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# 3rd International Congress on Fire in the Earth System: Humans and Nature

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# Abstracts

# Session 1: Quantitative Assessment of Wildfire Exposure and Risk

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Wildfires are a serious hazard across the planet, causing major economic and ecological impacts. Extreme wildfire seasons, with intense and large-scale fires, such as those recorded in 2019 in Australia, in 2022 in Europe or in 2023 in Chile and Canada, are a recent warning of the growing threat posed by global warming and global change. These extraordinary fire seasons are related to extreme weather conditions, such as severe droughts and heat waves, coupled with increased fuel availability and continuity. Specifically in Chile, forest fires burned more than 430,000 hectares in 2023 and caused the loss of 24 lives, leading the government to declare a state of emergency in multiple regions of the country. This proposal is oriented towards the use of cross-cutting methods to assess wildfire risk. This includes the use of empirical (based on historical data) and/or stochastic (simulation algorithms) models to assess the exposure of natural values and human communities to wildfire. We seek to provide quantitative insights through specific metrics of exposure, risk transmission and related information (Alcasena et al., 2021; Rodrigues et al., 2022). All of this supports the implementation of proactive strategies (fuel management and/or rearrangement, urban development or building codes) for risk mitigation and adaptation to extreme wildfire conditions.

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# A spatially explicit containment modelling approach for escaped wildfires in a Mediterranean climate

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## Abstract

Characterised by a Mediterranean climate, Catalonia faces the recurring threat of wildfires. The inherent variability in weather patterns across Catalonia has given rise to diverse landscapes, each exhibiting a unique response to the prevalent Mediterranean climate and variations in fire regimes across its territories. Regional climate projections have shown drier and warmer conditions due to climate change; thus, mega-fires are expected to increase. This is evident in the lengthening of fire seasons and the occurrence of large fires outside the summertime. The region's continuous susceptibility to wildfires necessitates a crucial understanding of the likelihood of containment within specific areas for effective management planning and suppression activities. Although there is an existing containment model for Catalonia, we observed a limitation in this previously developed model as it does not capture the impact of weather conditions and ignores the temporal dimension, hence being unable to forecast windows of opportunity for containment. To address this limitation, we developed a predictive model using detailed geospatial data and machine learning capable of accounting for temporal variation in containment probability across the fire seasons in Catalonia. We further explored the threshold of each variable in promoting fire containment success in Catalonia. From our results, we observed various breaking points of containment probability for each variable. Specifically, containment probably was higher at temperatures below 10ºC, beyond which the probability reduced significantly, reaching minimum probability above 21ºC. Similarly, lower windspeed (< $3ms^{-1}$) corresponds to a high containment with success rate reducing drastically beyond this point. We also observed the crucial role of road accessibility in promoting success rate, with areas within the roadside having a higher containment probability of around 0.78. Our findings provide valuable insights that can inform strategic resource allocation for firefighting efforts and guide decision-making regarding extended attack strategies. Moreover, they contribute to enhancing strategic fuel management initiatives to create defensible areas and strategically break up landscapes to improve firefighting operations. Our framework and methodology offer a replicable blueprint for developing similar containment models tailored to diverse regions, climates, ecosystems, and landscape features.

**Keywords:** Megafires, Machine learning, Geospatial, Fire suppression, Spatial-Temporal.

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# Wildland Fires Recognition using Deep Learning on Aerial and Ground Images

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## Abstract

Wildland fires are one of the important challenges facing the world today due to climate change. They are rapidly spreading out of control, and their control requires considerable effort, time, and resources. They pose significant threats, inflicting ecological, economic, and health damages with devastating consequences that extend to loss of life. For instance, in 2023, Canada faced a record year for wildfires, with a total of 6,623 fires burning 18,401,197 hectares (Natural Resources Canada, 2024). In 2022, Europe recorded the worst wildfire year, with around 900,000 hectares affected, significantly increasing the risk of economic losses (European Commission, 2024). The United States also suffered considerable economic damage from wildfires, with losses ranging from $63.5 to $285 billion (Thomas et al., 2022). To reduce their damage, we adopted a recent ensemble learning method, namely CT-Fire, which combines the vision transformer EfficientFormerV2 and the deep convolutional neural network RegNetY-16GF in recognizing wildland fires using aerial and ground images (Ghali and Akhloufi, 2023). Combining aerial and terrestrial images provides a diverse range of forest and wildland scenarios. This allows accurate wildland fire recognition from a wide range of viewpoints, whether collected by camera or drone. Testing results demonstrated that CT-Fire achieved high performance with an F1-score of 85.09 % better than the baseline methods Swin transformerV2, ResNeXt-50, and RegNetY-16GF. It also outperformed challenging limitations related to wildfires, including the complexity of background, the detection of small wildfire zones, and varying size, intensity, and shape of fires. This confirms its robustness and adaptability to a wide range of real wildland fire scenarios. Additionally, this method achieved a fast inference time of 0.014 seconds. This allows real time detection of wildfires when integrated with a surveillance camera or drone reducing the risk of fires.

**Keywords:** Wildland fires, Fire recognition, Deep learning, Aerial images, Ground images

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# Understanding fire regimes and fire-conducive conditions in Chile

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## Abstract

Over the last decade, Chile has faced unprecedented wildfire seasons, such as Fire Storms of January 2017 and February 2023, which burned more than 760.000 hectares, and the most devastating event, in February 2024, that caused 134 fatalities. The factors that have led to these record-breaking fire seasons are manifold and span from climate and weather conditions to land management or the lack of effective policies related to Disaster Risk Reduction.

Chile's geography is wild and unique in many ways, and it experiences some of the main challenges relating to wildfire risk in his central region. Chile encompasses different climatic conditions due to its large latitudinal variation, with a north-south transition from warm to cold desert conditions intermingled with Mediterranean climate, and a steep west-east elevation gradient towards the Andes Mountains. Native vegetation and fuels are distributed accordingly, showing a variety of forest types. Large monoculture eucalyptus and pine plantations interrupt Chilean landscapes in the central regions, increasing fuel availability and continuity. In turn, a fast-growing wildland-urban interface is increasing population's exposure and exacerbating risk situations.
These contrasting conditions govern fire activity, resulting in distinct fire regimes and risk factors that require specific actions. In this work, we seek to understand the interplay of factors leading to increased wildfire incidence. To do so, we characterized the temporal and spatial dynamics of wildfire activity using historical records provided by CONAF. We analysed temporal trends in fire frequency, area burned, extreme wildfires, and causality during the period 1984-2023. We also provide information on spatial clustering of fire activity and links between meteorological factors (temperature and relative humidity) and fire occurrence. To this end, we combine information from the ERA5 Land Reanalysis dataset with historical fires, identifying fire typologies and meteorological conditions conductive to fires. Our results constitute a first step towards a dynamic ignition probability model that will feed stochastic simulations of fire spread and, ultimately, enabling the assessment of wildfire risk.

**Keywords:** fire occurence, burned area, Chile, risk, fire regime

**Acknowledgments:** This work was financed by the AXA Research Fund under the Joint Research Initiative \\\"Developing a framework for assessing the wildfire risk at local scale\\\" (2024/0159)

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# Mapping open burning of agricultural residues from Earth Observations and modelling of air quality impacts

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## Abstract

The field burning of pruning material and other agricultural or forestry residues can be an important source of atmospheric pollution. In Portugal, the burning of materials such as vine pruning, olive pruning, among others, as well as the use of fire for pasture renewal or elimination of stubble and surplus from forestry or agricultural operations, are common practices that typically occur from October to April. The estimate of atmospheric emissions resulting from the open burning of agricultural or forestry residues is commonly done based on activity data and combustion factors. However, this methodology does not identify when and where those field burns occur, posing thus challenges to the assessment of the impact these emissions have on air quality. In the scope of the PRUNING exploratory research project, this work aims at exploring Earth Observation Satellites as a source of data for spatial and temporal mapping of those events, allowing the improvement of emission estimates, and thus the assessment of the atmospheric pollution impact caused by these practices. For this, a regional modelling approach is used, based on the meteorological model WRF and the chemical transport model CHIMERE. Modelling estimates are also compared with available observations from the national air quality monitoring network. This communication will share the results obtained for a specific case study of major open burning of agricultural residues in the North and Center regions of Portugal, in terms of particulate matter (PM10 and PM2.5) and gaseous pollutants concentrations. The information on air quality impacts due to field burning of pruning material and other agricultural residues may help policymakers and citizens to take informed decisions, while promoting knowledge sharing and education for both stakeholders and researchers.

**Keywords:** air quality modelling, satellite observations, open burning, atmospheric pollution

**Acknowledgments:** We gratefully acknowledge the financial support received from FCT/MCTES through national funds to support the PRUNING Project (grant number 2022.01045.PTDC, DOI 10.54499/2022.01045.PTDC), as well as the support provided to CESAM through grant numbers UIDP/50017/2020+, UI- DB/50017/2020+, and LA/P/0094/2020.

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# The firefighters on the frontline of forest fires: from the exposure to adverse health effects

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## Abstract

Over recent decades, the intensity and severity of wildland fires have been increasing. In a warmer world facing the challenges of climate change, this trend is expected to persist. Accelerating wildland fire activity requires a growing number of firefighters for wildland fire suppression activities. Wildland firefighters encounter dangerous occupational exposures to hazardous pollutants, including gaseous chemicals and particulate matter, in the field. The International Agency for Research on Cancer (IARC) has recently classified firefighting occupational exposure as carcinogenic to humans. However, scarce studies have focused on the exposure-induced biological mechanisms that may lead to such adverse health effects. Gathering data during fire seasons is challenging, which has led to a lack of information in this area.
Biomonitoring studies are crucial for understanding the health risks faced by firefighters in this occupation. The use of biomarkers of effect is essential to detect early signs of health problems. Combining exposure data with effect biomarkers information furnishes a better understanding of possible short-term and long-term health risks.
This longitudinal study engaged a group of Northern Portuguese Wildland Firefighters during two different phases of their activity. Data on firefighters' characteristics, health status, lifestyle, and occupation, was retrieved by a questionnaire. Biological samples, namely blood, buccal cells and urine were collected from firefighters in both phases. Different biomarkers were used to measure genetic instability, DNA damage, oxidative DNA damage and other biological endpoints. By comparing data from different phases of

the study (before and during a wildfire season), and linking exposure levels with biomarkers and individual information, we gained a better understanding of the impact of firefighters' occupational exposure in real-wildfire scenarios. Our findings highlight the need for surveillance-based biomonitoring programs, safety measures, and awareness campaigns to protect the well-being and health of wildland firefighters.

**Keywords:** Wildland firefighters, firefighting occupational exposure, biomarkers, pollutants, health effects

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# Analysis of severity conditions in sixth-generation fires

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## Abstract

Climate change feedbacks are increasing the frequency of extreme wildfires throughout the Mediterranean Basin. This type of wildfire, characterized by high intensity and severity, may pose a great risk to the functioning and provision of ecosystem services of forest ecosystems.
We selected three study sites in Spain to investigate the influence of pre-fire fractional vegetation cover (FCOVER), ecosystem type and fire recurrence as potential driving factors of the severity of extreme wildfires: Sierra de la Culebra (2022), Sierra de la Cabrera (2017) and Navalacruz (2021) wildfires.
Sentinel-2 level 2A pre- and post-fire scenes were used to assess fire severity by means of the differenced Normalized Burn Ratio (dNBR) index. The composite burn index (CBI) measured in the field was used to validate the dNBR estimates and generate classified fire severity maps. A time period of 30 years was established to analyze fire recurrence within the study sites by identifying and digitizing wildfire perimeters in Sentinel-2 and Landsat false color composites. The pre-fire ecosystem type distribution was extracted from the Spanish Forest Map at 1:25,000 scale (SFM25). The pre-fire FCOVER was calculated from pre-fire Sentinel-2 level 2A scenes by the inversion of the PROSAIL radiative transfer model in Sentinel Application Platform (SNAP) software. The effect of pre-fire FCOVER, ecosystem type and fire recurrence (as well as their interactions) on fire severity was evaluated by means of multivariate linear regression models.
The analysis revealed areas burned up to four times in the southwest of the Sierra de la Cabrera wildfire perimeter. The dominant pre-fire ecosystem types in frequently burned areas were shrublands and coniferous forests. FCOVER significantly influenced fire severity, since the higher the FCOVER, the greater the amount of fuel available. The most relevant interactions were between FCOVER - ecosystem type, and FCOVER - recurrence. In general, a high pre-fire FCOVER promotes a more pronounced increase in fire severity in shrublands and coniferous forests than in broadleaf forests. The increase in fire severity is also more pronounced in areas of high recurrence than in areas of low recurrence. The results of this study demonstrate the importance of reducing fuel continuity and promoting native forests with high resistance to fire severity.

**Keywords:** fire severity, spectral indices, recurrence, FCOVER, ecosystem type

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# Session 2: The Impact of Forest Fires on Soil and Watershed Hydrology

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Forest fires induce changes in vegetation and soil properties that finally trigger changes in soil infiltration, soil water retention, sediment transport, and runoff generation. The impact of fire on soil and watershed hydrology is highly affected by the measurement scale. Measurements and experiments carried out at different scales show that fire induces a sudden increase in runoff (less interception, lack of soil litter, water repellency..) and an increase in sediment transport, soil crust development, and finally a more degraded soil. There is a need to understand better the impact of fire on the connectivity of flows and sediments, the role of water repellency, and the strategies to recover the ecosystems after the forest fire. The session welcomes pure and applied scientific research to discuss the best strategies to manage fire and avoid the impact on soil and watersheds as a consequence of the fire. Experimental and theoretical research with site demonstration and literature review are welcome.

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# The impact of fire on soil infiltration rates in forest soils. The Vall d'Ebo forest fire in Eastern Iberian Peninsula

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## Abstract

Forest fire induces the removal of the aerial part of the plant cover, the heating of the upper soil layer and the building of the ash bed. All those changes result in changes in the soil's hydrological properties, and within them, soil infiltration is a key process in the hydrological cycle. Before and after the forest fire of Vall d'Ebo (August, 13 2022) a set of water infiltration measurements using ring infiltrometers was developed in September, October and December 2022, and February, April, June and August 2023 to determine the evolution of the infiltration rates in fire affected and control (macchia vegetation cover) along the one year. A set of 25 measurements were carried out at each of the paired plots and each of the 7 experimental field periods with a total of 350 measurements done along a distance of 25 m (one ring infiltration measurements per metre) at each paired plot: Fire-affected and Control. The results show higher infiltration rates immediately after the wildfire due to the ash bed effect. After December we found a decrease in the infiltration rates due to the increase in infiltration and finally, this resulted in a lower infiltration rate in the fire-affected site. Fire and season resulted in higher erosion.

**Keywords:** Soil, Water, Fire, Land, Soil, Infiltration, Mediterranean.

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# Temporal Impacts on the microbial communities of prescribed fires in semi-arid Mediterranean forest

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## Abstract

Low-intensity burnings could be an effective silvicultural tool to prevent the occurrence and severity of wildfires. However, these burns can affect soil microbial communities, especially in in semi-arid areas. Our study aims to evaluate changes in the diversity and composition of the soil bacterial communities in a semiarid Mediterranean forest in SE Spain (Sierra Filabres; 37° 13′ 25″ N, 02° 20′ 33″ W). Two similar stands were treated by the Andalusian Forest Fire Extinction Service (INFOCA) with a low-intensity prescribed burn in spring (PB1) and autumn (PB2) 2018 and were compared to an unburned stand (UB). All soil samples were collected after the autumn fire. The fire consumed 2.5 cm of the litter but the temperature at a soil depth of 3 cm did not exceed 35 ºC. Microbial soil DNA was extracted using the DNeasy PowerSoil kit (QIAGEN, Germany) and regions V4-V5 (400-500 bp) of bacterial 16S ribosomal RNA gene were amplified in vitro by polymerase chain reaction (PCR) using primers 515F/806R (Walters et al., 2016). ). Paired-end sequencing was performed using the Illumina MiSeq platform. Raw DNA sequences were grouped into Amplicon sequence variants (ASVs) and classified against the SILVA library database. Alpha diversity indices were estimated with QIIME2 software. The phylogenetic diversity indices of Faith, Pielou and Shannon were sampled uniformly at 20,000 reads per sample. Those taxa more related to each type of soil samples were estimated using the Indicspecies package of the R 4.3.2 software. Results showed, on one hand, no statistical differences among the that diversity indices for burned/natural conditions. Mean values and standard deviation were the following: Number of ASVs (1047± 4), Faith (53,80 ± 0.55), Shannon (8.79 ± 0.17), Pielou (0.87 ± 0.02). On the other hand, some taxa were more promoted in each soil conditions: PB1 (genera RB41, Cohnella, families Solirubrobacteraceae and WD2101); PB2 (genera Massilia, Dokdonella, Edaphobacter, Bacillus, families Xanthobacteraceae, Microscillaceae, Rhizobiaceae; UB (genera WX27, Methylobacterium, Pseudonocardia, Gemmata, families Sphingomonadaceae, f_JG30KFCM45, Beijerinckiaceae, Methyloligellaceae and Acidobacteria Subgroup 6 and 17). Results suggest that fire did not produce a significant overall change in the microbial communities, but some taxa differentially changed their abundance. Specifically, the biggest changes happened after the fire (PB2 vs UB), as they showed the higher number of indicator taxa, meanwhile the

PB1 situation (7 months after fire) highlighted a reduced number of indicator taxa, which denotes a recovery of the bacterial community composition in the short-term.

**Keywords:** Prescribed fires, bacteria, NGS, Mediterranean forest

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# Amendment Improves Depleted Soil Chemical Properties and Microbial Populations after Prescribed Fire under an Agricultural System in Nigeria

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## Abstract

Prescribed fire is used for land preparation in agricultural soil by farmers. However, it could negatively affect the chemical and biological properties of soil resulting in unsustainability of soil. Amendments could reverse these negative impacts and protect soil ecosystems. In this study, we investigated the influence of prescribed fire and grass mulch on selected soil chemical and biological properties in an agricultural system. Also, the potential of amendments to reverse the negative impacts of prescribed fire on chemical and biological properties was studied. The land preparation treatments include two prescribed fire intensities (200 oC and 500 oC), grass mulch and bare soil (control) (Ibitoye et al., 2024). Amendment treatments were combined poultry manure at 7.5 t ha-1 with urea at 40 kg N ha-1, a single dose of urea at 80 kg N ha-1 and control (no amendment). The experiment was carried out across three seasons in 2019 and 2020 at Obafemi Awolowo University Teaching and Research Farm. The selected biological and chemical soil properties were determined immediately after burning and three months after amendments were applied. Results showed some chemical properties such as soil pH, soil organic matter (SOM) and Mg2+ were significantly increased while others including total nitrogen and available phosphorus significantly reduced in prescribed fire treatments immediately after burning compared to the control. Soil bacterial populations significantly reduced by an average of 18.1 and 11.3 % in 500 oC and 200 oC treatments, respectively across the three seasons compared to the control immediately after burning. Soil fungi populations also significantly reduced compared to the control in prescribed fire treatments. However, total nitrogen was significantly improved only in both prescribed fire treatments while SOM was not improved in any land preparation treatment three months after the amendments were applied. Nevertheless, the fungal population was improved in all the land preparation methods three months with and without amendment while bacterial population was improved by an average of 40.0 and 33.6% in 500 oC and 200 oC, respectively when amended with poultry manure + urea. Our results suggest soil chemical properties respond differently to prescribed fire while soil bacterial and fungal populations are reduced immediately after prescribed fire. However, some soil chemical properties and bacterial and fungal populations depleted by prescribed fires were improved three months after the application of amendments. These findings highlight the role of amendments in improving soil properties negatively affected

by prescribed fires under agricultural systems

**Keywords:** Prescribed fire, Chemical properties, Biological properties, Fungal population, Amendment

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# The impact of forest fires on groundwater, an approximation of their effects in several case studies

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## Abstract

Forest fires have existed on our planet since the beginning of terrestrial ecosystems, about 420 million years ago. Although fire is part of the natural dynamics of many of these ecosystems, in recent decades forest fires have been growing disproportionately in extension and intensity, causing major socio-economic and environmental disasters, with their most important environmental consequences being the Mediterranean region and, particularly, in Spain. Traditionally, their effects have been studied from the perspective of the impact they produce on the biotic environment, soil and atmosphere, although there are other components, such as surface water and groundwater, in which the impacts are notable. One of the most innovative approaches that must be addressed today to propose a comprehensive analysis of the problem is the study of the direct or indirect effect that ashes from forest fires can have on aquifers and groundwater, considering that these effects can affect both the quantity and quality of the water resource. In the current climate change scenario, it is foreseeable that forest fires will occur with increasing frequency and severity and, in addition, will occupy a greater area of territory. Therefore, in order to propose actions and palliative strategies or control measures, and with the aim of mitigating their harmful effects on groundwater, the Geological and Mining Institute of Spain (CN IGME-CSIC) launched the project “Forest Fires and Groundwater” that has been developed since 2016. After an extensive bibliographic review, different methodological approaches have been developed and different case studies have been studied, to establish, in a first approximation, the qualitative and quantitative impact on the aquifers. Likewise, a methodology has been proposed for the economic evaluation of the potential risk of affecting groundwater masses. On the other hand, the results of two case studies, the May 2015 fire in Vall de Ebo (Alicante) and the June 2017 fire in the Doñana Protected Natural Area (Huelva), show that, in the years after -fire, there is changes in the hydrochemical signature of groundwater, in particular in the magnesium content, the pH value and the concentration of some heavy metals, which can serve as a quantitative tool for evaluating the impact of forest fires on groundwater.

**Keywords:** Groundwater, pollution, impacts, fires, methodology

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# Fire and water: Effect of forest fires on soil hydrobionts from long-time perspective

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## Abstract

Hydrobiont communities are very common and abundant in all soils, even in those that frequently dry out. All groups of hydrobiont microfauna are well adapted to desiccation with anhydrobiosis. Dry forests on sandstone rocks are susceptible to forest fires, which occur relatively frequently in the area of the Bohemian Switzerland National Park in the Czech Republic. We studied the effects of such disturbances on different groups of soil fauna on a chronosequence of burnt areas ranging from recent to more than a hundred years old. The abundance of rotifers varied between 104 and 106 individuals m-2, that of nematodes between 105 and 107 individuals m-2. All traditionally recognized feeding traits are present, such as bacterivores, fungivores, omnivores, predators and plant parasites. Among the rotifers, bdelloid rotifers dominate, but monogononts are also regularly represented. The results indicate that although the community is severely affected after a fire, it can recover within a short time and that the age of the plot has minimal long-term effects on it. On the contrary, communities responded considerably to fires of high severity. The significant changes, i.e., a decrease of mean abundances, plant parasites, omnivores and predators, species number, and nematode diversity, but an increase in the abundance of bacterivores were recorded immediately after the fire. Full recovery of communities was found approximately 20 years after the disruption. Overall, our results showed that fire severity was a considerable element affecting soil nematode communities immediately after events, as well as the time needed to recover communities' structure during post-fire chronosequence. Some species avoid burnt plots more than unburnt ones. We can say that a severe fire strongly changes the conditions in the soil profile, mainly by removing the upper litter layer, which in turn affects the microfauna community.

**Keywords:** Soil microfauna, rotifers, nematodes, forest fire, limnoterrestrial communities, soil organic matter.

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# Fire in agricultural land in citrus plantations in Spain. Impact on soil infiltration

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## Abstract

Fire has been used in the Mediterranean orchards and groves to remove the pruned branches. The EU policies are promoting the use of chipped pruned branches to promote the restoration of the soil system. Soils under the use of fire to burn the chipped pruned branches use to be bare and induce high erosion rates and loss of water due to surface wash. On the other hand, the soils covered with chipped pruned branches show higher erosion rates. Moreover, farmers use to light fire on the leaves cover during winter to maintain “tidy” the soil which results in a bare soil surface. This research investigates the impact of chipped pruned leaves and burnt leaves on soil water infiltration in the soils of persimmon plantations in Valencia, Spain. We selected 10 paired plots to compare chipped pruned branches mulch covered soils and ask-covered soils. The measurements were done in January and August 2022. We used a single-ring infiltrometer. Ten samples per site were carried out. The results show an increase in infiltration in the areas where chipped pruned branches were used. The use of fire resulted in a reduction in soil infiltration capacity. The use of mulches has been found in Mediterranean orchards as a sustainable practice and is a positive nature-based solution.

**Keywords:** Key words. Soil, Water, Infiltration, Mediterranean, Degradation, Chipped branches, Mulch.

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# The impact of fire on soil infiltration rates in forest soils. The Vall d'Ebo forest fire in Eastern Iberian Peninsula

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## Abstract

Forest fire induces the removal of the aerial part of the plant cover, the heating of the upper soil layer and the building of the ash bed. All those changes result in changes in the soil's hydrological properties, and within them, soil infiltration is a key process in the hydrological cycle. Before and after the forest fire of Vall d'Ebo (August, 13 2022) a set of water infiltration measurements using ring infiltrometers was developed in September, October and December 2022, and February, April, June and August 2023 to determine the evolution of the infiltration rates in fire affected and control (macchia vegetation cover) along the one year. A set of 25 measurements were carried out at each of the paired plots and each of the 7 experimental field periods with a total of 350 measurements done along a distance of 25 m (one ring infiltration measurements per metre) at each paired plot: Fire-affected and Control. The results show higher infiltration rates immediately after the wildfire due to the ash bed effect. After December we found a decrease in the infiltration rates due to the increase in infiltration and finally, this resulted in a lower infiltration rate in the fire-affected site. Fire and season resulted in higher erosion.

**Keywords:** Soil, Water, Fire, Land, Soil, Infiltration, Mediterranean.

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# The use of chipped pruned branches as an alternative to burning to reduce fire risk and improve soil quality in the Mediterranean region

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## Abstract

Forest fires are part of the Earth system, but the causes behind them have been changing in parallel with the social and economic development of humans. Natural causes have been diminishing in favor of human-induced ones, with carelessness, negligence, and deliberate fires representing the highest percentage in industrialized regions of the planet.
In recent months, numerous forest fires have occurred outside the typical season in the Mediterranean basin. Given this shift in occurrence trends, it is crucial to address the fires that can largely be prevented, namely those caused by carelessness and negligence, with agricultural practices being a significant contributor. Among these, agricultural activities represent a high percentage of such causes and offer ample opportunity for intervention.
Therefore, it is essential to alter agricultural techniques, which can serve as effective preventative measures. Shredding agricultural pruning waste presents an alternative to burning, mitigating the risks associated with open burning. Furthermore, utilizing pruning waste to create vegetative mulch aids in soil and moisture conservation, recycles nutrients, controls pests and diseases, and reduces air pollution and emissions generated by burning.
Moreover, given the persistently high or very high risk of forest fires even outside the typical season, many institutions are imposing bans on burning for a significant portion of the year. This results in biomass accumulation in fields, once again making shredding agricultural waste the preferable alternative.
Changing farmers' customs and habits is a challenging task, but initiatives supported by institutions, such as the European project React4med PRIMA, aim to emphasize the importance of adopting new techniques. Assessing the efficacy of projects like this in effecting technique changes should be a focus of future research.

**Keywords:** Fire, agriculture, forest, Mediterranean, soil, degradation, restoration

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# Session 3: Uncertainty in Forest Fire

M.I. Asensio

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A. Trucchia

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Uncertainty affects many aspects related to forest fires. It is a cross-cutting issue that affects forest fires in their entirety, from prevention, detection, spreading prediction, simulation, fighting, management and restoration. The wildfire phenomenon itself has an uncertain and complex behaviour because of its multiscale nature. Data on the state of vegetation and meteorology has a high level of uncertainty due to their spatial and temporal variation, which in turn affects both risk mapping and fire behaviour simulations, regardless of the type of model used. In particular, the simulation of forest fires is affected not only by the uncertainty of the input data already mentioned, but also by the uncertainty of the model itself due to its numerical solution but also due to a lack of knowledge as a consequence of scale interaction, as well as in the adjustment of the model parameters. Post-fire erosion risk models are also affected by uncertainty, due to the complex interactions between burned landscapes, rainfall events, and soil properties. This scientific session is intended to be an open forum to present scientific work related to uncertainty in all aspects related to forest fires.

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# Triple die double mirror drawing.

Heyer, L. Bret

*Self*

## Abstract

I have some ideas I've accumulated since 2010, doing stuff on the computer. I have a parti design that lends an idea to thorough pathways, and ducting. This ideas is some multi stack thorough pathways system that has holes around the structure that give an idea to prosperity and pathways to accumulate better ideas about architecture and what is needed for productive more sustainable buildings with better patterns for saving material and coming up with comprehensive details that relate to design and parti. The idea about multi-stack systems has a really small hole on the bottom. This is in the opening on the lateral side of the sheath goes up a level it's a little bit bigger of the hole, it goes up another layering it's a long agent in that whole layer at that point in junction. The two bottom shapes are mirrored above the elongated shape that brings better ideas some thorough pathway air systems. This project can be in number of different colours kind of gives the idea to what colour would be necessary for designing this thing for a better design characteristic of Design colouring systems. Each unit has about six layers of it and is mirrored together to make it from a half unit to a whole unit for better interpretation of this design I think making a 3D model can interpret some of the design characteristics for better model making. The greenhouse shape is made of panel units that help drive air spaceways pathways of ducting channels. There's different designs for it but I think getting the photograph laid together for this would be a good idea. I think this idea is a greater mass for generating an idea about isometric and analogous shapes that form better viewing constants. This building may also be a building in Sheraton Iowa with company in Des Moines Iowa for a library project that I have been talking about with a gentleman at the Des Moines partnership for about a year and a half after meeting with him at a restaurant in my hometown. We think this could be a good structure for an interior line thing that has book storage and the possibility of raising into the ceiling for a screen layout system that allows for children in the library to make sense of a movie in below for the site at hand for a library iteration.

**Keywords:** Greenhouse, drawing

**References**
Tim O'Brien, Cal Lewis

**Acknowledgments:** BA ARCH Span Minor 2016'

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# test

Ayushi Mishra

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## Abstract

Only abstracts in English will be accepted. Please use British spelling (e.g. colour vs color). Keep text in singe paragraph. Prefer SI units, use space between number and unit (keep % and ± signs with number). When using references, please format as Smith et al. (2021) or (Smith et al., 2021) and include full reference list in the respective sectifasdfaon. Write text directly on the form or use the functionality "paste as plain text". Alternatively you can first copy the text in a notepad and then on the form. This will ensure text editor formatting is removed which is required for pdf production.Only abstracts in English will be accepted. Please use British spelling (e.g. colour vs color). Keep text in singe paragraph. Prefer SI units, use space between number and unit (keep % and ± signs with number). When using references, please format as Smith et al. (2021) or (Smith et al., 2021) and include full reference list in the respective sectifasdfaon. Write text directly on the form or use the functionality "paste as plain text". Alternatively you can first copy the text in a notepad and then on the form. This will ensure text editor formatting is removed which is required for pdf production.

**Keywords:** test

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# Deciphering the impact of input data uncertainty in the PhyFire model

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## Abstract

PhyFire is a simplified 2D physical wildfire spread model with some 3D effects, developed by the research group on Numerical Simulation and Scientific Calculation at the University of Salamanca. The fundamental principles of energy and mass conservation set the governing equations, while convection and non-local radiation are the main transfer mechanisms. It is a one phase model, the solid phase, as the gaseous phase is parametrized through a factor affecting the convective term, and the flame temperature and height in the radiation term. It also considers the effect of the FMC through a multivalued operator in the enthalpy, the effect of the flame tilt due to wind or terrain slope, and it can also include some random phenomena such as fire-spotting (Asensio et al. 2002, Asensio et al., 2023). Previous studies on the influence of uncertainty in various parameters of the model have been carried out (Prieto et al., 2015, Asensio et al. 2020). This time, we address the effect of uncertainty in the wildfire case input data that is fed into the model. We focus our study on those inputs that are most susceptible to uncertainty. Regarding the cartographic input data, those related to vegetation, fuel type and fuel load. Regarding meteorological input data, the data being considered are ambient temperature, relative humidity, and wind direction and intensity. Finally, the other data susceptible to uncertainty to be considered is the position of the initial ignition point. We will present a series of simulations on a real scenario varying the above input data to decipher the effect of this variability on the model using global sensitivity analysis techniques. This will allow the design of a model output in terms of probability of affected area, providing probabilistic rather than deterministic forecasts.

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Asensio, Santos-Martín, Álvarez-León, Ferragut. (2020). Global sensitivity analysis of fuel-type-dependent input variables of a simplified physical fire spread model. Mathematics and Computers in Simulation, 172, 33-44. https://doi.org/10.1016/J.MATCOM.2020.01.001

**Keywords:** physical wildfire spread model, uncertainty, input data, PhyFire

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# Statistical Analysis of Wildfire Dynamics Using a Cellular Automata Software: Four-Parameter Beta Distribution as the Optimal Parametric Model

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## Abstract

The dynamics and statistics of a wildland fire were analyzed using a quasi-empirical stochastic cellular automaton model. This software, PROPAGATOR, can account for probabilistic short-range interactions between the ignited cell and its Moore neighborhood and long-range connections due to firebrands' emissions yielding spot fires in the presence of wind. The time evolution of the mean and variance of the burned area was found to exhibit a non-linear increase through time, enhanced by increasing wind intensity and terrain slope. However, the skewness decreases with time, indicating the existence of an increasingly left-skewed distribution of the burned area where large wildfires (outlier events) become predominant while a few smaller burned areas still exist through the landscape, affecting the distribution's shape. The burned area's kurtosis increases non-linearly, implying that the burned area's distribution becomes more leptokurtic as the wildfire propagates, with a heavier tail and sharper peak than a normal distribution.
The results have shown that higher wind speeds and steeper terrain's slopes do not only contribute to the increase of the average burned area (mean) and its erratic behavior (variance), but also amplify drastically the occurrence of large (outlier) forest fires. At the same time, the distribution becomes more negatively skewed (longer left tail), indicating a higher frequency of smaller fires. These latter can affect overall fire management strategies, as they suggest a persistent hazard that extends beyond the large-scale fires.
In order to find the most suitable parametric model for the distributional characteristics and dynamics of the burned area, we applied a Z-score normalization method to the cleansed data. Then, by using a method of moments, we could derive analytically new generalized formulas for the shape parameters (a, b). We found that a four-parameter beta distribution (a, b, L, U, with L<U) provides the most accurate fit for the burned area's distribution, suggesting that this model can successfully capture the variability and extremes in fire spread behavior. The effects of meteorological conditions and terrain topography on the statistical moments of this beta distribution were investigated, which offered deeper insights on the characteristics of fire spread.

**Keywords:** Forest fires, Cellular automata, PROPAGATOR, Beta distribution

**Acknowledgments:** This research is supported by the Basque Government through the BERC 2022–2025 program, by the Ministry of Science and Innovation: BCAM Severo Ochoa accreditation CEX2021-001142-S / MICIN / AEI / 10.13039/501100011033 and the project PID2019-107685RB-I00, and by the Spanish State Research Agency (AEI) through the project PDC2022-133115-I00 entitled ”B_2 F_2: Be a Better digital Fire-Fighter” funded by MCIN/AEI/10.13039/501100011033 and by European Union “NextGenerationEU"/PRTR.

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# Architecting Wildfire Resilience: A Framework for Software-Driven Detection and Response

Despotopoulou, Angela-Maria, Christidis, Konstantinos and Magoutas, Babis

*Frontier Innovations*

## Abstract

Aiming at addressing the uncertainty and socio-economic dimensions inherent in wildfire management, and to minimize the impact of wildfires through timely and informed decision-making, our research introduces an architectural framework for a software platform for Detection of Emerging Fire-related Situations and Response Process Management. The platform digests real-time and heterogeneous data from a variety of sources (i.e. meteorological stations, environmental sensors, satellite-based fire detection services and AI-processed UAV photographs), to continuously assess and predict critical situations. Current conditions are repeatedly monitored and juxtaposed to fire propagation simulation scenarios and event patterns pre-defined with the active involvement of domain experts. Depending on those contextual cues, analytics algorithms leveraging similarity metrics trigger fire response workflows. Those have been accordingly elicited from the main crisis management actors such as local authorities, firefighters, wildlife administrators and environmental engineers fostering stakeholder engagement and collaborative wildfire response efforts. The analysis results as well as additional information, such as animals or vehicles in danger as detected by visual recognition algorithms on UAVs, are then redirected to a variety of user interfaces, such as map-equipped dashboards, mobile applications, AR-enabled helmets, or simple text messaging systems. In the context of the TREEADS project, funded by European Commission’s Horizon 2020 Programme, validation of our approach will take place in autumn 2024 at two pilot sites, the Samaria Gorge in Crete, Greece and the Sorrento Peninsula in Campania, Italy.

**Keywords:** software architecture, event-driven architectures, decision support system, response process management, wildfire management system, real-time risk assessment, real-time analytics, data stream processing, context-aware wildfire detection

**Acknowledgments:** This research has been carried out in the scope of the TREEADS project (contract number 766994), which has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No. 101036926. The authors acknowledge valuable help and contributions from all partners of the TREEADS project.

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# SenForFire: Smart wireless sensor networks for forest fire surveillance and early warning

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## Abstract

Nowadays there is a growing interest in the development of scalable, real-time techniques for the comprehensive management of forest fires using wireless sensor networks (WSNs). One example is the SenForfire project that is presented here. The project aims to demonstrate the suitability of WSNs for use in surveillance and early warning systems of forest fires. To this end, WSNs will be deployed and operated continuously for periods of up to two years in a variety of rural and forest locations in Spain, Portugal, and Andorra (pilot sites). This will involve the collaboration of professionals from fire prevention and extinction services, civil protection and emergencies, and volunteers from the local population. The ultimate goal is to provide municipalities with a sustainable, affordable tool that allows them to act quickly and effectively to avoid or minimize the impact of wildfires on the territories. In SenForFire, sensor nodes are being developed for fire prevention by monitoring the meteorological and soil parameters that determine the humidity of forest fuel and, therefore, the danger of fire ignition and spread. In addition, sensor nodes are being developed for fire detection that monitor infrared radiation, particulate matter, carbon monoxide, carbon dioxide, and other gases indicative of the occurrence of fire. When available, miniaturized low-cost, low-power sensors based on microelectromechanical systems (MEMS) and nanotechnology are the preferred choice; these are commercial OEM sensors and research prototypes developed within the project. The WSNs will be tailored (type, number, and spatial distribution of sensor nodes) to take into account the purpose (fire prevention or early detection); as well as the climatology, orography, vegetation, historical data of forest fires, and availability and performance of wireless infrastructures in the pilot sites. Additionally, routing protocols for communication and data transmission between nodes and with the gateway will be optimized to achieve maximum energy efficiency and network robustness while minimizing delay times and network complexity. The time series of the parameters recorded during the field campaigns will be used to prepare local maps of the fire weather index (FWI) and the air quality index (AQI) several days in advance and will be compared with the values of these indices obtained from satellite images and data collected by meteorological and/or air quality networks.

**Keywords:** Fire prevention, fire early detection, wireless sensor network, MEMS sensor, fire weather index, air quality index

**Acknowledgments:** The SenForFire project receives funds from the ERDF through the European Union\'s Interreg VI-B Sudoe program (Grant Agreement S1/1.1/E0040)

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# Fire-spotting modelling in operational cellular automata simulators

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## Abstract

Fire-spotting is a crucial mechanism in the spread of wildfires. It is a random phenomenon that occurs when airborne embers are transported over large distances. This phenomenon poses significant challenges for modelling due to its non-linear, multi-scale nature. Fire-spotting accelerates the rate of spread and initiates new ignitions, presenting a formidable challenge to firefighting efforts. Often, operational fire-spread simulators overlook spotting events, leading to underestimation of their consequences. In this study, three distinct fire-spotting parameterisations are incorporated as sub-models into the operational wildfire simulator PROPAGATOR (Trucchia et al., 2020), which employs a Cellular Automata (CA) scheme. RandomFront (Trucchia et al., 2019), a novel parameterisation grounded in physical principles, is introduced and evaluated within CA simulators for the first time (López-De-Castro et al., 2024). RandomFront is compared with two existing parameterisations adopted in CA-based simulators, those developed by Alexandridis et al. and by Perryman et al. The three proposed parametrisations are characterised by increasing complexity, with RandomFront encompassing the most physical processes. To test the sub-models with a real case scenario, a wildfire occurred in the municipality of Campomarino (Molise, Italy) in the summer of 2021 where spotting effects were clearly reported, is used as a case study. This case study featured explicit airborne transport of firebrands, which ignited a pine forest flying over a water body. The presented research paved the way for a framework for comparing parameterised spotting models used in operational scenarios. RandomFront produced a more complex burning probability pattern than the other parameterisations, with a wider fan of possible ember landing spots. Despite its more dispersed probability pattern, RandomFront predicted a higher probability of burning in the area primarily affected by fire-spotting during the real wildfire scenario, outperforming the other sub-models.

**Keywords:** Cellular Automata, Fire Spotting, Fire Spread Simulation

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# Evaluation of post-fire vegetation cover prediction using feed-forward neural networks

Pinto, Rayo, Fernández Guisuraga, José Manuel, Beltrán Marcos, David, Frades Morán, Rebeca, Marcos, Elena and Calvo, Leonor

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## Abstract

The post-fire resilience of vegetation is critical from both ecological and management perspectives. Predicting post-fire vegetation cover is therefore essential for helping land managers in decision-making processes. Post-fire recovery depends on various factors, including the fire regime attributes, climate, topography and also biological factors. In our study, we aimed to assess the effectiveness of feed-forward neural network models in predicting vegetation cover one year after wildfire in fire prone ecosystems. To achieve this goal, we have employed eight large and severe wildfires occurred along the Atlantic-Mediterranean climatic gradient in Iberian Peninsula. Our dataset consisted of 93,325 points, from which we extracted information on variables related to the fire regime, climate, topography, and pre-fire vegetation within the affected areas. Fire regime attributes included the fire severity of the target wildfires, recurrence, time since last fire, and the fire severity of the previous wildfire. Climatic variables encompassed the bioclimatic region, standardized precipitation evapotranspiration index, topographic wetness index, and insolation. Topographic variables consisted of altitude, orientation, slope, and erosion. Finally, biotic variables related to the pre-fire vegetation characteristics, such as cover fraction and ecosystem type. Following one-hot encoding of categorical variables, a total of 27 dependent variables were used in the models to predict the fraction of vegetation cover one year after wildfire.
Our baseline linear model exhibited an adjusted R-squared (R2) of 0.586 on the test data. Non-parametric regression tree and K-nearest neighbors (KNN) models displayed a significant improvement in prediction performance over the linear model, with 0.662 and 0.668, respectively, on the test data. Finally, the application of feed-forward neural networks demonstrated a substantial improvement in model fit, achieving R2 values of 0.721. This study demonstrates the usefulness of using neural networks to search for complex patterns that allow us to make predictions about post-fire ecosystem recovery.

**Keywords:** Feed-forward neural networks, post-fire recovery, Fraction of vegetation cover

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# Surveying some key properties to identify potential hotspots in the 2022 Guájares forest fire (Granada, Spain)

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## Abstract

A devastating forest fire tore through 5,000 hectares of land in Los Guájares, Granada, in 2022, leaving a scorched path 150 kilometers long. The cause of this inferno remains unknown. This research project aims to lay the foundation for creating the first map of soil properties in the affected area. The map will focus on water movement and geomorphological processes in both recently burned zones and nearby areas with different land uses. This initial project serves as a stepping stone for a more extensive investigation.
The research team is taking a multi-faceted and interconnected approach to address a pressing global concern: the complex relationship between soil health, water availability, and plant life within the context of agricultural production and natural hazards. To achieve this, we have established 30 sampling points – 15 within the severely burned area and 15 in a healthy mango plantation. These points will be used to evaluate the soil's resistance to water infiltration (using the drop test), the rate at which water flows through saturated soil, and the soil's capacity to retain water (HYPROP 2, KSAT and WP4C), soil aggregate stability and some key properties.

**Keywords:** Forest fire, soil properties, soil hydrological characteristics, geomorphology

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# Session 4: Measure Dynamic Processes and Impact of Wildfires

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The forest is a source of income and livelihood: wood, employment, grazing, gain for farmers in agricultural area (clearing). For forest managers, the Status of forest is decisive for the choice and direction of watershed development. A well-preserved forest allows for gains and benefits in terms of resources (soil, water) in terms of downstream development and investments. Similarly, grasslands and forests have the potential to sequester carbon in soils and there is a great need for cultural practices capable of restoring and increasing soil carbon storage and productivity in case of forest fire. Monitoring land degradation by fire and its impact on natural resources requires strengthening consultation and coordination between different stakeholders. Strengthening observation networks through the harmonization of data collection and methods and the development of sets of ecological and socio-economic impact indicators Strengthening methods of characterization, diagnosis and monitoring of forest degradation is necessary for decision support plan for better forest / forest fire governance.

Session topics
• Diagnostic tools and methods for monitoring land degradation by fire
• The Impact of forest fire on ecosystems and carbon dynamics.
• Decision support plan for better forest / forest fire governance
• Preventive measures against the risk of forest fire

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# Wave severity driving extreme fire behavior in tropical forests

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## Abstract

Tropical forests are considered low-flammable and ecologically fire-sensitive ecosystems. However, forest fires are increasingly frequent and destructive in rainforests, driven by climate change. To understand the dynamics of fire in this new scenario, we analyzed a protected area, located on the edge of the Amazon biome, which has seen a large increase in forest fires in recent decades. The Xingu Indigenous Land covers approximately 26,420 km2 and 16 ethnic groups live there. It was well preserved until the end of the 20th century, when it began to be hit by a sequence of large forest fires in the years 1999, 2007, 2010, 2016, 2017, 2019, 2020 and 2022. During the 2020 wildfires suppression operations, the high severity and extreme fire behavior caught the attention of Brazilian experts, who began to investigate the phenomenon through satellite images, forest fuel maps, assessment overflights, field visits and reports of suppression operations. It was observed that the first fires in the forest show large differences in intensity throughout the day, due to variations in meteorological conditions such as temperature, relative humidity and wind. This results in the formation of forest severity waves, perfectly visible in satellite images, mainly, in forest fuel maps. The most severe waves kill large trees, which subsequently fall to the ground, making room for light to enter and stimulating the growth of secondary vegetation, resulting in an increase in the quantity and continuity of fuel. This results in increasing intensity and speed of subsequent fires, expanding wave width, further increasing severity and available fuel. From the third consecutive fire onwards, the accumulation of fuel, associated with critical meteorological conditions, resulted in indicators of extreme fire behavior, such as the formation of pyrocumulonimbus clouds, emission of charred leaves at distances of up to 45 km, emission of burning material at distances of hundreds of meters and total destruction of the forest as it existed before. This phenomenon observed in the Xingu has been recorded in other parts of the Amazon and may be indicative of the future of the tropical forests, with terrible negative consequences for the control of the forest fires, the survival of indigenous communities and the nature’s services they provide.

**Keywords:** Tropical forests, Amazon rainforest, Wildfires

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# The role of fire as a driver of tropospheric ozone concentration exceedances in Portugal

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## Abstract

High tropospheric ozone ($O_3$) production occurs in conditions of strong sunlight and high temperature, as the acceleration of $O_3$ formation is associated with high temperatures and photolysis. However, the combination of sunlight with non-methane hydrocarbons (NMHCs) and $NO_x$ (NO + $NO_2$) from biomass burning results in significant photochemical production of $O_3$. Portugal has often recorded high levels of atmospheric pollutants, experiencing multiple instances of pollution episodes where $O_3$ level have consistently exceeded legal limits over the past decade. Furthermore, the fire season in Portugal occurs during the summer when solar radiation and temperatures are higher, leading to the emission of $O_3$ precursors that contribute to $O_3$ production. Above background concentrations, tropospheric $O_3$ exerts negative effects on human health and vegetation. The main objective of this research is to identify the principal drivers of tropospheric $O_3$ concentration, between 2004 and 2022, over Portugal's mainland. In the present analysis, several predictors were used, such as Surface Solar Radiation Downwards (SSRD), Fire Radiative Power (FRP), Temperature, Nitrogen Dioxide ($NO_2$), and Time of the Year (TOY). The FRP data used has been delivered in near real-time, since 2004, by the EUMETSAT Land Surface Analysis Satellite Applications Facility (LSA-SAF). The SSRD, ozone concentration and the remaining variables were collected from the Copernicus Atmosphere Monitoring Service (CAMS) reanalysis. A stepwise regression was applied to evaluate the influence of each predictor on $O_3$ concentration and two models to estimate mean and maximum ozone tropospheric concentration were proposed. A relationship between temperature, FRP, and tropospheric $O_3$ concentration was identified, and the proposed models revealed to be a useful tool for estimating tropospheric $O_3$ concentration during the recent extreme fire events in the affected regions where in-situ observations are sparse. The impact assessment of $O_3$ exceedances associated to such extreme events on human health and vegetation dynamics is extremely important mainly in the context of climate change and associated foreseen increase of fire activity and

severity.

**Keywords:** Ozone, Fire, Temperature, Portugal

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# Recurrence of large forest fires, and land use: cause and consequence

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## Abstract

Some forest areas have a tendency to recurrently develop large forest fires (LFF). The coincidence of these events in a few years requires a double line of research. First, if the pre-existing vegetation can be the cause of this recurrence. Secondly, if the repetition of large fires can produce such an impact on forest vegetation as to cause its permanent alteration.
The 14 areas of the province of Huelva that were affected by more than one large fire (considering as such those of 100 or more hectares) between 1988-2020 were selected, and the evolution of forest vegetation in them was checked by analyzing five land use maps: 1984, 1999, 2003, 2007 and 2013. The conclusions are that, indeed, the recurrence of LFF is related to the presence of certain productive tree kinds of forest plantations (eucalyptus and, to a lesser extent, pine forests). However, and this is the second conclusion, that recurrence did not cause profound modifications in the forest vegetation, in part precisely because, being mostly productive stands, this land use tends to be maintained after the fire. Also, the analyzed cases showed an advance of dense shrub formations (cistaceae and, to a lesser extent, ericaceae), but quickly replaced by the replanting of commercial trees.
From a conceptual point of view, the existence of these areas frequently affected by wildfires (up to four in the 33 years considered) could open a reflection on the existence of return periods for large fires. However, it is somewhat forced to speak of a return period in a risk which, despite developing in semi-natural areas, has a markedly human origin (natural fires account for a minimal percentage: about 2% in Andalusia, and 4% in Spain).

**Keywords:** Large forest fires, fire recurrence, land use, reforestation, Province of Huelva.

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# Numerical solution of conjugate problem of forest fire spread

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## Abstract

The results of a theoretical study of crown fire initiation and spread based on a numerical solution of the full system of Reynolds equations are given. It is assumed that the forest during a fire can be modelled as a two-temperature multiphase non-deformable porous reactive medium. Analysis of the characteristics of crown forest fires spread reveals their dependence on the specific conditions under which the experiments were conducted. It is impossible to control the meteorological situation and the homogeneity of the forest fuel layer. For this reason the physical modelling of forest fires must be combined with mathematical experiments. Mathematical modelling contains the following relatively independent stages: physical analysis of the phenomenon of forest fire; determination of the reaction and thermophysical properties of the medium and its structural parameters; deduction of the basic system of equations with boundary and initial conditions; selection of a method of numerical solution, programming; test check of program; evaluation of the accuracy of the difference scheme; numerical solution of the system of differential equations; testing to see how well the derived results comply with the real system; their physical interpretation; development of new technical suggestions for ways of fighting forest fires. Using the forest fire models, turbulent heat and mass transfer in the forest, as well as heat and mass exchange between the near-ground layer of atmosphere and the forest canopy are incorporated in a so-called conjugate formulation. The latter manages to take into consideration the mutual effects of the forest canopy and the turbulent atmosphere most accurately. This approach made it possible to solve a problem of forest fire spread that takes into account different scales of physical and chemical processes in the combustion region and the atmospheric boundary layer.

**Keywords:** forest fire, mathematical model, reactive media, turbulence, numerical method

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# Variations in fire behaviour dynamics in Betula sp. forest stands with various taxation indices

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## Abstract

The key elements shaping fire behaviour and distribution are climate, topography and surface fuels, regulating the probability of ignition, fire spread rate, fuel consumption and the effect on the ecosystem during and after the fire event. Global climate change directly affects the fire regime and dynamics; forest ecosystems become more susceptible to fire with increased prolonged periods of drought and higher mean temperature values. Climate also indirectly affects the available fuels not only through reduction of fuel moisture, but also through changes in ground vegetation species composition and vitality. The distribution of fine fuels is directly linked with the specific forest stand and its heterogeneity. Compared to Betula sp. forest stands, conifers produce more flammable, fast-drying fuels, whereas in Betula stands the vegetation varies between Vaccinium-rich and herb-rich communities. While the types of fuel are mostly determined by the specific forest stand, the amount of available fuels is determined by the local meteorological regime.
It is expected that fire return intervals will diminish in hemiboreal forest zone, where Latvia is located. With increasing length of vegetation period, the fire season is expected to set in earlier in spring and expand into the autumn months, increasing the risk of fire event. The increasing distribution of Betula sp. forest stands create variations on the landscape level, therefore impacting the fire dynamics. It creates a necessity to study fire dynamics and behaviour in forest stands with Betula sp. as a dominant species.
An ongoing study about fire behaviour in mixed and pure Betula sp. stands compared to coniferous forest stands is being carried out. The aim of this study is to assess the impact of parameters of forest stand on the types, distribution and availability of surface fuels, which in turn defines the dynamics of fire temperature and fire spread rate.

**Keywords:** fire behaviour, fire weather, surface fuels, birch, mixed stands

# Session 5: The Interaction of Fire with Nature and Humans. Environmental Planning and Fire in the 21st Century

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Artemi Cerdà

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Manuel Pulido

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Forest fires are part of nature, and our society must learn how to live and adapt to the presence of fire in Planet Earth and human societies. The use of fire as a tool, environmental planning using the use of fire, and fire management are key topics for the planning of the human use of the land in the next decades. This session welcomes pure and applied scientific research to discuss the best strategies to manage fire and avoid the impact on soil and watersheds because of fire. Experimental and theoretical research with site demonstration and literature review are welcome. Field and laboratory studies, modelling, and urban and rural planning studies from different regions are of interest to the audience. Studies to show fire as a Nature-Based Solution are milestones for the research shown at the fEs2024 conference.

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# Forest fires in Iran

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## Abstract

Iran's geographical diversity, spanning from arid desert expanses in the south and center to lush forested areas in the north and northwest, presents a unique opportunity to explore the dynamics and impacts of forest fires. To comprehensively investigate the subject, we conducted a systematic review of literature indexed in Scopus, utilizing key search terms such as "Fire," "Forest," and "Iran." Our search yielded 126 relevant papers published between 2006 and 2024, indicating a notable increase in scholarly attention towards this topic over the past two decades. Six papers were published in 2000s, 66 papers in 2010s, and 54 articles after 2021. The temporal distribution of these publications shows a steady increase in the number of articles as new year’s approach. Geographically, the majority of the research endeavors have been concentrated in the northern and northwestern regions of Iran, reflecting the significance of these areas in terms of forest fire dynamics. The thematic focus of the reviewed literature predominantly revolves around the prediction and modeling of fire risk, as well as the interplay between fire incidents and various ecological, climatic, and socio-economic factors. Specifically, a substantial portion of the studies (73 out of 126) delved into the assessment and mitigation of fire risks, underscoring the urgency and importance of proactive measures in fire management. However, the attention given to socio-economic dimensions remains disproportionately low, with only a scant number of publications (5 out of 126) addressing this aspect. This disparity underscores the need for greater research emphasis on understanding the socio-economic implications of forest fires and devising strategies for post-fire restoration and rehabilitation. In light of these findings, we advocate for a more holistic approach to forest fire research in Iran, one that encompasses not only ecological and climatic considerations but also socio-economic dimensions. We conclude that forest fire is an emerging issue and need to be researched in Iran to face the climate change and the land use change in a diverse country. The Hyrcanian forest, situated in the northern region of Iran, serves as an ideal focal point for studying forest fire phenomena due to its ecological significance and susceptibility to fire incidents.

**Keywords:** Forest fire, Iran, Fire risk, Socio-economic, Ecological impact

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# Forest structure and fire severity in the pine forest of La Palma, Spain

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## Abstract

Forest fires are an integral part of the disturbance regime of the pine forest on the island of La Palma, a forest characterised by the dominance of Pinus canariensis. Although low severity, ground fires, can have beneficial effects on forest health, high severity, crown fires, can be detrimental to the ecosystem. Vertical (e.g. properties of the understory layer) and horizontal (e.g. forest canopy) components of forest structure and fuel properties (e.g. ladder fuels) play an important role in fire potential, and their influence on fire severity requires more attention. Here, we aim to investigate the relationship between forest structural components and the likelihood of high severity fires in general, and whether the understory layer could serve as a fuel ladder that could lead to crown fires in particular. In addition, we aim to disentangle the interactions between vertical fuel continuity and canopy connectivity with respect to severe fire events. To do so, we conducted a field campaign on La Palma and collected field data on forest structure in burned and unburned patches of the pine forest. In addition, we launched a drone flight mission and collected drone data using LiDAR, RGB and Multispectral sensors. We then assigned each sampled location to a fire severity class based on both field observations and the analysis of the difference in (δ)NDVI and (δ)NBR – two spectral indices that are commonly used to characterise vegetation change and burn severity respectively. Subsequently, we analysed both field and drone data, to reveal associations between forest structure metrics and fire severity, and fit a model to assess which metrics are the most important predictors for fire severity. We expect that the precense of fuel ladders and canopy connectivity would increase the likelihood of high severity fires, and that topography also plays a role in this process. Our results highlight the critical role that vertical and horizontal fuel continuity plays in severe fire events, potential ways for forest management to reduce such a risk, and how an integrated approach of data collection methods can help to better understand the complex interactions between forest structure and fire severity.

**Keywords:** fire severity, forest structure, disturbance, ladder fuels

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# Educating for wildfires: Where we are, where we need to get to

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## Abstract

Climate change and its effects on Earth's natural cycles are among the most pressing concerns of our time. Recent projections suggest that wildfires will occur more often and with higher intensity. For this reason, it is crucial to educate and prepare the population to be ready to deal with these events. This work reviews educational materials on wildfires available online worldwide to identify the main topics covered and what is still missing. A total of 225 references from 37 countries were analysed. Most of them are from regions with a Mediterranean climate with fire-prone ecosystems. Their target audience was mostly the general public (about 48%), followed by students from various age groups (around 40%). Written documents, websites, and videos are the most frequent materials made for the general public. As for students, pedagogical resources are available in a greater variety, ranging from mobile phone applications to slides for classes and reading materials. The remaining references focus on the rural population and firefighters' training. Most materials present the main concepts and ecological aspects of fire, along with safety and prevention measures. However, few discuss climate change, recovery, and socioeconomic or health concerns. This gap should be addressed in future wildfire educational materials to better prepare and inform society. Within this context, the Centre for Applied Ecology, Prof. Baeta Neves from the University of Lisbon, is currently involved in two projects that address the issue of wildfire education: The EduFire Toolkit and The Fire Education Platform. The EduFire Toolkit is an Eramus+ project that is creating multidisciplinary educational resources that focus on the socioeconomic and environmental complexities around wildfires. It follows a Project-based Learning approach and targets secondary school teachers and students (ages 12-16). The Fire Education Platform is an online tool being developed within the scope of the Fire-Res European project. The Platform addresses "fire culture" in a multifaced way, and it is targeted at three main audiences: the general public, educators, and practitioners. Its goal is to help society understand wildfires and the various cultural uses of fire, establishing a common culture of risk that people are aware of, can accept, and can be better informed and prepared to protect their communities and themselves. Hopefully, both of these research and educational efforts will fill knowledge gaps identified in the literature review and help the current and future generations be better prepared to deal with a changing climate and wildfire regimes.

**Keywords:** Wildfire education, Climate change, Preparedness, Fire culture.

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# Long-term management actions of fire-prone Mediterranean ecosystems under climate change using fuel reduction and post-fire restoration

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## Abstract

Forest fires and severe droughts are anticipated to persist as primary disruptions in Mediterranean ecosystems, given the continuous and projected climatic shifts. Indeed, an exacerbation of certain elements of their regime is foreseen. In this context, it is imperative to formulate adaptive management strategies aimed at mitigating the impact of disturbances and enhancing ecosystem resilience. To achieve this goal, the development of an integrated management approach is essential, capable of identifying the optimal combination of restoration measures for various scenarios.
This study focuses on evaluating the efficacy of a multifaceted approach involving fuel reduction and post-fire restoration over the long term to augment the prevalence of resprouting species and alleviate the incidence of fires under different future climate change scenarios. Fuel reduction treatments encompass the implementation of shrub clearing at varying intensities and frequencies, while restoration actions involve the introduction of resprouting species through plantation, with the objective of bolstering ecosystem resilience.
Employing a straightforward ecological model tailored specifically for Mediterranean ecosystems, which incorporates species competition and post-fire responses, we calibrated the model based on observed vegetation reactions to the applied treatments. Our findings underscore that the pursuit of more resilient ecosystems in the coming decades necessitates an intensification of fuel reduction treatments. Importantly, planting resprouting species has a significant impact on the ecosystem. However, the success of these interventions will vary depending on the specific climate scenario.

**Keywords:** post-fire response, long-term management, climate change, forest resilience, modelling

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# Mapping target areas for introducing agroforestry systems as a management approach for wildfire risk mitigation in Europe

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## Abstract

Agroforestry systems have emerged as a promising management tool for mitigating wildfire risk and safeguarding ecosystems in Europe (Damianidis et al., 2020). This analysis aims to identify specific target areas where the implementation of agroforestry (AF) can provide environmental benefits, enhance climate resilience, and effectively reduce wildfire risk in Europe.
The methodological framework applied is based on an adaptation of the one used by Kay et al. (2019) for agroforestry systems. The selection of these target areas is based on a spatial approach which consists of four steps: (1) selection of suitable potential areas from the total agricultural area in Europe, excluding nature conservation sites and AF areas identified in the land use/land cover cartography, (2) analysis of environmental risks in the potential areas, (3) definition of target areas, and, finally, (4) analysis of the socio-economic context.
A total of 14 environmental indicators were used to determine risks related to soils, biodiversity, water, and climate change in potential areas. To evaluate the effects of those risks, threshold values were defined for each indicator, identifying the limits above or below which sustainability is compromised in potential areas. After combining these indicators, heat maps were produced to highlight the intensity of a total of 14 environmental risks. Areas showing 7 or more accumulated pressures were defined as target areas to introduce AF, which amounted a total of 506,249 km2.
Regarding the analysis of the socio-economic context in the target areas, a total of relevant 6 social and economic variables, related to economy (economic size and unemployment rate), training and willingness of farmers to change (training of farm managers, number of organic farming holdings) and demography (ratio of young farm managers to elderly farm managers, degree of urbanisation), were selected to characterize these aspects in the NUTS 2 regions. Each indicator was analysed individually to identify regions with different socio-economic backgrounds.
While the analysis of environmental pressures allowed to identify agricultural areas that reported higher concentration of pressures, the characterization of the socio-economic context showed that the social and economic factors varied across the European regions where those target areas were located. The relation between regions reporting higher environmental pressures and the different socio-economic factors that characterize them is key to identify opportunities for establishing AF.

**Keywords:** Agroforestry systems, Europe, Environmental pressures

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# Spatial characterization of forest fire in Extremadura (SW, Spain): main patterns and causal relationship

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## Abstract

In recent decades, the dynamics of forest fires have sparked spatial interest regarding their impact on various aspects such as the environment and the economy. However, regions like Extremadura, which host one of Spain's largest forested areas (approximately 4.2 million hectares), have received limited attention regarding the spatial analysis of forest fires. Therefore, the aim of this study is to identify spatial patterns and determining factors of forest fires in Extremadura (southwest Spain). To achieve this, spatial analysis based on clustering, outliers (Anselin Local Moran’s I), and hotspots (Getis-Ord Gi), as well as principal component analysis (PCA), have been employed using data obtained from the General Statistics of Forest Fires from the Ministry for the Ecological Transition and the Demographic Challenge. The results reveal three main patterns associated with the distribution of the number of fires: urban areas, mountainous zones, and border regions. Likewise, it has been observed that the burned area follows three high-density patterns: large fires, accumulation of area due to high fire frequency, and a combination of both. Additionally, fire regimes and areas with homogeneous regimes have been identified. PCA demonstrated relationships between the number of fires and urban influence, burned area, and areas with pyrophytic scrubland. Moreover, a direct relationship was found between fire occurrence and factors such as terrain slope, length of roads and paths, urban-forest interface, forest-cropping interface, pastureland, olive groves, and certain fuel models. This spatial analysis has allowed the outlining of potential scenarios of Large Forest Fires, providing a solid foundation for the implementation of preventive actions.

**Keywords:** wildfires, dynamics, forested regions, spatial analysis, density patterns

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# Good fires, bad fires in the Western Catalan Pyrenees. Is the tool becoming a threat?

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## Abstract

The probability of having a big fire in an area like the Pyrenees is low, but this probability increases year after year. What has happened so that fire in the Pyrenees, considered for centuries as a management tool, has become a threat? It is true that temperatures are rising, the precipitation regime is changing, water availability for plants is decreasing and the frequency of drought is increasing. However, one of the main answers to the question lies in land use and land cover change (LULCC). The main objective of this research is to provide evidence of LULUC in the Western Catalan Pyrenees. It is intended to generate knowledge and contribute to the reflection on the need and/or feasibility of the recovery of traditional practices for the mitigation of the impacts of forest fires. The spatial analysis from LULC mapping (1993, 2009 and 2018) and fire statistics (1995-2023), provides information on landscape dynamics and fire behavior that allow us to argue that the Pyrenees is becoming increasingly vulnerable to fires. Rural depopulation and the loss of knowledge of the forest management culture that shaped the Pyrenean landscapes, transmitted over generations, has led to a process of scrub and afforestation in areas previously occupied by agricultural and livestock activities. This is leading to a more homogeneous landscape that is more vulnerable to fires. At the same time, traditional practices such as controlled burns and prescribed fires are seen by society as a threat. Although the number of fires and the area burned has been decreasing over the last 30 years in Western Catalan Pyrenees for which data are available, there are clear signs of vulnerability. The accumulation of fuel offers the optimal conditions to have a fire threat in an area where fire has traditionally been a management tool and where the risk was not even contemplated. The changes detected are accompanied by an increasing distance from the culture of risk. But, is it possible to recover the ancestral knowledge of the use of fire and those techniques that were developed and adapted to specific conditions, for the management of landscapes that have disappeared or have been transformed? This is a complex question that requires complex answers and is at the basis of good fires vs. bad fires.

**Keywords:** Land use land cover change, recent historic fires, vulnerability, prescribed fires, risk culture, GIS

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# Forest fires in Portugal caused by negligent causes: assessing the contribution of pile burning and extensive burning practices

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## Abstract

The burning of agricultural and forestry residues, either in piles or extensively, is an important source of atmospheric pollutants with a strong impact on air quality in various regions of the world. In addition to the direct impacts caused, these practices can sometimes get out of control and result in large fires with serious ecological and socioeconomic consequences. The aim of this study is to characterise the pile burning and extensive burning practices in Portugal and to assess the contribution of these activities to the wildfires that occur in the country. For this, we analyse data from the national database of pile burning and extensive burning authorised requests, from the Portuguese Institute for Nature Conservation and Forests (ICNF), the wildfires database, also from the ICNF, and daily meteorological data from the E-OBS gridded dataset (Cornes et al., 2018), from 2019 to 2023. By employing data analysis techniques, we investigate pile burning and extensive burning practices in Portugal, and their contribution to wildfires, depending on: (i) temporal variables (month, day of the week); (ii) spatial variables (district, municipality); (iii) meteorological variables (temperature, wind speed, relative humidity, and precipitation); and (iv) characteristics of the wildfires (duration, burned area, etc.). Preliminary findings indicate that pile burning and extensive burning occur throughout the country, with Saturdays generally being the preferred day for these activities. However, their role as igniters of large fires has a large spatial variability. In certain districts from the North and Centre regions (e.g., Viana do Castelo, Vila Real, and Viseu), rural fires due to pile burning and extensive burning practices can represent more than half of their total annual burned area. This study provides valuable insights into the pile burning and extensive burning practices and highlights their relative importance within the broader context of fires in Portugal. Understanding these dynamics is essential for informing wildfire management strategies and mitigating their impact on ecosystems and communities.

**Keywords:** wildfires, pile burning, extensive burning, Portugal

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# Changes in forest distribution in the La Safor District since 1956

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## Abstract

Ancient aerial photographs serve as a significant source of information, revealing the past landscape in La Safor. Comparing these historical territories with the present ones highlights significant changes that directly impact current forest fires.
By comparing the oldest aerial photograph of Spain, the 1956 General Flight of Spain or American Flight, with a current aerial photograph, photointerpretation can detect that in the 1956 territory, major forest masses were restricted to areas farther from human settlements, with most forested areas lacking mature forests. In contrast, today we observe a greater proportion of forested land.
The millennia-long human settlement pressure on natural resources explains this phenomenon. Traditional trades involved continuous forest management and fire prevention efforts, yet they also exploited mountains, leaving them devoid of biomass susceptible to fueling forest fires.
Following the industrial revolution, economic development, lifestyle changes, and the abandonment of traditional mountain-related trades have led to natural vegetation growth, with fire being its only limitation.
Today, we have more biomass in our forests susceptible to fueling forest fires. Striking a balance in mountain management between the past and present could be key to reducing both the frequency and severity of fire episodes.

**Keywords:** Fire, Forest, La Safor, Mediterranean, Remote Sensing, Aerial Photographs

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# Grazing as a tool to prevent forest fires in Eastern Iberian Peninsula. The “Ramat de Foc de Gandia” study case.

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## Abstract

The mountains are natural spaces where historically humans have developed their economic, vital and social activity. Both the rural habitat, the traditional activities linked to nature, and the relationships between the different settlements and their inhabitants were developed in the mountains. The rural exodus, the growth of cities and the advantages of the urban way of life have resulted in the majority of humans currently living in cities, and with it, a manifest human disconnection from forest spaces.
This is why there is talk of the abandonment of the mountains, not only due to the loss of traditional trades linked to the mountains, but also because of ceasing to inhabit them and live in them, turning these spaces into a simple place of leisure and recreation. .
This abandonment has meant that we have forests that are more vulnerable to forest fires, both due to their greater biomass and their lesser monitoring and management. Furthermore, climate change makes many regions even more vulnerable to natural risks. That is why recovering grazing activity can be a nature-based solution that, in addition to helping prevent forest fires and managing forest spaces, can help diversify the economy, boost the primary sector and its products, and maintain This ancient craft is practically extinct in many regions.
The pilot project “ramat de foc de Gandia” was born from the Llutxent forest fire, resulting in the need to adopt measures for greater prevention and management of the forests, among which this project would arise. Through a herd of almost a hundred goats of different species, the Parpalló-Borrell natural area of Gandia is being maintained, in addition to spreading the importance of grazing and its products in the region.
Studying the evolution of the forest fire prevention project, and analyzing its transferability to other regions, can be essential to have more sustainable techniques based on nature.

**Keywords:** Fire, Grazing, Management, Prevention, Mediterranean

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# Session 6: Climate and Wildfires

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Exploring how wildfires are influenced by both current climate patterns and anticipated shifts in climate is crucial for improving fire management practices and shaping effective prevention strategies. While significant progress has been made in comprehending the impact of climate on wildfire behavior, it remains a challenging area of study due to the intricate interplay of factors like climate, vegetation (which serves as fuel), and fire itself, including the feedback loops they create. The goal of this session is to assemble experts who are examining this topic from various perspectives. The focus is on analyzing the factors that contribute to wildfires, utilizing a range of fire-related climate indicators, and assessing the potential changes in these dynamics due to climate change across diverse geographical and temporal contexts. We encourage contributions that enhance our understanding of the connection between climate and wildfires, especially studies that utilize or develop new methods in remote sensing, on-the-ground observations, and experiments.

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# Evaluating Fire Weather Index Approximations Using ERA5 Reanalysis: Global Trends and Implications for Fire Danger Assessment (1980-2020)

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## Abstract

This study evaluates the Fire Weather Index (FWI) using approximate values for temperature, humidity, precipitation, and wind. These variables, based on the ERA5 reanalysis data, aim to reconstruct fire weather evolution globally from 1980 to 2020. Originally developed in Canada, the FWI system has been effectively adapted worldwide for predicting wildfire danger using meteorological inputs.
We introduced four approximations for calculating FWI based on daily values, seeking to identify the method that least deviates from standard noon measurements. These approximations were benchmarked against the FWI standards provided by The Copernicus Programme and detailed in Vitolo et al. (2020).
Our analysis, both spatial and temporal, revealed significant trends in fire weather conditions, indicating an increase in FWI across most regions during the study period. These trends were statistically validated using the Mann-Kendall trend test and Theil-Sen slope estimates, which confirmed the robustness of our trend analysis despite the inherent uncertainties present in climate data reanalysis.
The findings offer a comprehensive comparison of FWI calculations using different meteorological approximations. This insight is crucial for making potential adjustments necessary for more accurate fire danger assessments in climate simulations, thus enhancing our understanding and management of wildfire risks under varying climatic conditions.

**Keywords:** Fire Weather Index (FWI), ERA5 reanalysis, Wildfire danger assessment, Climate simulations, Meteorological variables, Trend analysis

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# Increasing trends of burned area in Western Mediterranean Europe? A comparative trend analysis of different burned area products.

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## Abstract

This study analyses burned area (BA) trends in Western Mediterranean Europe using four different products of burned area: MCD64CMQ (2001-2021; Giglio et al., 2018), FireCCI51 (2001-2020; Lizundia-Loiola et al., 2020), GFED5 (1997-2020; Chen et al., 2023), and the recently published ONFIRE (1985-2015; Gincheva et al., 2024). The analysis is performed both over the full periods of each dataset and over the common period from 2001 to 2015.
We evaluate burned area trends in three specific periods: the annual fire season (January to December), the fire season (June to September), and the off-fire season (January to May and October to December). This analysis allows for a detailed understanding of the seasonal dynamics of fires, providing a comparative view between the different products in terms of how each record changes in burned areas.
Preliminary results reveal differences in the amount of BA recorded by each product, although consistently all indicate that BA has not increased in Western Mediterranean Europe in the last decades. This analysis also shows the usefulness of incorporating a variety of data sources for a more complete understanding of fire evolution.

**Keywords:** burned area, fires, trends, Mediterranean region

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# Towards understanding future fire risks: integrating climate, vegetation dynamics, and fuel management

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## Abstract

Climate warming and fuel accumulation threaten to increase fire risk in the future. These two factors govern, respectively, weather conditions, which lead to increased fire danger by decreasing fuel moisture content; and fuel arrangement, which favours connectivity and fuel loading, for example. The influence of weather and fuels on fire hazard, exposure and risk is widely recognized, being key components of most fire simulation and/or risk assessment frameworks. To date, efforts have been mainly devoted to predicting hazard conditions using meteorological indicators, without considering vegetation and fuels dynamics. However, climate-vegetation-fire interactions play a fundamental role in defining fire regimes. Climate evolution can alter the patterns and types of plant communities; in turn, it is the vegetation that “supports” fire, whose incidence is also conditioned by climatic variations.
In this work, we show a methodological framework that integrates simulation models to estimate the temporal dynamics of fire behaviour during the 21st century. The core of the process lies in the modelling of vegetation dynamics at stand level (*medfate*) as a function of different climatic and forest management scenarios to characterize the state and typology of fuels and the subsequent simulation of surface fire behaviour. We have applied this procedure to a set of 41 stands of *Pinus halepensis* communities, located in different enclaves of the eastern Spain. The network of plots was surveyed in 2017, to produce a forest inventory suitable for the simulation of forest dynamics. The plots were distributed in four sites (corresponding to historical fires occurred in the summer of 1994), representing different climatic conditions, but also considering site-specific parameters such as slope and aspect, or severity of burning.
Forest dynamics simulations were performed using the SSP climate scenarios (SSP 126, 245, 370 and 585), also used to characterize the fuel moisture content (dead and live) for fire behaviour modelling together with fuel parameters obtained from medfate. Forest dynamics were simulated considering 2 possible silvicultural itineraries (risk mitigation and forest adaptation to climate change) plus 2 other itineraries that served as baseline (unmanaged and business-as-usual). The first two combined fuel treatments in the understory (shrub removal) and canopy (thinning and selective cutting). Our results suggest increased fire danger (extremely low DFMC days) and behaviour (flame length) in all 4 climate configurations. The absence of management typically led to the most

hazardous conditions, whereas fire mitigation prescriptions tended to be more effective in controlling surface fire behaviour.

**Keywords:** fire behavior, climate change, fuel management, simulation, forest dynamics

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# The exceptionality of the fire over Alexandroupolis region in 2023

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## Abstract

Europe has been affected by unprecedented mega heatwaves, namely Western Europe in 2003, South-eastern Europe in 2007, Eastern Europe in 2010 and central Europe in 2018. Both summer heat and precipitation deficits contributed to the extreme summer drought. The fire season of 2023 was particularly devastating for Greece, with an estimated of around 175 000 ha of burned area, the second worsr year since 1980 following the all-time record of 2007. The season was remarkably severe in eastern sector of the West Thrace region in the northern continental Greece. A major fire started near the city of Alexandroupolis in 21st August and in 28th the main part of the Dadia forest and surrounding pine forests had burnt, recording more than 80 000 ha and stating by EU officials as the largest recorded fire in the EU.
The exceptionality of the fire in Alexandroupolis behavior is evaluated, considering the spring drought conditions, summer heatwaves and strong wind patterns observed over the region. To achieve these goals, we use ERA5 reanalyses to characterize drought conditions and heatwaves and active fires from SEVIRI, MODIS and VIIRS programs to characterize fire occurrence and severity. The role of synoptic conditions and weather extremes is evaluated and related with fire activity and behavior during the considered event.  Fire beahviour is also linked with strong wind patterns that affected the region during the summer season. Vegetation dynamics throughout the pre fire period is analysed over the affetcted region using the Enhanced Vegetation Index retrived from MODIS data. The study attempts to bring new light to the synergistic effect between fuel availability and weather conditions that created extraordinary conditions for fire propagation.

**Keywords:** Fire Activity, Compound climate extremes, active fires, weather, vegetation.

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# Forest related nature-based solutions for climate-change induced effects: wildfires risk and post-fire managment

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## Abstract

In line with the EU Mission for a Climate Resilient Europe, and analysis of Nature-Based Solutions (NBS) for their effectiveness to create more climate resilience and restore nature was done. In 2021-2023 the work focused on the upscaling potential of nature-based solutions, and particularly on their possible contribution to achieving overarching ecosystem restoration targets. The work focused first on collecting different type of NBS and their potential for large-scale upscaling. Secondly, insights on NBS assessment frameworks, scaling frameworks, and the socio-economic levers and barriers involved in NBS deployment were included in the analysis. The work comprised of NBS evaluation and assessment, including an interview-based review of selected cases that were drawn from the Climate-ADAPT database. From this study that mainly focussed on agricultural system it was concluded that wider application of nature-based solutions (NBS) in agricultural systems would deliver multiple societal benefits, and contribute to both climate resilience and nature restoration. However, there is limited experience of scaling solutions beyond local contexts. However, NBS for forestry are not as well-known, therefore, this current year (2024) the focus lies on understanding the role of NBS in increasing resilience to wildfires under the predicted climate change. Two types of effects of climate change that can be mitigated by NBS will be assessed: Wildfires risk and post-fire management. Wildfires are increasingly causing economic losses and costs and issues for the LULUCF contribution on climate change mitigation.
The way NBS are used in climate change induced disturbances wildfire are two-fold:
1. Wildfire risk management: Key to wildfire management is the reduction of fuel in the forest: fire management starts with understanding forest processes and forest management. Ways to do this comprise grazing, agroforestry and prescribed fires.
2. Post-fire management. Key to post-fire management is the reduction of connectivity; improving the infiltration of the soil and the reduction of overland flow.
An analysis of socio-economic aspects and enablers/barriers relevant to upscaling the suitability and potential of NBS in forestry will be evaluated, specifically for wildfire prevention and post-fire management. This work will give and overview of existing NBS for fire risk and post-fire management; and make an indepth suitability analysis on 6 Climate-Adapt cases.
, Laurène Lebelt, Daniel Zimmer, Margaretha Breil,

**Keywords:** Nature-based solutions, wildfire risk suppression, post-fire management

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# Examining Climate Drivers and Land Cover for Italian Burned Area Prediction

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## Abstract

The Mediterranean region is vulnerable to extended forest fires, with dramatic effects on human activities and ecosystems alike. Such events are usually driven by drought conditions and land cover characteristics prone to fire spread. Therefore, climate and vegetation should, at least in principle, carry enough information to predict the size of the area burned by forest fires.
We predict the regional and the provincial monthly burned area in Italy adopting a selection of suitable climatic variables and land cover aggregations as predictors in a random forest regression. Aside from assessing the sheer predictive power, we focus on highlighting the most important predictors and, furthermore, which predictors are prominent on specific spatial scales.
As a result, we build drivers' importance rankings both on regional scale, where climate variables suffice for a reliable prediction, and on provincial scale, where land cover information is necessary to the task. Indeed, even though quantities such as soil water and 2m temperature lead on, respectively, regional and provincial scales, the latter requires further knowledge about vegetation cover, which can promote or hinder extended fires.

**Keywords:** Burned area extension, climate drivers, land cover, random forest regression, Mediterranean fires

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# Trends in Forest Fire Incidences in the Iberian Mediterranean

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## Abstract

Climate change is altering the wildfire season in the Mediterranean basin, with increasingly frequent off-season fires beginning to confirm this trend. Specifically, in the Valencian Mediterranean coast, recent forest fires occurred in November, such as the fire in the municipality of Montitxelvo, and in March, with the fire in the municipality of Tàrbena, among other events. Furthermore, the risk of forest fires in the Valencian region remained high or very high for much of this period. Considering that the fire season in the region typically runs from June to September, we can observe a shift in the recurrence of forest fires.
In recent years, changes in precipitation trends have also been observed, with fewer and less intense episodes occurring, as evidenced by the minimum precipitation values in the Mediterranean basins of the Iberian Peninsula, directly affecting water availability in forested areas. This dryness, coupled with higher temperatures, including record high temperatures in winter months, results in a territory more vulnerable to forest fires.
Additionally, poor forest management, due to the abandonment of resource utilization and traditional trades, leads to a greater accumulation of biomass susceptible to fueling forest fires.
The combination of all these factors necessitates not only increased investments in forest fire prevention but also the adaptation of existing techniques to those more compatible with the new climatic and human reality. Analyzing the discussed alterations and implementing new forest fire prevention techniques should be the focus of future research.

**Keywords:** Fire, risk, Mediterranean, Evolution, Social, Economic, Biophysical

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# Session 7: From Science to Society: INFORMA\\\'s Journey in Integrating Stakeholder Voices for Forest Wildfire Resilience

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