

# SUPPLEMENTARY MATERIAL

Gonçalves et al., 2024. *Fostering post-fire research towards a more balanced wildfire science agenda to navigate global environmental change.* Submitted to MDPI *Fire* journal.

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# 1. Search strings for each wildfire stage

## 1.1. Criteria for categorizing wildfire stages

Search terms and expressions and the categorization of research papers broadly adapted the notions and concepts from the *Shared Wildfire Governance* framework (Tedim et al., 2020). In a nutshell, Tedim et al. outline the three critical stages of the wildfire continuum: before, during, and after, each critical to effective and adaptive wildfire management. The “before fire” stage focuses on prevention, preparedness, and risk reduction through ignition prevention, hazard identification, fuel management, (emergency) planning, vulnerability assessment, community readiness and fostering resilience by integrating local knowledge and shared governance. The “during fire” stage emphasizes real-time crisis management, operational coordination, balancing fire suppression with community safety through effective communication, advanced fire modelling/simulation, and evacuation analysis and support. The “after fire” stage centres on recovery and resilience, addressing losses in multiple aspects, rebuilding infrastructure to mitigate future risks, supporting ecosystem regeneration, and learning from the event to inform adaptive strategies.

Building on the framework proposed by Tedim et al. (2020), we expanded the stages to encompass specific areas, research themes, and topics in wildfire science beyond merely identifying actions associated with each stage—the primary focus of Tedim's paper (e.g., including fire regimes in the “before stage”, wildfire detection in the “during stage” and burn severity assessment in the “after fire” stage). This iterative process involved integrating (early) findings and enhancements from the systematic literature review, engaging in team discussions to refine each stage, and incorporating the team's expertise and knowledge across various wildfire science domains.

## 1.2. Aligning search strings with categorization criteria/Main workflow

The selection of search strings for each wildfire stage was based on the previously mentioned criteria with an additional preliminary scoping search and literature mapping. We carried out additional test searches in SCOPUS and Web of Science (WOS) engines to iteratively improve the search strings. At this stage, we also included exclusion terms in the search strings to obtain results more accurately related to our review goals, which focused on contemporary or recent studies and research on wildfires at the before, during and after stages that were mostly set up at the landscape or ecosystem levels.

We applied the search strings to the title field, the title plus the abstract fields and the title, abstract and keywords fields in each database to ensure that the choice of search field did not affect our estimates of the research volume in each stage.

The search expressions and terms presented in subsections 1.1, 1.2 and 1.3 are for the title field search, but the same search terms were used for the remaining fields.

Search terms were proportionally allocated to each stage, independent of the search field (i.e., title, keywords, abstract, or all combined) and post hoc filtering of scientific papers retrieved at each stage.

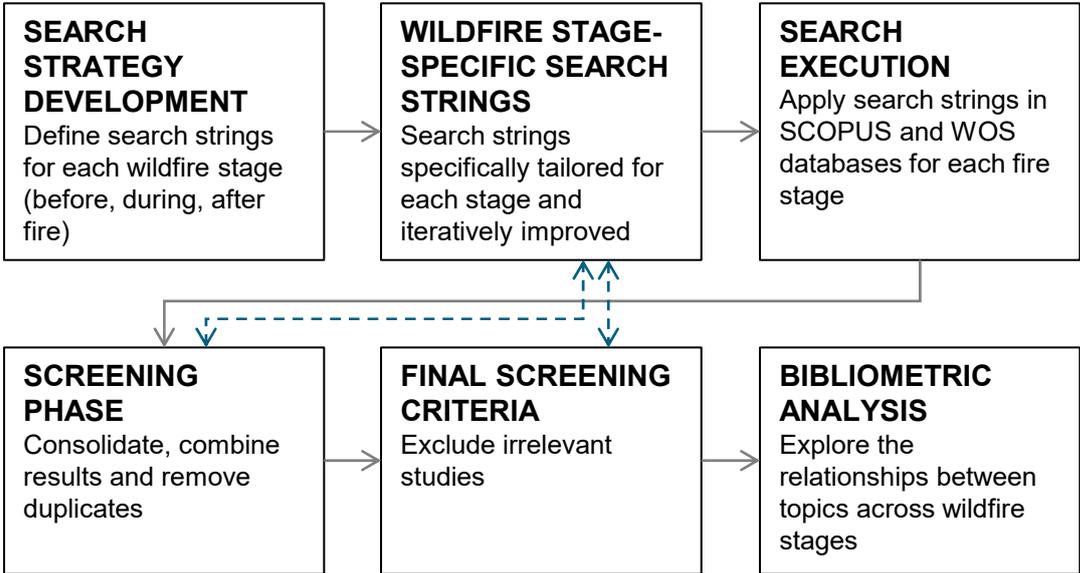


Figure S1. Main workflow for literature search for each wildfire stage.

### 1.3. Before fire search strings

#### **SCOPUS**

TITLE (("fire" OR wildfire OR "wildland fire\$" OR "forest fire\$" OR bushfire OR "rural fire\$" OR "desert fire\$" OR "peat fire\$" OR "vegetation fire\$" OR "veld fire\$" OR "prairie fire\$") AND (prevention OR planning OR management OR risk OR hazard OR weather OR treatment OR "prescribed fire\$" OR "prescribed burn\*" OR preparedness OR vulnerability OR prediction OR regionalization OR regime OR protection OR strateg\* OR "community preparedness" OR "community readiness" OR "preparedness drill" OR communication OR policy OR governance OR "fuel management" OR "fuel treatment" OR "controlled burn" OR "fire break" OR "defensible space") AND NOT (indoor OR building OR industr\* OR domestic OR tunnel OR road OR house OR enclosure OR ventilation OR foam OR "fire retardant\$" OR "flame retardant\$" OR "fire extinguisher\*" OR hydrocarbon OR polymer OR clothing OR patient OR injury OR tox\* OR occupational OR epidemiology OR medical OR clinical OR paleo\* OR holocene OR quaternary OR "evolutionary" OR "fire reconstruction\$" OR attitude OR belief OR "human behavior\*" OR perception OR emotion\* OR media OR insurance OR law OR galaxy) ) AND PUBYEAR > 1999 AND PUBYEAR < 2024 AND LANGUAGE ( english ) AND DOCTYPE ( ar )

#### **WOS**

TI= (("fire" OR wildfire OR "wildland fire\$" OR "forest fire\$" OR bushfire OR "rural fire\$" OR "desert fire\$" OR "peat fire\$" OR "vegetation fire\$" OR "veld fire\$" OR "prairie fire\$") AND (prevention OR planning OR management OR risk OR hazard OR weather OR treatment OR "prescribed fire\$" OR "prescribed burn\*" OR preparedness OR vulnerability OR prediction OR regionalization OR regime OR protection OR strateg\* OR "community preparedness" OR "community readiness" OR "preparedness drill" OR communication OR policy OR governance OR "fuel management" OR "fuel treatment" OR "controlled burn" OR "fire break" OR "defensible space") NOT (indoor OR building OR industr\* OR domestic OR tunnel OR road OR house OR enclosure OR ventilation OR foam OR "fire retardant\$" OR "flame retardant\$" OR "fire extinguisher\*" OR hydrocarbon OR polymer OR clothing OR patient OR injury OR tox\* OR occupational OR epidemiology OR medical OR clinical OR paleo\* OR holocene OR quaternary OR "evolutionary" OR "fire reconstruction\$" OR attitude OR belief OR "human behavior\*" OR perception OR emotion\* OR media OR insurance OR law OR galaxy)) AND (PY=(2000-2023)) AND (LA=(English)) AND (DT=(Article))

## 1.4. During fire search strings

### **SCOPUS**

TITLE (("fire" OR wildfire OR "wildland fire\$" OR "forest fire\$" OR bushfire OR "rural fire\$" OR "desert fire\$" OR "peat fire\$" OR "vegetation fire\$" OR "veld fire\$" OR "prairie fire\$") AND (detection OR activity OR behaviour OR spread OR growth OR monitoring OR simulat\* OR model\* OR suppression OR "effort allocation" OR firefight\* OR extinction OR operational OR dynamic OR exclusion OR control OR evacuat\* OR communication OR intensity OR fireline OR propagation OR "heat flux" OR "smoke dynamic\*" OR "smoke plume\*" OR "real-time" OR "early warning\*" OR "emissions" OR "interagency coordination" OR "alert system\*" OR "ground operation\*") AND NOT (indoor OR building OR industr\* OR domestic OR tunnel OR road OR house OR enclosure OR ventilation OR foam OR "fire retardant\$" OR "flame retardant\$" OR "fire extinguisher\*" OR hydrocarbon OR polymer OR clothing OR patient OR injury OR tox\* OR occupational OR epidemiology OR medical OR clinical OR paleo\* OR holocene OR quaternary OR "evolutionary" OR "fire reconstruction\$" OR attitude OR belief OR "human behavio\*" OR perception OR emotion\* OR media OR insurance OR law OR galaxy) ) AND PUBYEAR > 1999 AND PUBYEAR < 2024 AND LANGUAGE ( english ) AND DOCTYPE ( ar )

### **WOS**

TI= (("fire" OR wildfire OR "wildland fire\$" OR "forest fire\$" OR bushfire OR "rural fire\$" OR "desert fire\$" OR "peat fire\$" OR "vegetation fire\$" OR "veld fire\$" OR "prairie fire\$") AND (detection OR activity OR behaviour OR spread OR growth OR monitoring OR simulat\* OR model\* OR suppression OR "effort allocation" OR firefight\* OR extinction OR operational OR dynamic OR exclusion OR control OR evacuat\* OR communication OR intensity OR fireline OR propagation OR "heat flux" OR "smoke dynamic\*" OR "smoke plume\*" OR "real-time" OR "early warning\*" OR "emissions" OR "interagency coordination" OR "alert system\*" OR "ground operation\*") NOT (indoor OR building OR industr\* OR domestic OR tunnel OR road OR house OR enclosure OR ventilation OR foam OR "fire retardant\$" OR "flame retardant\$" OR "fire extinguisher\*" OR hydrocarbon OR polymer OR clothing OR patient OR injury OR tox\* OR occupational OR epidemiology OR medical OR clinical OR paleo\* OR holocene OR quaternary OR "evolutionary" OR "fire reconstruction\$" OR attitude OR belief OR "human behavio\*" OR perception OR emotion\* OR media OR insurance OR law OR galaxy) ) AND (PY=(2000-2023)) AND (LA=(English)) AND (DT=(Article))

## 1.5. After fire search strings

### **SCOPUS**

TITLE (("fire" OR wildfire OR "wildland fire\$" OR "forest fire\$" OR bushfire OR "rural fire\$" OR "desert fire\$" OR "peat fire\$" OR "vegetation fire\$" OR "veld fire\$" OR "prairie fire\$") AND (post-fire OR severity OR "burn severity" OR "burn\* area" OR recovery OR resilience OR regeneration OR restoration OR "impact assessment" OR "air pollution" OR "water pollution" OR "soil contamination" OR "soil erosion" OR "soil degradation" OR "biodiversity impact\$" OR "post-fire succession" OR "rebuild\*" OR "community impact" OR "community effect" OR "community recovery" OR "watershed" OR "flood\*" OR "fire effect\$" OR "stabilization" OR "salvage logging" OR "rehabilitation" OR "soil hydrophobicity" OR "fire scar\*" OR "hydrological impact\*" OR "water retention" OR "landslid\*") AND NOT (indoor OR building OR industr\* OR domestic OR tunnel OR road OR house OR enclosure OR ventilation OR foam OR "fire retardant\$" OR "flame retardant\$" OR "fire extinguisher\*" OR hydrocarbon OR polymer OR clothing OR patient OR injury OR tox\* OR occupational OR epidemiology OR medical OR clinical OR paleo\* OR holocene OR quaternary OR "evolutionary" OR "fire reconstruction\$" OR attitude OR belief OR "human behavio\*" OR perception OR emotion\* OR media OR insurance OR law OR galaxy)) AND PUBYEAR > 1999 AND PUBYEAR < 2024 AND LANGUAGE ( english ) AND DOCTYPE ( ar )

### **WOS**

TI= (("fire" OR wildfire OR "wildland fire\$" OR "forest fire\$" OR bushfire OR "rural fire\$" OR "desert fire\$" OR "peat fire\$" OR "vegetation fire\$" OR "veld fire\$" OR "prairie fire\$") AND (post-fire OR severity OR "burn severity" OR "burn\* area" OR recovery OR resilience OR regeneration OR restoration OR "impact assessment" OR "air pollution" OR "water pollution" OR "soil contamination" OR "soil erosion" OR "soil degradation" OR "biodiversity impact\$" OR "post-fire succession" OR "rebuild\*" OR "community impact" OR "community effect" OR "community recovery" OR "watershed" OR "flood\*" OR "fire effect\$" OR "stabilization" OR "salvage logging" OR "rehabilitation" OR "soil hydrophobicity" OR "fire scar\*" OR "hydrological impact\*" OR "water retention" OR "landslid\*") NOT (indoor OR building OR industr\* OR domestic OR tunnel OR road OR house OR enclosure OR ventilation OR foam OR "fire retardant\$" OR "flame retardant\$" OR "fire extinguisher\*" OR hydrocarbon OR polymer OR clothing OR patient OR injury OR tox\* OR occupational OR epidemiology OR medical OR clinical OR paleo\* OR holocene OR quaternary OR "evolutionary" OR "fire reconstruction\$" OR attitude OR belief OR "human behavio\*" OR perception OR emotion\* OR media OR insurance OR law OR galaxy)) AND (PY=(2000-2023)) AND (LA=(English)) AND (DT=(Article))

## 2. Screening phase

### 2.1. Main criteria

Due to the high number of search results for each wildfire stage, we used only the search for the title field in the following analysis to ensure the screening was feasible.

We joined the search results from SCPOUS and WOS for each fire stage and removed duplicates. We removed duplicates based on the title field using the R package 'revtools' (Westgate, 2019) automatic and manual screening functions. We also removed articles from 2024 since the year had not ended at the time of the database search.

We carried out an additional manual/supervised screening to remove non-relevant publications based on the title and, when necessary, the abstract.

In an initial assessment of the search results, we detected several articles about themes, topics or sub-areas considered non-relevant to the present review. These included numerous articles relating to indoor fires, infrastructures, transportation, buildings and materials science, fire safety, as well as organisms or biological structures that include the word "fire" in their common names (e.g., fire ant, fire blight).

Due to the lack of relevance to this review's objectives/goals, we excluded studies on the following topics:

- Construction and materials: joints, panels, cements, metals, alloys and plastics;
- Indoors, buildings, infrastructure or industrial fires and safety: indoor fires, road, tunnel, residential, care homes, hospitals and power plants;
- Industry: engines, machinery and coal mines;
- Fuel: oil tanks;
- Transportation: aircrafts, trains, automobiles, electric vehicles, ships, vessels and subway;
- Specific organisms or biological structures: Fire blight, fire ants, fire salamander and fire neurons;
- Clinical, medical, occupational or epidemiological studies (in a strict sense, since some observational studies on wildfire health effects were kept);
- Astronomy and geology: galaxy, planets, stars and volcanoes;
- Palaeontology and archaeology-related studies: Jurassic, Holocene and Quaternary, ar;
- Human perception, emotion, attitude or behavioural-related studies;
- Figurative use of the word "fire" in literary, economics or social studies;
- Law, legal or insurance-related studies.

A frequency analysis using the R bibliometrix package based on terms and n-grams (n<4) from titles allowed us to collect specific terms and expressions to streamline the removal of papers in the above-mentioned situations. Records identified through this method were manually screened to ensure appropriate exclusions.

## 2.2. Categorizing papers with search terms/expressions spanning multiple stages

In addition, specific/additional criteria were employed to check the relevance of a paper to each stage, given its title, context, and core objectives. This assessment was especially relevant in cases where broad/ample terms span two or all stages. We present our rationale for classifying the most relevant terms/expressions in that situation.

For broad and complex search expressions such as "fire weather", papers were classified according to the context and specific application of the term within the wildfire continuum. Examples are shown below.

Before stage: if "fire weather" is discussed in the context of guiding prescribed fire, forecasting medium- to long-term fire activity, or addressing issues related to prevention, preparedness, planning, or climate change, the paper is categorized in the "before stage".

During stage: if "fire weather" is used to anticipate, simulate, or predict the near-real-time behavior or rate-of-spread (RoS) of an active wildfire, the paper is classified in the "during stage". Similarly, if fire weather is used post hoc to ("forensically") assess the behavior, RoS, or emissions of wildfires—particularly large or extreme wildfires—these are also attributed to the "during stage" because they directly analyze conditions while the wildfire was active.

After stage: if "(post-)fire weather" is used to evaluate impacts in the aftermath of a wildfire, such as soil erosion, runoff, degradation, contamination, water quality/quantity, biodiversity impacts, or ecosystem recovery/regeneration, the paper is therefore classified in the "after fire" stage.

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For "prescribed fire", papers were also classified into the wildfire continuum stages based on the specific context and application of the term, as shown below:

Before stage: if "prescribed fire" is discussed as a tool for prevention, preparedness, or planning—such as managing fuel loads, reducing wildfire risk, or creating firebreaks—the paper is categorized in the "before stage". This includes studies on the design and implementation of prescribed fire measures, consequences or impacts, adequate fire-weather conditions or temporal window of application or effectiveness of prescribed fire in mitigating future wildfire impacts or as part of broader land management strategies.

During stage: if a research paper presents a study emphasizing evaluating, modelling, simulating, or predicting prescribed fire behavior or rate-of-spread, then the paper is classified as the "during stage". The same is true for studies encompassing research methods to investigate (post hoc), predict or anticipate emissions during the active use of prescribed fire.

After stage: studies that address prescribed fire through the lens of their effects, consequences or effectiveness on post-wildfire severity or that exclusively delve into the post-fire impacts on soil, biodiversity, ecosystem functions or services are classified as the "after stage".

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For a broad and multifaceted expression such as "climate change", papers were classified into the wildfire continuum stages based on the specific context and application of the term, as outlined below:

Before stage: if "climate change" is discussed in the context of understanding its role in altering fire regimes, increasing fire risk, influencing vegetation or fuel patterns, or informing long-term planning, prevention, or preparedness strategies, the paper is categorized in the "before stage." This includes studies on projections of future wildfire conditions due to climate change or strategies for mitigation and adaptation.

During stage: if "climate change" is addressed in the context of its influence on near-real time wildfire behavior, such as intensifying fire weather conditions (e.g., heatwaves, droughts, or wind patterns) during active wildfire events, the paper is classified in the "during stage." This includes studies that examine real-time or event-specific impacts of climate change on fire spread, intensity, or behavior.

After stage: if "climate change" is used to examine post-fire impacts or recovery processes, such as changes in ecosystem resilience, shifts in species regeneration patterns, or the long-term recovery of landscapes under altered climate conditions, the paper is classified in the "after fire" stage. This includes studies on how climate change influences erosion, water quality, carbon storage, or biodiversity following a wildfire.

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For adaptive/wildfire/fire/wildland fire management, we employed the following criteria to assess the relevance of these search terms/expressions to each stage:

Before stage: if management is discussed in the context of prevention, preparedness, or planning—such as developing strategies to reduce wildfire risk, applying prescribed fire, designing management approaches/frameworks based on evolving fire regimes (e.g., due to climate or land-use changes), community preparedness/readiness scenarios or incorporating lessons from past wildfires into planning for future scenarios—the paper is categorized in the "before stage." This includes studies on how adaptive strategies inform proactive measures like fuel management treatments or forest/land-use planning. The same applies to the preemptive assessment and management of known or projected wildfire risks.

During stage: if management in a broad sense is in the context of or targets active fire suppression or (near) real-time decision-making during a wildfire event, such as adjusting suppression tactics based on changing fire behavior, fire weather, development or use of simulation models or tools to evaluate fire behaviour or spread, address and allocate resources and their availability, manage and plan for communication issues or assess evacuation routes (also post hoc assessments), then the papers are classified in the "during stage". This mainly includes studies that focus on how adaptive management principles are/can be applied to manage active wildfires, using models or tools to simulate fire behaviour and spread (e.g., mechanistic or physically realistic models), or also training staff for engaging in real dynamic/active wildfires scenarios (e.g., virtual reality).

After stage: if management is examined in the context of post-fire recovery, rebuilding, learning, or adaptation, such as incorporating post-fire evaluations into future management practices, fostering ecosystem resilience, or addressing long-term socio-ecological or health impacts, the paper is categorized in the "after fire" stage. This

broadly includes research on how adaptive management contributes to recovery efforts and informs future wildfire management cycles.

### 3. Bibliometric analysis

The screened bibliographic datasets were then used for the bibliometric analysis using the R package 'bibliometrix' (Aria & Cuccurullo, 2017). We tested several of the bibliometric analyses available to understand the structure of each fire stage. However, we opted to focus on the more informative method (based on several tests performed at the time) based on co-word analysis. This analysis explores the relationship between topics in a research field using the written content of the publications, thus describing the conceptual structure of the field. We used a word co-occurrence network analysis based on author keywords to ensure feasibility, considering the high number of records and individual terms.

We iteratively improved the synonymization of terms to enhance network visualization. Some very generic terms, which do not hold informative value to understand the conceptual or thematic structure of each wildfire stage, such as terms regarding particular geographies (e.g., Mediterranean, USA, Australia, California, Sierra Nevada), species (e.g., ponderosa pine, Douglas fir, eucalyptus, lodgepole pine) or ecosystems/habitats (e.g., chaparral, forest, grassland, shrubland), were removed from the network mapping/development.

### Additional references

Aria, M., & Cuccurullo, C. (2017). bibliometrix: An R-tool for comprehensive science mapping analysis. *Journal of Informetrics*, 11(4), 959-975.

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Westgate, M. J. (2019). revtools: An R package to support article screening for evidence synthesis. *Research Synthesis Methods*, 10(4), 606-614.

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