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Applies to studies from the research program line

A) Project data

General information about the project	
Short title:	Austria Fire Futures
Full title:	Integrated Future Wildfire Hot Spot Mapping for Austria
Suggested citation:	Integrated Future Wildfire Hot Spot Mapping for Austria
Program including year:	ACRP 14th Call
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Coordinator / Project Submitter :	International Institute of Applied Systems Analysis (IIASA)
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Project and cooperation partner (incl. federal state):	Universität für Bodenkultur Wien (BOKU) Bundesforschungs- und Ausbildungszentrum für Wald, Naturgefahren und Landschaft (BfW)
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Total project costs:	€352,027.72
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Climate Fund No .:	C265157
Created on:	15/03/2026

B) Project overview

1 Summary

(max. 2 pages, language German)
Brief description of the project, summary of the main project results qualitatively and quantitatively (for scenarios, cost analyses, economic studies, potential studies, selected numerical values should be recorded – in % as well as the values themselves).

Austria Fire Futures (AFF) befasste sich mit der zunehmenden Relevanz von Waldbränden in Österreich und entwickelte vorausschauende Karten zu Waldbrandrisiko und Hotspots unter Klimawandel. Ziel war es, wissenschaftlich fundierte Ergebnisse in eine Form zu bringen, die Prävention, Einsatzvorbereitung und längerfristige Planung unterstützt. Dafür wurden Österreich-spezifische Datensätze zu Klima und Feuerwetter, Brennstoffen und Waldstruktur, sowie menschlichen Brandursachen zusammengeführt und im Wildfire Climate Impacts and Adaptation Model (FLAM) integriert. Ein zentraler methodischer Fortschritt war die Parametrisierung und Kalibrierung von FLAM für österreichische Bedingungen, wodurch konsistente nationale Auswertungen und eine hochaufgelöste Fallstudie möglich wurden. Ergänzend wurden tourismusbezogene Analysen, ein Feldstudien-Baustein sowie Stakeholder-Austausch und die Bereitstellung ausgewählter Ergebnisse über eine Plattform umgesetzt.

Auf nationaler Ebene wurde eine österreichweite Waldbrandrisiko-Kartierung mit 1-km-Auflösung für historische Bedingungen und mehrere zukünftige Klimaszenarien erstellt. Die Ergebnisse umfassen räumlich explizite Ebenen wie Entzündungswahrscheinlichkeit, Lösch-/Unterdrückungseffizienz und verbrannte Fläche. Historische Simulationen für 2001–2021 zeigen, dass zeitliche Muster der verbrannten Fläche auf monatlicher Skala nachvollzogen werden konnten (Korrelation r = 0,63). Die Szenarioprojektionen deuten in den meisten Fällen auf ein steigendes Waldbrandrisiko bis zum Ende des Jahrhunderts hin. Wiederkehrende Hotspot-Signale betreffen insbesondere Niederösterreich und Tirol; zusätzliche Zunahmen werden für Kärnten, Burgenland und Salzburg angezeigt. Abhängig von der Szenarienauswahl umfasst die berichtete Spanne u.a. eine Zunahme der mittleren jährlichen verbrannten Fläche von bis zu +52,8 % gegen Ende dieses Jahrhunderts (2081–2100) gegenüber der historischen Referenz (2001–2020). Insgesamt stützen die Ergebnisse die Einschätzung, Waldbrandrisiko in Österreich als wachsenden, räumlich differenzierten Klimarisikofaktor zu betrachten.

Über die nationale Betrachtung hinaus lieferte AFF eine hochaufgelöste Risikostudie für Niederösterreich mit 250-m-Auflösung. Diese Implementierung nutzte einen stochastischen Simulationsansatz (30 Realisierungen pro Jahr), um interannuelle Variabilität und Extremjahre als Verteilung abzubilden (statt als einzelne deterministische Zeitreihe). Für 2000–2020 lag die mittlere jährliche verbrannte Fläche bei 19,8 ± 7,4 ha (250 m Auflösung) bzw. 17,4 ± 6,2 ha (1 km

Auflösung, auf Niederösterreich zugeschnitten) gegenüber beobachteten 15,4 ± 18,1 ha. Der Vergleich zeigt, dass die 250-m-Ergebnisse lokalere und heterogenere Hotspot-Strukturen sichtbar machen als die geglätteten 1-km-Ergebnisse, was die regionale Interpretation und gezieltere Planung unterstützt.

Ein wesentlicher Beitrag des Projekts ist die verbesserte Abbildung menschlich verursachter Zündungen. Anstelle einer Annäherung über Bevölkerungsdichte allein wurde eine Entzündungswahrscheinlichkeits-Ebene aus 1.232 menschlich verursachten Brandentstehungspunkten und räumlich expliziten sozioökonomischen bzw. infrastrukturellen Prädiktoren abgeleitet. Zusätzlich wurde ein praxisnahes Produkt zur Überlagerung von Tourismus/Freizeitaktivität und Entzündungsgefahr erstellt: Touristische Routen/Aktivitäts-Layer wurden mit Entzündungsgefahr-Layern räumlich abgeglichen und über einen einfachen Index (0 = keine Überlappung bis 3 = hohe Überlappung) kombiniert. Damit lassen sich Bereiche identifizieren, in denen hohe Freizeitnutzung mit erhöhter Entzündungsgefahr zusammenfällt. Die Tourismusdimension wurde durch eine Feldstudie in der Region Rax–Schneeberg ergänzt: 927 Fragebögen wurden erhoben, 905 gültige Antworten ausgewertet. Die Ergebnisse liefern Evidenz zu Risikowahrnehmung, Verhalten und Akzeptanz präventiver Maßnahmen und zeigen Unterschiede zwischen Aktivitätsgruppen, was gezielte Prävention und Kommunikation unterstützt.

AFF legte zudem Wert auf praktische Verwendbarkeit und Wissensaustausch. Ausgewählte Outputs sind für Anwenderinnen und Anwender über das integrierte Waldbrand-Gefahrenmodell auf waldbrand.at verfügbar; derzeit bestehen rund 150 aktive Nutzerinnen und Nutzer aus Feuerwehren, Forstbehörden und Warnzentralen. Der abschließende Stakeholder-Workshop diente dem Austausch zu Ergebnissen und floss in ein konsolidiertes Empfehlungspaket für integriertes Waldbrandmanagement ein (Politik und Forstmanagement, Einsatzplanung und Brandbekämpfung sowie prioritäre nächste Schritte).

Die Projektergebnisse bilden auch eine Grundlage für zukünftige Weiterentwicklungen. Die Modellkette, Datensätze und Kartenprodukte können mit verbesserten downskalierten Klimaprojektionen sowie aktualisierten Feuer- und Waldinformationen fortgeschrieben werden; der stochastische Ansatz bietet darüber hinaus eine Basis für vertiefte Analysen von Extremereignissen. Die Projektionen der verbrannten Fläche ermöglichen außerdem Folgeanalysen mit hoher Policy-Relevanz, etwa zu Waldschäden und Kostenimplikationen, zu waldbrandbedingten Treibhausgasemissionen und zur Einordnung im Rahmen der Kohlenstoffbilanzierung sowie zu weiterführenden Bewertungen unter Einbezug von Exposition und Vulnerabilität.

2 Executive Summary

(max. 2 pages, language English)
See above.

Austria Fire Futures (AFF) addressed the increasing relevance of wildfires in Austria by developing predictive wildfire risk hotspot maps under climate change and translating the results into products that can support prevention, preparedness, and longer-term planning. The project brought together Austria-specific datasets on climate and fire weather, fuels and forest structure, and human drivers of ignition, and integrated them in the Wildfire Climate Impacts and Adaptation Model (FLAM). A key methodological achievement was the parameterization and calibration of FLAM for Austrian conditions, enabling consistent national mapping and a higher-resolution regional case study, complemented by tourism-focused field research, stakeholder exchange, and platform-based access to selected results.

At the national scale, FLAM was applied to produce wildfire risk maps at 1 km resolution under historical conditions and multiple future climate scenarios. Outputs include spatially explicit layers such as ignition probability, suppression efficiency, and burned area. A historical simulation for 2001–2021 showed that temporal burned-area patterns were reproduced at monthly scale with correlation $r = 0.63$. Scenario projections indicate increasing wildfire risk toward the end of the century in most cases, with persistent hotspot signals highlighting Niederösterreich and Tirol and additional increases indicated in Kärnten, Burgenland and Salzburg. Depending on scenario choice, the reported results include increases in average annual burned area of up to +52.8% in the late-century period (2081–2100) compared with the historical reference (2001–2020). These findings support treating wildfire risk as a growing and spatially differentiated climate-related risk for Austria rather than a rare anomaly.

Beyond national screening, AFF delivered a high-resolution fire risk study for Lower Austria at 250 m resolution. This implementation applied a stochastic simulation approach (30 realizations per year) to represent interannual variability and extreme years as a distribution rather than a single deterministic outcome. Over 2000–2020, mean annual burned area was 19.8 ± 7.4 ha in the 250 m setup and 17.4 ± 6.2 ha in the national 1 km simulation clipped to Lower Austria, compared with observed 15.4 ± 18.1 ha. Comparison across resolutions confirmed that the 250 m simulations capture more localized and heterogeneous hotspot structures than the smoother 1 km outputs, improving regional interpretability and supporting targeted planning in areas where risk concentrates.

A major project contribution was the improved representation of human-caused ignitions. Instead of relying mainly on population density, an ignition probability layer was derived from 1,232 human-caused fire ignition points and spatially explicit socio-economic and infrastructure predictors. The project also developed a practical tourism–ignition overlay product by aligning tourism route/activity

layers with ignition danger layers and computing a simple index from 0 (no overlap) to 3 (high overlap), highlighting areas where recreational use coincides with elevated ignition danger. The tourism dimension was further supported through a dedicated field study in the Rax–Schneeberg region where 927 questionnaires were collected and 905 valid responses were analysed, providing evidence on awareness, risk behaviour, and acceptance of preventive measures, and showing that relevant differences exist across recreationist groups.

AFF also focused on practical relevance and knowledge exchange. Selected project outputs are accessible to practitioners through the integrated fire danger assessment model hosted under waldbrand.at, which currently has around 150 active users from fire brigades, forest authorities, and state warning centres. The final stakeholder workshop supported direct exchange on results and informed a consolidated recommendations package for integrated fire management, covering policy and forest management, emergency planning and suppression, and priority next steps to reduce wildfire risk.

The project results also provide a foundation for future work. The modelling chain, datasets, and mapping products can be updated as improved downscaled climate projections and fire/forest datasets become available, and the stochastic framework offers a basis for analysing extreme-event risk in more detail. The burned-area projections further enable follow-up assessments relevant for policy, such as forest damage and cost implications, wildfire-related greenhouse gas emissions and carbon accounting, and broader impact screening when combined with exposure and vulnerability information.

3 Background and Objectives

(max. 2 pages) Description of the initial situation, task and objective.

Forest fires endanger human life, infrastructure, the agriculture and forestry sectors, biodiversity, and the recreational function of forests. Austrian forests, although not characteristic of a typical fire-prone ecosystem, are grappling with escalating forest fire risks owing to climate change, forest management, topographical variables, and human activities. Recent wildfire seasons (2003, 2013, 2015, 2018, 2021) have proved how widespread forest fires may occur (Vacik, 2011; Sass, 2014) and how they become an important issue in the event of critical weather conditions (Lorz et al., 2010), particularly when viewed in the context of other climate change impacts, such as extensive drought periods in spring and summer.

To proactively address this hazard to Austrian society, its economy, and the environment, the Austria Fire Futures project was created as a cooperative endeavor between the International Institute of Applied System Analysis (IIASA), the University of Natural Resources and Life Sciences Vienna (BOKU), and the Bundesforschungszentrum für Wald (BfW). The project has six work packages, structured as seen in Figure 1.

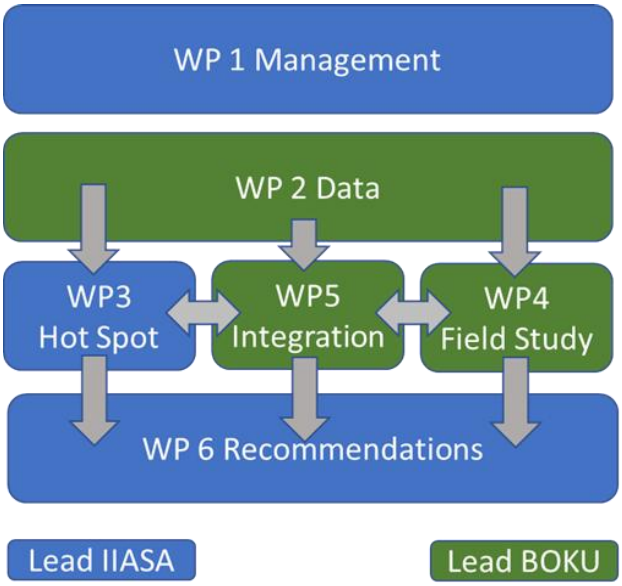

Figure 1. Overview of the work packages and responsible party.

In line with this approach, the project combined modelling, data work and spatial analysis with structured stakeholder exchange, including a stakeholder workshop where results were presented and stakeholder inputs were collected to support the final recommendations for integrated fire management. Based on the above motivation, the project pursued the following three main objectives:

O1: The development of new forward-looking fire hotspot maps for Austria - based on integrated fire risk modeling considering climate change, novel fuel monitoring, and additional variables such as topography

O2: The assessment and integration of key fire risk impact by hiking tourism through a deep-dive case study in Lower Austria/Rax mountain range.

O3: The improvement of the Austrian Fire Information Platform through implementation of project results and insights to "Waldbrand.at" and "fire.BOKU.at" for public display.

Stakeholder involvement was included as a cross-cutting element to support knowledge transfer and practical use of results, including workshops intended to integrate practice-relevant insights and to jointly elaborate recommendations for policy and practice.

4 Project content and result(s)

(max. 20 pages)
Description of the project, its objectives, and the activities carried out within the project. Description of the main work packages and activities. Presentation of the project results.

The activities performed and methods employed are reported on a work package basis and are presented together with the corresponding results and milestones. The work performed spans data identification and preprocessing (WP2), integrated modelling and parameterization (WP3), tourism field study and survey work (WP4), regional implementation and platform integration (WP5), and stakeholder engagement and recommendations (WP6).

WP 1: Management, Stakeholder Interaction, Communication, and Dissemination

The WP1 objectives and activities for the project were accomplished with minor timing adjustments during implementation. As part of Milestone 1.1, IIASA organized an internal kick-off meeting at the start of the project (Month 1) to initiate discussions and planning across the consortium. Regarding intermediate meetings, the consortium held regular meetings under Milestone 1.2 and 1.3 to ensure good communication, collaboration, and to provide platform for the discussion of scientific and administrative questions. These talks have included ongoing data exchange, collaborative report writing, and results discussions and dissemination.

As part of Task 1.4, IIASA established and maintained a shared site for partners to review project timelines and deadlines, exchange data, and share project-related documents and information. This supported structured collaboration and efficient coordination between work packages. Stakeholder Workshop was held where the consortium presented key project results and gathered stakeholder inputs to support the final recommendations output. Dissemination activities were implemented throughout the project and included conference contributions, scientific publications, and media communication in addition to in person communication of results.

WP 2: Data Identification, Collection and Processing

The Institute of Meteorology and Climatology at BOKU provided gridded wind speed data and the Fine Fuel Moisture Code (FFMC) as daily inputs to the FLAM model for the historical period (2000-2022), for five different climate scenarios. All the input data was pre-processed, bias-adjusted and downscaled to a 1x1km grid for Austria and on a 250x250m grid for Lower Austria. The approach of global warming levels compares the time slices of each scenario when the global mean temperature reaches for example a 2°C increase compared to the pre-industrial period. For the analysis we selected five regional climate models. None of the selected climate models can be described as extreme, but MOHC-HadGEM2 represents a dry climate scenario, and ICHEC-EC is a summer dry scenario. The degree in bracket indicates the global climate change signal at the end of the century:

- MPI-M-MPI-ESM-LR_rcp45_r1i1p1_CLMcom-CCLM4-8-17 (< +2°C)
- MPI-M-MPI-ESM-LR_rcp85_r1i1p1_CLMcom-CCLM4-8-17 (+ 3°C)
- ICHEC-EC-EARTH_rcp85_r1i1p1_KNMI-RACMO22E (+ 3°C)
- ICHEC-EC-EARTH_rcp85_r12i1p1_SMHI-RCA4 (+ 4°C)
- MOHC-HadGEM2-ES_rcp85_r1i1p1_CLMcom-CCLM4-8-17 (+ 4°C)

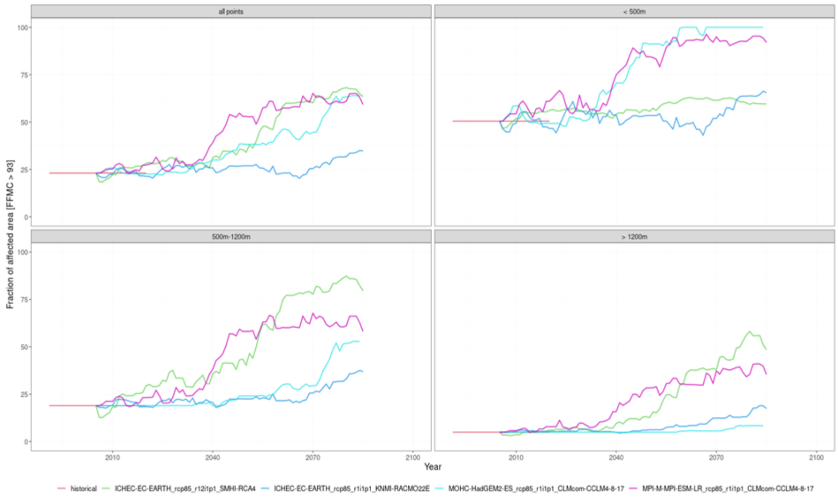

Figure 2. Change in an event with a 10-year return period of the spatial extent of FFMC values > 93 for low elevation (< 500 m), mean elevation (500m – 1200m), high elevation (> 1200m) and all pixels.

The results indicate an increase of days with high fire risk (FFMC > 93) for eastern and southern Austria, especially for the summer months (Fig. 2). This trend is present for a global warming level of 2°C and 3°C (see Fig. 2. and Fig.3). The trend of extreme events is even more present for higher altitudes, with an increase of about 20% to 50 % until the end of the century. This increase is substantial as the historical period and all climate scenarios show that this area is not affected at all in the current climate.

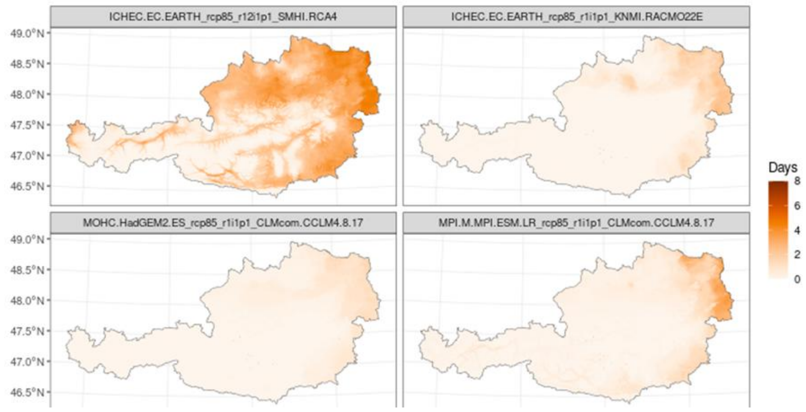

Figure 3.Average days of FFMC values > 93 under a global warming level of +3°C in August

In achieving Milestone 2.2, BFW were able to identify, process, and provide maps on forest structure in Austria at high resolution to produce and validate spatial layers of forest conditions (species type, fuel type). The following data items were processed and provided by BFW:

Canopy Cover Map with a 1-meter grid. This map originates from the BFW vegetation height model and represents the percentage of adjacent pixels exceeding 2 meters in height.

1-meter resolution Gaps Map. Initially, contiguous regions exceeding 20 pixels with canopy cover percentages below 60% were identified and marked as gaps. In the second phase, all connected non-gap areas within gap regions, spanning fewer than 10 pixels, were also classified as gaps. This process resulted in a more comprehensive map.

10x10m Tree Species Map (Figure 4). This map was developed through the integration of advanced neural networks, Sentinel-2 phenology index time series, and surface models. It serves the purpose of classifying different tree species. The validation method and methods to improve the accuracy for species relevant to the project were improved and implemented (oversampling of underrepresented classes and training data filtering), and new phenology model input data were integrated into the preprocessing, feature and modelling workflow.

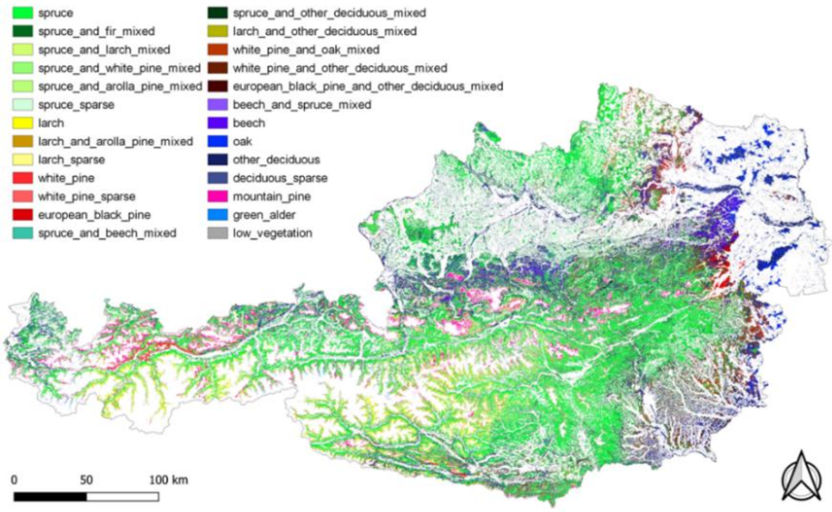

Figure 4. Tree species map for Austrias federal territory

1x1m Timber Volume Map (Figure 5). It incorporates vegetation heights, the Tree Species Map, and national Austrian forest inventory models to generate predictions for timber volume. It uses the percentage of hardwood, derived from the tree species map.

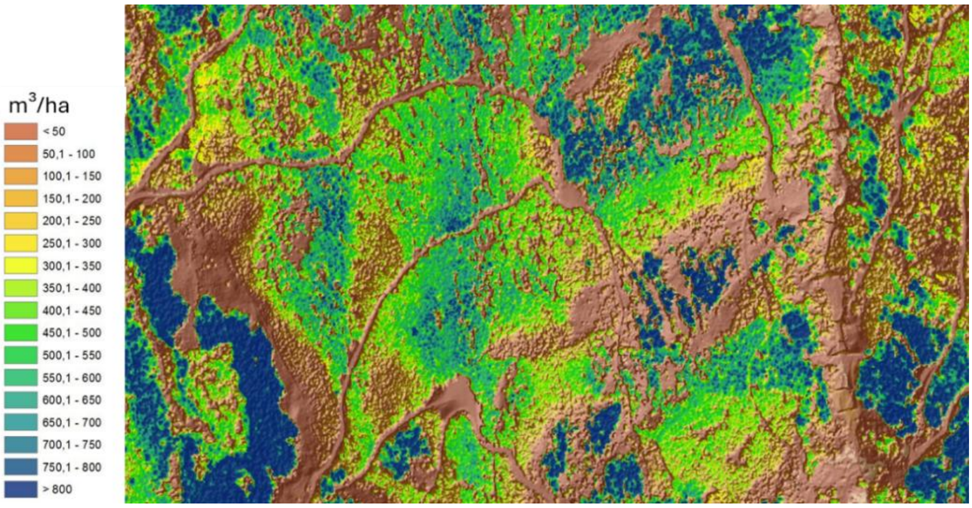

Figure 5. Timber volume map for the Austrian federal territory

Task 2.4. The Institute of Silviculture at BOKU provided essential fuel load data to enhance the FLAM model with Austria-specific input. These data include information on various fuel types, including 1h, 10h, 100h, and 1000h fuels, as well as live vegetation (both woody and herbaceous) and litter. BOKU mapped fuel types in Austria, using Neumann et al. (2022) as a guide for field assessments conducted in Lower Austria, Styria, and Carinthia, focusing on conifer, broadleaved, and mixed forests. Fuel loads were calculated from data collected at the research sites, covering different types of vegetation and fuel loads. A new mapping approach integrates existing data, field measurements, and forest inventories. BOKU has developed tiers of fuel information with increasing detail, resolution, and accuracy but covering progressively smaller areas for large-scale analysis.

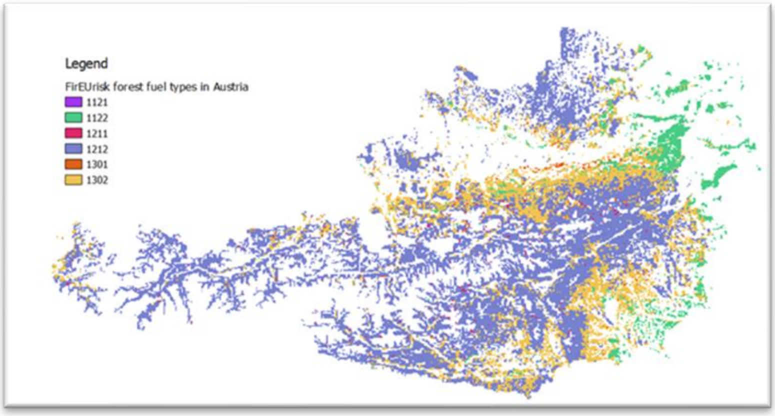

Figure 6. Austrian forest fuel map based on the FirEUrisk project.

Part 1: there is a Europe-wide fuel type map with a spatial resolution of 1km, developed as part of the 'FirEUrisk' project (Aragoneses et al. 2023), designed for large-scale fuel assessments. In Austria, 6 of 10 forest fuel types in FireEUrisk are present, according to the fuel type map. These fuel types assume consistent fuel load (t/ha) and structural characteristics, such as fuel structure and fuel depth, across Europe. The preparation of this data (Figure 6) has been completed building up on the "FirEUrisk" fuel type map.

Part 2: "Austrian fuel map" at 100 m resolution including 1000-hour fuel, using Austrian field measurements and literature values (Neumann et al., 2022) and new field plots across the country, including plots at locations such as Allentsteig (Lower Austria), Leoben (Styria), and Saubersdorf (Lower Austria).

For Task 2.5, IIASA conducted statistical assessment of potential explanatory variables to support selection of the most relevant predictors for FLAM components (ignition potential, fire spread, and suppression efficiency). Under Task 2.1, BOKU Silviculture shared data on fire-related morphological and socio-economic variables to help calibrate the FLAM model's capabilities to simulate fire ignition, spread, and suppression efficiency. The submitted data included detailed information on burned areas and fire ignitions in Austria that is used for FLAM calibration and validation. This includes dataset of all forest fires in Austria from 2001 to 2022, socio-economic factors like population density, roads, and other human related factors influencing fire ignition. WP2 outputs are documented in the attached internal reports D2.1 (climate module) and D2.2 (key fire-related variables for Austria), which were delivered and used as inputs to WP3 modelling.

WP3: Integrated Modeling and Monitoring for Fire Hotspot Mapping

Within WP3, IIASA led the integration of WP2 inputs into the wildfire climate impacts and adaptation model (FLAM) and produced the core national mapping outputs for Austria. WP3 activities covered (i) development of an Austria-adapted fuel module, (ii) FLAM parameterization and calibration for Austrian conditions, and (iii) application of the calibrated model to generate Austria-wide fire risk maps under historical and future climate scenarios.

As part of Task 3.1, the project, developed an Austria-specific fuel classification and mapping approach using the high-resolution tree species map, satellite data, field/literature data, and the FirEUrisk fuel classification framework (Aragoneses et al., 2023). The resulting system consists of 13 distinct forest fuel types (see Table 1), building on FirEUrisk but adapted to better represent Austrian forest conditions. The fuel module documents both (i) the low-resolution European fuel map basis (1 km) and (ii) a higher-resolution national fuel representation based on Austrian information sources to support improved modelling inputs.

Table 1. Fuel classification for Austria provided by BFW and BOKU Silviculture

Class	Code FirEUrisk	New_code	Tree species
Needleleaf	1212	1212 a	Spruce
	1212	1212b	Spruce and white pine, spruce and arolla pine mixed
	1212	1212c	White pine, black pine
	1212	1212d	Mountain pine
		1612	Larch and spruce, larch and arolla pine mixed
		1511	Larch
Broadleaf	1122	1122a	Beach
	1122	1122b	Oak
	1122	1122c	Other deciduous
	1122	1122d	Green alder
Mixed	1302	1302a	Spruce and beech mixed, spruce and other deciduous mixed
	1302	1302b	White pine and deciduous mixed and European black pine and deciduous mixed
		1402	Larch and other deciduous mixed

A standard application of FLAM requires three main data categories (climate, fuel, and human activity) to calculate ignition probability, calibrate spatial suppression efficiency, and calculate the total probability of fire (Figure 7). The FLAM allows for the inclusion of additional fire-related input variables or factors into probabilistic algorithms as needed to capture local and regional fire ignition and burned area characteristics. It is run on a daily time-step and can be applied at various temporal and spatial scales, with output resolution determined by the resolution of available input data. FLAM uses parameterization algorithms to calculate conditional probabilities that together form a daily, pixel-level probability of fire occurrence. The conditional probabilities are computed from the input variables developed within AFF. Assuming a positive probability of fire occurrence, burned area is then calculated from fire spread potential, fuel moisture, and fire suppression efficiency.

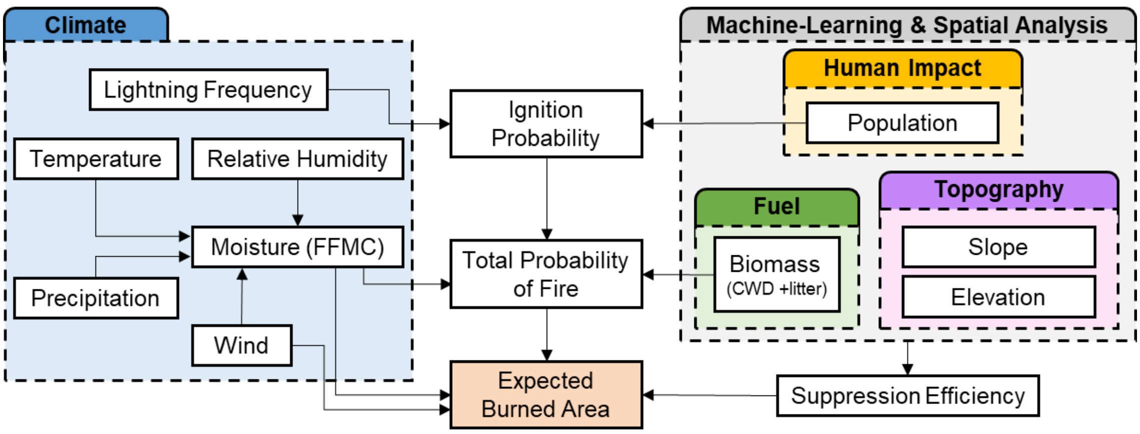

Figure 7. FLAM Workflow

The probability of fire occurrence dependent on climate uses the FFMC from the Canadian Forest Fire Weather Index to estimate fuel moisture content and represent short- and long-term effects of daily weather conditions (Lawson and Armitage, 2008). In FLAM, the probability of ignition due to fuel moisture (Pm) is calculated by converting FFMC to moisture content (Hyun Woo et al., 2023):

$$Pm = 1 - \tanh^2\left(1.75 \times \frac{m}{m_e}\right) \quad (1)$$

where m_e = 0.35 is the moisture of extinction, a ratio between 0-1 and corresponding to a FFMC = 70, and m is a transformation of FFMC into moisture content:

$$m = \frac{0.01\,(59.5 \times 250 - 147.2 \times V_{FFMC})}{V_{FFMC} + 59.5} \quad (2)$$

Fuel availability is represented through fuel available to burn (B), commonly derived from above-ground biomass (AGB) and key components such as litter and coarse woody debris (CWD), representing fine and dead/large fuels respectively (Krasovskii et al., 2018). The probability of fire as a function of fuel availability (P_b) is calculated as a normalized fuel load:

$$P_b = \max\left[\frac{B - B_l}{Bu - B_l}\right] \quad (3)$$

where $B_u$and B_l are the upper and lower boundaries of probability attributable to fuel availability. These are adjustable based on study area resolution; at higher resolutions, the distribution of B can broaden due to improved representation of local conditions (Hyun Woo et al., 2023).

FLAM considers both anthropogenic and lightning ignitions (Krasovskii et al., 2018). Human influence is typically represented through population density and related variables. Human presence increases ignition likelihood but also increases the likelihood of rapid detection and suppression, and FLAM represents this dual role through separate ignition and suppression components. The impact of human activity on fire ignition (Ph) is calculated using the following equation:

$$P_h = \min\left(1, \frac{p}{p_{up}}^{0.43}\right) \quad (4)$$

where p is population density and $p_{up}$is an upper threshold above which ignition probability does not increase further. A standard value used in FLAM is p_{up} = 300people/km² (Kloster et al., 2010), and this threshold can be adjusted during calibration to reflect local conditions.

Suppression efficiency related to human presence ($Fsup$) is:

$$F_{sup} = 1 - ((1 - Sup\ max) + \exp\,(-C\sup * p) \quad (5)$$

where $Supmax$ represents the maximum probability of instant fire suppression, *Csup* is the suppression coefficient of population density, and p is the population density.

The influence of lightning is calculated as follows:

$$B_l = \max\left(0,\ \min\left(\frac{l_f - l_{f,low}}{l_{f,up} - l_{f,low}}\right)\right) \tag{6}$$

where B_l is the normalized value of monthly lightning strikes (L_f) per km2 from 0-1 based on $L_{f,low}$ and $L_{f,up}$, with default values of 0.02 and 0.85, respectively. B_l is then used to calculate the probability of ignition due to lightning (P_l) as follows:

$$\text{Pl} = \frac{B_l}{B_l + (1.5 - 6B_l)} \tag{7}$$

A total probability of ignition (Pi) from all sources would be calculated considering the three values found in Equations 3, 4, and 7 with the following equation:

$$P_i = (P_l + (1 - P_l)P_h)(1 - F_{sup}) \tag{8}$$

The total probability of fire (P) is calculated based a multiplicative of the individual probabilities described above (Krasovskii et al., 2018). It considers both natural and anthropogenic sources of fire ignition and current conditions to calculate the daily probability of fire occurrence and spread:

$$P = P_i \times P_m \times P_b \tag{9}$$

Burned areas are calculated based on the total probability of fire, wind speed, and suppression efficiency.

AFF advanced FLAM's suppression efficiency algorithm using a segmentation-based calibration approach (Figure 8). Compared to approaches relying only on pixel-level calibration or segmentation by spatial adjacency, this approach uses both spatial adjacency and biophysical feature similarity to define calibration units. The method consists of three steps:

1. Pixel segmentation: Land surface features (including topography, fuel availability, and population density) are used to segment the study area into homogeneous groups. Multiple segmentation iterations are generated, with different runs emphasizing either spatial adjacency or feature similarity.
2. Calibration: Suppression efficiency is calibrated for each segment using historical burned area data. Calibration is performed monthly to reflect seasonal variation in fire dynamics.
3. Ensemble modelling: Suppression efficiency estimates from multiple segmentation iterations are ensembled to produce more robust values and reduce sensitivity to any single segmentation strategy.

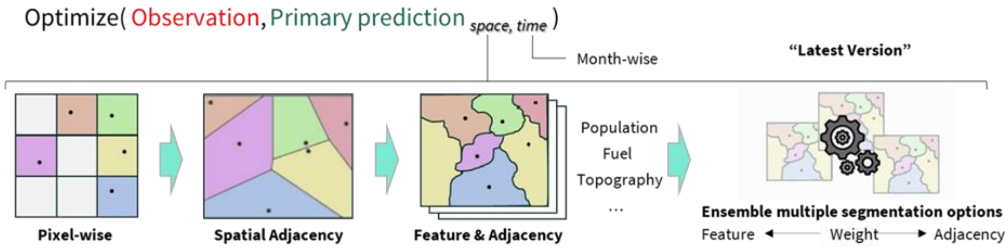

Figure 8. Development phase of suppression efficiency calibration algorithm of FLAM.

Building on the calibrated FLAM implementation from D3.2, the project produced Austria-wide wildfire risk maps at 1 km resolution under historical conditions and future climate scenarios. In the Deliverable 3.3, FLAM was recalibrated where years 2001–2020 was used as baseline with model calibration placed in 2006–2015 and validation against 2001–2005 and 2016–2020 (Figure 9). The report shows improved agreement with observed fire patterns compared to earlier model versions, where monthly correlation is 0.632 and 0.618 for yearly.

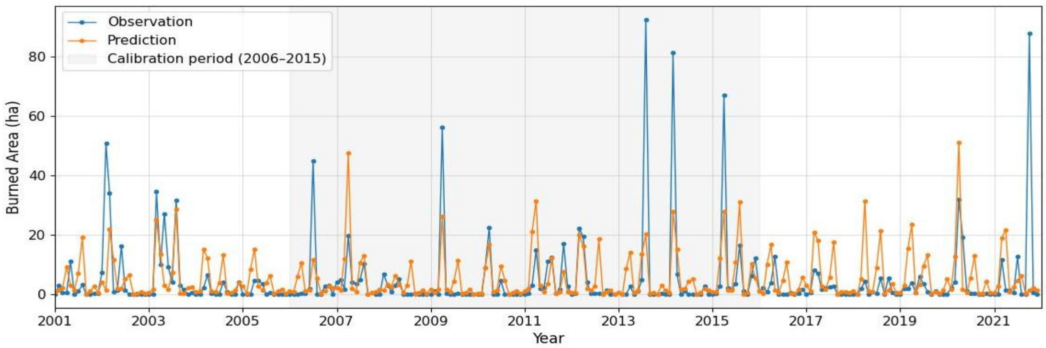

Figure 9. Monthly burned area patterns between FLAM predictions and observations (2001 - 2021)

The model has simulated burned area hotspots (Figure 10) that aligns well with observed patterns, particularly for larger fires (>10 ha). Reported areas of strong spatial consistency include Tirol, western Kärnten, and southeastern Niederösterreich around Burgenland.

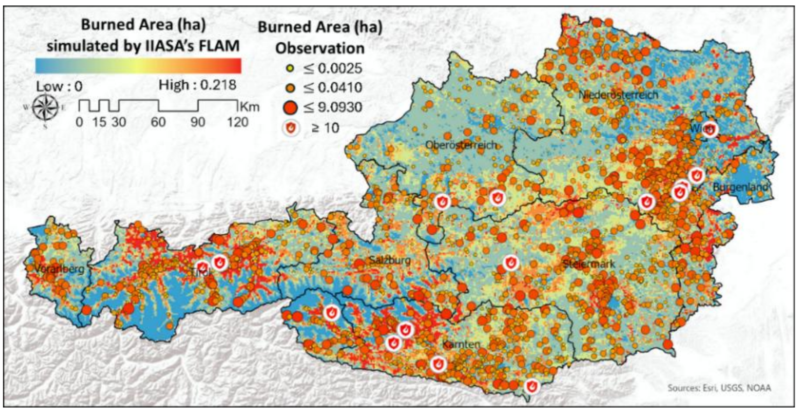

Figure 10. Simulated burned area by FLAM (aggregated mean of yearly total burned area from 2001 to 2020) overlapped with observed fires.

For future projections, it was revealed that all RCP8.5-based models project increasing burned areas toward the end of the century, with differences in magnitude and trend strength across the climate models (Figure 11). The largest increases are reported for SMHI-RCA4, with MOHC-HadGEM2 also showing a strong rise. In contrast, MPI45 (RCP4.5) shows the smallest changes and the most stable track.

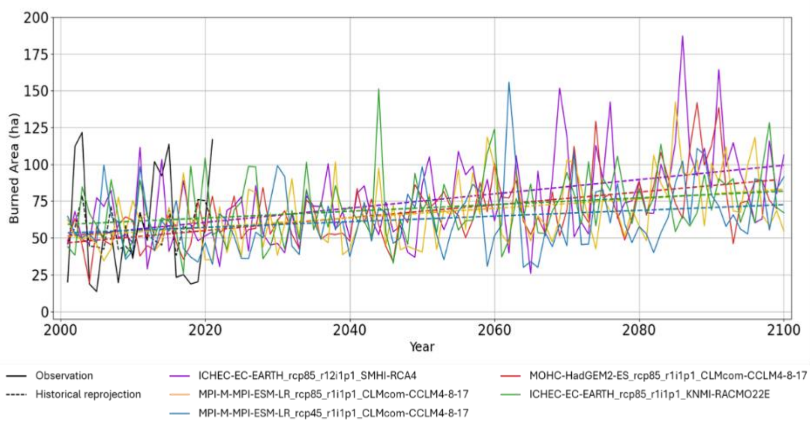

Figure 11. Simulated yearly total burned areas under different climate models.

Looking at the province-level aggregation, Niederösterreich and Tirol consistently show the highest values, indicating that these two provinces contribute substantially to national burned area totals. In Niederösterreich, mean annual burned area increases from 17.42 ha (historical 2001–2020) to 29.33 ha in the late-century projection, while Tirol increases from 16.40 ha to 21.23 ha (with some fluctuations across intermediate time periods and models). In contrast, Wien and Vorarlberg remain consistently low across all periods and scenarios, with values not exceeding 2.20 ha in any scenario. Other provinces, including Kärnten, Burgenland, and Salzburg, also show increases, generally smaller in magnitude but steady across the future periods.

While these results describe the overall trajectory of wildfire danger in Austria under climate change, it is equally important to consider how Austria's emergency response system relates with this rising threat. Understanding where suppression capacity may be limited relative to projected fire activity provides crucial insights for preparedness and adaptation.

WP4. Tourism x Fire Risk – Field Study

BOKU-ILEN provided information about tourism facilities, tourism use and visitor-use traces in the Rax–Schneeberg region. The methodological approach and results of the inventories are documented in the internal report on tourism facilities including area maps (D4.1). Between 2022 and 2023, existing tourism infrastructure in the study area was recorded. Mapping of visitor-use traces focused on traces that could contribute to ignition risk (e.g., cigarette butts, broken glass, ashes of campfires) and was carried out during several field visits in 2023. All collected data were transferred into GIS. The spatial distribution of tourism use was based on existing data from a previous on-site survey of visitor use of the Rax area and data generated from OpenStreetMap; the spatial distribution of tourists within the trail network was processed in ArcGIS Pro.

A GIS-based tourism infrastructure map (Figure 12) was developed including mountain huts, hiking trails, viewpoints/sights, parking lots, gravel banks along the Schwarza River, the Rax cable car, and the Schneeberg railway. The most frequently visited mountain huts include Bergstation/Berggasthof, Ottohaus, Neue Seehütte, Habsburghaus, and Waxriegelhaus on the Rax; Am Wasserwerk and

Weichtalhaus on the Schwarza River; and Naturfreundehaus Knofleben on the Schneeberg. Gravel banks along the Schwarza River were identified as popular outdoor recreation areas and are easily accessible by car due to numerous free parking lots along the river. Based on initial hotspot analyses combining visitor frequency and tourism facilities (Figure 13), four tourism hotspots were identified: (1) around the top station of the Rax cable car including Ottohaus, (2) along the Schwarza River between the bottom station of the Rax cable car and Kaiserbrunn, (3) between Edelweißhütte and Waxriegelhaus, and (4) around Weichtalhaus.

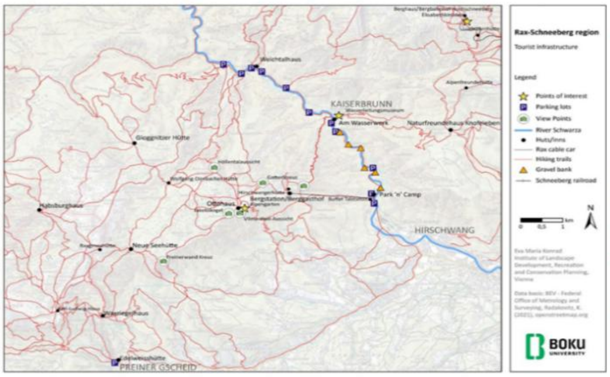

Figure 12. Tourism infrastructure map of the Rax-Schneeberg region.

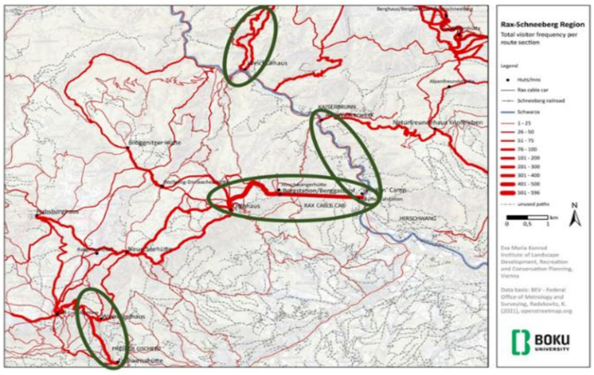

Figure 13. Initial results of the hot-spot analyses including visitor use frequencies and tourism facilities.

BOKU-ILEN assessed awareness and perception of forest fire danger and fire-related behaviour among recreationists in the Rax–Schneeberg region. The survey design and implementation included questionnaire development (agreed with the project team and key stakeholders), successful ethics approval, selection of survey sites to capture different recreationist groups, and a pre-test prior to launch. The survey was conducted as an on-site survey at 12 well-frequented locations in the region during July to early October 2023 and was completed in October 2023. In total, 927 questionnaires were collected, of which 905 were usable after data plausibility checks and exclusion of incomplete/low-quality responses. Survey results show:

- Sample/visit characteristics: Gender distribution was relatively balanced; the average age was 44.5% of respondents had their main residence in Vienna and 37% in Lower Austria. 53% were day visitors, 36% overnight visitors, and 11% local residents; around 70% of overnight visitors stayed in mountain huts. Roughly three-quarters arrived by car and about 20% used public transport. Hiking was the most common activity (81%), followed by walking (19%), swimming (14%), and climbing (10%). Respondents reported high satisfaction with the region as a recreation area.
- Risk perception and climate change: 98% believe forest fires can occur in Austria. The majority consider climate change important in the region and expect wildfire danger to increase in the next 10 years due to climate change. Forest fires in spring protection areas were also perceived as a risk for local drinking water supply.

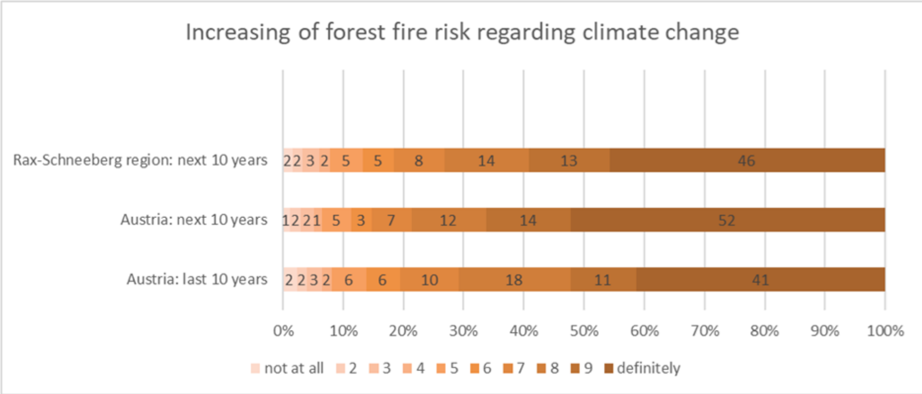

Figure 14. Changes in forest fire risk due to climate change (N=900/900/899).

- Information and awareness gaps: About one third reported not feeling sufficiently informed about wildfire risk; another third reported feeling very well informed. Local residents felt significantly better informed than tourists. Around 60% had not seen or read information boards on correct behaviour in the spring protection area, and 70% were not aware of the current district wildfire regulation (or had never heard of wildfire regulations in Austria).

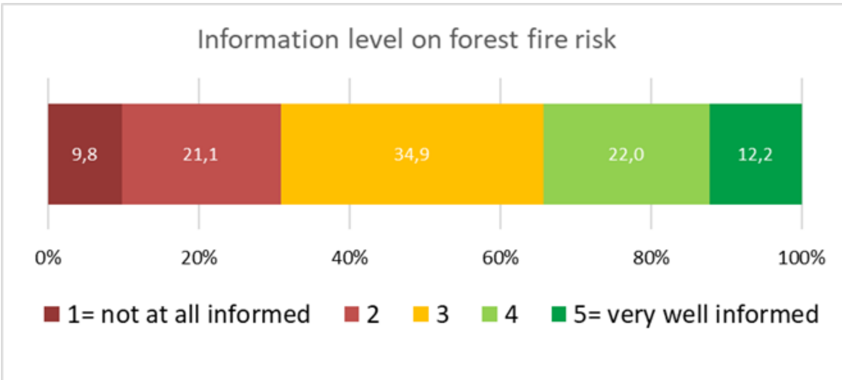

Figure 15. Self-reported information level on forest fire risk (N=891).

- Knowledge and (self-reported) behaviour: Respondents identified cigarettes, prohibited campfires, prohibited barbecuing, and careless playing with fire as key perceived causes; 60% rated disposal of smouldering cigarettes as a very common cause. Discarded cigarettes were also the most frequently observed sign of potentially risky behaviour. In general, listed risky activities were reported as rarely observed and rarely practiced by respondents themselves; however, climbers and those doing water-based activities showed significantly higher risky behaviour compared to some other groups (e.g., hikers).
- Acceptance of measures: Acceptance was very high for information and awareness measures and for controls by supervisory authorities during high-risk periods. Lower acceptance was reported for measures that strongly restrict recreation (e.g., closures) and for some proactive forestry measures (e.g., creating firebreaks, regular shrub removal along trails). Table 1 in the summary reports the highest mean acceptance for information boards and strict penalties for gross negligence, and the lowest acceptance for closing camping sites and closing hiking trails.

WP5. Integration and Web Platform Implementation

WP5 focused on preparing and integrating project outputs into a GIS-ready format suitable for dissemination and practical use through the Austrian fire information platform (waldbrand.at). On the platform waldbrand.at, an integrated fire danger assessment system (IFDS) has been implemented in the context of several ongoing projects.

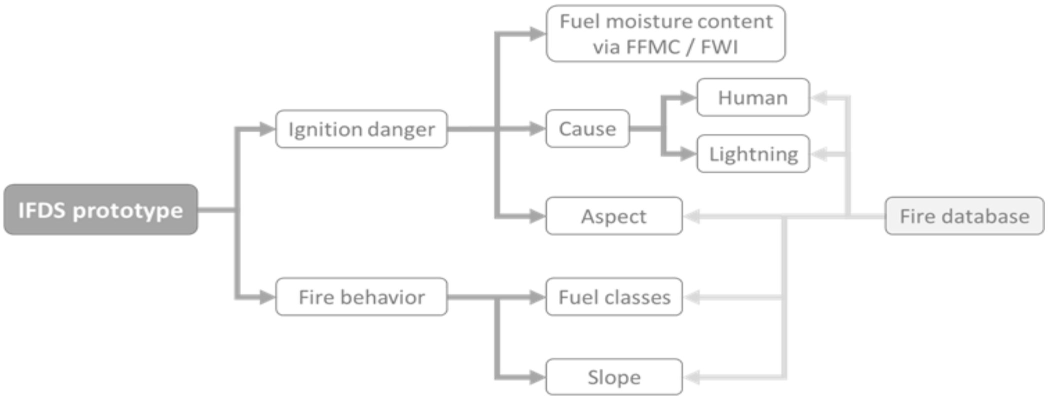

Figure 16. Schematic illustration of the IFDS prototype and the included data layers.

The conceptual approach of the IFDS (Figure 16) considers the combined use of factors that influence fire ignition danger and fire behavior. The used datasets and data layers included i) information on forest fire occurrence, retrieved from the Austrian wildfire database, ii) fire weather indices derived from meteorological data (Canadian Fire Weather Index, FWI, and its subindex the Fine Fuel Moisture Code, FFMC), iii) a spatial analysis on the human influence on fire ignition, iv) a lightning fire hazard map, v) an area-wide classification of vegetation to derive a fuel type map, and vi) a high-resolution topography map, where we extracted aspect and slope. The different combinations and weighting of these factors allowed the calculation of an expert model.

As part of WP5, D 5.1 provides information on the human caused ignition danger and provides examples for the implementation in Lower Austria. The deliverable documents the workflow to link tourism-related layers with ignition danger and fire risk outputs. In addition, the fire hotspots mapping was conducted at 250 m resolution and includes a stochastic simulation approach (multiple realizations per year) to represent variability in annual fire occurrence and burned areas. The reported outputs support identification of local fire risk hotspots and comparison against the Austria-wide 1 km results.

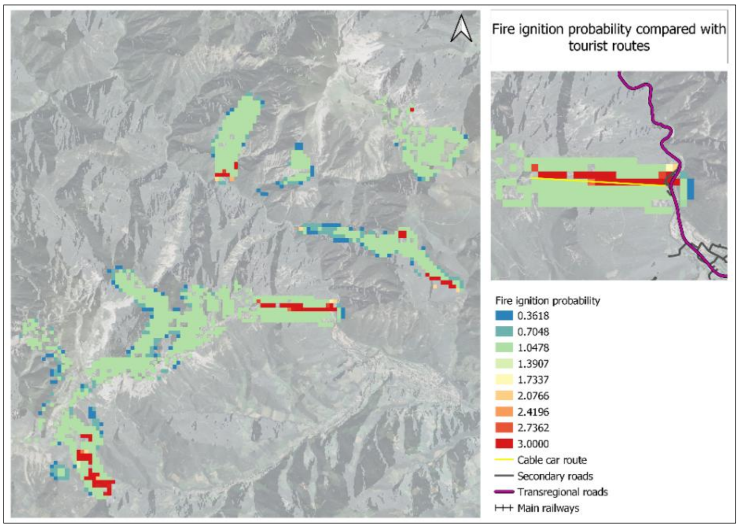

Figure 17. Touristic routes and fire ignition danger analysis

To identify areas where tourism overlaps with ignition danger, the tourism activity layer was spatially aligned with the ignition danger layer (Austria Lambert 31278). A grid-based overlay was then applied by multiplying the aligned grid values to produce a simple risk indicator ranging from 0 (no fire danger along route) to 3 (high fire risk overlap). As a result, a map illustrating the analysis of tourist routes and fire ignition danger is shown in Figure 17. The red pixels represent areas with a higher probability of fire, combining higher tourist activity along those routes. An area in the Rax mountain is highlighted as an example of a high-risk zone. This is due to the significant tourist traffic in the region, particularly around the cable cars and popular hiking trails. These attractions draw large numbers of visitors, increasing human activity, and consequently, the likelihood of fire ignition in the area.

On another note, a higher-resolution FLAM-based implementation was produced at 250 × 250 m, including a stochastic simulation approach to represent year-to-year variability in fire occurrence and burned areas. In this study, 30 stochastic runs were conducted to represent the range of potential annual wildfire risks for each year. The model output is further processed to identify extreme fire years, defined using the same statistical threshold applied in the national workflow.

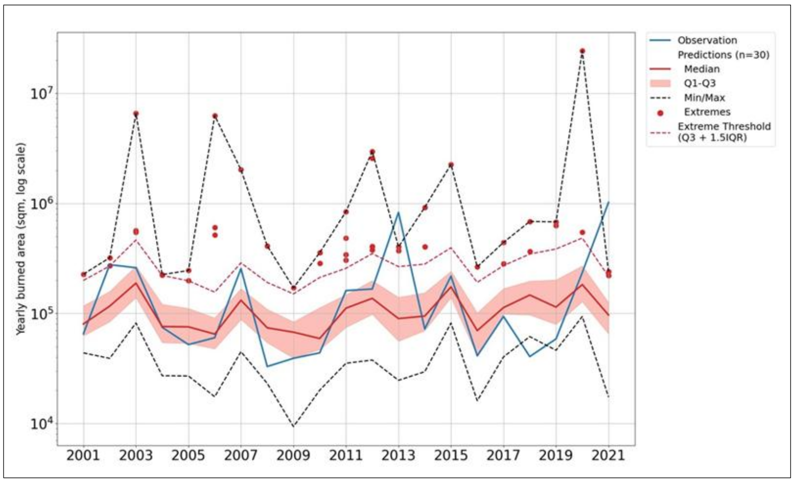

Figure 18. Stochastic Simulation of FALM for 2001-2021.

The comparison between observed burned area and the simulated distribution is shown in Figure 18. The median of the simulations (red line) and the interquartile range (Q1–Q3) closely follow the observed annual burned area (blue line), indicating that the model reproduces the central tendency and variability of most fire years. The full simulated range (min–max, dashed line) captures the interannual variability of the observations.

Figure 18 shows the historical burned area in Lower Austria for 2001–2020, red dots represent the observed fire locations overlaid on the simulated mean annual burned area produced by FLAM. The model reproduced observed fire activity well, with an average predicted burned area of 19.8 ha compared to the observed 19.5 ha. The figure shows how the model captures the major spatial patterns of fire occurrence, with yellow and red zones aligning with regions that host the highest density of observed fire events.

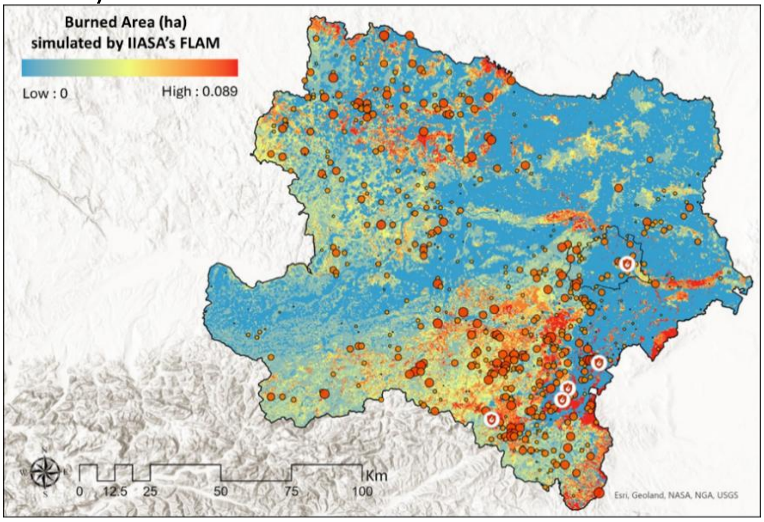

Figure 19. Simulated burned area by FLAM at 250m resolution, showing the mean annual burned area over the period 2001-2020.

To assess the effects of spatial resolution on simulated burned area patterns, we compared FLAM outputs generated at 1km resolution for Austria (Figure 4, Deliverables D3.3) with the 250m resolutions for Lower Austria (Figure 19).

Figure 20 shows the difference in burned area between the two simulations (250 m – 1 km) and relates these differences to changes in fuel load. The largest differences occur in southeastern Lower Austria, although their magnitude remains relatively small (−0.26 to 2.0 ha per pixel aggregated over 20 years).

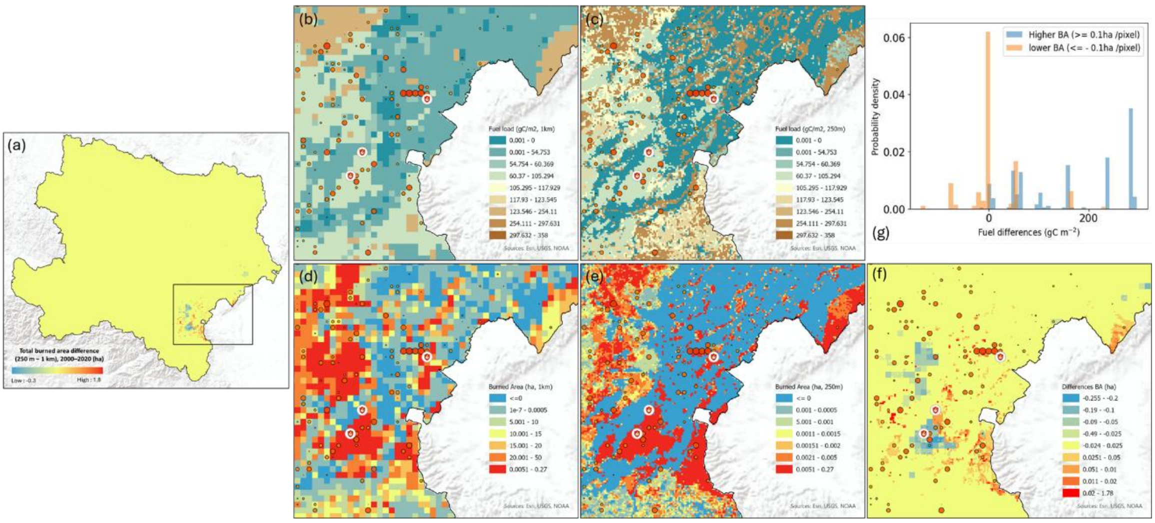

Figure 20. Spatial patterns of burned area and input example (fuel load) differences between 250m and 1km simulation for the period 2001-2020. (a) differences in total burned area aggregated over 2001-2020, (b - c) Fuel load distribution at 1km and 250m resolution

In general, pixels where the 250 m simulation produces higher burned area coincide with higher fuel loads at finer resolution. This pattern likely reflects the use of higher-resolution fuel data, which captures more detailed spatial variability in fuel distribution. Consistently, pixels with higher burned area at 250 m (≥ 0.1

ha per pixel) tend to show positive fuel-load differences, whereas pixels with lower burned area (≤ −0.1 ha per pixel) generally show neutral or negative fuel-load differences.

Differences between resolutions also reflect the model optimization scope. The 250 m setup was optimized specifically for Lower Austria and incorporated fire-response/suppression information (e.g., distance to fire stations) during suppression-efficiency optimization, while the 1 km simulation was calibrated at the national scale using calibration units defined across all Austria. As a result, the two outputs differ due to a combination of (i) resolution-dependent representation of input variables, (ii) different in data sources, (iii) differences in optimization domain, and (iv) differences in how calibration units were defined. Overall, the comparison shows that resolution should be treated as a fit-for-purpose modelling choice (local hotspot detail vs national overview), rather than as a universally "better" representation.

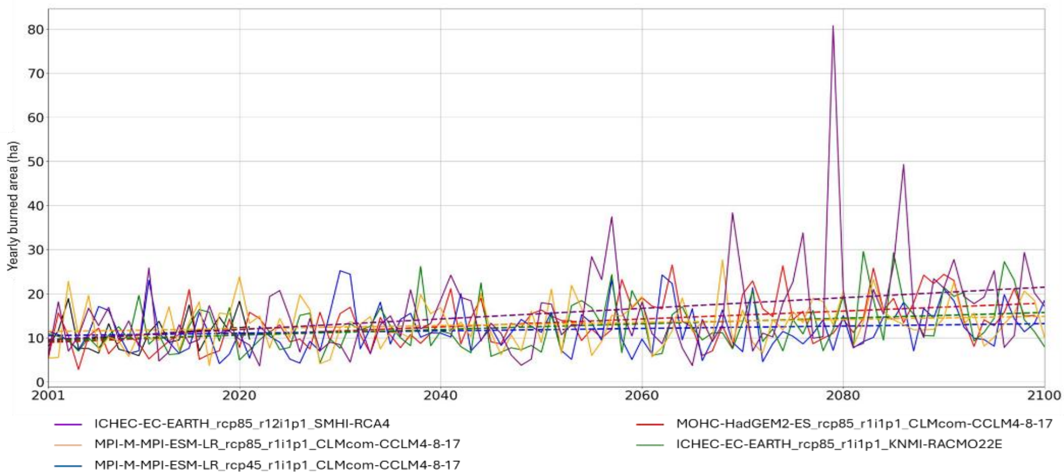

Figure 21. Simulated burned area based on the median of 30 stochastic FLAM simulations for the period 2001–2100 under different climate models.

Future burned area in Lower Austria was projected under five climate scenarios (SMHI, MOHC, KNMI, MPI8.5, MPI4.5). Across all scenarios, results show strong interannual variability with recurring high-burned-area years throughout 2001–2100 (Figure 21).

D5.2 describes the web implementation of new hot spot maps. In 2025, the new GIS-layers were implemented on waldbrand.at which were produced during the AFF project. The aim of these new GIS layers was to make them accessible to experts, and subsequently also for further research questions and presentations.

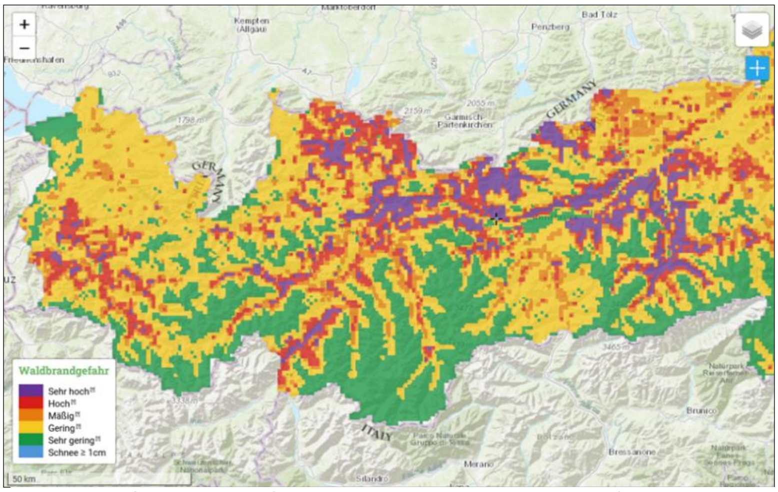

Figure 22. Screenshot of the map showing the assumed future burnt forest area in western Austria created within the AFF project and implemented on waldbrand.at.

One of the new maps indicates the modeled future burnt forest areas in Austria using the outputs of the fire model FLAM (Figure 22). This map shows the modeled distribution of burnt areas in a future scenario (2080-2100) and under a regional climate model ensemble (SMHI-RCA4). The higher the danger level, the higher the expected total burnt area. The spatial resolution of this map is 1 km². The creation and preparation of this map was carried out with the fire model FLAM as part of the Austria Fire Futures (AFF) project.

In addition, a new fuel type map was integrated on waldbrand.at (Figure 23). It was created with the contribution of the tree species information provided by BFW during the AFF and other related projects. The map shows the fuel classes in Austria translated to the standardized fuel models (FBFM40) according to Scott and Burgan (2005). The new fuel classification based on Scott and Burgan is planned to replace the old fuel map currently used on waldbrand.at in 2026 which should improve fire danger modeling results.

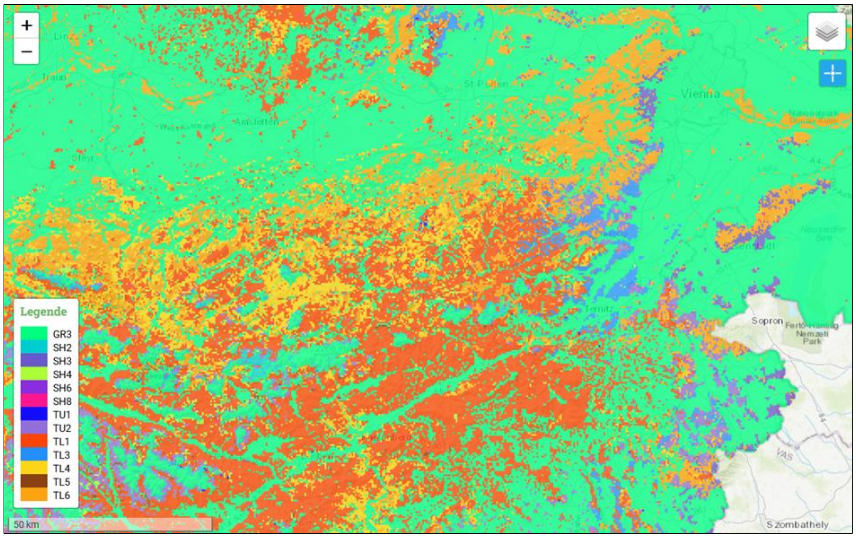

Figure 23. Screenshot of the map showing the fuel classification according to Scott and Burgan (2005) in eastern Austria created within the AFF and other projects and implemented on waldbrand.at.

WP6. Stakeholder-involved Recommendations for Forest Fire Policy and Emergency Planning

The tasks under WP6 (T6.1–T6.3) were implemented through a coordinated stakeholder engagement and synthesis process. This included preparing and delivering the final stakeholder workshop, presenting project results, collecting stakeholder feedback, and consolidating this input into one recommendations package for integrated fire management. The stakeholder engagement was centered on the final workshop, which served as the main forum for presenting results and consolidating stakeholder feedback. It was held in Laxenburg on October 28, 2025, attended by a broad network of stakeholders, including Representatives from IUFRO, Austrian Federal Forests, Tourism Association, Fire Department, WIFO, and several regional authorities. In the final implementation, the planned three deliverables (D6.1, D6.2, D6.3) were merged into a single consolidated stakeholder recommendations document, covering the full intent of the original deliverables: recommendations for policy and forest management, emergency planning and fire suppression, and priority future steps to reduce fire risk. The merged recommendations package provides a consolidated set of recommended actions (labelled A–Q) with relevance across stakeholder groups, and tailored recommendation sets for authorities/communities, policy makers, tourism associations, firefighters, and forest owners.

Table 2. Summary of recommendations (A-Q) and their relevance for different stakeholder groups

Recommendation	Stakeholder group				
	Authorities / Communities	Policy makers	Tourism associations	Firefighters	Forest owners
A. Use education and communication to increase fire literacy and preparedness	X	X	X	X	X
B. Use 2.0 Warning tools (e.g. selected cellphone warning messages)	X	X	X	X	X
C. Harmonize sectoral policies and foster interdisciplinary cooperation to reduce conflicts	X	X	X	X	X
D. Learn to live with fire and embrace its role	X		X	X	X
E. Include community members in fire prevention	X			X	X
F. Learn/train extreme fire scenarios at the WUI				X	X
G. Use information on suppression efficiency and response capacity to guide planning	X	X		X	X
H. New firefighting techniques (e.g. less water)		X		X	
I. Identify high-risk areas	X				X
K. Fuel management (buffer zones, fuel reduction, grazing)	X				X
M. Fuel management (prescribed burning)	X	X		X	X
N. Use adapted and resilient tree species	X	X			X
O. Keep access routes in the forest clear	X				X
P. Shift money from firefighting to fire prevention	X	X			X
Q. Foster compact urban development	X	X			

Key themes include education and communication, warning tools and information exchange, cross-sector coordination, risk-informed planning and preparedness (incl. WUI considerations), fuel management options where appropriate, resilient forest management measures, maintaining access routes, and prevention-oriented prioritization and financing.

Below are the project activities and achievements highlights:

– Austria-wide wildfire risk map at 1 km resolution. A core project highlight is the delivery of Austria-wide wildfire risk mapping at 1 km resolution under historical conditions and multiple future climate scenarios, producing spatially explicit outputs using Austria-specific input datasets and with improved core modelling components to better improve the pattern predictions and projections. The outputs provide a national basis to identify where wildfire risk is likely to be more relevant over time and support longer-term planning.

– High resolution fire risk study focused on Lower Austria. Beyond national mapping, the project delivered a 250 m fire risk study focused on Lower Austria, including a stochastic simulation approach. This highlights the benefit of finer spatial detail for identifying localized hotspots and for understanding how input heterogeneity can influence spatial patterns compared to smoother national-scale outputs.

– Improved representation of human-caused ignitions and tourism related risks. A key project highlight is the improved representation of human-caused ignition drivers in the modelling workflow. Instead of relying mainly on population density, the project used a broader set of socio-economic and infrastructure variables together with historical human-caused fire data to derive a more detailed ignition probability layer for Austria. In addition, the project linked fire ignition danger with tourist routes through a spatial overlay analysis, allowing the identification of areas where elevated ignition danger coincides with high recreational use. This provides a practical basis for targeted prevention and visitor-oriented risk communication.

- First parameterization of FLAM in Austria. The project strengthened the national suitability of the FLAM by using Austria-specific input datasets and improving core modelling components to better reproduce observed patterns. A key methodological highlight is the enhanced treatment of suppression efficiency and model calibration/validation using Austria's historical period. This enabled the production of calibrated Austria-wide wildfire risk maps under historical and future climate scenarios and represents a key methodological step from generic wildfire modelling toward an Austria-specific modelling framework.
- This study is possibly one of the first in Central Europe and the first in Austria to investigate forest fire risky behaviours, climate change-related beliefs toward forest fire danger and the acceptability of preventive forest fire measures among recreationists in a heavily used alpine area that was recently affected by a large forest fire. This study extended previous research on social factors on human-caused ignition by providing a case study in a country where wildfires are less common.
- Stakeholder's input and knowledge exchange on the project results. AFF placed emphasis on stakeholder involvement and translation of results into actionable recommendations. A key highlight is the final stakeholder exchange and the delivery of a consolidated recommendations package for the key target stakeholder groups
- Strong dissemination and visibility of project outputs. The project results were disseminated through conference presentations, scientific publications, and public communication activities. This includes presentations at major events like FOBI2025 where we reached a practitioner audience from the Austrian Fire Service, peer-reviewed publications linked to project methods and datasets, and media visibility including regional and national Austrian news coverage. This dissemination helped increase the visibility of project results among scientific, policy, and practitioner audiences.
- Access to the project results by forest fire experts and forest managers through waldbrand.at. Experts from fire brigades, forest authorities and state warning centres in Austria can access selected outputs from the AFF project via the integrated fire danger assessment model hosted under waldbrand.at. Currently, there are around 150 active users from different institutions all over Austria.
- Strong national experts' collaboration. A key project highlight is the close collaboration between three established Austrian research partners, combining expertise in wildfire modelling, climate/fire-weather analysis, forest and fuel science, and social research on recreation behaviour, to address wildfire risk in Austria in an integrated way.

5 Conclusions and Recommendations

(Max. 5 pages)
Description of the key project results. What conclusions can be drawn from them, and what recommendations can be made?

- *Fire risk is increasing under climate change particularly in certain areas (hotspots) (D3).* Across the national simulations and scenario projections, wildfire risk increases toward the end of the century in most scenarios, and the spatial signal repeatedly highlights provinces and zones that require particular attention (notably Niederösterreich and Tirol, with additional increases in Kärnten, Burgenland and Salzburg). These supports treating wildfire risk as a growing, spatially differentiated climate impact rather than a rare anomaly.
- *Fire risks and hotspots are driven by climate, fuel, topography and human activity (D2 and D3).* The project confirms that wildfire risk cannot be explained by weather or climate alone. The modelling framework and supporting datasets developed in WP2 and WP3 show that risk patterns depend on the interaction of meteorological conditions (including FFMC-based fire weather indicators), fuel availability and fuel type, forest structure, topography, and human-related ignition drivers.
- *Tourism and recreation are relevant factors as ignition (D4 and D5).* Our analysis demonstrates that proximity to touristic facilities and infrastructure, particularly secondary roads, transregional routes, and cable cars corridors, is a key socio-economic driver of forest fire danger in Austria. Human accessibility and recreational pressure concentrate ignition sources, aligning with evidence that over 85% of forest fires in Austria are human caused.
- The study included local residents, day and overnight visitors and covered different on-site activity groups displaying different risky behaviours at different locations during the fire danger seasons to capture the most representative sample possible for that topic. It found that heterogeneity among recreationists regarding their acceptance of preventive forest fire measures exist: Climbers, for example, exhibited increased risky behaviour, low risk awareness, and were less accepting measures that restrict recreational activities.
- *FLAM integrated approach and uncertainty in future projections driven by climate change scenarios* The FLAM integrated modeling approach combines datasets provided by project partners based on their respective expertise. These include information on fuel available for burning, forest structure, human ignition probabilities, and climate variables related to fire danger. By integrating these components within a unified framework, FLAM enables a comprehensive assessment of wildfire risk under both current and future conditions. The results demonstrate the spatial distribution and quantitative magnitude of potential burned areas under future climate scenarios. The projections illustrate how wildfire risk and burned areas may evolve over time and identify regions where vulnerability is expected to increase. Uncertainty in the analysis is addressed through the use of multiple daily climate projections that were downscaled for Austria and represent different plausible climate pathways. This ensemble approach captures the range of possible future developments in fire regimes and enhances the robustness of the results for risk assessment and planning purposes.
- *Bias in climate scenarios.* The climate scenarios used are based on Euro-Cordex models driven by CMIP-5 generation global models. The entire scenario

ensemble shows insufficient warming in Austria in particular for the period from 1980 to the present day. This underestimation of climate sensitivity will have a particular impact in the near future, meaning that a significantly faster development is to be expected, especially by the middle of the century, and that the warmest scenario for this period is the most likely.

- *The project results are operationally relevant as the they were translated into stakeholders-oriented outputs.* The project translated modelling and mapping outputs designed into practical use, including the policy recommendations and integration of results into the waldbrand.at platform. This supports the project's core objective of improving accessibility and understanding of wildfire risk information by different stakeholders.

Recommendations for further steps: Globally, warming is accelerating; in Central Europe and the Austrian Alps in particular, the historical rate of increase has been three times faster than the global average. Consequently, local warming has been significantly more pronounced over the past 50 years than assumed in regional climate scenarios. Although we used the best available high-resolution climate data and projections for Austria, our results are based on current climate projections and therefore do not fully reflect possible future impacts. The climate projections used are regionally adapted to Central European conditions; however, they currently do not accurately reflect the ongoing temperature changes in the Earth's atmosphere, oceans, land surface, and ice, and underestimate historical and possibly future trends. This is often referred to as "cold bias" in the climate modeling community. This "cold bias" leads to an underestimation of the FWI indices. For the interpretation of the results, this means that the trends over the next two decades are systematically underestimated and that the actual trends will unfold more rapidly. The latest regional climate projections based on EURO-CORDEX and driven by CMIP-6 global models will not be made publicly available until 2026. Once available, this should be integrated in future work to refine the projections of burned areas and hotspots.

The consortium intends to build on the completed outputs and explore a follow-up project to further develop and apply the approach as new and updated input data become available. This would include maintaining and further improve input data and validation, strengthen transfer into practice. In parallel, the updated projections of potential burned area under climate change scenarios provide a foundation for assessing forest damage, wildfire-related greenhouse gas emissions, and implications for carbon accounting. They also enable preliminary evaluation of potential impacts on wood supply and forest-based value chains, offering a basis for further analysis in future projects.

Target groups that can draw relevant and interesting conclusions from the project results

- Authorities and municipalities can use hotspot maps and scenario-based insights to support local/regional prevention planning, WUI-related measures, infrastructure/access planning, and coordinated preparedness across sectors.
- Policy and decision makers can draw conclusions for longer-term policy and funding priorities, including harmonised warning systems, cross-sector strategy alignment (forestry, land use, environment, tourism), and shifting emphasis from suppression to prevention and preparedness.
- Tourism actors (tourism associations, destination managers, site managers) can use the tourism case-study insights to strengthen multilingual risk

communication, targeted warnings/signage in high-use areas, and cooperation with municipalities/forest owners to reduce ignition risks linked to recreation.

- Fire services and emergency responders can use the results to inform preparedness, training for extreme scenarios (including WUI), and discussions on where accessibility/logistics may constrain response, supporting prioritisation of operational improvements in higher-risk areas.
- Forest owners and forest managers can use the outputs to support risk-informed forest management and fuel-related measures (where appropriate), maintain access routes, and coordinate with authorities and fire services in higher-risk zones.
- Research and technical agencies can continue developing and updating risk assessments, modelling, early-warning approaches, and evaluation of suppression effectiveness and accessibility indicators, and support transfer of methods into planning and practice.

C) Project details

6 Methodology

(max. 10 pages)
Justification and description of the chosen research approach.

The wildfire risk in Austria is driven by interacting biophysical and human factors and therefore cannot be represented by climate/fire weather alone. For this reason, the Austria Fire Futures (AFF) combined Austria-specific datasets on fire weather and climate, fuels and forest structure, and human ignition drivers with wildfire modelling, spatial hotspot mapping, a tourism-focused case study, and structured stakeholder exchange. Across work packages, the project followed a consistent workflow: (i) Data identification, access, and harmonisation as input datasets; (ii) Model integration and parameterization for Austrian conditions.; (iv) Multi-scale hotspot mapping including national (1 km) and regional (250 m) mapping outputs under historical and future climate scenarios; (v) Assessment of the human dimension of ignition through tourism infrastructure mapping and an on-site recreation survey; and (vi) Results consolidation and synthesis for policy recommendations and make the results accessible through an existing platform.

WP1 focused on coordination and quality control across partners and work packages and established the organisational basis for data exchange, reporting, and joint synthesis. The project relied on regular coordination between partners to align datasets, modelling inputs, deliverables, and reporting deadlines. Shared coordination structures were used to manage ongoing communication, clarify roles and dependencies between tasks, and support collaborative report writing and dissemination planning.

Compilation and processing of core datasets

The methodological focus was harmonization to ensure that variables from different sources were made spatially and temporally consistent for modelling at national and regional scale.

For the climate and fire-weather inputs, daily meteorological variables were processed, bias-adjusted and downscaled to 1×1 km for Austria and 250×250 m for Lower Austria to derive gridded wind speed and FFMC data. Inputs were prepared for the historical period and for five climate-model scenarios used for future projections. Future meteorological forcing was based on CMIP5 EURO-CORDEX regional climate model simulations (~10×10 km). Five models were selected to represent a plausible range of conditions (dry, summer-dry, and more average). Results were analysed using a Global Warming Level (GWL) approach, comparing time slices when global mean temperature reaches approximately 2°C and 3°C above pre-industrial.

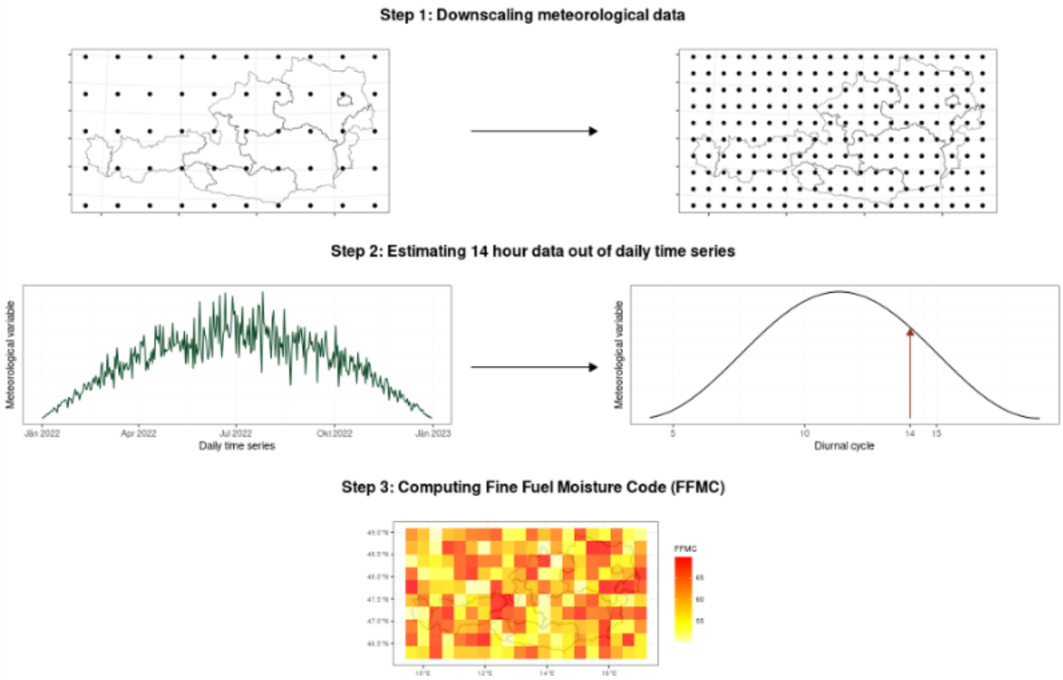

Figure 24**:** Graphical representation of the workflow – (i) statistical downscaling of the meteorological input data (Lehner et al., 2023), (ii) estimating 14-hour values out of daily time series of the specific variables and (iii) calculation of FFMC.

Historical temperature forcing was based on the SPARTACUS gridded dataset (daily maximum and minimum temperature at 1×1 km). Because 14:00 temperature is not available as a gridded Austrian variable, AFF approximated 14:00 temperature by scaling daily maximum temperature using station observations. The scaling factor was computed as:

$$SF_{temperature} = \frac{T_{max} - T_{14}}{T_{range}},$$

(T_{max}–T_{14}) and the daily temperature range (T_{max}–T_{min}), averaged for each day of year at each station (using stations with continuous records for 2011–2020 to avoid inhomogeneities). A spatio-temporal generalized additive model (GAM) was then fitted to represent (i) the seasonal cycle (cyclic spline), (ii) spatial variation (using a kriging/Gaussian-process structure on station coordinates), and (iii) a space–time interaction term. The fitted model was evaluated via spatial and temporal cross-validation and then applied to estimate 14:00 temperature for 1981–2020 on both grids (1 km and 250 m).

For the 250×250 m Lower Austria grid, daily maximum temperature was downscaled using (i) local regression with altitude to represent complex terrain and (ii) a topographic correction for sunny/shady slopes using a multiple regression framework, where daily wind speed and global radiation served as predictors of the daily temperature range. Regression coefficients were computed for three altitude bands (0–900 m, 900–1400 m, >1400 m) and interpolated across bands. For daily minimum temperature, only the altitude-based local regression step was applied.

Historical daily precipitation was taken from SPARTACUS (1×1 km) and downscaled to 250×250 m for Lower Austria using a local regression approach with altitude as predictor (analogous to the minimum/maximum temperature downscaling step).

Relative humidity was derived from station data by interpolating dew point temperature (because relative humidity can be computed from dew point and temperature). Stations were selected from the GeoSphere data hub with a minimum record length of 10 years. Time series were checked for change points using the Standard Normal Homogeneity Test (SNHT). When change points were detected, earlier parts of the time series were corrected. Because SNHT mainly targets shifts in the mean, quantile mapping was additionally applied to adjust higher-moment differences. For daily interpolation, Austria was separated into three climatological regions; in each region, a piecewise non-linear regression model was fitted separately for each day, and residuals were interpolated using 3D inverse distance weighting.

Mean daily wind speed was interpolated using a similar workflow (station selection with ≥10 years, change-point detection/correction). Monthly climatologies were computed for 2009–2021, and ridge regression was used to fit the climatologies using elevation and additional topographic variables. Daily residuals were interpolated using 3D inverse distance weighting, yielding gridded daily mean wind speed. To obtain 14:00 wind speed, AFF computed a daily scaling factor as the ratio between 14:00 wind speed and mean daily wind speed from hourly station data (2010–2020). The day-of-year scaling factor was modelled with a spatio-temporal GAM (including kriging/Gaussian-process spatial structure) and then applied to convert daily mean wind speed to 14:00 wind speed for both the historical period and scenario forcing.

In WP2 as well, we assembled and processed socio-economic and infrastructure data to support modelling of human-caused ignitions in Austria. The database contains 9 layers and 21 original variables, expanded to 65 processed variables. Data sources include BML, BFW, Statistik Austria and BOKU. The common projection used was EPSG:31278 (MGI / Austria Lambert). Most processed outputs were produced at 100×100 m resolution.

A tiered workflow was implemented to derive a national human ignition probability layer that could be integrated into FLAM. In Tier 1, the national fire dataset was filtered to include only human-caused fires with location uncertainty ≤500 m, resulting in 1,232 ignition points. Predictor layers were selected to represent human accessibility and activity, including buildings/residents layers and multiple transport and recreation networks (e.g., alpine/forest roads, other roads, cycling and hiking trails, cable cars, local/regional/transregional/highway networks, supplementary and main railways, and forest roads from BFW).

To represent location uncertainty, each ignition point was buffered using its reported uncertainty (buffer radii between 50 m and 500 m), defining a plausible fire occurrence zone ("fire buffer"). Infrastructure predictors were buffered by 10 m to represent the zone of highest ignition relevance when overlapping forest. Each buffered infrastructure layer was rasterised at 10×10 m resolution. A national 100×100 m grid was then created and clipped to each fire buffer area; within each grid cell, the number of 10×10 m pixels of each predictor was counted (and stored as predictor intensity/relative-share metrics). Building variables were rasterised to 10×10 m but not buffered because they are originally provided on a 100×100 m grid; their raster cells were counted analogously.

To build a presence–absence dataset for modelling, an equal number of non-fire points (n=1,232) was randomly generated, and the exact same buffering, gridding, rasterisation and pixel-count extraction workflow was applied. Logistic regression was then used to model the probability of fire occurrence (fire vs. no-fire) from the predictor set. Models were fitted in R. Multicollinearity was assessed using Variance Inflation Factor (VIF); predictors with VIF > 10 were excluded. Model performance was evaluated using ROC curves and AUC. The final model was applied spatially to compute ignition probability in pixels where significant predictors intersect forest areas, producing a national ignition probability map.

In Tier 2, ignition probability and significant predictors were aggregated from 100×100 m to 1×1 km to align with national-scale modelling. Mean values were computed within INCA grid cells using zonal statistics, producing a 1 km ignition probability layer. For presentation and categorisation, the resulting 1 km layer was classified into five classes using natural breaks. For scale transformation of key raster predictors, bilinear interpolation was used for upscaling and B-spline methods were used for downscaling.

Fuel availability was represented through fuel-load layers. AFF implemented a fuel module that builds on the FirEUrisk fuel framework and adds Austria-specific refinement using high-resolution tree species mapping, satellite information, and field/literature inputs. Forest structure layers (e.g., canopy cover and tree species distribution and related products) supported the fuel representation and interpretation of spatial patterns. The resulting system comprised 13 forest fuel types and supported improved representation of fuels for modelling and mapping.

FLAM Description

The wildfire climate impacts and adaptation model (FLAM) utilizes a process-based fire parameterization algorithm to capture the impacts of climate, fuel availability, topography, and human activity on wildfire frequency, probability, and resultant burned areas and emissions. FLAM requires variable data to establish historical, current, and (in the case of projections) future wildfire dynamics. The modular nature of FLAM allows for the inclusion of additional fire-related input variables or factors into probabilistic algorithms as needed to capture local and regional fire ignition and burned area characteristics. It is run on a daily time-step and can be applied at various temporal and spatial scales, with output resolution determined by the resolution of available input data.

Initial FLAM results are analyzed to assess the accuracy of FLAM in modelling burned areas as compared to actual burned areas. FLAM is calibrated by harmonizing the monthly and yearly number of burned pixels between actual and modelled burned areas, then by adjusting standard parameter values to increase the number of correctly identified pixels. FLAM is validated by testing its accuracy in modelling burned area for a validation period. A schematic of the FLAM workflow can be found in Figure 1. An important calibration parameter is suppression efficiency in each pixel, determined as the probability of extinguishing a fire within one day. Calibrated suppression efficiency maps can help identify hot spots for fires and burned areas across the study area.

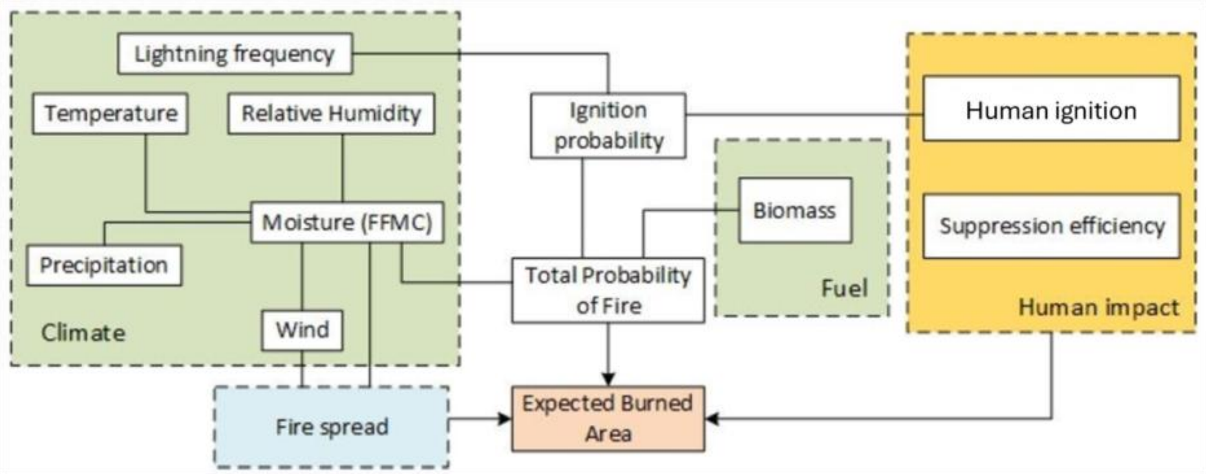

Figure 25. Schematic overview of FLAM.

Based on the data made available by project partners and the results described in Deliverables 2.1 and 2.2/3.1, in addition to the typical input variables described above, several novel variables were used for fire modelling in this project.

Daily weather data were kept consistent to the variables described in section 2.2 in the form of daily FFMC and wind speed, and lightning strike data as provided by BOKU-MET and BOKU-WALDBAU, respectively. These data include historical values as well as future (projected) values under the chosen climate change scenarios at resolutions of 1km x 1km (Austria-wide) and 250m x 250m (Lower Austria). More information on the climate change scenarios to be used and methodology for their production can be found in Deliverable 2.1.

For fuel, the results of the new fuel module (Deliverable 2.2/3.1) were used in conjunction with additional data provided by BFW. The results from D2.2/3.1 include fuel load values across Austria calculated based on improved remote sensing data and ground-truth case study data (more information available in D2.2/3.1). In addition, BFW provided data related to canopy cover (percentage of pixel covered by forest canopy).

In place of calculating ignition probability based on population density, an ignition probability map (0-100) was produced as part of D2.2/3.1. This map provides the probability of ignition based on significant socioeconomic risk factors, such as road density/nearness to roads, primary and secondary dwellings, population density, and railways.

For improved calculation of suppression efficiency, a map was generated of firefighting response time to each pixel in the event of a fire, based on actual locations of Austrian firefighting resources and actual (observed) response times. This will be used to improve the calibration and validation of the suppression efficiency values calculated by FLAM.

The variables and their sources are summarized in Table 3.

Table 3. Variables used by FLAM in AFF.

Variable	Unit/Description	Frequency	Source
Fine Fuel Moisture Code (FFMC)	Moisture content of fuels, numerical (0-101)	Daily	BOKU-MET
Wind speed	Km/h	Daily	BOKU-MET
Canopy cover map	Share of pixel in canopy	Once	BFW
Fuel load	tC/ha	Once	BOKU-WALDBAU
Ignition probability map	Ignition probability (0-100) based on significant socio-economic risk factors	Once	BOKU-WALDBAU
Observed burned area	Fire burned area/sums, daily/monthly	Daily/monthly	BOKU-WALDBAU
Topography	Slope	Once	
Population map	People/km2	Once	CIESIN

As part of the development in Deliverables D 2.2, a more sophisticated method was applied for estimating Human Ignition probability (Ph) incorporating socioeconomic factors such as dwellings, road, and population density. This allowed for a more comprehensive representation of anthropogenic ignition risk. Regarding fuel data, fuel load map introduced in Deliverables D 2.2 and D 3.1 was employed. This map was derived from improved remote sensing datasets and validated through ground-truth case studies. Additionally, the fraction of canopy cover map, provided by BfW, was integrated to support a detailed analysis of forest fire behavior.

IIASA has developed an enhanced treatment of suppression efficiency using a segmentation-based approach that groups areas by spatial adjacency and similarity of biophysical features, applies monthly calibration to reflect seasonality, and ensembles across segmentation variants to reduce sensitivity to any single grouping. Model performance was assessed using the historical fire data with calibration in 2006–2015 and validation against 2001–2005 and 2016–2021. Using the calibrated framework, WP3 produced Austria-wide wildfire risk maps at 1 km resolution under historical and future climate scenarios. Outputs included ignition probability, suppression-related outputs (reported as expected fire duration for interpretability), and burned area.

WP5 delivered a 250 m implementation for Lower Austria using 30 stochastic realisations per year to represent interannual variability and to allow interpretation of wildfire risk as a distribution rather than a single deterministic outcome. Extreme years were identified using the same threshold definition as in the national workflow (Q3 + 1.5×IQR). This higher-resolution setup allowed finer representation of local heterogeneity compared to the national 1 km mapping and supported more detailed hotspot interpretation.

Human dimension of ignition

The methodological aim was to represent recreational pressure and ignition-relevant behaviour through a combination of (i) GIS-based inventories and hotspot analyses and (ii) an on-site visitor survey.

GIS-based inventories (D4.1) recorded tourism infrastructure and spatial patterns of use between 2022 and 2023. Mapped features included mountain huts, the trail network, viewpoints and sights, parking lots, gravel banks along the Schwarza River, and major access infrastructure such as the Rax cable car and the Schneeberg railway. Visitor-use traces with potential ignition relevance (e.g., cigarette butts, broken glass, campfire residues) were recorded during multiple field visits in 2023. All observations were transferred into GIS for spatial analysis. Tourism-use distribution was derived from existing on-site survey information and OpenStreetMap-based network data; use intensity along the trail network was implemented in ArcGIS Pro.

Hotspot analyses combined indicators of visitor frequency and tourism facilities to identify priority recreation areas. Based on the initial hotspot analyses, four tourism hotspots were highlighted: (i) the Rax cable-car top station area including the Ottohaus, (ii) the Schwarza River corridor between the cable-car bottom station and Kaiserbrunn, (iii) the Edelweißhütte–Waxriegelhaus area, and (iv) the Weichtalhaus area.

The on-site visitor survey (D4.2) assessed awareness and perception of forest fire risk, self-reported risk behaviour, and acceptance of preventive measures. The questionnaire was aligned with project partners and local stakeholders, and ethics approval was obtained prior to implementation. Data were collected at 12 predefined survey locations during July–early October 2023. In total, 927 questionnaires were collected; after plausibility checks and quality screening, 905 questionnaires were retained for analysis.

Survey data were analysed using the SPSS statistical package, applying descriptive statistics and inferential tests including chi-square tests, t-tests, ANOVA, Kruskal–Wallis tests and correlation analysis. The analysis covered visit characteristics (e.g., activity type, visitor group), risk perception and climate-change expectations, knowledge and information levels, and acceptance of management measures. This empirical component provided evidence to interpret the human dimension of ignition risk and supported prevention and communication recommendations.WP5 focused on making results usable through platform preparation and a regional high-resolution mapping application. The national map provides strategic screening, while regional applications at higher resolution improve local interpretability. The platform ensures that scientific outputs can be accessed and used beyond the project team.

To identify where tourism overlaps with elevated ignition danger, tourism activity layers were spatially aligned with ignition danger layers (Austria Lambert 31278) and combined in a grid-based overlay. The resulting indicator ranged from 0 (no overlap) to 3 (high overlap) and highlighted high-use areas where recreational activity coincides with elevated ignition danger.

Project outputs were prepared for use within the existing web platform context (waldbrand.at), supporting access by practitioners (e.g., fire brigades, forest authorities, warning centres).

WP6. AFF aimed not only to generate maps but also to support decision perspectives. Stakeholder exchange was therefore used to validate relevance, interpretability, and implementation needs, and to compile recommendations in a format suitable for key user groups. The original set of three WP6 recommendation deliverables was consolidated into a single, integrated recommendations package to reduce overlap and improve usability for the target audience.

7. Work and time schedule

(max. 1 page)
Brief overview of the work and time schedule (no details).

The deviations in the work and timeline schedule are related to Section 2.2.4 and 2.2.6. In particular, the deviations affecting WP1 and WP6 are linked to coordination and scheduling constraints across partners and external stakeholders. The deviations affecting WP2 and WP3, and parts of WP5, are linked to dataset exchange/preparation issues and the need to address specific input limitations, including fuel-related requirements. The approved project extension and its implications for final consolidation which covered parts of the deviations on WP6.

month #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
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8 Publications and dissemination activities

Tabular list of scientific publications resulting from the project, as well as other relevant dissemination activities .

Various publication and dissemination activities were carried out to communicate project results to the scientific community and relevant stakeholders. These activities included peer-reviewed journal publications as well as oral and poster presentations at national and international conferences. Topics that were focused on include climate-driven wildfire risk, wildfire hot spot mapping, integrated fire danger assessment, fuel flammability in Alpine Forest ecosystems, and large-scale tree species mapping.

Events where the project related topics were presented include European Geosciences Union (EGU) General Assembly in 2023 and 2024, the 24th Österreichischer Klimatag in 2024, the 26th International Union of Forest Research Organizations (IUFRO) World Congress in 2024, the European Space Agency (ESA) Living Planet Symposium in 2025, and Wildfire 2023. In addition, further contributions were submitted for this year including the 21st Symposium on Systems Analysis in Forest Resources (SSAFR2026) and EGU 2026. In addition to scientific publications and conference presentations, the project also achieved media visibility and direct outreach to practitioners and stakeholders. Project results and key messages were featured in media outlets including ORF Niederösterreich, ORF ON, APA-Science, Forstzeitung, IIASA News, and BFW communication channels, helping convey the project results and show wildfire risk related issues to a broader audience. The Austria Fire Futures Final Stakeholder Workshop, held at IIASA on 28 October 2025, further supported dissemination by bringing together scientists, policymakers, practitioners, and other stakeholders to discuss project results and their practical implications for wildfire prevention, forest management, and climate adaptation. In addition, Florian Kraxner presented the project results in the FOBI 2025 of the Niederösterreichischer Landesfeuerwehrverband in Tulln on 7 November 2025, in a session on "Waldbrandgefahr – Klimawandel – Maßnahmen," to an audience of fire service leadership and practitioners. This broadened the transfer of project knowledge beyond academia to operational wildfire and emergency-response stakeholders. Below is the list of the publications and dissemination activities:

- Corning, S.; Krasovskiy, A.; Kiparisov, P.; San Pedro, J.; Viana, C.M.; Kraxner, F. Anticipating Future Risks of Climate-Driven Wildfires in Boreal Forests. Fire 2024, 7, 144. https://doi.org/10.3390/fire7040144
- Krasovskiy, A., Jo, H.-W., Vacik, H., Silva Andrade, M., Formayer, H., Laimighofer, J., Arnberger, A., Schadauer, T., Müller, M., Park, E., San-Pedro, J., and Kraxner, F.: Wildfire Hot Spot Mapping in the Alps - Austria Fire Futures, EGU General Assembly 2026, Vienna, Austria, 3–8 May 2026, EGU26-19168, https://doi.org/10.5194/egusphere-egu26-19168, 2026.
- Kraxner, F., Krasovskiy, A., Kottusch, C., Corning, S., Schepaschenko, D., Vacik, H., Neumann, M., Mueller, M., Arnberger, A., Formayer, H., Leidinger, D., Schadauer, T., Karel, S., and Bauerhansl, C.: Wildfire Hot Spot Mapping - Austria Fire Futures, EGU General Assembly 2023, Vienna, Austria, 23–28 Apr 2023, EGU23-9805, https://doi.org/10.5194/egusphere-egu23-9805, 2023.

- Kraxner, F. et al. (2024) Austria Fire Futures (AFF): Integrated Future Wildfire Hot Spot Mapping for Austria. Poster presented at the 24th Österreichischer Klimatag, Vienna, Austria, 2–4 April.
- Kraxner F, Krasovskiy A, Corning S, Shchepashchenko D, Shvidenko A, Vacik H, et al. Wildfire Hot Spot Mapping in the Alps - Austria Fire Futures. In: IUFRO , editor. Forests & Society Towards 2050. 26th IUFRO World Congress - Book of Abstracts [Internet]. IUFRO International Union of Forest Research Organizations; 2024. Available from: iufro2024.com/wp-content/uploads/iufro2024abstracts.pd
- Müller, M; Silva Andrade, M; Neumann, M; Kaiser, G; Immitzer, M; Atzberger, C; Formayer, H; Rieder, H; Hollaus, M; Kraxner, F; Krasovskiy, A; Corning, S; Bauerhansl, C; Karel, S; Schadauer, T; Vacik, H 2024 - An integrated fire danger assessment system for mountain forests with high resolution vegetation data 26th IUFRO World Congress 2024
- Park, E., Jo, H.-W., San Pedro, J., Krasovskiy, A., Silva Andrade, M., Müller, M., Vacik, H., Schadauer, T., Laimighofer, J., Formayer, H., & Kraxner, F. (2026). Future wildfire risk in Lower Austria under climate change: A stochastic simulation approach [Abstract submitted]. 21st Symposium on Systems Analysis in Forest Resources (SSAFR2026), San Sebastián / Donostia, Basque Country, Spain, 17–21 May 2026.
- Schadauer, T. et al. (2025) Large-scale Sentinel-2 tree species mapping: Independent probability sample validation and mixed-species classifications. Poster presented at the ESA Living Planet Symposium 2025, Vienna, Austria, 23–27 June.
- Schadauer, T.; Karel, S.; Loew, M.; Knieling, U.; Kopecky, K.; Bauerhansl, C.; Berger, A.; Graeber, S.; Winiwarter, L. Evaluating Tree Species Mapping: Probability Sampling Validation of Pure and Mixed Species Classes Using Convolutional Neural Networks and Sentinel-2 Time Series. *Remote Sens.* 2024, *16*, 2887. https://doi.org/10.3390/rs16162887
- Silva Andrade, M; Bortoli, M; Buchriegler, E; Dolleschka, M; Horna, T; Jagsch, N; Klumpp, AM; Koller, M; Müller, MM; Neumann, M; Zhou, M; Vacik, H A comparative study on characteristics of the fuel flammability of forest ecosystems in the Alpine region 26th IUFRO World Congress 2024
- Silva Andrade, M; Müller, M; Kuhnen, K; Vacik, H Relation between the distribution of fuel types and forest fires in Austria EGU General Assembly 2024
- Vacik H, Müller M, Vila Vilardell L, Hoang T, Mayer C, Mayr S, et al. State of knowledge, future challenges and options for an integrated fire management in the European Alps. In: AGIF (Regional and sub-regional coordination centers for integrated rural fire management) , editor. Conference Abstracts (online) [Internet]. 2023. Available from: https://www.wildfire2023.pt/
- Vacik H, Müller M, Silva Andrade M, Immitzer M, Dioszegi G, Atzberger C, et al. Improving an integrated fire danger assessment with high resolution vegetation parameters. In: AGIF (Regional and sub-regional coordination centers for integrated rural fire management) , editor. Conference Abstracts (online) [Internet]. 2023. Available from: https://www.wildfire2023.pt

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