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And it burns, burns, burns, the ring-of-fire: Reviewing and harmonizing terminology on wildfire management and policy

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ABSTRACT

In recent decades, extreme wildfire seasons worldwide have disrupted coupled human and natural systems owing to both changing climatic conditions and inadequate land and fire management policies. Given that wildfires are expected to become more frequent, the number of relevant scientific studies has also boomed in recent years. Simultaneously, shifts in fire management approaches have resulted in the development of new policies and vice versa. Originating from diverse fields, the terminology used in research and policy communities is far from consistent, which hinders science-based, up-to-date engagement between wildfire researchers and policymakers. Hence, this study aims to harmonize the terminology on key concepts and establish a typology for systematically classifying all wildfires and management actions observed in the literature. We conducted a scoping literature review and developed a cyclical analytical framework, called the ring-of-fire, drawing on cyclical conceptions of fire management and public policy, respectively. Consequently, we propose criteria for establishing a common dialogue between wildfire actors by providing a system for classifying actions and presenting a reference system for wildfire definitions. Furthermore, we present results by geographical regions regarding fire management actions and discuss the use of the "fire suppression" concept given its ambiguity. This review highlights the importance of consistent terminology in interpreting the differences between management actions and fire types. We hope that removing linguistic uncertainty in wildfire management-related concepts will result in a more rigorous use of the terms among scientists while also clarifying their use in communication between scientists, policymakers, and the broader public.

1. Introduction

Wildfires and societies have co-evolved over millennia, with fires also being a cost-effective management tool (Pausas and Keeley 2019a; Lecina-Díaz et al., 2023). However, wildfires pose significant challenges worldwide. To effectively manage its current and anticipated impacts, it is imperative to integrate actions into wildfire management, land use planning, and climate change adaptation policies (Canosa et al., 2023). Across countries, diverse policy approaches have been proposed targeting management actions at different stages of any fire event (Pandey et al., 2023). While there are countries that have focused on establishing policies aiming at avoiding fires, others have suggested actions for the control of fires or fuel loads. In some fire-prone ecosystems, zero-fire policies have been replaced by active fire management to mitigate large, high-intensity wildfires and the associated emissions as well as reduce high fire suppression costs (Martin-Fernández et al., 2002). Moreover, recent efforts have been made to restore burnt areas (Lopes et al., 2022; Scheper et al., 2021).

However, the complexity of wildfire management leads to the need of separated yet interconnected operational actions which require complex policy formulation (Nohrstedt and Bodin, 2020). These actions, normally interdependent and not always coordinated, call for diverse social structures to address multiple roles, from unmet social needs to fostering collective reflection upon newly revealed vulnerabilities (Rodríguez Fernández-Blanco et al., 2022). The involvement of both practitioners and researchers, alongside policymaking domains, adds complexity as different viewpoints and terminologies intersect. The objectives of a fire management organization are shaped by the social, economic, and political institutions governing it, thereby influencing fire's impact on people (Martell, 2015). Yet, social sciences contributions

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to wildfire research are still scarce (Rodríguez Fernández-Blanco et al., 2022), and there is a noticeable absence of a comprehensive overview that integrates both management actions and policy in relation to wildfire events.

Despite the current trend towards homogenizing the use of terminology in policy (Sande Silva et al., 2010), considerable differences exist in the terms used in English-language scientific literature, when describing fires in vegetated landscapes. Examples include terms like wildfire, forest fire, vegetation fire, bushfire, rangeland fire. These differences stem from various disciplines employing distinct terminologies and can arise due to specific research focuses, regional differences, or the contextual nuances surrounding the fire discourse (Tedim et al., 2018). This diversity in terminology is not limited to fire descriptions alone; it extends to classifications of management and non-management actions such as the term "fire suppression", interpreted differently across different contexts, limiting the impact of scientific studies. The use of different terms can lead to confusion and contradiction because they are intended to determine different actions. It is known that research fields without a theoretical consensus on key terminology have their validity seriously challenged (Hirsch and Levin, 1999). This calls for clearly conceptualizing and harmonizing of terms to bring together different disciplines. However, as world temperatures rise and fire regimes become increasingly novel, it is critical to operate and conceptualize consistent terminology and clear concepts to ensure understanding and alignment among actors (Linley et al., 2022; Tedim et al., 2018).

Linguistic uncertainty pervades many areas of science (Johnson and Lidström, 2018) and includes vagueness (the inability of a concept to categorize borderline cases), ambiguity (terms with multiple meanings), context dependency (a missing context that allows meanings to be understood), and indeterminacy (unforeseen ambiguity arising from changes in meanings over time) (Regan et al., 2002). This is seen in the case of the so-called "umbrella constructs" and "floating signifiers," which usually arise in academic fields where there is no theoretical consensus (Mijailoff and Burns, 2023). While some emerging terminologies are maintained, others become a language game in which "labels" and "relabels" end up being created. These labels follow patterns based on a dialectic that strengthens the research field even when there are moments when they seem to create a disruption (Hirsch and Levin, 1999).

Against this background, this study aims to take stock of and harmonize key wildfire terminology with regard to fire management and policy. In doing so it reviews the *types of fires* occurring in vegetated landscapes and establishes a *typology* for systematically classifying all related management and policy actions reported in the scientific literature thus far. To do so, we conducted a scoping literature review and developed a cyclical analytical framework, drawing on the cyclical conceptions of disaster risk management and public policy, respectively.

2. Analytical framework: the ring-of-fire

In order to classify wildfire management and policy actions, we first present a framework, called the "ring-of-fire" (Fig. 1). This framework integrates elements from both the disaster risk management cycle and the policy cycle. Within the inner rings, we depict risk management elements categorized according to the time of the fire event. Meanwhile, the outer rings illustrate the policies, relating each action to a policy governing the actions to be taken by the many actors involved. In turn these policies encompass the elements of the policy cycle. Further elucidation of this elements follows below. The framework's degree of abstraction is based on intentional and legitimate human decision-making and is represented from the inside out.

2.1. Disaster risk management elements

Owing to the cyclical nature of fires (Farkhondehmaal and Ghaffarzadegan, 2022), we propose understanding the time dimension of fire management actions as a cycle that is constantly adapting. This cycle is conceptualized as constantly evolving and is delineated based on the time of a fire event (pre-, during, and post-fire), corresponding to the inner ring of the framework. Moving outwards, the second ring corresponds to the themes (Level 1) of the disaster risk management cycle, colour-coded to denote their alignment with the time of fire event in which they occur. Within these overarching themes, we further categorized the subthemes (Level 2) in the third ring. It is within these subthemes in which the actions (Level 3), later classified in the results section, take place. Actions were defined as "the accomplishment of a thing usually over a period of time, in stages, or with the possibility of repetition" (Merriam-Webster 2023a).

2.2. Pre-fire

Two themes are identified before a fire event: risk reduction and pre-

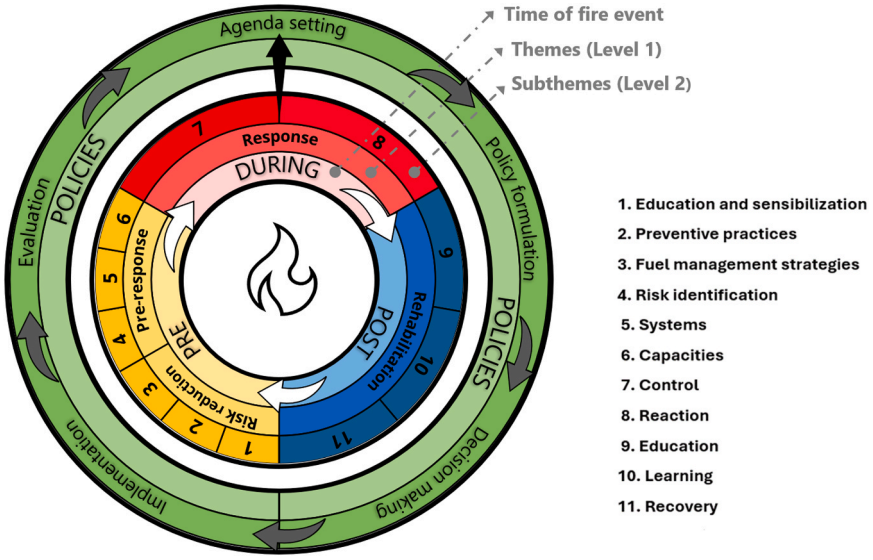


Fig. 1. The ring-of-fire: combining cyclical models of disaster risk management (inner rings) and policies (outer rings). From the inside out: first ring, fire stages according to the time of the event; second ring, fire management themes (Level 1); third ring, subthemes (Level 2); fourth ring policies embracing actions; last ring the policy cycle.

response. The primary goal of risk reduction is to minimize the occurrence of fires, regardless of whether they are caused by humans. It involves education, sensibilization, implementation of preventive measures, such as controlled burning and avoidance of fires by imposing restrictions, and fuel management strategies. The second theme relates to pre-suppression actions, which involve the establishment of systems, capacities, and risk identification to ensure that fires are addressed promptly and cost-effectively.

2.3. During fire

After a fire outbreak, the reactive action stage comes into play, which includes the control, coordination, and dispatch of resources. Control refers to the initial response or first suppression action taken on a wildfire with the aim of ceasing and decreasing the burnt area. Most fire management agencies attempt to initiate suppression actions while fires are still small, hoping to contain them quickly. During an initial response, dispatchers must decide which resources to use. These resources include fire crews, air tankers, fire trucks, transport vehicles, and fire itself (Martell, 2015). Moreover, other actors must decide on action plans, such as evacuation, emergency investment, sheltering, crisis communication, and coordination with potential collaborators.

2.4. Post-fire

This last stage is a more "looking ahead" approach relating to management activities once a fire is extinguished. From a control perspective, a wildfire is officially extinguished after "cold trailing," which involves monitoring the burned area to detect fire re-ignition (NWCG, 2006). The post-fire phase of the cycle includes rehabilitation practices, including conducting an evaluation of the impacts and causes; assessment of future actions for prevention and pre-suppression; and learning and recovery including social, economic, and ecological aspects.

2.5. Policy cycle elements

Surrounding the fire-related rings are the policies which conceptualize as a ring in which actions are reflected in the process of social bargaining and where policymaking can occur at any stage of a fire event. Following Krott (2005) policy can be defined as a social bargaining process which regulates conflicts of interest. Embracing the policies ring are the elements of the policy cycle. We consider a five-stages format (agenda setting, policy formulation, decision making and evaluation) of a policy cycle originally proposed by Lasswell (1956).

The continuous adaptation of fire management actions after a fire occurs is explained by the arrows indicating the turning of the cycle, also considering the uncertainty in the context of climate and global change. Since the policy cycle is a heuristic tool through which different stages of the ongoing policy processes are understood (Capano and Pritoni, 2020), we present this never-ending process in the framework with arrows. Furthermore, we discuss that, during an extreme fire event, there is a window of opportunity that opens up and can work as a basis for selecting issues to consider, namely the agenda-setting stage of the policy cycle (Shivakoti and Howlett, 2022). In other words, major attention is given during the response period to a fire event. This is evident from the substantial body of research on agenda-setting that has mainly focused on government reactions to rapid-onset events (Tosun and Howlett, 2021). Nonetheless, the fact that a given issue has gained agenda status merely tells us that there might exist a "policy window" or an "opportunity for action" (Kingdom 1984 on Dery, 2000).

3. Methodology

To conduct the global scoping review of the scientific literature, we selected peer-reviewed articles from scientific journals in which actions and concepts related to wildfires were identified. The protocol for the literature selection and subsequent analytical strategy is indicated in Fig. 2 and is further elaborated below.

3.1. Literature selection

The first selection of literature was made by searching in the SCOPUS online bibliographic database (1) using the following search string ("forest fire*" OR wildfire* OR "forest burn*" OR "land* fire*") within the article title, abstract, and keywords. (2) Searches in which subject areas were considered irrelevant to our study, such as "energy" or "medicine," were excluded. (3) As a document category, the search was limited to peer-reviewed articles (4) and to a period of ten years, from 2013 to 2022. This was done because it was in the last decade that the largest number of publications was found, as well as to condense terminology used during the last decade, and avoid terminology which is not contemporarily in use. A total of 13,887 documents were found, of which (5) the titles, abstracts, and keywords were reviewed to verify whether they met the second criterion for inclusion, that is, presenting an action or an active verb (e.g., recover, managing) related to the words "fire," "burn," or "fuel" within the article title, abstract, or keywords. Only the documents that fulfilled the aforementioned criteria were analyzed.

3.2. Analytical strategy

The final selection (see Supplementary Material) of 2101 article abstracts was reviewed in greater detail. (6a) We coded the terminology used to describe fires occurring in vegetated landscapes and identified the contexts in which they were applied, namely the cause (why), the situation (where/when), the land use /cover (what), the extension (how much), and if the use was of specific region. (7) To better understand the terms used to describe this phenomenon, we consulted four wildfire glossaries from the U.S, Canada, Australia and New Zealand, and Europe (afac, 2012; CIFFC, 2017; EUFOFINET, 2012; NWCG, 2006). We referenced both a dictionary (Merriam-Webster) and an encyclopedia (Encyclopedia Britannica) to elucidate terms that were not found or lacked consensus in the official glossaries. While these resources are not tailored specifically to scientific terminology, they provide clarity and understanding. As a result, the terminology was then classified in a reference system according to the five above-mentioned contexts. Similarly, the study areas were coded by continent whenever information was obtained.

In addition to coding terminology to describe fires, (6b) the identified actions were analyzed starting with open coding and selective coding along the ring-of-fire categories (Fig. 1) using a top-down approach in qualitative data analysis software (MAXQDA 2022). (8) Content analysis was performed to derive themes (Level 1) and subthemes (Level 2), considering that there are concepts with similarities or possible synonymities to an already derived subset of actions. The groups of actions were classified as pre-, during, and post-fire according as described in the analytical framework section. The collected data were then reviewed, and the actions were categorized. (9) For a subset of actions, the categorization was validated by the group of authors based on their expertise in forest management, wildfire management, and forest policy and governance. In rare cases of disagreement between the coder and the co-authors, a consensus was sought.

4. Results

4.1. Terminology for fires occurring on vegetated landscapes

There are several explanatory terms used in the literature to describe fires occurring on vegetated landscapes, calling for more precisely defined *wildfire terms* (Linley et al., 2022; Špulák, 2022). By conducting the literature review, we identified 36 English terms that describe the types of fires (Table 1). By far the most frequently used term was

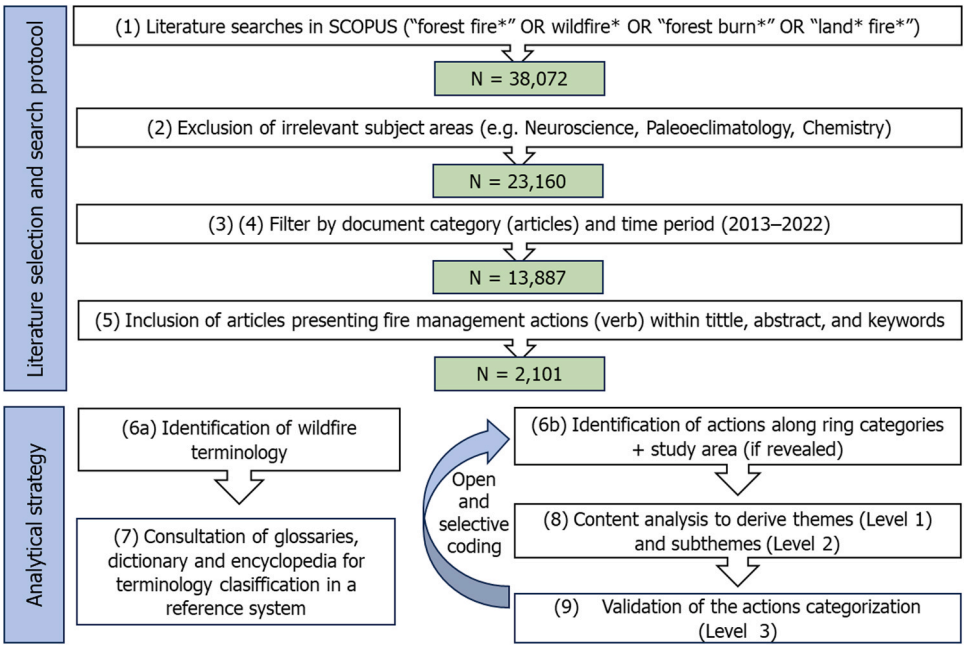


Fig. 2. Literature selection and analysis process to derive terminology in a reference system and classification of management and policy actions (Level 3).

Table 1
English terminology used for fires occurring on vegetated landscapes, found as part of a literature review.

Wildfire				
Cause (Why)	**Situation (Where / When)**	**Land use /cover (What)**	**Extension (How much)**	**Region-specific**
• **Natural fire** (Mokhov et al., 2020; Moris et al., 2020) • **Prescribed fire** (Harper et al., 2018; Weir et al., 2019) • **Controlled fire** (Meddour-Sahar et al., 2013; Smith et al., 2022) • **Arson fire** (Costa and Thomaz, 2021) • **Accidental fire** (Abt et al., 2015) • **Uncontrolled fire** (Pivello et al., 2021)	• **Rural fire** (Raposo et al., 2020; Salvati, 2014) • **Tropical fire** (Armenteras et al., 2020) • **Boreal fire** (De Groot et al., 2013) • **Farming fire** (Ribeiro et al., 2022) • **Rangeland fire** (Salavati et al., 2022) • **Summer fire** (Faivre et al., 2014) • **Wildland-urban interface fire** (Hou et al., 2019; Mahmoud and Chulahwat, 2020) • **Crown fire** (Jiménez et al., 2013; Vaillant et al., 2013) • **Surface fire** (Bravo et al., 2014; Kennedy and Johnson, 2014) • **Ground fire** (Smirnov et al., 2015)	• **Wildland fire** (Calkin et al., 2014; Mickler et al., 2017) • **Forest fire** (Pourtaghi et al., 2015; Rabin et al., 2022) • **Land fire** (Achmad and Alfan, 2018; Purnomo et al., 2018) • **Landscape fire** (Barreiro et al., 2021; Nikonovas et al., 2022) • **Vegetation fire** (Nezval et al., 2022; Reddy and Sarika, 2022) • **Grassland fire** (Fultz et al., 2016; Overholt et al., 2014) • **Grass fire** (Collins et al., 2018; Renkas et al., 2022) • **Savanna fire** (Armenteras et al., 2021; Russell-Smith et al., 2021) • **Pasture fire** (Salavati et al., 2022) • **Brush fire** (José et al., 2014) • **Peat fire** (Krasovskii et al., 2018; Sirin and Medvedeva, 2022) • **Peatland fire** (Syaufina and Sitanggang, 2018; Uda et al., 2019) • **Plantation fire** (Varkkey, 2013)	• **Large fire** (Benyon and Lane, 2013; Clarke et al., 2020) • **Mega-fire** (Davies et al., 2016; San-Miguel-Ayanz et al., 2013) • **Giga-fire** (Linley et al., 2022) • **Tera-fire** (Linley et al., 2022)	• **Bushfire** (Blanchi et al., 2018; Whittaker et al., 2020) • **Veld fire** (Nieman et al., 2021)

wildfire, 58% of the reviewed articles mentioned it. This term is predominant in North America and is being increasingly used worldwide. All the glossaries consulted provide definitions for this term and generally agree that it refers to an unintentional vegetation fire, whether natural or human-caused, using varying levels of detail (NWCG, 2006; CIFFC, 2017; EUFOFINET, 2012). However, the glossary for Australia and New Zealand refers to see the bushfires definition (afac, 2012).

On the other hand, the definition for **wildland fire**, is not recognized by all the glossaries. While in the European glossary is not defined but presented as an alternative to the wildfire term, the glossary from Australia and New Zealand does not recognize it. The U.S glossary defines it as any non-structure fire that occurs in the wildland which includes wildfire, wildland fire use and prescribed fire (NWCG, 2006), it does not mention *unintentional human-caused*. (CIFFC, 2017). Nonetheless, it refers to a natural ecosystem process, in which case it is referred to as **natural fire,** or, in the case of human-caused on purpose to **arson fire** or on accident, to **accidental fire**. When afire event was planned and created intentionally by a team of fire experts to achieve a set of objectives under specific weather conditions, resulting in a **prescribed fire** (afac, 2012; CIFFC, 2017). Some authors define prescribed fires as controlled low–medium-severity fires used as management tools for reducing fuel loads and modifying subsequent wildfire dynamics (Addington et al., 2015; Alfaro-Sánchez et al., 2018). However, if a fire is set under supervision, but the conditions have not been prescribed, it is called a **controlled fire**, used for hunting, gathering, waste management, smallholder agriculture, and pastoralism (Smith et al., 2022). Moreover, **uncontrolled fire**, according to glossaries from North America, is considered to act as a *wildfire* synonym (NWCG, 2006).

While the terms mentioned above refer to the causality of an event, other terms are also used to describe the same phenomenon, depending on the context in which it occurs. We identified the following terms: **rural fire**, **wildland–urban interface fire, farming fire**, **rangeland fire**, **tropical fire**, **boreal fire**, and even a term related to seasons, **summer fire**. Other types of fires that relate to the context are **crown fire, ground fire** and **surface fire**. Under the question *what type of vegetation burns?* we listed terms related to land cover or land use, namely **grass fire**, **grassland fire**, **savanna fire**, **pasture fire**, **brush fire**, **peat fire, peatland fire** and **plantation fire**. Among these terms, **forest fire** was the second most used term in our review, 27% of the reviewed articles mentioned this term. According to Encyclopedia Britannica (2023), *forest fire* is defined as *uncontrolled fire occurring in vegetation over more than 1,8 m*, while Merriam-Webster (2023b) defines it as *an uncontrolled fire in a wooded area*. In North American glossaries, this term is variously defined for legal purposes, and its types are **ground**, **surface**, and **crown fires**. However, it is often used for wildfires occurring in broad land-use categories, such as forest stands, shrublands, and even grasslands. We noticed that in other languages, the term "forest" paired with "fire" or "burning" is utilized to describe a wide range of fires in vegetated ecosystems, as seen in *incendio forestal* (Spanish), *Waldbrand* (German), *feu de foret* (French). Tedim et al. (2015) used the term *forest fires* to designate unwanted fires burning forests and wildlands in Europe. In fact, *wildland*, refers to an area in which development is essentially non-existent, except for the presence of basic infrastructure such as roads, railroads, and power lines (EUFOFINET, 2012). According to Montiel and San-Miguel-Ayanz (2009), the term *wildland fire* seems less restrictive and more appropriate than forest fire referring to the Mediterranean region. Regarding the term *rural fires*, in Portugal, its literal translation *fogos rurais* is commonly used to describe any wildfire (AGIF, 2021). Woodlands are a very complex land-use category, especially in Mediterranean countries, and includes forests and other wooded lands. The terms **land fire**, **landscape fire**, and **vegetation fire** were also listed as terms related to land cover and land use, though none of them were listed in the glossaries or found to have a similar denotation as wildland fire.

Although fire phenomena whereby vegetation combustion occurs in an open environment follow the same physical and chemical laws in all locations (Tedim and Leone, 2020), specific terms are used to describe the ecological and socioeconomic severity of events (Tedim et al., 2015). Linley et al. (2022) mention the term **megafire** *as an emerging concept commonly used to describe fires that are extreme in terms of size, behavior, and/or impacts*. Although the term is widely used, its meaning remains ambiguous (Williams et al., 2011). To overcome this ambiguity, it was suggested to define it as fires larger than 10,000 ha arising from single or multiple related ignition events. Furthermore, they introduced two additional terms: **giga-fire** (>100,000 ha) and **tera-fire** (>1,000,000 ha). The term **large fire**, which describes a wildfire spatially, was identified in our review to describe a wildfire with an average area of >100 ha (Cardil and Molina, 2013). Finally, region-specific English terms were found, namely **bushfire**, used in Australia and New Zealand, and **veld fires**, used in South Africa; both terms define unplanned vegetation fire.

After identifying several terms referring to types of fires occurring in vegetated landscapes, we classified them as i) cause (why they burn), ii) situation, (where or when they burn), iii) land use/cover (what it burns), iv) magnitude (how much burns), and v) if were terms of specific use in a region (Table 1). This classification intends to take stock of and harmonize the use of terms for types of fires occurring in vegetated landscapes, indicating their use according to the five identified contexts. However, more terms keep emerging to describe not only the physical factors but the magnitude of their threat to society and environment. An in-depth analysis of these terms as *extreme wildfire event and normal* wildfire *event* is presented by Tedim et al., (2018).

Based on the definition of *wildland*, we consider that the term *wildland fire* should also belong to the category of land use and land cover, although, as we have seen, its use is widely accepted in some countries and is defined as a type of fire that indicates not only the origin of its cause but also the type of vegetation that burns.

4.2. Fire management and policy actions along the "ring-of-fire" framework

Table 2 presents the groups of actions identified in the literature review based on our analytical framework. We applied a top-down approach, classifying action themes (Level 1) and subthemes (Level 2) according to the time of the fire. The typology uses a deductive-inductive reasoning process that involves several adjustments and readjustments of the categories, resulting in 45 ring-of-fire action categories being added to the typology at Level 3. More than half of the management actions identified in Level 3 were found in the pre-fire stage (23 actions). The other half were found between the during-fire (9 actions) and post-fire (13 actions) stages. Since more concepts related to the actions for the subcategory of Level 3 were identified, we listed those actions as synonyms or "Concepts related to the Action." Additionally, at the end of Table 2, we classify the identified policy types according to the time of the fire event, and the actions identified that were directly related to the policy cycle.

The results of this classification of actions provide an analytical shortcut for the underlying actions on wildfire management and policy, facilitating the comparability of future research results, fire policies and management approaches, and measures across countries. It also provides a view of the diversity of terminology in the field, including diversity in actions, beliefs, and management/non-management objectives.

As part of the key findings of the classification process of fire management and policy actions, we identified ambiguity in the meaning of the term "suppression" as an action. On the one hand, we found that, in the literature, this noun is used to indicate prohibitions on the use of fire, which, in terms of the time of the fire event, is a pre-fire policy. On the other hand, it is also used to indicate the action of extinguishing a fire, which corresponds to the during-fire phase. Because of the importance of this term, we have described it further in the discussion section.

Table 2
Classification of identified fire management actions and policies from N = 2101 studies according to the time of the fire event.

Time of fire event	Theme (Level 1)	Subtheme (Level 2)	Action (Level 3)	Concepts related to the action
PRE-FIRE	Risk reduction	Education and sensibilization	Values at risk assessment	Loss prediction
			Resilience building	Enhancing / developing resilience / Increasing adaptation response
			Training	Knowledge transfer / Preparation / Capacity building
			Knowledge integration	Local knowledge characterization / Science integration
			Public education and awareness	Community engagement
		Preventive practices	Fire regime restoration	Reconstructing fire regimes / Restoration of pre-suppression
			Pre-fire restoration	Afforestation / Restoration of pre-suppression forest composition and structure
			Cost–benefit analysis	Suppression cost savings estimation / Annual budget justification
			Land-use planning	Urban / Landscape planning
			Suppression (avoidance)	Ignition prevention / Prolonged suppression
		Fuel management Strategies	Fire-break construction	Fuel-break management / Fire-break building
			Open burning	Land burning / Cultural burning / Traditional burning / Fire use / Pile burning / Waste handling / Slash burning treatment
			Sylvicultural fuel treatments	Mastication / Grazing / Thinning / Clearing / Logging
			Prescribed burning	Fuel treatment prescriptions—*controlled burning
	Pre-response	Risk identification	Assessing risk	Danger estimation / Fire risk analysis
			Detection	Early detection / Spotting fires / Active fire detection / Forest fire recognition / Smoke identification
			Forecasting	Fire prediction / Fire weather prediction / Fuel conditions assessment
		Systems	Environmental surveillance	Warning information / Use of early warning systems / Detection
			Fire management planning	Strategy planning / Aid planning
			Decision making	Prioritization of management operations
			Use of remote sensing data	Monitoring / Modelling / Mapping / Spatial analysis Simulation
		Capacities	Resource allocation	Budgeting / Resource deployment / Disbursement of funds / Funds release / Emergency investment
			Taking precautionary measurements	Readiness / Preparedness
DURING FIRE	Response	Control	Fire assistance	Emergency response
			Firefighting	Combat / Battling /Suppression/ Extinguish /Reactive management / Reduce burned area
		Reaction	Equipment and personal dispatch	Logistics operations
			Fire evacuation	Civil protection operations

(*continued on next page*)

Table 2 (*continued*)

Time of fire event	Theme (Level 1)	Subtheme (Level 2)	Action (Level 3)	Concepts related to the action
			Plan implementation	Logistic operations / Strategic decision making / Evacuation decisions
			Fire rescue	Search and rescue initiative
			Crisis communication	Informing / Coordinated communication / Reporting
			Sheltering	Development of ad-hoc infrastructures
			Coordination and collaboration	Cooperative disaster response / Bridging organizations / Inter-agency collaboration / Crowdsourcing
POST -FIRE	Rehabilitation	Evaluation	Costs evaluation	Expenditures quantification / Post economic assessment
			Health impacts assessment	Identification of health adversities
			Burning emissions assessment	Emissions quantification / Estimation
			Restorative justice	Damage liability / Arsonists punishing
			Impact evaluation	Determining level of losses / Damage assessment
		Learning	Planning post-fire	Decision making / Preparedness after risk / Post adaptation
			Civic engagement	Social learning / Reconciliation / Social rebuilding / Community adaptation
		Recovery	Economic and social recovery	Subsidizing housing / Improving economic indicators / Funding / Rebuilding / Emergency stabilization
			Ecological restoration	(Re)planting / Seeding / Regeneration / Reforestation
			Salvage logging	Salvage harvesting / Landscape maintenance
			Control erosion	Stabilization practices / Reduce runoff / Mulching
			Post-monitoring	Post-fire evaluation
			Conservation management	Preservation / Biodiversity maintenance

	Time	Policy types	Related actions
POLICIES	Pre	Environmental and climate change policies / Disaster risk policies / Civil protection policies	Fire policy making /policy change /policy adaptation / policy design / policy formulation /policy analysis / policy implementation / policy enhancement
		Fire management policies / Fire mitigation policies /Prevention policies	
	During	Zero-burning policies / Fire exclusion policies	
		Suppression policies / Fire control policies / Firefighting policies / Response policies	
		Prescribed burn policies / Emergency management policies	
	Post	Restoration policies / Conservation policies / Forest policies	
		Public health policies	

4.3. Wildfire management and policy actions by geographic region and time of a fire event

To gain an overview of which actions are more prevalent in certain regions and which moments of the fire events have received more attention in the scientific literature during the last decade, we generated diagrams showing the frequency of actions found in the review according to the moment of the fire and the study area if known. It was immediately noticed that the number of studies found with the applied search string has been increasing progressively over the years, with the most considerable increase being from 2020 to 2022. Among the selected studies, a considerably larger number were published in 2020 compared to other years. Most actions registered that year were reported in North American studies during the pre-fire phase.

Regarding the geographical regions, 34% of the studies were performed in North America, followed by 26% performed in European countries, of which 70% were in Mediterranean Europe, mainly in the Iberian Peninsula. Asian countries were represented by 12,5% of the studies, Oceania 11%, and Latin America and the Caribbean 8%. Only 2% of the studies were conducted in African countries, with Algeria and South Africa being the most mentioned. Most actions identified in the articles were in the pre-fire phase. However, this phase included most action categories according to our classification. The second phase in which most actions were mentioned was the post-fire phase, except for articles in which the study site was not determined (Table 3).

Taking a closer look at the subcategories within the fire stages (Table 4), we noticed that, in the pre-fire phase, actions related to preventive practices and capacities were the least frequently mentioned. Actions related to fuel management strategies were most frequently mentioned in North America and Europe, followed by Oceania. As for the actions related to systems, this subtheme presented the highest frequencies for the entire pre-fire phase, which is explained by the number of studies that use tools such as modelling or monitoring, in addition to the different fire mitigation and management planning activities that can be carried out in this phase.

In the during-fire phase, Europe had the highest frequency of actions related to fire control, followed by North America. North America had the highest number of actions related to agenda-setting in this category. Africa had the lowest number of actions identified in the two subcategories of this phase. In terms of post-fire phase actions, those related to recovery had the highest frequency, mainly in North America and Europe, followed by Oceania, Latin America, and the Caribbean. Learning was the least mentioned category, not only in the post-fire phase, but also in all categories.

Overall, the findings from the analysis of actions by region show that the primary focus of studies conducted during the last decade was on pre-fire mitigation efforts, both in risk reduction and pre-response initiatives. Approximately a quarter of the articles focused on actions during and post fire. The current review by region provides a wider overview of where research efforts have been invested and the key themes identified in the response to wildfires.

5. Discussion

5.1. The added value of a systematic and rigorous language

Inconsistencies in terminology can result in divergent interpretation of trends within the general public. In scientific settings, such inconsistencies can pose challenges in classification processes that are meant to yield consistent and replicable measurements. Similarly, in the policy-making context they can influence the outcome of a policy (Linley et al., 2022). In the context of fires, our researched showed that the number of terms related to wildfires reflects its relevance in different research, political, operational and cultural domains, but also reveals the missing common understanding of wildfire "nature"; hence, different representations and misunderstandings of the same phenomenon make it difficult to establish a sustainable wildfire management policy (Pausas and Keeley, 2019b). Moreover, since wildfire management involves a series of collaborative yet separate actions, it is important to use the same terminology (Nohrstedt and Bodin, 2020). This is confirmed by a key finding of the 2001 U.S. Federal Fire Policy Review of the 1995 policy, which was that *multiple terms for various management options to respond to wildland fire have confused agency managers and employees, operators, partners, and the public, and have perpetuated multiple fire management program elements* (Wildland Fire Leadership Council, 2009).

Agreement on standardized terminology is not a minor concern if the scientific community wants to effectively transfer knowledge to enhance wildfire management policy and practice (Tedim et al., 2018). Hence, we call for the common use of terms and the avoidance of geographical jargon in scientific literature. Importantly, this call for standardization does not imply a diminishment of terminological diversity. Oversimplification of the issue leads to communication with a broader audience, whereas precision in language appeals to a narrower but more engaged public.

Although European legislation has contributed to homogenizing national legal frameworks, there are still important differences among countries with respect to terminology. An example of this is the wide range of definitions of "forest," each adapted to an ecological or socio-economic context (Sande Silva et al., 2010). It is also pertinent to note that the relevance of adopting common wildfire terminology in the English language is reflected when considering the potential need for a European Framework Directive on fire management, especially given the absence of consensus on the matter (Montiel-Molina, 2013). A common reference that guarantees effectiveness and adaptation to the European context should be defined (Rego et al., 2010). This important communication issue will only be resolved through federal, state, local, and tribal engagements to build a foundation for common terms with understanding and support by all (USDA, 2009).

Although many "catch-all" terms may lack conceptual validity, they are still an important unifier among researchers trying to organize an area (from both managerial and scholarly perspectives) (Hirsch and Levin, 1999). By achieving consensus on terminology, researchers can

Table 3
Diagram representing the relation between the frequency of identified actions in the three stages of the fire event and the study regions. Frequency is represented by colors, where red represents the highest frequencies and blue represents the lowest. 3246 actions were considered in the N = 2101 studies reviewed.

Regions	North America	Europe	Asia	Oceania	Latam & the Caribbean	No determined	Africa	Global	SUM
%reviewed studies	34%	26%	12%	11%	8%	5%	2%	1%	100%
Pre-fire	684	555	303	209	142	128	52	31	2,014
During fire	170	150	45	55	41	45	6	4	516
Post-fire	251	182	50	65	52	7	13	6	626
SUM	1,105	887	398	329	235	180	71	41	3,246

Table 4
Diagram representing the frequency of the identified actions detailed up to Level 2 of the proposed classification. Frequency is represented by colors, where red represents the highest frequencies and blue represents the lowest. 3246 actions were considered in the N = 2101 studies reviewed.

Regions	Global	Africa	Asia	Latam & the Caribbean	Europe	North America	Oceania	No determined	SUM
Pre-fire									
> Risk reduction									
> Education & sensibilization	2	1	11	4	25	52	18	2	115
> Preventive practices	1	2	2	2	21	50	5	1	84
> Fuel management strategies	6	6	25	21	142	237	64	7	508
> Pre-response									
> Risk identification	6	9	93	32	116	97	32	57	442
> Systems	14	34	160	80	229	219	64	59	859
> Capacities	2	0	12	3	22	29	26	2	96
During fire									
> Reaction									
> Control	3	5	38	36	124	94	29	34	363
> Decision making	1	1	7	5	26	76	26	11	153
Post-fire									
> Rehabilitation									
> Evaluation	3	5	24	14	47	62	14	4	173
> Learning	0	1	1	1	14	19	9	1	46
> Recovery	3	7	25	37	121	170	42	2	407
SUM	41	71	398	235	887	1,105	329	180	3,246

more effectively synthetize findings and compare results across studies, enabling them to build upon existing knowledge and develop more robust theories and methodologies for studying wildfires. Moreover, we recognize the global scope of wildfire research is presented in various linguistic contexts, creating confusions across different communities. While our study focused on scientific literature, we acknowledge that important terminology is generated from traditional knowledge and should also be integrated.

5.2. Ambiguity in omnipresent suppression terminology

Of special attention in this review is the use of the term "fire suppression." Although fire suppression is deeply rooted in many countries, (Sande Silva et al., 2010) some recognize fires as a management action (Aguilar and Montiel, 2011). However, this term can lead to misinterpretations when classifying wildfire management actions in the time dimension. On one hand, fire suppression is the action concerned with controlling and extinguishing a fire following its detection (CIFFC, 2017) (namely during a fire event). In addition, there are many synonyms that express the action of fire extinction in the literature: *battling the flames, punching the fire line, combating the fire, fighting the fire, attacking the fire, controlling the fire, putting out the fire…* On the other hand, suppression can be understood, and has been mentioned by authors of the reviewed articles, as the action of avoiding a fire event. In our review, we found 58 studies that mentioned the term suppression, which we classified as a pre-fire action. E.g., <<*Wildfires in these forests are impactful owing to conifer infilling during prolonged fire suppression in post-Euro-American settlements*. (Ziegler et al., 2020)>>. In this case, it is understood as the prolonged action of having avoided the occurrence of fires, indicating a preventive action and a time when a fire has not yet occurred (pre-fire event). This prevention of a fire event is, in many cases, led by a legal prohibition of the use of fire which, in the long-term, results in a "pre-suppression." The introduction of enhanced fire-suppression policies, including early intervention, fire lighting prevention, and fuel management, reduced in both frequency and severity of fires within regions such as the North American boreal forest, where large infrequent fires dominate (Cumming, 2005; DeWilde and Chapin, 2006; Ruffault and Mouillot, 2015). In Canada, fire suppression practices fall into three categories: preventive measures, initial attack, and the management of large campaign fires, which also shows that this very same term is indicating actions in different times of the fire event (Martell 2001 in Cumming, 2005).

In the English literature, so-called fire suppression policies refer not only to extinguishing a fire but also to avoiding its occurrence by excluding the ignition source and applying preventive measures such as fire breaks or even prescribed fires (Rigolot et al., 2009). The legacy of this policy is rooted in early 20th century policies when the U.S. Forest Service instituted a policy of total fire suppression. This policy had two goals: to prevent and suppress fires as quickly as possible (Forest History Society, 2023). The term exclusion is also found in the literature as a synonym for withholding its appearance. In German, this type of "fire suppression" is called "Feuerverbot," which literally translates as fire prohibition and avoids mix-ups with the action of extinguishing a fire at the moment it occurs. In Spanish, policies referring to control use the word "extinción" and those referring to prevention use the term "prevención." The distinctiveness of wildfires becomes evident by the fact that they can be controlled by the fire itself under different suppression forms (counter fire, backfire, and burnout) and prescribed fire (Tedim and Leone, 2020).

Political efforts have recently evolved towards a fire policy centered on emergency suppression measures (DellaSala 2022 et al., 2022; Rossi et al., 2022; Sande Silva et al., 2010). This legal prohibition can be a "full suppression" (Iniguez et al., 2022; Rossi et al., 2022; Bond, 2001), or a total control model that maximizes fire suppression (Hayes, 2021). Thus, the approach of full fire suppression has begun to shift focus from the mandate of complete elimination to one of controlling fire progression wherever feasible (Bond and Keane, 2017). However, exceptions have been made. For example, in Germany, the use of fires in open landscapes has been banned since 1975, as noted by Montiel-Molina (2013). Nevertheless, as seen in the case of the Drover Heath, open fires were carried mainly for experimental purposes (Mause et al., 2010). Despite the Federal Nature Conservation Act does not explicitly mention the use of fire.

5.3. Why a cycle and why policies?

Because of the cyclical nature of fires (Farkhondehmaal and Ghaffarzadegan, 2022), and the different stages implied in fire management, we drew an understanding of fire management as a cycle in which actions are primarily categorized by the time the event occurred. We related the actions to a policy ring governing the actions to be taken by the many actors involved. Forest and fire management can be viewed from a supply-chain management perspective (Martell, 2007), which also indicates its cyclical nature, not only at the ecological level. On the

other hand, public policies are represented by a cycle in which the process starts with agenda-setting. Rapid-onset events such as wildfires can push the agenda for policymaking when they occur, especially when they represent extreme events, opening a window of opportunity in the policy cycle to make changes to public policies (Mockrin et al., 2018). However, wildfire legislation and policies have generally been fast and ad hoc reactions to catastrophic situations, as opposed to proactive mitigation measures (Montiel-Molina, 2013). This means that the actions identified in the pre-fire phase of the cycle are "skipped" and new opportunities for preventive and pre-response activities are set by calling only for those actions in the during-fire phase.

Policy design occurs far from the regions where policy implementation happens (Mintrom and Luetjens, 2017). These differences between policy designers and public managers can result in vastly different outcomes across organizations (Howlett and Rayner, 2007). Therefore, it is useful to explore the linkages between policy and management using a framework that combines the two cyclical views of wildfire policies and management actions. Because of the strategic choices that actors make and their actions, they influence policy outcomes (Meier and O'toole, 2001). Despite this, contributions from social sciences to wildfire research remains limited (Rodríguez Fernández-Blanco et al., 2022). This scarcity is underscored by our extensive decade-long review, wherein we observed that only a 13% of the studies within this domain either directly addressed policy or governance in their abstracts, often as concluding remarks or in relation to specific types of environmental policies. Additionally, just a 2,5% of the total reviewed articles were aimed at comprehending wildfire policies and their implications.

Although wildfires have a beneficial side, they also pose major threats to public safety, property, and forest resources (Myers, 2006). This creates special challenges not only for fire managers responsible for achieving an appropriate balance between the beneficial and detrimental impacts of fire (Martell, 2015) but also for policymakers accountable for financing management and making cost-effective decisions. Furthermore, socioeconomic changes, certain forest management actions, and other policy measures outside the forest sector have generally influenced the flammability of ecosystems and increased the risk of wildfires (Montiel-Molina, 2013). Hence, policies and legislation are of major relevance in fire management and should consider all aspects of wildfire management at different but interconnected stages.

6. Conclusions

It is important to critically evaluate the relevant shortcomings of popular concepts used in research and policy to describe or interpret phenomena because their misuse can lead to confusion and ambiguity. This is illustrated in the case of wildfires, where a plethora of terms are used not only to name actions but also to describe different types of wildfires. This study helps overcome vagueness and ambiguities in terminology. We found that 36 terms were used to describe fires in vegetated landscapes depending on their cause, situation, land use or cover, and magnitude. Additionally, country-specific terms are considered. While we do not provide a definition for each term, we suggested using "wildfire" as a standard term for types of fires occurring in vegetated landscapes. For those seeking specific fire descriptions we present a compilation of these terms as a reference system (Table 1).

Understanding the linkages between policy and management is crucial to tackling the problem of wildfires. One effective approach is through a framework that integrates cyclical views of wildfire policies and management, with a particular view to concrete actions. It is important to recognize that the strategic choices made by various actors and their actions can strongly influence the outcomes of these policies. By adopting a holistic approach and exploring these linkages, we can work towards more effective and sustainable solutions to this pressing issue. Therefore, we proposed a typology that integrates management and policy actions by considering policies as embracing rings that mirror management actions. This implies that the actions taken by various actors directly reflect these policies. On the other hand, we consider that wildfires open a window of opportunity in the policy cycle to make changes in public policies, starting with setting the agenda. With our *ring-of-fire*, we hope to provide a comprehensive and systematic classification tool for future comparative analyses, as well as approaches and measures across countries that considers policies as a part of all management actions.

We would like to call for special attention to be paid to the "suppression" term and suggest that the English literature should be unambiguous and hence allow direct comparison of studies. The term "suppression" should only refer to the action of extinguishing a fire during a fire event. For any other management actions or policies related to the pre-fire phase, clear terminology should be employed to ensure effective communication.

Different uses or misuses of terminology can affect knowledge production, leading to differences in wildfire management and policy actions. Hence, divergent representations and misunderstandings make it even more difficult to establish sustainable wildfire management policies. Wildfire management is complex not only because of the diverse mix of actors involved, the uncertainty about outcomes and future conditions, and the unavoidable trade-offs that require ongoing negotiation but also because of its cyclic and "paradoxical" nature. However, as presented in this review, we have added a large number of actions. Nevertheless, some authors claim that the "wildfire paradox" is not a natural phenomenon, but rather a reflection of policies and historical actions that have fed fire and natural ecosystems.

CRediT authorship contribution statement

Gabriela Huidobro: Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Conceptualization. **Sarah L. Burns:** Conceptualization, Supervision, Writing – review & editing. **Lukas Giessen:** Conceptualization, Supervision, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known financial interests or personal relationships that could have appeared to influence this research.

Data Availability

Data will be made available on request.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.envsci.2024.103776.

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