIS** MCD64A1 product used here
- Within each cell of domain:
  - Know **area** that burned
  - Know **day** it burned






9

## Fuel characteristics and emission factors

- **Emission factors** allow us to derive emissions for each air-pollutant
- **Burnable biomass per area** is obtained from **Orchidee** and depends on:
  - Fuel moisture
  - Vegetation type
  - Biomass density...

Emission factors (in g/kg dry fuel mass) used in APIFLAME

| Name | Tropical Forest | Savanna | Crop Residue | Pasture Maintenance | Boreal Forest | Temperate Forest | Peatland Forest | Chaparral |
|---|---|---|---|---|---|---|---|---|
| Carbon Dioxide | 1643 | 1686 | 1585 | 1548 | 1489 | 1637 | 1563 | 1680 |
| Carbon Monoxide | 93 | 63 | 102 | 155 | 127 | 88 | 182 | 67.6 |
| Methane | 5.07 | 2 | 5.82 | 8.71 | 5.96 | 3.36 | 11.8 | 3 |

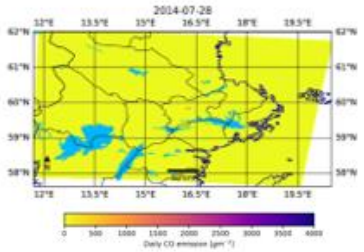


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## APIFLAME emissions

**Carbon Monoxide Example**

- For **each day** and **each cell** of the domain we know:
  - Burned area
  - Fraction of vegetation types
  - Burnable biomass per vegetation type
- **Calculate emissions** of CO using its **emission factors**
- This is repeated for **all 27 air pollutants**






11

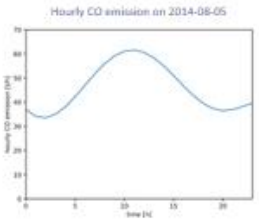
## CHIMERE emissions allocation

**Diurnal profile**

- The **emissions** on each cell can**not** be assumed **constant** throughout the day
- A **general diurnal profile** is applied to **all** cells

For a better diurnal allocation SEVIRI can be used with APIFLAME

SEVIRI provides continuous FRP readings



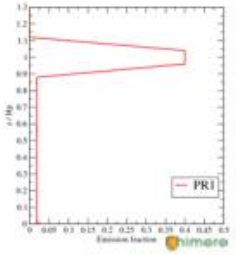



12

## CHIMERE emissions allocation

**Smoke plume vertical profile**

- Altitude reached by the smoke (**smoke injection height**)
- Smoke **vertical distribution**
- Hotter smoke is carried higher into the atmosphere
- Injection height is parametrized as **function of FRP** and **state of the atmosphere**

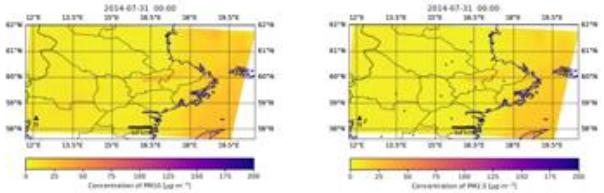





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## CHIMERE modelling results

**Hourly Particulate Matter ground-level concentrations**



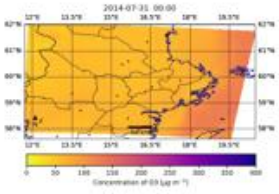



14

## CHIMERE modelling results

**Hourly Particulate Matter ground-level concentrations**

- $O_3$ is produced by photolysis of $NO_x$ and VOCs
- $O_3$ no longer produced during nighttime, instead cloud registers minimum due to reaction of $O_3$ with smoke






15

## Conclusions

- The wildfire had a clear impact on air-quality during the Västmaland wildfire
- Luckily, wind was blowing away from Stockholm on the 4th
- However, other other cities were affected
- Little wind and changes in direction on the 5th led to accumulation of smoke, affecting cities close to the fire
- CHIMERE-APIFLAME can be used to analyze impacts of wildfires in air-quality in Sweden
- Inaccuracies in temporal allocation of burned areas
- Can improve by:
  - adding SEVIRI diurnal variability
  - merging satellite products
- Little information about impacts of wildfires on air-quality in Sweden

tobiasvoswald@ua.pt

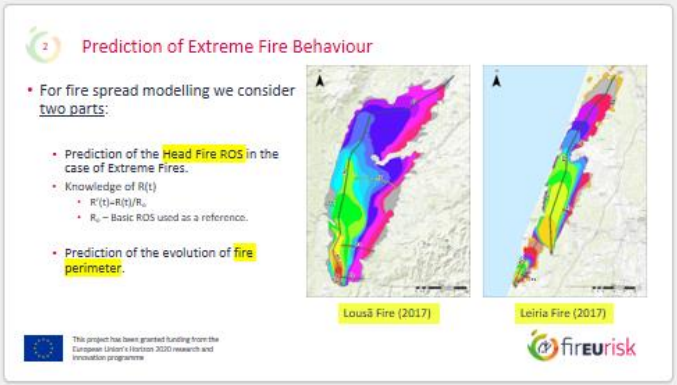


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## Intermittent behaviour of mega fires




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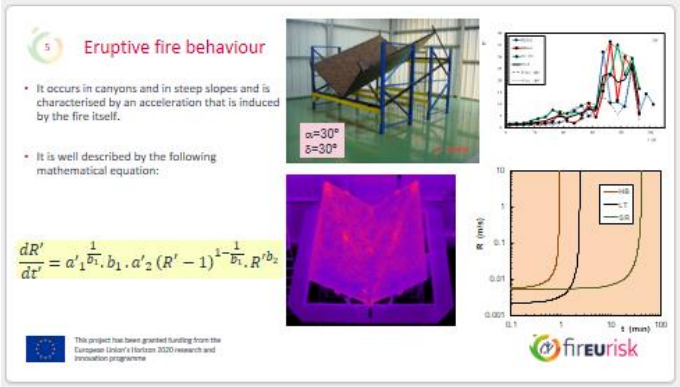

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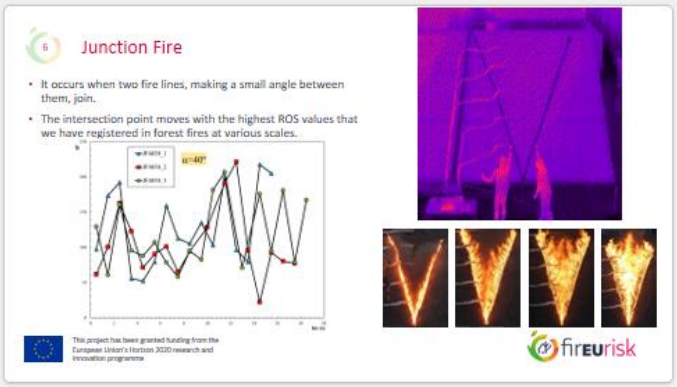

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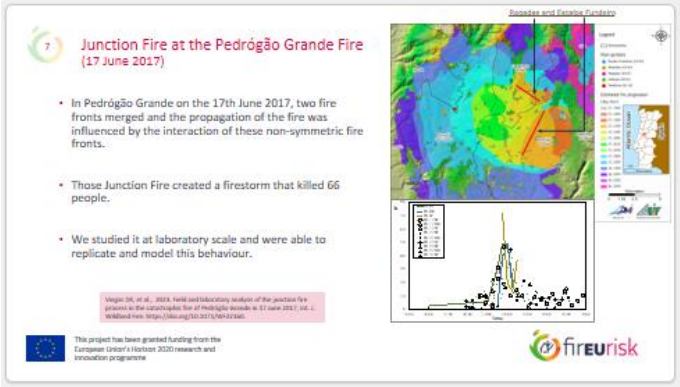

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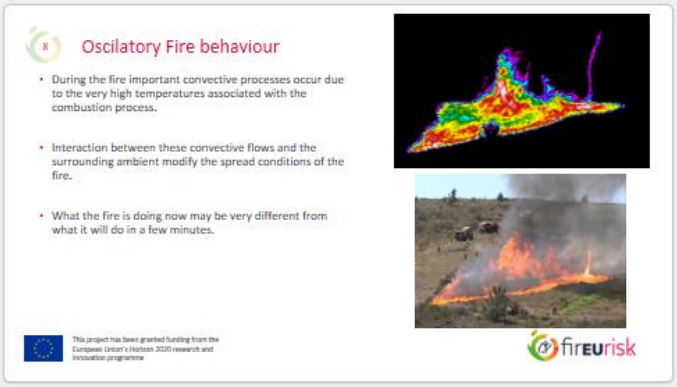

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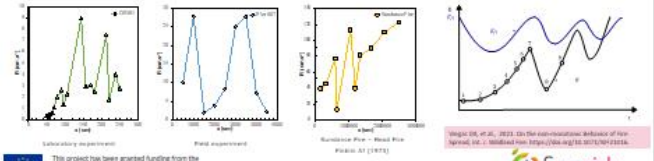

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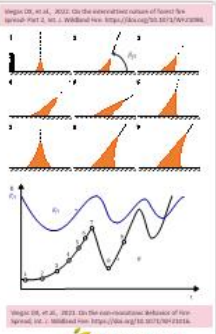



8

## Oscilatory Fire behaviour

- It was shown that the behaviour of a fire is oscillatory and intermittent in the sense that its ROS may increase but then the convective flow induced by the fire neutralizes the acceleration tendency and decreases the ROS value.
- If the boundary conditions remain the same the fire will undergo another cycle with increased and decreased ROS.
- Dynamic Fire Behaviour shows an Oscillatory Fire Behaviour.
- This effect is observed at all scales of analysis. The amplitude and frequency of the oscillations depend on the size of the fire and increase with the ROS.





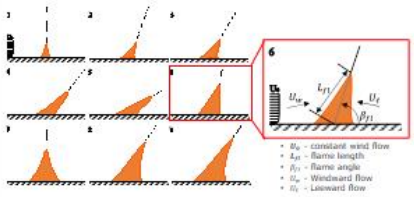
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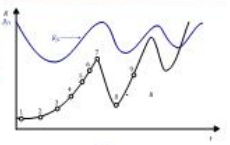
9 ★

## Oscilatory Fire behaviour

- A novel concept of fire growth was proposed to describe and interpret the oscillatory growth of a fire over time due to the interaction between the fire, the fuel and the environment.







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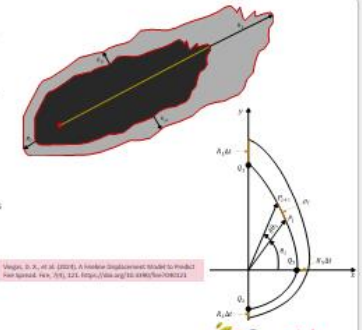
## Modelling the Fire Perimeter

We assume that the value of the ROS of the head fire, the back and the flanks is known:

- $R_1$
- $R_2$
- $R_w$
- $R_{el}$

The movement of each element of the fire perimeter is modeled according to the concepts of:

- Fireline rotation
- Fireline extension
- Fireline translation



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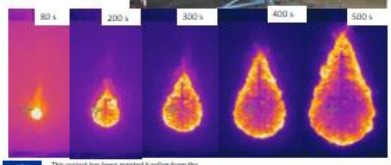
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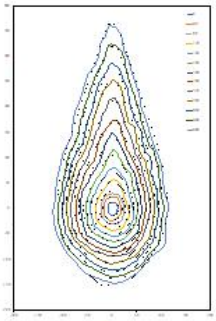
11 ★

## Modelling the Fire Perimeter

30º slope





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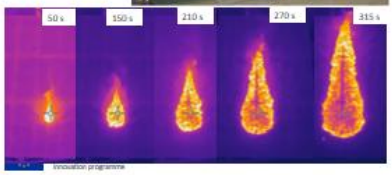
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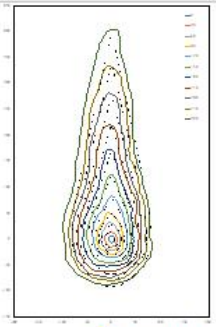
12

## Modelling the Fire Perimeter

40º slope





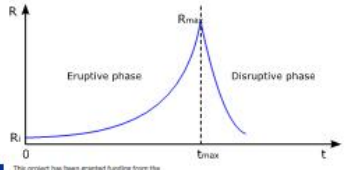
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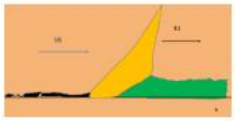
13

## Fire acceleration and deceleration

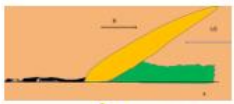
- The evolution of the head fire is a succession of acceleration and deceleration processes.
- In some extreme fires this has occurred with dramatic consequences.
- We are studying this process.




Acceleration (Eruptive phase)



Deceleration (Disruptive phase)



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14

## Mathematical model

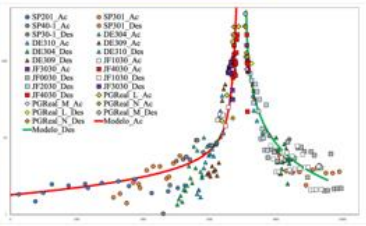
$a'_1$=0.83, $a'_2$= $a'_3$=0.24
$b_1$=0.95, $b_2$= $b_3$=1.3

Acceleration (Eruptive phase)

$$\frac{dR'}{dt'} = a'_1{}^{\frac{1}{b_1}} b_1 a'_2 (R'-1)^{1-\frac{1}{b_1}} R'^{b_2}$$

Deceleration (Disruptive phase)

$$\frac{dR'}{dt'} = -a'_1{}^{\frac{1}{b_1}} b_1 a'_3 (R'-1)^{1-\frac{1}{b_1}} R'^{b_3}$$




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15




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# Intermittent behaviour of mega fires

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